Renesas RA Family

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 controls 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)
- RA Flexible Software Package Documentation
- e² studio Getting Started Guide (R20UT4204)
- Tuning procedure of Bluetooth dedicated clock frequency (R01AN4887)
- Bluetooth Low Energy Profile Developer's Guide (R01AN5428)
- EK-RA4W1 Quick Start Guide (R20QS0015)

Contents

1. Overview

The Demo project shown in Table 1 is provided as the sample application using the BLE module.

Table 1. Demo Project

Demo Project	Description
BLE_Baremetal_Peripheral_Example	GATT Server demo application for EK-RA4W1
BLE_FreeRTOS_Peripheral_Example	GATT Server demo application for EK-RA4W1 using FreeRTOS

1.1 BLE Features

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

Bluetooth 5.0 Features

- LE 2M PHY
- LE Coded PHY
- LE Advertising Extensions
- LE Channel Selection Algorithm #2
- High Duty Cycle Non-Connectable Advertising

Bluetooth 4.2 Features

- LE Secure Connections
- Link Layer Privacy
- Link Layer Extended Scanner Filter policies
- LE Data Packet Length Extension

Bluetooth 4.1 Features

- LE L2CAP Connection Oriented Channel Support
- Low Duty Cycle Directed Advertising
- 32-bit UUID Support in LE
- LE Link Layer Topology
- LE Ping

1.2 Software Structure

Figure 1 shows the software structure using the BLE module.

