Bluetooth® Low Energy Protocol Stack Introduction

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Renesas Electronics Corporation

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Introduction

This document will help you to understand Bluetooth low energy (BLE) Protocol Stack, before you start an application which works on RL78/G1D. This document introduces following items.

- Overview of BLE Protocol Stack
- Development Environment for BLE Application
- Documents for Developing BLE Application
- Sample Programs and Tools for Developing BLE Application

Note that under-lined and blue word has a link to web page or document.

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Overview of BLE Protocol Stack

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Device for BLE Protocol Stack

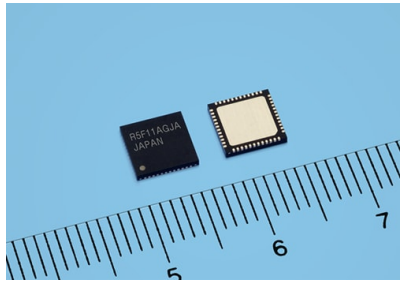
The BLE Protocol Stack **works on RL78/G1D supporting Bluetooth low energy**.

RL78/G1D (Product Info)

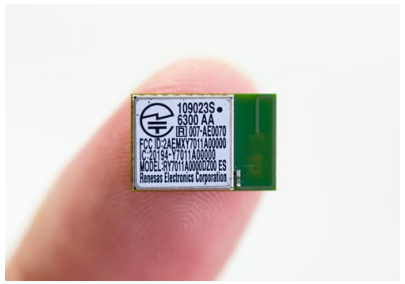
A microcomputer incorporating the RL78 CPU core and RF transceiver supporting the Bluetooth low energy

RL78/G1D Module [RY7011] (Product Info)

A module incorporating the RL78/G1D, a 32MHz crystal resonator for the RF transceiver, and an antenna



RL78/G1D



RL78/G1D Module
(including RL78/G1D)

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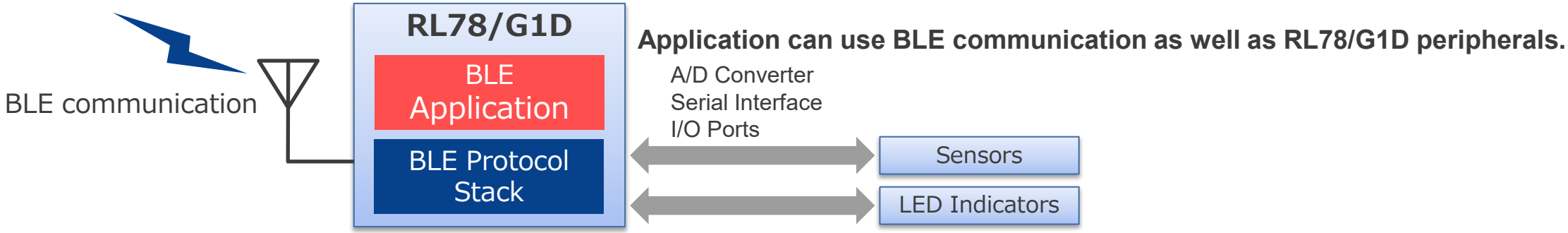
System Configuration of RL78/G1D

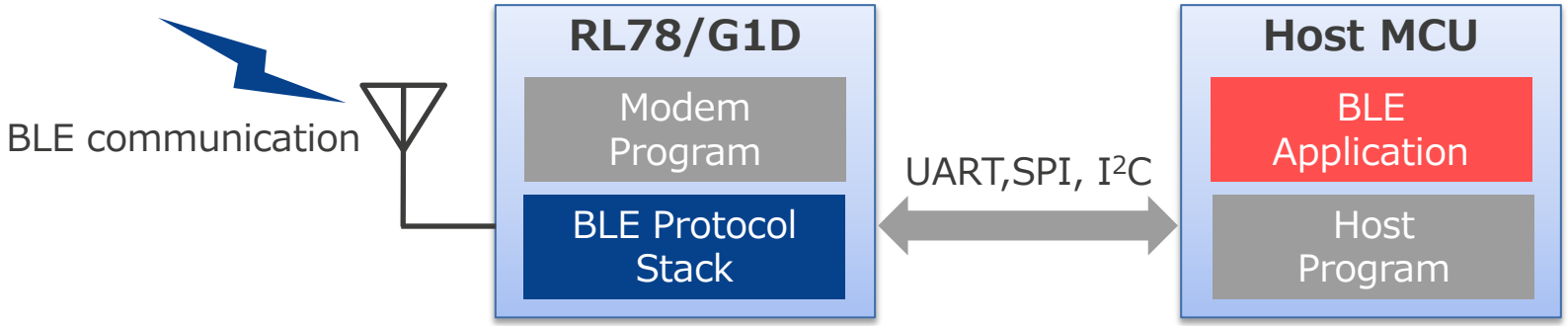
RL78/G1D can make either of the following **two system configurations** by using BLE Protocol Stack.

