# RA4W1 Group

## BLE sample application

### Introduction

This document describes the accompanying sample application which controls the Bluetooth® Low Energy communication module. In this document, the module which performs Bluetooth® Low Energy communication is referred to as the BLE module.

### Target Device

RA4W1 Group

### Related Documents

Bluetooth Core Specification (https://www.bluetooth.com)

RA4W1 Group User's Manual: Hardware (R01UH0883)

Renesas Flexible Software Package User's Manual

e$^2$ studio Getting Started Guide (R20UT4204)

Renesas Flash Programmer User's manual (R01UT5757)

Tuning procedure of Bluetooth dedicated clock frequency (R01AN4887)

RA4W1 Group Bluetooth LE Profile API Document User's Manual (R11UM0154)

Bluetooth Low Energy Profile Developer's Guide (R01AN5428)

Host Controller Interface Firmware(R01AN5429)

Public BD Address writing tool(R01AN5439)

EK-RA4W1 Quick Start Guide (R20QS0015)

QE for BLE [RA, RE, RX] V1.5.0 Release Note (R20UT5145EJ)

### Related Environments

Refer to section 2.1 Operating environment.

## Contents

# 1. Overview

Demo projects accompanying this document are shown in Table 1. These projects are provided as BLE sample application using BLE module.

**Table 1. Demo Projects**

| Demo Project | Description |
|---|---|
| ble_baremetal_ek_ra4w1 | GATT Server demo project for EK-RA4W1 without RTOS. |
| ble_freertos_ek_ra4w1 | GATT Server demo project for EK-RA4W1 using FreeRTOS and event group technique has been used for task synchronization. This project provides for backward compatibility with versions prior to FSP3.8. |
| ble_freertos_ek_ra4w1_semaphore | GATT Server demo project for EK-RA4W1 using FreeRTOS and semaphore give / take method has been used for task synchronization. |
| ble_azurertos_ek_ra4w1 | GATT Server demo project for EK-RA4W1 using Azure RTOS. |
| ble_bearmetal_ek_ra4w1_client | GATT Client demo project for EK-RA4W1 without RTOS |
| ble_freertos_ek_ra4w1_client | GATT Client demo project for EK-RA4W1 using FreeRTOS and event group technique has been used for task synchronization. This project provides for backward compatibility with versions prior to FSP3.8. |
| ble_freertos_ek_ra4w1_client_semaphore | GATT Client demo project for EK-RA4W1 using FreeRTOS and semaphore give / take method has been used for task synchronization. |
| ble_azurertos_ek_ra4w1_client | GATT Client demo project for EK-RA4W1 using Azure RTOS |

These projects can work on EK-RA4W1 board or user’s custom board. GATT Server demo projects perform GATT Server role. They can change the blink rate of LED mounted on the board from remote device (e.g. smart phone) and send notification by pushing switch mounted on the board to remote device via BLE communication. LED and switch (e.g. push button) connected to RA4W1 GPIOs are necessary on user’s custom board when this demo project running on user’s custom board.

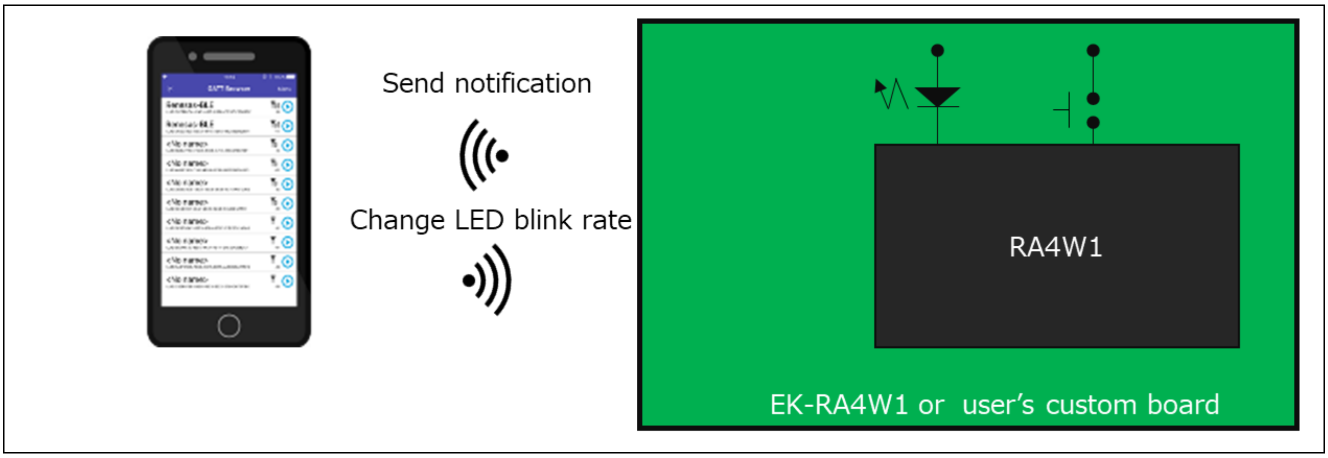


Figure 1. GATT Server demo project operating environment

GATT Client demo projects perform GATT Client role. They have the functionality of CLI (Command Line Interface) which can be accessed by the terminal emulator like Tera Term on PC connecting with EK-RA4W1 board via USB cable. They can perform various procedures in relation to GATT Client by receiving commands via CLI.

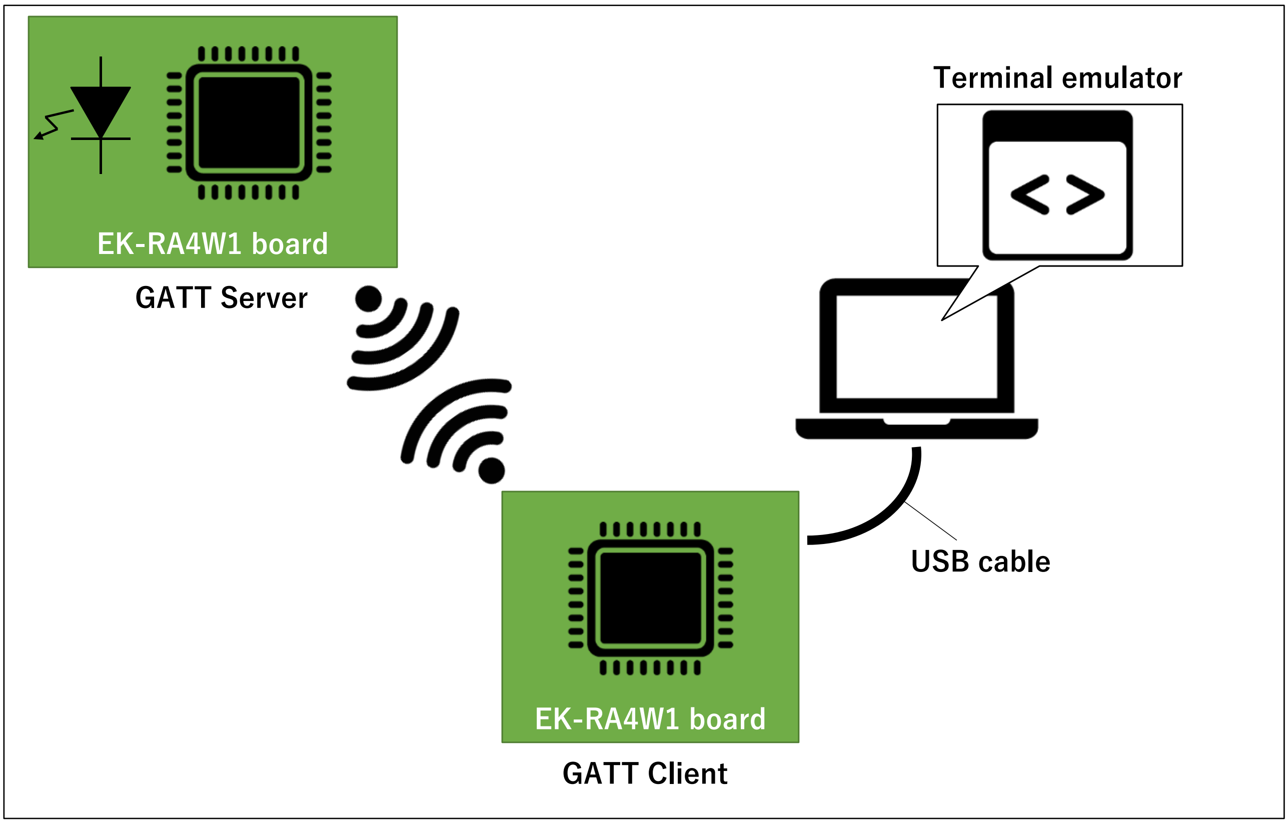


**Figure 2. GATT Client demo project operating environment**

## 1.1 BLE features

BLE module provides following BLE features which are compliant with Bluetooth version 5.0.

**Bluetooth 5.0 Features**

- LE 2M PHY

  Supports BLE communication with 2Msym/s PHY.
- LE Coded PHY

  Supports BLE communication with Coded PHY. Communication over long range than 1M PHY and 2M PHY is possible.
- LE Advertising Extensions

  An extension of Advertising. Up to 4 independent advertising can be performed simultaneously.
- LE Channel Selection Algorithm #2

  Selects a channel using the algorithm for selecting a hopping channel added in Bluetooth 5.0.
- High Duty Cycle Non-Connectable Advertising

  Supports non-connectable advertising with a minimum interval of 20 msec.

**Bluetooth 4.2 Features**

- LE Secure Connections

  Elliptic curve Diffie-Hellman key agreement method (ECDH) supports passive eavesdropping pairing.
- Link Layer Privacy

  Avoids tracking from other BLE devices by changing the BD Address periodically.
- Link Layer Extended Scanner Filter policies

  Resolvable private addresses as well as part of the filtering process.
- LE Data Packet Length Extension

  Expands the BLE data communication packet size up to 251bytes.

**Bluetooth 4.1 Features**

- LE L2CAP Connection Oriented Channel Support

  Supports communication using the L2CAP credit based flow control channel.
- Low Duty Cycle Directed Advertising

  Supports low duty cycle advertising for reconnection with known devices.
- 32-bit UUID Support in LE

  Supports GATT 32-bit UUID.
- LE Link Layer Topology

  Supports both Master and Slave roles and can operate as Master when connected to a remote device and as Slave when connected to another remote device.
- LE Ping

  After connection encryption, this feature checks whether connection is maintained by a packet transmission request including MIC field.

**GAP Role**

GAP Role supports the following.

- Central: A device that sends a connection request to a peripheral device.
- Peripheral: A device that accepts connection requests from Central and establishes a connection.
- Observer: A device that scans Advertising.
- Broadcaster: A device that sends Advertising.

**GATT Role**

GATT Role supports the following.

- Server: A device that prepares Characteristic provided by service in GATT Database and responds to requests from Client.
- Client: A device that makes request for services provided by Server.

## 1.2 BLE application software structure

Figure 3 shows software structure of BLE application in BareMetal environment.

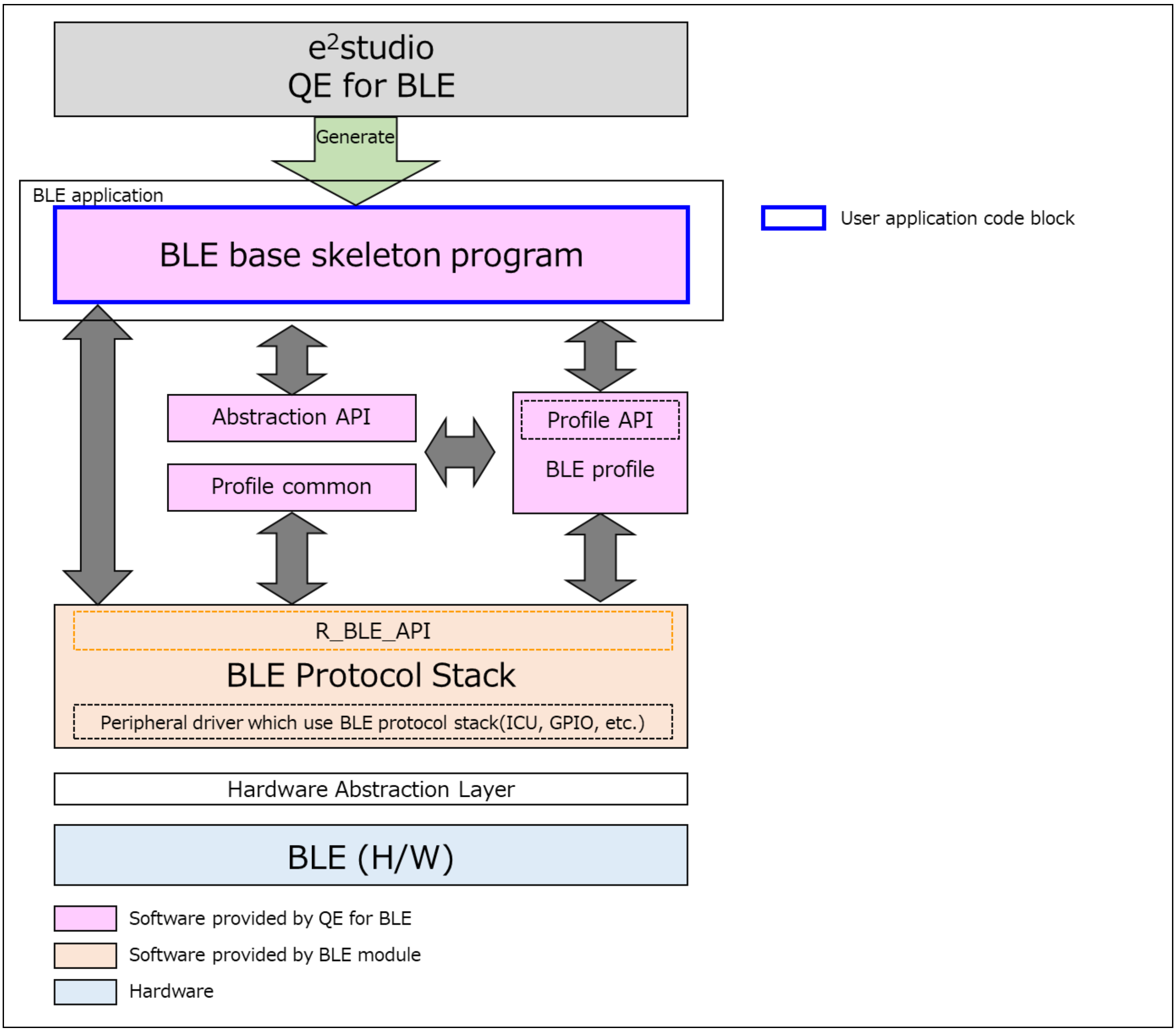


Figure 3. Software structure (BareMetal)

Figure 4 shows software structure of BLE application in case of FreeRTOS environment and event group technique has been used for task synchronization. BLE application is divided it into two or more tasks, BLE Core Task and GATT application tasks. BLE Core Task performs initialization and BLE related processing except profile event processing. GATT application task performs profile event processing.

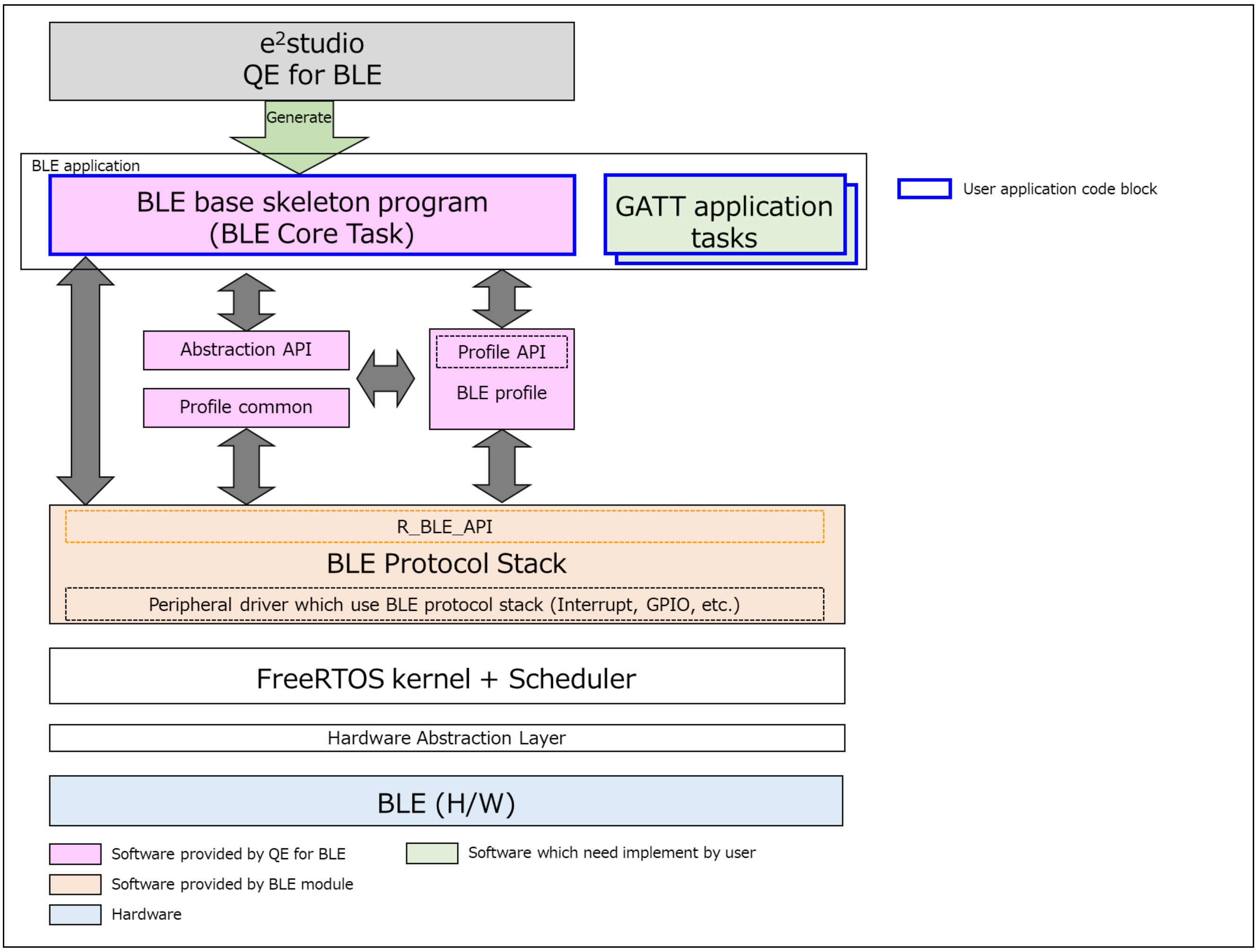


Figure 4. Software structure (FreeRTOS, Event group)

Figure 5 shows software structure of BLE application in case of FreeRTOS environment and semaphore give / take method has been used for task synchronization. BLE application is divided it into three or more tasks, BLE Core Task, BLE Execute Task and GATT application tasks. BLE Core Task performs initialization. BLE Execute Task performs BLE related processing except profile event processing. GATT application task performs profile event processing.

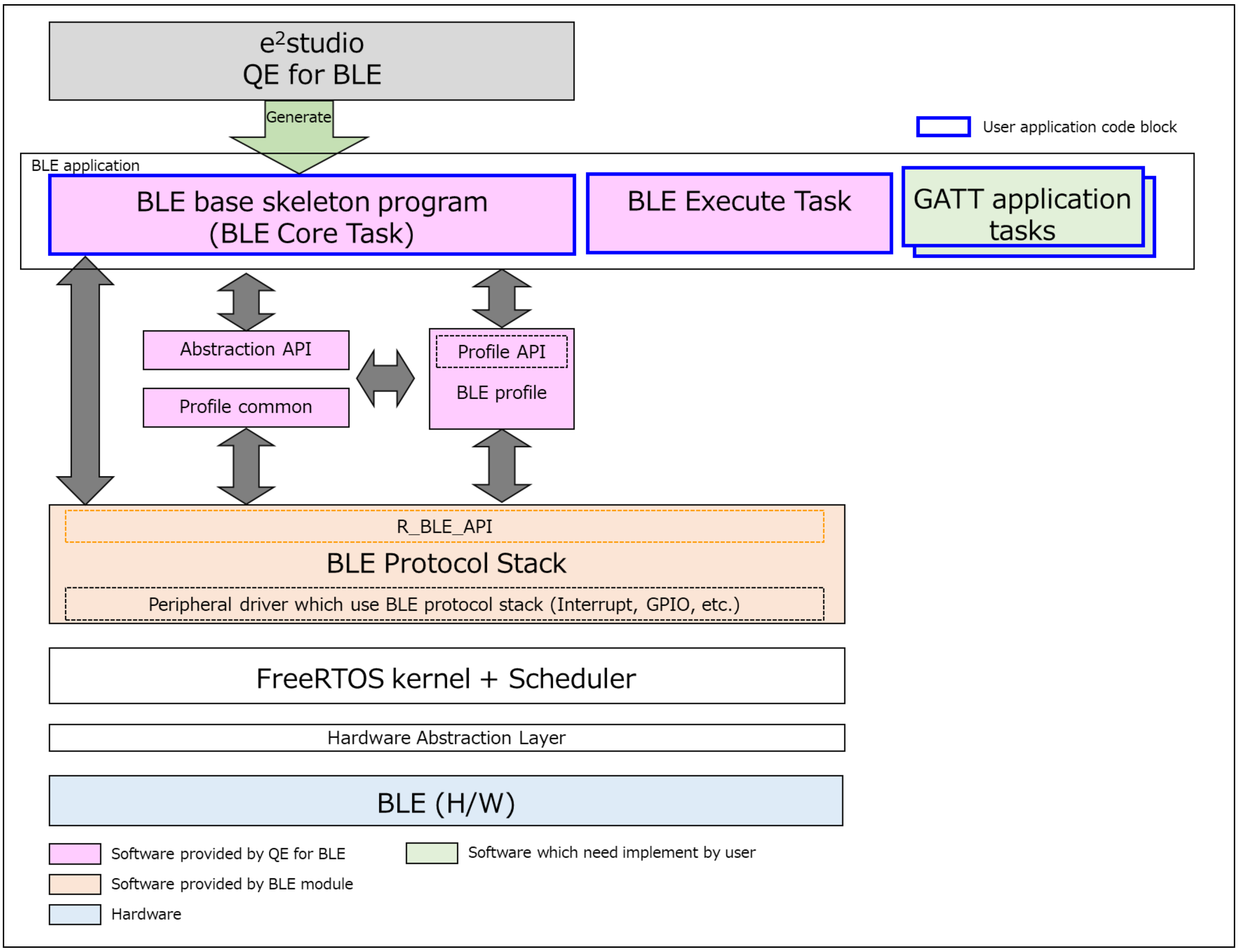
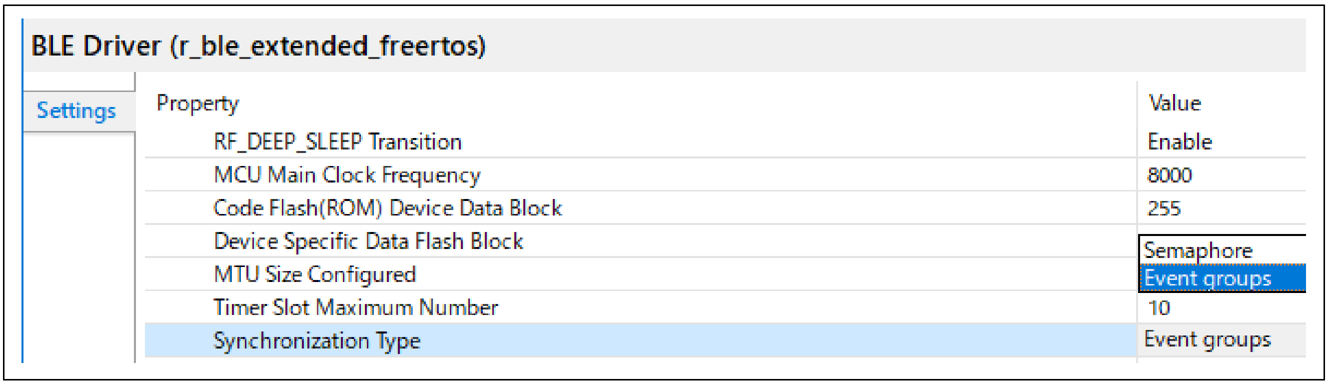


Figure 5. Software structure (FreeRTOS, Semaphore)

Task switching from interrupt context by using event group method should through FreeRTOS daemon task (Prior FSP3.8 environment). To reduce such overhead, made it possible to select semaphore synchronization method as *Synchronization Type* property of *BLE_Driver* FSP module from FSP4.0 or later.



**BLE Driver (r_ble_extended_freertos)**

| Property | Value |
|---|---|
| RF_DEEP_SLEEP Transition | Enable |
| MCU Main Clock Frequency | 8000 |
| Code Flash(ROM) Device Data Block | 255 |
| Device Specific Data Flash Block | Semaphore |
| MTU Size Configured | Event groups |
| Timer Slot Maximum Number | 10 |
| Synchronization Type | Event groups |

Figure 6. Synchronization Type

Figure 7 shows software structure of BLE application in Azure RTOS environment. BLE application is divided it into three or more tasks, BLE Core Task, BLE Execute Task and GATT application tasks. BLE Core Task performs initialization. BLE Execute Task performs BLE related processing except profile event processing. GATT application task performs profile event processing.

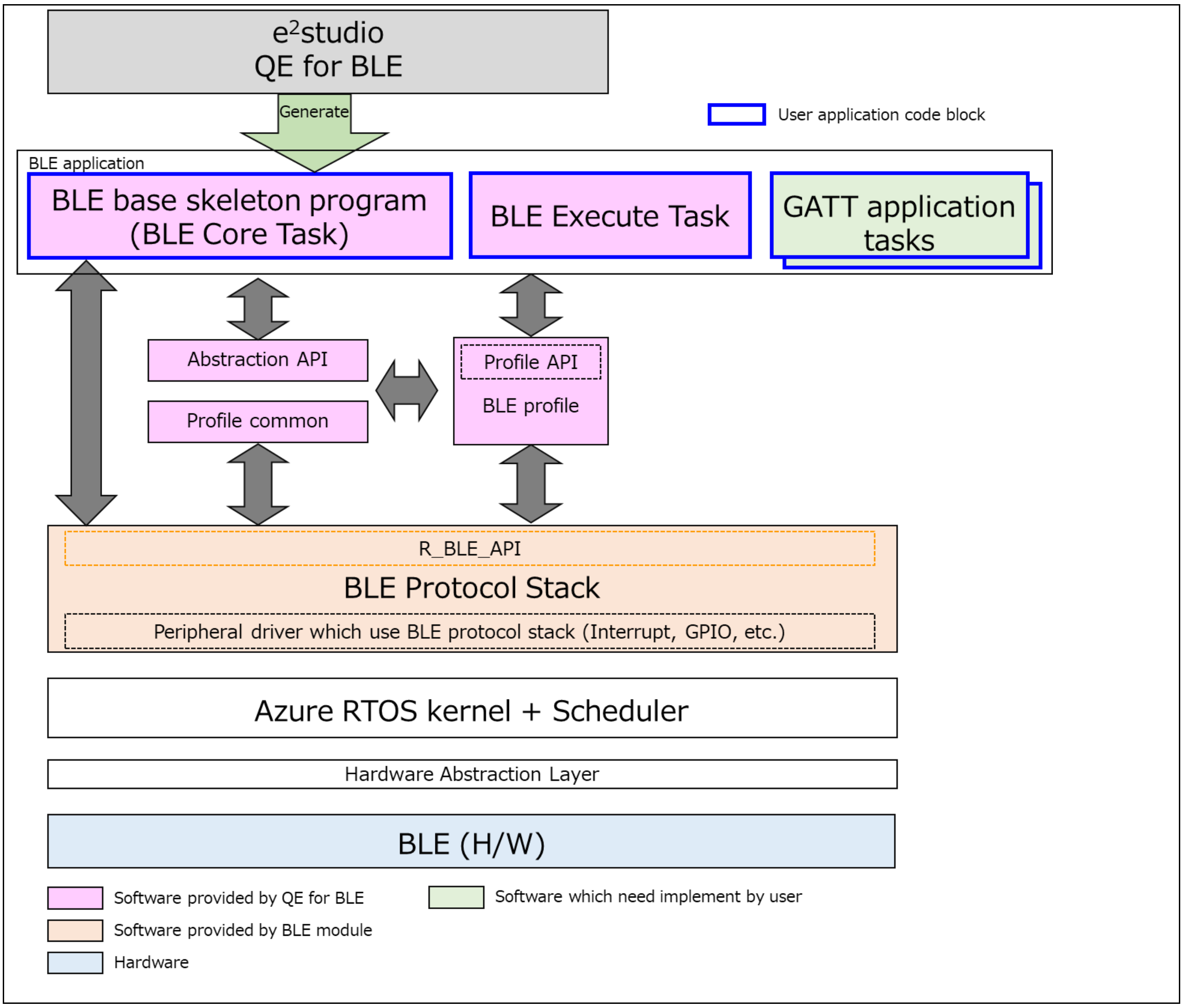


**Figure 7. Software structure (Azure RTOS)**

The QE for BLE tool generates C source codes of BLE base skeleton program for BLE application and BLE Profile. Renesas recommends using the QE for BLE tool when developing BLE application.

BLE application uses BLE functions via following APIs.

- **GAP API (R_BLE_GAP_XXX, R_BLE_L2CAP_XXX, R_BLE_VS_XXX)**
  To use BLE function. Refer to “Renesas Flexible Software Package User’s Manual” for details.

- **Discovery API (R_BLE_Disc_XXX)**
  To perform service discovery. These APIs are generated by QE for BLE. Refer to “Bluetooth Low Energy Profile Developer’s Guide(R01AN5428)” and “RA4W1 Group Bluetooth LE Profile API Document User's Manual (R11UM0154)” for the details of the API.

- **GATT Server API (R_BLE_GATTS_XXX)**
  To use GATT profile server function. These APIs are generated by QE for BLE. Refer to "Bluetooth Low Energy Profile Developer's Guide(R01AN5428)" and "RA4W1 Group Bluetooth LE Profile API Document User's Manual (R11UM0154)" for the details of the API.
- **GATT Client API (R_BLE_GATTC_XXX)**
  To use GATT profile client function. These APIs are generated by QE for BLE. Refer to "Bluetooth Low Energy Profile Developer's Guide(R01AN5428)" and "RA4W1 Group Bluetooth LE Profile API Document User's Manual (R11UM0154)" for the details of the API.

- **GATT service API (R_BLE_[GATT service abbreviation + S(Server) or C(Client)]_XXX)**
  Auxiliary functions available for the BLE Application. These APIs are generated by QE for BLE. Refer to "Bluetooth Low Energy Profile Developer's Guide(R01AN5428)" and "RA4W1 Group Bluetooth LE Profile API Document User's Manual (R11UM0154)" for the details of the API.

- **Abstraction API (RM_BLE_ABS_XXX)**
  Makes it easy to use the frequently used BLE functions. Refer to "Renesas Flexible Software Package User's Manual" for details.

APIs that can be called from BLE core task and GATT application task in FreeRTOS and Azure RTOS environment have the restrictions. Following categories of API can call only from BLE core task.

- GAP API (R_BLE_GAP_XXX, R_BLE_L2CAP_XXX, R_BLE_VS_XXX)
- Discovery API (R_BLE_Disc_XXX)
- GATT Server API (R_BLE_GATTS_XXX)
- GATT Client API (R_BLE_GATTC_XXX)
- Abstraction API (RM_BLE_ABS_XXX)

Following category of API can call from either BLE core task or GATT application task.

- GATT service API (R_BLE_[GATT service abbreviation + S(Server) or C(Client)]_XXX)

When BLE GATT Application task calls GATT service API, GATT communication is processed in BLE core task or BLE execute task. Figure 8 shows Bluetooth LE communication when two BLE GATT Application tasks control GATT services and send notification of the GATT service characteristic on FreeRTOS / Azure RTOS environment.

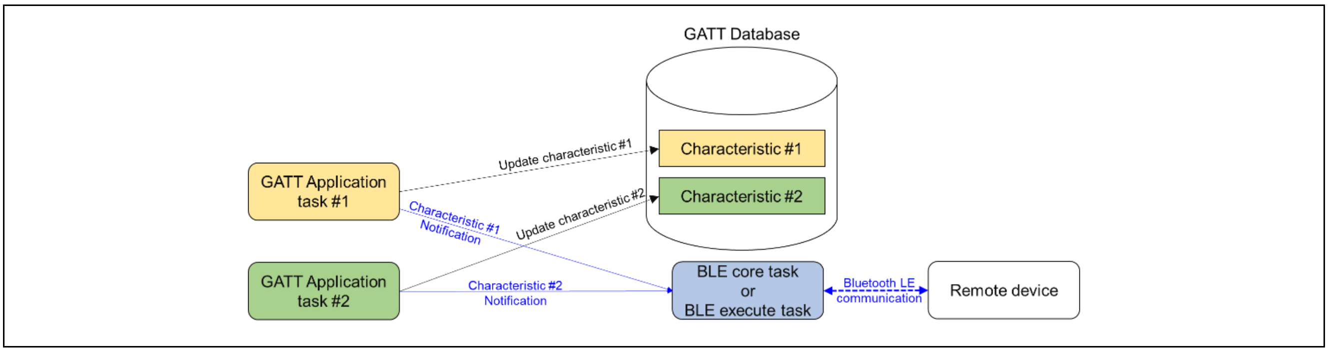


Figure 8. BLE core task and GATT Application task

Table 2 shows the directory / file structure of BLE application when using QE for BLE. Items shown in **bold** could add / modify according to use case.

**Table 2. Directory / File structure**

| Directory/File structure | | | | Description |
|---|---|---|---|---|
| qe_gen | ble | discovery | | Service discovery related APIs |
| | | profile_cmn | | Profile common APIs |
| | | **app_main.c** | | **Main code**<br>**C source code where user describe the BLE application.** |
| | | gatt_db.c | | GATT Database |
| | | gatt_db.h | | GATT Database |
| | | r_ble_XXX.c | | Profile API<br>XXX depends on the included profile name. |
| | | r_ble_XXX.h | | Profile API<br>XXX depends on the included profile name |
| ra | fsp | inc | api | BLE interface file<br>r_ble_api.h<br>rm_ble_abs_api.h |
| | | | instances | Abstraction API(GAP)<br>rm_ble_abs.h |
| | | lib | r_ble | BLE Protocol Stack<br>See also section 1.3. |
| | | src | rm_ble_abs | Abstraction API(GAP)<br>rm_ble_abs.c |
| | aws | amazon-freertos | | FeeRTOS kernel<br>(Only FreeRTOS environment) |
| | microsoft | azure-rtos | | Azure RTOS kernel<br>(Only Azure RTOS environment) |
| ra_gen | --- | --- | | RA configuration generated. |
| ra_cfg | fsp_cfg | r_ble_cfg.h | | Configuration option file |
| | | rm_ble_abs_cfg.h | | Configuration option file |
| | | azure | tx/tx_user.h | Azure RTOS configuration<br>(Only Azure RTOS environment) |
| | aws | FreeRTOSConfig.h | | FreeRTOS configuration<br>(Only FreeRTOS environment) |
| **src** | **---** | **hal_entry.c** | | **User code entry point.**<br>**(BareMetal)** |
| | | **XXX_entry.c** | | **User task creation.**<br>**XXX depends on task name which defined by user.**<br>**(Only RTOS environment)** |
| | | ***.c | | **User created C source codes** |
| | | ***.h | | **User created header files** |

## 1.3 BLE protocol stack

The Bluetooth protocol stack provides as static library. Customer can select “Extended”, “Balance” and “Compact” type according to the supported BLE features. Supported BLE features of each type are shown in Table 3.

**Table 3. Features supported by each type of BLE Protocol Stack**

| BLE Features | Library type | | |
|---|---|---|---|
| | Extended | Balance | Compact |
| GAP role | Central,<br>Peripheral,<br>Observer,<br>Broadcaster | Central,<br>Peripheral,<br>Observer,<br>Broadcaster | Peripheral,<br>Broadcaster |
| GATT role | Server,<br>Client | Server,<br>Client | Server,<br>Client |
| LE 2M PHY | Yes | Yes | No |
| LE Coded PHY | Yes | Yes | No |
| LE Advertising Extensions | Yes | No | No |
| LE Channel Selection Algorithm #2 | Yes | Yes | No |
| High Duty Cycle Non-Connectable Advertising | Yes | Yes | Yes |
| LE Secure Connections | Yes | Yes | Yes |
| Link Layer privacy | Yes | Yes | Yes |
| Link Layer Extended Scanner Filter policies | Yes | Yes | No |
| LE Data Packet Length Extension | Yes | Yes | Yes |
| LE L2CAP Connection Oriented Channel Support | Yes | No | No |
| Low Duty Cycle Directed Advertising | Yes | Yes | Yes |
| LE Link Layer Topology | Yes | Yes | No |
| LE Ping | Yes | Yes | Yes |
| 32-bit UUID support in LE | Yes | Yes | Yes |

## 2. How to use demo project

This chapter describes how to use demo project with this document.

### 2.1 Operating environment

Table 4 shows the hardware requirements for building and debugging BLE software.

**Table 4. Hardware requirements**

| Hardware | Description |
|---|---|
| Host PC | Windows® 10 PC with USB interface. |
| MCU Board | The MCU used must support BLE functions.<br>EK-RA4W1 [RTK7EKA4W1S00000BJ] |
| On-chip debugging emulators | The EK-RA4W1 has an on-board debugger (J-Link OB), therefore it is not necessary to prepare an emulator. |
| E2 lite emulator | Needed if user wants to write device-specific data (refer to section 4.2) in custom board by using Renesas Flash Programmer. |
| USB cables | Used to connect to the MCU board.<br>EK-RA4W1: 2 USB A-microB cable |

Table 5 shows the software requirements for build and debug BLE software.

**Table 5. Software requirements**

| Software | | Version | Description |
|---|---|---|---|
| GCC environment | e$^2$ studio | 2022-10 | Integrated development environment (IDE) for Renesas devices. |
| | GCC ARM Embedded | 10.3-2021.10 | C/C++ Compiler. (Download from e$^2$ studio installer) |
| | Renesas Flexible Software Package (FSP) | V4.1.0 | Software package for making applications for the RA microcontroller series. |
| | QE for BLE[RA] | V1.5.0 | Generates the source codes (BLE base skeleton program) as a base for the BLE Application and the BLE Profile.<br>Install latest QE for BLE and QE utility by referring release note on following link.<br>https://www.renesas.com/us/en/software-tool/qe-ble-development-assistance-tool-bluetooth-low-energy |
| | QE utility [RA] | V1.5.0 | |
| | SEGGER J-Flash | V7.80c | Tool for programming the on-chip flash memory of microcontrollers. |
| Header files | | | All API calls and their supporting interface definitions located in r_ble_api.h and rm_ble_abs_api.h. |
| Integer types | | | It uses ANSI C99 “Exact width integer types”. These types are defined in stdint.h. |
| Endian | | | Little endian |

## 2.2 Importing demo project

Demo project provided with this document may be imported into e² studio using following steps in this section.

1. Select **File → Import**.

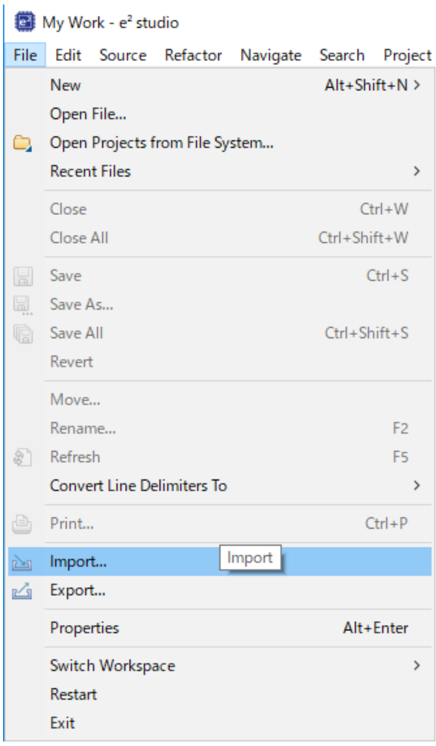
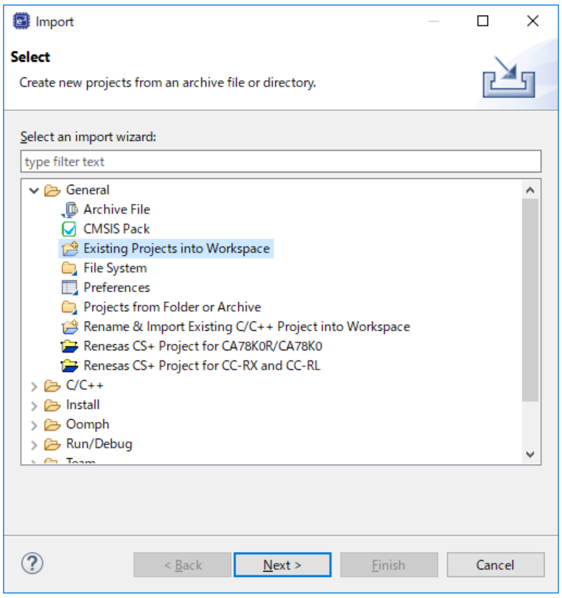


Figure 9. File menu

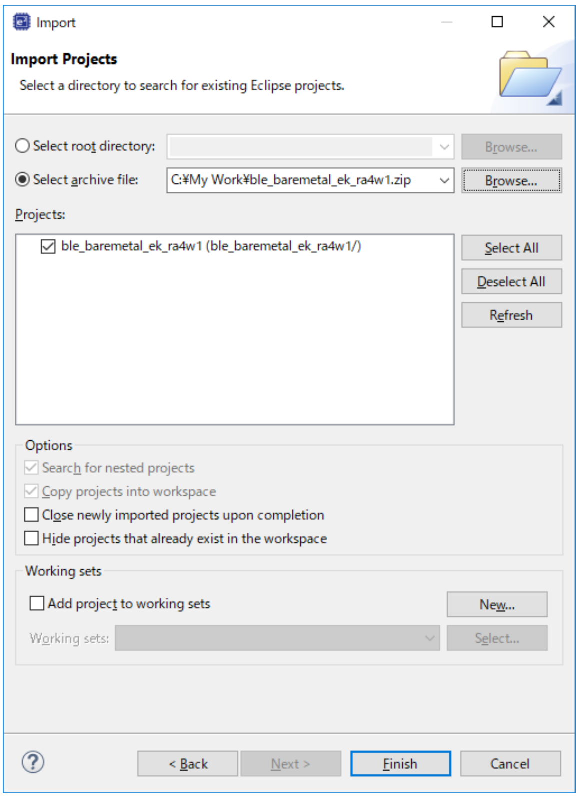
2. Select **Existing Projects into Workspace** and click **Next** button.



Create new projects from an archive file or directory.

Figure 10. Select an import wizard

3. Select **Select archive file**, click **Browse…** button and select the demo project archive files. Click **Finish** button and the demo project is imported. Imported project include r01an5402.



Import

**Import Projects**

Select a directory to search for existing Eclipse projects.

○ Select root directory:

● Select archive file: C:¥My Work¥ble_baremetal_ek_ra4w1.zip

Projects:

☑ ble_baremetal_ek_ra4w1 (ble_baremetal_ek_ra4w1/)

Options

☑ Search for nested projects

☑ Copy projects into workspace

☐ Close newly imported projects upon completion

☐ Hide projects that already exist in the workspace

Working sets

☐ Add project to working sets

Working sets:

**Figure 11. Import Project**

4. Open FSP configuration by selecting **Project→Open FSP configuration.**

5. Press Generate Project Content button and then source code of related peripheral driver will automatically generate.

As a result of import, following file structure will appear in e$^2$ studio project explorer.

**Table 6. File structure about demo project**

| Directory/File structure | | | | Description |
|---|---|---|---|---|
| qe_gen | ble | discovery | | Service discovery related APIs |
| | | profile_cmn | | Profile common APIs |
| | | app_main.c | | Main code |
| | | gatt_db.c | | GATT Database |
| | | gatt_db.h | | GATT Database |
| | | r_ble_lss.c | | Profile API |
| | | r_ble_lss.h | | Profile API |
| ra | fsp | Inc | api | BLE interface file<br>r_ble_api.h<br>rm_ble_abs_api.h |
| | | | instances | Abstraction API(GAP)<br>rm_ble_abs.h |
| | | lib | r_ble | BLE Protocol Stack (Extended type) |
| | | src | rm_ble_abs | Abstraction API(GAP)<br>rm_ble_abs.c |
| | aws | amazon-freertos | | FreeRTOS kernel (Only FreeRTOS environment) |
| | microsoft | azure-rtos | | Azure RTOS kernel (Only Azure RTOS environment) |
| ra_gen | --- | --- | | RA configuration generated. |
| ra_cfg | fsp_cfg | r_ble_cfg.h | | Configuration option file |
| | | rm_ble_abs_cfg.h | | Configuration option file |
| | | azure | tx/tx_user.h | Azure RTOS configuration (Only Azure RTOS environment) |
| | aws | FreeRTOSConfig.h | | FreeRTOS configuration (Only FreeRTOS environment) |
| src | --- | hal_entry.c | | User code entry point. (BareMetal) |
| | | ble_core_task_entry.c | | BLE task implementation (Only RTOS environment) |
| | | lss_task.c | | LED switch service task implementation (Only RTOS environment) |
| | | task_function.h | | LED switch service task header file (Only RTOS environment) |
| | app_lib | cli | | CLI functionality provided by this demo project |
| | | cmd | | Commands of CLI provided by this project |
| | | logger | | Logger functionality provided by this demo project |

## 2.3 Building and debugging

Refer to “e$^2$ studio Getting Started Guide (R20UT4204)”.

## 2.4 Demo project behavior

### 2.4.1 Preparation of demo

GATT Server demo projects can work by standalone. In case of making them work by standalone, refer to "EK-RA4W1 Quick Start Guide (R20QS0015)". GATT Client demo projects and GATT Server demo projects with CLI can accept commands received via r_sci_uart. User can handle the communication between PC and EK-RA4W1 the same as COM ports by the terminal emulator like Tera Term because EK-RA4W1 board equips the USB-Serial converter IC. Setting of the terminal software for these demo projects is following table.

**Table 7. Setting of the terminal software**

| | |
|---|---|
| New line (Receive) | LF |
| New line (Transmit) | CR |
| Terminal Mode | VT100 |
| Baud rate | 115200 |
| Data bits | 8bits |
| Parity | None |
| Stop bits | 1bit |
| Flow control | None |

### 2.4.2 GATT Server projects behavior

GATT Server demo projects provided with this document will work as mentioned next. Refer to "EK-RA4W1 Quick Start Guide (R20QS0015)" for the details of the EK-RA4W1 and the GATT Browser.

- When powered ON EK-RA4W1 or user's custom board with the demo project programmed will start advertising.
- By scanning from remote device (e.g. smart phone with GATT browser), the remote device will detect EK-RA4W1 or user's custom board as "TEST_RBLE" or "RBLE".

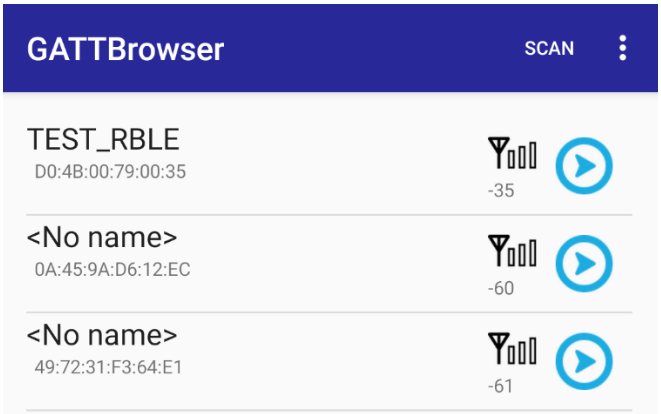
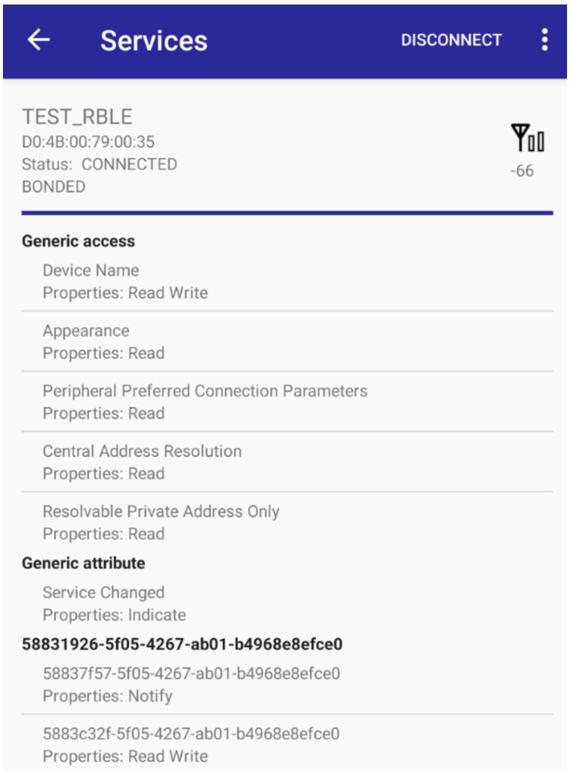


Figure 12. Scan result example

- When BLE connection is established between EK-RA4W1 or user's custom board and the remote device, EK-RA4W1 or user's custom board will stop advertising.