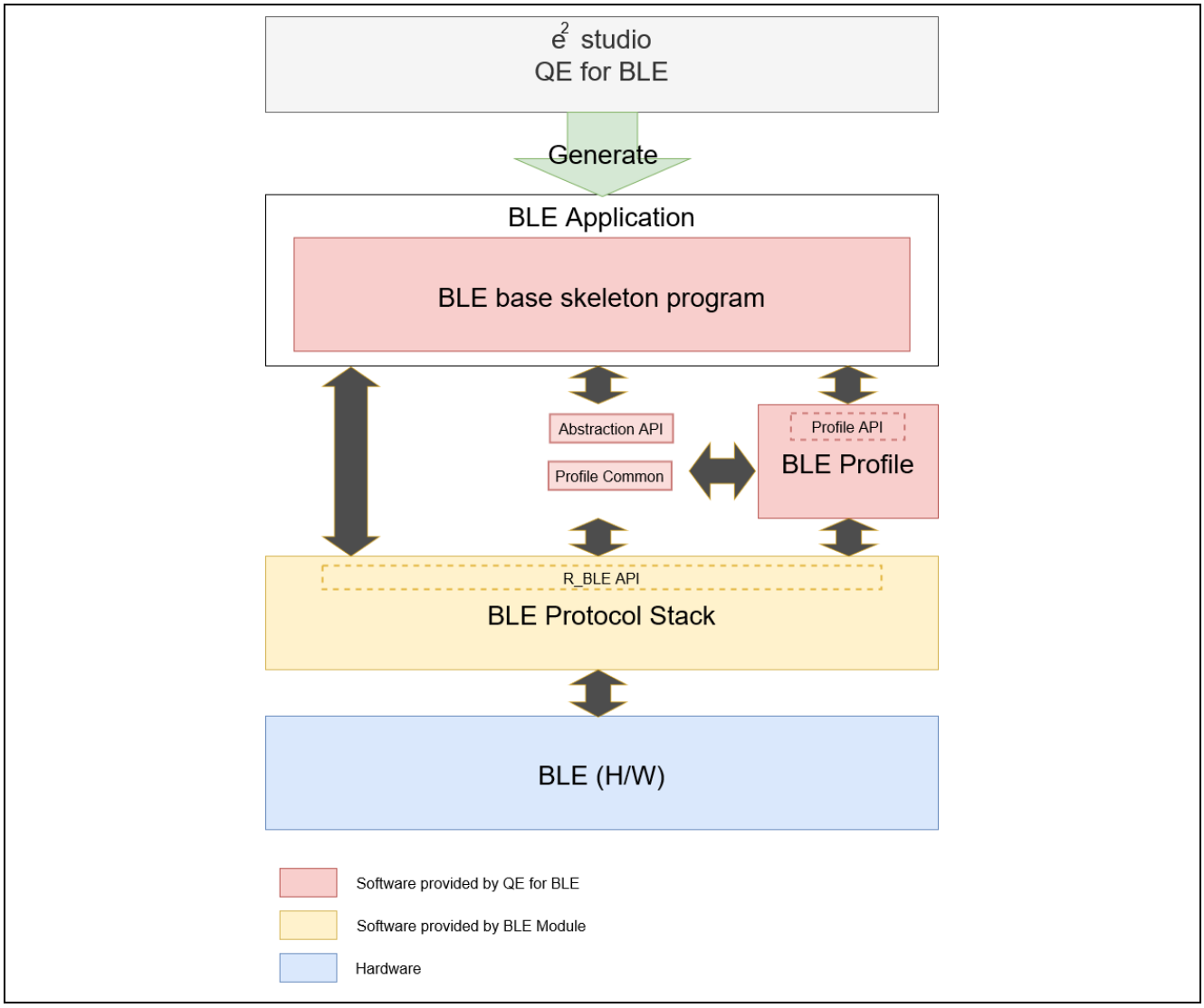

Figure 1. Software Structure

The BLE Application uses the BLE functions via the R_BLE API provided by the BLE Protocol Stack.

The `Abstraction` API and `Profile Common` include auxiliary functions available for the BLE Application. The `Abstraction` API makes it easy to use the frequently used BLE functions.

The QE for BLE generates the source codes (BLE base skeleton program) as a base for the BLE Application and the BLE Profile. Renesas recommends using the QE for BLE for the development of the BLE Application.

1.3 Directory/File Structure

Table 2 shows the directory/file structure of the software operating the BLE module.

Table 2. Directory/File Structure

Directory/File Structure				Description
qe_gen	ble	discovery		Profile common (discovery function)
		profile_cmn		Profile common
		app_main.c		Main code
		gatt_db.c		GATT Database
		gatt_db.h		GATT Database
		r_ble_XXX.c		Profile API
		r_ble_XXX.h		Profile API
ra	fsp	Inc	api	BLE interface file r_ble_api.h rm_ble_abs_api.h
			instances	Abstraction API(GAP) rm_ble_abs.h
		lib	r_ble	BLE Protocol Stack (ALL Features) BLE Protocol Stack (Balance) BLE Protocol Stack (Compact)
		src	rm_ble_abs	Abstraction API(GAP) rm_ble_abs.c
ra_cfg	fsp_cfg		r_ble_cfg.h	Configuration option file
			rm_ble_abs_cfg.h	Configuration option file

2. Sample Application

2.1 Operating Environment

Table 3 shows the hardware requirements for building and debugging BLE software.

Table 3. Hardware Requirements

Hardware	Description
Host PC	Windows® 10 PC with USB interface.
MCU Board	The MCU used must support BLE functions. EK-RA4W1 [RTK7EKA4W1S00000BJ]
On-chip debugging emulators	The EK-RA4W1 has an on-board debugger (J-Link OB), so there is no need to prepare an emulator.
USB cables	Used to connect to the MCU board. EK-RA4W1: 2 USB A-microB cable

Table 4 shows the software requirements for build and debug BLE software.

Table 4. Software Requirements

Software		Version	Description
GCC environment	e² studio	v7.8.0	Integrated development environment (IDE) for Renesas devices.
	GCC ARM Embedded	V9	C/C++ Compiler. (download from e² studio installer)
	Renesas Flexible Software Package (FSP)	v1.1.0	Software package for writing applications for the RA microcontroller series.

Software		Version	Description
	QE for BLE[RA]	v1.0.0	Generates the source codes (BLE base skeleton program) as a base for the BLE Application and the BLE Profile.
	SEGGER J-Flash	v6.70e	Tool for programming the on-chip flash memory of microcontrollers.
Header files			All API calls and their supporting interface definitions are 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 the Demo Project

The sample application provided with this document may be imported into e² studio using the steps in this section.