Embedded Configuration: RL78/G1D only



Application can use BLE communication as well as RL78/G1D peripherals.

Modem Configuration: RL78/G1D and Host MCU which controls BLE communication



Application of Host MCU can use BLE communication functionality.

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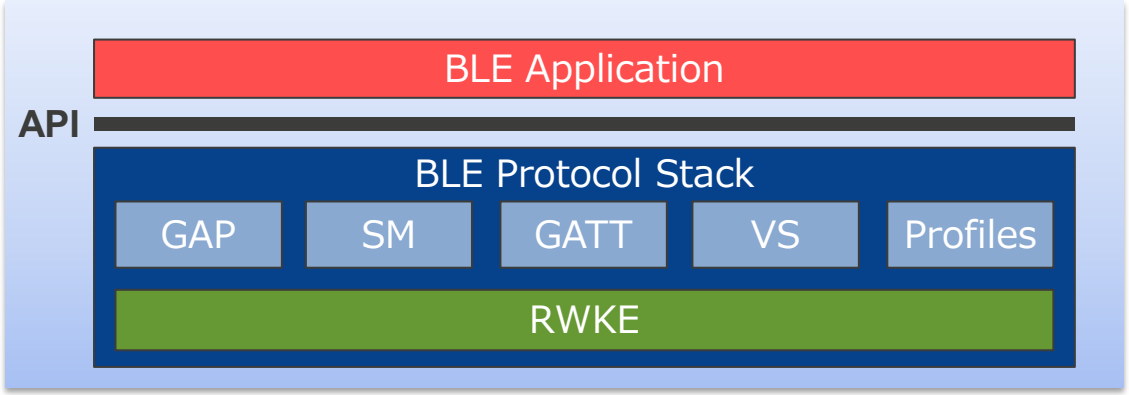
Functionalities of BLE Protocol Stack

The BLE Protocol Stack has the following functionalities.
BLE Application can use the functionalities of the BLE Protocol Stack by accessing API.

- **GAP (Generic Access Profile)**: Device Discovery, Connection Management, and Security
- **SM (Security Manager)**: Pairing, Authentication, and Encryption
- **GATT (Generic Attribute Profile)**: Application Data Communication
- **Profiles**: GATT-based Data Communication specified by Bluetooth SIG
- **VS (Vendor Specific)**: Extended Functionality specified by Renesas
- **RWKE**: simple OS Functionality



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BLE Protocol Stack

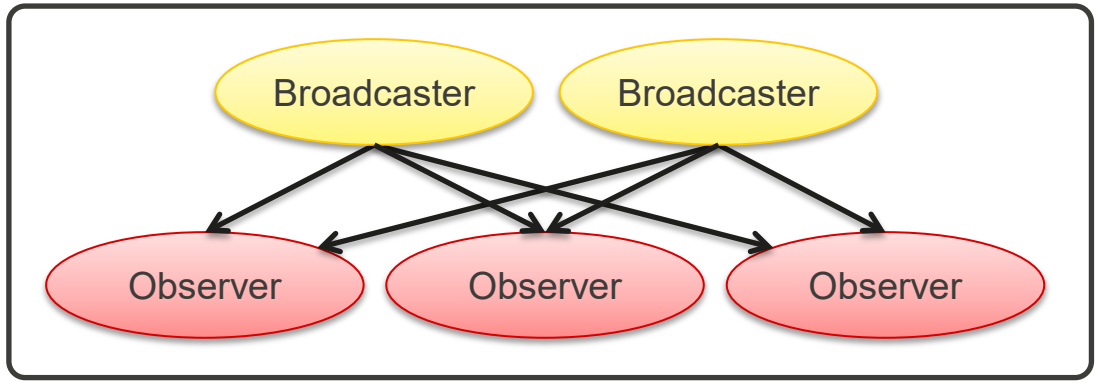
GAP(Generic Access Profile)