- The services and characteristics will be displayed after performing GATT service discovery from the remote device. This demo project includes following services.
  - ➢ LED Switch Service (UUID: 5883**1926**-5F05-4267-AB01-B4968E8EFCE0)
  - ➢ Switch State Characteristic (UUID: 5883**7F57**-5F05-4267-AB01-B4968E8EFCE0)
  - ➢ LED Blink Rate Characteristic (UUID: 5883**C32F**-5F05-4267-AB01-B4968E8EFCE0)



TEST_RBLE
D0:4B:00:79:00:35
Status: CONNECTED
BONDED
-66

**Generic access**
Device Name
Properties: Read Write
Appearance
Properties: Read
Peripheral Preferred Connection Parameters
Properties: Read
Central Address Resolution
Properties: Read
Resolvable Private Address Only
Properties: Read

**Generic attribute**
Service Changed
Properties: Indicate

**58831926-5f05-4267-ab01-b4968e8efce0**
58837f57-5f05-4267-ab01-b4968e8efce0
Properties: Notify
5883c32f-5f05-4267-ab01-b4968e8efce0
Properties: Read Write

**Figure 13. GATT Services**

All included services are shown below. (WR : Write, RD : Read, IN : Indication, NT : Notification)

**Table 8. GATT services**

| ATT Handle | ATT Type | Properties | ATT Values | Definition |
|---|---|---|---|---|
| GAP Service | | | | |
| 0x0001 | 0x28,0x00 | RD | 0x00,0x18 | GAP Service Declaration |
| 0x0002 | 0x28,0x03 | RD | 0x0A,0x03,0x00,0x00,0x2A | Device Name characteristic Declaration |
| 0x0003 | 0x00,0x2A | RD,WR | 0x00,0x00,0x00,0x00,0x00,0x00... | Device Name characteristic value |
| 0x0004 | 0x28,0x03 | RD | 0x02,0x05,0x00,0x01,0x2A | Appearance characteristic Declaration |
| 0x0005 | 0x01,0x2A | RD | 0x00,0x00 | Appearance characteristic value |
| 0x0006 | 0x28,0x03 | RD | 0x02,0x07,0x00,0x04,0x2A | Peripheral Preferred Connection Parameters characteristic Declaration |
| 0x0007 | 0x04,0x2A | RD | 0x00,0x00,0x00,0x00,0x00,0x00... | Peripheral Preferred Connection Parameters characteristic value |
| 0x0008 | 0x28,0x03 | RD | 0x02,0x09,0x00,0xA6,0x2A | Central Address Resolution characteristic Declaration |
| 0x0009 | 0xA6,0x2A | RD | 0x00 | Central Address Resolution characteristic value |
| 0x000A | 0x28,0x03 | RD | 0x02,0x0B,0x00,0xC9,0x2A | Resolvable Private Address Only characteristic Declaration |
| 0x000B | 0xC9,0x2A | RD | 0x00 | Resolvable Private Address Only characteristic value |
| GATT Service | | | | |
| 0x000C | 0x28,0x00 | RD | 0x01,0x18 | GATT Service Declaration |
| 0x000D | 0x28,0x03 | RD | 0x20,0x0E,0x00,0x05,0x2A | Service Changed characteristic Declaration |
| 0x000E | 0x05,0x2A | IN | 0x00,0x00,0x00,0x00 | Service Changed characteristic value |
| 0x000F | 0x02,0x29 | RD,WR | 0x00,0x00 | Client Characteristic Configuration descriptor |
| LED Switch Service(Custom Service) | | | | |
| 0x0010 | 0x28,0x00 | RD | 0xE0, 0xFC, 0x8E, 0x8E, 0x96, 0xB4, 0x01, 0xAB, 0x67, 0x42, 0x05, 0x5F, 0x26, 0x19, 0x83, 0x58 | LED Switch Service(Custom Service) Declaration |
| 0x0011 | 0x28,0x03 | RD | 0xE0, 0xFC, 0x8E, 0x8E, 0x96, 0xB4, 0x01, 0xAB, 0x67, 0x42, 0x05, 0x5F, 0x57, 0x7F, 0x83, 0x58 | Switch State characteristic Declaration |
| 0x0012 | 0xE0,0xFC,0x8E... | NT | 0x00 | Switch State characteristic value |
| 0x0013 | 0x02,0x29 | RD,WR | 0x00,0x00 | Client Characteristic Configuration descriptor |
| 0x0014 | 0x28,0x03 | RD | 0xE0, 0xFC, 0x8E, 0x8E, 0x96, 0xB4, 0x01, 0xAB, 0x67, 0x42, 0x05, 0x5F, 0x2F, 0xC3, 0x83, 0x58 | LED Blink Rate characteristic Declaration |
| 0x0015 | 0xE0,0xFC,0x8E... | RD,WR | 0x00 | LED Blink Rate characteristic value |

- If the LED Switch Service second parameter in the gs_gatt_service variable in the gatt_db.c is set to **BLE_GATT_DB_SER_SECURITY_UNAUTH**, the demo project will request pairing to access to the characteristic in the LED Switch Service.

```
static const st_ble_gatts_db_serv_cfg_t gs_gatt_service[] =
{
………
    /* LED Switch Service(Custom Service) */
    {
        /* Num of Services */
        {
            1,
        },
        /* Description */
        BLE_GATT_DB_SER_SECURITY_UNAUTH,
        /* Service Start Handle */
        0x0010,
………
};
```

**Code 1. The security setting of the access to the LED Switch Service. (Necessary pairing case)**

If the LED Switch Service second parameter in the gs_gatt_service variable in the gatt_db.c is set **0** is set, the demo project will not request pairing.

```
static const st_ble_gatts_db_serv_cfg_t gs_gatt_service[] =
{
………
    /* LED Switch Service(Custom Service) */
    {
        /* Num of Services */
        {
            1,
        },
        /* Description */
        0,
        /* Service Start Handle */
        0x0010,
………
};
```

**Code 2. The security setting of the access to the LED Switch Service. (Not necessary pairing case)**

- After enabling notification in the switch state characteristic, notification packet will send by pushing switch on EK-RA4W1 or user’s custom board.
- LED on RA4W1 or user’s custom board will blink according to numeric value which is written to the LED blink rate characteristic from the remote device. Note that the LED will turn off by writing 0x00 to the characteristic and remain on by writing 0xFF to the characteristic.
- When disconnected between EK-RA4W1 or user’s custom board and the remote device, EK-RA4W1 or user’s custom board will re-start advertising.

Figure 14 shows message sequence chart about behavior of demo projects accompanying this document.

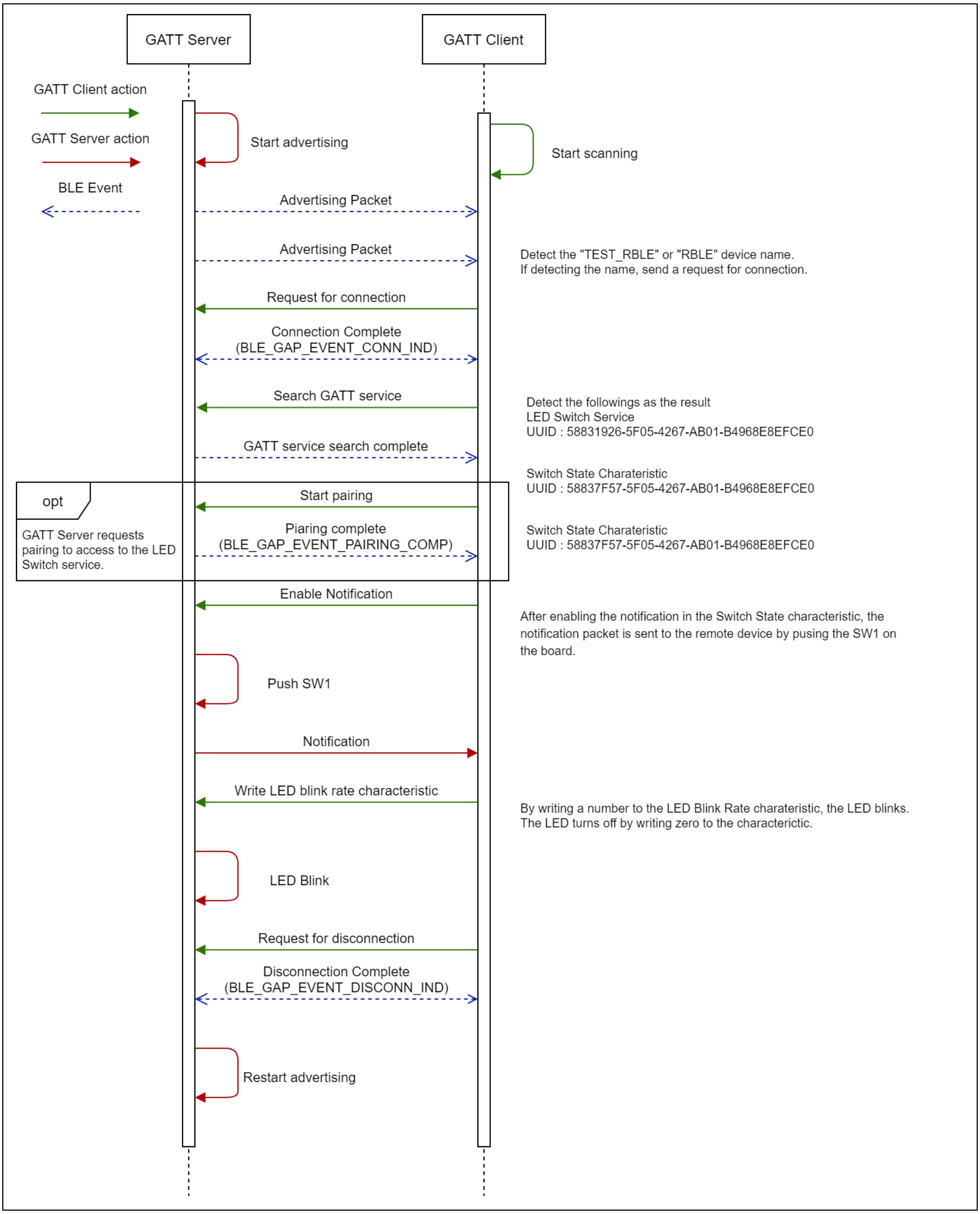


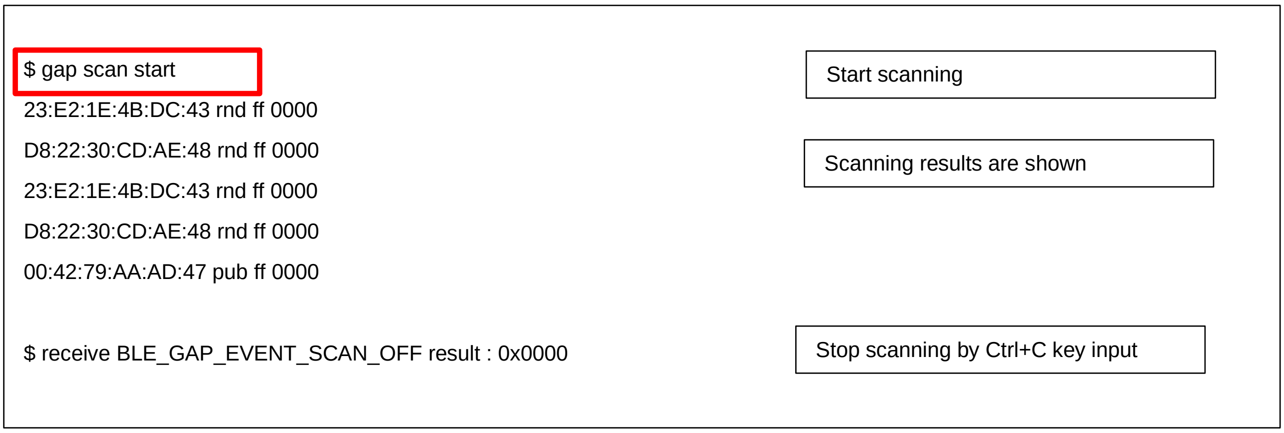
Figure 14. Usage example for demo projects

### 2.4.3 GATT Client demo projects behavior

GATT Client can perform various procedures in relation to GATT Client role by receiving commands via the terminal emulator. Some parts of following procedures can be also applied to GATT Server. Please refer to section 4.6. for details of each command.

#### (1) Scanning

GATT Client can start scanning procedure by following command. Then GATT Client can stop scanning procedure by Ctrl+C key input to terminal emulator.



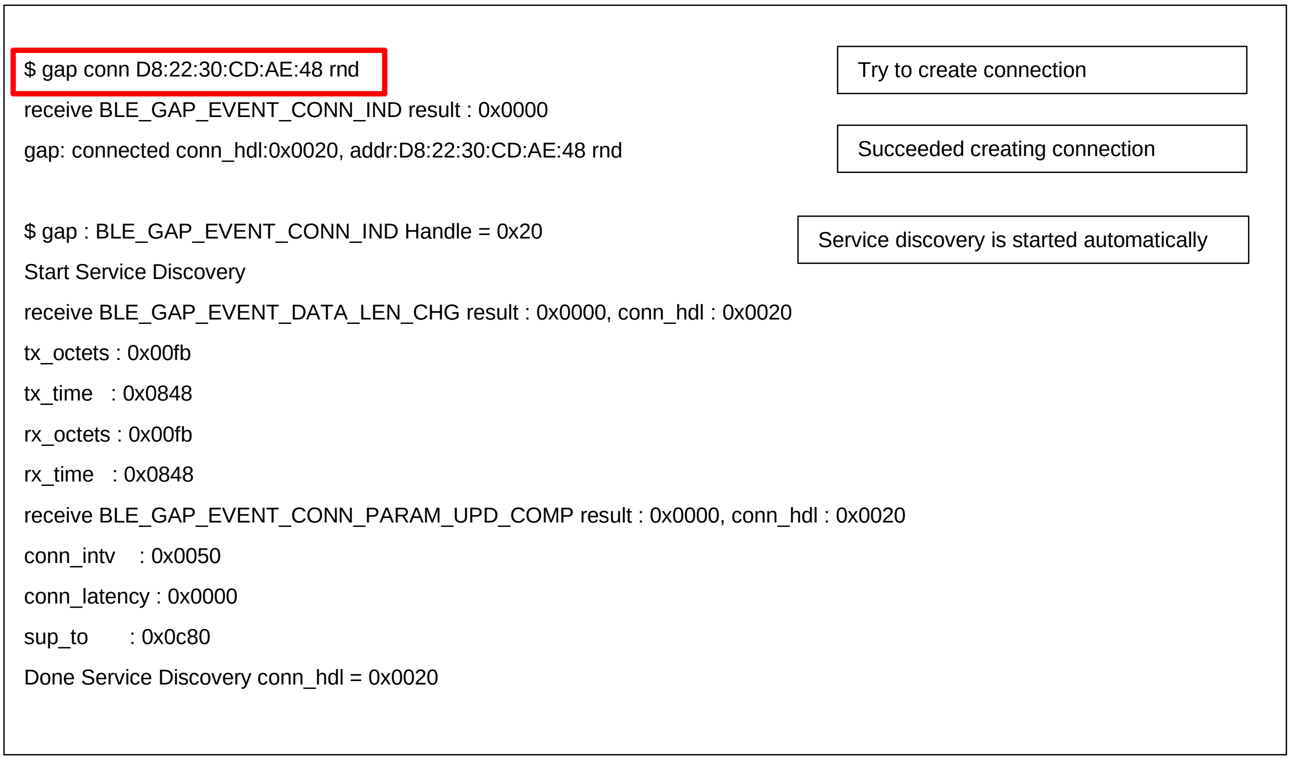
```
$ gap scan start
23:E2:1E:4B:DC:43 rnd ff 0000
D8:22:30:CD:AE:48 rnd ff 0000
23:E2:1E:4B:DC:43 rnd ff 0000
D8:22:30:CD:AE:48 rnd ff 0000
00:42:79:AA:AD:47 pub ff 0000

$ receive BLE_GAP_EVENT_SCAN_OFF result : 0x0000
```

Figure 15. Scanning command and response

#### (2) Connection

GATT Client can try to create connection with GATT Server by following command.



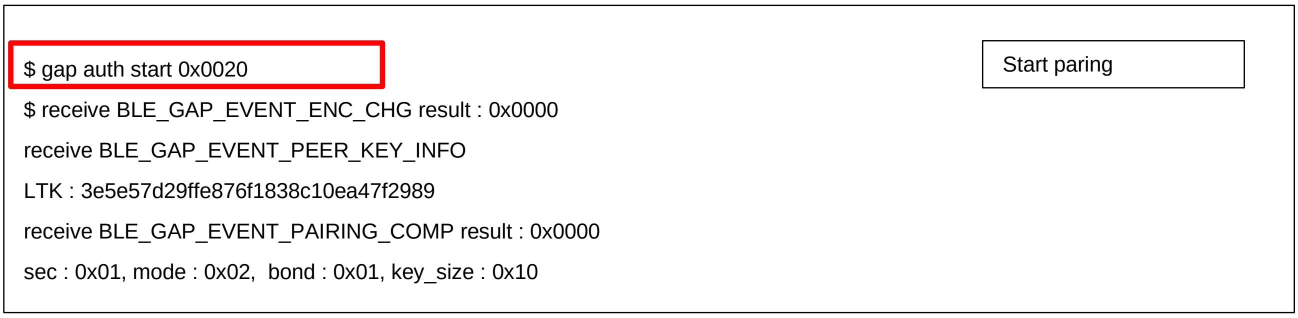
```
$ gap conn D8:22:30:CD:AE:48 rnd
receive BLE_GAP_EVENT_CONN_IND result : 0x0000
gap: connected conn_hdl:0x0020, addr:D8:22:30:CD:AE:48 rnd

$ gap : BLE_GAP_EVENT_CONN_IND Handle = 0x20
Start Service Discovery
receive BLE_GAP_EVENT_DATA_LEN_CHG result : 0x0000, conn_hdl : 0x0020
tx_octets : 0x00fb
tx_time   : 0x0848
rx_octets : 0x00fb
rx_time   : 0x0848
receive BLE_GAP_EVENT_CONN_PARAM_UPD_COMP result : 0x0000, conn_hdl : 0x0020
conn_intv    : 0x0050
conn_latency : 0x0000
sup_to       : 0x0c80
Done Service Discovery conn_hdl = 0x0020
```

Figure 16. Creating connection command and response

### (3) Paring (Option)

GATT Client and GATT Server can start paring procedure with the device which it is connecting with by following command.

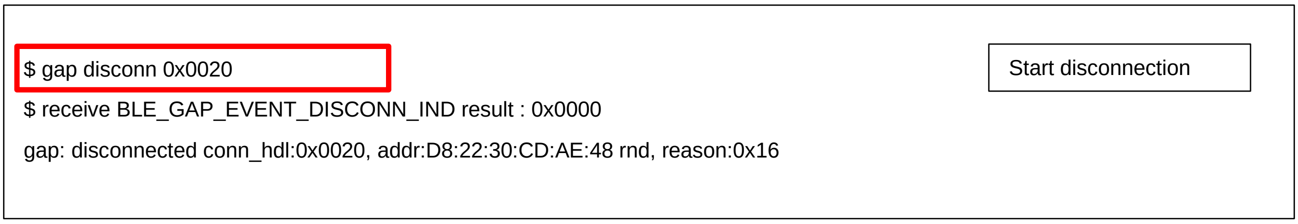


```
$ gap auth start 0x0020
$ receive BLE_GAP_EVENT_ENC_CHG result : 0x0000
receive BLE_GAP_EVENT_PEER_KEY_INFO
LTK : 3e5e57d29ffe876f1838c10ea47f2989
receive BLE_GAP_EVENT_PAIRING_COMP result : 0x0000
sec : 0x01, mode : 0x02,  bond : 0x01, key_size : 0x10
```

Figure 17. Paring command and response

### (4) Disconnection

GATT Client and GATT Server can disconnect connection with the device which it is connecting with by following command.

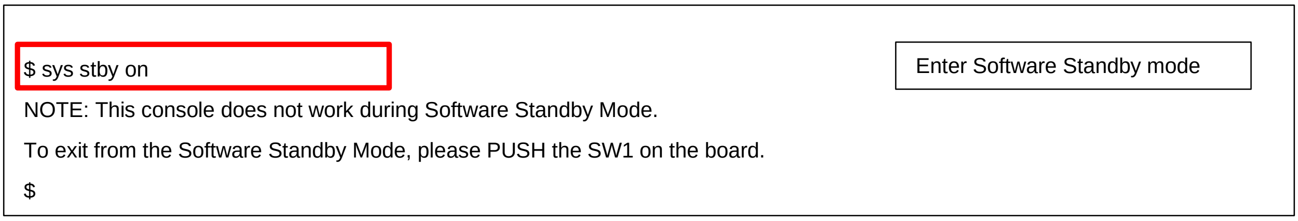


```
$ gap disconn 0x0020
$ receive BLE_GAP_EVENT_DISCONN_IND result : 0x0000
gap: disconnected conn_hdl:0x0020, addr:D8:22:30:CD:AE:48 rnd, reason:0x16
```

Figure 18. Disconnection command and response

### (5) Entering Software Standby mode

GATT Client and GATT Server can enter Software Standby mode by receiving following command. Pressing SW1 on EK-RA4W1 board, when making EK-RA4W1 board exit from Software Standby mode.



```
$ sys stby on
NOTE: This console does not work during Software Standby Mode.
To exit from the Software Standby Mode, please PUSH the SW1 on the board.
$
```

Figure 19. Standby command and response

### (6) LED switch service

GATT Client enables receiving notifications from GATT Server by following command. Notifications can be sent by pressing SW on EK-RA4W1 board of GATT Server side. And GATT Client can write and read value LED blink rate of GATT Server by following commands. LED0 on EK-RA4W1 of GATT Server side blinks, turns on and off according to value written by GATT Client.

```
$ lsc set_switch_state_ntf 0x0020 1
$
$ lsc : Recieve Notification from Server

$ lsc write_led_blink_rate 0x0020 0x01
$
$ lsc read_led_blink_rate 0x0020
$ lsc : LED blink rate = 0x1
```

Figure 20. LED switch service commands and responses

# 3. Demo project implementation

This chapter describes demo project implementation.

## 3.1 BareMetal environment (Server)

BLE application implemented in app_main.c. The app_main.c includes initialization processing and implementation of the main loop.

Note: When using QE for BLE, the skeleton code of the app_main.c is automatically generated.

### 3.1.1 Entry point

Call *app_main()* in hal_entry.c as following.

```
void hal_entry(void) {
  /* TODO: add your own code here */
  app_main();
}
```

**Code 3. Application entry point**

### 3.1.2 Main loop

The *app_main()* includes initialization and main loop. Main loop of this demo project is following.

```
void app_main(void)
{
…………
    /* Initialize Low Power Module */
    g_lpm0.p_api->open(g_lpm0.p_ctrl, g_lpm0.p_cfg);
```

MCU low Power driver initialization.

```
    /* Initialize BLE and profiles */
    ble_init();
```

BLE module initialization.

```
…………
    R_BLE_CMD_SetResetCb((ble_event_cb_t)ble_init);
/* End user code. Do not edit comment generated here */

    /* main loop */
    while (1)
    {
```

Main loop (Call *R_BLE_Execute*, Transition to MCU low power consumption state by *lowPowerModeEnter*)

```
………
        /* Process BLE Event */
        R_BLE_Execute();
…………
/* Hint: Input process that should be done during main loop such as calling processing functions */
/* Start user code for process during main loop. Do not edit comment generated here */
…………
        /* Disable IRQ */
        __disable_irq();

        /* UART reception on-going ? */
        if (false != get_uart_reception())
        {
            set_uart_reception(false);
            __enable_irq();
        }
        else
        {
            /* UART transmission on-going ? Allow enter software standby by sys stby command ? */
            if (true != g_inhibit_software_standby && true != get_uart_transmission() && true != g_led_blink_active)
            {
                /* Check whether there are executable BLE task or not */
                if (0 != R_BLE_IsTaskFree())
                {
                    /* There are no executable BLE task */
                    /* Terminate Command line */
                    R_BLE_CLI_Terminate();

                    /* Enter low power mode */
                    g_lpm0.p_api->lowPowerModeEnter(g_lpm0.p_ctrl);
```

Enter Software Standby mode

```
                    /* Enable interrupt for processing interrupt handler after wake up */
                    __enable_irq();

                    /* Resume Command line */
                    R_BLE_CLI_Init();

                }
                else
                {
                    /* There is BLE related task */
                    __enable_irq();
                }
            }
            else
                __enable_irq();
        }

…………
    /* Terminate BLE */
    RM_BLE_ABS_Close(&g_ble_abs0_ctrl);
………
}
```

**Code 4. app_main function**

### 3.1.3 Initialization process

The *ble_init()* initializes the BLE module, and register callback function and GATT database. Initialization process of this demo project is following.

```
ble_status_t ble_init(void)
{
    ble_status_t status;
    fsp_err_t err;

    /* Initialize BLE */
    err = RM_BLE_ABS_Open(&g_ble_abs0_ctrl, &g_ble_abs0_cfg);
    if (FSP_SUCCESS != err)
    {
        return err;
    }

    /* Initialize GATT Database */
    status = R_BLE_GATTS_SetDbInst(&g_gatt_db_table);
    if (BLE_SUCCESS != status)
    {
        return BLE_ERR_INVALID_OPERATION;
    }

    /* Initialize GATT server */
    status = R_BLE_SERVS_Init();
    if (BLE_SUCCESS != status)
    {
        return BLE_ERR_INVALID_OPERATION;
    }

    /*Initialize GATT client */
    status = R_BLE_SERVC_Init();
    if (BLE_SUCCESS != status)
    {
        return BLE_ERR_INVALID_OPERATION;
    }

    /* Set Prepare Write Queue */
    R_BLE_GATTS_SetPrepareQueue(gs_queue, BLE_GATTS_QUEUE_NUM);

    /* Initialize LED Switch Service server API
    status = R_BLE_LSS_Init(lss_cb);
    if (BLE_SUCCESS != status)
    {
        return BLE_ERR_INVALID_OPERATION;
    }

    return status;
}
```

BLE module initialization (*RM_ABS_BLE_Open*)

GATT database registration (*R_BLE_GATTS_SetDbInst*)
Note: Code-generated when GATT role is set as whichever Server and Client by QE for BLE.

GATT Server function initialization (*R_BLE_SERVS_Init*)
Note: Code-generated when GATT role is set as whichever Server and Client by QE for BLE.

GATT Client function initialization (*R_BLE_SERVC_Init*)
Note: Code-generated when GATT role is set as whichever Server and Client by QE for BLE.

Service initialization

**Code 5. Initialization**

Note: When using QE for BLE, the source code of the *ble_init()* function is automatically generated.

### 3.1.4 Register callback function

Registration of callback function is required to execute processing according to event from each layer of BLE protocol stack. Table 9 shows the callback registration API for each layer of BLE protocol stack.

**Table 9. Callback function registration API**

| Function block | Callback registration API | Comment |
|---|---|---|
| GAP | *RM_BLE_ABS_Open* or *R_BLE_GAP_Init* | Registered callback function is called when receiving the result of *R_BLE_GAP_XXX* such as Advertising, Scan, Connection establishment and so on. |
| GATT Server (Profile common) | *RM_BLE_ABS_Open* or *R_BLE_GATTS_RegisterCb* | Registered callback function is called when accessed from GATT Client. |
| GATT Client (Profile common) | *RM_BLE_ABS_Open* or *R_BLE_GATTC_RegisterCb* | Registered callback function is called when accessed from GATT Server. |
| Service Discovery (Profile common) | *R_BLE_DISC_Start* | Registered callback function is called when completing Service Discovery. |
| Vendor Specific | *RM_BLE_ABS_Open* or *R_BLE_VS_Init* | Registered callback function is called when receiving the result of *R_BLE_VS_XXX*. |
| L2CAP | *R_BLE_L2CAP_RegisterCfPsm* | Registered callback function is called when receiving the result of *R_BLE_L2CAP_XXX* such as that the response of L2CAP Credit-Based Flow Control request is received.<br>Note: Not code-generated by QE for BLE. |
| Server side profile API | *R_BLE_XXXS_Init*<br>(XXX is Service name) | Registered callback function is called when accessed from Client. |
| Client side profile API | *R_BLE_XXXC_Init*<br>(XXX is Service name) | Registered callback function is called when accessed from Server. |

Note1: *RM_BLE_ABS_Open* can register GAP, GATT Server, GATT Client, and VS callback functions for each layer.

Note2: “XXX” included in name of callback registration API is “LSS” in demo project.

Note3: Callback registration API which is not used in demo project is also listed for reference.

### 3.1.5 Registering GATT database (R_BLE_GATTS_SetDbInst)

When creating a GATT service application, QE for BLE generates a service database code in the following file.

- gatt_db.c
- gatt_db.h

This GATT database is registered by *R_BLE_GATTS_SetDbInst()*.

### 3.1.6 Main loop and scheduler (R_BLE_Execute)

BLE protocol stack include a scheduler to process R_BLE API called by BLE application. Task to be performed are loaded to message queue in the scheduler when the API is called in BLE application. Call *R_BLE_Execute()* in main loop to start the scheduler and process the task in BLE protocol stack. Events that occur when a task is processed in BLE protocol stack are notified to callback function registered in section 3.1.4. Figure 21 shows typical sequence chart of BLE application.

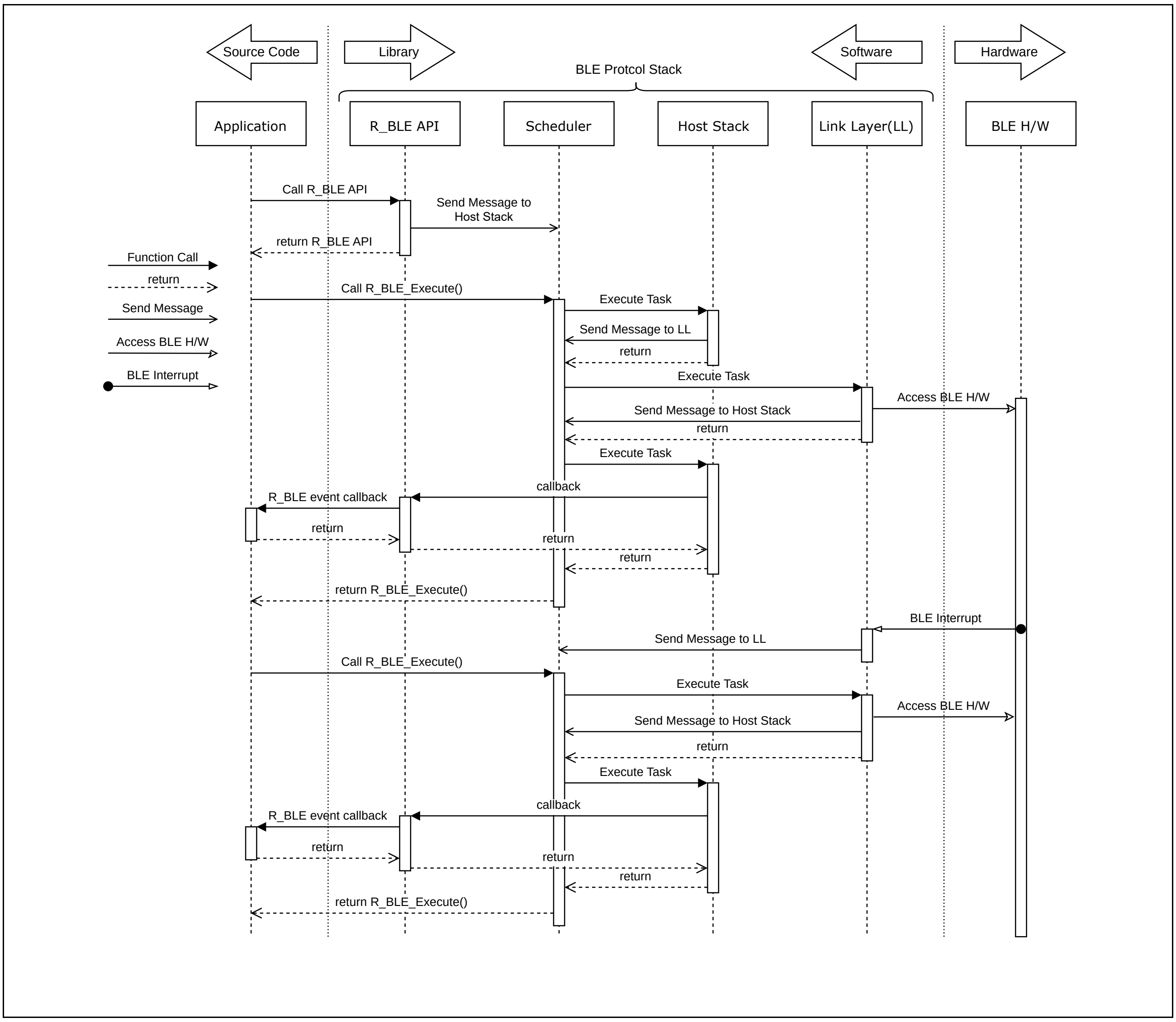


Figure 21. Basic sequence chart of BLE Protocol Stack

Relationship between callback function and event from each layer describe from the next section.

### 3.1.7 GAP event (gap_cb function)

GAP callback function receives following events.

```
enum   e_ble_gap_evt_t {
   BLE_GAP_EVENT_INVALID = 0x1001,
   BLE_GAP_EVENT_STACK_ON,
   BLE_GAP_EVENT_STACK_OFF,
   BLE_GAP_EVENT_LOC_VER_INFO,
   BLE_GAP_EVENT_HW_ERR,
   BLE_GAP_EVENT_CMD_ERR = 0x1101,
   BLE_GAP_EVENT_ADV_REPT_IND,
   BLE_GAP_EVENT_ADV_PARAM_SET_COMP,
   BLE_GAP_EVENT_ADV_DATA_UPD_COMP,
   BLE_GAP_EVENT_ADV_ON,
   BLE_GAP_EVENT_ADV_OFF,
   BLE_GAP_EVENT_PERD_ADV_PARAM_SET_COMP,
   BLE_GAP_EVENT_PERD_ADV_ON,
   BLE_GAP_EVENT_PERD_ADV_OFF,
   BLE_GAP_EVENT_ADV_SET_REMOVE_COMP,
   BLE_GAP_EVENT_SCAN_ON,
   BLE_GAP_EVENT_SCAN_OFF,
   BLE_GAP_EVENT_SCAN_TO,
   BLE_GAP_EVENT_CREATE_CONN_COMP,
   BLE_GAP_EVENT_CONN_IND,
   BLE_GAP_EVENT_DISCONN_IND,
   BLE_GAP_EVENT_CONN_CANCEL_COMP,
   BLE_GAP_EVENT_WHITE_LIST_CONF_COMP,
   BLE_GAP_EVENT_RAND_ADDR_SET_COMP,
   BLE_GAP_EVENT_CH_MAP_RD_COMP,
   BLE_GAP_EVENT_CH_MAP_SET_COMP,
   BLE_GAP_EVENT_RSSI_RD_COMP,
   BLE_GAP_EVENT_GET_REM_DEV_INFO,
   BLE_GAP_EVENT_CONN_PARAM_UPD_COMP,
   BLE_GAP_EVENT_CONN_PARAM_UPD_REQ,
   BLE_GAP_EVENT_AUTH_PL_TO_EXPIRED,
   BLE_GAP_EVENT_SET_DATA_LEN_COMP,
   BLE_GAP_EVENT_DATA_LEN_CHG,
   BLE_GAP_EVENT_RSLV_LIST_CONF_COMP,
   BLE_GAP_EVENT_RPA_EN_COMP,
   BLE_GAP_EVENT_SET_RPA_TO_COMP,
   BLE_GAP_EVENT_RD_RPA_COMP,
   BLE_GAP_EVENT_PHY_UPD,
   BLE_GAP_EVENT_PHY_SET_COMP,
   BLE_GAP_EVENT_DEF_PHY_SET_COMP,
   BLE_GAP_EVENT_PHY_RD_COMP,
   BLE_GAP_EVENT_SCAN_REQ_RECV,
   BLE_GAP_EVENT_CREATE_SYNC_COMP,
   BLE_GAP_EVENT_SYNC_EST,
   BLE_GAP_EVENT_SYNC_TERM,
   BLE_GAP_EVENT_SYNC_LOST,
   BLE_GAP_EVENT_SYNC_CREATE_CANCEL_COMP,
   BLE_GAP_EVENT_PERD_LIST_CONF_COMP,
   BLE_GAP_EVENT_PRIV_MODE_SET_COMP,
   BLE_GAP_EVENT_PAIRING_REQ = 0x1401,
   BLE_GAP_EVENT_PASSKEY_ENTRY_REQ,
   BLE_GAP_EVENT_PASSKEY_DISPLAY_REQ,
   BLE_GAP_EVENT_NUM_COMP_REQ,
   BLE_GAP_EVENT_KEY_PRESS_NTF,
   BLE_GAP_EVENT_PAIRING_COMP,
   BLE_GAP_EVENT_ENC_CHG,
   BLE_GAP_EVENT_PEER_KEY_INFO,
   BLE_GAP_EVENT_EX_KEY_REQ,
   BLE_GAP_EVENT_LTK_REQ,
   BLE_GAP_EVENT_LTK_RSP_COMP,
   BLE_GAP_EVENT_SC_OOB_CREATE_COMP
}
```

**Code 6. GAP event**

Reception condition of the frequently occurring events are shown below.

**Table 10. Frequently use event of GAP callback**

| Event | Reception condition |
|---|---|
| BLE_GAP_EVENT_STACK_ON(0x1001) | Complete *R_BLE_GAP_Init* |
| BLE_GAP_EVENT_ADV_PARAM_SET_COMP(0x1003) | Complete *R_BLE_GAP_SetAdvParam* |
| BLE_GAP_EVENT_ADV_DATA_UPD_COMP (0x1004) | Complete *R_BLE_GAP_SetAdvSresData* |
| BLE_GAP_EVENT_ADV_ON (0x1005) | Start Advertising |
| BLE_GAP_EVENT_ADV_OFF (0x1006) | End Advertising |
| BLE_GAP_EVENT_ADV_REPT_IND (0x1102) | Received advertising report |
| BLE_GAP_EVENT_SCAN_ON (0x1111) | Start Scan |
| BLE_GAP_EVENT_SCAN_OFF (0x1112) | End Scan |
| BLE_GAP_EVENT_CONN_IND (0x1115) | Start Connection |
| BLE_GAP_EVENT_CONN_IND (0x1115) | End Connection |
| BLE_GAP_EVENT_DISCONN_IND (0x1116) | End Disconnection |

GAP callback function in this demo project is following.

```
void gap_cb(uint16_t type, ble_status_t result, st_ble_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for GAP callback function common process. Do not edit comment generated here */

    R_BLE_CMD_AbsGapCb(type, result, p_data);

/* End user code. Do not edit comment generated here */

    switch(type)
    {
        case BLE_GAP_EVENT_STACK_ON:
        {
            R_BLE_CLI_Printf("gap : BLE_GAP_EVENT_STACK_ON \n");

            /* Get BD address for Advertising */
            R_BLE_VS_GetBdAddr(BLE_VS_ADDR_AREA_REG, BLE_GAP_ADDR_RAND);
        } break;

        case BLE_GAP_EVENT_CONN_IND:
        {
…………
        } break;

        case BLE_GAP_EVENT_DISCONN_IND:
        {
…………
        } break;

        case BLE_GAP_EVENT_CONN_PARAM_UPD_REQ:
        {
…………
        } break;

/* Hint: Add cases of GAP event macros defined as BLE_GAP_XXX */
/* Start user code for GAP callback function event process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */
    }
}
```

In this demo project, many parts of processing when receiving events are also implemented in R_BLE_CMD_AbsGapCb().

Complete GAP initialization

Get BD address

Connection complete

Disconnection has happened

Connection parameter request come from client

**Code 7. GAP callback function**

QE for BLE generates skeleton code for GAP callback function. User can add their own code into the skeleton code.

### 3.1.8 GATTS event (gatts_cb function)

GATT server (GATTS) callback function receives following events.

```
enum   e_r_ble_gatts_evt_t {
   BLE_GATTS_EVENT_EX_MTU_REQ = 0x3002,
   BLE_GATTS_EVENT_READ_BY_TYPE_RSP_COMP = 0x3009,
   BLE_GATTS_EVENT_READ_RSP_COMP = 0x300B,
   BLE_GATTS_EVENT_READ_BLOB_RSP_COMP = 0x300D,
   BLE_GATTS_EVENT_READ_MULTI_RSP_COMP = 0x300F,
   BLE_GATTS_EVENT_WRITE_RSP_COMP = 0x3013,
   BLE_GATTS_EVENT_PREPARE_WRITE_RSP_COMP = 0x3017,
   BLE_GATTS_EVENT_EXE_WRITE_RSP_COMP = 0x3019,
   BLE_GATTS_EVENT_HDL_VAL_CNF = 0x301E,
   BLE_GATTS_EVENT_DB_ACCESS_IND = 0x3040,
   BLE_GATTS_EVENT_CONN_IND = 0x3081,
   BLE_GATTS_EVENT_DISCONN_IND = 0x3082,
   BLE_GATTS_EVENT_INVALID = 0x30FF
}
```

**Code 8. GATTS event**

Reception condition of frequently occurring events is shown below.

**Table 11. Frequently use events of GATTS callback**

| Event | Reception condition |
|---|---|
| BLE_GATTS_EVENT_CONN_IND(0x3081) | Establish Connection |
| BLE_GATTS_EVENT_EX_MTU_REQ(0x3002) | Changing MTU is requested from GATT Client after Connection |
| BLE_GATTS_EVENT_DB_ACCESS_IND(0x3040) | Accessed to GATT database |
| BLE_GATTS_EVENT_READ_BY_TYPE_RSP_COMP(0x3009) | Complete sending Read By Type Response |
| BLE_GATTS_EVENT_WRITE_RSP_COMP(0x3013) | Complete sending Write Response |
| BLE_GATTS_EVENT_HDL_VAL_CNF(0x301E) | Complete receiving Confirmation from GATT Client |
| BLE_GATTS_EVENT_DISCONN_IND(0x3082) | End Disconnection |

GATTS callback function in this demo project is following.

```
void gatts_cb(uint16_t type, ble_status_t result, st_ble_gatts_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for GATT Server callback function common process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */

    R_BLE_SERVS_GattsCb(type, result, p_data);
    switch(type)
    {
/* Hint: Add cases of GATT Server event macros defined as BLE_GATTS_XXX */
/* Start user code for GATT Server callback function event process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */
    }
}
```

**Code 9. GATTS callback function**

QE for BLE generates skeleton code for GATTS callback function. User can add their own code into the skeleton code.

### 3.1.9 GATTC event (gattc_cb function)

GATT client (GATTC) callback function receives following events.

```
enum   e_r_ble_gattc_evt_t {
   BLE_GATTC_EVENT_ERROR_RSP = 0x4001,
   BLE_GATTC_EVENT_EX_MTU_RSP = 0x4003,
   BLE_GATTC_EVENT_CHAR_READ_BY_UUID_RSP = 0x4009,
   BLE_GATTC_EVENT_CHAR_READ_RSP = 0x400B,
   BLE_GATTC_EVENT_CHAR_PART_READ_RSP = 0x400D,
   BLE_GATTC_EVENT_MULTI_CHAR_READ_RSP = 0x400F,
   BLE_GATTC_EVENT_CHAR_WRITE_RSP = 0x4013,
   BLE_GATTC_EVENT_CHAR_PART_WRITE_RSP = 0x4017,
   BLE_GATTC_EVENT_HDL_VAL_NTF = 0x401B,
   BLE_GATTC_EVENT_HDL_VAL_IND = 0x401D,
   BLE_GATTC_EVENT_CONN_IND = 0x4081,
   BLE_GATTC_EVENT_DISCONN_IND = 0x4082,
   BLE_GATTC_EVENT_PRIM_SERV_16_DISC_IND = 0x40E0,
   BLE_GATTC_EVENT_PRIM_SERV_128_DISC_IND = 0x40E1,
   BLE_GATTC_EVENT_ALL_PRIM_SERV_DISC_COMP = 0x40E2,
   BLE_GATTC_EVENT_PRIM_SERV_DISC_COMP = 0x40E3,
   BLE_GATTC_EVENT_SECOND_SERV_16_DISC_IND = 0x40E4,
   BLE_GATTC_EVENT_SECOND_SERV_128_DISC_IND = 0x40E5,
   BLE_GATTC_EVENT_ALL_SECOND_SERV_DISC_COMP = 0x40E6,
   BLE_GATTC_EVENT_INC_SERV_16_DISC_IND = 0x40E7,
   BLE_GATTC_EVENT_INC_SERV_128_DISC_IND = 0x40E8,
   BLE_GATTC_EVENT_INC_SERV_DISC_COMP = 0x40E9,
   BLE_GATTC_EVENT_CHAR_16_DISC_IND = 0x40EA,
   BLE_GATTC_EVENT_CHAR_128_DISC_IND = 0x40EB,
   BLE_GATTC_EVENT_ALL_CHAR_DISC_COMP = 0x40EC,
   BLE_GATTC_EVENT_CHAR_DISC_COMP = 0x40ED,
   BLE_GATTC_EVENT_CHAR_DESC_16_DISC_IND = 0x40EE,
   BLE_GATTC_EVENT_CHAR_DESC_128_DISC_IND = 0x40EF,
   BLE_GATTC_EVENT_ALL_CHAR_DESC_DISC_COMP = 0x40F0,
   BLE_GATTC_EVENT_LONG_CHAR_READ_COMP = 0x40F1,
   BLE_GATTC_EVENT_LONG_CHAR_WRITE_COMP = 0x40F2,
   BLE_GATTC_EVENT_RELIABLE_WRITES_TX_COMP = 0x40F3,
   BLE_GATTC_EVENT_RELIABLE_WRITES_COMP = 0x40F4,
   BLE_GATTC_EVENT_INVALID = 0x40FF
}
```

**Code 10. GATTC event**

Reception condition of frequently occurring events is shown below.

**Table 12. Frequently use events of GATTC callback**

| Event | Reception condition |
|---|---|
| BLE_GATTC_EVENT_CONN_IND(0x4081) | Establish Connection |
| BLE_GATTC_EVENT_EX_MTU_RSP(0x4003) | Request Changing MTU to GATT Server after Connection and receive normal response |
| BLE_GATTC_EVENT_ERROR_RSP(0x4001) | Receive error response from GATT Server |
| BLE_GATTC_EVENT_HDL_VAL_NTF(0x401B) | Complete receiving Notification |
| BLE_GATTC_EVENT_HDL_VAL_IND(0x401D) | Complete receiving Indication |
| BLE_GATTC_EVENT_DISCONN_IND(0x4082) | End Disconnection |

GATTC callback function is following.

```
void gattc_cb(uint16_t type, ble_status_t result, st_ble_gattc_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for GATT Client callback function common process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */

    R_BLE_SERVC_GattcCb(type, result, p_data);
    switch(type)
    {
/* Hint: Add cases of GATT Client event macros defined as BLE_GATTC_XXX */
/* Start user code for GATT Client callback function event process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */
    }
}
```

**Code 11. GATTC callback function**

QE for BLE generates skeleton code for GATTC callback function. User can add their own code into the skeleton code.

### 3.1.10 VS event (vs_cb function)

Vender specific (VS) callback function receives following events.

```
enum   e_r_ble_vs_evt_t {
   BLE_VS_EVENT_SET_TX_POWER = 0x8001,
   BLE_VS_EVENT_GET_TX_POWER = 0x8002,
   BLE_VS_EVENT_TX_TEST_START = 0x8003,
   BLE_VS_EVENT_TX_TEST_TERM = 0x8004,
   BLE_VS_EVENT_RX_TEST_START = 0x8005,
   BLE_VS_EVENT_TEST_END = 0x8006,
   BLE_VS_EVENT_SET_CODING_SCHEME_COMP = 0x8007,
   BLE_VS_EVENT_RF_CONTROL_COMP = 0x8008,
   BLE_VS_EVENT_SET_ADDR_COMP = 0x8009,
   BLE_VS_EVENT_GET_ADDR_COMP = 0x800A,
   BLE_VS_EVENT_GET_RAND = 0x800B,
   BLE_VS_EVENT_TX_FLOW_STATE_CHG = 0x800C,
   BLE_VS_EVENT_FAIL_DETECT = 0x800D,
   BLE_VS_EVENT_SET_SCAN_CH_MAP = 0x800E,
   BLE_VS_EVENT_GET_SCAN_CH_MAP = 0x800F,
   BLE_VS_EVENT_INVALID = 0x80FF
}
```

**Code 12. VS event**

Reception condition of frequently occurring events are shown below.

**Table 13. Frequently use events of VS callback**

| Event | Reception condition |
|---|---|
| BLE_VS_EVENT_SET_TX_POWER(0x8001) | Complete *R_BLE_VS_SetTxPower* |
| BLE_VS_EVENT_GET_TX_POWER(0x8002) | Complete *R_BLE_VS_GetTxPower* |
| BLE_VS_EVENT_SET_ADDR_COMP(0x8009) | Complete *R_BLE_VS_SetBdAddr* |
| BLE_VS_EVENT_GET_ADDR_COMP(0x800A) | Complete *R_BLE_VS_GetBdAddr* |

VS callback function in this demo project is following.

```
void vs_cb(uint16_t type, ble_status_t result, st_ble_vs_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for vender specific callback function common process. Do not edit comment generated here */

   R_BLE_CMD_VsCb(type, result, p_data);

/* End user code. Do not edit comment generated here */

    R_BLE_SERVS_VsCb(type, result, p_data);
    switch(type)
    {
        case BLE_VS_EVENT_GET_ADDR_COMP:
        {
………
            RM_BLE_ABS_StartLegacyAdvertising(&g_ble_abs0_ctrl, &g_ble_advertising_parameter);
        } break;

/* Hint: Add cases of vender specific event macros defined as BLE_VS_XXX */
/* Start user code for vender specific callback function event process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */
    }
}
```

In this demo project, many parts of processing when receiving events are also implemented in R_BLE_CMD_VsCb().

Get BD address event

**Code 13. VS callback function**

QE for BLE generates skeleton code for VS callback function. User can add their own code into the skeleton code.

### 3.1.11 Server-side Profile API event ([service_name]s_cb function)

Callback function of the server side Profile API receives following events.

```
enum   e_ble_servs_event_t {
   BLE_SERVS_WRITE_REQ = 0x00,
   BLE_SERVS_WRITE_CMD = 0x01,
   BLE_SERVS_WRITE_COMP = 0x02,
   BLE_SERVS_READ_REQ = 0x03,
   BLE_SERVS_HDL_VAL_CNF = 0x04
}

enum   e_ble_[service name]s_event_t {
   BLE_[service name]S_EVENT_[characteristic name]_WRITE_REQ = 0xXX00,
   BLE_[service name]S_EVENT_[characteristic name]_WRITE_CMD= 0xXX01,
   BLE_[service name]S_EVENT_[characteristic name]_WRITE_COMP = 0xXX02,
   BLE_[service name]S_EVENT_[characteristic name]_READ_REQ = 0xXX03,
   BLE_[service name]S_EVENT_[characteristic name]_HDL_VAL_CNF = 0xXX04,
   BLE_[service name]S_EVENT_[characteristic name]_[descriptor name]_WRITE_REQ = 0xYY00,
   BLE_[service name]S_EVENT_[characteristic name]_[descriptor name]_READ_REQ = 0xYY03,
   :
   :
}
```

**Code 14. Server-side Profile API event**

Note1: The 10th to 15th bits are serial numbers that distinguish attributes (characteristics and descriptors). XX and YY are 00, 04, 08, 10, ..., FC.