1. Select **File** → **Import**.

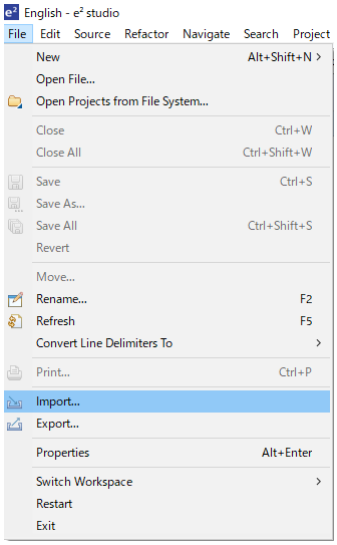

Figure 2. File Menu

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

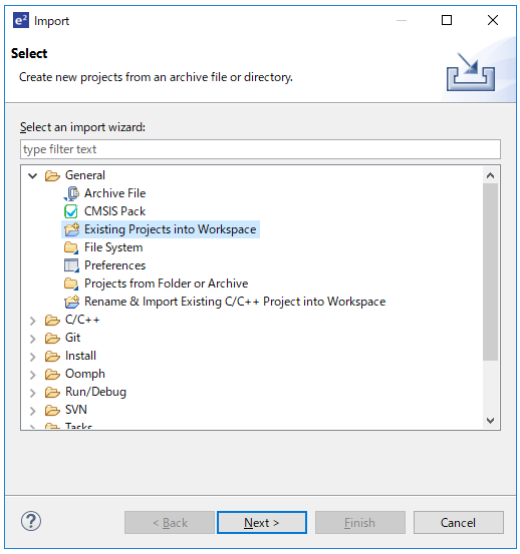

Figure 3. Import Wizard Selection

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

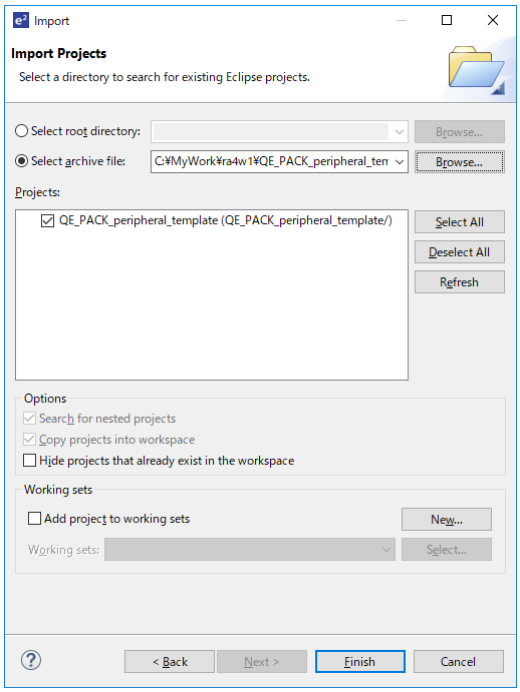

Figure 4. Import Projects

2.3 Building and Debugging

Refer to the "e^2 studio Getting Started Guide (R20UT4204)".

Note: Prior to downloading the demo project to the EK-RA4W1, change ESW1-2 to ON and connect your PC and ECN1 connector with an A – micro B type USB cable.

2.4 GATT Server Demonstration Project Overview

The GATT Server demo works as shown below. Refer to the “EK-RA4W1 Quick Start Guide (R20QS0015)” for the details of the EK-RA4W1 and the GATT Browser.

- After starting, it starts advertising.
- By scanning from a remote device, it is detected by the “RBLE-DEV” or “RBLE” device name.

Figure 5. Scan Result Example

- When connected, it stops advertising.
- The following services and characteristics are visible upon searching GATT services from a remote device.
  - LED Switch Service (LSS, UUID : 58831926-5F05-4267-AB01-B4968E8EFCE0)
  - Switch State Characteristic (UUID : 58837F57-5F05-4267-AB01-B4968E8EFCE0)
  - LED Blink Rate Characteristic (UUID : 5883C32F-5F05-4267-AB01-B4968E8EFCE0)