BLE Protocol Stack has the functionality of GAP (Generic Access Profile) to execute the follows:

- **Data Broadcast without establishing a connection**
- **Device Discovery in the surrounding area**
- **Establishment and Termination of a connection between peer device**

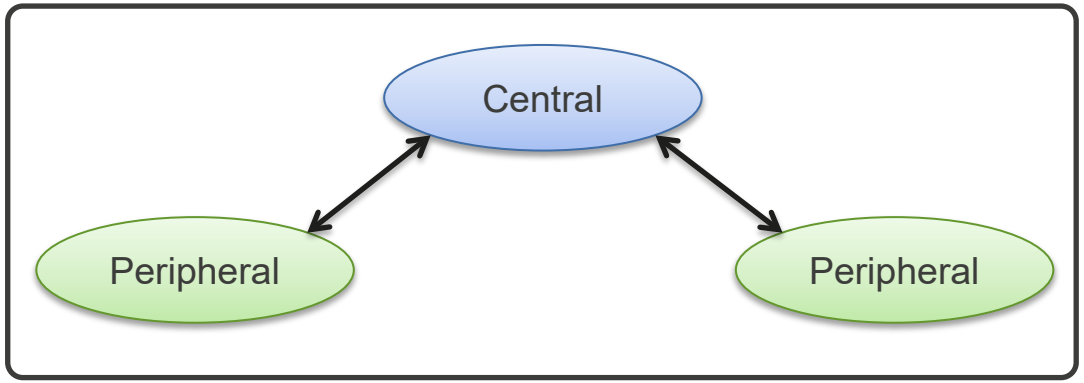
BLE Application can create the following networks.

Data Broadcast without establishing a connection



Broadcaster: transmits data to unspecified Observers
Observer: receives data from unspecified Broadcasters

Device Discovery and Connection



Peripheral: establishes connection to Central
Central: establishes connections to Peripherals (max.8)

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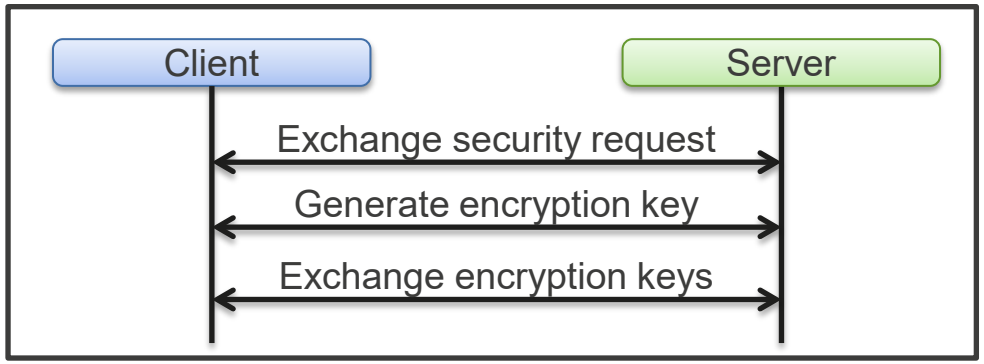
BLE Protocol Stack
SM(Security Manager)

BLE Protocol Stack has the functionality of SM (Security Manager) to execute the follows:

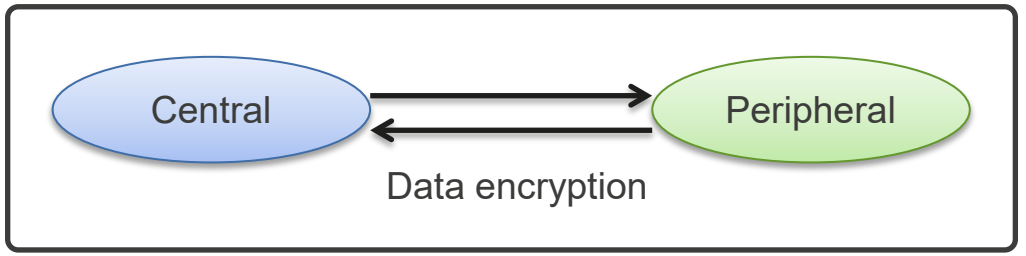
- **Pairing for exchanging encryption keys**
- **Data Encryption, and Random Address Generation and Resolution**