Note2: [service name] is “LS” in this demo project.

Reception condition of frequently occurring events are shown below.

**Table 14. Frequently use events of Profile Server callback**

| Event | Reception condition |
|---|---|
| XXX_WRITE_REQ (0xXXX0) | Complete receiving Write Request |
| XXX_WRITE_CMD (0xXXX1) | Complete receiving Write Without Response |
| XXX_WRITE_COMP (0xXXX2) | Complete sending Write Response |
| XXX_READ_REQ (0xXXX3) | Complete receiving Read Request |
| XXX_HDL_VAL_CNF (0xXXX4) | Complete receiving Confirmation |

Note3: ”XXX” is “LSS” in this demo project.

Callback function of server side profile API in this demo project is following.

```
static void lss_cb(uint16_t type, ble_status_t result, st_ble_servs_evt_data_t *p_data)
{
    switch(type)
    {
………
        case BLE_LSS_EVENT_BLINK_RATE_WRITE_REQ:
        {
            g_current_blinky_interval = *(uint8_t *)p_data->p_param;

            if (g_current_blinky_interval == 0x00)
            {
                /* LED OFF */
                g_ioport.p_api->pinWrite(g_ioport.p_ctrl, BSP_IO_PORT_01_PIN_06, BSP_IO_LEVEL_HIGH);
                g_led_blink_active = false;
            }
            else if (g_current_blinky_interval == 0xFF)
            {
                /* LED ON */
                g_ioport.p_api->pinWrite(g_ioport.p_ctrl, BSP_IO_PORT_01_PIN_06, BSP_IO_LEVEL_LOW);
                g_led_blink_active = false;
            }
            else
            {
                g_led_blink_active = true;
                g_interval_update_flag = true;
            }
        } break;

        default:
            break;
/* End user code. Do not edit comment generated here */    }
}
```

Change LED blink rate

**Code 15. Profile Server callback function**

QE for BLE generates skeleton code for Profile Server callback function. User can add their own code into the skeleton code.

### 3.1.12 L2CAP event

L2CAP callback function receives following events.

```
enum   e_r_ble_l2cap_cf_evt_t {
   BLE_L2CAP_EVENT_CF_CONN_CNF = 0x5001,
   BLE_L2CAP_EVENT_CF_CONN_IND = 0x5002,
   BLE_L2CAP_EVENT_CF_DISCONN_CNF = 0x5003,
   BLE_L2CAP_EVENT_CF_DISCONN_IND = 0x5004,
   BLE_L2CAP_EVENT_CF_RX_DATA_IND = 0x5005,
   BLE_L2CAP_EVENT_CF_LOW_RX_CRD_IND = 0x5006,
   BLE_L2CAP_EVENT_CF_TX_CRD_IND = 0x5007,
   BLE_L2CAP_EVENT_CF_TX_DATA_CNF = 0x5008,
   BLE_L2CAP_EVENT_CMD_REJ = 0x5009
}
```

**Code 16. L2CAP event**

L2CAP callback function is following.

```
static void l2cap_cb(uint16_t type, ble_status_t result, st_ble_l2cap_cf_evt_data_t *p_data)
{
    switch (type)
    {
    Note: Add processing when an event is received here.
     }
}
```

**Code 17. L2CAP callback function**

QE for BLE does not generate skeleton code for L2CAP callback function. Users have to define / implement L2CAP callback function and register it by using *R_BLE_L2CAP_RegisterCfPsm()* at *app_main()* when user needs to use l2cap function.

### 3.1.13 Event notification and exiting from Software Standby mode

Event notification can be added to scheduler in BLE application by using *R_BLE_SetEvent()* API. If an event has occurred, the corresponding callback function will execute at the next call of the *R_BLE_Execute()*. The *R_BLE_Set_Event()* API should be used address the following cases.

- To perform time-consuming application processing within an interrupt service routine.
- To control program flow of a function which cannot be executed from an interrupt service routine.

Event notification use case in this document is following.

```
static void sw_cb(void)
{
    uint8_t state = 1;
    R_BLE_LSS_NotifySwitchState(g_conn_hdl, &state);
    g_inhibit_software_standby = true;
}


void Callback_ble_sw_irq(external_irq_callback_args_t *p_args)
{
     FSP_PARAMETER_NOT_USED(p_args);
     R_BLE_SetEvent(sw_cb);

}
```

Send notification

Clear flag to exit Software Standby mode

Interrupt callback function for push switch

Register sw_cb function as callback function

**Code 18. Event notification**

In above use case, BLE module will send notification to remote device when the user operates tactile switch which connected with RA4W1 GPIO.

In this demo project, IRQ4 assigned SW1 on EK-RA4W1 is designated as Wakeup Source of Low Power Module. When SW1 on EK-RA4W1 under Software Standby mode is pressed, Software Standby mode is exited then *Callback_ble_sw_irq()* function is executed because it is registered as callback function of IRQ4 interrupt.

### 3.1.14 CLI (Command Line Interface)

This demo project provides the functionality of CLI (Command Line Interface). CLI can be access with the terminal emulator like Tera Term on PC connecting EK-RA4W1 board via USB cable. Each command of CLI is registered to gsp_cmds structure in app_main.c like following. User defined commands can be added to gsp_cmds structure by the same scheme depending on the necessity. Refer to section 4.6.6 when user wants to create new command.

```
/* CommandLine parameters */
static const st_ble_cli_cmd_t * const gsp_cmds[] =
{
     &g_abs_cmd,
     &g_vs_cmd,
     &g_sys_cmd,
     &g_ble_cmd
};
```

**Code 19. gsp_cmds**

CLI is initialized by the following procedure in *app_main()* function in app_main.c.

```
void app_main(void)
{
………
    /* Initialize BLE and profiles */
    ble_init();

/* Hint: Input process that should be done before main loop such as calling initial function or
   variable definitions */
/* Start user code for process before main loop. Do not edit comment generated here */
………
    /* Configure CommandLine */
    R_BLE_CLI_Init();
    R_BLE_CLI_RegisterCmds(gsp_cmds, sizeof(gsp_cmds)/sizeof(gsp_cmds[0]));
    R_BLE_CLI_RegisterEventCb(NULL);
    R_BLE_CMD_SetResetCb((ble_event_cb_t)ble_init);
/* End user code. Do not edit comment generated here */

     /* main loop */
    while (1)
    {………
```

**Code 20. Initialization of CLI**

The processing of CLI is executed by *R_BLE_CLI_Process()* API in main loop in app_main.c.

```
    /* main loop */
    while (1)
    {
        /* Process BLE Event */
        R_BLE_Execute();
………
/* Hint: Input process that should be done during main loop such as calling processing functions */
/* Start user code for process during main loop. Do not edit comment generated here */

        /* Process Command Line */
        R_BLE_CLI_Process();
………
/* End user code. Do not edit comment generated here */
```

**Code 21. Executing the processing of CLI**

The processing of the event occurred as a result of calling *R_BLE_CLI_Process()* API is described as shown in the top part of Code 7 (The description of calling *R_BLE_CMD_***** API).

## 3.2 FreeRTOS environment (Server, EventGroup as Synchronization Type case)

In case of selected *Event Group* as *Synchronization Type* property of *BLE Driver* FSP module, BLE application is divided it into two or more tasks, BLE Core Task and GATT application tasks. BLE Core Task performs initialization and BLE related processing except GATT related event processing. The BLE Core task should be highest priority. In this demo project, BLE Core Task implemented in app_main.c and GATT application task (LED switch service) implemented in lss_task.c. This section describes BLE related task creation, task switching between BLE related task and implementation each task in following sections.

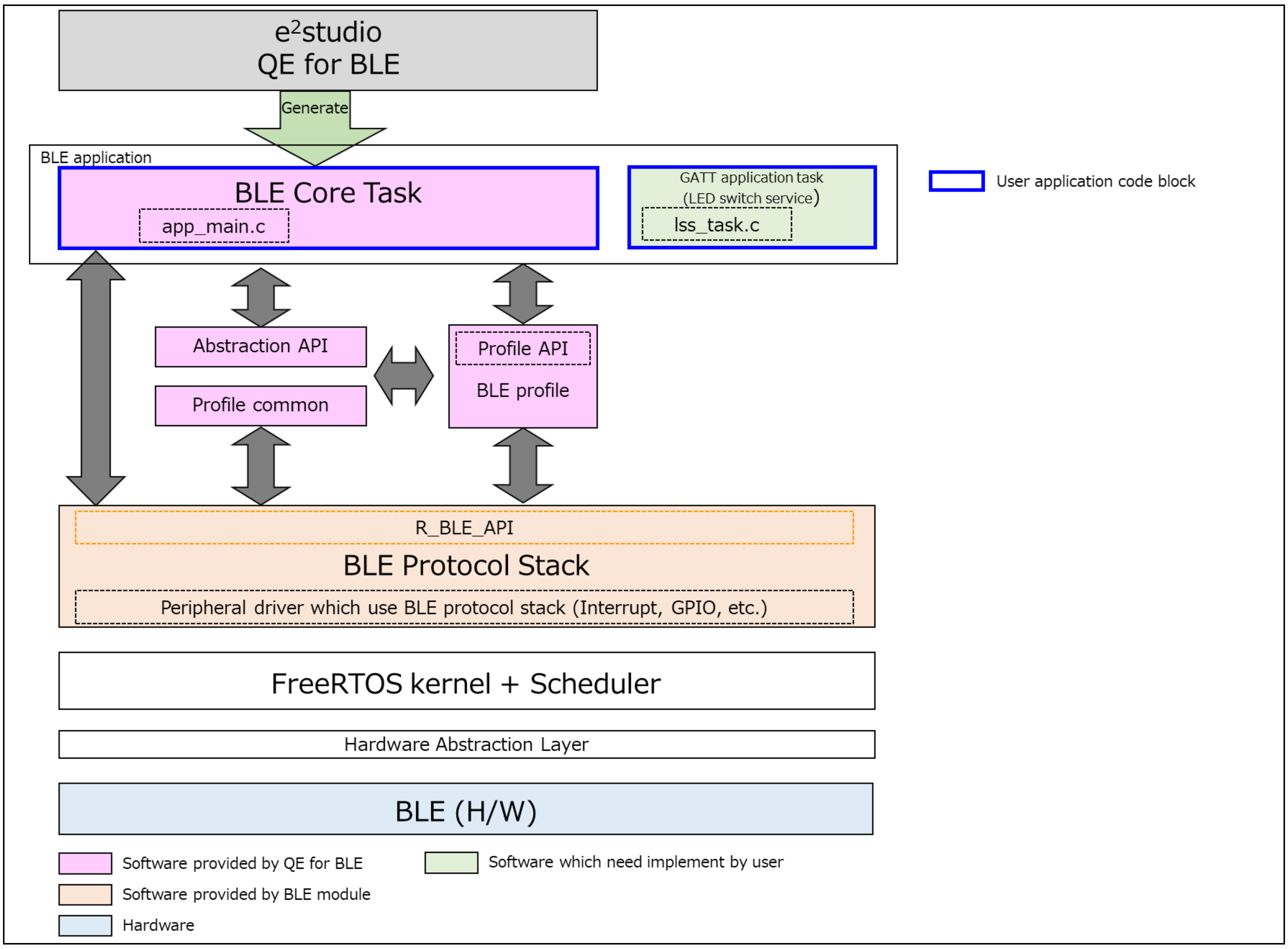


**Figure 22. Software structure (FreeRTOS, EventGroup as Synchronization Type case)**

Note1: When using QE for BLE, source code of the app_main function is automatically generated.

Note2: QE for BLE does not generate source code of the lss_task. User needs to define and the functionality for the lss_task.c. The user may this document and sample code for reference.

### 3.2.1 Create / delete task

- **Include ble_core_task.h**

Add the description of including “ble_core_task.h” as following to app_main.c.

```
/******************************************************************************
 User file includes
*******************************************************************************/
/* Start user code for file includes. Do not edit comment generated here */
#include "ble_core_task.h"
/* End user code. Do not edit comment generated here */
```

**Code 22. app_main.c**

- **BLE Core task**

Initialization and main loop of BLE core task included in *app_main()*. Call the *app_main()* in ble_core_task_entry.c as following.

```
void ble_core_task_entry(void *pvParameters)
{
    FSP_PARAMETER_NOT_USED (pvParameters);

    /* TODO: add your own code here */
    app_main();

    while (1)
    {
        vTaskDelay (1000 / portTICK_PERIOD_MS);
    }
}
```

**Code 23. app_main entry point**

- **GATT application task**

GATT server event processing of GATT application task included in *lss_task_entry()*. The GATT application task is created when remote device connects to the RA4W1. And the task is deleted when the remote device disconnects from the RA4W1. This task creation/deletion is performed by GATT server callback function (gatts_cb) in app_main.c.

```
void gatts_cb(uint16_t type, ble_status_t result, st_ble_gatts_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for GATT Server callback function common process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */

    R_BLE_SERVS_GattsCb(type, result, p_data);
    switch(type)
    {
/* Hint: Add cases of GATT Server event macros defined as BLE_GATTS_XXX */
/* Start user code for GATT Server callback function event process. Do not edit comment generated here */

        case BLE_GATTS_EVENT_CONN_IND:
        {
            ………
            /* task create */
            xTaskCreate(lss_task_entry, "lss_task", 128, &g_conn_hdl, 4, &g_lss_task);

        }break;

        case BLE_GATTS_EVENT_DISCONN_IND:
        {
      ………
            /* Delete Task */
            delete_lss_task_rsrc();
        }break;

        default:
            /* Do Nothing */
            break;
/* End user code. Do not edit comment generated here */
    }
}
```

Create GATT application task.

Delete GATT application task.

**Code 24. LED switch service task creation**

### 3.2.2 Task switching between BLE core task and GATT application task

If event notified by scheduler, part of the BLE protocol stack, is an event for GATT application task, BLE core task activates GATT application task and provides a notification of the event by using event group setting and cleaning technique. In this demo project, event group bit defined in task_functon.h as following.

**Table 15. Defined event group bit**

| Macro name (Value) | Usage |
|---|---|
| LSS_WAIT_EN_CCCD (0x0001) | Enable CCCD in LED Switch Service |
| LSS_WAIT_DIS_CCCD (0x0002) | Disable CCCD in LED Switch Service |
| LSS_WAIT_PUSH_SW (0x0004) | Notify push switch |
| LSS_WAIT_WR_BLINK (0x0008) | Change LED blink rate |

Function which sets event group bit need to implement by the user. The function in this demo project is as follows.

```
void set_lss_event(EventBits_t uxBitsToSet)
{
    R_BLE_LSS_GetSwitchStateCliCnfg(gs_conn_hdl, &cccd);

    switch(uxBitsToSet)
    {                                                           Enable CCCD in LED Switch Service
        case LSS_WAIT_EN_CCCD:
            xEventGroupClearBits(xLssEvent, (LSS_WAIT_DIS_CCCD | LSS_WAIT_PUSH_SW));
            xEventGroupSetBits(xLssEvent, uxBitsToSet);
            break;

        case LSS_WAIT_DIS_CCCD:                                 Disable CCCD in LED Switch Service
            uxBitsToSet = LSS_WAIT_DIS_CCCD;
            xEventGroupClearBits(xLssEvent, (LSS_WAIT_EN_CCCD | LSS_WAIT_PUSH_SW));
            xEventGroupSetBits(xLssEvent, uxBitsToSet);
            break;

        case LSS_WAIT_PUSH_SW:                                  Notify push switch
            if(BLE_GATTS_CLI_CNFG_NOTIFICATION == cccd)
            {
                xEventGroupSetBits(xLssEvent, uxBitsToSet);
            }
            break;

        case LSS_WAIT_WR_BLINK:                                 Change LED blink rate
            xEventGroupSetBits(xLssEvent, uxBitsToSet);
            break;
    }
}
```

**Code 25. Set event group bit**

### 3.2.3 Main loop of BLE core task

The *app_main()* includes initialization and main loop of BLE Core task. The program flow of this demo project is following.

```
void app_main(void)
{
………
    /* Create Event Group */
    g_ble_event_group_handle = (void *)xEventGroupCreate();
    assert(g_ble_event_group_handle);
………

    /* Initialize BLE and profiles */
    ble_init();

/* Hint: Input process that should be done before main loop such as calling initial function or variable
definitions */
/* Start user code for process before main loop. Do not edit comment generated here */
…………
    R_BLE_CMD_SetResetCb((ble_event_cb_t)ble_init);
/* End user code. Do not edit comment generated here */

    /* main loop */
    while (1)
    {
………
        /* Process BLE Event */
        R_BLE_Execute();

        if(0 != R_BLE_IsTaskFree())
        {
            /* If the BLE Task has no operation to be processed, it transits block state until the event from
              RF transciever occurs. */
            xEventGroupWaitBits((EventGroupHandle_t)g_ble_event_group_handle,
                                (EventBits_t)BLE_EVENT_PATTERN,
                                pdTRUE,
                                pdFALSE,
                                portMAX_DELAY);
        }
………
    }

………
    /* Terminate BLE */
    RM_BLE_ABS_Close(&g_ble_abs0_ctrl);
}
```

Create event group for transition task status.

BLE module initialization.

Main loop (Call *R_BLE_Execute*, Transition to Block state by `xEventGroupWaitBits`)

**Code 26. app_main function**

### 3.2.4 Main loop of GATT application task

The *lss_task_entry()* includes main loop of GATT application task. The program flow of this demo project is following.

```
void lss_task_entry(void *pvParameters)
{
    ble_status_t retval;
    uint8_t push_state;
    EventBits_t event;

    gs_conn_hdl = *(uint16_t *)pvParameters;
    xLssEvent = xEventGroupCreate();
```

Store connection handle

Create event group for transition task status.

```
    xBlinkTimerHdl = xTimerCreate("Blink" , 1000, pdTRUE , 0, blink_timer_cb);

    R_BLE_LSS_GetSwitchStateCliCnfg(gs_conn_hdl, &cccd);
    if(BLE_GATTS_CLI_CNFG_INDICATION != cccd)
    {
        cccd = BLE_GATTS_CLI_CNFG_DEFAULT;
    }

    wait_event = LSS_WAIT_EN_CCCD | LSS_WAIT_DIS_CCCD | LSS_WAIT_WR_BLINK | LSS_WAIT_PUSH_SW;

    while (1)
    {
        event = xEventGroupWaitBits(
```

Wait for event from BLE core task

```
                                    xLssEvent,
                                    wait_event,
                                    pdTRUE,
                                    pdFALSE,
                                    portMAX_DELAY);

        if(LSS_WAIT_EN_CCCD & event)
```

Wait for enable CCCD event from BLE core task

```
        {
………
        }
        else if(LSS_WAIT_DIS_CCCD & event)
```

Wait for disable CCCD event from BLE core task

```
        {
………
        }
        else if((LSS_WAIT_PUSH_SW & event) && (BLE_GATTS_CLI_CNFG_NOTIFICATION == cccd))
        {
```

Wait for push switch event from BLE core task

```
………
        }
        else if(LSS_WAIT_WR_BLINK & event)
```

Wait for LED blink rate change event from BLE core task

```
        {
………
        }
    }
    vTaskDelete(NULL);
    /* End user code. Do not edit comment generated here */
}
```

**Code 27. lss_task_entry function**

### 3.2.5 Initialization process

Same as section 3.1.3.

### 3.2.6 Register callback function

Same as section 3.1.4.

### 3.2.7 Registering GATT database (R_BLE_GATTS_SetDbInst)

Same as section 3.1.5.

### 3.2.8 Main loop and scheduler (R_BLE_Execute)

The operation of the main loop and scheduler is similar to the description in section 3.1.6. The difference from BareMetal environment is that, if the event notified by scheduler which include BLE protocol stack is an event for GATT application task, BLE core task activates GATT application task and notify the event by using event group technique. Figure 23 shows the typical sequence chart of BLE module.

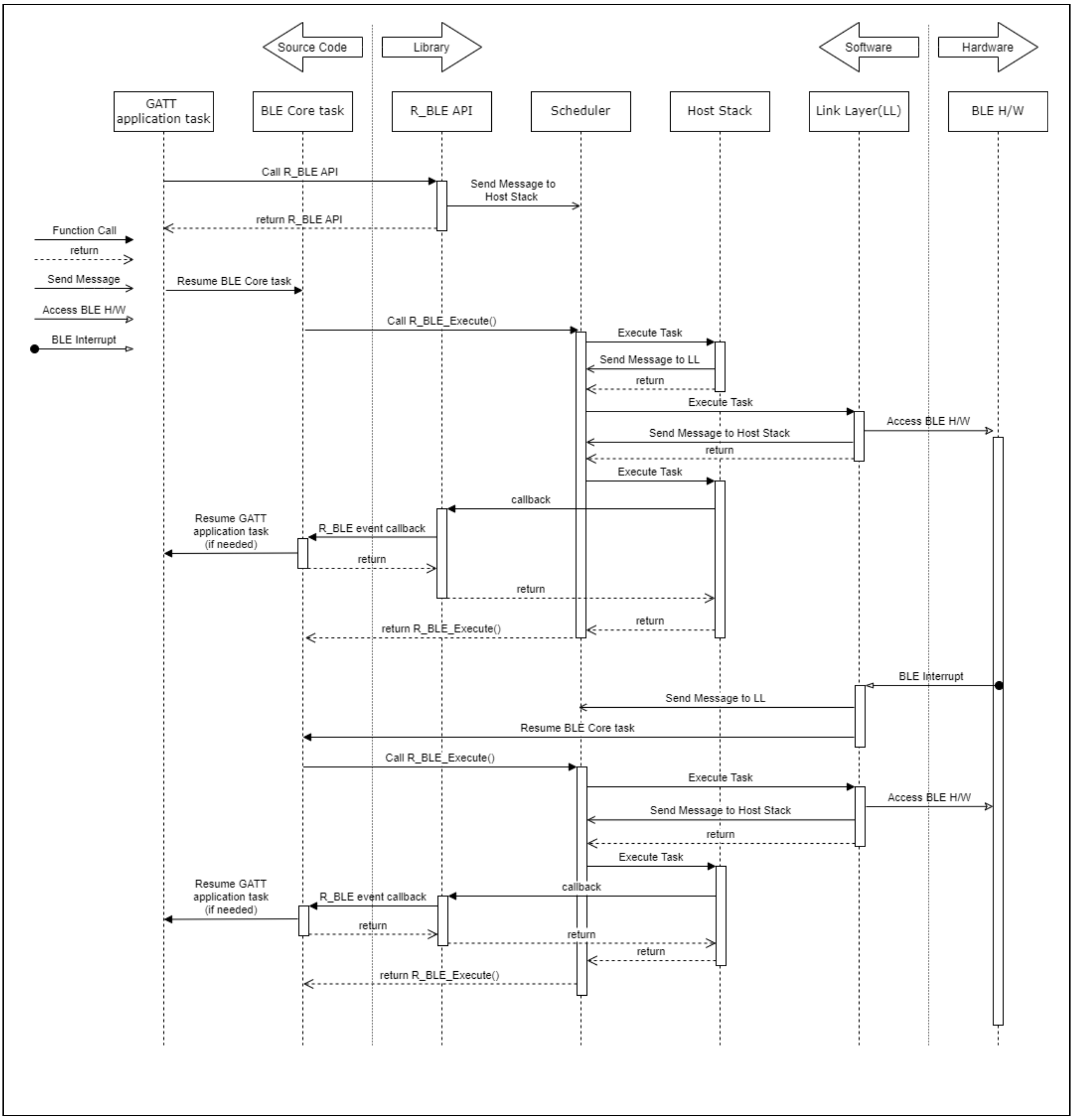


Figure 23. Basic sequence chart of BLE Protocol Stack

### 3.2.9 GAP event (gap_cb function)

Same as section 3.1.7.

### 3.2.10 GATTS event (gatts_cb function)

Almost the same as section 3.1.8. The difference from BareMetal environment is that,

- GATT application task is created when connection is established with the client.
- GATT application task is deleted when client disconnects.

Implementation of this demo project is following.

```
void gatts_cb(uint16_t type, ble_status_t result, st_ble_gatts_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for GATT Server callback function common process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */

    R_BLE_SERVS_GattsCb(type, result, p_data);
    switch(type)
    {
/* Hint: Add cases of GATT Server event macros defined as BLE_GATTS_XXX */
/* Start user code for GATT Server callback function event process. Do not edit comment generated here */

        case BLE_GATTS_EVENT_CONN_IND:
        {
………
            /* task create */
            /* LED Switch */
            xTaskCreate(lss_task_entry, "lss_task", 128, &g_conn_hdl, 4, &g_lss_task);
        }break;

        case BLE_GATTS_EVENT_DISCONN_IND:
        {
            /* Delete GATT Application Task */
            delete_lss_task_rsrc();
        }break;

        default:
            /* Do Nothing */
            break;
/* End user code. Do not edit comment generated here */
    }
}
```

Create GATT application task

Delete GATT application task

**Code 28. GATTS callback function**

### 3.2.11 GATTC event (gattc_cb function)

Almost the same as section 3.1.9. The difference from BareMetal environment is that,

- GATT Application task is created when connection is established with the server.
- GATT Application task is deleted when upon disconnecting from the server.

### 3.2.12 VS event (vs_cb function)

Same as section 3.1.10.

### 3.2.13 Server-side Profile API event ([service_name]s_cb function)

Almost the same as section 3.1.11. The difference from BareMetal environment is that event group bits are adjusted according to the data received from server-side profile API event. As a result, the GATT Application task is activated per the function definition provided in Section 3.2.2. Implementation of this demo project is following.

```
static void lss_cb(uint16_t type, ble_status_t result, st_ble_servs_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for LED Switch Service(Custom Service) Server callback function common process. */
    /* Do not edit comment generated here */
/* End user code. Do not edit comment generated here */


    uint16_t    data;


    switch(type)
    {
/* Hint: Add cases of LED Switch Service(Custom Service) server events defined in e_ble_lss_event_t */
/* Start user code for LED Switch Service(Custom Service) Server callback function event process. Do not edit
comment generated here */
        case BLE_LSS_EVENT_SWITCH_STATE_CLI_CNFG_WRITE_COMP :
        {
            R_BLE_LSS_GetSwitchStateCliCnfg(p_data->conn_hdl, &data);
            if (data)
                set_lss_event(LSS_WAIT_EN_CCCD);
            else
                set_lss_event(LSS_WAIT_DIS_CCCD);
        } break;

        case BLE_LSS_EVENT_BLINK_RATE_WRITE_COMP:
        {
            set_lss_event(LSS_WAIT_WR_BLINK);
        } break;

        default:
        {
            /* Do nothing. */
        } break;
/* End user code. Do not edit comment generated here */
    }
}
```

Change CCCD event.

Change LED blink rate

**Code 29. Profile Server callback function**

### 3.2.14 L2CAP event

Same as section 3.1.12.

### 3.2.15 Event notification

Event notification use case for FreeRTOS is following.

```
static void sw_cb(void)
{
    set_lss_event(LSS_WAIT_PUSH_SW);
}

void Callback_Sw_1(external_irq_callback_args_t *p_args)
{
    FSP_PARAMETER_NOT_USED(p_args);
    R_BLE_SetEvent(sw_cb);
}
```

Send notification

Interrupt callback function for push switch

Register sw_cb function as callback function

Code 30. Event notification

### 3.2.16 CLI (Command Line Interface)

Same as section 3.1.14.

## 3.3 FreeRTOS environment (Server, Semaphore case)

In case of selected *Semaphore* as *Synchronization Type* property of *BLE Driver* FSP module, BLE application is divided it into three or more tasks, BLE Core Task, Execute task and GATT application tasks. BLE Core Task performs initialization and BLE related processing except GATT related event processing. Execute task periodically calls *R_BLE_Execute* API. The execute task should be highest priority. In this demo project, BLE Core Task and Execute task implemented in app_main.c. GATT application task (LED switch service) implemented in lss_task.c. This section describes BLE related task creation, task switching between BLE related task and implementation each task in following sections.

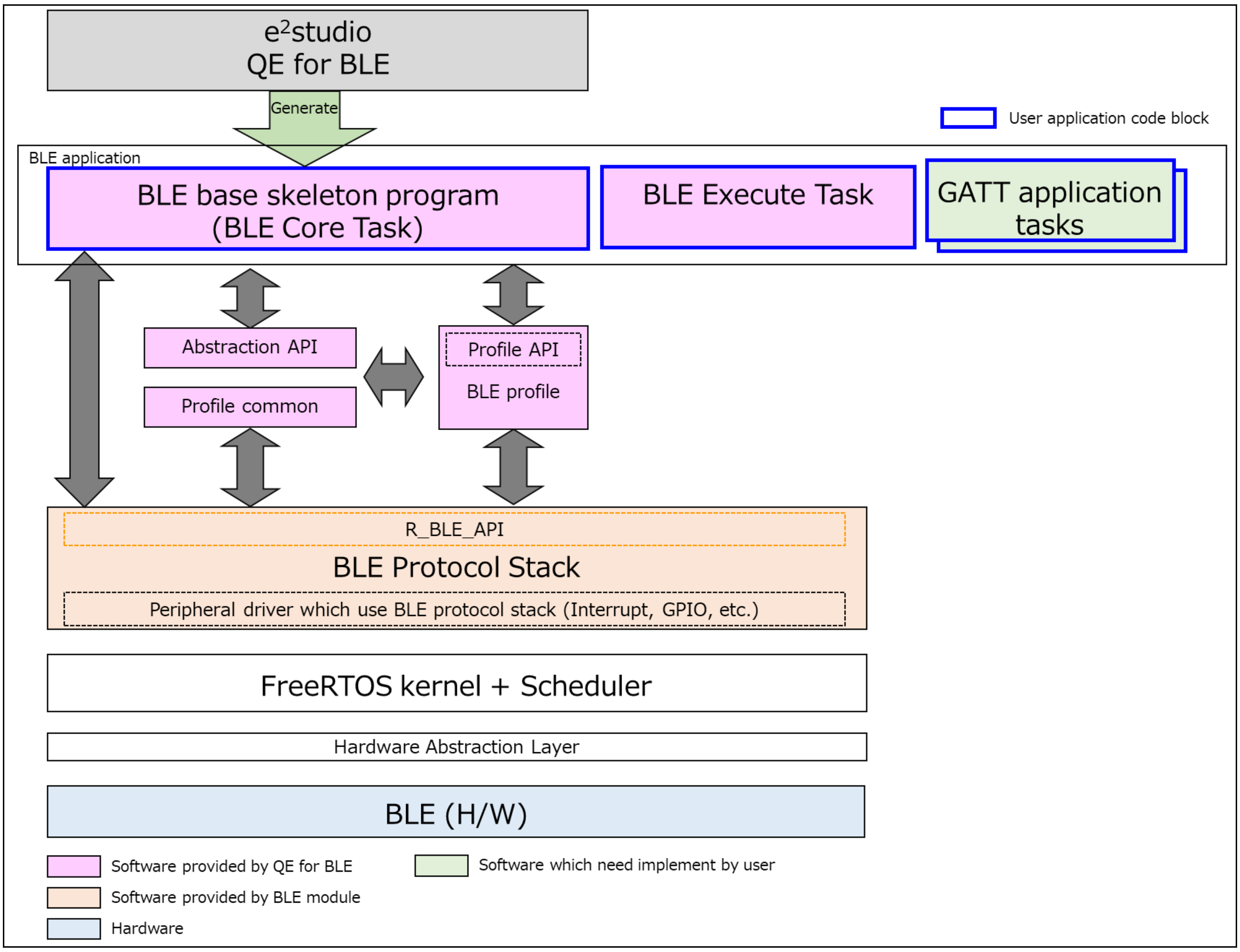


**Figure 24. Software structure (FreeRTOS, Semaphore as Synchronization Type case)**

Note1: When using QE for BLE, source code of the app_main function is automatically generated.

Note2: QE for BLE does not generate source code of the lss_task. User needs to define and the functionality for the lss_task.c. The user may this document and sample code for reference.

### 3.3.1 Create / delete task

- **Include ble_core_task.h**

Add the description of including “ble_core_task.h” as following to app_main.c.

```
User file includes
#include "ble_core_task.h"
/* End user code. Do not edit comment generated here */#
```

**Code 31. app_main.c**

- **BLE Core task**

Initialization and main loop of BLE core task included in *app_main()*. Call the *app_main()* in ble_core_task_entry.c as following.

```
void ble_core_task_entry(void *pvParameters)
{
    FSP_PARAMETER_NOT_USED (pvParameters);

    /* TODO: add your own code here */
    app_main();

    while (1)
    {
        vTaskDelay (1000 / portTICK_PERIOD_MS);
    }
}
```

**Code 32. app_main entry point**

- **Execute task**

Execute task will be created in app_main() as following. QE for BLE generated skeleton code includes the task creation and implementation.

```
void app_main(void)
{
………
    /* Get Current Task handle */
    gs_ble_core_task_ptr = xTaskGetCurrentTaskHandle();

    /* Create Execute Task */
    xTaskCreate(ble_execute_task_func, "execute_task", EXECUTE_STACK_SIZE, NULL, configMAX_PRIORITIES-1,
                &gs_ble_execute_task);
………
    While(1)
    {
        if(0 != R_BLE_IsTaskFree())
            vTaskSuspend(NULL);
        else
            xSemaphoreGive(gs_ble_exe_smpr);
    }
………
}
………
static void ble_execute_task_func(void *pvParameters)
{
   while(1)
   {
      xSemaphoreTake(gs_ble_exe_smpr, portMAX_DELAY);
      while(0 == R_BLE_IsTaskFree())
         R_BLE_Execute();

      vTaskResume(gs_ble_core_task_ptr);
   }
}
```

**Code 33. Execute task creation and implementation**

- **GATT application task**

Same as section 3.2.1.

### 3.3.2 Task switching between BLE core task and GATT application task

Same as section 3.2.2.

### 3.3.3 Main loop of BLE core task

The *app_main()* includes initialization and main loop of BLE Core task. The program flow of this demo project is following.

```
void app_main(void)
{
………
    gs_ble_exe_smpr = xSemaphoreCreateBinary();
    assert(gs_ble_exe_smpr);
    g_ble_event_group_handle = (void *)gs_ble_exe_smpr;
………
   /* Initialize BLE and profiles */
    ble_init();
………
    /* Get Current Task handle */
    gs_ble_core_task_ptr = xTaskGetCurrentTaskHandle();

    /* Create Execute Task */
    xTaskCreate(ble_execute_task_func, "execute_task", EXECUTE_STACK_SIZE, NULL, configMAX_PRIORITIES-1,
                &gs_ble_execute_task);
………
/* Hint: Input process that should be done before main loop such as calling initial function or variable
definitions */
/* Start user code for process before main loop. Do not edit comment generated here */
…………
    R_BLE_CMD_SetResetCb((ble_event_cb_t)ble_init);
/* End user code. Do not edit comment generated here */

    /* main loop */
    while (1)
    {
………
        if(0 != R_BLE_IsTaskFree())
        {
            vTaskSuspend(NULL);
        }
        else
        {
            xSemaphoreGive(gs_ble_exe_smpr);
        }
………
    }

………
    /* Terminate BLE */
    RM_BLE_ABS_Close(&g_ble_abs0_ctrl);
}
```

Create semaphore for transition task status.

BLE module initialization.

Create execute task.

Main loop (Give semaphore when scheduler queue does not empty)

**Code 34. app_main function**

### 3.3.4 Main loop of BLE execute task

Execute tasks by calling *R_BLE_Execute* API until running out all of them in queue once semaphore has been given.

```
static void ble_execute_task_func(void *pvParameters)
{
    while(1)
    {
        xSemaphoreTake(gs_ble_exe_smpr, portMAX_DELAY);
        while(0 == R_BLE_IsTaskFree())
            R_BLE_Execute();

        vTaskResume(gs_ble_core_task_ptr);
    }
}
```

Waiting for the semaphore forever until success to get it.

Call R_BLE_Execute API once semaphore has been given.

Resume BLE Core Task after completing to execute all BLE tasks.

**Code 35. ble_execute_task_func function**

### 3.3.5 Main loop of GATT application task

Same as section 3.2.4.

### 3.3.6 Initialization process

Same as section 3.1.3.

### 3.3.7 Register callback function

Same as section 3.1.4.

### 3.3.8 Registering GATT database (R_BLE_GATTS_SetDbInst)

Same as section 3.1.5.

### 3.3.9 Main loop and scheduler (R_BLE_Execute)

The operation of the BLE Core task, execute task and GATT application task are shown in Figure 25.

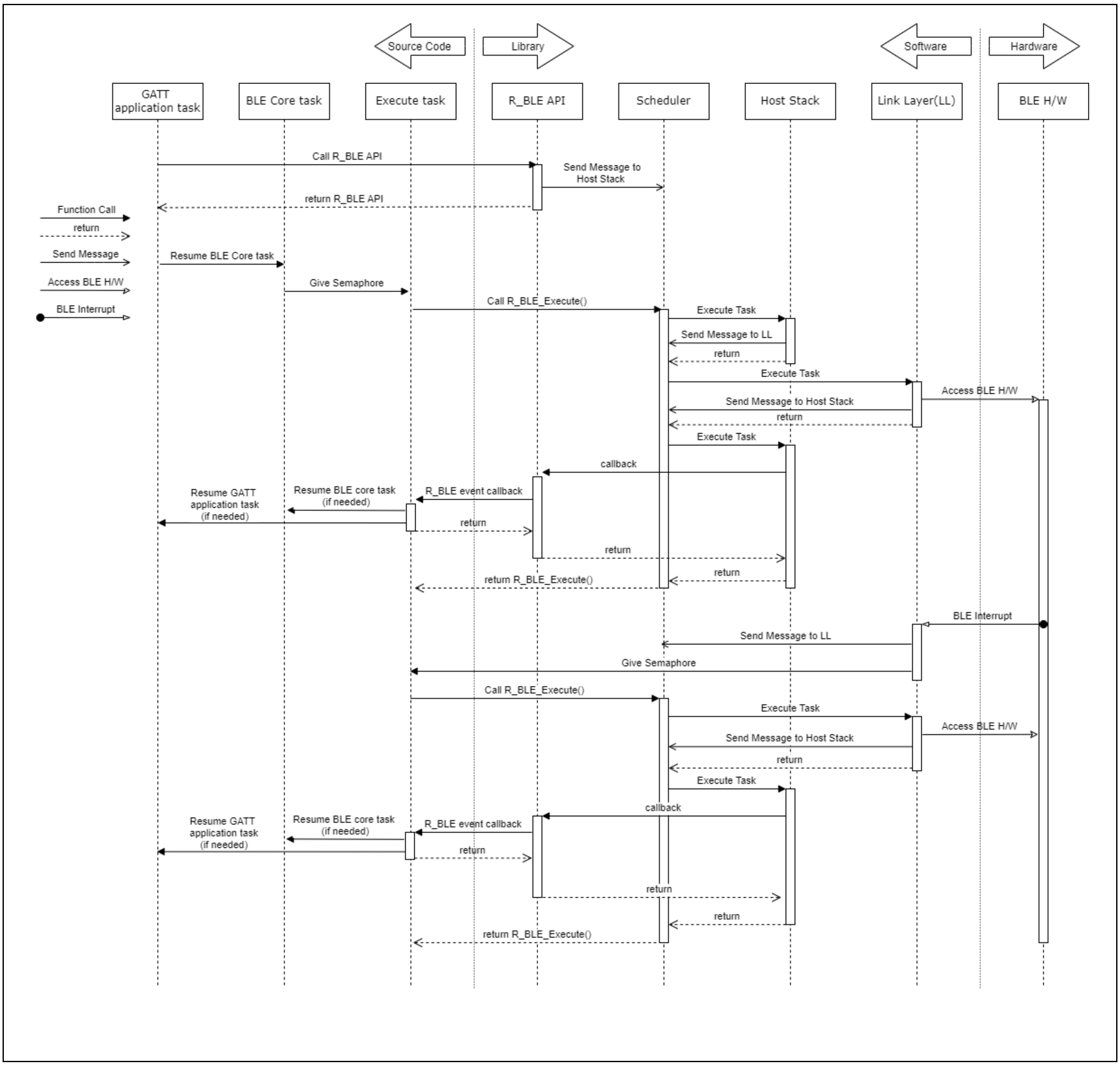


**Figure 25. Basic sequence chart of BLE Protocol Stack**

### 3.3.10 GAP event (gap_cb function)

Same as section 3.1.7.

### 3.3.11 GATTS event (gatts_cb function)

Same as section 3.2.10.

### 3.3.12 GATTC event (gattc_cb function)

Same as section 3.2.11.

### 3.3.13 VS event (vs_cb function)

Same as section 3.1.10.

### 3.3.14 Server-side Profile API event ([service_name]s_cb function)

Same as section 3.2.13.

### 3.3.15 L2CAP event

Same as section 3.1.12.

### 3.3.16 Event notification

Same as section 3.2.15.

### 3.3.17 CLI (Command Line Interface)

Same as section 3.1.14.

### 3.4 Azure RTOS environment (Server)

BLE application is divided it into three or more tasks, BLE Core Task, Execute task and GATT application tasks. BLE Core Task performs initialization and BLE related processing except GATT related event processing. Execute task periodically calls *R_BLE_Execute* API. The execute task should be highest priority. In this demo project, BLE Core Task and Execute task implemented in app_main.c. GATT application task (LED switch service) implemented in lss_task.c. This section describes BLE related task creation, task switching between BLE related task and implementation each task in following sections.

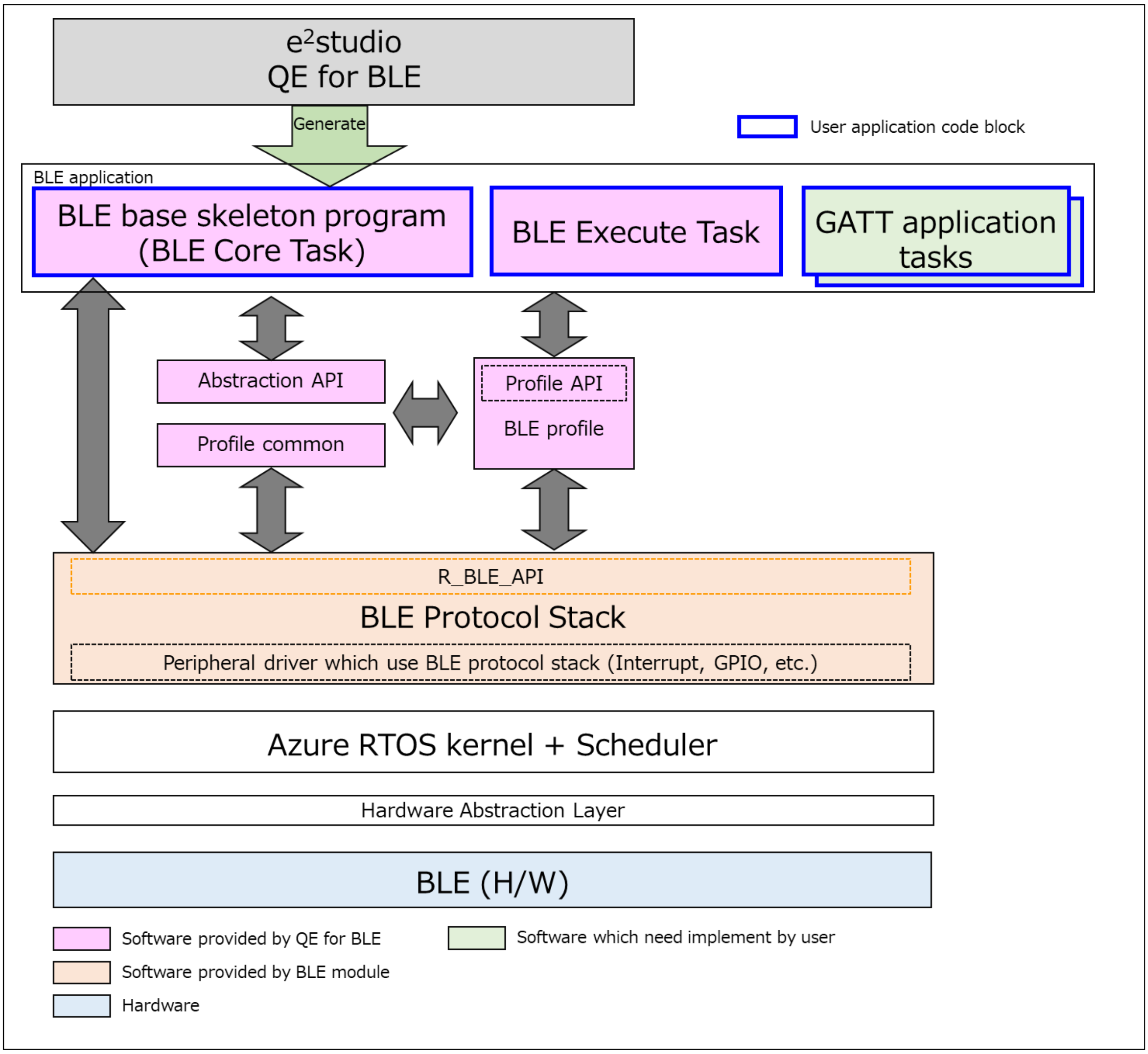


**Figure 26. Software structure (Azure RTOS)**

Note1: When using QE for BLE, source code of the app_main function is automatically generated.

Note2: QE for BLE does not generate source code of the lss_task. User needs to define and the functionality for the lss_task.c. The user may this document and sample code for reference.

### 3.4.1 Create / delete task

- **Include ble_core_task.h**

Add the description of including “ble_core_task.h” as following to app_main.c.

```
User file includes

/* Start user code for file includes. Do not edit comment generated here */
#include "ble_core_task.h"
/* End user code. Do not edit comment generated here */
```

**Code 36. app_main.c**

- **BLE Core task**

Initialization and main loop of BLE core task included in *app_main()*. Call the *app_main()* in ble_core_task_entry.c as following.

```
void ble_core_task_entry(void)
{
    /* TODO: add your own code here */
    app_main();
    while (1)
    {
        tx_thread_sleep (1);
    }
}
```

**Code 37. app_main entry point**

- **Execute task**

Execute task will be created in app_main() as following. QE for BLE generated skeleton code includes the task creation and implementation.

```
void app_main(void)
{
………
    /* Create Semaphore */
    tx_semaphore_create(&gs_ble_exe_smpr, "BLE_CORE_TASK_SEMAPHOR", TX_NO_INHERIT);

    /* Get Own thread handle */
    gs_ble_core_task_ptr = tx_thread_identify();

    /* Create BLE Execute Task */
    tx_thread_create(&gs_ble_execute_task, (CHAR*) "BLE_EXECUTE_TASK", ble_execute_task_func, (ULONG) NULL,
                        &gs_ble_execute_task_stack, EXECUTE_STACK_SIZE, 1, 1, TX_NO_TIME_SLICE,
                        TX_AUTO_START);
………
    While(1)
    {
        if(0 != R_BLE_IsTaskFree())
            tx_thread_suspend(gs_ble_core_task_ptr);
        else
            tx_semaphore_put(&gs_ble_exe_smpr);
    }
}
………
static void ble_execute_task_func(void *pvParameters)
{
  while(1)
  {
    tx_semaphore_get(&gs_ble_exe_smpr, TX_WAIT_FOREVER);
    while(0 == R_BLE_IsTaskFree())
      R_BLE_Execute();

    tx_thread_resume(gs_ble_core_task_ptr);
  }
}
```

**Code 38. Execute task creation and implementation**

- **GATT application task**

GATT server event processing of GATT application task included in *lss_task_entry()*. The task is created when remote device connects to the RA4W1. And the task is deleted when the remote device disconnects from the RA4W1. This task creation/deletion is performed by GATT server callback function (gatts_cb) in app_main.c.

```
void gatts_cb(uint16_t type, ble_status_t result, st_ble_gatts_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for GATT Server callback function common process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */

    R_BLE_SERVS_GattsCb(type, result, p_data);
    switch(type)
    {
/* Hint: Add cases of GATT Server event macros defined as BLE_GATTS_XXX */
/* Start user code for GATT Server callback function event process. Do not edit comment generated here */
        case BLE_GATTS_EVENT_CONN_IND:
        {
            /* Enable Notification SW */
            g_external_irq_sw1.p_api->enable(g_external_irq_sw1.p_ctrl);

            /* Create LED Switch Service Task */
            tx_thread_create(&ble_lss_task, (CHAR*) "BLE_LSS_TASK", lss_task_entry, g_conn_hdl,
                                    &ble_lss_task_stack, 512, 4, 4, 4, TX_AUTO_START);
        } break;

        case BLE_GATTS_EVENT_DISCONN_IND:
        {
            delete_lss_task_rsrc();

            /* Disable Notification SW */
            g_external_irq_sw1.p_api->disable(g_external_irq_sw1.p_ctrl);

            /* LED turn OFF */
            g_ioport.p_api->pinWrite(g_ioport.p_ctrl, BSP_IO_PORT_01_PIN_06, BSP_IO_LEVEL_HIGH);

        } break;
/* End user code. Do not edit comment generated here */
    }
}
```

Create GATT application task.

Delete GATT application task.

Code 39. LED switch service task creation

### 3.4.2 Task switching between BLE core task and GATT application task

If event notified by scheduler, part of the BLE protocol stack, is an event for GATT application task, BLE core task activates GATT application task and provides a notification of the event by using event flags setting and cleaning technique. In this demo project, event flag bit defined in task_functon.h as following.