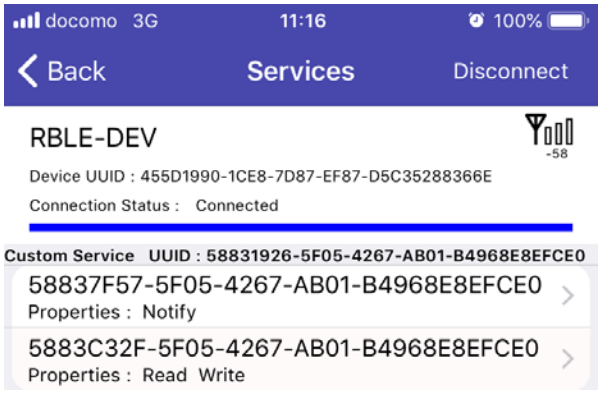

Figure 6. GATT Services

- 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 GATT Server requests pairing to access to the Characteristic in the LED Switch Service. If **0** is set, pairing is not necessary.

```
static const st_ble_gatts_db_serv_cfg_t gs_gatt_service[] =
{

    ...

   /* LED Switch */
    {
        /* Num of Services */
        {
            1,
        },
        /* Description */
        BLE_GATT_DB_SER_SECURITY_UNAUTH,
        /* Service Start Handle */
        0x0010,
        /* Service End Handle */
        0x0015,
        /* Characteristic Start Index */
        6,
        /* Characteristic End Index */
        7,
    },

};
```

Pairing is necessary.

```
static const st_ble_gatts_db_serv_cfg_t gs_gatt_service[] =
{

    ...

   /* LED Switch */
    {
        /* Num of Services */
        {
            1,
        },
        /* Description */
        0,
        /* Service Start Handle */
        0x0010,
        /* Service End Handle */
        0x0015,
        /* Characteristic Start Index */
        6,
        /* Characteristic End Index */
        7,
    },

};
```

Pairing is not necessary.

Figure 7. The security setting of the access to the LED Switch Service

- After enabling the notification in the Switch State characteristic, the notification packet is sent to the remote device by pushing SW1 on the board.
- By writing a number to the LED Blink Rate characteristic, the LED blinks. The LED turns off by writing zero to the characteristic.
- When disconnected, it restarts advertising.

Figure 8 shows usage example for the GATT Server demo project and a remote device.