Pairing Sequence after connection



complete

Improve security of communication by data encryption



Pairing: Confirm security requirement and exchange the following encryption keys

- Key to **encrypt data** (LTK)
- Key to **add a signature to data** (CSRK)
- Key to **change address dynamically** (IRK)

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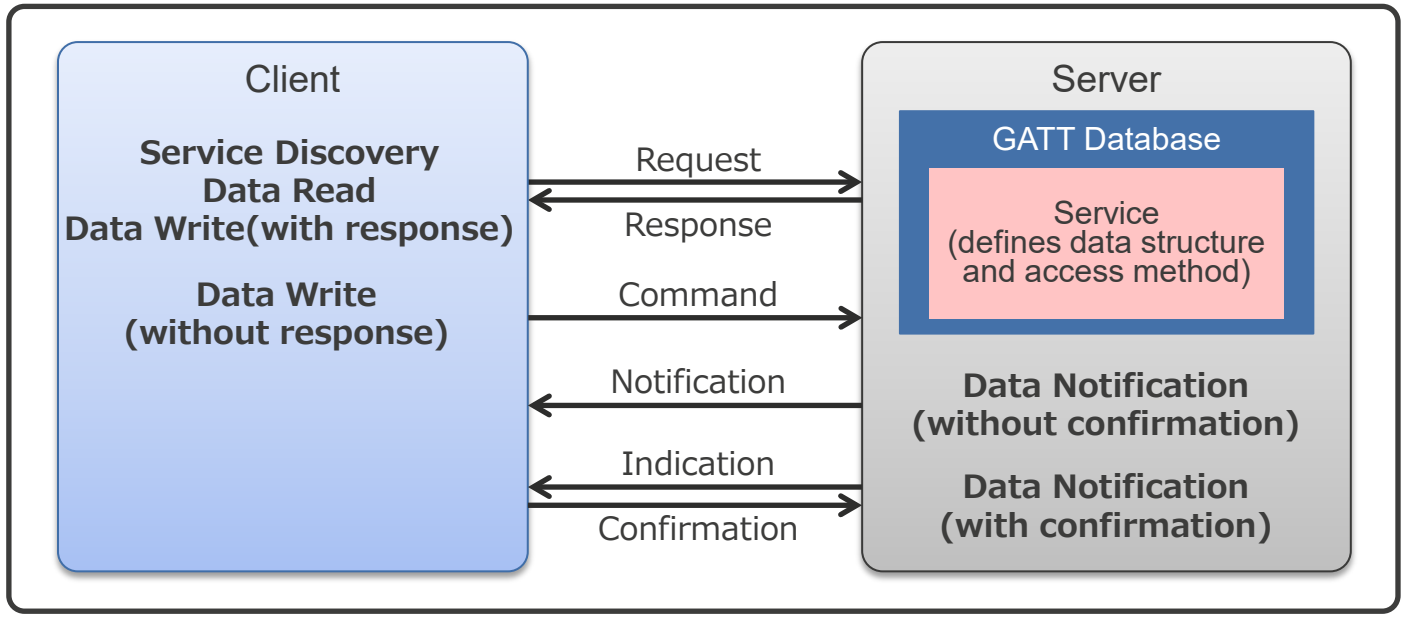
BLE Protocol Stack

GATT(Generic Attribute Profile)

BLE Protocol Stack has the functionality of GATT (Generic Attribute Profile) to **communicate application data** by the following Client / Server Architecture after establishing a connection.

Client / Server Architecture



BLE Application can communicate data in accordance with **the profile specified by user (custom profile)** by using the GATT functionality.

Note that which, of Central or Peripheral performs Client or Server, is different from each use-case.