**Table 16. Defined event group bit**

| Macro name (Value) | Usage |
|---|---|
| LSS_WAIT_EN_CCCD (0x0001) | Enable CCCD in LED Switch Service |
| LSS_WAIT_DIS_CCCD (0x0002) | Disable CCCD in LED Switch Service |
| LSS_WAIT_PUSH_SW (0x0004) | Notify push switch |
| LSS_WAIT_WR_BLINK (0x0008) | Change LED blink rate |

Function which sets event flag bit need to be implemented by the user. The function in this demo project is as following.

```
void set_lss_event(unsigned long uxBitsToSet)
{
    R_BLE_LSS_GetSwitchStateCliCnfg(gs_conn_hdl, &cccd);

    switch(uxBitsToSet)
    {
        case LSS_WAIT_EN_CCCD:
            tx_event_flags_set(&xLssEvent, uxBitsToSet, TX_OR);
            break;
        case LSS_WAIT_DIS_CCCD:
            uxBitsToSet = LSS_WAIT_DIS_CCCD;
            tx_event_flags_set(&xLssEvent, uxBitsToSet, TX_OR);
            break;
        case LSS_WAIT_PUSH_SW:
            if(BLE_GATTS_CLI_CNFG_NOTIFICATION == cccd)
            {
                tx_event_flags_set(&xLssEvent, uxBitsToSet, TX_OR);
            }
            break;
        case LSS_WAIT_WR_BLINK:
            tx_event_flags_set(&xLssEvent, uxBitsToSet, TX_OR);
            break;

        default:
            break;
    }
}
```

**Code 40. Set event flags**

.

### 3.4.3 Main loop of BLE core task

The *app_main()* includes initialization and main loop of BLE Core task. The program flow of this demo project is following.

```
void app_main(void)
{
…………
    /* Initialize BLE and profiles */
    ble_init();

/* When this BLE application works on the Azure RTOS */
#if (BSP_CFG_RTOS == 1)

    /* Create Semaphore */
    tx_semaphore_create(&ble_exe_smpr, "BLE_CORE_TASK_SEMAPHOR", TX_NO_INHERIT);

    /* Get Own thread handle */
    ble_core_task_ptr = tx_thread_identify();

    /* Create BLE Execute Task */
    tx_thread_create(&ble_execute_task, (CHAR*) "BLE_EXECUTE_TASK", ble_execute_task_func, (ULONG) NULL,
                     &ble_execute_task_stack, EXECUTE_STACK_SIZE, 1, 1, TX_NO_TIME_SLICE, TX_AUTO_START);
#endif

/* Hint: Input process that should be done before main loop such as calling initial function or variable
definitions */
/* Start user code for process before main loop. Do not edit comment generated here */
…………
    R_BLE_CMD_SetResetCb((ble_event_cb_t)ble_init);

    /* Open external interrupt */
    g_external_irq_sw1.p_api->open(g_external_irq_sw1.p_ctrl, g_external_irq_sw1.p_cfg);
/* End user code. Do not edit comment generated here */

    /* main loop */
    while (1)
    {
…………
#if (BSP_CFG_RTOS == 1)
        if(0 != R_BLE_IsTaskFree())
        {
            tx_thread_suspend(ble_core_task_ptr);
        }
        else
        {
            tx_semaphore_put(&ble_exe_smpr);
        }
…………
#endif

/* Hint: Input process that should be done during main loop such as calling processing functions */
/* Start user code for process during main loop. Do not edit comment generated here */

        /* Process Command Line */
        R_BLE_CLI_Process();

/* End user code. Do not edit comment generated here */
    }

/* Hint: Input process that should be done after main loop such as calling closing functions */
/* Start user code for process after main loop. Do not edit comment generated here */
    g_external_irq_sw1.p_api->close(g_external_irq_sw1.p_ctrl);
/* End user code. Do not edit comment generated here */

    /* Terminate BLE */
    RM_BLE_ABS_Close(&g_ble_abs0_ctrl);
}
```

Create semaphore for BLE Execute Task

Create BLE Execute Task

When there are no BLE Task, suspend BLE Core Task

When there are BLE Tasks, put semaphore for BLE Execute Task

**Code 41. app_main function**

### 3.4.4 Main loop of BLE execute task

Execute tasks by calling *R_BLE_Execute* API until running out all of them in queue once semaphore has been given.

```
static void ble_execute_task_func(unsigned long Parameters)
{
    FSP_PARAMETER_NOT_USED(Parameters);
    while(1)
    {
        tx_semaphore_get(&ble_exe_smpr, TX_WAIT_FOREVER);
        while(0 == R_BLE_IsTaskFree())
            R_BLE_Execute();

        tx_thread_resume(ble_core_task_ptr);
    }
}
```

Waiting for the semaphore forever until success to get it.

Call R_BLE_Execute API once semaphore has been given.

Resume BLE Core Task after completing to execute all BLE tasks.

**Code 42. ble_execute_task_func function**

### 3.4.5 Main loop of GATT application task

The *lss_task_entry()* includes main loop of GATT application task. The program flow of this demo project is following.

```
void lss_task_entry(unsigned long Parameters)
{
    uint8_t push_state;
    unsigned long event;

    gs_conn_hdl = (uint16_t)Parameters;
    tx_event_flags_create(&xLssEvent, "LSS_EVENT_FLAG");

    /* Create Timer for LED blink */
    tx_timer_create(&xBlinkTimerHdl, "Blink", blink_timer_cb, NULL, 0x00000001, 0x00000001, TX_NO_ACTIVATE);

    R_BLE_LSS_GetSwitchStateCliCnfg(gs_conn_hdl, &cccd);
    if(BLE_GATTS_CLI_CNFG_INDICATION != cccd)
    {
        cccd = BLE_GATTS_CLI_CNFG_DEFAULT;
    }

    wait_event = LSS_WAIT_EN_CCCD | LSS_WAIT_DIS_CCCD | LSS_WAIT_WR_BLINK | LSS_WAIT_PUSH_SW;

    while (1)
    {
        tx_event_flags_get(&xLssEvent, wait_event, TX_OR_CLEAR, &event, TX_WAIT_FOREVER);

        if(LSS_WAIT_EN_CCCD & event)
        {
..............

        }
        else if(LSS_WAIT_DIS_CCCD & event)
        {
..............
        }
        else if((LSS_WAIT_PUSH_SW & event) && (BLE_GATTS_CLI_CNFG_NOTIFICATION == cccd))
        {
..............
        }
        else if(LSS_WAIT_WR_BLINK & event)
        {
..............
        }
    }
}
```

Store connection handle

Create event flags for transition task

Wait for event from BLE core task

Wait for enable CCCD event from BLE core task

Wait for disable CCCD event from BLE core task

Wait for push switch event from BLE core task

Wait for LED blink rate change event from BLE

**Code 43. lss_task_entry function**

### 3.4.6 Initialization process

Same as section 3.1.3.

### 3.4.7 Register callback function

Same as section 3.1.4.

### 3.4.8 Registering GATT database (R_BLE_GATTS_SetDbInst)

Same as section 3.1.5.

### 3.4.9 Main loop and scheduler (R_BLE_Execute)

Same as section 3.3.9.

### 3.4.10 GAP event (gap_cb function)

Same as section 3.1.7.

### 3.4.11 GATTS event (gatts_cb function)

Almost the same as section 3.1.8. The difference from BareMetal environment is that,

- GATT application task is created when connection is established with the client.
- GATT application task is deleted when client disconnects.

Implementation of this demo project is following.

```
void gatts_cb(uint16_t type, ble_status_t result, st_ble_gatts_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for GATT Server callback function common process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */

    R_BLE_SERVS_GattsCb(type, result, p_data);
    switch(type)
    {
/* Hint: Add cases of GATT Server event macros defined as BLE_GATTS_XXX */
/* Start user code for GATT Server callback function event process. Do not edit comment generated here */
        case BLE_GATTS_EVENT_CONN_IND:
        {
            /* Enable Notification SW */
            g_external_irq_sw1.p_api->enable(g_external_irq_sw1.p_ctrl);

            /* Create LED Switch Service Task */
            tx_thread_create(&ble_lss_task, (CHAR*) "BLE_LSS_TASK", lss_task_entry, g_conn_hdl,
                                    &ble_lss_task_stack, 512, 4, 4, 4, TX_AUTO_START);
        } break;

        case BLE_GATTS_EVENT_DISCONN_IND:
        {
            delete_lss_task_rsrc();

            /* Disable Notification SW */
            g_external_irq_sw1.p_api->disable(g_external_irq_sw1.p_ctrl);

            /* LED turn OFF */
            g_ioport.p_api->pinWrite(g_ioport.p_ctrl, BSP_IO_PORT_01_PIN_06, BSP_IO_LEVEL_HIGH);

        } break;
/* End user code. Do not edit comment generated here */
    }
}
```

Create GATT application task

Delete GATT application task

**Code 44. GATTS callback function**

### 3.4.12 GATTC event (gattc_cb function)

Same as section 3.2.11.

### 3.4.13 VS event (vs_cb function)

Same as section 3.1.10.

### 3.4.14 Server-side Profile API event ([service_name]s_cb function)

Same as section 3.2.13.

### 3.4.15 L2CAP event

Same as section 3.1.12.

### 3.4.16 Event notification

Same as section3.2.15..

### 3.4.17 CLI (Command Line Interface)

Same as section 3.1.14.

## 3.5 BareMetal environment (Client)

### 3.5.1 Entry point

Same as section 3.1.1.

### 3.5.2 Main loop

The *app_main()* includes initialization and main loop. Main loop of this demo project is following.

```
void app_main(void)
{
…………
    /* Initialize Low Power Module */
    g_lpm0.p_api->open(g_lpm0.p_ctrl, g_lpm0.p_cfg);

    /* Initialize BLE and profiles */
    ble_init();
…………
    R_BLE_CMD_SetResetCb((ble_event_cb_t)ble_init);

    g_ble_sw_irq.p_api->open(g_ble_sw_irq.p_ctrl, g_ble_sw_irq.p_cfg);
    g_ble_sw_irq.p_api->enable(g_ble_sw_irq.p_ctrl);
/* End user code. Do not edit comment generated here */

    /* main loop */
    while (1)
    {
        /* Process BLE Event */
        R_BLE_Execute();
…………
        /* Disable IRQ */
        __disable_irq();

        /* UART reception on-going ? */
        if (false != get_uart_reception())
        {
            set_uart_reception(false);
            __enable_irq();
        }
        else
        {
            /* UART transmission on-going ? Allow enter software standby by sys stby command ? */
            if (true != g_inhibit_software_standby && true != get_uart_transmission())
            {
                /* Check whether there are executable BLE task or not */
                if (0 != R_BLE_IsTaskFree())
                {
                    /* There are no executable BLE task */
                    /* Terminate Command line */
                    R_BLE_CLI_Terminate();

                    /* Enter low power mode */
                    g_lpm0.p_api->lowPowerModeEnter(g_lpm0.p_ctrl);

                    /* Enable interrupt for processing interrupt handler after wake up */
                    __enable_irq();

                    /* Resume Command line */
                    R_BLE_CLI_Init();

                }
                else
                {
                    /* There is BLE related task */
                    __enable_irq();
                }
            }
            else
                __enable_irq();
        }
…………
```

MCU low Power driver initialization.

BLE module initialization.

Main loop (Call *R_BLE_Execute*, Transition to MCU low power consumption state by *lowPowerModeEnter*)

Enter Software Standby mode

**Code 45. app_main function**

### 3.5.3 Initialization process

The *ble_init()* initializes the BLE module, and register callback function and GATT database. Initialization process of this demo project is following.

```
ble_status_t ble_init(void)
{
    ble_status_t status;
    fsp_err_t err;

    /* Initialize BLE */
    err = RM_BLE_ABS_Open(&g_ble_abs0_ctrl, &g_ble_abs0_cfg);
    if (FSP_SUCCESS != err)
    {
        return err;
    }

    /* Initialize GATT Database */
    status = R_BLE_GATTS_SetDbInst(&g_gatt_db_table);
    if (BLE_SUCCESS != status)
    {
        return BLE_ERR_INVALID_OPERATION;
    }

    /* Initialize GATT server */
    status = R_BLE_SERVS_Init();
    if (BLE_SUCCESS != status)
    {
        return BLE_ERR_INVALID_OPERATION;
    }

    /*Initialize GATT client */
    status = R_BLE_SERVC_Init();
    if (BLE_SUCCESS != status)
    {
        return BLE_ERR_INVALID_OPERATION;
    }

    /* Set Prepare Write Queue */
    R_BLE_GATTS_SetPrepareQueue(gs_queue, BLE_GATTS_QUEUE_NUM);
    /* Initialize GATT Discovery Library */
    status = R_BLE_DISC_Init();
    if (BLE_SUCCESS != status)
    {
        return BLE_ERR_INVALID_OPERATION;
    }

    /* Initialize LED Switch Service client API */
    status = R_BLE_LSC_Init(lsc_cb);
    if (BLE_SUCCESS != status)
    {
        return BLE_ERR_INVALID_OPERATION;
    }

    return status;
}
```

BLE module initialization (*RM_ABS_BLE_Open*)

GATT database registration (*R_BLE_GATTS_SetDbInst*)
Note: Code-generated when GATT role is set as whichever Server and Client by QE for BLE.

GATT Server function initialization (*R_BLE_SERVS_Init*)
Note: Code-generated when GATT role is set as whichever Server and Client by QE for BLE.

GATT Client function initialization (*R_BLE_SERVC_Init*)
Note: Code-generated when GATT role is set as whichever Server and Client by QE for BLE.

Service initialization

**Code 46. ble_init function**

### 3.5.4 Register callback function

Same as section 3.1.4.

### 3.5.5 Registering GATT database (R_BLE_GATTS_SetDbInst)

Same as section 3.1.5.

### 3.5.6 Main loop and scheduler (R_BLE_Execute)

Same as section 3.1.6.

### 3.5.7 GAP event (gap_cb function)

Refer to section 3.1.7. for details of GAP events which callback function receives. GAP callback function in this demo project is following.

```
void gap_cb(uint16_t type, ble_status_t result, st_ble_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for GAP callback function common process. Do not edit comment generated here */
    R_BLE_CMD_AbsGapCb(type, result, p_data);
/* End user code. Do not edit comment generated here */

    switch(type)
    {
        case BLE_GAP_EVENT_STACK_ON:
        {
…………
        } break;

        case BLE_GAP_EVENT_CONN_IND:
        {
…………
            }
        } break;

        case BLE_GAP_EVENT_DISCONN_IND:
        {
…………
        } break;

        case BLE_GAP_EVENT_CONN_PARAM_UPD_REQ:
        {
…………
        } break;

        case BLE_GAP_EVENT_ADV_REPT_IND:
        {
…………
        } break;

        case BLE_GAP_EVENT_SCAN_OFF:
        {
…………
        } break;

/* Hint: Add cases of GAP event macros defined as BLE_GAP_XXX */
/* Start user code for GAP callback function event process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */
    }
}
```

In this demo project, many parts of processing when receiving events are also implemented in R_BLE_CMD_AbsGapCb().

Complete GAP initialization

Connection complete

Disconnection has happened

Connection parameter request come from server

Notification of receiving advertising reports from server

Stop scanning

**Code 47. GAP callback function**

### 3.5.8 GATTS event (gatts_cb function)

Same as section 3.1.8.

### 3.5.9 GATTC event (gattc_cb function)

Refer to section 3.1.9. for details of GATTC events which callback function receives. GATTC callback function in this demo project is following.

```
void gattc_cb(uint16_t type, ble_status_t result, st_ble_gattc_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for GATT Client callback function common process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */

    R_BLE_SERVC_GattcCb(type, result, p_data);
    switch(type)
    {
        case BLE_GATTC_EVENT_CONN_IND:
        {
            R_BLE_CLI_Printf("Start Service Discovery\n");
            /* Start discovery operation after connection established */
            R_BLE_DISC_Start(p_data->conn_hdl, gs_disc_entries, ARRAY_SIZE(gs_disc_entries), disc_comp_cb);
        } break;

/* Hint: Add cases of GATT Client event macros defined as BLE_GATTC_XXX */
/* Start user code for GATT Client callback function event process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */
    }
}
```

Complete connection with GATT server

**Code 48. GATTC callback function**

### 3.5.10 VS event (vs_cb function)

Same as section 3.1.10.

### 3.5.11 Client side Profile API event ([service_name]c_cb function)

Callback function of the client side profile API receives following events.

```
enum   e_ble_servc_event_t {
   BLE_SERVC_WRITE_RSP,
   BLE_SERVC_READ_RSP,
   BLE_SERVC_HDL_VAL_NTF,
   BLE_SERVC_HDL_VAL_IND
}

enum   e_ble_[service name]c_event_t {
   BLE_[service name]C_EVENT_[characteristic name]_WRITE_RSP = 0xXX00,
   BLE_[service name]C_EVENT_[characteristic name]_READ_RSP= 0xXX01,
   BLE_[service name]C_EVENT_[characteristic name]_HDL_VAL_NTF = 0xXX02,
   BLE_[service name]C_EVENT_[characteristic name]_HDL_VAL_IND = 0xXX03,
   BLE_[service name]C_EVENT_[characteristic name]_[descriptor name]_WRITE_RSP = 0xYY00,
   BLE_[service name]C_EVENT_[characteristic name]_[descriptor name]_READ_RSP = 0xYY01,
   :
   :
}
```

**Code 49. Client-side Profile API event**

Note: The 10th to 15th bits are serial numbers that distinguish attributes (characteristics and descriptors). XX and YY are 00, 04, 08, 10, ..., FC.

Reception condition of the frequently occurring events are shown below.

**Table 17. Frequently use events of Profile Client callback**

| Event | Reception condition |
|---|---|
| XXX_WRITE_RSP (0xXXX0) | Complete receiving Write Response |
| XXX_READ_RSP (0xXXX1) | Complete receiving Read Response |
| XXX_HDL_VAL_NTF (0xXXX2) | Complete receiving Notification |
| XXX_HDL_VAL_IND (0xXXX3) | Complete receiving Indication |

Callback function of client-side profile API is following. (Example of LED switch service)

```
static void lsc_cb(uint16_t type, ble_status_t result, st_ble_servc_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for LED Switch Service Client callback function common process. Do not edit comment
generated here */
/* End user code. Do not edit comment generated here */

    switch(type)
    {
/* Hint: Add cases of LED Switch Service client events defined in e_ble_lsc_event_t */
/* Start user code for LED Switch Service Client callback function event process. Do not edit comment
generated here */
        case BLE_LSC_EVENT_SWITCH_STATE_HDL_VAL_NTF:
        {
            if (BLE_SUCCESS == result)
                R_BLE_CLI_Printf("lsc : Recieve Notification from Server \n");
        } break;

        case BLE_LSC_EVENT_BLINK_RATE_READ_RSP:
        {
            if (BLE_SUCCESS == result)
                R_BLE_CLI_Printf("lsc : LED blink rate = 0x%X \n", *(uint8_t *)((st_ble_lsc_evt_data_t
*)(p_data)->p_param));
        } break;

        default:
            break;
/* End user code. Do not edit comment generated here */
    }
}
```

**Code 50. Client side profile API callback function**

QE for BLE generates skeleton code for Profile client callback function. User can add their own code into the skeleton code.

### 3.5.12 L2CAP event

Same as section 3.1.12.

### 3.5.13 Exiting from Software Standby mode

In this demo project, IRQ4 assigned SW1 on EK-RA4W1 is designated as Wakeup Source of Low Power Module. When SW1 on EK-RA4W1 under Software Standby mode is pressed, Software Standby mode is exited then *Callback_ble_sw_irq()* function is executed because it is registered as callback function of IRQ4 interrupt.

```
static void sw_cb(void)
{
    g_inhibit_software_standby = true;
}
…………
void Callback_ble_sw_irq(external_irq_callback_args_t *p_args)
{
    FSP_PARAMETER_NOT_USED(p_args);
    R_BLE_SetEvent(sw_cb);
}
```

Clear flag to manage state of Software Standby mode

Interrupt callback function for push switch

**Code 51. Callback function of IRQ4 interrupt**

### 3.5.14 CLI (Command Line Interface)

This section is almost same as section 3.1.14. LSC command is registered to gsp_cmds structure in GATT Client demo projects.

```
static const st_ble_cli_cmd_t * const gsp_cmds[] =
{
     &g_abs_cmd,
     &g_vs_cmd,
     &g_sys_cmd,
     &g_lsc_cmd,
     &g_ble_cmd
};
```

**Code 52. gsp_cmds structure**

## 3.6 FreeRTOS environment (Client, EventGroup as Synchronization Type case)

### 3.6.1 Create / delete task

Same as section 3.2.1.

### 3.6.2 Task switching between BLE core task and GATT application task

If event notified by scheduler, part of the BLE protocol stack, is an event for GATT application task, BLE core task activates GATT application task and provides a notification of the event by using event group setting and cleaning technique. In this demo project, event group bit defined in task_functon.h as following.

**Table 18. Defined event group bit**

| Macro name (Value) | Usage |
|---|---|
| LSC_WAIT_EN_CCCD (0x0001) | Enable CCCD in LED Switch Service |
| LSC_WAIT_DIS_CCCD (0x0002) | Disable CCCD in LED Switch Service |
| LSC_WAIT_RECV_NTF (0x0004) | Receive notification from server |
| LSC_WAIT_WR_BLINK (0x0008) | Change LED blink rate |
| LSC_WAIT_RD_BLINK (0x0010) | Read LED blink rate |

Function which sets event group bit need to implement by the user. The function in this demo project is as follows.

```
void set_lsc_event(EventBits_t uxBitsToSet)
{
    switch(uxBitsToSet)
    {
        case LSC_WAIT_EN_CCCD:
        {
            xEventGroupClearBits(xLscEvent, LSC_WAIT_DIS_CCCD);
        } break;
        case LSC_WAIT_DIS_CCCD:
        {
            xEventGroupClearBits(xLscEvent, LSC_WAIT_EN_CCCD);
        } break;
        default:
            /* Do Nothing */
            break;
    }

    xEventGroupSetBits(xLscEvent, uxBitsToSet);
}
```

**Code 53. Set event group bit**

### 3.6.3 Main loop of BLE core task

Same as section 3.2.3.

### 3.6.4 Main loop of GATT application task

The *lsc_task_entry()* includes main loop of GATT application task. The program flow of this demo project is following.

```
void lsc_task_entry(void * pvParameters)
{
    FSP_PARAMETER_NOT_USED (pvParameters);

    ble_status_t    retval;
    EventBits_t     event;

    gs_conn_hdl = *(uint16_t *)pvParameters;
    xLscEvent = xEventGroupCreate();
    wait_event = LSC_WAIT_EN_CCCD | LSC_WAIT_DIS_CCCD | LSC_WAIT_RECV_NTF | LSC_WAIT_WR_BLINK | LSC_WAIT_RD_BLINK;
    while (1)
    {
        event = xEventGroupWaitBits(
                                        xLscEvent,
                                        wait_event,
                                        pdTRUE,
                                        pdFALSE,
                                        portMAX_DELAY);

        if (LSC_WAIT_EN_CCCD & event)
        {
            retval = R_BLE_LSC_WriteSwitchStateCliCnfg(gs_conn_hdl, (uint16_t *)&g_lsc_ntf_value);
            if (BLE_SUCCESS == retval)
            {
                wait_event = LSC_WAIT_DIS_CCCD | LSC_WAIT_RECV_NTF | LSC_WAIT_WR_BLINK | LSC_WAIT_RD_BLINK;
                r_ble_wake_up_task((void *)g_ble_event_group_handle);
            }
        }
        else if (LSC_WAIT_DIS_CCCD & event)
        {
            retval = R_BLE_LSC_WriteSwitchStateCliCnfg(gs_conn_hdl, (uint16_t *)&g_lsc_ntf_value);
            if (BLE_SUCCESS == retval)
            {
                wait_event = LSC_WAIT_EN_CCCD | LSC_WAIT_RECV_NTF | LSC_WAIT_WR_BLINK | LSC_WAIT_RD_BLINK;
                r_ble_wake_up_task((void *)g_ble_event_group_handle);
            }
        }
        else if (LSC_WAIT_WR_BLINK & event)
        {
            R_BLE_LSC_WriteBlinkRate(gs_conn_hdl, &g_blink_rate);
        }
        else if (LSC_WAIT_RD_BLINK & event)
        {
            retval = R_BLE_LSC_ReadBlinkRate(gs_conn_hdl);
            if (BLE_SUCCESS == retval){
                r_ble_wake_up_task((void *)g_ble_event_group_handle);
            }
        }
    }

    vTaskDelete(NULL);
}
```

Store connection handle

Create event group for transition task status.

Wait for event from BLE core task

Wait for enable CCCD event from BLE core task

Wait for disable CCCD event from BLE core task

Wait for write LED blink rate event from BLE core task

Wait for read LED blink rate event from BLE core task

**Code 54. lsc_task_entry function**

### 3.6.5 Initialization process

Same as section3.5.3.

### 3.6.6 Register callback function

Same as section 3.1.4

### 3.6.7 Registering GATT database (R_BLE_GATTS_SetDbInst)

Same as section 3.1.5.

### 3.6.8 Main loop and scheduler (R_BLE_Execute)

Same as section 3.2.8.

### 3.6.9 GAP event (gap_cb function)

Same as section 3.5.7.

### 3.6.10 GATTC event (gattc_cb function)

Almost the same as section 3.5.9. The difference from BareMetal environment is that,

- GATT application task is created when connection is established with the client.
- GATT application task is deleted when client disconnects.

Implementation of this demo project is following.

```
void gattc_cb(uint16_t type, ble_status_t result, st_ble_gattc_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for GATT Client callback function common process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */

    R_BLE_SERVC_GattcCb(type, result, p_data);
    switch(type)
    {
        case BLE_GATTC_EVENT_CONN_IND:
        {
            /* Start discovery operation after connection established */
            R_BLE_CLI_Printf("Start Service Discovery\n");

            R_BLE_DISC_Start(p_data->conn_hdl, gs_disc_entries, ARRAY_SIZE(gs_disc_entries), disc_comp_cb);

            /* Create GATT application task */
            xTaskCreate(lsc_task_entry, "lsc_task", 128, &g_conn_hdl, 4, &g_lsc_task);

        } break;

        case BLE_GATTC_EVENT_DISCONN_IND:
        {

            /* task delete */
            delete_lsc_task_rsrc();

        } break;

        default:
            /* Do nothing */
            break;

/* Hint: Add cases of GATT Client event macros defined as BLE_GATTC_XXX */
/* Start user code for GATT Client callback function event process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */
    }
}
```

**Code 55. GATTC callback function**

### 3.6.11 VS event (vs_cb function)

Same as section 3.1.10.

### 3.6.12 Client side Profile API event ([service_name]c_cb function)

Almost the same as section 3.5.11. The difference from BareMetal environment is that event group bits are adjusted according to the data received from client-side profile API event. As a result, the GATT Application task is activated per the function definition provided in Section 3.6.2.

```
static void lsc_cb(uint16_t type, ble_status_t result, st_ble_servc_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for LED Switch Service(Custom Service) Client callback function common process. */
/*Do not edit comment generated here */
/* End user code. Do not edit comment generated here */


    switch(type)
    {
/* Hint: Add cases of LED Switch Service(Custom Service) client events defined in e_ble_lsc_event_t */
/* Start user code for LED Switch Service(Custom Service) Client callback function event process. Do not edit
comment generated here */
```

Receive notification from server-side

```
        case BLE_LSC_EVENT_SWITCH_STATE_HDL_VAL_NTF:
        {
            Note: Add processing when an event is received here.
        } break;
```

Change LED blink rate

```
        case BLE_LSC_EVENT_BLINK_RATE_READ_RSP:
        {
            Note: Add processing when an event is received here.
        } break;

        default:
            break;

/* End user code. Do not edit comment generated here */
    }
}
```

**Code 56. Profile Client callback function**

### 3.6.13 L2CAP event

Same as section 3.1.12.

### 3.6.14 CLI (Command Line Interface)

Same as section 3.5.14.

## 3.7 FreeRTOS environment (Client, Semaphore as Synchronization Type case)

### 3.7.1 Create / delete task

Same as section 3.3.1.

### 3.7.2 Task switching between BLE core task and GATT application task

Same as section 3.6.2.

### 3.7.3 Main loop of BLE core task

Same as section 3.3.3.

### 3.7.4 Main loop of BLE execute task

Same as section 0.

### 3.7.5 Main loop of GATT application task

Same as section 3.6.4.

### 3.7.6 Initialization process

Same as section3.5.3.

### 3.7.7 Register callback function

Same as section 3.1.4.

### 3.7.8 Registering GATT database (R_BLE_GATTS_SetDbInst)

Same as section 3.1.5.

### 3.7.9 Main loop and scheduler (R_BLE_Execute)

Same as section 3.3.9..

### 3.7.10 GAP event (gap_cb function)

Same as section 3.5.7.

### 3.7.11 GATTC event (gattc_cb function)

Same as section 3.6.12.

### 3.7.12 VS event (vs_cb function)

Same as section 3.1.10.

### 3.7.13 Client side Profile API event ([service_name]c_cb function)

Same as section 3.6.12.

### 3.7.14 L2CAP event

Same as section 3.1.12.

### 3.7.15 CLI (Command Line Interface)

Same as section 3.5.14.

## 3.8 Azure RTOS environment (Client)

### 3.8.1 Create / delete task

Same as section 3.4.1.

### 3.8.2 Task switching between BLE core task and GATT application task

Same as section 3.4.2.

### 3.8.3 Main loop of BLE core task

Same as section 3.4.3.

### 3.8.4 Main loop of BLE execute task

Same as section 3.4.4.

### 3.8.5 Main loop of GATT application task

The *lsc_task_entry()* includes main loop of GATT application task. The program flow of this demo project is following.

```
void lsc_task_entry(unsigned long Parameters)
{

    ble_status_t    retval;
    unsigned long event;

    gs_conn_hdl = (uint16_t)Parameters;
    tx_event_flags_create(&xLscEvent, "LSC_EVENT_FLAG");
    wait_event = LSC_WAIT_EN_CCCD | LSC_WAIT_DIS_CCCD | LSC_WAIT_RECV_NTF | LSC_WAIT_WR_BLINK | LSC_WAIT_RD_BLINK;

    while (1)
    {
        tx_event_flags_get(&xLscEvent, wait_event, TX_OR_CLEAR, &event, TX_WAIT_FOREVER);

        if (LSC_WAIT_EN_CCCD & event)
        {
            retval = R_BLE_LSC_WriteSwitchStateCliCnfg(gs_conn_hdl, (uint16_t *)&g_lsc_ntf_value);
            if (BLE_SUCCESS == retval)
            {
                wait_event = LSC_WAIT_DIS_CCCD | LSC_WAIT_RECV_NTF | LSC_WAIT_WR_BLINK | LSC_WAIT_RD_BLINK;
                r_ble_wake_up_task((void *)g_ble_event_group_handle);
            }
        }
        else if (LSC_WAIT_DIS_CCCD & event)
        {
            retval = R_BLE_LSC_WriteSwitchStateCliCnfg(gs_conn_hdl, (uint16_t *)&g_lsc_ntf_value);
            if (BLE_SUCCESS == retval)
            {
                wait_event = LSC_WAIT_EN_CCCD | LSC_WAIT_RECV_NTF | LSC_WAIT_WR_BLINK | LSC_WAIT_RD_BLINK;
                r_ble_wake_up_task((void *)g_ble_event_group_handle);
            }
        }
        else if (LSC_WAIT_WR_BLINK & event)
        {
            retval = R_BLE_LSC_WriteBlinkRate(gs_conn_hdl, &g_blink_rate);
            if (BLE_SUCCESS == retval)
            {
                wait_event = LSC_WAIT_EN_CCCD | LSC_WAIT_RECV_NTF | LSC_WAIT_WR_BLINK | LSC_WAIT_RD_BLINK;
                r_ble_wake_up_task((void *)g_ble_event_group_handle);
            }
        }
        else if (LSC_WAIT_RD_BLINK & event)
        {
            retval = R_BLE_LSC_ReadBlinkRate(gs_conn_hdl);
            if (BLE_SUCCESS == retval){
                r_ble_wake_up_task((void *)g_ble_event_group_handle);
            }
        }
    }
}
```

Store connection

Create event flags for transition task status.

Wait for event from BLE core task

Wait for enable CCCD event from BLE core task

Wait for disable CCCD event from BLE core task

Wait for write LED blink rate event from BLE core task

Wait for read LED blink rate event from BLE core task

**Code 57. lsc_task_entry function**

### 3.8.6 Initialization process

Same as section 3.5.3.

### 3.8.7 Register callback function

Same as section 3.1.4

### 3.8.8 Registering GATT database (R_BLE_GATTS_SetDbInst)

Same as section 3.1.5.

### 3.8.9 Main loop and scheduler (R_BLE_Execute)

Same as section 3.3.9.

### 3.8.10 GAP event (gap_cb function)

Same as section 3.5.7.

### 3.8.11 GATTC event (gattc_cb function)

Almost the same as section 3.5.9. The difference from BareMetal environment is that,

- GATT application task is created when connection is established with the client.
- GATT application task is deleted when client disconnects.

Implementation of this demo project is following.

```
void gattc_cb(uint16_t type, ble_status_t result, st_ble_gattc_evt_data_t *p_data)
{
/* Hint: Input common process of callback function such as variable definitions */
/* Start user code for GATT Client callback function common process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */

    R_BLE_SERVC_GattcCb(type, result, p_data);
    switch(type)
    {
        case BLE_GATTC_EVENT_CONN_IND:
        {
            R_BLE_CLI_Printf("Start Service Discovery\n");
            /* Start discovery operation after connection established */
            R_BLE_DISC_Start(p_data->conn_hdl, gs_disc_entries, ARRAY_SIZE(gs_disc_entries), disc_comp_cb);

            /* Create LED Switch Service Task */
            tx_thread_create(&ble_lsc_task, (CHAR*) "BLE_LSC_TASK", lsc_task_entry, g_conn_hdl,
                                    &ble_lsc_task_stack, 512, 4, 4, 4, TX_AUTO_START);
        } break;

/* Hint: Add cases of GATT Client event macros defined as BLE_GATTC_XXX */
/* Start user code for GATT Client callback function event process. Do not edit comment generated here */
        case BLE_GATTC_EVENT_DISCONN_IND:
        {
            /* task delete */
            delete_lsc_task_rsrc();

        } break;
/* End user code. Do not edit comment generated here */
    }

/* Start user code for GATT Client callback function closing process. Do not edit comment generated here */
/* End user code. Do not edit comment generated here */
}
```

**Code 58. GATTC callback function**

### 3.8.12 VS event (vs_cb function)

Same as section 3.1.10.

### 3.8.13 Client side Profile API event ([service_name]c_cb function)

Same as section 3.6.12.

### 3.8.14 L2CAP event

Same as section 3.1.12.

### 3.8.15 CLI (Command Line Interface)

Same as section 3.5.14.

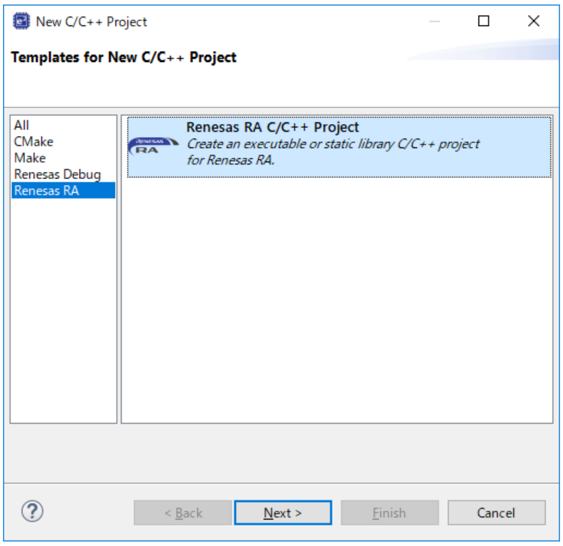
# 4. Appendix

## 4.1 How to make and configure new project

This section describes required configuration to create a project for BLE application.

### 4.1.1 Create a new project

1. Launch e$^2$ studio and select **File→New→C/C++ Project**. In **New C/C++ Project** dialog, select **Renesas RA** and **Renesas RA C Executable Project** and click on the **Next** button.



New C/C++ Project

Templates for New C/C++ Project

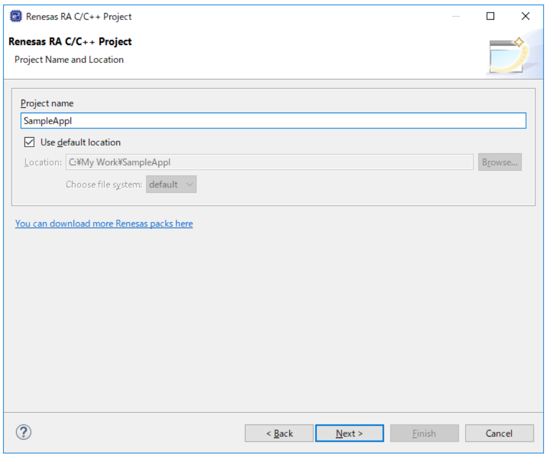
Renesas RA

Renesas RA C/C++ Project

*Create an executable or static library C/C++ project for Renesas RA.*

**Figure 27. Templates for New C/C++ Project**

2. Enter project name and click on **Next** button. The project named **SampleAppl** in this document.



Renesas RA C/C++ Project

Renesas RA C/C++ Project

Project Name and Location

Project name: SampleAppl

☑ Use default location

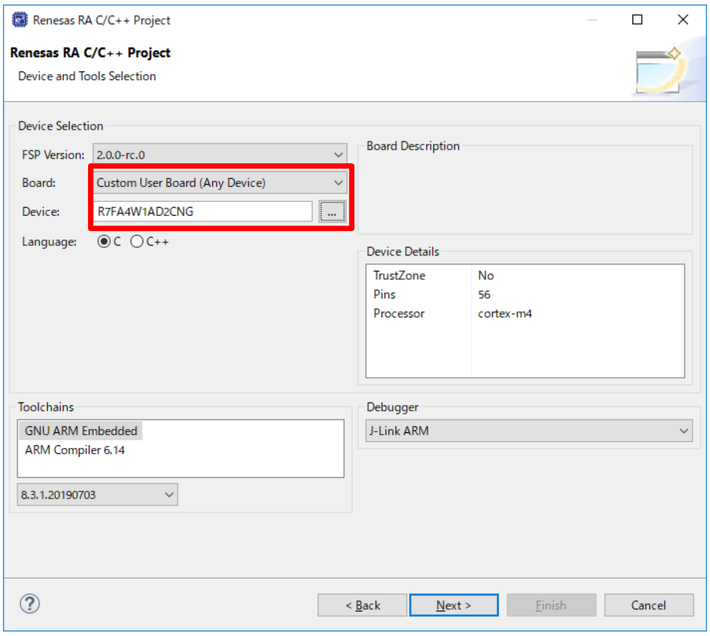
Location: C:¥My Work¥SampleAppl

Choose file system: default

You can download more Renesas packs here

**Figure 28. New Renesas Executable Project**

3. Select the **Custom User Board (Any Device)** from **Board**, **R7FA4W1AD2CNG** from **Device**.



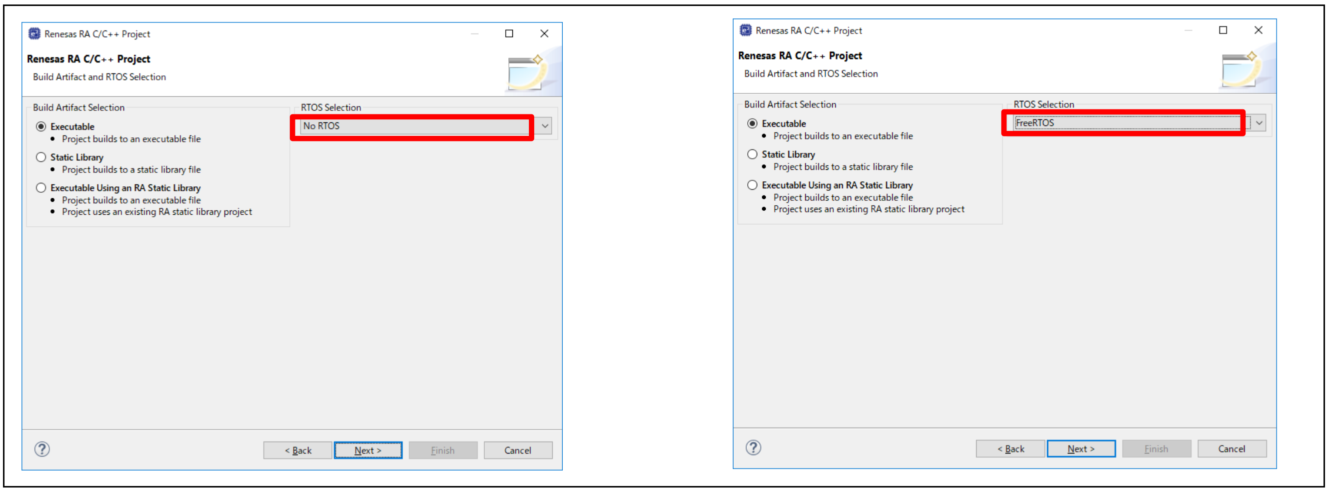
FSP Version: 2.0.0-rc.0
Board: Custom User Board (Any Device)
Device: R7FA4W1AD2CNG
Language: ● C ○ C++

| | |
|---|---|
| TrustZone | No |
| Pins | 56 |
| Processor | cortex-m4 |

Toolchains: GNU ARM Embedded, ARM Compiler 6.14; 8.3.1.20190703
Debugger: J-Link ARM

**Figure 29. Project Configuration (Board and Device)**

4. When making BLE application on BareMetal environment, choose **No RTOS**. When making the application on FreeRTOS environment, choose **FreeRTOS**. When making the application on Azure RTOS environment, choose **Azure RTOS ThreadX**.



Build Artifact Selection:
- ● Executable
  - Project builds to an executable file
- ○ Static Library
  - Project builds to a static library file
- ○ Executable Using an RA Static Library
  - Project builds to an executable file
  - Project uses an existing RA static library project

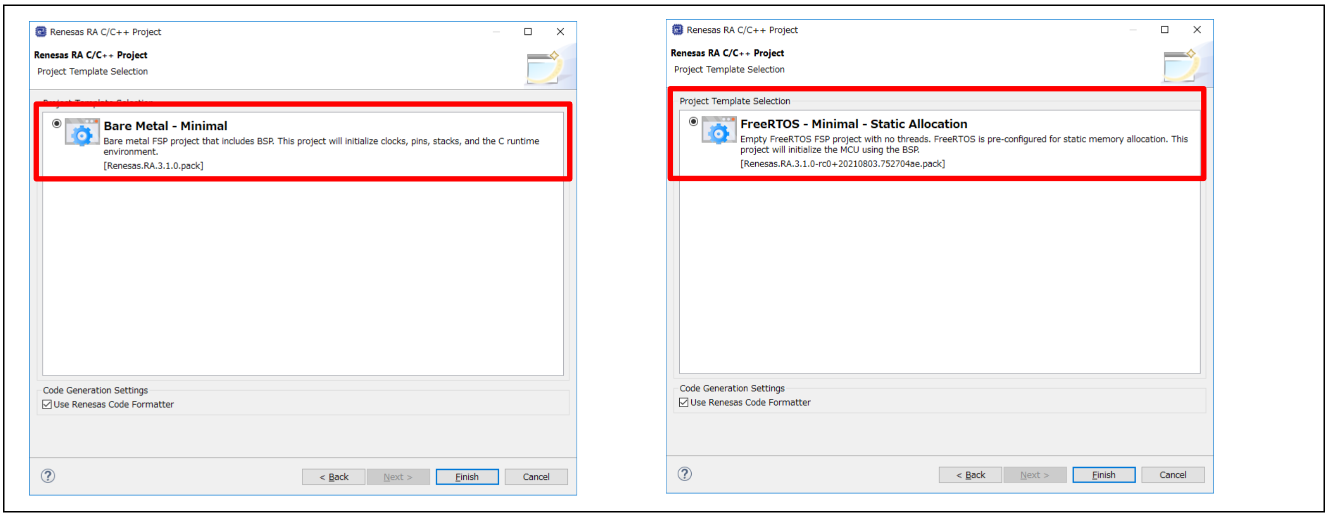
RTOS Selection: No RTOS

RTOS Selection: FreeRTOS

**Figure 30. Project Configuration**

5. Click **Next** button.

6. When making BLE application on BareMetal environment, choose **BareMetal -Minimal**. When making the application with FreeRTOS environment, choose **FreeRTOS -Minimal- Static Allocation**. When making the application with Azure RTOS environment, choose **Azure RTOS ThreadX – Minimal**.



Renesas RA C/C++ Project

**Renesas RA C/C++ Project**

Project Template Selection

● **Bare Metal - Minimal**
Bare metal FSP project that includes BSP. This project will initialize clocks, pins, stacks, and the C runtime environment.
[Renesas.RA.3.1.0.pack]

Code Generation Settings
☑ Use Renesas Code Formatter

Renesas RA C/C++ Project

**Renesas RA C/C++ Project**

Project Template Selection

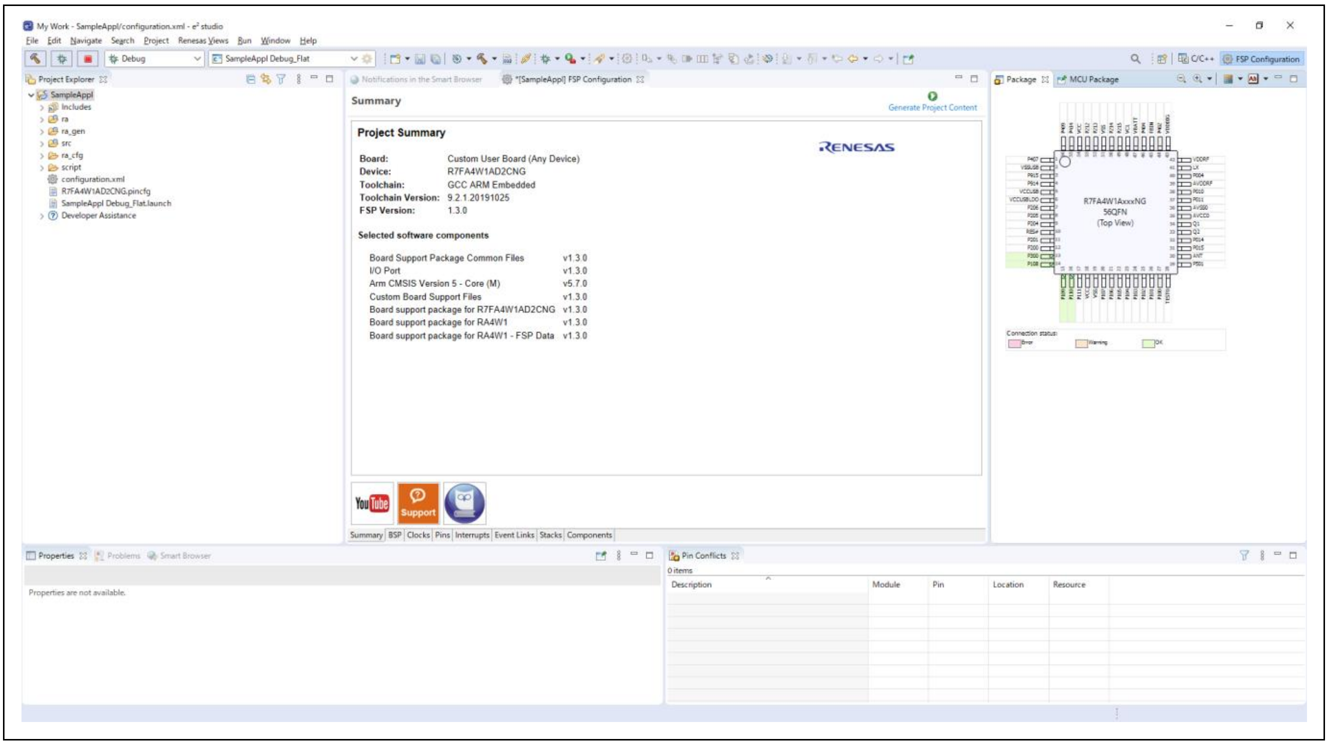
Project Template Selection

● **FreeRTOS - Minimal - Static Allocation**
Empty FreeRTOS FSP project with no threads. FreeRTOS is pre-configured for static memory allocation. This project will initialize the MCU using the BSP.
[Renesas.RA.3.1.0-rc0+20210803.752704ae.pack]

Code Generation Settings
☑ Use Renesas Code Formatter

Figure 31. Project Configuration (Select Template)

7. Click **Finish** button. After a while, project will be created



My Work - SampleAppl/configuration.xml - e² studio

*[SampleAppl] FSP Configuration

Summary

**Project Summary**

Board: Custom User Board (Any Device)
Device: R7FA4W1AD2CNG
Toolchain: GCC ARM Embedded
Toolchain Version: 9.2.1.20191025
FSP Version: 1.3.0

Selected software components

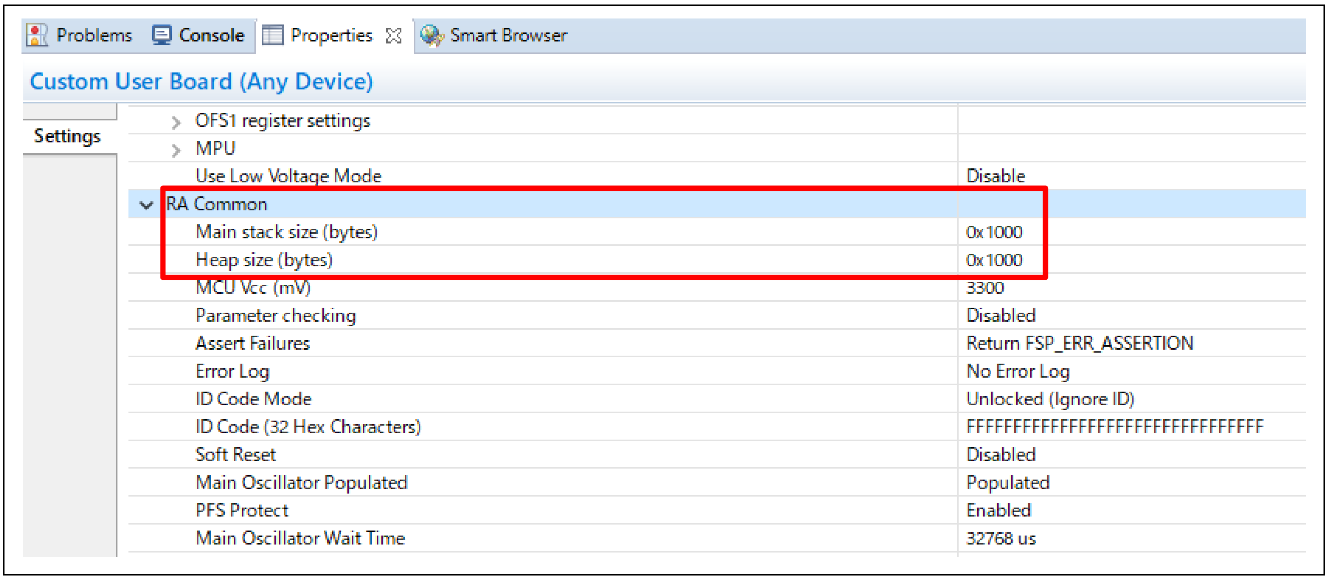
| | |
|---|---|
| Board Support Package Common Files | v1.3.0 |
| I/O Port | v1.3.0 |
| Arm CMSIS Version 5 - Core (M) | v5.7.0 |
| Custom Board Support Files | v1.3.0 |
| Board support package for R7FA4W1AD2CNG | v1.3.0 |
| Board support package for RA4W1 | v1.3.0 |
| Board support package for RA4W1 - FSP Data | v1.3.0 |

Figure 32. Project Overview

### 4.1.2 Heap and Stack configuration

Set heap and stack configuration as following on FSP configuration **BSP** tab.