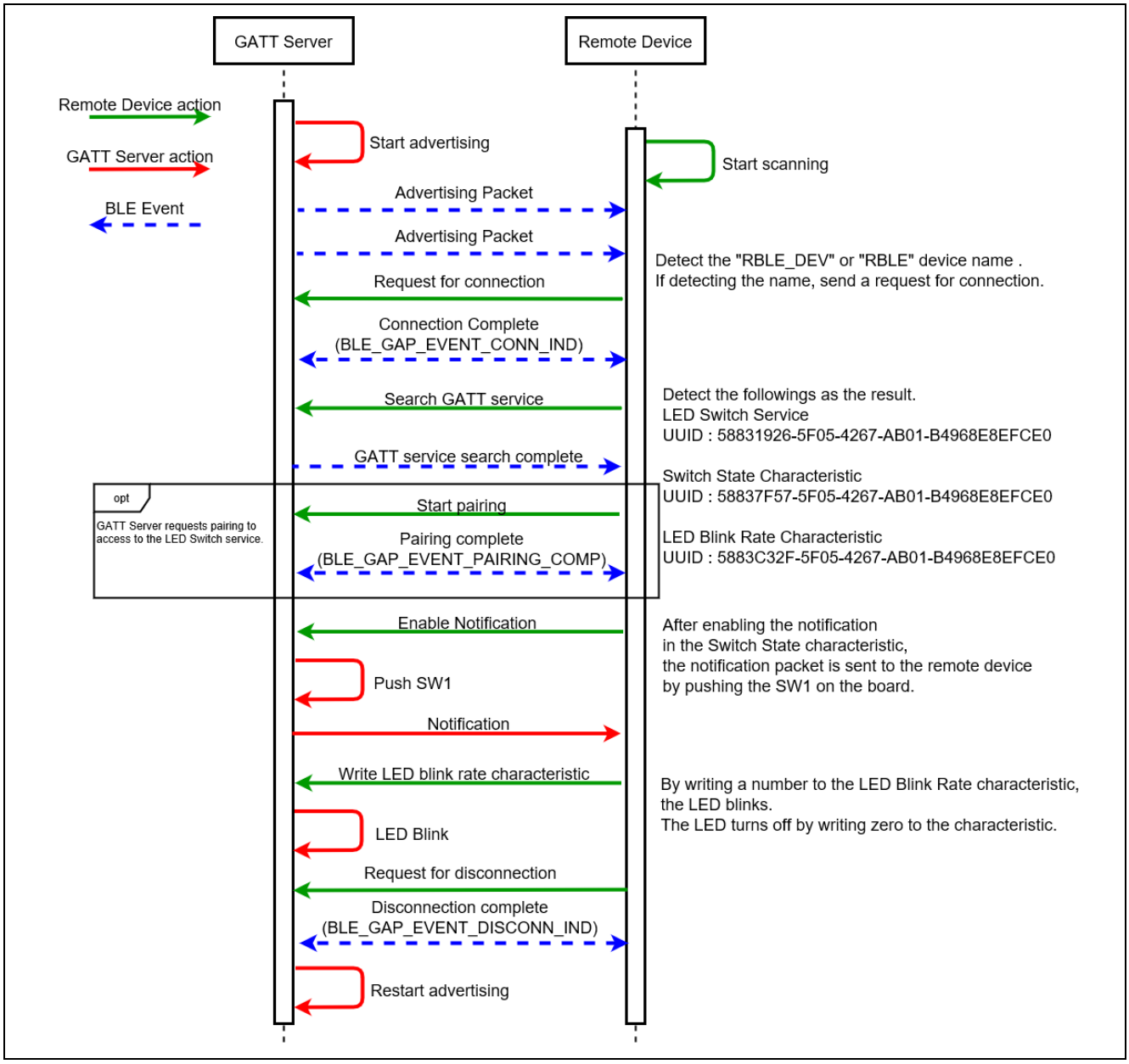

Figure 8. Usage Example for the GATT Server Demo Project and a Remote Device

3. BLE Module Detail

3.1 Configuration Options

The configuration options of the BLE module can be configured using the RA Configurator. The changed options are automatically reflected to the `r_ble_cfg.h` and `rm_ble_abs_cfg.h` when generating code. The option names and setting values are listed in the table shown as follows.

Table 5. Configuration Options

Configuration Options (rm_ble_abs_cfg.h)	
BLE_ABS_CFG_RF_DEBUG_PUBLIC_ADDRESS Default : "{0xFF,0xFF,0xFF,0x50,0x90,0x74}"	Initial Public Address. If the public addresses in the Code Flash and the Data Flash are all 0x00 or 0xFF, the device adopts this public address. If all 0x00 or 0xFF is set, the device uses 74:90:50:FF:FF:FF as public address.
BLE_ABS_CFG_RF_DEBUG_RANDOM_ADDRESS	Initial Static Address. If the static addresses in the Code Flash and the Data Flash are all 0x00 or 0xFF, the device adopts this static