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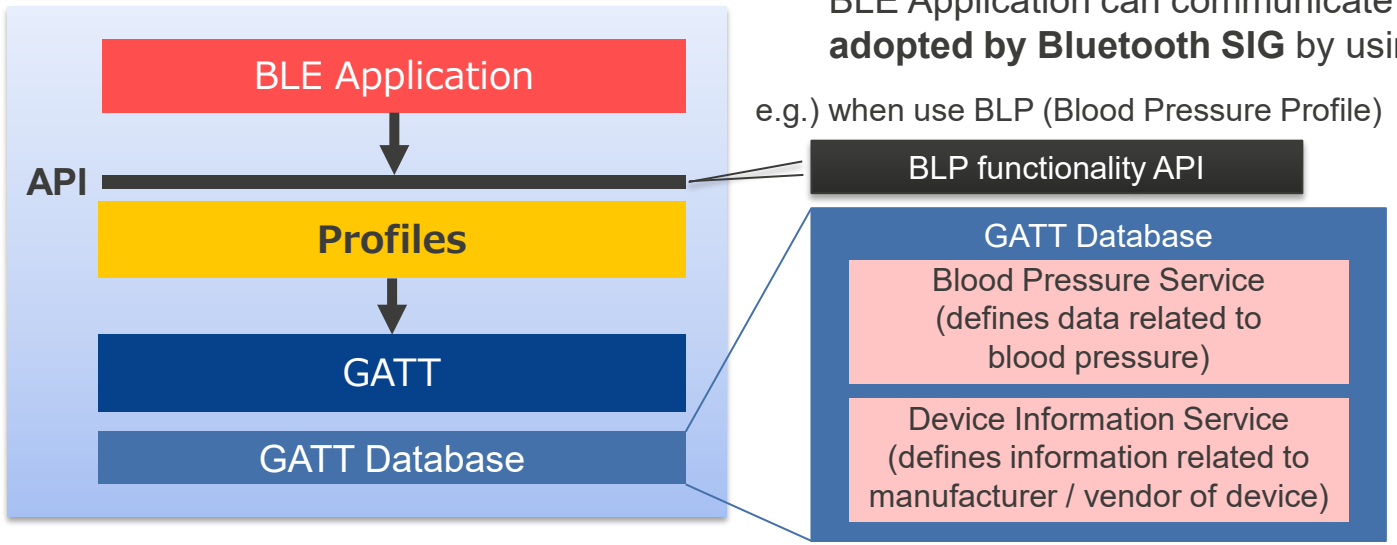
BLE Protocol Stack
Profiles

BLE Protocol Stack has the functionality to **communicate data in accordance with the GATT-based profile adopted by Bluetooth SIG such as the follows .**

BLE Protocol Stack corresponds to multiple profiles:
FMP(Find Me), PXP(Proximity), HTP(Health Thermometer), HRP(Heart Rate), BLP(Blood Pressure), GLP(Glucose), HOGP(HID Over GATT), CPP(Cycling Power), CSCP(Cycling Speed and Cadence), TIP (Time Profile), etc.



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BLE Protocol Stack
VS (Vendor Specific)

The BLE Protocol Stack has the following vendor specific functionalities to control and evaluate RL78/G1D.

- **Peak Current Notification** : notifies start and stop of transmission and reception operation of RF unit
- **Sleep** : switches MCU and RF state to low power consumption mode automatically
- **Bluetooth Device Address Write** : writes device address to data flash memory area
- **Direct Test Mode** : executes RF transmission and reception to evaluate RF characteristic
- **Transmission Power Selection** : changes RF transmission power
- **RF GPIO Port Control** : controls GPIO ports of RF unit
- **Adaptable Mode** : manages RF characteristic dynamically
- **RF Unit Power Control** : changes RF unit power states

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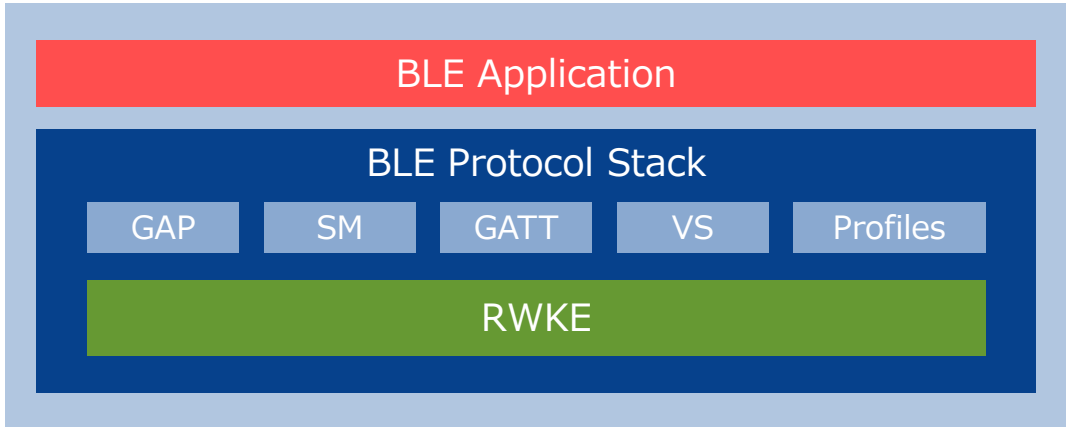
BLE Protocol Stack
RWKE (Simple OS)

The BLE Protocol Stack has a **simple OS functionality to manage BLE application processing**.