- [RA Common]→[Main stack size (bytes)] : 0x1000
- [RA Common]→[Heap size (bytes)] : 0x1000



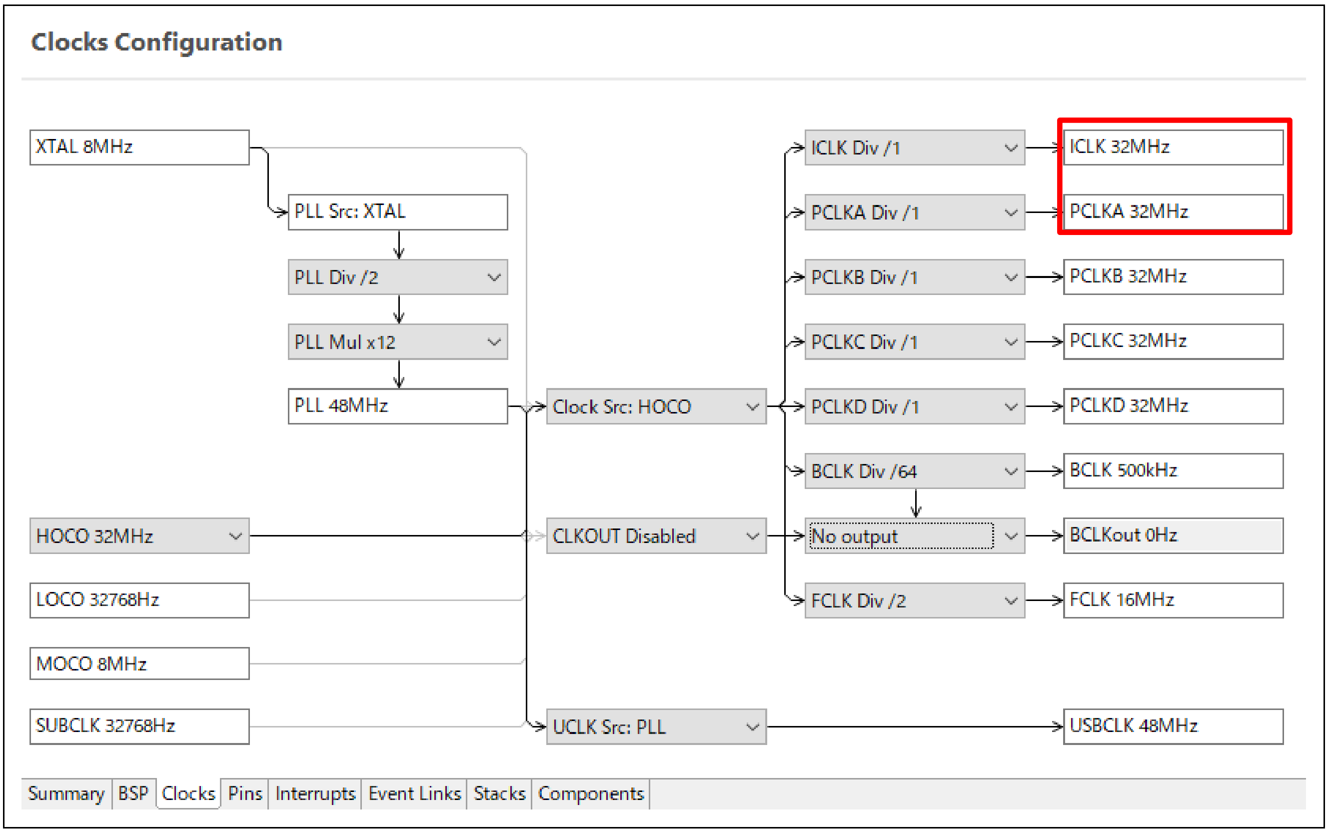
| | |
|---|---|
| OFS1 register settings | |
| MPU | |
| Use Low Voltage Mode | Disable |
| RA Common | |
| Main stack size (bytes) | 0x1000 |
| Heap size (bytes) | 0x1000 |
| MCU Vcc (mV) | 3300 |
| Parameter checking | Disabled |
| Assert Failures | Return FSP_ERR_ASSERTION |
| Error Log | No Error Log |
| ID Code Mode | Unlocked (Ignore ID) |
| ID Code (32 Hex Characters) | FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF |
| Soft Reset | Disabled |
| Main Oscillator Populated | Populated |
| PFS Protect | Enabled |
| Main Oscillator Wait Time | 32768 us |

**Figure 33. BSP configuration**

If the Properties tab is not visible, choose **Window→Show View→Properties** on e$^2$ studio menu bar.

### 4.1.3 Clocks configuration

Set clock frequencies as following on FSP configuration **Clocks** tab.



Clocks Configuration

XTAL 8MHz

PLL Src: XTAL

PLL Div /2

PLL Mul x12

PLL 48MHz

HOCO 32MHz

LOCO 32768Hz

MOCO 8MHz

SUBCLK 32768Hz

Clock Src: HOCO

CLKOUT Disabled

UCLK Src: PLL

ICLK Div /1

PCLKA Div /1

PCLKB Div /1

PCLKC Div /1

PCLKD Div /1

BCLK Div /64

No output

FCLK Div /2

ICLK 32MHz

PCLKA 32MHz

PCLKB 32MHz

PCLKC 32MHz

PCLKD 32MHz

BCLK 500kHz

BCLKout 0Hz

FCLK 16MHz

USBCLK 48MHz

Figure 34. Clocks configuration

The minimum clock frequency for BLE module is following.

- System clock (ICLK) : 8MHz
- Peripheral module clock A (PCLKA) : 8MHz

However, the BLE module is optimized to operate with ICLK = 32MHz and PCLKA=32MHz.Therefore, Renesas recommends configuring frequency of ICLK and PCLKA to 32MHz for maximizing BLE performance.

## 4.1.4 Add and configure BLE module

This section describes how to add / configure BLE module into BLE application. Click **configuration.xml** in the project and add / configure BLE module on FSP configuration **Stacks** tab. Procedure about adding BLE module is different for BareMetal, FreeRTOS and Azure RTOS environment. Section 4.1.4.1 describes the procedure for BareMetal environment. Section 4.1.4.2 describes the procedure for FreeRTOS environment. Section 4.1.4.3 describes the procedure for Azure RTOS. And BLE module configuration is common to BareMetal, FreeRTOS and Azure RTOS environment. The configuration is described in detail in section 4.1.4.4 and 4.1.4.5.

### 4.1.4.1 Add BLE module in BareMetal environment

1. Click **New Stack** and add **Middleware→BLE Abstraction Driver on rm_ble_abs** to **HAL/Common**.

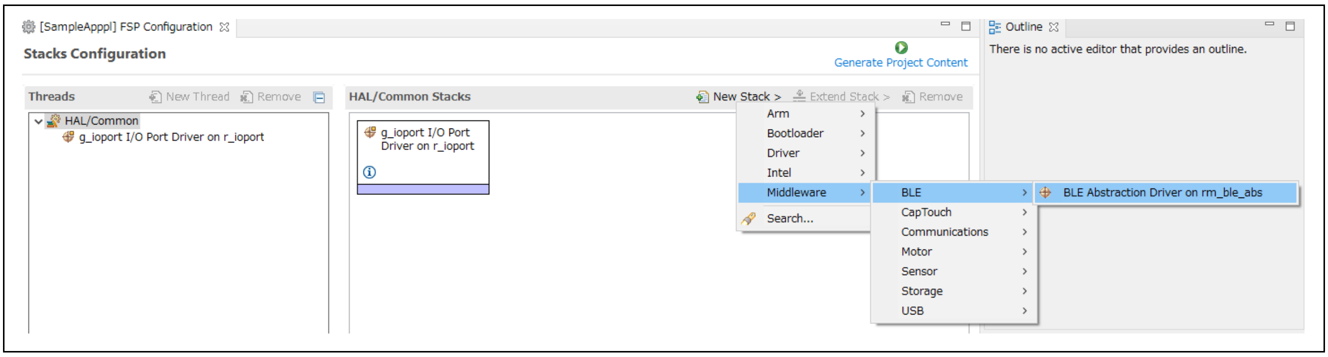


Figure 35. Add BLE module

2. Click **Add BLE Library for Network** box and select **New→Network Driver on r_ble_XXX.**

   “Extended”, “Balance”, and “Compact” can be selected for XXX according to the supported BLE features. Refer to section 1.3 about supported BLE features of each library type.

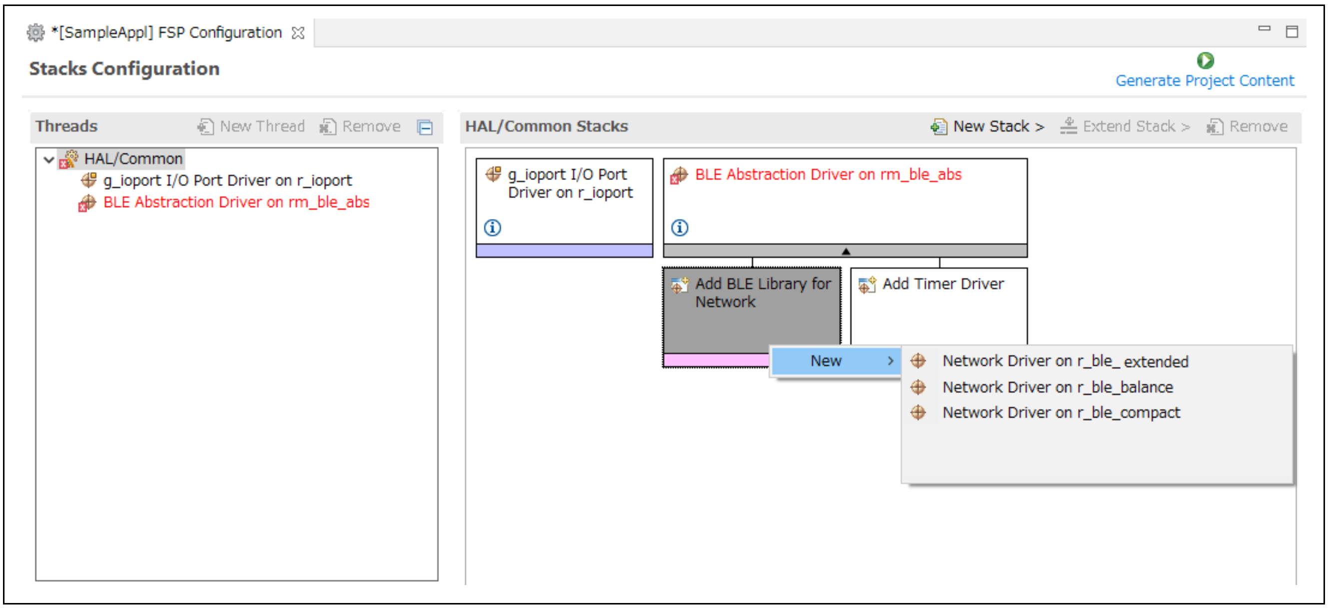
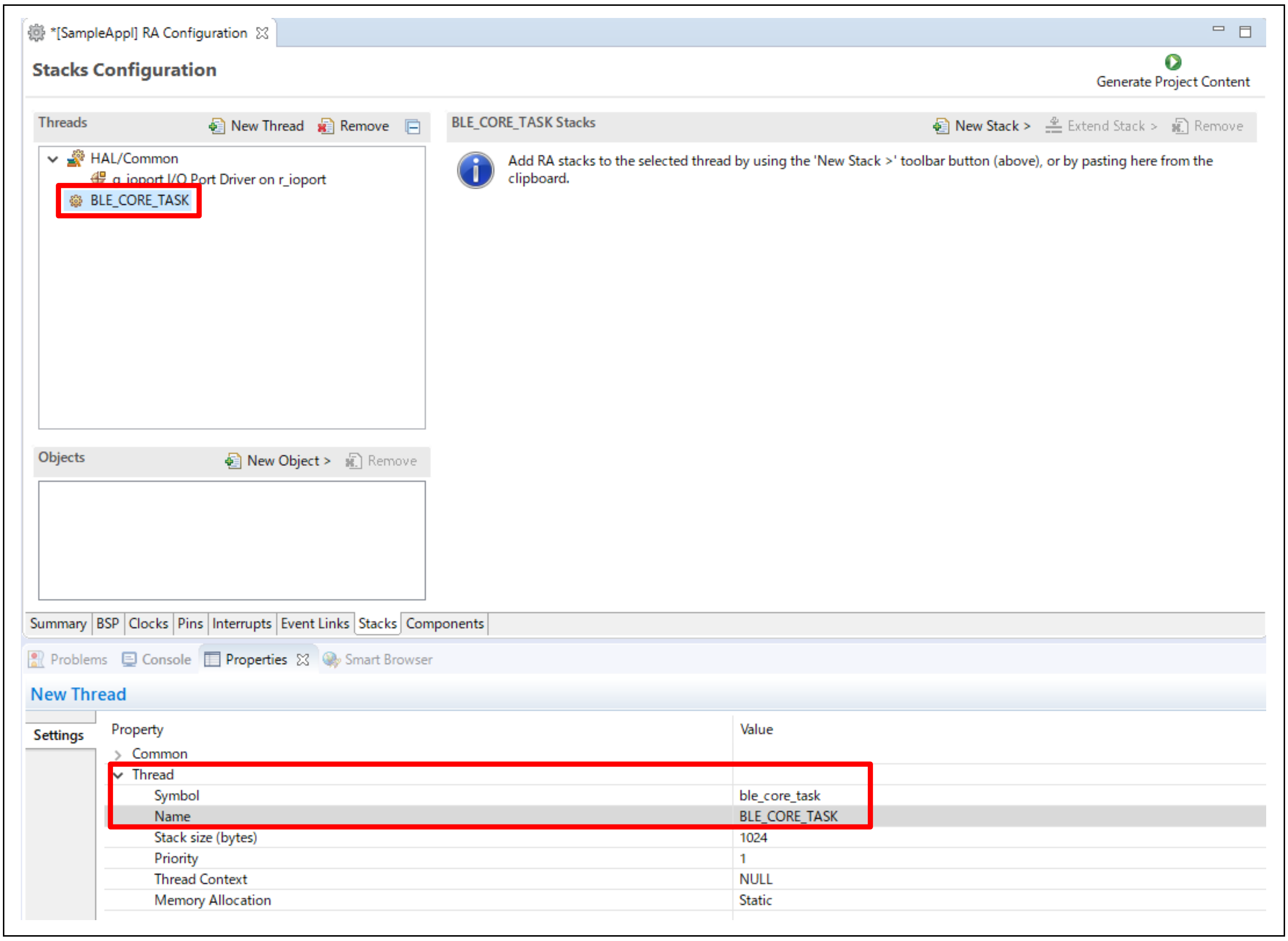


Figure 36. Select module type

The BLE FSP module has properties which may change according to user scenario. Refer to section 4.1.4.4 about description of the properties. And The driver includes some peripheral driver. Configuration for these peripherals describes in section 4.1.4.5.

#### 4.1.4.2 Add BLE module in FreeRTOS environment

1. Click **New Thread** on Thread area and add New Thread. In this example, the New Thread is named BLE Core Task. Note that the symbol of the New Thread should be “ble_core_task” in case of using QE for BLE, because QE for BLE expects so.

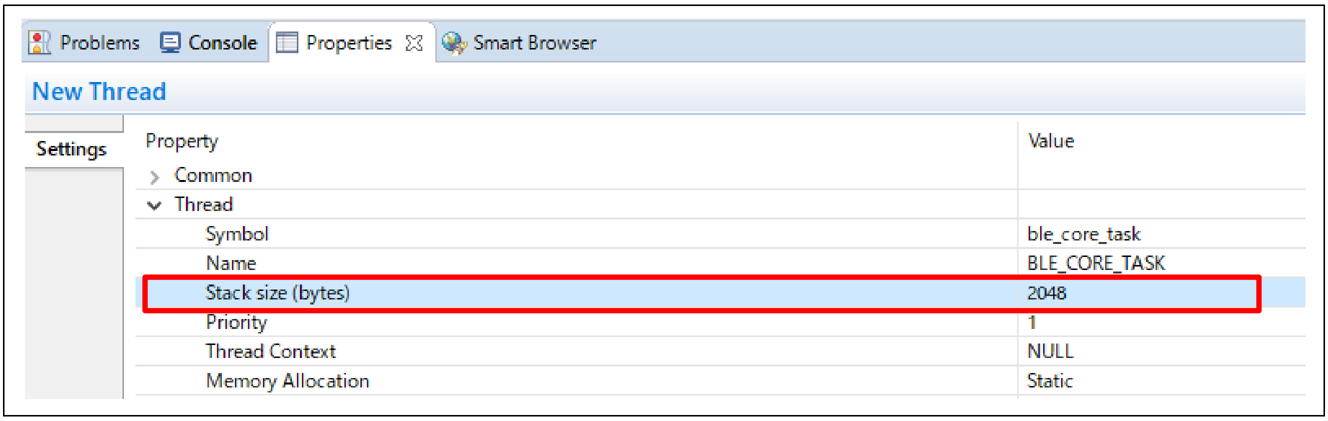


Add RA stacks to the selected thread by using the 'New Stack >' toolbar button (above), or by pasting here from the clipboard.

| Property | Value |
|---|---|
| > Common | |
| ∨ Thread | |
| Symbol | ble_core_task |
| Name | BLE_CORE_TASK |
| Stack size (bytes) | 1024 |
| Priority | 1 |
| Thread Context | NULL |
| Memory Allocation | Static |

Figure 37. Add BLE Core Task

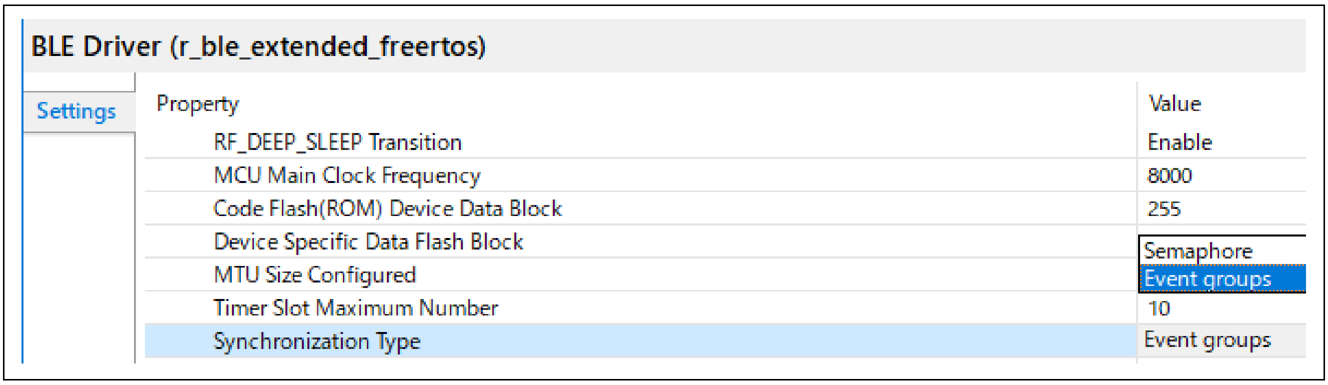
2. Change Stack size as 2048[bytes]. The BLE stack included in this application requires 1.5 [KB] of memory space to use. And the profile itself included in this application requires 0.4[KB] memory space to use.



| Property | Value |
|---|---|
| > Common | |
| ∨ Thread | |
| Symbol | ble_core_task |
| Name | BLE_CORE_TASK |
| Stack size (bytes) | 2048 |
| Priority | 1 |
| Thread Context | NULL |
| Memory Allocation | Static |

Figure 38. Stack size of BLE Core Task

3. BLE_CORE_TASK priority depends on following *BLE_Driver* FSP module property.

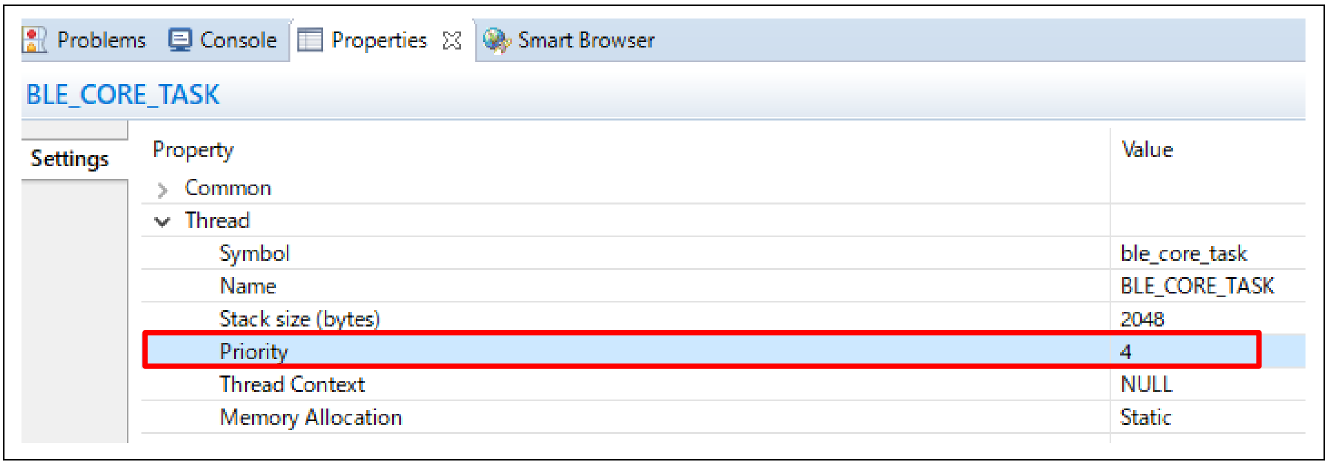


**BLE Driver (r_ble_extended_freertos)**

| Property | Value |
|---|---|
| RF_DEEP_SLEEP Transition | Enable |
| MCU Main Clock Frequency | 8000 |
| Code Flash(ROM) Device Data Block | 255 |
| Device Specific Data Flash Block | Semaphore |
| MTU Size Configured | Event groups |
| Timer Slot Maximum Number | 10 |
| Synchronization Type | Event groups |

**Figure 39. Synchronization Type**

In case of choose *Event group*, priority of BLE Core Task should be highest priority (configMAX_PRIORITIES-1).

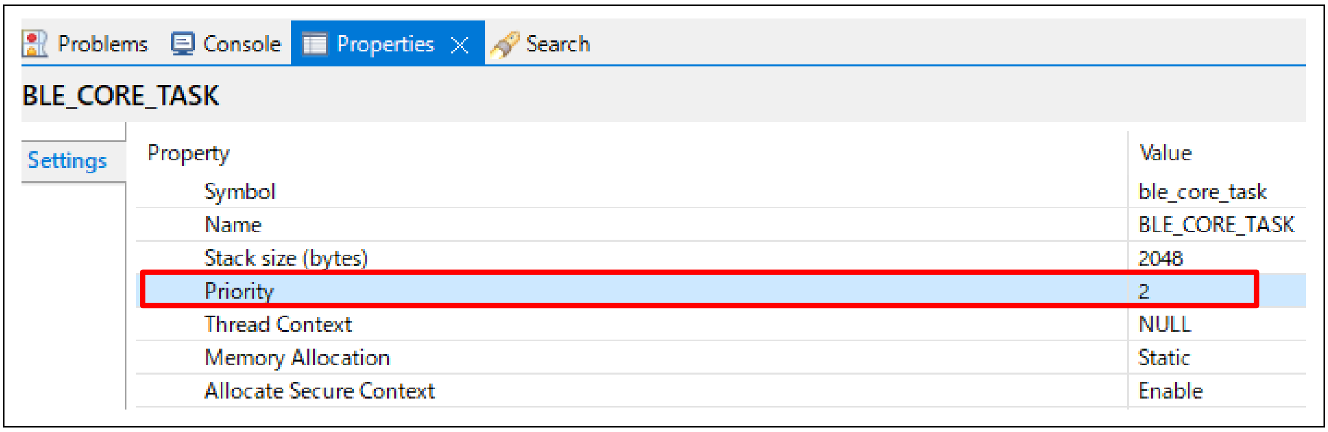


BLE_CORE_TASK

| Property | Value |
|---|---|
| Common | |
| Thread | |
| Symbol | ble_core_task |
| Name | BLE_CORE_TASK |
| Stack size (bytes) | 2048 |
| Priority | 4 |
| Thread Context | NULL |
| Memory Allocation | Static |

**Figure 40. Priority of BLE Core Task (Event Group case)**

In case of choose *Semaphore*, priority of BLE Core Task should NOT be highest priority. In demo project, priority of the task configured as 2.



BLE_CORE_TASK

| Property | Value |
|---|---|
| Symbol | ble_core_task |
| Name | BLE_CORE_TASK |
| Stack size (bytes) | 2048 |
| Priority | 2 |
| Thread Context | NULL |
| Memory Allocation | Static |
| Allocate Secure Context | Enable |

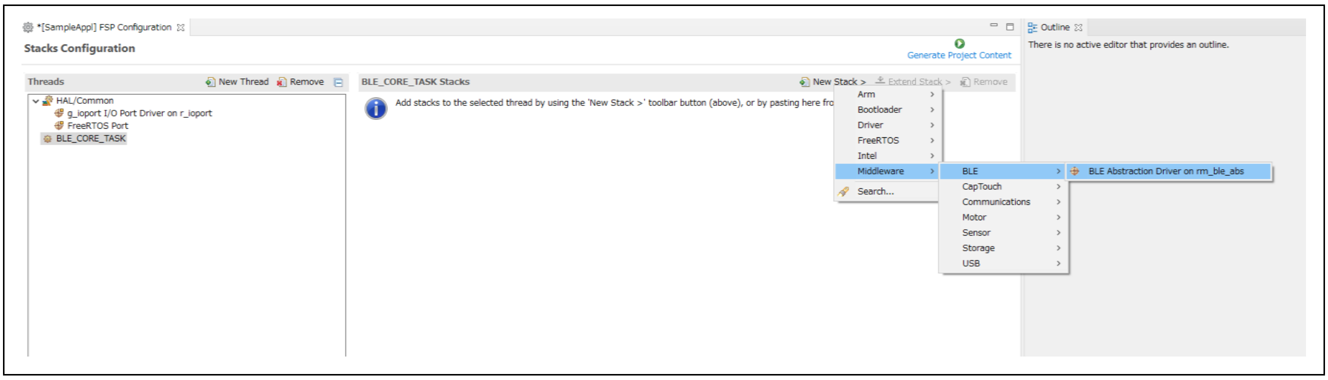
**Figure 41. Priority of BLE Core Task (Semaphore case)**

4. Change FreeRTOS configurations as following on BLE Core task **Properties** tab.

**Table 19. FreeRTOS configuration**

| Item | Changed Value | Default Value |
|---|---|---|
| Common > General > Use Mutexes | Enabled | Disabled |
| Common > General > Use Recursive Mutexes | Enabled | Disabled |
| Common > Memory Allocation > Support Dynamic Allocation | Enabled | Disabled |
| Common > Memory Allocation > Total Heap Size | 4096 | 0 |
| Common > Optional Functions > *xTimerPendingFunctoinCall()* Function | Enabled | Disabled |

5. Click **New Stack** and add **Middleware→BLE Abstraction Driver on rm_ble_abs** to **BLE Core task**.



There is no active editor that provides an outline.

Add stacks to the selected thread by using the 'New Stack >' toolbar button (above), or by pasting here fro

Figure 42. Add BLE module

6. Click **Add BLE Library for Network** box and select **New→Network Driver on r_ble_XXX_freertos.**

   “Extended”, “Balance”, and “Compact” can be selected for XXX according to the supported BLE features. Number of supported BLE features decreases in the order of “Extended”, “Balance”, “Compact”. Refer to section 1.3 about supported BLE features of each library type.

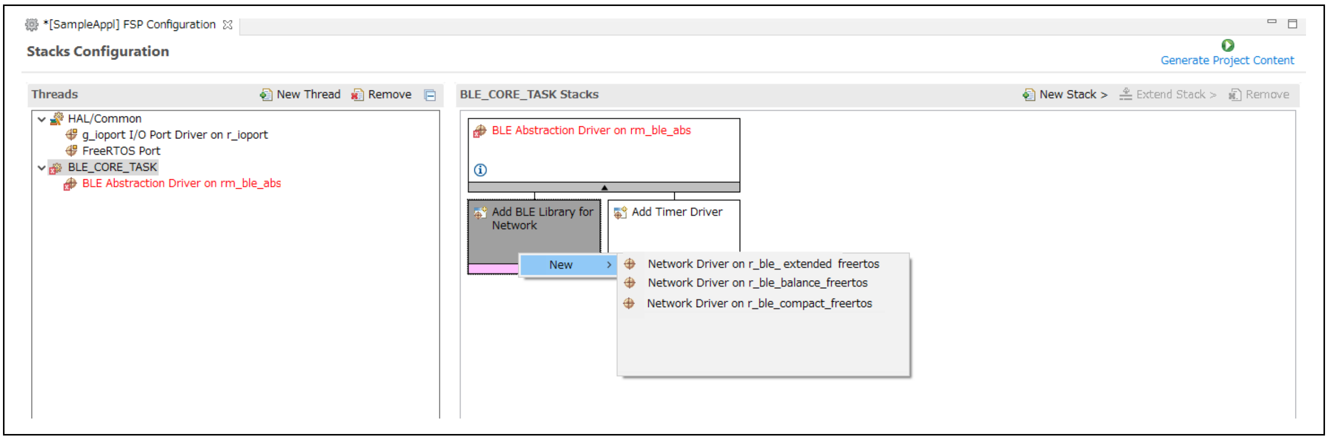


**Figure 43. Select module type**

The driver includes some peripheral driver. Configuration for these peripherals describes in section 4.1.4.5.

6. Add **Heap4** module to **HAL/Common**.

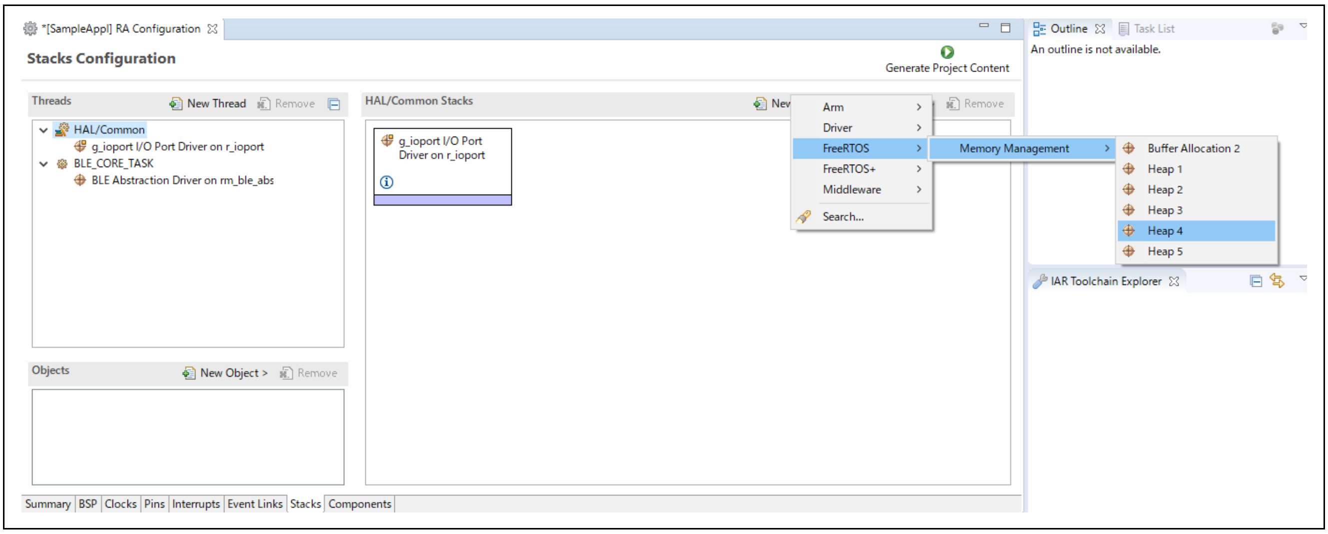
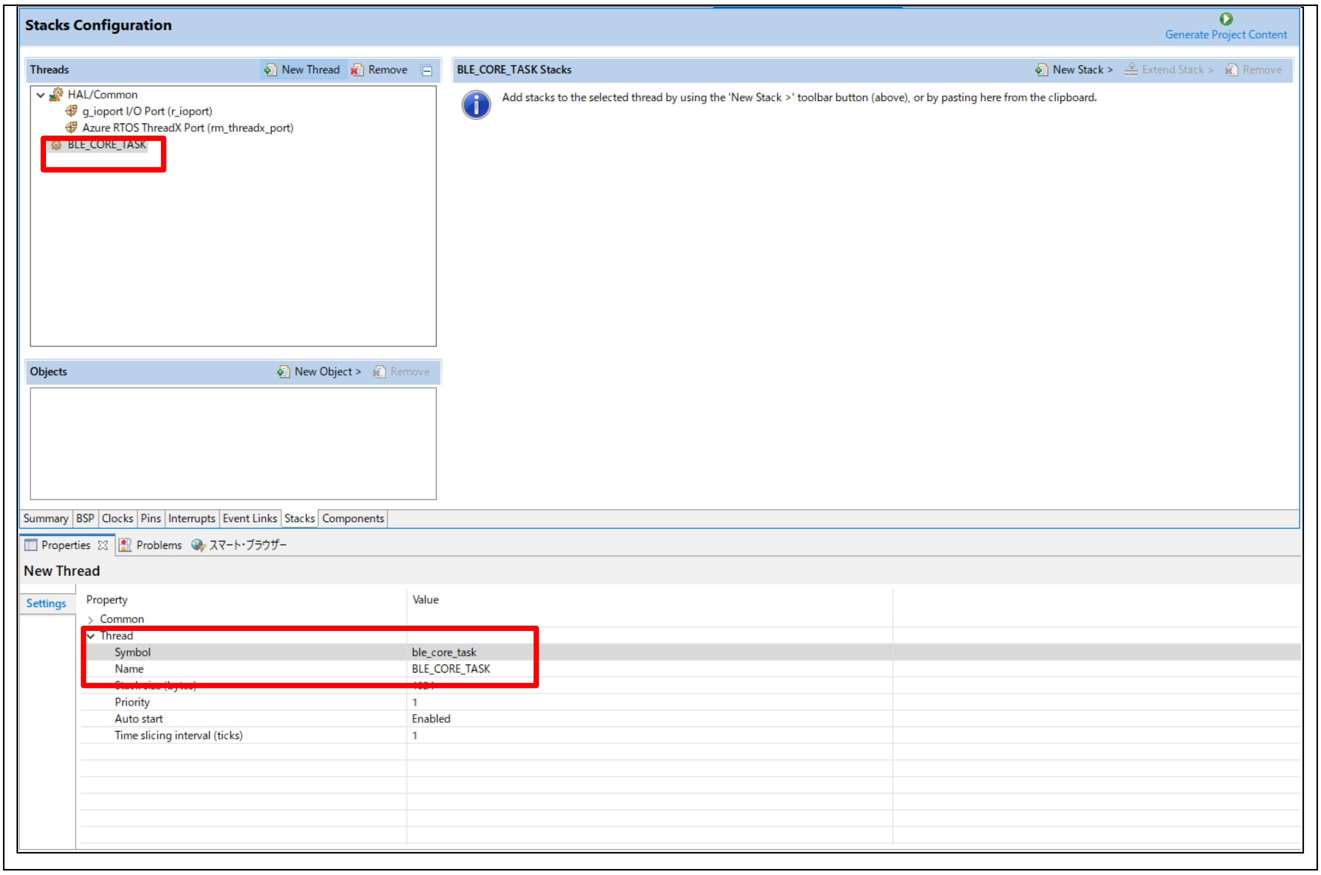


**Figure 44. Add Heap4 module**

### 4.1.4.3 Add BLE module in Azure RTOS environment

1. Click **New Thread** on Thread area and add New Thread. In this example, the New Thread is named BLE Core Task. Note that the symbol of the New Thread should be “ble_core_task” in case of using QE for BLE, because QE for BLE expects so.



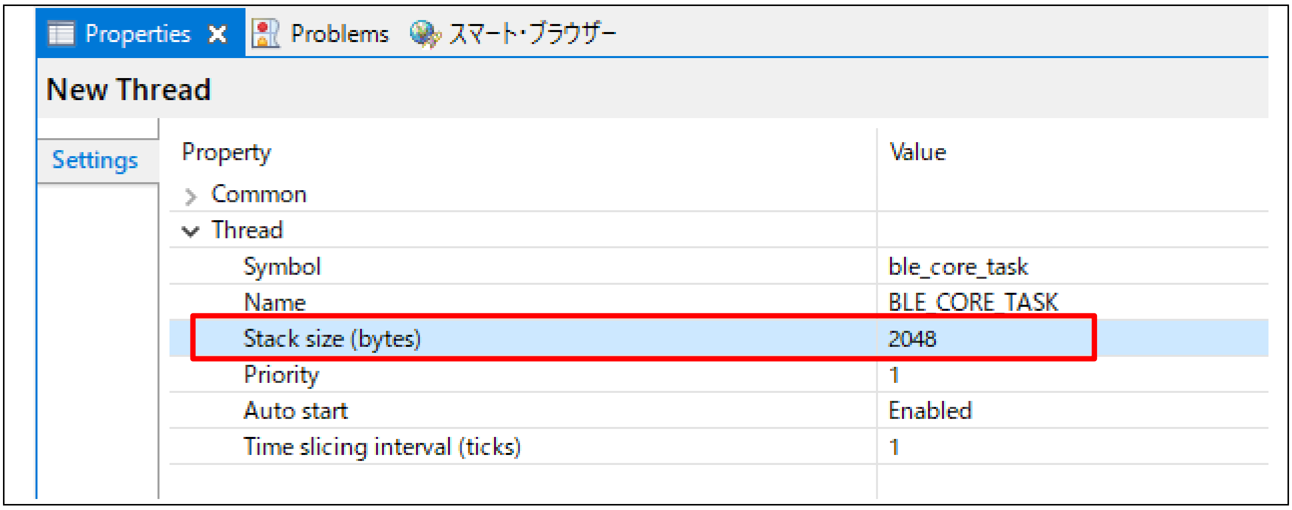
Add stacks to the selected thread by using the 'New Stack >' toolbar button (above), or by pasting here from the clipboard.

New Thread

| Property | Value |
|---|---|
| Common | |
| Thread | |
| Symbol | ble_core_task |
| Name | BLE_CORE_TASK |
| Stack size (bytes) | 1024 |
| Priority | 1 |
| Auto start | Enabled |
| Time slicing interval (ticks) | 1 |

Figure 45. Add BLE Core Task

2. Change Stack size as 2048[bytes]. The BLE stack included in this application requires 1.5 [KB] of memory space to use. And the profile itself included in this application requires 0.4[KB] memory space to use.

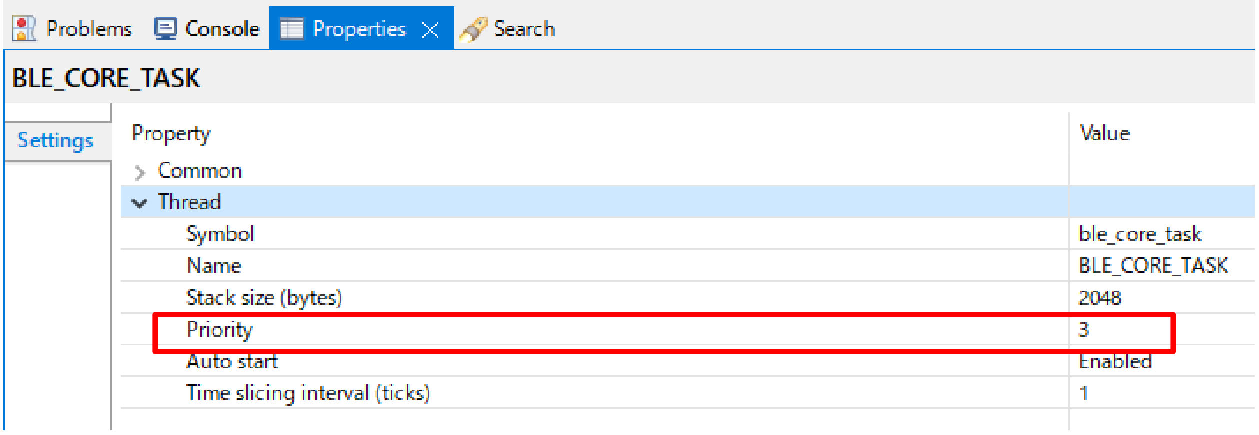


New Thread

| Property | Value |
|---|---|
| Common | |
| Thread | |
| Symbol | ble_core_task |
| Name | BLE_CORE_TASK |
| Stack size (bytes) | 2048 |
| Priority | 1 |
| Auto start | Enabled |
| Time slicing interval (ticks) | 1 |

Figure 46. Change Stack Size

3. Priority of BLE Core Task should NOT be highest priority. In demo project, priority of the task configured as 3.



BLE_CORE_TASK

| Property | Value |
|---|---|
| Common | |
| Thread | |
| Symbol | ble_core_task |
| Name | BLE_CORE_TASK |
| Stack size (bytes) | 2048 |
| Priority | 3 |
| Auto start | Enabled |
| Time slicing interval (ticks) | 1 |

Figure 47. Change Priority and Time slicing interval (ticks)

4. Change Azure RTOS configurations as following on BLE Core task **Properties** tab.

**Table 20. AzureRTOS configuration**

| Item | Changed Value | Default Value |
|---|---|---|
| Common > Timer > Timer Ticks Per Second | 1000 | 100 |
| Common > Timer > Timer Thread Priority | 2 | 0 |

5. Click **Add BLE Library for Network** box and select **New→BLE Driver on r_ble_XXX_threadx.**

   “Extended”, “Balance”, and “Compact” can be selected for XXX according to the supported BLE features. Number of supported BLE features decreases in the order of “Extended”, “Balance”, “Compact”. Refer to section 1.3 about supported BLE features of each library type.

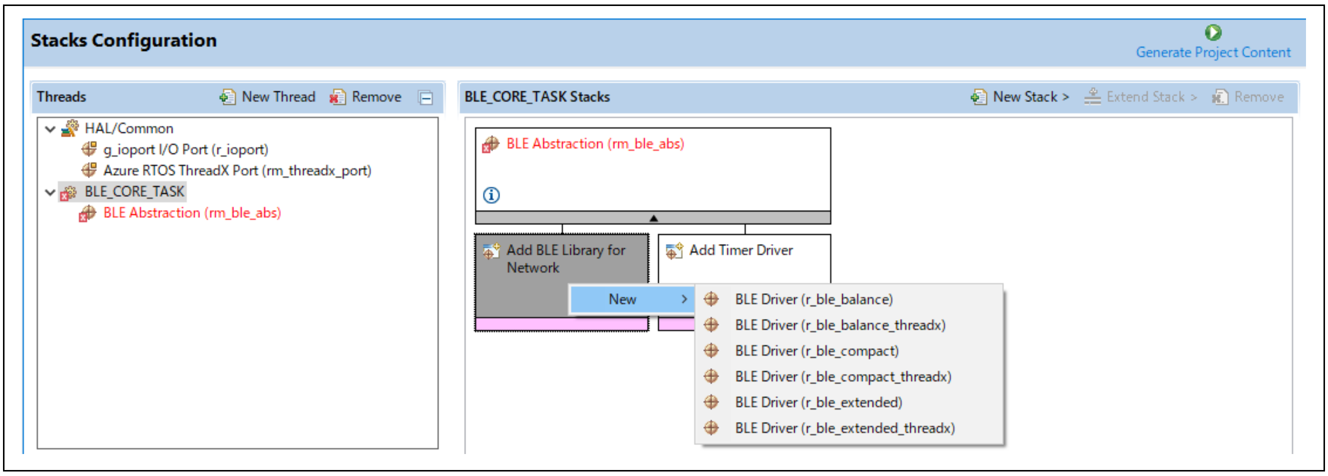


**Figure 48. Select module type**

The BLE FSP module has properties which may change according to user scenario. Refer to section 4.1.4.4 about description of the properties. And The driver includes some peripheral driver. Configuration for these peripherals describes in section 4.1.4.5.

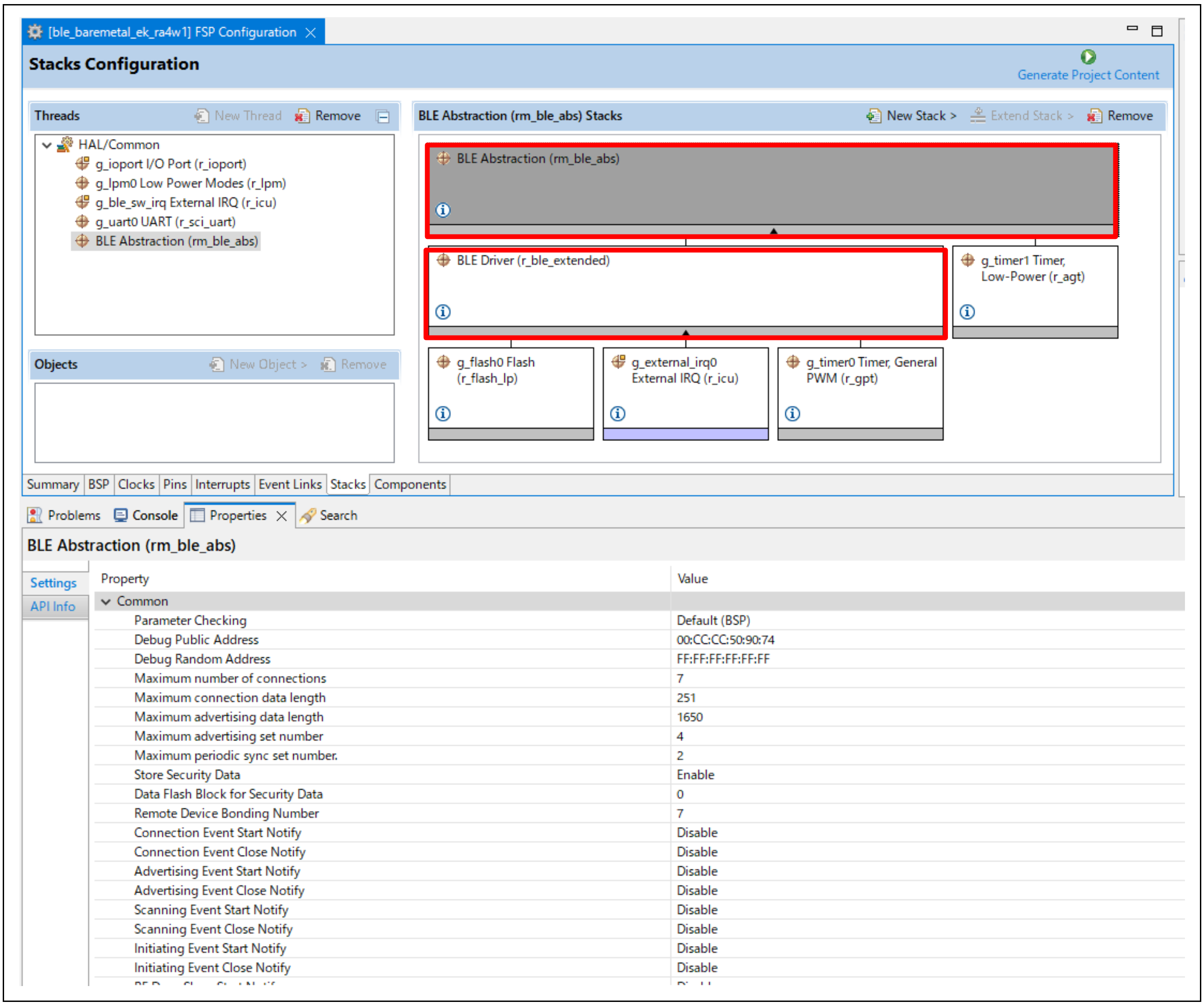
### 4.1.4.4 BLE module configurations

This section describes BLE module configuration options and related modules. BLE module include following configuration categories. About each category will describe from following.

- Common
- Module BLE Abstraction Driver on rm_ble_abs

### 1. Common options

The BLE module can change BD address etc. by modifying common options on FSP configuration. **BLE Abstraction (rm_ble_abs) FSP module and BLE Driver (r_ble_xxxx) module have same properties. Users need to enter the same values for both modules.** The changed options are automatically reflected to the r_ble_cfg.h when generating code.



BLE Abstraction (rm_ble_abs)

| Property | Value |
|---|---|
| Common | |
| Parameter Checking | Default (BSP) |
| Debug Public Address | 00:CC:CC:50:90:74 |
| Debug Random Address | FF:FF:FF:FF:FF:FF |
| Maximum number of connections | 7 |
| Maximum connection data length | 251 |
| Maximum advertising data length | 1650 |
| Maximum advertising set number | 4 |
| Maximum periodic sync set number. | 2 |
| Store Security Data | Enable |
| Data Flash Block for Security Data | 0 |
| Remote Device Bonding Number | 7 |
| Connection Event Start Notify | Disable |
| Connection Event Close Notify | Disable |
| Advertising Event Start Notify | Disable |
| Advertising Event Close Notify | Disable |
| Scanning Event Start Notify | Disable |
| Scanning Event Close Notify | Disable |
| Initiating Event Start Notify | Disable |
| Initiating Event Close Notify | Disable |

Figure 49. Common options

Option names and setting values in the configuration are listed following. Items shown in **bold may be modified** according to user's environment.