Configuration Options (rm_ble_abs_cfg.h)	
Default : “{0xFF,0xFF,0xFF,0xFF,0xFF,0xFF}"	address. If all 0x00 or 0xFF is set, the device uses the value generated with the device specific value the static address.
BLE_ABS_CFG_RF_CONNECTION_MAXIMUM Default : "7"	Maximum number of simultaneous connections. Range : 1 to 7
BLE_ABS_CFG_RF_CONNECTION_DATA_MAXIMUM Default : "251"	Maximum packet data length (bytes). Range : 27 to 251 Refer to section 3.2, Feature of BLE Protocol Stack for details.
BLE_ABS_CFG_RF_ADVERTISING_DATA_MAXIMUM Default : "1650"	Maximum advertising data length (bytes). Range : 31 to 1650 The maximum advertising data length of the BLE Protocol Stack libraries other than "All features" is fixed to 31bytes. Refer to section 3.2, Feature of BLE Protocol Stack for details.
BLE_ABS_CFG_RF_ADVERTISING_SET_MAXIMUM Default : "4"	Maximum number of the advertising set. Range : 1 to 4 The number of the advertising set of the BLE Protocol Stack libraries other than "All features" is fixed to one. Refer to section 3.2, Feature of BLE Protocol Stack for details.
BLE_ABS_CFG_RF_SYNC_SET_MAXIMUM Default : "2"	Maximum number of periodic sync set. Range : 1 to 2 If the BLE Protocol Stack library is other than "All features", this option is not used.
BLE_ABS_CFG_ENABLE_SECURE_DATA Default : "1"	Enable or disable the security data management. The bonding information is stored in the Data Flash block specified by BLE_ABS_CFG_SECURE_DATA_DATAFLASH_BLOCK by this option. 0: Disable 1: Enable If this option is enabled, add the Data Flash module.
BLE_ABS_CFG_SECURE_DATA_DATAFLASH_BLOCK Default : "0"	The Data Flash block for the security data management to store the bonding information. Range : 0 to 7 Specify a different block from the block specified by BLE_ABS_CFG_DEV_DATA_DF_BLOCK.
BLE_ABS_CFG_NUMBER_BONDING Default : "7"	Maximum number of the bonding information stored in the Data Flash. Range : 1 to 7
BLE_ABS_CFG_EVENT_NOTIFY_CONNECTION_START Default : "0"	Enable or disable start interrupt notification of a connection complete event. 0: Disable 1: Enable Because the start notification is triggered by the interrupt, it occurs after the actual RF event.

Configuration Options (rm_ble_abs_cfg.h)	
BLE_ABS_CFG_EVENT_NOTIFY_CONNECTION_CLOSE Default : "0"	Enable or disable end interrupt notification of a connection complete event. 0: Disable 1: Enable
BLE_ABS_CFG_EVENT_NOTIFY_ADVERTISING_START Default : "0"	Enable or disable the advertising event start interrupt notification. 0: Disable 1: Enable The notification occurs at the following timings. - Start Primary Advertising channel. - Start Secondary Advertising Channel - Start Periodic Advertising. (When the Extended Advertising is enabled.) Because the start notification is triggered by the interrupt, it occurs after the actual RF event.
BLE_ABS_CFG_EVENT_NOTIFY_ADVERTISING_CLOSE Default : "0"	Enable or disable the advertising event complete interrupt notification. 0: Disable 1: Enable The notification occurs at the following timings: - Complete Primary Advertising channel. - Complete Secondary Advertising Channel - Complete Periodic Advertising (When the Extended Advertising is enabled) Because the start notification is triggered by the interrupt, it occurs after the actual RF event. If the advertising is terminated by a command, the notification does not occur.
BLE_ABS_CFG_EVENT_NOTIFY_SCANNING_START Default : "0"	Enable or disable the scan start interrupt notification. 0: Disable 1: Enable If the scan interval is equal to the scan window, this notification does not occur. Because the start notification is triggered by the interrupt, it occurs after the actual RF event.
BLE_ABS_CFG_EVENT_NOTIFY_SCANNING_CLOSE Default : "0"	Enable or disable the scan complete interrupt notification 0: Disable 1: Enable If the scan interval is equal to the scan window, this notification does not occur. If the scan is terminated by a command, the notification does not occur.