RWKE Functionalities

- **Kernel Event Management**: manages execution order of processing associated with an event such as interrupt
- **Message Communication Management**: manages a message to communicate parameter among processing
- **Task State Management** : manages a state of task, and switch processing in accordance with the task state
- **Timer Management** : manages a timer to execute after expiration of time
- **Memory Management** : allocates memory dynamically from heap area

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Development Environment for BLE Application

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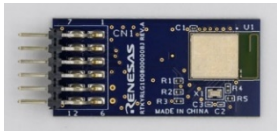
Development Environment (Hardware)

- **RL78/G1D Evaluation Board** [RTK0EN0001D01001BZ]（Product Info）

- **RL78/G1D BLE Module Expansion Board** [RTKYRLG1D0B00000BJ]（Product Info）



- On-chip Debugging Emulator
  - **E2 Emulator Lite** [RTE0T0002LKCE00000R]（Product Info）

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Development Environment (Software)

- **BLE Protocol Stack** (Product Info, Download)
- Flash Libraries
  - **Data Flash Library** (Product Info, Download)
  - **Code Flash Library** (Product Info, Download)
- Either one of IDE and Compiler
  - **CS+**: CC-RL Compiler (recommended) or CA78K0R Compiler (Product Info)
  - **e^{2}studio**: CC-RL Compiler only (Product Info)
  - **IAR Embedded Workbench for Renesas RL78 V2.21.5**: IAR Compiler only (Product Info)
- Flash memory programming software
  - **Renesas Flash Programmer** (Product Info)

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Sample Programs of BLE Protocol Stack

- **Programs for Evaluating Functionalities**
  - ✓ **Console-based Sample Program**: for evaluating BLE Functionalities by controlling through console
  - ✓ **Direct Test Mode Sample Program**: executes Direct Test Mode for evaluating RF characteristic of RL78/G1D
- **Programs for developing BLE Application**
  - ✓ **Modem Configuration Sample Program**: base program for developing Modem configuration BLE Application
  - ✓ **Simple Sample Program**: base program for developing Embedded configuration BLE Application
- **Practical Programs**
  - ✓ **Sample Custom Profile Sample Program**: executes a demonstration by using custom profile
  - ✓ **FW Update Program**: update BLE Application of RL78/G1D by BLE communication

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Documents for Developing BLE Application

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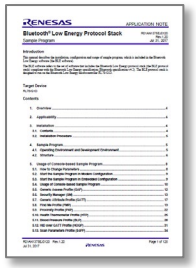
Documents for Developing BLE Application