**Table 21. Common options**

| Configuration options | |
|---|---|
| **Debug Public Address**<br>Default: {0xFF,0xFF,0xFF,0x50,0x90,0x74} | Initial Public Address. If the public addresses in Code Flash and Data Flash are all 0x00 or 0xFF, the demo project will use this value as public address.<br>Refer to section 4.2 for details. |
| **Debug Random Address**<br>Default: {0xFF,0xFF,0xFF,0xFF,0xFF,0xFF} | Initial Static Address. If the static addresses in the Code Flash and the Data Flash are all 0x00 or 0xFF, the demo project will use this value as static address.<br>Refer to section 4.2 for details. |
| **Maximum number of connections**<br>Default: 7 | Maximum number of simultaneous connections.<br>Range : 1 to 7 |
| **Maximum connection data length**<br>Default: 251 | Maximum packet data length (bytes).<br>Range: 27 to 251 |
| **Maximum advertising data length**<br>Default: 1650 | Maximum advertising data length (bytes).<br>Range: 31 to 1650<br>This configuration will be ignored and fix at 31 bytes when "balance" or "compact" is selected for BLE library. |
| **Maximum advertising set number**<br>Default: 4 | Maximum number of the advertising set.<br>Range: 1 to 4<br>This configuration will be ignored and fix at 1 when "balance" or "compact" is selected for BLE library. |
| **Maximum periodic sync set number**<br>Default: 2 | Maximum number of simultaneous synchronizations against periodic advertising.<br>Range: 1 to 2<br>This configuration will be ignored and fix at 1 when "balance" or "compact" is selected for BLE library. |
| **Store Security Data**<br>Default: Disable | Enable or disable the security data management.<br>Range: Enable or Disable<br>Bonding information is stored in Data Flash block when this property set to Enable. And the bonding information will be stored to Data Flash block which specified by **Data Flash Block for Security Data** option.<br>Refer to section 4.3.1 for details. |
| **Data Flash Block for Security Data**<br>Default: 0 | Specify Data Flash block which stores the bonding information.<br>Range: 0 to 7<br>Choose a different block from **Device Specific Data** Refer to section 4.3.1 for details. |

| Configuration options | |
|---|---|
| **Remote Device Bonding Number**<br>Default: 7 | Maximum number of the bonding information stored in the Data Flash.<br>Range : 1 to 7<br>This value should be set same as **Maximum number of connections**.<br>Refer to section 4.3.1 for details. |
| Connection Event Start Notify<br>Default: Disable notify | Enable or disable start connection event start interrupt notification.<br>Range: Disable notify or Enable notify<br>This notification event occurs after actual RF event because this notification event is triggered by the interrupt from BLE(H/W). |
| Connection Event Close Notify<br>Default: Disable notify | Enable or disable close connection event interrupt notification.<br>Range: Disable notify or Enable notify<br>This notification event occurs after actual RF event because this notification event is triggered by the interrupt from BLE(H/W). |
| Advertising Event Start Notify<br>Default: Disable notify | Enable or disable start advertising event interrupt notification.<br>Range: Disable notify or Enable notify<br>The notification event occurs at the following timings.<br>- Start Primary Advertising channel.<br>- Start Secondary Advertising Channel<br>- Start Periodic Advertising. (When Extended Advertising is enabled.)<br>This notification event occurs after actual RF event because this notification event is triggered by the interrupt from BLE(H/W). |
| Advertising Event Close Notify<br>Default: Disable notify | Enable or disable close advertising event interrupt notification.<br>Range: Disable notify or Enable notify<br>The notification occurs at the following timings.<br>- Complete Primary Advertising channel.<br>- Complete Secondary Advertising Channel<br>- Complete Periodic Advertising. (When the Extended Advertising is enabled.)<br>This notification event occurs after actual RF event because this notification event is triggered by the interrupt from BLE(H/W). |
| Scanning Event Start Notify<br>Default: Disable notify | Enable or disable start scan interrupt notification.<br>Range: Disable notify or Enable notify<br>This notification event occurs after actual RF event because this notification event is triggered by the interrupt from BLE(H/W). |

| Configuration options | |
|---|---|
| Scanning Event Close Notify<br>Default: Disable notify | Enable or disable close scan interrupt notification.<br>Range: Disable notify or Enable notify<br>This notification event occurs after actual RF event because this notification event is triggered by the interrupt from BLE(H/W). |
| Initiating Event Start Notify<br>Default: Disable notify | Enable or disable notification that scan start interrupt has occurred in sending a connection request.<br>Range: Disable notify or enable notify<br>This notification will not occur when scan interval and scan window is equal. This notification event occurs after actual RF event because this notification event is triggered by the interrupt from BLE(H/W). |
| Initiating Event Close Notify<br>Default: Disable notify | Enable or disable notification that scan complete interrupt has occurred in sending a connection request.<br>Range: Disable notify or enable notify<br>This notification will not occur when scan interval and scan window is equal. This notification event occurs after actual RF event because this notification event is triggered by the interrupt from BLE(H/W). |
| RF Deep Sleep Start Notify<br>Default: Disable notify | Enable or disable notification event when BLE(H/W) enter deep sleep.<br>Range: Disable notify or enable notify |
| RF Deep Sleep Wakeup Notify<br>Default: Disable notify | Enable or disable notification event when BLE(H/W) wake up from deep sleep.<br>Range: Disable notify or enable notify |
| **Bluetooth dedicated clock**<br>Default: 6 | Load capacitance adjustment value for 32MHz BLE dedicated crystal. Adjust this value so that the crystal oscillates at the frequency closest to 32MHz.<br>Range: 0 to 15<br>Refer to "Tuning procedure of Bluetooth dedicated clock frequency(R01AN4887)" for details. |
| **DC-DC Converter**<br>Default: Disable DC-DC Converter | Enable or disable the DC-DC on BLE(H/W).<br>Range: Disable DC-DC Converter or Enable DC-DC Converter.<br>Refer to “RA4W1 Group User’s Manual: Hardware (R01UH0883)" for details. |
| Slow Clock Source<br>Default: Use RF_LOCO | Slow clock source for BLE (H/W)<br>Range: Use RF_LOCO or Use External 32.768kHz.<br>Do NOT change. |

| Configuration options | |
|---|---|
| MCU CLKOUT Port<br>Default: P109 | Port of the MCU CLKOUT.<br>Range: P109 or P205<br>This option will be ignored if the Slow Clock Source option is Use RF_LOCO. |
| MCU CLKOUT Frequency Output<br>Default: MCU CLKOUT Frequency 32.768kHz | Output frequency from the MCU CLKOUT Port.<br>Range : MCU CLKOUT frequency 32.768kHz or MCU CLKOUT frequency 16.384kHz<br>This option will be ignored if the Slow Clock Source option is Use RF_LOCO. |
| Sleep Clock Accuracy (SCA)<br>Default: 250 | Clock Accuracy (SCA) of Slow clock source for BLE(H/W).<br>Range: 0 to 500 ppm<br>Value of this option is fixed to more than 250ppm when Slow Clock Source option is Use RF_LOCO. |
| **Transmission Power Maximum Value**<br>Default: max +4dBm | Maximum transmit power configuration.<br>Range: max +4dBm or max 0dBm. |
| **Transmission Power Default Value**<br>Default: High | Actual BLE air packet transmit power.<br>Range: High or Mid or Low<br>This option depends on the **Transmission Power Maximum Value** configuration.<br>If the **transmission Power Maximum Value** option set to 0dBm, relationship this option and Actual BLE air packet transmit power is as follows.<br>High : 0dBm<br>Mid : 0dBm (same as High)<br>Low : -18dBm<br>If the **transmission Power Maximum Value** option set to +4dBm, relationship this option and Actual BLE air packet transmit power is as follows.<br>High : +4dBm<br>Mid : 0dBm<br>Low : -20dBm |
| **CLKOUT_RF Output**<br>Default: No output | Specify CLKOUT_RF(P414) output frequency.<br>Range:<br>No output<br>4MHz output<br>2MHz output<br>1MHz output |
| **RF_DEEP_SLEEP Transition**<br>Default: Enable | Enable or disable BLE(H/W) Deep Sleep.<br>Range: Disable or Enable |

| Configuration options | |
|---|---|
| **MCU Main Clock Frequency**<br>Default: 8000 | MCU main clock frequency (kHz).<br>This option needs to be configured according to System Clock Source configuration.<br>If the HOCO is used as System Clock Source, this option is ignored.<br>If the Main Clock is used as System Clock Source, set a value within the range between 1000 and 20000.<br>If the PLL Circuit is used as System Clock Source, set a value within the range between 4000 and 12500.<br>Set clock frequency according to user’s system clock source configuration. |
| **Code Flash (ROM) Device Data Block**<br>Default: 255 | Specify Code Flash (ROM) block which stored the device specific data (e.g. BD address, etc.)<br>Range: -1 to 255<br>If this option is set to -1, Code Flash will not use for this purpose. Refer to section 4.2 for details. |
| **Device Specific Data Flash Block**<br>Default: -1 | Specify Data Flash (RAM) block which stored the device specific data (e.g. BD address, etc.)<br>Range: -1 to 7<br>If this option is set to -1, Data Flash will not use for this purpose. Specify a different block from Data Flash Block for Security Data.<br>Refer to section 4.2 for details. |
| **MTU size configured**<br>Default: 247 | MTU size (bytes) for the GATT communication.<br>Range: 23 to 247 |
| Timer Slot Maximum Number<br>Default: 10 | N/A<br>Do NOT change. |
| **Synchronization Type**<br>**Default : Event groups** | This property is available for FreeRTOS only. The property is specified task synchronization method in FreeRTOS environment. Also refer to section 1.2.<br>Range: Event groups or Semaphore |
| **Parameter Checking**<br>Default: Default (BSP) | Enable or disable the validity check of the parameters for BLE module.<br>Range: Default (BSP) or Enabled or Disabled |

When **RF_DEEP_SLEEP Transition** option is set to enable, when there is no task to be executed by the BLE protocol stack, and when there is a time of 80ms or more before the start of the next RF event time, transition to RF sleep mode to reduce the current consumption of the RF part. This time does not mean the "interval time" of an RF event, but the "RF idle time" between the completion of one RF event and the start of the next RF event. Therefore, it is necessary to set the RF event interval to 100ms or more in consideration of the processing time of each layer in order to shift the RF part to sleep mode. The BLE protocol stack performs RF sleep processing and RF wake-up processing to transition the RF part to sleep mode. Figure 50 shows MCU/RF operation overview with RF sleep.

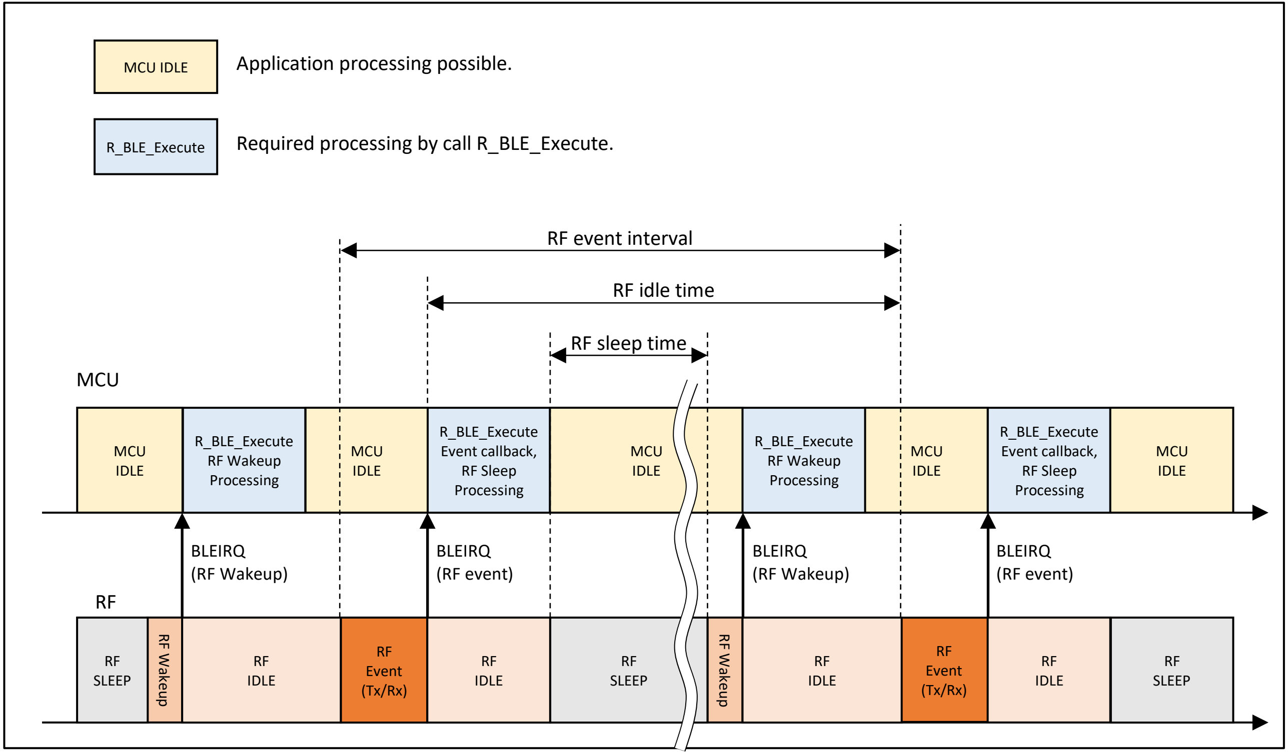


Figure 50. MCU/RF operation overview with RF sleep

While the MCU is idle, it is possible to transition the MCU to the low power consumption mode or execute application processing. However, if the RF wakeup process by *R_BLE_Execute* is not performed before the RF event starts, the RF event cannot be executed. Therefore, application processing must be implemented so as not to interfere with the *R_BLE_Execute* call.

When **RF_DEEP_SLEEP Transition** option is set to disable, or when **RF_DEEP_SLEEP Transition** option is set to enable but the RF sleep transition condition is not satisfied (e.g. RF event interval < 100 msec ), the BLE protocol stack does not transition RF part to sleep mode. In this case, the current consumption during RF idle time increases, but the MCU idle time that can be used by the application increases because RF sleep processing and RF wakeup processing are not performed. Figure 51 shows MCU/RF operation without RF sleep.

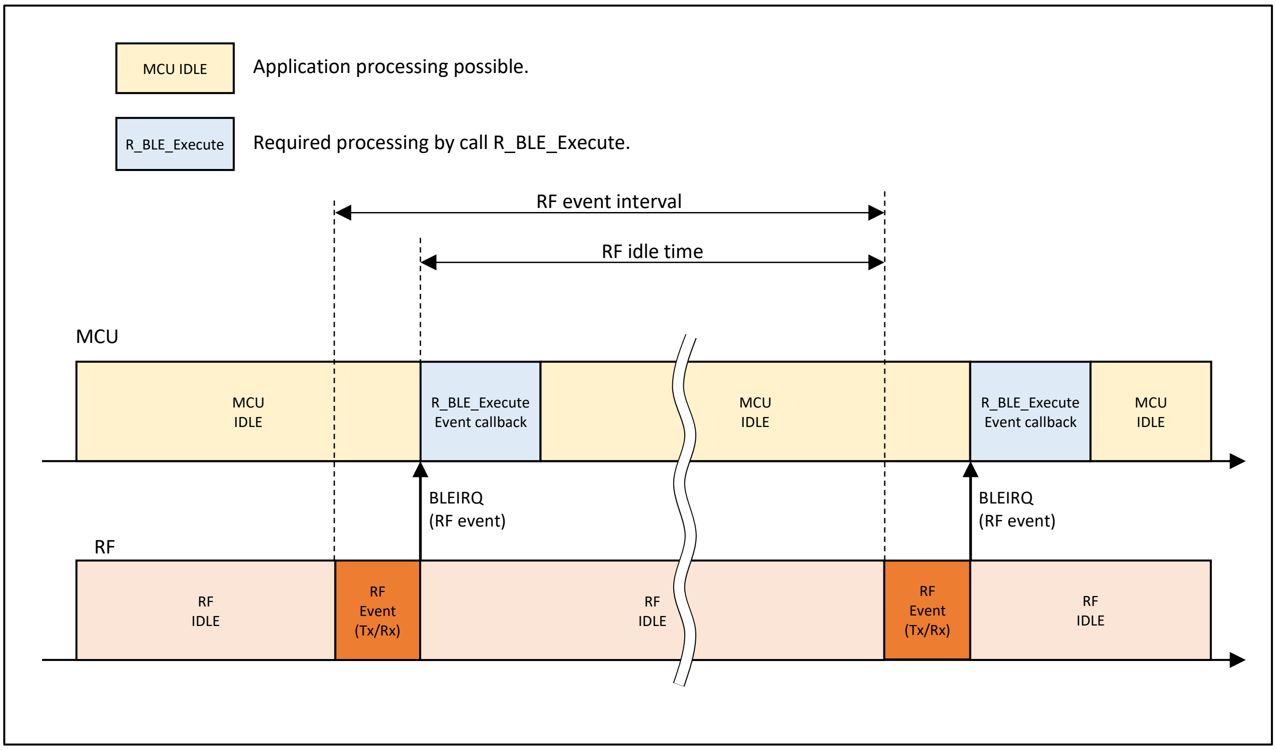
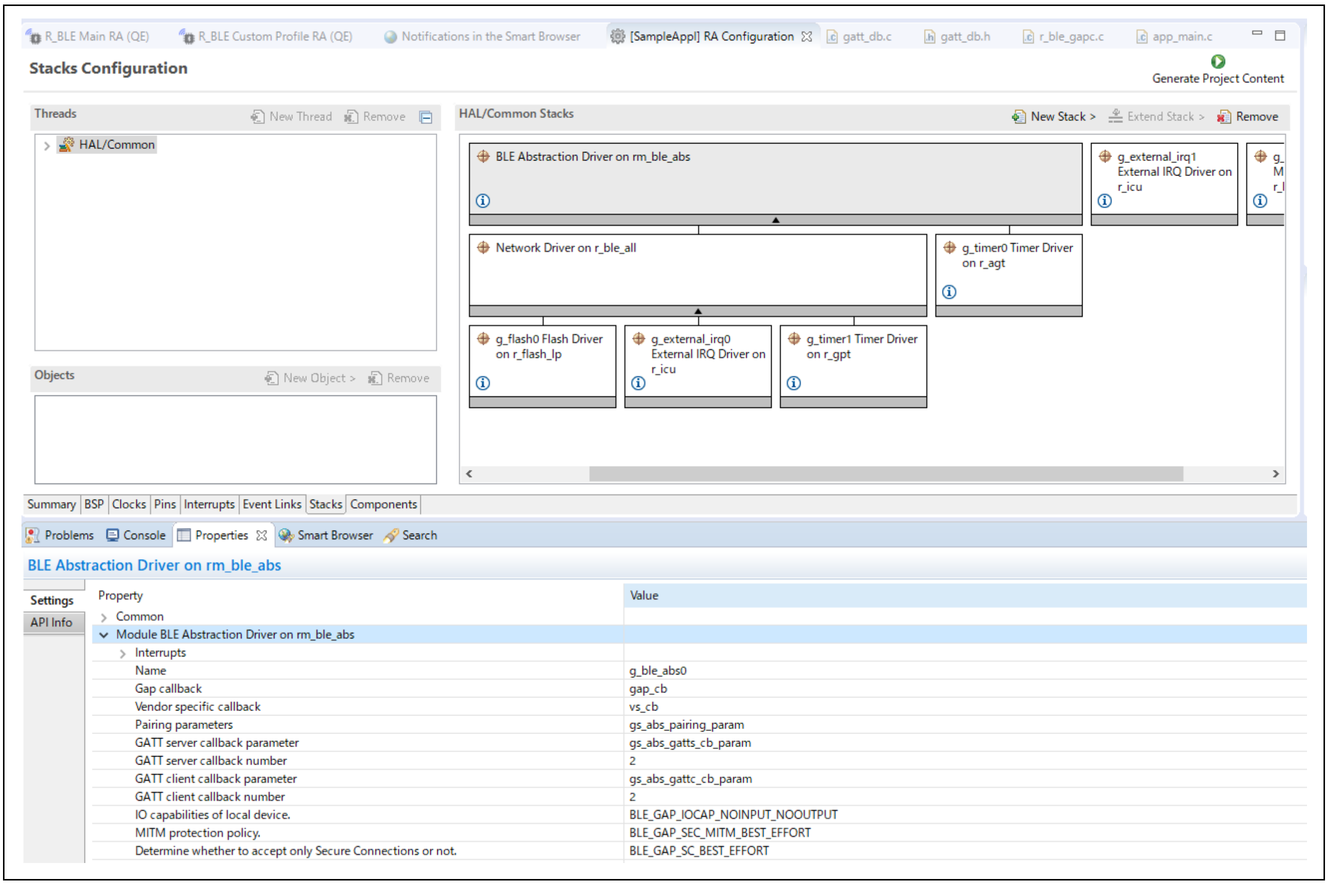


**Figure 51. MCU/RF operation overview without RF sleep**

Regardless of the RF sleep state, if the application process continuously occupies the MCU and *R_BLE_Execute* is not called, the connection may not be maintained. Therefore, it is recommended that the application processing is active for a short time or Task performing R_BLE_Execute is given an appropriate priority to allow periodic execution.

## 2. BLE Abstraction Driver on rm_ble_abs options

The BLE module can change IO capability on local device etc. by modifying Module **BLE Abstraction Driver on rm_ble_abs** options on FSP configuration. The changed options are automatically reflected to the rm_ble_abs_cfg.h when generating code.



| Property | Value |
|---|---|
| > Common | |
| ⌄ Module BLE Abstraction Driver on rm_ble_abs | |
| > Interrupts | |
| Name | g_ble_abs0 |
| Gap callback | gap_cb |
| Vendor specific callback | vs_cb |
| Pairing parameters | gs_abs_pairing_param |
| GATT server callback parameter | gs_abs_gatts_cb_param |
| GATT server callback number | 2 |
| GATT client callback parameter | gs_abs_gattc_cb_param |
| GATT client callback number | 2 |
| IO capabilities of local device. | BLE_GAP_IOCAP_NOINPUT_NOOUTPUT |
| MITM protection policy. | BLE_GAP_SEC_MITM_BEST_EFFORT |
| Determine whether to accept only Secure Connections or not. | BLE_GAP_SC_BEST_EFFORT |

Figure 52. BLE Abstraction Driver on rm_ble_abs options

Option names and setting values in the configuration are listed following. Items shown in **bold may be modified** according to user's environment.

### Table 22. Module BLE Abstraction Driver on rm_ble_abs options

| Configuration options | |
|---|---|
| Interrupts > Callback provided when an ISR occurs<br>Default: NULL | Do NOT change. |
| Name<br>Default: g_ble_abs0 | Do NOT change. |
| Gap callback<br>Default: gap_cb | Do NOT change. |

| Configuration options | |
|---|---|
| Vendor specific callback<br>Default: vs_cb | Do NOT change. |
| Pairing parameters<br>Default: gs_abs_pairing_param | Do NOT change. |
| GATT server callback parameter<br>Default: gs_abs_gatts_cb_param | Do NOT change. |
| GATT server callback number<br>Default: 2 | Do NOT change. |
| GATT client callback parameter<br>Default: gs_abs_gattc_cb_param | Do NOT change. |
| GATT client callback number<br>Default: 2 | Do NOT change. |
| **IO capabilities of local device**<br>Default: BLE_GAP_IOCAP_NOINPUT_NOOUTPUT | IO capabilities.<br>Range: Select one of the following.<br>• **BLE_GAP_IOCAP_DISPLAY_ONLY**<br>Output: local device has ability to display 6 digits decimal number.<br>Input: None.<br>• **BLE_GAP_IOCAP_DISPLAY_YESNO**<br>Output: local device has ability to display 6 digits decimal number.<br>Input: local device has ability to indicate ‘yes’ or ‘no’.<br>• **BLE_GAP_IOCAP_KEYBOARD_ONLY**<br>Output: None.<br>Input: local device has ability to input the number ‘0’ – ‘9’.<br>• **BLE_GAP_IOCAP_NOINPUT_NOOUTPUT**<br>Output: None.<br>Input: None.<br>• **BLE_GAP_IOCAP_KEYBOARD_DISPLAY**<br>Output: local device has ability to display 6 digits decimal number.<br>Input: local device has ability to input the number ‘0’ – ‘9’. |
| **MITM protection policy**<br>Default: BLE_GAP_SEC_MITM_BEST_EFFORT | MITM protection policy.<br>Range: Select one of the following.<br>• **BLE_GAP_SEC_MITM_BEST_EFFORT**<br>MITM Protection not required.<br>• **BLE_GAP_SEC_MITM_STRICT**<br>MITM Protection required. |

| Configuration options | |
|---|---|
| **Determine whether to accept only Secure Connections or not**<br>Default: BLE_GAP_SC_BEST_EFFORT | Determine whether to accept only Secure Connections or not.<br>Range: Select one of the following.<br>• **BLE_GAP_SC_BEST_EFFORT**<br>Accept Legacy pairing and Secure Connections.<br>• **BLE_GAP_SC_STRICT**<br>Accept only Secure Connections. |
| **Type of keys to be distributed from local device**<br>Default: BLE_GAP_KEY_DIST_ENCKEY | Type of keys to be distributed from local device. This field is set to a bitwise OR of the following values.<br>• **BLE_GAP_KEY_DIST_ENCKEY**<br>Distribute LTK.<br>• **BLE_GAP_KEY_DIST_IDKEY**<br>Distribute IRK and Identity address.<br>• **BLE_GAP_KEY_DIST_SIGNKEY**<br>Distribute CSRK. |
| **Type of keys which local device requests a remote device to distribute**<br>Default: BLE_GAP_KEY_DIST_ENCKEY | Type of keys which local device requests a remote device to distribute. This field is set to a bitwise OR of the following values.<br>• **BLE_GAP_KEY_DIST_ENCKEY**<br>Distribute LTK. In case of Secure Connections,<br>LTK is notified even if this bit is not set.<br>• **BLE_GAP_KEY_DIST_IDKEY**<br>Distribute IRK and Identity address.<br>• **BLE_GAP_KEY_DIST_SIGNKEY**<br>Distribute CSRK. |
| **Maximum LTK size**<br>Default: 16 | The maximum LTK size(byte) to be requested to a remote device.<br>Range: 7 – 16<br>When the LTK size of a remote device is less than this configuration size, the pairing fails. |

### 4.1.4.5 Add and configure related peripherals for BLE module

BLE module used below following peripherals to perform BLE communication.

**Table 23. Related peripherals**

| Item | Usage |
|---|---|
| Flash Driver on r_flash_lp | Store Bonding information etc. |
| External IRQ driver on r_icu | Interrupt from BLE(H/W) |
| GPT Driver | Timer for BLE protocol stack |
| Timer Driver | Timer for BLE abstraction API |

This section describes how to configure related peripherals (timers, interrupt) for BLE module which added previous section. Procedure describes in this section is common to BareMetal, FreeRTOS and Azure RTOS environment.

1. Click **Add GPT Driver** box and select **New→Timer Driver on r_gpt**.

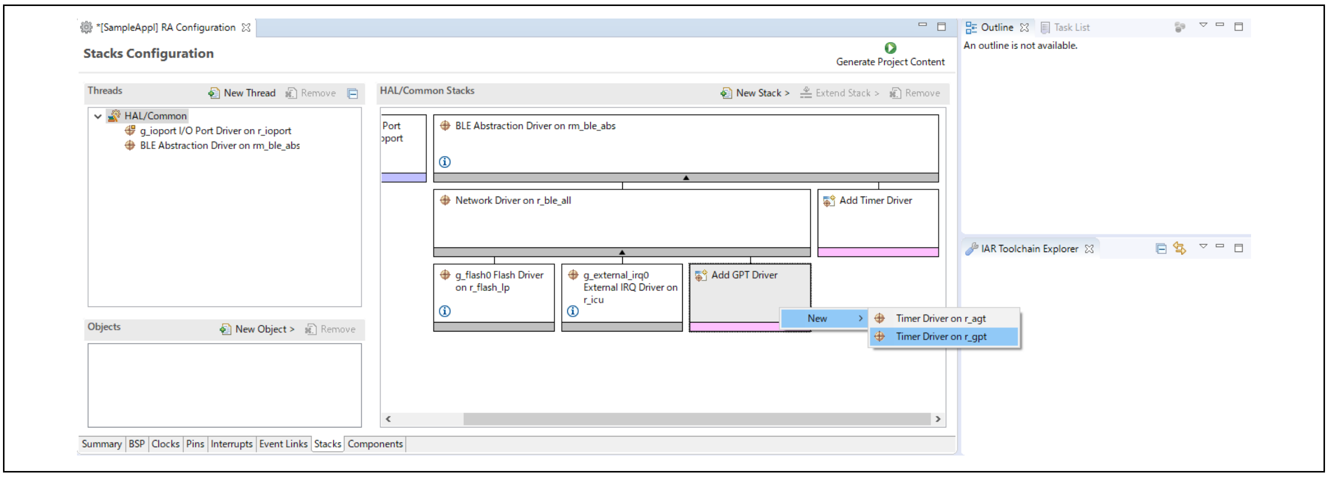
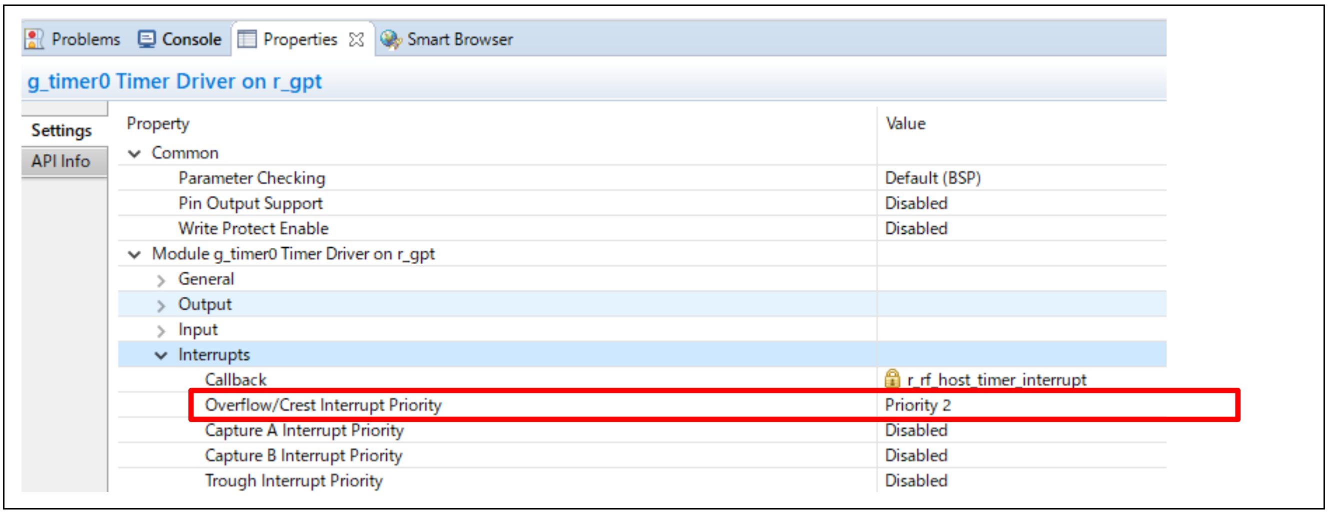


**Figure 53. Add GPT Driver**

2. Set **Overflow/Crest Interrupt Priority** of **g_timer0 Timer Driver on r_gpt** as **Priority 2** on **Properties** tab.



| Property | Value |
|---|---|
| Common | |
| Parameter Checking | Default (BSP) |
| Pin Output Support | Disabled |
| Write Protect Enable | Disabled |
| Module g_timer0 Timer Driver on r_gpt | |
| General | |
| Output | |
| Input | |
| Interrupts | |
| Callback | r_rf_host_timer_interrupt |
| Overflow/Crest Interrupt Priority | Priority 2 |
| Capture A Interrupt Priority | Disabled |
| Capture B Interrupt Priority | Disabled |
| Trough Interrupt Priority | Disabled |

**Figure 54. GPT Driver configuration**

3. Click **Add Timer Driver** box and select **New→Timer Driver on r_agt**.

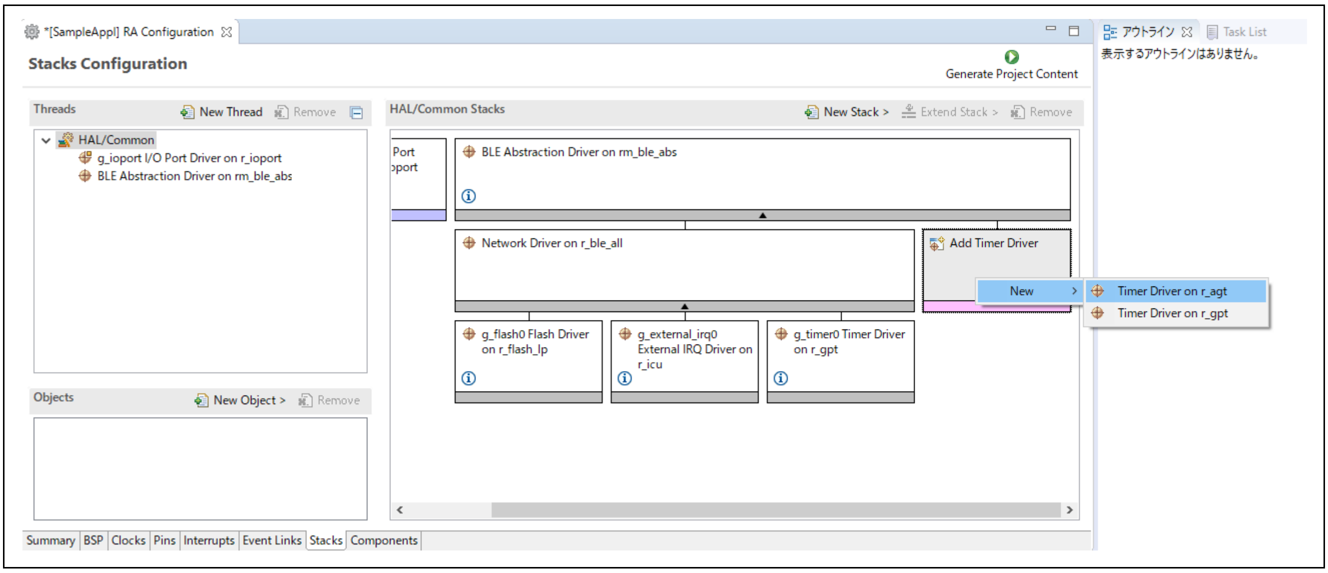
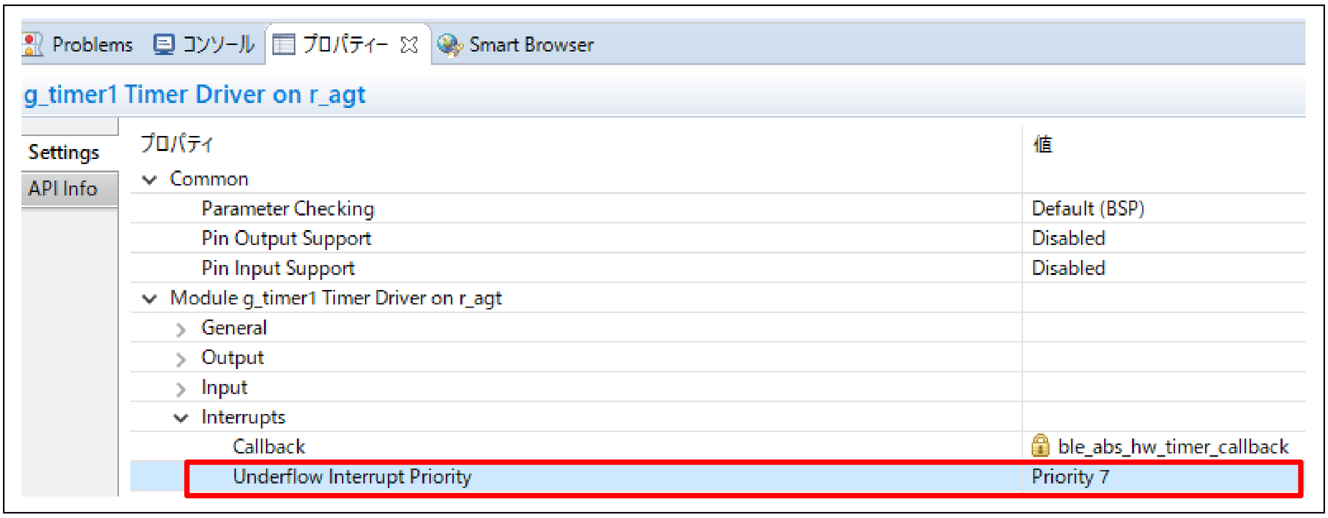


Figure 55. Add AGT Driver

4. Set **Underflow Interrupt Priority** of **g_timer1 Timer Driver on r_agt** as **Priority 7** on **Properties** tab.



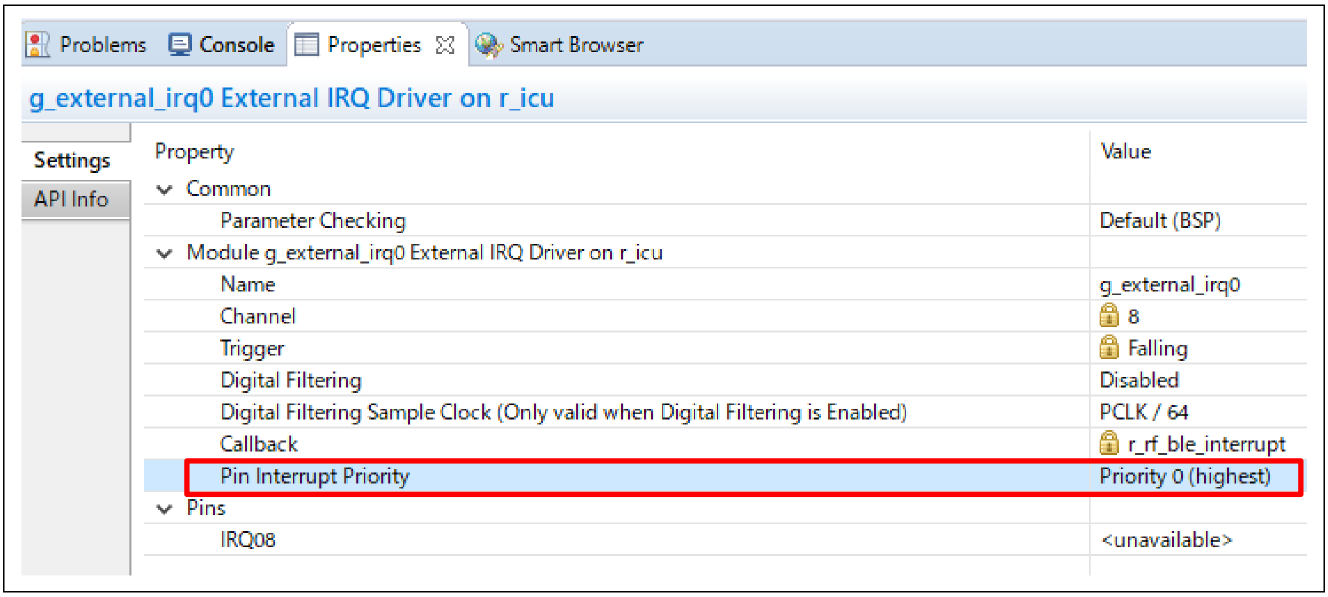
g_timer1 Timer Driver on r_agt

| プロパティ | 値 |
|---|---|
| Common | |
| Parameter Checking | Default (BSP) |
| Pin Output Support | Disabled |
| Pin Input Support | Disabled |
| Module g_timer1 Timer Driver on r_agt | |
| General | |
| Output | |
| Input | |
| Interrupts | |
| Callback | ble_abs_hw_timer_callback |
| Underflow Interrupt Priority | Priority 7 |

Figure 56. AGT Driver configuration

5. Set **Pin Interrupt Priority of g_external_irq0 External IRQ Driver** on **r_icu** as,

- **BareMetal environment**
  Priority 0 on Priority.

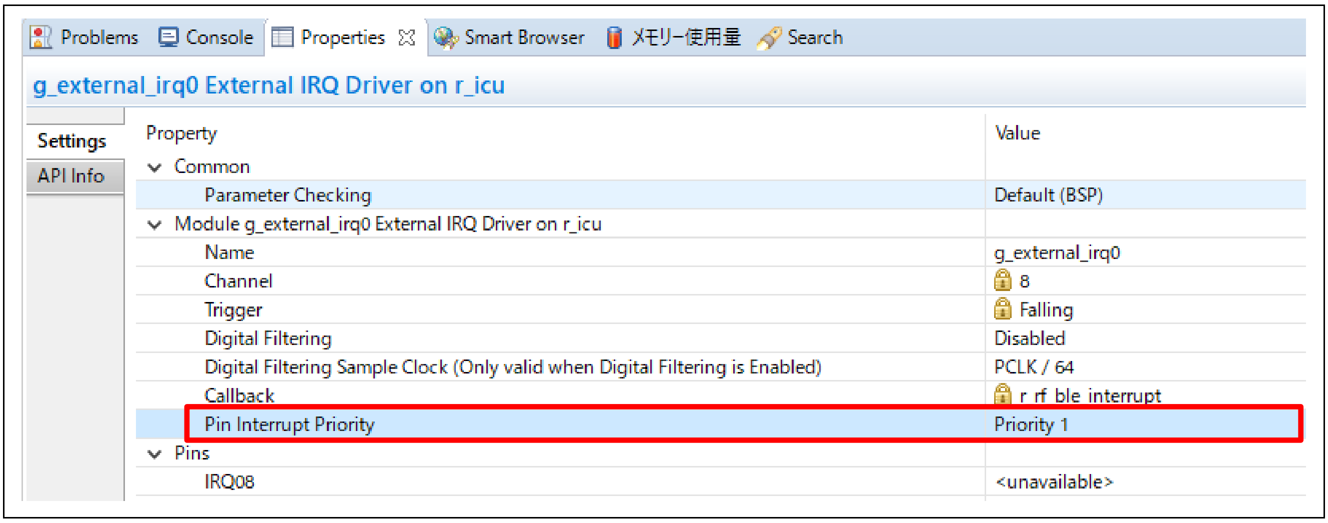


g_external_irq0 External IRQ Driver on r_icu

| Property | Value |
|---|---|
| Common | |
| Parameter Checking | Default (BSP) |
| Module g_external_irq0 External IRQ Driver on r_icu | |
| Name | g_external_irq0 |
| Channel | 8 |
| Trigger | Falling |
| Digital Filtering | Disabled |
| Digital Filtering Sample Clock (Only valid when Digital Filtering is Enabled) | PCLK / 64 |
| Callback | r_rf_ble_interrupt |
| Pin Interrupt Priority | Priority 0 (highest) |
| Pins | |
| IRQ08 | <unavailable> |

**Figure 57. ICU Driver configuration (BareMetal Environment)**

- **FreeRTOS and Azure RTOS environment**
  Priority 1 on Priority. Because the highest priority used FreeRTOS and Azure RTOS kernel.



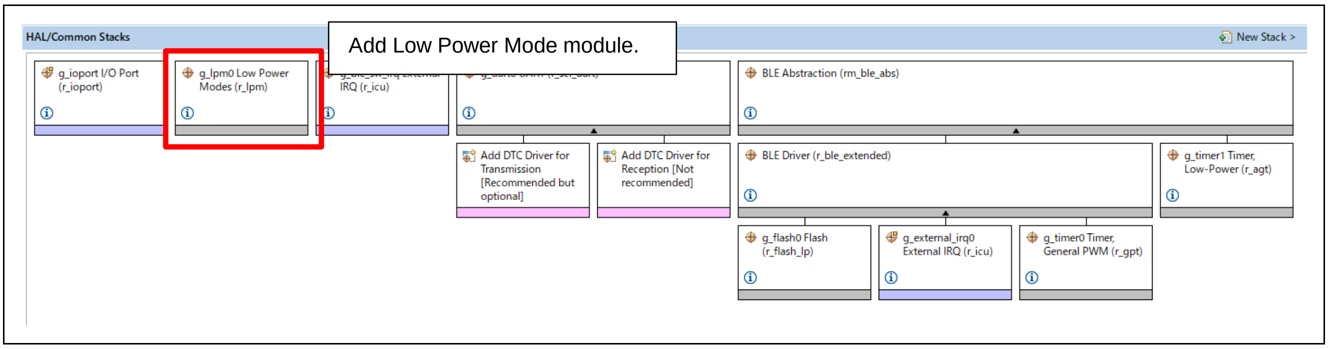
g_external_irq0 External IRQ Driver on r_icu

| Property | Value |
|---|---|
| Common | |
| Parameter Checking | Default (BSP) |
| Module g_external_irq0 External IRQ Driver on r_icu | |
| Name | g_external_irq0 |
| Channel | 8 |
| Trigger | Falling |
| Digital Filtering | Disabled |
| Digital Filtering Sample Clock (Only valid when Digital Filtering is Enabled) | PCLK / 64 |
| Callback | r_rf_ble_interrupt |
| Pin Interrupt Priority | Priority 1 |
| Pins | |
| IRQ08 | <unavailable> |

**Figure 58. ICU Driver configuration (FreeRTOS and Azure RTOS Environment)**

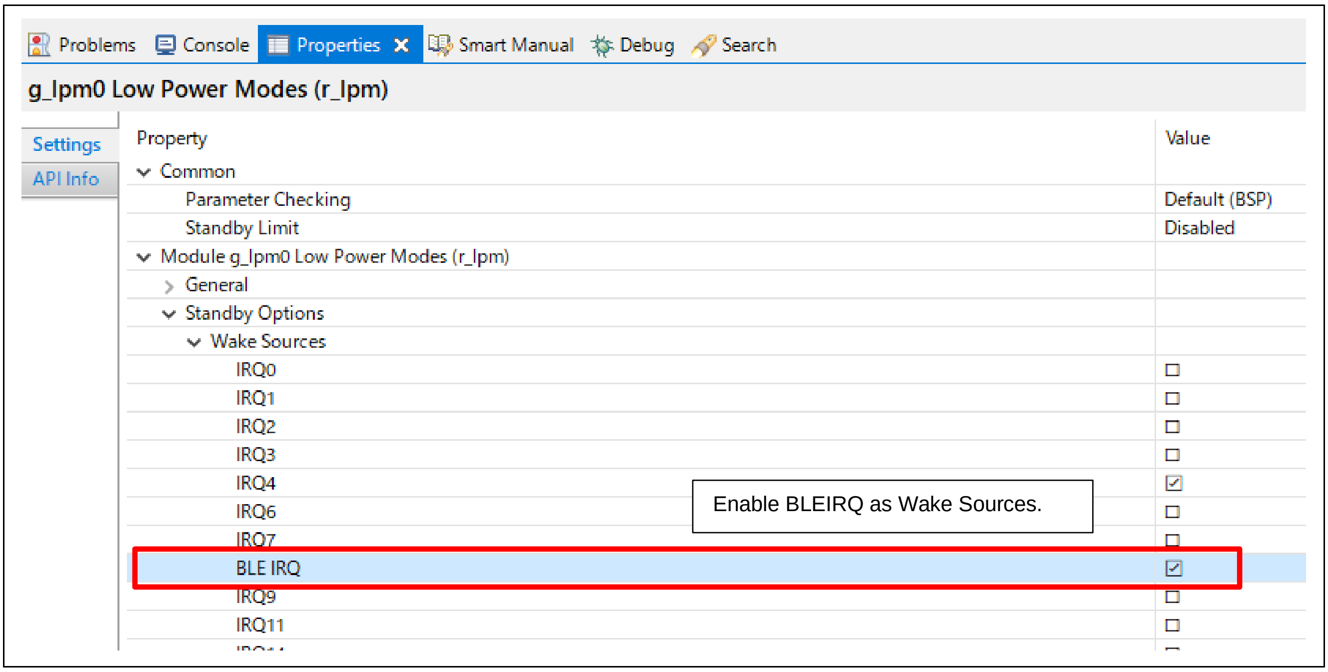
### 4.1.5 Low Power Mode

*Software standby mode*, which is one of MCU’s Low Power mode feature, can be used to reduce power consumption. It is necessary to add *Low Power Mode (r_lpm)* module to your project and configure *BLEIRQ* as Wake Sources.



Add Low Power Mode module.

Figure 59. Add Low Power Mode



g_lpm0 Low Power Modes (r_lpm)

| Property | Value |
|---|---|
| Common | |
| Parameter Checking | Default (BSP) |
| Standby Limit | Disabled |
| Module g_lpm0 Low Power Modes (r_lpm) | |
| General | |
| Standby Options | |
| Wake Sources | |
| IRQ0 | ☐ |
| IRQ1 | ☐ |
| IRQ2 | ☐ |
| IRQ3 | ☐ |
| IRQ4 | ☑ |
| IRQ6 | ☐ |
| IRQ7 | ☐ |
| BLE IRQ | ☑ |
| IRQ9 | ☐ |
| IRQ11 | ☐ |

Enable BLEIRQ as Wake Sources.

Figure 60. Wake Sources

Refer to section 3.1.2 for how to use the low power mode in your application.

### 4.1.6 Make profile and BLE application skeleton code

QE for BLE can generate profile and BLE application skeleton code. And user can modify these codes according to use case. Refer to *Bluetooth Low Energy Profile Developer's Guide(R01AN5428)* about usage of QE for BLE.

## 4.2 Device-specific Data Management

Bluetooth Device Address (hereinafter referred to as BD address) used by BLE Protocol Stack can be written to Data Flash area and Code Flash area as device-specific data. This allows user to set different BD address for multiple devices using the same firmware. Device-specific data is placed in a different area from the firmware program area. If the device-specific data is not deleted when rewriting the firmware, the same BD address can be used continuously.