Configuration Options (rm_ble_abs_cfg.h)	
BLE_ABS_CFG_EVENT_NOTIFY_INITIATING_START Default : "0"	Enable or disable the notification that the scan start interrupt has occurred in sending a connection request. 0: Disable 1: Enable If the scan interval is equal to the scan window, this notification does not occur. Because the start notification is triggered by the interrupt, it occurs after the actual RF event.
BLE_ABS_CFG_EVENT_NOTIFY_INITIATING_CLOSE Default : "0"	Enable or disable the notification that the scan complete interrupt has occurred in sending a connection request. 0: Disable 1: Enable If the scan interval is equal to the scan window, this notification does not occur. If the connection request is terminated by a command, the notification does not occur.
BLE_ABS_CFG_EVENT_NOTIFY_DEEP_SLEEP_START Default : "0"	Enable or disable the RF_DEEP_SLEEP start notification. 0: Disable 1: Enable
BLE_ABS_CFG_EVENT_NOTIFY_DEEP_SLEEP_WAKEUP Default : "0"	Enable or disable the RF_DEEP_SLEEP wakeup notification. 0: Disable 1: Enable
BLE_ABS_CFG_RF_CLVAL Default : "6"	Adjustment value of the 32MHz crystal oscillator. Set this option according to the board environment. Range : 0 to 15 Refer to "Tuning procedure of Bluetooth dedicated clock frequency(R01AN4887)" for details.
BLE_ABS_CFG_RF_DCDC_CONVERTER_ENABLE Default : "0"	Enable or disable the DC-DC on the RF. 0: Disable 1: Enable
BLE_ABS_CFG_RF_EXT32K_EN Default : "0"	Slow clock source to the RF. Range : 0 to 1 0: RF_LOCO 1: External 32.768kHz If this option is set to 1, the sub clock is required to be enabled in the RA Configurator clock configuration screen.
BLE_ABS_CFG_RF_MCU_CLKOUT_PORT Default : "0	Port of the MCU CLKOUT. Range : 0 to 1 0: P109 1: P205 If the BLE_ABS_CFG_RF_EXT32K_EN option is 0, this option is ignored.

Configuration Options (rm_ble_abs_cfg.h)	
BLE_ABS_CFG_RF_MCU_CLKOUT_FREQ Default : "0"	Output frequency from the MCU CLKOUT. Range : 0 to 1 0: MCU CLKOUT frequency 32.768kHz 1: MCU CLKOUT frequency 16.384kHz If the BLE_CFG_RF_EXT32K_EN option is 0, this option is ignored.
BLE_ABS_CFG_RF_SCA Default : "500"	Sleep Clock Accuracy(SCA) for the RF slow clock. Range : 0 to 500 If the BLE_CFG_RF_EXT32K_EN option is 0, the SCA is fixed to more than 250ppm and this option is ignored.
BLE_ABS_CFG_RF_MAX_TX_POW Default : "1"	Maximum transmit power configuration. Range : 0 to 1 0: max +0dBm 1: max +4dBm
BLE_ABS_CFG_RF_DEF_TX_POW Default : "0"	Default transmit power level. Range : 0 to 2 This option depends on the BLE_ABS_CFG_RF_MAX_TX_POW option. If the BLE_ABS_CFG_RF_MAX_TX_POW option is 0(0dBm), this option is as follows: 0(High) : 0dBm 1(Mid) : 0dBm 2(Low) : -18dBm If the BLE_CFG_RF_MAX_TX_POW option is 1(+4dBm), this option is as follows: 0(High) : +4dBm 1(Mid) : 0dBm 2(Low) : -20dBm
BLE_ABS_CFG_RF_CLKOUT_EN Default : "0"	CLKOUT_RF output. Select one of the followings. 0: No output 5: 4MHz output 6: 2MHz output 7: 1MHz output
BLE_ABS_CFG_RF_DEEP_SLEEP_EN Default : "1"	Enable or disable the RF Deep Sleep. 0: Disable 1: Enable
BLE_ABS_CFG_MCU_MAIN_CLK_KHZ Default : "4000"	MCU main clock frequency (kHz). This option needs to be configured according to the board environment. If the HOCO is used, this option is ignored. If the Main Clock is used, set a value within the range between 1000 and 20000.

Configuration Options (rm_ble_abs_cfg.h)	
	If the PLL Circuit is used, set a value within the range between 4000 and 12500.
BLE_ABS_CFG_DEV_DATA_CF_BLOCK Default : "16"	The Code Flash(ROM) block stored the device specific data. Range : -1 to 255 If this option is set to -1, the device specific data in the Code Flash isn't used. The blocks from "0" to "15" are the Start-Up Program Protection block. If the Start-Up Program Protection is used, do not use the blocks from "0" to "15".
BLE_ABS_CFG_DEV_DATA_DF_BLOCK Default : "7"	The Data Flash block stored the device specific data. Range : -1 to 7 If this option is set to -1, the device specific data in the Data Flash is not used. Specify a different block from the block specified by BLE_ABS_CFG_SECURE_DATA_DATAFLASH_BLOCK.
BLE_ABS_CFG_GATT_MTU_SIZE Default : "247"	The MTU size (bytes) for the GATT communication. Range : 23 to 247
BLE_ABS_CFG_TIMER_NUMBER_OF_SLOT Default : "10"	Maximum number of the timer used by Abstraction API. Range : 1 to 10
BLE_ABS_CFG_PARAMETER_CHECKING_ENABLE Default : "0"	Enable or disable the validity check of the parameters for `Abstraction` API. 0: Disable 1: Enable

3.2 Feature of BLE Protocol Stack

Following are the list of features supported by the BLE protocol stack.