### 4.2.1 Specify device-specific data location block

**1. Data flash area**

The block number of data flash area where device-specific data is located can be specified with **Data Flash (RAM) Device Data Block** configuration options. Relationship between block number and address is following.

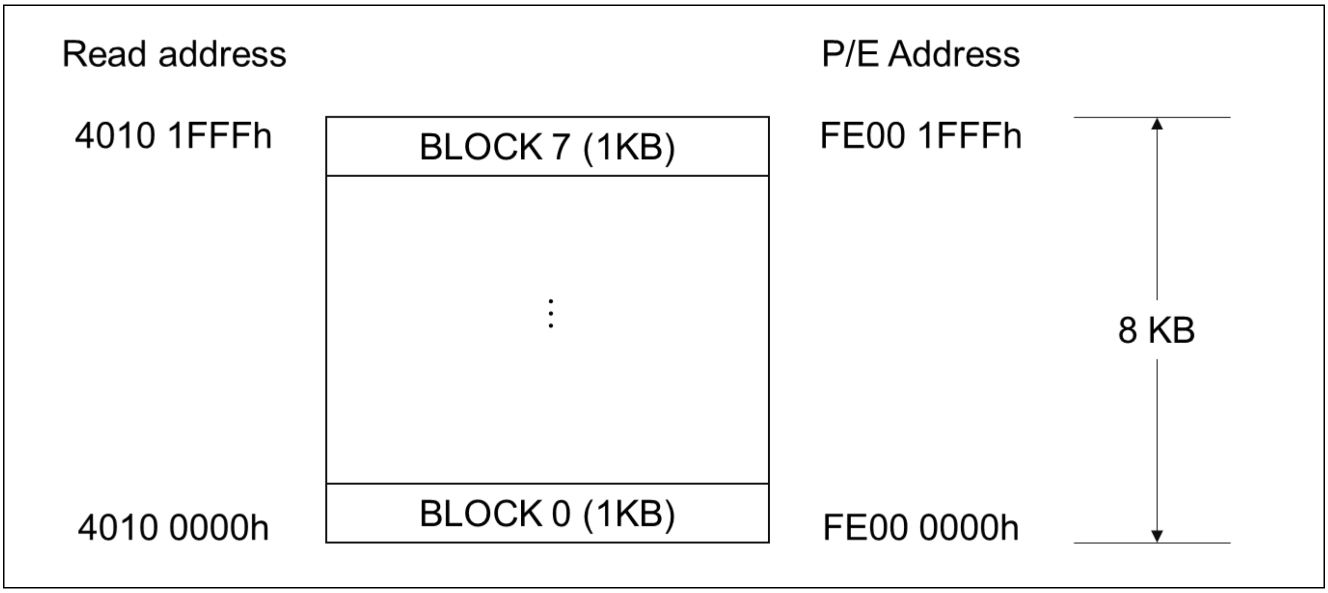


**Figure 61. Data flash memory block configuration**

Device-specific data is written at the top of the block specified by Device Specific Data Flash Block option. Do not write other data to the block where device-specific data is placed.

## 2. Code flash area

The block number of code flash where device-specific data is located can be specified with **Code Flash (ROM) Device Data Block** configuration options. Relationship between block number and address is following.

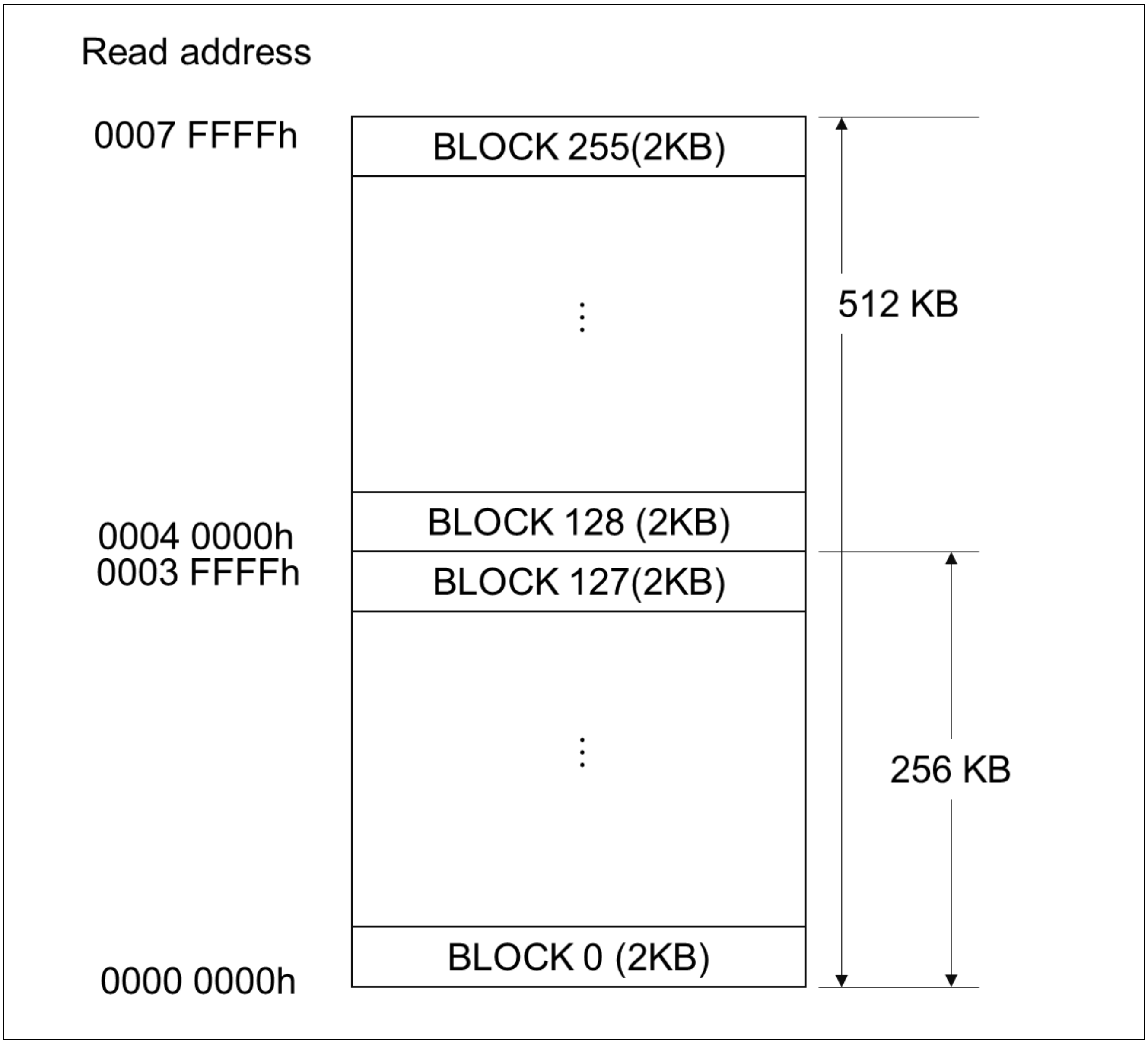


Figure 62. Code flash memory block configuration

When placing device-specific data in code flash area, it is necessary to specify blocks that are not used in program code. In addition, device-specific data is written at the top of the block specified by **Code Flash (ROM) Device Data Block** configuration.

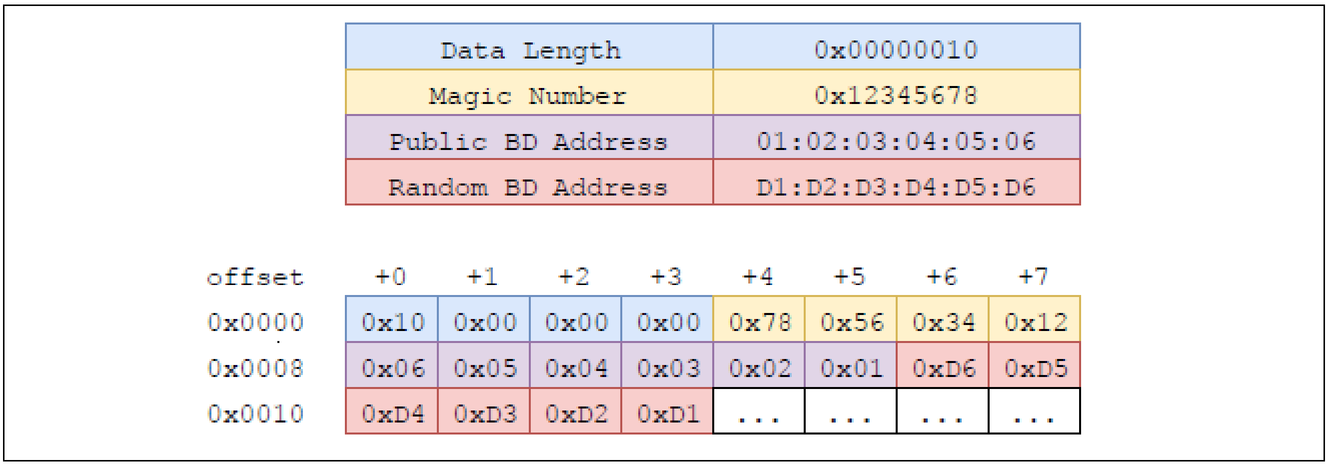
### 4.2.2 Device-specific data format

Table 24 shows the device-specific data format.

**Table 24. device-specific data format**

| Offset | Size[bytes] | Type | Description |
|---|---|---|---|
| 0 | 4 | uint32_t | Data length after magic number (fixed to 0x00000010) |
| 4 | 4 | uint32_t | Magic number (fixed 0x12345678) |
| 8 | 6 | uint8_t [6] | Public BD address |
| 14 | 6 | uint8_t [6] | Random BD address |

Each data must be written in little endian. For example, if BD address is “01:02:03:04:05:06”, write to the flash memory in the order of 0x06,0x05,0x04,0x03,0x02,0x01. Figure 63 shows an example of device-specific data flash memory layout.



| | |
|---|---|
| Data Length | 0x00000010 |
| Magic Number | 0x12345678 |
| Public BD Address | 01:02:03:04:05:06 |
| Random BD Address | D1:D2:D3:D4:D5:D6 |

| offset | +0 | +1 | +2 | +3 | +4 | +5 | +6 | +7 |
|---|---|---|---|---|---|---|---|---|
| 0x0000 | 0x10 | 0x00 | 0x00 | 0x00 | 0x78 | 0x56 | 0x34 | 0x12 |
| 0x0008 | 0x06 | 0x05 | 0x04 | 0x03 | 0x02 | 0x01 | 0xD6 | 0xD5 |
| 0x0010 | 0xD4 | 0xD3 | 0xD2 | 0xD1 | ... | ... | ... | ... |

**Figure 63. Device-specific data flash memory layout**

### 4.2.3 How to write device-specific data

User can write device specific data by following way. When device-specific data is written to the data flash area, the written BD address is adopted after reset of MCU.

#### 1. Write to data flash area using R_BLE API

Use *R_BLE_VS_SetBdAddr()* API to write device-specific data to data flash area. When device-specific data is written to the data flash area, BD address written by reboot once RA4W1 is adopt. Refer to “Renesas Flexible Software Package User’s Manual” for details of the API.

#### 2. Write to data area using BD address writing tool

User can write Public BD address to data area by using Public BD address writing tool for the RA4W1 device with HCI mode firmware. Refer to “Host Controller Interface Firmware(R01AN5429)” and “Public BD Address writing tool(R01AN5439)”.

Note: The BD address writing tool does not support Random BD address writing.

### 3. Write to code flash area

To write device-specific data to code flash area, use Renesas Flash Programmer V3.1.0 (RFP) unique code Function. The unique code function is functionality to write the device specific data to user area at the same time as firmware program data. Refer to Renesas Flash Programmer User's manual (R01UT5757) about usage of RFP.

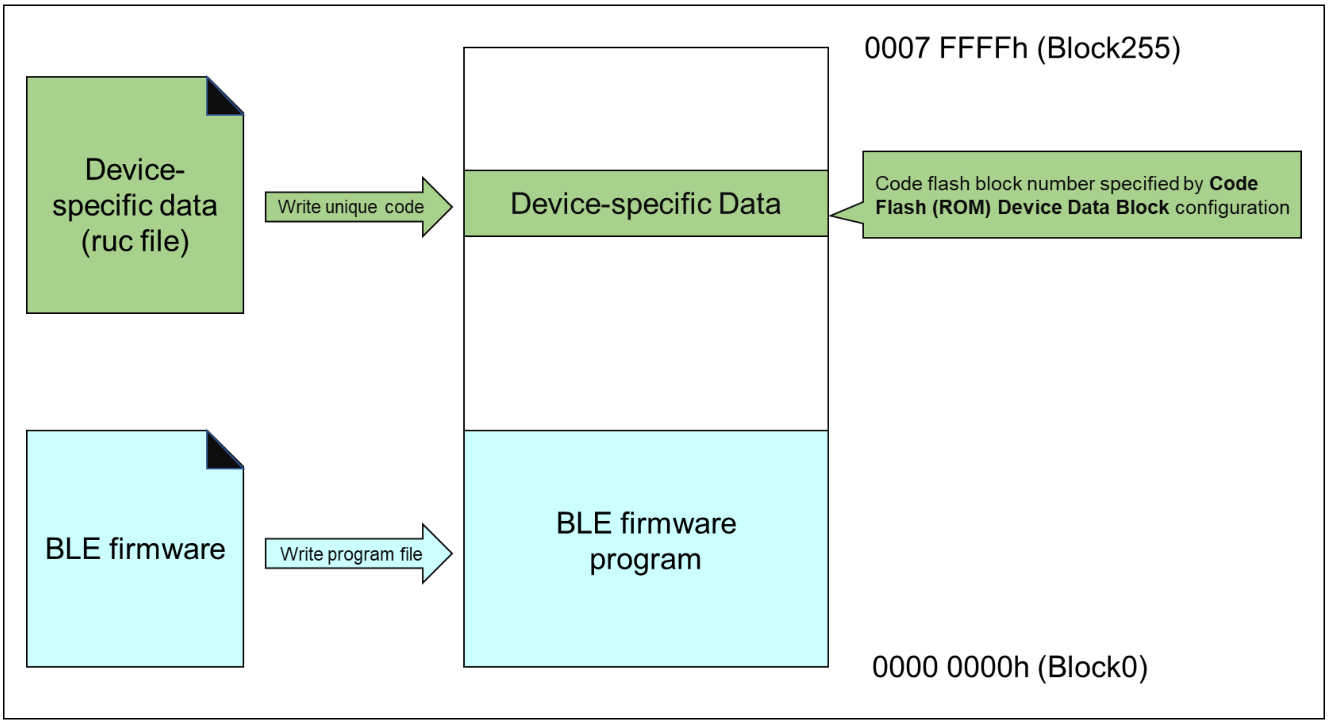
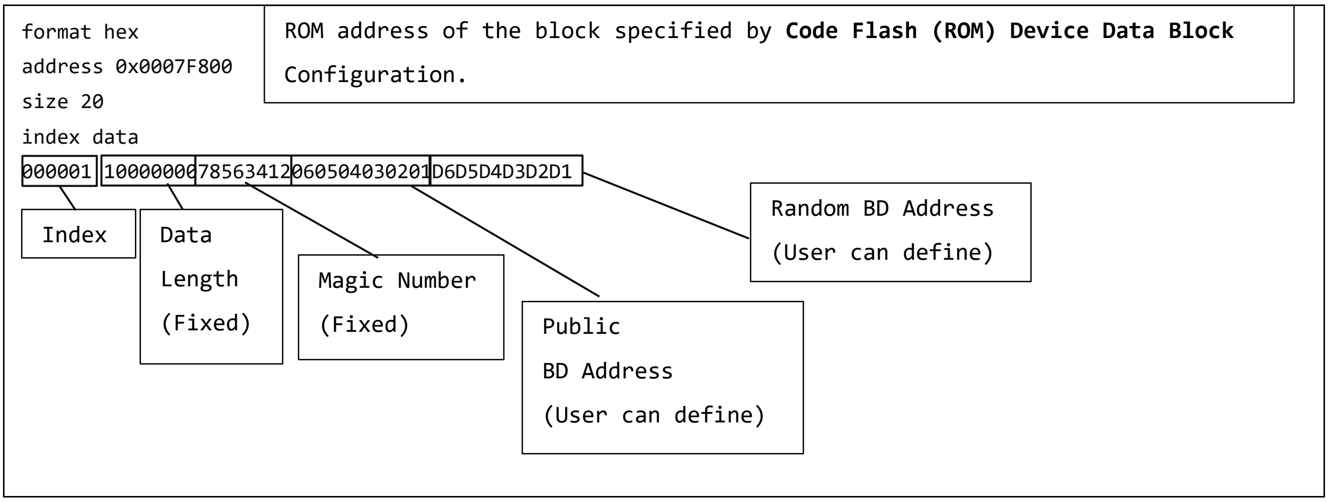


Figure 64. writing device-specific data by using RFP

Code 59 shown an example of setting device-specific data for RFP unique code (*.ruc) file.



```
format hex
address 0x0007F800
size 20
index data
000001 1000000078563412060504030201D6D5D4D3D2D1
```

ROM address of the block specified by **Code Flash (ROM) Device Data Block** Configuration.

Code 59. Setting device-specific data for RFP unique code

This code writes the following configurations at the top of block 255 in code flash area.

- Public address : 0x01:02:03:04:05:06
- Random address : 0xD1:D2:D3:D4:D5:D6

### 4.2.4 BD address adoption flow

BLE Protocol Stack adopts initial value of BD address in following priority order in *RM_BLE_ABS_Open()* API.

(1) Data flash specified block

(2) Code flash specified block

(3) Firmware initial value (**Debug Public Address** or **Debug Random Address** configuration)

For Random BD address, if BD addresses for all areas are not specified, static address is generated from Unique ID of MCU. Generated static address can be obtained with the *R_BLE_VS_GetBdAddr()* API.

Even after BD address is adopted, the BD address can be changed again with *R_BLE_VS_SetBdAddr()* API.

Note: The generated static address is a fixed value that does not change when the MCU power off or reset.

Note: A static address consists of random numbers. The possibility of duplicate values with other devices is near zero.

Figure 65 shows BD address adoption flow of BLE Protocol Stack.

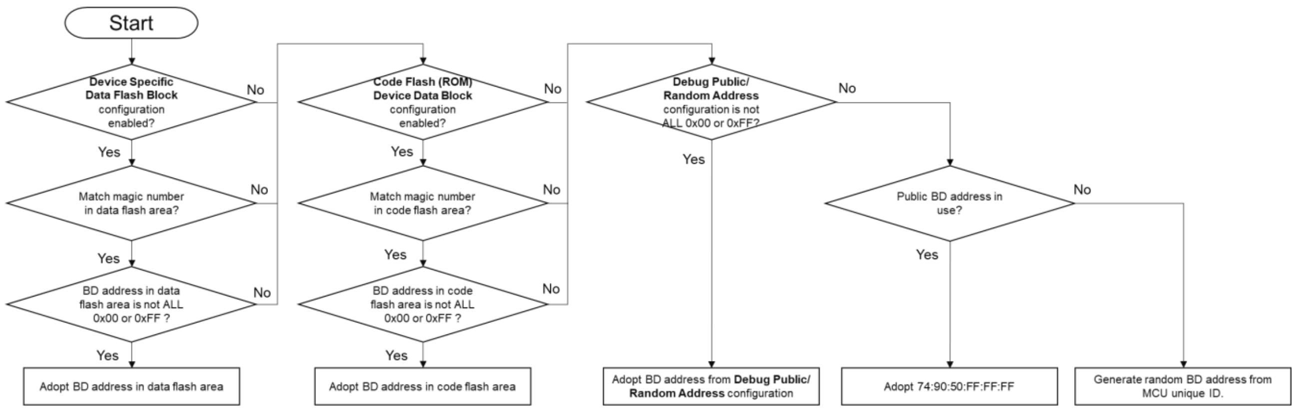


**Figure 65. BD address adoption flow of BLE Protocol Stack**

Since BLE Protocol Stack does not check format of BD address written in each area (1)-(3), when setting static address, set value that matches the format shown in Figure 66.

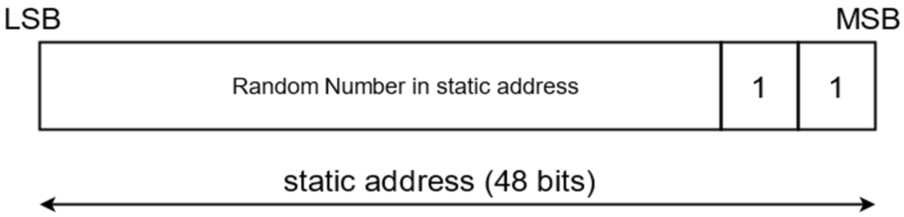


**Figure 66. Static address format**

## 4.3 Security Data Management

The security data management function read / write the following data in the data flash area.

- Local device key to distribute during pairing
- Key and information obtained from the remote device during pairing

The local device key and remote device key storage in the data flash is configurable in the BLE Protocol Stack using the security data management API. The Abstraction API uses the security data management API to manage security data for local and remote devices. The security data management function is set using the configuration options shown in Table 25.

**Table 25. Security data management configuration options**

| **Configuration Options** | Description |
|---|---|
| **Store Security Data**<br>Default: Disable | Enable or disable the security data management.<br>Range: Enable or Disable<br>Bonding information is stored in Data Flash block when this configuration set to Enable. And the bonding information will store Data Flash block which specified by **Data Flash Block for Security Data** option. |
| **Data Flash Block for Security Data**<br>Default: 0 | Specify Data Flash block which store the bonding information.<br>Range: 0 to 7<br>Choose a different block from **Device Specific Data** Refer to section 4.3.1 for details. |
| **Remote device bonding number**<br>Default: 7 | Maximum number of the bonding information stored in the Data Flash.<br>Range : 1 to 7<br>This value should be set same as **Maximum number of connections**.<br>Refer to section 4.3.1 for details. |

The security data management function manages security data management information, local device security data, and remote device security data. The memory map in the data flash is as shown in Figure 67.

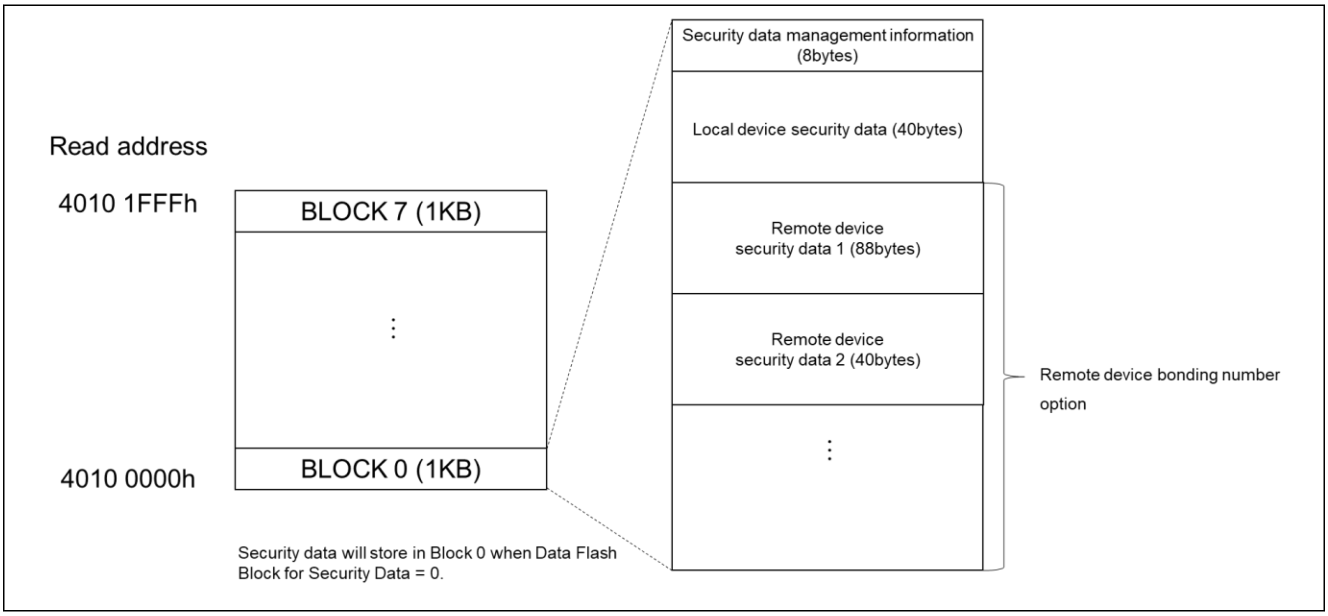


Figure 67. Memory map of security data in data flash

Each data information is described in following section.

### 4.3.1 Security data management information

The structure and structure elements of security data management information are shown in Figure 68 and Table 26. This data is handled internally by the security data management function and does not need to be updated by the user application.

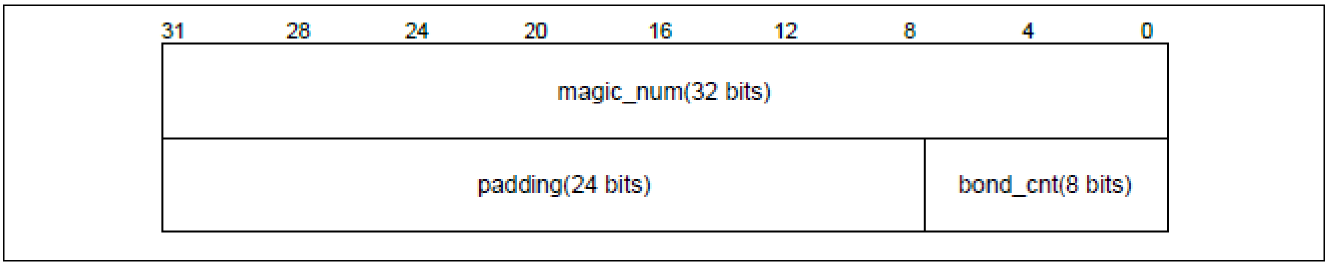


Figure 68. Security data management information structure

**Table 26. Security management information structure elements**

| Type | Element Name | size [bytes] | Description |
|---|---|---|---|
| uint32_t | magic_num | 4 | Magic number of security data.<br>Check whether security data is written.<br>Fixed to 0x12345678. 0xFFFFFFFF when not written. |
| uint8_t | bond_cnt | 1 | Number of bonding information stored. |
| uint8_t | padding[3] | 3 | Padding |

### 4.3.2 Local device security data

The security data structure and structure elements of the local device are shown in Figure 69 and Table 27.

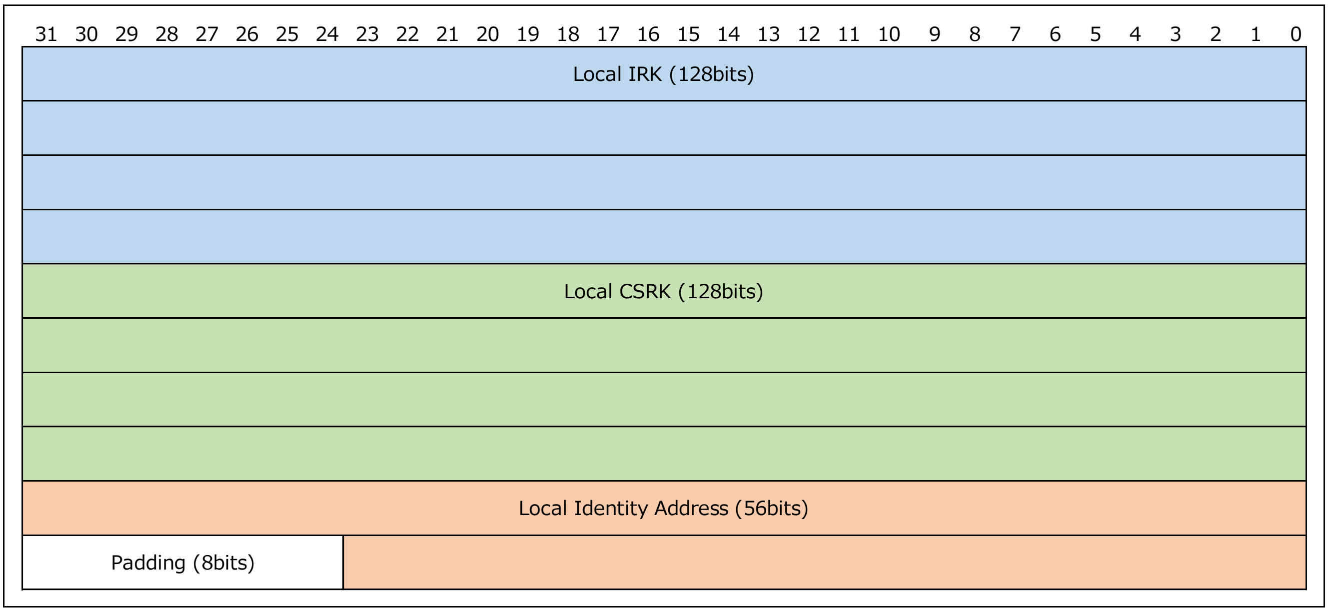


**Figure 69. Local device security data structure**

**Table 27. Local device security data structure elements**

| Element Name | size [bytes] | Description |
|---|---|---|
| Local Identity Resolving Key (IRK) | 16 | IRK distributed to remote devices during pairing.<br>Resolvable Private Address (RPA) is used when generating by Privacy feature. |
| Local Connection Signature Resolving Key (CSRK) | 16 | CSRK distributed to remote devices during pairing.<br>Used when sending with signed data. |
| Local Identity Address | 7 | The local device identity address that informs the remote device during pairing. |
| Padding | 1 | Padding |

The following describes security data settings for local devices.

- IRK and CSRK generate and set a 16-byte random number.
- To set BLE Protocol Stack, use *R_BLE_GAP_SetLocIdInfo()* (IRK, Identity Address) and *R_BLE_GAP_SetLocCsrk()* (CSRK).

By using API of security data management function, the generated security data can be written to data flash. It is possible to reconfigure to BLE Protocol Stack after reboot device. Figure 70 shows an example of local device security data setting processing that is performed when the BLE Protocol Stack is started.

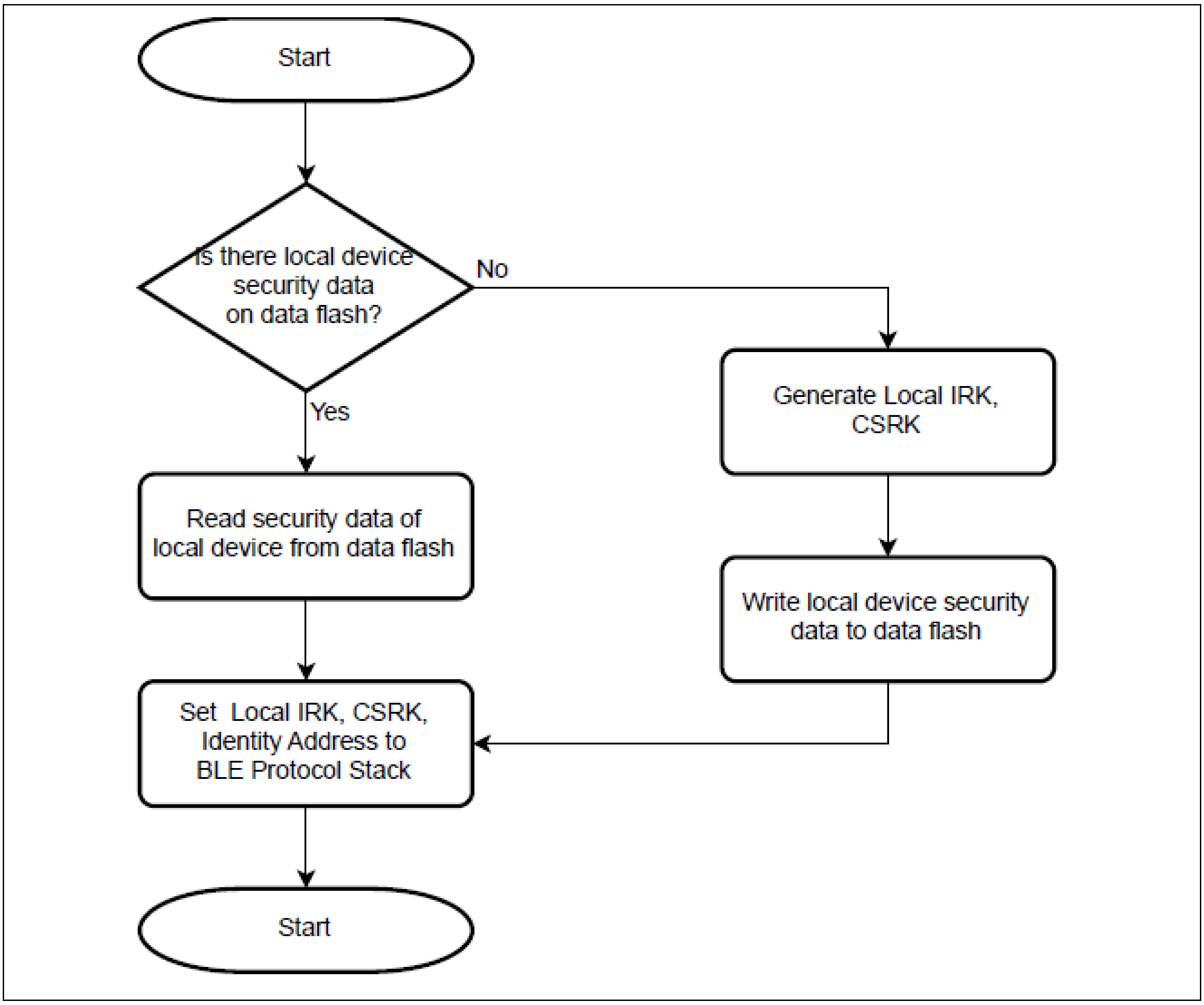
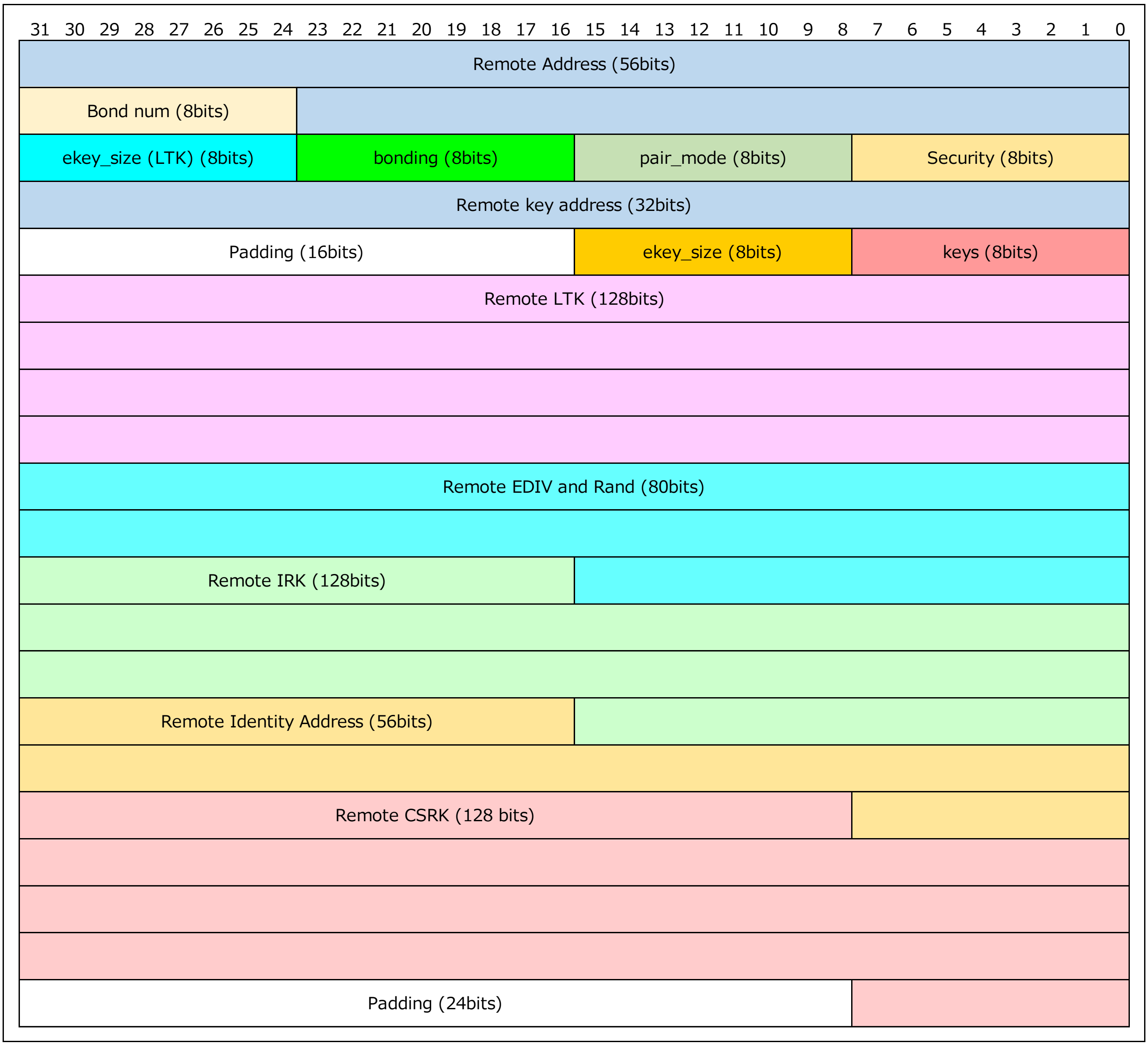


**Figure 70. Example of setting local device security data**

### 4.3.3 Remote device security data

The structure and structural elements of the remote device security data are shown in Figure 71 and Table 28.



| 31 30 29 28 27 26 25 24 | 23 22 21 20 19 18 17 16 | 15 14 13 12 11 10 9 8 | 7 6 5 4 3 2 1 0 |
|---|---|---|---|
| Remote Address (56bits) | | | |
| Bond num (8bits) | | | |
| ekey_size (LTK) (8bits) | bonding (8bits) | pair_mode (8bits) | Security (8bits) |
| Remote key address (32bits) | | | |
| Padding (16bits) | | ekey_size (8bits) | keys (8bits) |
| Remote LTK (128bits) | | | |
| | | | |
| | | | |
| | | | |
| Remote EDIV and Rand (80bits) | | | |
| | | | |
| Remote IRK (128bits) | | | |
| | | | |
| | | | |
| Remote Identity Address (56bits) | | | |
| | | | |
| Remote CSRK (128 bits) | | | |
| | | | |
| | | | |
| | | | |
| Padding (24bits) | | | |

**Figure 71. Remote device security data structure**

**Table 28. Remote device security data structure elements**

| Element Name | size [bytes] | Description |
|---|---|---|
| Remote Address | 7 | BD address used by remote device during pairing. |
| Bond num | 1 | Bonding serial number. |
| security | 1 | Security level of the pairing performed.<br>0x01: Perform pairing with Unauthenticated pairing.<br>0x02: Perform pairing with Authenticated pairing |
| pair_mode | 1 | Type of pairing performed.<br>0x01: Perform pairing with Legacy Pairing.<br>0x02: Perform pairing with Secure Connections. |
| bonding | 1 | Bonding policy of remote device.<br>0x00: Indicates that remote device does not bonding performed.<br>0x01 Indicates that remote device is bonding performed. |
| ekey_size (LTK) | 1 | Size of LTK. |
| remote key address | 4 | Start address of the data flash to store the remote device key (Remote LTK to Remote CSRK). |
| keys | 1 | Type of key distributed by remote device. |
| ekey_size | 1 | Negotiated LTK size. |
| Remote LTK | 16 | LTK distributed by remote device.<br>Used for connection encryption. |
| Remote EDIV and Rand | 10 | EDIV and Random number distributed by the remote device.<br>Used for connection encryption. |
| Remote IRK | 16 | IRK distributed by remote device.<br>Used for address resolution when the remote device uses the privacy feature. |
| Remote Identity Address | 7 | Identity address of remote device.<br>Used for address resolution when remote device uses the privacy feature. |
| Remote CSRK | 16 | CSRK distributed by remote device.<br>Used when receiving signed data. |

The following describes security data settings for remote devices.

- The remote device security data is received during pairing.
- security, pair_mode, bonding, and ekey_size in Table 28 are written to data flash at the BLE_GAP_EVENT_PAIRING_COMP event. Other data is written to the data flash at the BLE_GAP_EVENT_PEER_KEY_INFO event.
- Initializing process at the BLE_GAP_EVENT_STACK_ON event reads the remote device security data from data flash and calls *R_BLE_GAP_SetBondInfo()* to set remote device security data in the BLE Protocol Stack.
- If number of data written to data flash exceeds number specified by **Remote device bonding number** option, oldest security data entry is overwritten.

By using security data management function, the received remote device security data during pairing can be written to data flash. It is possible to reconfigure to BLE Protocol Stack after reboot device.

## 4.4 Data Flash Block

If your application holds data in Data Flash, use the block except the following.

- Data Flash (RAM) Device Data Block
- Data Flash Block for Security Data

## 4.5 Importing CLI (Command Line Interface) to user’s project

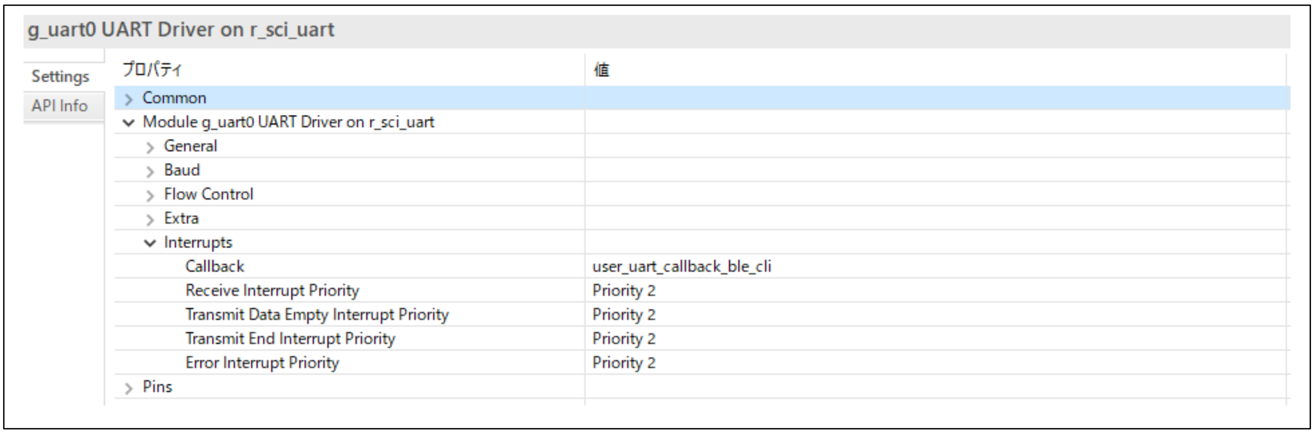
### 4.5.1 Related source files

Related source files to CLI are installed under app_lib in this demo project. User can add the CLI functionality by copying / adding path app_lib directory from this demo project to their own project.

### 4.5.2 Configurations of SCI

Please open FSP configuration of user’s project and select **Stacks** tab. Add **New Stack → Driver → Connectivity → UART Driver on r_sci_uart** to **HAL/Common**. And modify configuration of the added **r_sci_uart** as following.

- [Interrupts]→[Callback] : user_uart_callback_ble_cli



g_uart0 UART Driver on r_sci_uart

| プロパティ | 値 |
|---|---|
| > Common | |
| ∨ Module g_uart0 UART Driver on r_sci_uart | |
| > General | |
| > Baud | |
| > Flow Control | |
| > Extra | |
| ∨ Interrupts | |
| Callback | user_uart_callback_ble_cli |
| Receive Interrupt Priority | Priority 2 |
| Transmit Data Empty Interrupt Priority | Priority 2 |
| Transmit End Interrupt Priority | Priority 2 |
| Error Interrupt Priority | Priority 2 |
| > Pins | |

Figure 72. Interrupts of r_sci_uart

### 4.5.3 Designating module name

Edit value of BLE_UART_INSTANCE macro in app_lib / r_ble_console.c according to the module name of r_sci_uart which user named.

```
/***********************************************************************************
 Macro definitions
***********************************************************************************/

#define BLE_TX_BUFSIZ           (80)
#define BLE_UART_INSTANCE       (g_uart0)
```

Code 60. BLE_UART_INSTANCE macro

### 4.5.4 Serial data output of UART

Serial data output of UART can be performed by *R_BLE_CLI_Printf()* function. *R_BLE_CLI_Printf()* function can generate formatted character lines by the way like *printf()* function.

**Table 29. Syntax of *R_BLE_CLI_Printf()***

| Function Name | R_BLE_CLI_Printf | |
|---|---|---|
| Format | void R_BLE_CLI_Printf(const char *format, …); | |
| Return | void | - |
| Arguments | const char *format | Designate a constant character line including formats |
| | … | Variable number of arguments represented by formats can be designated. |

## 4.6 Command List

### 4.6.1 GAP command

### (1) Advertising command

| adv command | | |
|---|---|---|
| Format : | gap adv [adv_type] [operation] | |
| | Start, stop, or remove advertising. | |
| Parameters : | [adv_type] | Select one of the followings as the type of advertising.<br>legacy : legacy advertising<br>ext : extended advertising<br>non-conn : non-connectable advertising<br>periodic : periodic advertising |
| | [operation] | Start or stop advertising.<br>start : start advertising<br>stop : stop advertising.<br>remove : remove advertising set specified by adv_type. |
| Example : | gap adv legacy start<br>Start legacy advertising.<br>The local device address is a static address.<br><br>gap adv ext stop<br>Stop extended advertising. | |

Other parameters related to Advertising that cannot be set from this command are set in the Advertising parameter variables of gs_legacy_adv_param, gs_ext_adv_param, gs_non_conn_adv_param, and gs_periodic_adv_param in app_lib\cmd\r_ble_cmd_abs.c. Changing these variables will change the setting of Advertising parameters.

**Table 30. legacy advertising parameter: gs_legacy_adv_param**

| **Parameter Structure**<br>**st_ble_abs_legacy_adv_param_t** | | **gs_legacy_adv_param** | |
|---|---|---|---|
| **Type** | **Field Name** | **Description** | **Default Value** |
| st_ble_dev_addr_t * | p_addr | Specify the remote address registered in the Resolving List.<br>When o_addr_type is BLE_GAP_ADDR_RPA_ID_PUBLIC (0x02) or BLE_GAP_ADDR_RPA_ID_STATIC (0x03), specify the remote address registered in the Resolving List in p_addr. If o_addr_type is BLE_GAP_ADDR_PUBLIC (0x00) or BLE_GAP_ADDR_RAND (0x01), specify NULL for p_addr. | NULL |
| uint8_t * | p_adv_data | Specify Advertising Data.<br>If NULL is specified, Advertising Data is not set. | gs_adv_data |
| uint8_t * | p_sres_data | Specify Scan Response Data.<br>If NULL is specified, Scan Response Data is not set. | gs_sres_data |
| uint32_t | fast_adv_intv | Advertising is performed at the interval specified by fast_adv_intv for the period specified by the fast_period parameter.<br>Time (ms) = fast_adv_intv * 0.625.<br>Ignored if fast_period is 0.<br>The range is 0x00000020-0x00FFFFFF. | 0x00000100 |
| uint32_t | slow_adv_intv | After the time specified by the fast_period parameter elapses, advertising is performed at the interval specified by slow_adv_intv for the period specified by the slow_period parameter.<br>Time (ms) = adv_intv_max * 0.625<br>The range is 0x00000020-0x00FFFFFF. | 0x00000200 |
| uint16_t | fast_period | Specify the period for advertising in fast_adv_intv.<br>Time = duration * 10ms.<br>When the time specified in duration elapses, the BLE_GAP_EVENT_ADV_OFF event notifies that Advertising has stopped.<br>Range : 0x0000-0xFFFF.<br>If 0x0000 is specified, fast_period is ignored. | 0x0100 |
| uint16_t | slow_period | Specify the period for performing Advertising with slow_adv_intv.<br>Time = duration * 10ms.<br>When the time specified in duration elapses, the BLE_GAP_EVENT_ADV_OFF event notifies that Advertising has stopped.<br>The range is 0x0000-0xFFFF.<br>If 0x0000 is specified, slow_period is ignored. | 0x0000 |
| uint16_t | adv_data_length | Specify Advertising Data size (byte).<br>For Legacy Advertising PDU, the range is 0 to 31.<br>If 0 is specified, Advertising Data is not set. | sizeof(gs_adv_data) |
| uint16_t | sres_data_length | Specify the size (in bytes) of Scan Response Data.<br>For Legacy Advertising PDU, the range is 0 to 31.<br>If 0 is specified, Scan Response Data is not set. | sizeof(gs_sres_data) |
| uint8_t | adv_ch_map | Specify the channel to be used for advertising packet transmission.<br>It is possible to specify by the logical sum of the following macros.<br><br>**BLE_GAP_ADV_CH_37 (0x01)** 37 CH is used.<br>**BLE_GAP_ADV_CH_38 (0x02)** 38 CH is used.<br>**BLE_GAP_ADV_CH_39 (0x04)** 39 CH is used.<br>**BLE_GAP_ADV_CH_ALL (0x07)** 37-39 CH is used. | BLE_GAP_ADV_CH_ALL |

| **Parameter Structure**<br>**st_ble_abs_legacy_adv_param_t** | | **gs_legacy_adv_param** | |
|---|---|---|---|
| **Type** | **Field Name** | **Description** | **Default Value** |
| uint8_t | filter | Specify Advertising Filter Policy.<br>When p_addr parameter is NULL, advertising is performed according to the filter policy.<br>This parameter is ignored if the remote device address is specified in the p_addr parameter.<br><br>**BLE_ABS_ADV_ALLOW_CONN_ANY (0x00)**<br>Accepts Connection Requests from all devices.<br><br>**BLE_ABS_ADV_ALLOW_CONN_WLST (0x01)**<br>Only devices registered in the White List will accept Connection Requests. | BLE_ABS_ADV_ALLOW_CONN_ANY |
| uint8_t | o_addr_type | Specify Own BD Address Type.<br><br>**BLE_GAP_ADDR_PUBLIC (0x00)**<br>Indicates a public address.<br><br>**BLE_GAP_ADDR_RAND(0x01)**<br>Indicates a static address.<br><br>**BLE_GAP_ADDR_RPA_ID_PUBLIC (0x02)**<br>Indicates that RPA is to be used. If there is no IRK on the Resolving List, use the public address.<br><br>**BLE_GAP_ADDR_RPA_ID_RANDOM(0x03)**<br>Indicates that RPA is to be used. If there is no IRK on the Resolving List, use the static address. | BLE_GAP_ADDR_PUBLIC |
| uint8_t | o_addr[6] | When o_addr_type is BLE_GAP_ADDR_RAND (0x01) or BLE_GAP_ADDR_RPA_ID_RANDOM (0x03), specify the Random Address to be set in the Advertising Set. This parameter is ignored when using the Balance or Compact library. | Not set because o_addr_type is BLE_GAP_ADDR_PUBLIC. |

**Table 31. Extended advertising parameter: gs_ext_adv_param**

| **Parameter Structure**<br>**st_ble_abs_ext_adv_param_t** | | **gs_ext_adv_param** | |
|---|---|---|---|
| **Type** | **Field Name** | **Description** | **Default Value** |
| st_ble_dev_addr_t * | p_addr | Specify the remote address registered in the Resolving List.<br>When o_addr_type is BLE_GAP_ADDR_RPA_ID_PUBLIC (0x02) or BLE_GAP_ADDR_RPA_ID_STATIC (0x03), specify the remote address registered in the Resolving List in p_addr. If o_addr_type is BLE_GAP_ADDR_PUBLIC (0x00) or BLE_GAP_ADDR_RAND (0x01), specify NULL for p_addr. | NULL |
| uint8_t * | p_adv_data | Specify Advertising Data.<br>If NULL is specified, Advertising Data is not set. | gs_adv_data |
| uint32_t | fast_adv_intv | Advertising is performed at the interval specified by fast_adv_intv for the period specified by the fast_period parameter.<br>Time (ms) = fast_adv_intv * 0.625.<br>Ignored if fast_period is 0.<br>The range is 0x00000020-0x00FFFFFF. | 0x00000100 |
| uint32_t | slow_adv_intv | After the time specified by the fast_period parameter elapses, advertising is performed at the interval specified by slow_adv_intv for the period specified by the slow_period parameter.<br>Time (ms) = adv_intv_max * 0.625<br>The range is 0x00000020-0x00FFFFFF. | 0x00000200 |
| uint16_t | fast_period | Specify the period for advertising in fast_adv_intv.<br>Time = duration * 10ms.<br>When the time specified in duration elapses, the BLE_GAP_EVENT_ADV_OFF event notifies that Advertising has stopped.<br>The range is 0x0000-0xFFFF.<br>If 0x0000 is specified, fast_period is ignored. | 0x0300 |
| uint16_t | slow_period | Specify the period for performing Advertising with slow_adv_intv.<br>Time = duration * 10ms.<br>When the time specified in duration elapses, the BLE_GAP_EVENT_ADV_OFF event notifies that Advertising has stopped.<br>The range is 0x0000-0xFFFF.<br>If 0x0000 is specified, slow_period is ignored. | 0x0000 |
| uint16_t | adv_data_length | Specify Advertising Data size (byte).<br>The range is from 0 to 229.<br>If 0 is specified, Advertising Data will not be set. | sizeof(gs_adv_data) |
| uint8_t | adv_ch_map | Specify the channel to be used for advertising packet transmission.<br>It is possible to specify by the logical sum of the following macros.<br><br>**BLE_GAP_ADV_CH_37 (0x01)** 37 CH is used.<br>**BLE_GAP_ADV_CH_38 (0x02)** 38 CH is used.<br>**BLE_GAP_ADV_CH_39 (0x04)** 39 CH is used.<br>**BLE_GAP_ADV_CH_ALL (0x07)** 37-39 CH is used. | BLE_GAP_ADV_CH_ALL |
| uint8_t | filter | Specify Advertising Filter Policy.<br>When p_addr parameter is NULL, advertising is performed according to the filter policy.<br>This parameter is ignored if the remote device address is specified in the p_addr parameter.<br><br>**BLE_ABS_ADV_ALLOW_CONN_ANY (0x00)**<br>Accepts Connection Requests from all devices.<br>**BLE_ABS_ADV_ALLOW_CONN_WLST (0x01)**<br>Only devices registered in the White List will accept Connection Requests. | BLE_ABS_ADV_ALLOW_CONN_ANY |

| **Parameter Structure**<br>**st_ble_abs_ext_adv_param_t** | | **gs_ext_adv_param** | |
|---|---|---|---|
| **Type** | **Field Name** | **Description** | **Default Value** |
| uint8_t | o_addr_type | Specify Own BD Address Type.<br>**BLE_GAP_ADDR_PUBLIC (0x00)**<br>Indicates a public address.<br>**BLE_GAP_ADDR_RAND(0x01)**<br>Indicates a static address.<br>**BLE_GAP_ADDR_RPA_ID_PUBLIC (0x02)**<br>Indicates that RPA is to be used. If there is no IRK on the Resolving List, use the public address.<br>**BLE_GAP_ADDR_RPA_ID_RANDOM(0x03)**<br>Indicates that RPA is to be used. If there is no IRK on the Resolving List, use the static address. | BLE_GAP_ADDR_PUBLIC |
| uint8_t | adv_phy | Specify Primary ADV PHY.<br>In this parameter, only 1M PHY and Coded PHY can be specified, and 2M PHY cannot be specified.<br>**BLE_GAP_ADV_PHY_1M (0x01)**<br>1M PHY is used as Primary Advertising PHY.<br>**BLE_GAP_ADV_PHY_CD (0x03)**<br>Use Coded PHY as Primary Advertising PHY.<br>Coding scheme is the contents set by *R_BLE_VS_SetCodingScheme()*. | BLE_GAP_ADV_PHY_1M |
| uint8_t | sec_adv_phy | Specify Secondary ADV Phy.<br>**BLE_GAP_ADV_PHY_1M (0x01)**<br>1M PHY is used for Secondary Advertising PHY.<br>**BLE_GAP_ADV_PHY_2M (0x02)**<br>2M PHY is used for Secondary Advertising PHY.<br>**BLE_GAP_ADV_PHY_CD (0x03)**<br>Use Coded PHY for Secondary Advertising PHY.<br>Coding scheme is the contents set by *R_BLE_VS_SetCodingScheme().* | BLE_GAP_ADV_PHY_1M |

**Table 32. Non-Connectable advertising parameter: gs_non_conn_adv_param**

| **Parameter Structure** | | | |
|---|---|---|---|
| **st_ble_abs_non_conn_adv_param_t** | | **gs_non_conn_adv_param** | |
| **Type** | **Field Name** | **Description** | **Default Value** |
| st_ble_dev_addr_t * | p_addr | For the remote address specified by p_addr<br>Direct non-connectable advertising.<br>If p_addr is NULL, Undirect Non-Connectable Advertising is performed. | NULL |
| uint8_t * | p_adv_data | Specify Advertising Data.<br>If NULL is specified, Advertising Data is not set. | gs_adv_data |
| uint32_t | adv_intv | Advertising is performed at the interval specified by adv_intv for the period specified by the duration parameter.<br>Time (ms) = adv_intv * 0.625<br>When duration is 0x0000, the interval advertisement specified by adv_intv is continued.<br>The range is 0x00000020-0x00FFFFFF. | 0x000000a0 |
| uint16_t | duration | Specify the period for performing Advertising in adv_intv.<br>Time = duration * 10ms.<br>When the time specified in duration elapses, a BLE_GAP_EVENT_ADV_OFF event occurs.<br>The range is 0x0000-0xFFFF.<br>If 0x0000 is specified, duration is ignored. | 0x0000 |
| uint16_t | adv_data_length | Specify Advertising Data size (byte).<br>If BLE_ABS_ADV_PHY_LEGACY (0x00) is specified in the adv_phy parameter, the range is 0-31. Otherwise, it is 0-1650.<br>If 0 is specified, Advertising Data is not set. | sizeof(gs_adv_data) |
| uint8_t | adv_ch_map | Specify the channel to be used for advertising packet transmission.<br>It is possible to specify by the logical sum of the following macros.<br><br>**BLE_GAP_ADV_CH_37 (0x01)** 37 CH is used.<br>**BLE_GAP_ADV_CH_38 (0x02)** 38 CH is used.<br>**BLE_GAP_ADV_CH_39 (0x04)** 39 CH is used.<br>**BLE_GAP_ADV_CH_ALL (0x07)** 37-39 CH is used. | BLE_GAP_ADV_CH_ALL |
| uint8_t | o_addr_type | Specify Own BD Address Type.<br><br>**BLE_GAP_ADDR_PUBLIC (0x00)**<br>Indicates a public address.<br>**BLE_GAP_ADDR_RPA_ID_PUBLIC (0x02)**<br>Indicates that RPA is to be used.<br>If there is no IRK registered in the Resolving List, use Public Address. | BLE_GAP_ADDR_PUBLIC |
| uint8_t | adv_phy | Specify Primary ADV PHY.<br>In this parameter, only 1M PHY and Coded PHY can be specified, and 2M PHY cannot be specified.<br><br>**BLE_GAP_ADV_PHY_1M (0x01)**<br>1M PHY is used as Primary Advertising PHY.<br>**BLE_GAP_ADV_PHY_CD (0x03)**<br>Use Coded PHY as Primary Advertising PHY.<br>Coding scheme is the contents set by *R_BLE_VS_SetCodingScheme()*. | BLE_GAP_ADV_PHY_1M |

| **Parameter Structure**<br>**st_ble_abs_non_conn_adv_param_t** | | **gs_non_conn_adv_param** | |
|---|---|---|---|
| **Type** | **Field Name** | **Description** | **Default Value** |
| uint8_t | sec_adv_phy | Specify Secondary ADV Phy.<br>**BLE_GAP_ADV_PHY_1M (0x01)**<br>1M PHY is used for Secondary Advertising PHY.<br>**BLE_GAP_ADV_PHY_2M (0x02)**<br>2M PHY is used for Secondary Advertising PHY.<br>**BLE_GAP_ADV_PHY_CD (0x03)**<br>Use Coded PHY for Secondary Advertising PHY.<br>Coding scheme is the contents set by *R_BLE_VS_SetCodingScheme()*. | BLE_GAP_ADV_PHY_1M |

### Table 33. Periodic advertising parameter: gs_periodic_adv_param

| **Parameter Structure**<br>**st_ble_abs_perd_adv_param_t** | | **gs_periodic_adv_param** | |
|---|---|---|---|
| **Type** | **Field Name** | **Description** | **Default Value** |
| st_ble_abs_non_conn_adv_param_t | param | Specify the non-connectable advertising parameter. | gs_non_conn_adv_param (*1) |
| uint8_t * | p_perd_adv_data | Specify Periodic Advertising Data.<br>If NULL is specified, Periodic Advertising Data is not set. | gs_adv_data |
| uint16_t | perd_intv | Specify Periodic Advertising Interval.<br>Time (ms) = perd_intv * 1.25.<br>The range is 0x0006-0xFFFF. | 0x0040 |
| uint16_t | perd_adv_data_length | Specify the size (bytes) of Periodic Advertising Data.<br>The range is 0-1650.<br>If 0 is specified, Periodic Advertising Data is not set. | sizeof(gs_adv_data) |

*1: It is set in *exec_abs_adv()* of app_lib\cmd\r_ble_cmd_abs.c.

### (2) Scan command

| scan command | | |
|---|---|---|
| Format : | gap scan (operation) (filter_ad_type) (filter_data) (addr_type) (-wl) | |
| | Start scan.<br>It is not necessary to specify (operation) when starting scan.<br>When scan stops, input [ctrl] + [c]. | |
| Parameters : | (operation) | Specify operation for scan<br>stop : stop scan. |
| | (filter_ad_type) | The AD type for filtering.<br>Refer to Bluetooth SIG Assigned Numbers for generic access profile for the definition of the AD type.<br>If the filter is not used, this parameter can be omitted. |
| | (filter_data) | The data for filtering.<br>Specify the data for the filter_ad_type.<br>If the filter is not used, this parameter can be omitted.<br>If the filter_ad_type is not used, this parameter is ignored. |
| | (addr_type) | Specify the address type of scan request.<br>When this parameter is omitted, static address is selected.<br>pub : Public Address<br>rnd : Static Address |
| | (-wl) | Specify this parameter when using white list.<br>If white list is not used, this parameter is can be omitted. |
| Example : | gap scan<br>Start scan.<br><br>gap scan 2 0x01,0x29<br>Search the advertising report which of the AD Type :<br>Incomplete List of 16-bit Service Class UUIDs(0x02) and the service UUID : 0x2901. | |

Other parameters related to Scan that cannot be set from this command are set in the scan parameter variables of gs_phy_param_1m and gs_scan_param in app_lib\cmd\r_ble_cmd_abs.c. Changing these variables will change the scan parameter settings.

**Table 34. Scan parameter: gs_phy_param_1m**

| **Parameter Structure**<br>**st_ble_abs_scan_phy_param_t** | | **gs_phy_param_1m** | |
|---|---|---|---|
| **Type** | **Field Name** | **Description** | **Default Value** |
| uint16_t | fast_intv | Specify Fast Scan interval.<br>Fast Scan interval (ms) = fast_intv * 0.625<br>The range is 0x0004-0xFFFF. | 0x0200<br>(320ms) |
| uint16_t | slow_intv | Specify the Slow Scan interval.<br>Slow Scan interval (ms) = slow_intv * 0.625<br>The range is 0x0004-0xFFFF. | 0x0800<br>(1.28s) |
| uint16_t | fast_window | Specify Fast Scan window.<br>Fast Scan window (ms) = fast_window * 0.625<br>The range is 0x0004-0xFFFF. | 0x0100<br>(160ms) |
| uint16_t | slow_window | Specify Slow Scan window.<br>Slow Scan window (ms) = slow_window * 0.625<br>The range is 0x0004-0xFFFF. | 0x0100<br>(160ms) |
| uint8_t | scan_type | Specify Passive Scan / Active Scan as the scan type.<br><br>**BLE_GAP_SCAN_PASSIVE (0x00)**<br>Indicates that a passive scan is to be performed.<br>**BLE_GAP_SCAN_ACTIVE (0x01)**<br>Indicates that Active Scan is to be performed. | BLE_GAP_SCAN_PASSIVE |

**Table 35. Scan parameter: gs_scan_param**

| **Parameter Structure**<br>**st_ble_abs_scan_param_t** | | **gs_scan_param** | |
|---|---|---|---|
| **Type** | **Field Name** | **Description** | **Default Value** |
| st_ble_abs_scan_phy_param_t * | p_phy_param_1M | Specify the Scan parameter for 1M PHY.<br>Specify NULL when not scanning with 1M PHY.<br>Specify scan parameter for either p_phy_param_1M or p_phy_param_coded. | &gs_phy_param_1M |
| st_ble_abs_scan_phy_param_t * | p_phy_param_coded | Specify the Scan parameter for Coded PHY.<br>Specify NULL when not scanning with Coded PHY.<br>Specify scan parameter for either p_phy_param_1M or p_phy_param_coded. | NULL |
| uint8_t * | p_filter_data | Specify the data to be filtered.<br>Data included in a single Advertising Data PDU is targeted.<br>Filtering is not performed for data indicated by multiple Advertising Data PDUs.<br>When NULL is specified or when 0 is specified for filter_data_length, filtering is not performed. | gs_filt_data |
| uint16_t | fast_period | Specify the scanning time in Fast scan interval / Fast scan window.<br>Time (ms) = fast_period * 10.<br>The range is 0x0000-0xFFFF.<br>When 0x0000 is specified, scanning by Fast scan interval / Fast scan window is not performed.<br>When the time specified in fast_period elapses, a BLE_GAP_EVENT_SCAN_TO event occurs. | 0x0100 |
| uint16_t | slow_period | Specify the scan time in Slow scan interval / Slow scan window.<br>Time (ms) = slow_period * 10.<br>The range is 0x0000-0xFFFF.<br>When 0x0000 is specified, scanning with Slow scan interval / Slow scan window continues.<br>When the time specified by slow_period elapses, a BLE_GAP_EVENT_SCAN_TO event occurs. | 0x0000 |
| uint16_t | filter_data_length | Specifies the size of the filtering data indicated by the p_filter_data parameter.<br>If 0 is specified, or p_filter_data is NULL, no filtering is performed.<br>Up to 16 bytes can be specified. | 0 |
| uint8_t | dev_filter | Specify the Scan Filter Policy. Set one of the following values.<br>**BLE_GAP_SCAN_ALLOW_ADV_ALL (0x00)**<br>All Advertising PDUs and Scan Response PDUs are accepted.<br>**BLE_GAP_SCAN_ALLOW_ADV_WLST (0x01)**<br>Only Advertising PDUs and Scan Response PDUs of devices registered in the White List are accepted.<br>**BLE_GAP_SCAN_ALLOW_ADV_EXCEPT_DIRECTED (0x02)**<br>All Advertising PDUs and Scan Response PDUs are accepted, except when the Directed Advertising PDU destination is not the Scanner identity address. Directed Advertising PDUs are accepted even if the destination is the RPA of the local device.<br>**BLE_GAP_SCAN_ALLOW_ADV_EXCEPT_DIRECTED_WLST (0x03)**<br>Except for the following cases, all advertising, scan response PDUs are accepted.<br>• The address included in the Direct Advertising PDU is not the Scanner identity address.<br>• The Advertiser Identity Address is not registered in the White List. | BLE_GAP_SCAN_ALLOW_ADV_ALL |

| **Parameter Structure**<br>**st_ble_abs_scan_param_t** | | **gs_scan_param** | |
|---|---|---|---|
| **Type** | **Field Name** | **Description** | **Default Value** |
| uint8_t | filter_dups | Specify the presence or absence of duplicates filter to filter duplicate advertising packet notifications.<br>The number of devices that can be filtered is eight.<br>The duplicate filter is disabled for the ninth and subsequent devices.<br>**BLE_GAP_SCAN_FILT_DUPLIC_DISABLE (0x00)**<br>Disable duplicate filter.<br>**BLE_GAP_SCAN_FILT_DUPLIC_ENABLE (0x01)**<br>Enable duplicate filter. | BLE_GAP_SCAN_FILT_DUPLIC_DISABLE |
| uint8_t | filter_ad_type | Specify the AD type of the filtering data indicated by the p_filter_data parameter.<br>For details on AD type, refer to Assigned Numbers for generic access profile of Bluetooth SIG. | — |

### (3) Connection command

| conn command | | |
|---|---|---|
| Format : | gap conn [addr] [addr_type] | |
| | Send a connection request.<br>In case of stopping connection request, input [ctrl] + [c]. | |
| Parameters : | [addr] | Remote device address. |
| | [addr_type] | Specify the followings as remote device address type.<br>pub : Public Address<br>rnd : Random Address |
| Example : | gap conn 74:90:50:00:95:a8 pub<br>Send a connection request to the remote device whose public address is 74:90:50:00:95:a8.<br>gap conn d8:19:e3:30:92:21 pub<br>Send a connection request to the remote device whose random address is d8:19:e3:30:92:21. | |

Other parameters related to Connection that cannot be set from this command are set in the connection parameter variables of gs_conn_phy_1m and gs_conn_param in app_lib\cmd\r_ble_cmd_abs.c. Changing these variables will change the connection parameter settings.

**Table 36. Connection parameter: gs_conn_phy_1m**

| **Parameter Structure** | | **gs_conn_phy_1m** | |
|---|---|---|---|
| **st_ble_abs_conn_phy_param_t** | | | |
| **Type** | **Field Name** | **Description** | **Default Value** |
| uint16_t | conn_intv | Specify the Connection interval.<br>Time (ms) = conn_intv * 1.25.<br>The range is 0x0006-0x0C80. | 0x00A0 (200ms) |
| uint16_t | conn_latency | Specify Slave latency.<br>The range is 0x0000-0x01F3. | 0x0000 |
| uint16_t | sup_to | Specify Supervision timeout.<br>Time (ms) = sup_to * 10<br>The range is 0x000A-0x0C80. | 0x03E8 (10s) |

**Table 37. Connection parameter: gs_conn_param**

| **Parameter Structure**<br>**st_ble_abs_conn_param_t** | | **gs_conn_param** | |
|---|---|---|---|
| **Type** | **Field Name** | **Description** | **Default Value** |
| uint8_t | filter | Specify how to select a remote device to establish a connection and the address type of a local device.<br>**BLE_ABS_CONN_USE_ADDR_PUBLIC**<br>**(BLE_GAP_INIT_FILT_USE_ADDR \| (BLE_GAP_ADDR_PUBLIC << 4))**<br>Establish a connection with the remote device specified by p_addr.<br>Local device uses public address.<br>**BLE_ABS_CONN_USE_WLST_PUBLIC**<br>**(BLE_GAP_INIT_FILT_USE_WLST \| (BLE_GAP_ADDR_PUBLIC << 4))**<br>Establish a connection with a remote device registered in the White List.<br>Local device uses public address.<br>**BLE_ABS_CONN_USE_ADDR_STATIC**<br>**(BLE_GAP_INIT_FILT_USE_ADDR \| (BLE_GAP_ADDR_RAND << 4))**<br>Establish a connection with the remote device specified by p_addr<br>Local device uses static address.<br>**BLE_ABS_CONN_USE_WLST_STATIC**<br>**(BLE_GAP_INIT_FILT_USE_WLST \| (BLE_GAP_ADDR_RAND << 4))**<br>Establish a connection with a remote device registered in the White List.<br>Local device uses static address.<br>**BLE_ABS_CONN_USE_ADDR_RPA_PUBLIC**<br>**(BLE_GAP_INIT_FILT_USE_ADDR \| (BLE_GAP_ADDR_RPA_ID_PUBLIC << 4))**<br>Establish a connection with the remote device specified by p_addr<br>Use RPA. If the IRK is not registered in the Resolving List, public address is used.<br>**BLE_ABS_CONN_USE_WLST_RPA_PUBLIC**<br>**(BLE_GAP_INIT_FILT_USE_WLST \| (BLE_GAP_ADDR_RPA_ID_PUBLIC << 4))**<br>Establish a connection with a remote device registered in the White List.<br>Use RPA. If the IRK is not registered in the Resolving List, public address is used.<br>**BLE_ABS_CONN_USE_ADDR_RPA_STATIC**<br>**(BLE_GAP_INIT_FILT_USE_ADDR \| (BLE_GAP_ADDR_RPA_ID_RANDOM << 4))**<br>Establish a connection with the remote device specified by p_addr<br>Use RPA. If the IRK is not registered in the Resolving List, static address is used.<br>**BLE_ABS_CONN_USE_WLST_RPA_STATIC**<br>**(BLE_GAP_INIT_FILT_USE_WLST \| (BLE_GAP_ADDR_RPA_ID_RANDOM << 4))**<br>Establish a connection with a remote device registered in the White List.Use RPA. If the IRK is not registered in the Resolving List, static address is used. | BLE_ABS_CONN_USE_ADDR_PUBLIC |
| uint8_t | conn_to | Specify the time (s) from when the connection establishment request is issued until cancellation.<br>The range is 0 <= conn_to <= 10.<br>If 0 is specified, no cancellation is performed. | 7(s) |
| st_ble_abs_conn_phy_param_t * | p_conn_1M | Specify 1M PHY connection parameters.<br>When NULL is specified, connection with 1M PHY is not performed. | &gs_conn_phy_1m |

| **Parameter Structure**<br>**st_ble_abs_conn_param_t** | | **gs_conn_param** | |
|---|---|---|---|
| **Type** | **Field Name** | **Description** | **Default Value** |
| st_ble_abs_conn_phy_param_t * | p_conn_2M | Specify 2M PHY connection parameters.<br>If NULL is specified, 2M PHY connection is not performed. | NULL |
| st_ble_abs_conn_phy_param_t * | p_conn_coded | Specify the connection parameters for Coded PHY.<br>If NULL is specified, connection with Coded PHY is not performed. | NULL |
| st_ble_dev_addr_t * | p_addr | Specify the address of the remote device to be connected.<br>This parameter is ignored if the filter parameter is BLE_GAP_INIT_FILT_USE_WLST (0x01). | &gs_conn_bd_addr (*1) |

*1: Use the address entered on the command line.

### (4) Disconnection command

| disconn command | | |
|---|---|---|
| Format : | gap disconn [conn_hdl]<br>Disconnect the connection. | |
| Parameters : | [conn_hdl] | Connection handle of which the connection is disconnected. |
| Example : | gap disconn 0x0020<br>Disconnect the connection with connection handle 0x0020. | |

### (5) Device command

| device command | |
|---|---|
| Format : | gap device<br>Display the addresses of the connected devices. |
| Parameters : | None |
| Example : | gap device<br>Display the addresses of the connected devices. |

### (6) Privacy command

| priv command | | |
|---|---|---|
| Format : | gap priv [operation] (IRK) [priv_mode]<br>gap priv [operation] [addr] [addr_type]<br>gap priv [operation] | |
| | Operate the local device's privacy. | |
| Parameters : | [operation] | Select one of the followings as the operation of privacy.<br>set : Register the IRK of the local device in the resolving list and turn on the address generation function. It is used when the local device uses RPA in the advertising command and connection command.<br>remove : Delete the remote device registered in the resolving list. |
| | {params, …} | [operation] : set<br>(IRK) : The local device's IRK which is registered in the resolving list.<br>If this parameter is omitted, the IRK is generated with the random generation function.<br>[priv_mode] : Privacy mode and the address type of local device. Select one of the followings.<br>net : network privacy mode.<br>Static address is used as identity address.<br>dev : device privacy mode.<br>Static address is used as identity address.<br>[operation] : remove<br>[addr] : Specify the address (6 bytes) of the remote device registered in the Resolving list.<br>[addr_type] : Specify the address type of the remote device registered in the Resolving list. |
| Example : | gap priv set 000102030405060708090a0b0c0d0e0f dev<br>Register IRK : 0x0f0e0d0c0b0a09080706050403020100 and set the privacy mode to "device privacy mode". Static address is used as identity address.<br>gap priv set net<br>IRK is generated by the random number generation . The privacy mode is set to "network privacy mode". Static address is used as identity address.<br>gap priv remove 12:34:56:78:9a:bc pub<br>Delete the 12:34:56:78:9a:bc (public) remote device registered in the resolving list. | |

### (7) Connection config command

| conn_cfg command | | |
|---|---|---|
| Format : | gap conn_cfg [operation] {params, ...}<br>Connection configuration command. | |
| Parameters : | [operation] | Type of connection configuration. Select one of the followings.<br>update : Connection parameter update.<br>phy : Set PHY.<br>def_phy : Set default phy.<br>data_len : Set data packet length or data transmit time. |
| | {params, ...} | [operation] : update<br>Parameter1 : Connection handle.<br>Parameter2 : Connection interval. Time(ms) = Parameter2 x 1.25.<br>Valid range is 0x0006-0x0C80.<br>Parameter3 : Slave latency. Valid range is 0x0000-0x01F3.<br>Parameter4 : Supervision timeout. Time(ms) = Parameter4 x 10.<br>Valid range is 0x000A-0x0C80.<br>Input Parameter2-4 to meet the following condition.<br>Parameter4 x 10 >= (1 + Parameter3) x Parameter2 x 1.25<br>[operation] : phy<br>Parameter1 : Connection handle<br>Parameter2 : Transmitter PHY. Parameter2 is set to a bitwise OR of the following values.<br>bit0 : 1M PHY<br>bit1 : 2M PHY<br>bit2 : Coded PHY<br>Parameter3 : Receiver PHY. Parameter3 is set to a bitwise OR of the following values.<br>bit0 : 1M PHY<br>bit1 : 2M PHY<br>bit2 : Coded PHY<br>Parameter4 : Coding scheme of Coded PHY. Select one of the following.<br>0x00 : The controller's preferred value.<br>0x01 : S=2 Coding scheme.<br>0x02 : S=8 Coding scheme.<br>[operation] : def_phy<br>Parameter1 : Transmitter PHY preferences which a remote device may change.<br>Parameter1 is set to a bitwise OR of the following values.<br>bit0 : 1M PHY<br>bit1 : 2M PHY<br>bit2 : Coded PHY<br>Parameter2 : Receiver PHY preferences which a remote device may change.<br>Parameter2 is set to a bitwise OR of the following values.<br>bit0 : 1M PHY<br>bit1 : 2M PHY<br>bit2 : Coded PHY<br>[operation] : data_len<br>Parameter1 : Connection handle<br>Parameter2 : Maximum transmit packet data length (in bytes).<br>Valid range is 0x001B-0x00FB.<br>Parameter3 : Maximum transmit time (us). Valid range is 0x0148-0x4290. |

| | |
|---|---|
| Example : | gap conn_cfg update 0x0026 0x0100 0 0x0100<br>Change the connection parameters of the connection handle : 0x0026 to the following values.<br><br>connection interval : 0x0100<br>slave latency : 0<br>supervision timeout : 0x0100<br><br>gap conn_cfg phy 0x0026 2 2 0<br>Change the PHY of the connection (connection handle : 0x0026)<br>Transmitter PHY : 2M<br>Receiver PHY : 2M<br><br>gap conn_cfg def_phy 7 7<br>Accept the following change request.<br>Transmitter PHY : 1M, 2M and Coded PHY.<br>Receiver PHY : 1M, 2M and Coded PHY.<br><br>gap conn_cfg data_len 0x0026 0x00FB 0x4290<br>Change the following transmit packet length or transmit time<br>Max transmit packet length : 251 bytes<br>Max transmit time : 0x4290 us |

### (8) White List command

| wl command | | |
|---|---|---|
| Format : | gap wl [operation] {params, ...} | |
| | White List operation command. | |
| Parameters : | [operation] | White List operation. Select one of the followings.<br>reg : Register a device specified with the {params, ...} on the White List.<br>del : Delete the device specified with the {params, ...} on the White List.<br>clear : Clear the White List. |
| | {params, ...} | [operation] : reg<br>Parameter1 : Address of a device to be registered on the White List.<br>Parameter2 : Address type of a device to be registered on the White List.<br>pub : Public Address<br>rnd : Random Address<br>[operation] : del<br>Parameter1 : Address of a device to be deleted on the White List.<br>Parameter2 : Address type of a device to be deleted on the White List.<br>pub : Public Address<br>rnd : Random Address<br>[operation] : clear<br>Not used. |
| Example : | gap wl reg 74:90:50:00:95:a8 pub<br>Register the device whose public address is 74:90:50:00:95:a8 on the White List.<br>gap wl del 74:90:50:00:95:a8 pub<br>Delete the device whose public address is 74:90:50:00:95:a8 on the White List.<br>gap wl clear<br>Clear the White List. | |

### (9) Authentication command

| auth command | | |
|---|---|---|
| Format : | gap auth [operation] {params, ...} | |
| | Pairing or encryption command. | |
| Parameters : | [operation] | Security operation.<br>start : Start pairing or encryption.<br>passkey : Input 6-digit number(decimal) to be required in passkey entry pairing.<br>numcmp : Return the result of a numeric comparison.<br>del : Delete the pairing keys. |
| | {params,...} | [operation] : start<br>Parameter1 : Connection handle identifying the connection which local device starts pairing or encryption.<br>[operation] : passkey<br>Parameter1 : 6 digit passkey (decimal)<br>[operation] : numcmp<br>Parameter1 : Result of a numeric comparison.("yes" or "no")<br>Return "yes" if both devices display same number, otherwise "no".<br>[operation] : del<br>Parameter1 : Type of key to be deleted.<br>local : keys which local device distributes.<br>remote : keys distributed from the remote devices.<br>all : the above two types of keys.<br>Parameter2: Type of the remote device key deletion.<br>addr : Delete the keys specified by the Parameter3, 4.<br>all : Delete all the keys distributed from remote devices.<br>Parameter3 : Address of the remote device whose keys to be deleted.<br>Parameter4 : Address type of the remote device whose keys to be deleted.<br>pub : Public Address<br>rnd : Random Address |

| | |
|---|---|
| Example : | gap auth start 0x0026<br>Start pairing or encryption with the connection (connection handle : 0x0026).<br>gap auth passkey 123456<br>Input "123456" as a passkey.<br>gap auth numcmp yes<br>Return "yes" as a result of numeric comparison.<br>gap auth del remote all<br>Delete all the keys distributed from the remote devices. |

### (10) Synchronization command

| sync command | | |
|---|---|---|
| Format : | gap sync [operation] {params...} | |
| | Create or Terminate a periodic sync. | |
| Parameters : | [operation] | Periodic sync operation.<br>create : Create a periodic sync with the device whose address is specified by the {params...}. Scanning runs until a periodic sync is established.<br>In case of stopping creating periodic sync, input [ctrl] + [c].<br>term : Terminate the periodic sync whose sync_hdl is specified by the {params...}. |
| | {params,...} | [operation] : create<br>Parameter1 : Address of the advertiser.<br>Parameter2 : Address type of the advertiser.<br>[operation] : term<br>Parameter1 : Sync handle identifying the periodic sync to be terminated.<br>If no parameters are given, all the established periodic syncs are terminated. |
| Example : | gap sync create 74:90:50:00:95:a8 pub<br>Establish a periodic sync with the advertiser whose public address is 74:90:50:00:95:a8.<br>gap sync term 0x01<br>Terminate the periodic sync (sync handle : 0x01). | |

### (11) Version command

| ver command | |
|---|---|
| Format : | gap ver<br>Get the following BLE Protocol Stack version information.<br>- Link Layer<br>- HCI<br>- Host Stack<br>- Manufacturer ID |
| Parameters : | None |
| Example : | gap ver<br>Get the version information.<br><br>Result sample :<br>Link Layer / HCI Version<br>HCI version : 0x09 [*1]<br>HCI revision : 0x000b<br>Link Layer version : 0x09 [*1]<br>Link Layer subversion : 0x1908<br>Manufacturer ID : 0x0036<br>Host stack Version<br>major version : 0x0d<br>minor version : 0x19<br>subminor version : 0x08 |

*1 : The version number defined by Bluetooth SIG. The version number 0x09 shows Bluetooth 5.0 .

### 4.6.2 Vendor Specific (VS) command

#### (1) Tx Power command

| txp command | | |
|---|---|---|
| Format : | vs txp [operation] [conn_hdl] {params,...} | |
| | Set / Get the transmit power. | |
| Parameters : | [operation] | Transmit power operation.<br>set : Set the transmit power.<br>get : Get the transmit power. |
| | [conn_hdl] | Connection handle identifying the connection whose transmit power to be set or retrieved.<br>Inputting 0xFFFF sets / gets the transmit power in the non-connected state. |
| | {params,...} | [operation] : set<br>Parameter1 : Tx power level to be set.<br>0 : High<br>1 : Middle<br>2 : Low<br>[operation] : get<br>Not used. |
| Example : | vs txp set 0xFFFF 0<br>Set the non-connected state transmit power to the High level.<br>vs txp get 0x0026<br>Get the transmit power of the connection (connection handle : 0x0026). | |

#### (2) Coded Scheme command

| scheme command | | |
|---|---|---|
| Format : | vs scheme [type] | |
| | Set the coding scheme of the Coded PHY. | |
| Parameters : | [type] | Coding scheme for Primary advertising PHY, Secondary advertising PHY, request for connection establishment. This parameter is set to a bitwise OR of the following values.<br>By default, S=8 coding scheme is enabled.<br>bit0 : Coding scheme for Primary Advertising PHY(0:S=8/1:S=2).<br>bit1 : Coding scheme for Secondary Advertising PHY(0:S=8/1:S=2).<br>bit2 : Coding scheme for Connection(0:S=8/1:S=2). |
| Example : | vs scheme 7<br>Set coding scheme for Primacy Advertising, for Secondary Advertising, and for Connection to S=2. | |

### (3) Extended Direct Test Mode(DTM) command

| test command | | |
|---|---|---|
| Format : | vs test [operation] {params, ...} | |
| | DTM test command. | |
| Parameters : | [operation] | DTM test operation. Select one of the followings.<br>tx : Start DTM transmitter test.<br>Set "channel", "length", "payload", "phy", "tx_power", "option" and "number of packet" to {params, ..,}.<br>rx : Start DTM receiver test.<br>Set "channel" and "phy" to {params, ...}.<br>end : Terminate DTM test.<br>No parameter. |
| | {params, ...} | [operation] : tx<br>Parameter1 : Channel used in Tx test.<br>Valid range is 0 to 39.<br>Frequency range is 2402 MHz to 2480 MHz.<br>Parameter2 : Length(in bytes) of the packet used in Tx Test.<br>Valid range is 0 to 255.<br>Parameter3 : Packet Payload.<br>Valid range is 0x00-0x07.<br>If the Parameter6 is set to "non-modulation", this parameter is ignored.<br>Payload type:<br>0x00 : PRBS9 sequence '11111111100000111101..'.<br>0x01 : Repeated '11110000'<br>0x02 : Repeated '10101010'<br>0x03 : PRBS15 sequence<br>0x04 : Repeated '11111111'<br>0x05 : Repeated '00000000'<br>0x06 : Repeated '00001111'<br>0x07 : Repeated '01010101'<br>Parameter4 : Transmitter PHY used in test. Select one of the following.<br>If the Parameter6 is set to "non-modulation", this parameter is ignored.<br>If the Parameter6 is configured to "modulation" and "continuous transmission",<br>0x03 : Coded PHY (S=8) and 0x04 : Coded PHY (S=2) are not supported.<br>0x01 : 1M PHY<br>0x02 : 2M PHY<br>0x03 : Coded PHY (S=8)<br>0x04 : Coded PHY (S=2) |

| | | |
|---|---|---|
| Parameters : | {params, ...} | Parameter5 : Tx Power Level used in DTM Tx Test.<br>Select one of the following.<br>0x00 : High<br>0x01 : Middle<br>0x02 : Low<br>Parameter6 : The test option configuration.<br>This parameter is set to a bitwise OR of the following bits.<br>bit0 : 0:modulation, 1:non-modulation<br>bit1 : 0:packet transmission, 1:continuous transmission<br>Parameter7 : The number of packets to be sent. Valid range is 0x0000-0xFFFF.<br>If the Parameter6 is configured to "continuous transmission", this parameter is ignored. If this parameter is set to 0x0000, the packets are continuously transmitted until test end command is issued.<br>[operation] : rx<br>Parameter1 : Channel used in the test.<br>Valid range is 0 to 39.<br>Frequency range is 2402 MHz to 2480 MHz.<br>Parameter2 : Receiver PHY used in the test. Select one of the following.<br>0x01 : 1M PHY<br>0x02 : 2M PHY<br>0x03 : Coded PHY<br>The coding scheme (S=8/S=2) doesn't need to be specified in the receiver test.<br>[operation] : end<br>Not used. |
| Example : | vs test tx 39 251 1 3 1 0 1<br>Start DTM transmitter test.<br>CH : 39ch<br>Packet length : 251 bytes<br>payload : Repeated '11110000' sequence<br>phy : Coded PHY(S=8)<br>tx_power : Middle<br>option : modulation packet transmission<br>num_of_packet : 1<br>vs test rx 39 2<br>Start DTM receiver test.<br>CH : 39ch<br>phy : 2M PHY<br>vs test end<br>Terminate DTM test. | |

### (4) BD Address command

| addr command | | |
|---|---|---|
| Format : | vs addr [operation] [area] {params...}<br>Set/Get the address of the local device. | |
| Parameters : | [operation] | Address operation. Select one of the followings.<br>set : Set an address to the local device.<br>Set address type and address to {params...} .<br>If [area] is "df", the address is enabled after reset.<br>get : Get the address of the local device.<br>Set the address type to {params...}. |
| | [area] | The area where the address is stored.<br>curr : The temporary area storing the address.<br>df : The area storing the address in the Data Flash. |
| | {params...} | [operation] : set<br>Parameter1 : Address type<br>pub : Public Address<br>rnd : Random Address<br>Parameter2 : Address<br>[operation] : get<br>Parameter1 : Address type<br>pub : Public Address<br>rnd : Random Address |
| Example : | vs addr set df pub 78:90:50:00:95:a8<br>Set the public address : 78:90:50:00:95:a8 to the Data Flash.<br>vs addr get curr pub<br>Get the current public address. | |

### (5) Random Number generation command

| rand command | | |
|---|---|---|
| Format : | vs rand [rand_size] | |
| | Generate a random number. | |
| Parameters : | [rand_size] | Specify the size of the random number to be generated.<br>Range: 4 to 16 [bytes]. |
| Example : | vs rand 16<br>Generate a 16 bytes random number. | |

### (6) Scan Channel command

| scan_ch_map command | | |
|---|---|---|
| Format : | vs scan_ch_map [operation] {params,...} | |
| | Set/Get the scan channel map. | |
| Parameter : | [operation] | Scan Channel operation. Select one of the followings.<br>set : Set the channel map specified by {params,...} as scan channel.<br>get : Get the current scan channel map. |
| | {params,...} | [operation] : set<br>Parameter 1 : The channel map to be set.<br>It is a bitwise OR of the following values.<br>bit 0 : 37 ch<br>bit 1 : 38 ch<br>bit 2 : 39 ch<br>other than the above : reserved<br>[operation] : get<br>“Get” operation does not use parameter. |
| Example : | vs scan_ch_map set 7<br>Set 37, 38, 39ch as scan channel.<br>vs scan_ch_map get<br>Get the current scan channel map. | |

### 4.6.3 SYS command

#### (1) MCU Software Standby command

| stby command | | |
|---|---|---|
| Format : | sys stby [operation] | |
| | Control the software standby mode. | |
| Parameters : | [operation] | Software standby operation. Select one of the followings.<br>on : Enter the software standby mode.<br>off : Come back from the software standby mode.<br>get : Get the current software standby status. |
| Example : | sys stby on<br>Enter the software standby mode. | |

### 4.6.4 BLE command

#### (1) BLE protocol stack Reset command

| stby command | |
|---|---|
| Format : | ble reset |
| | Reset the BLE protocol stack. |
| Parameters : | None |
| Example : | ble reset |

#### (2) BLE protocol stack Close command

| stby command | |
|---|---|
| Format : | ble close |
| | Terminate the BLE protocol stack.<br>To restart the BLE protocol stack, execute “ble reset” command. |
| Parameters : | None |
| Example : | ble close |

### 4.6.5 LSC command

#### (1) Set switch state notification command

| set_switch_state_ntf command | | |
|---|---|---|
| Format : | lsc set_switch_state_ntf [conn_hdl] [enable] | |
| | Enable receiving notification from GATT server. | |
| Parameters : | [conn_hdl] | Connection handle identifying the connection whose receive notification from GATT server. |
| | [enable] | Designate if receiving notification is enable.<br>0 : Disable<br>1 : Enable |
| Example : | lsc set_switch_state_enable 0x0020 1<br>Enable receiving notification from GATT server of 0x0020 | |

#### (2) Write led blink rate command

| write_led_blink_rate command | | |
|---|---|---|
| Format : | lsc write_led_blink_rate [conn_hdl] [blink rate] | |
| | Write value of LED blink rate of GATT server. | |
| Parameters : | [conn_hdl] | Connection handle identifying the connection with GATT server which is written its LED blink rate. |
| | [blink rate] | Designate LED blink rate<br>0x00 : LED turns off<br>0x01 – 0xFE : LED blinks in the frequency based on this value<br>0xFF : LED turns on |
| Example : | lsc write_led_blink_rate 0x0020 0xA0<br>Write 0xA0 as value of LED blink rate of GATT server of 0x0020 | |

#### (3) Read led blink rate command

| read_led_blink_rate command | | |
|---|---|---|
| Format : | lsc read_led_blink_rate [conn_hdl] [blink rate] | |
| | Read value of LED blink rate of GATT server written. | |
| Parameters : | [conn_hdl] | Connection handle identifying the connection with GATT server which is read its LED blink rate. |
| Example : | lsc read_led_blink_rate 0x0020<br>Read value of LED blink rate of GATT server of 0x0020 | |

### 4.6.6 Command creation procedure

In the command line interface feature, user can create their own commands by defining commands in the st_ble_cli_cmd_t type variable. This section describes an example of creating a new command to operate the custom profile LED Switch service Client (hereafter “lsc”) provided in the demo project.

#### (1) Command definition

Defines command name, subcommand group, number of subcommands, and the message string output by “help” command. For “lsc” command, define a command structure variables as following.

```
const st_ble_cli_cmd_t g_lsc_cmd =
{
    .p_name      = "lsc",
    .p_cmds      = lsc_sub_cmds,
    .num_of_cmds = ARRAY_SIZE(lsc_sub_cmds),
    .p_help      = "Sub Command: set_switch_state_ntf, write_led_blink_rate, read_led_blink_rate\n"
                   "Try 'lsc sub-cmd help' for more information",
};
```

**Code 61. Command definition example**

### (2) Subcommand definition

Defines subcommand. For “lsc” command, define a subcommand structure variables as following.

If user wants to create a command such as the "Connection command” or "Scan command” that manually abort the process, user needs to set a abort handler.

During execution of a command for which the abort handler is set, no other command input will be accepted until the command execution is aborted by pressing Ctrl+C key.

```
static const st_ble_cli_cmd_t lsc_set_switch_state_ntf_cmd =
{
    .p_name = "set_switch_state_ntf",
    .exec   = cmd_lsc_set_switch_state_ntf,
    .p_help = "Usage: lsc set_switch_state_ntf conn_hdl value",
};
…………
static const st_ble_cli_cmd_t lsc_read_led_blink_rate_cmd =
{
    .p_name = "read_led_blink_rate",
    .exec   = cmd_lsc_read_led_blink_rate,
    .p_help = "Usage: lsc read_led_blink_rate conn_hdl",
};

…………
static const st_ble_cli_cmd_t lsc_write_led_blink_rate_cmd =
{
    .p_name = "write_led_blink_rate",
    .exec   = cmd_lsc_write_led_blink_rate,
    .p_help = "Usage: lsc write_led_blink_rate conn_hdl blink_rate",
};
…………
static const st_ble_cli_cmd_t * const lsc_sub_cmds[] =
{
    &lsc_set_switch_state_ntf_cmd,
    &lsc_write_led_blink_rate_cmd,
    &lsc_read_led_blink_rate_cmd,
};
```

**Code 62. Subcommand definition example**

### (3) Subcommand function definition

Define the function to be processed when the subcommand is executed.

For “lsc” command, define a subcommand function as following.

```
/*----------------------------------------------------------------
    lsc set_switch_state_ntf command
----------------------------------------------------------------*/
static void cmd_lsc_set_switch_state_ntf(int argc, char *argv[])
{
    if (argc != 3)
    {
        pf("lsc %s: unrecognized operands\n", argv[0]);
                return;
    }

    uint16_t conn_hdl;
    conn_hdl = (uint16_t)strtol(argv[1], NULL, 0);

    long value = strtol(argv[2], NULL, 0);

    ble_status_t ret;
    ret = R_BLE_LSC_WriteSwitchStateCliCnfg(conn_hdl, (uint16_t *)&value);
    if (ret != BLE_SUCCESS)
    {
        pf("lsc %s: failed with 0x%04X\n", argv[0], ret);
                return;
        }
}
```

**Code 63. Subcommand function example**

### (4) Registering commands

After defining the command and subcommand, register the command using *R_BLE_CLI_RegisterCmds()* API as following so that it can be used as an application-specific command.

```
static const st_ble_cli_cmd_t * const gsp_cmds[] =
{
     &g_abs_cmd,
     &g_vs_cmd,
     &g_sys_cmd,
     &g_lsc_cmd,
     &g_ble_cmd
};

…………
void app_main(void)
{

…………
    R_BLE_CLI_Init();
    R_BLE_CLI_RegisterCmds(gsp_cmds, sizeof(gsp_cmds)/sizeof(gsp_cmds[0]));
    R_BLE_CLI_RegisterEventCb(NULL);

…………
}
```

**Code 64. Command register example**

## Revision History

| Rev. | Date | Description | |
|---|---|---|---|
| | | Page | Summary |
| 1.00 | Mar.31.2020 | — | First edition issued. |
| 1.01 | Oct.07.2020 | — | Add Chapter 4.<br>Move “3. BLE Module Detail” to “4. Appendix”.<br>Update attached sample project. |
| 1.02 | Mar.03.2021 | — | In this revision, GATT client demo projects were newly added and this document was also revised with accompanying it.<br>Following items were revised or added in this revision.<br>• Revised “1 Overview”<br>• Revised “2.1 Operating environment”<br>• Revised “2.2 Importing demo project”<br>• Revised “2.4 Demo project behavior”<br>• Revised “3.1 BareMetal environment (Server)”<br>• Revised “3.2 FreeRTOS environment (Server, EventGroup as Synchronization Type case)”<br>• Added “3.5 BareMetal environment (Client)”<br>• Added “3.6 FreeRTOS environment (Client, EventGroup as Synchronization Type case)”<br>• Added “4.5 Importing CLI (Command Line Interface) to user’s project”<br>• Added “4.6 Command List”<br>Following GATT server demo projects were updated.<br>• ble_baremetal_ek_ra4w1<br>• ble_freertos_ek_ra4w1<br>Following GATT client demo projects were newly added.<br>• ble_baremetal_ek_ra4w1_client<br>• ble_freertos_ek_ra4w1_client |
| 1.03 | Aug.31.2021 | — | • Add section 1.3<br>• Add section 2.2 item 4 and 5.<br>• Add explanation about “extended”, “balance” and “compact” configuration in section 4.1.4.<br>• Update attached sample application for FSP3.2. |
| 1.04 | Feb.25.2022 | — | • Add section 3.4, section 3.8.<br>• Add attached sample application for Azure RTOS.<br>• Update attached sample application for FSP3.6. |
| 1.0.5 | Apr.27.2022 | --- | • Update Table 5.<br>• Add section 4.1.5. |
| 1.0.6 | Oct.06.2022 | --- | • Add explanation for task synchronization method for FreeRTOS in section 1.2.<br>• Add section 3.3 and 3.7.<br>• Correction of typo about security data structure in section 4.3.3.<br>• Update attached sample project for FSP4.0. |

| Rev. | Date | Description | |
|---|---|---|---|
| | | **Page** | **Summary** |
| 1.0.7 | Oct.26.2022 | 120 | • Updated how to write device specific data to code flash area by using Renesas Flash Programmer.<br>• Update attached sample project for FSP4.1. |

# 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 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.
5. 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.
6. 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.
7. 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.
8. 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.
9. 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.
10. 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.
11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. 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.4.0-1 November 2017)

## Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

## 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/.

## Trademarks

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

© 2020 Renesas Electronics Corporation. All rights reserved.