Table 6. List of Features of the BLE Protocol Stack

BLE Features
LE 2M PHY
LE Coded PHY
LE Advertising Extensions
LE Channel Selection Algorithm #2
High Duty Cycle Non-Connectable Advertising
LE Secure Connections
Link Layer privacy
Link Layer Extended Scanner Filter policies
LE Data Packet Length Extension
LE L2CAP Connection Oriented Channel Support
Low Duty Cycle Directed Advertising
LE Link Layer Topology
LE Ping
GAP Role (Central Peripheral Observer Broadcaster)
GATT Role (Sever Client)
32-bit UUID Support in LE

- LE 2M PHY
  Supports BLE communication with 2Msym/s PHY.
- LE Coded PHY
  Supports BLE communication with Coded PHY.
  Communication over a long range than 1M PHY and 2M PHY is possible.
- LE Advertising Extensions
  An extension of Advertising. The features of this function are as follows.
  - Up to 4 independent advertising can be executed simultaneously.
    (Use the configuration option BLE_ABS_CFG_RF_ADVERTISING_SET_MAXIMUM to set the number of Advertising executed simultaneously.)
  - Expansion of Advertising Data / Scan Response Data size up to 1650 bytes.
    (Set the maximum size (bytes) with the configuration option BLE_ABS_CFG_RF_ADVERTISING_DATA_MAXIMUM.)
  - Periodic Advertising is possible.
- LE Channel Selection Algorithm # 2
  This function selects a channel using the algorithm for selecting a hopping channel added in Version 5.0.
- High Duty Cycle Non-Connectable Advertising
  This function supports non-connectable advertising with a minimum interval of 20 msec.
- LE Secure Connections
  Elliptic curve Diffie-Hellman key agreement method (ECDH) supports passive eavesdropping pairing.
- Link Layer privacy
  This function avoids tracking from other BLE devices by changing the BD Address periodically.
- LE Data Packet Length Extension
  This function expands the BLE data communication packet size.
  It can be expanded to 251 bytes.
  (Set the maximum size (bytes) with the configuration option BLE_ABS_CFG_RF_CONNECTION_DATA_MAXIMUM.)
- LE L2CAP Connection Oriented Channel Support
  This function supports communication using the L2CAP credit based flow control channel.
- Low Duty Cycle Directed Advertising
  This function supports low duty cycle advertising for reconnection with known devices.
- LE Link Layer Topology
  This function 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.

- 32-bit UUID Support in LE
  Supports GATT 32-bit UUID.

Table 7 shows R_BLE API support for the BLE Protocol Stack.

Table 7. R_BLE API Support for BLE Protocol Stack

BLE APIs
Common API
GAP API
GATT Common API
GATT Server API
GATT Client API
L2CAP API
Vendor Specific API
MCU Low Power Consumption API

3.2.1 R_BLE API Functions

Refer to “RA Flexible Software Package Documentation” for details.

3.3 Abstraction API

Abstraction API simplifies the procedure used with the BLE Protocol Stack. Refer to “RA Flexible Software Package Documentation” for details.

3.4 Profile Common

This function provides the common interfaces in the BLE Profile. The interfaces are used by the code generated by the QE for BLE. Refer to “Bluetooth Low Energy Profile Developer’s Guide (R01AN5428)” for the details of the profile development and the profile common.

Website and Support

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

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

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Jun.10.20	—	First release document

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

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

1. Precaution against Electrostatic Discharge (ESD)

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

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

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

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

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

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

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

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

Notice

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Corporate Headquarters

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

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