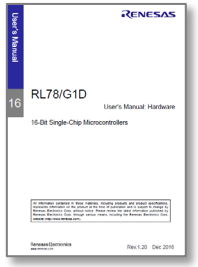
For evaluating BLE Protocol Stack

Quick Start Guide

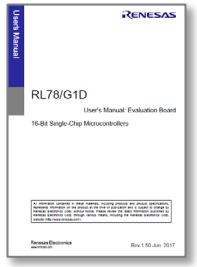


Sample Program Application Note

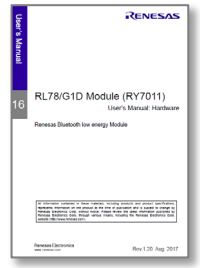
Hardware Specification



RL78/G1D User's Manual

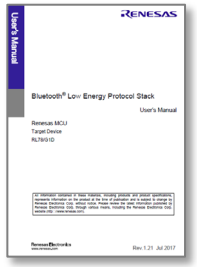


RL78/G1D Evaluation Board User's Manual

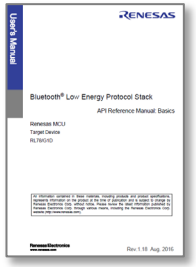


RL78/G1D Module User's Manual

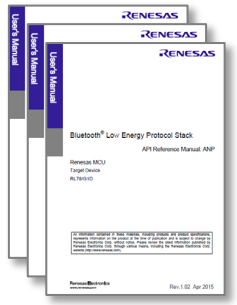
For developing BLE Application



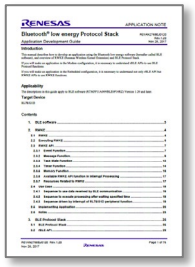
User's Manual



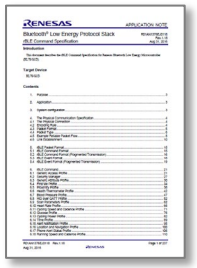
API Reference Manual Basics



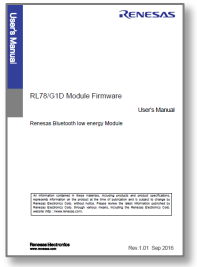
API Reference Manual Profiles



Application Development Guide



rBLE Command Specification



RL78/G1D Module Firmware User's Manual

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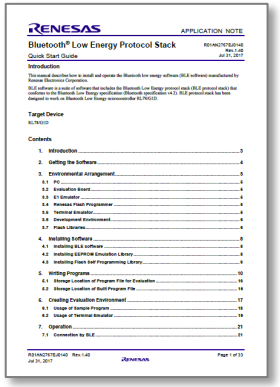
Quick Start Guide

Environment Setup for Developing BLE Application

The Quick Start Guide describes **procedures to setup environment for developing BLE Application, and evaluate**.


RENESAS APPLICATION NOTE

Bluetooth® Low Energy Protocol Stack

Quick Start Guide

Introduction

Target Device

Contents

Quick Start Guide

- **BLE Protocol Stack Quick Start Guide** (Download)
  - ✓ How to get environment (Chapter 1 - Chapter 3)
  - ✓ How to setup environment (Chapter 4 - Chapter 6)
  - ✓ How to evaluate BLE wireless communication (Chapter 7)
  - ✓ How to customize and build BLE firmware (Chapter 8 and Chapter 9)

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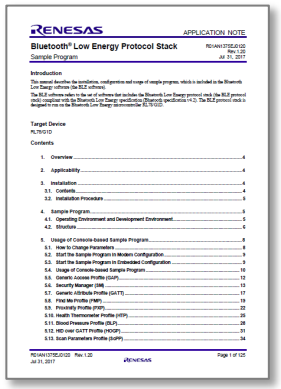
Sample Program Application Note
Evaluation Procedure of BLE Protocol Stack Sample Program

Sample Program Application Note describes **procedures to evaluate sample programs** included in BLE Protocol Stack. Evaluating sample program will help you to understand how BLE communication works.


RENESAS APPLICATION NOTE

Bluetooth® Low Energy Protocol Stack

Sample Program

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Sample Program Application Note

- **BLE Protocol Stack Sample Program Application Note** (Download)
  - ✓ Console-based Sample Program (Chapter 5)
    - ✓ How to use Modem configuration (Section 5.2)
    - ✓ How to use Embedded configuration (Section 5.3)
    - ✓ How to evaluate GAP, SM, GATT, and Profiles (Section 5.5 – Section 5.19)
  - ✓ Simple Sample Program (Chapter 6)
  - ✓ Direct Test Mode Sample Program (Section 7.7)
  - ✓ FW Update Sample Program (Section 7.9)

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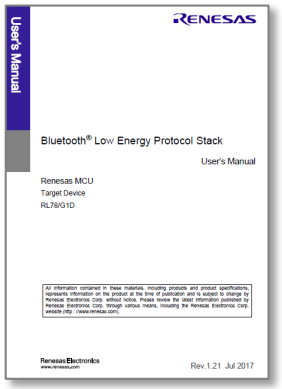
User's Manual
Functional Specification of BLE Protocol Stack

User's Manual describes **software structure of BLE Protocol Stack and details of its functions**.
This document will help you to understand functions provided by BLE Protocol Stack.



User's Manual

- **BLE Protocol Stack User's Manual** (Download)
  - ✓ BLE Software Configuration (Chapter 5)
  - ✓ BLE Protocol Stack Features(Chapter 7, Chapter 11, and Chapter 12)
    - ✓ GAP (Section 7.2)
    - ✓ SM (Section 7.3)
    - ✓ GATT (Section 7.4)
    - ✓ Profiles (Section 7.5 – Section 7.19)
    - ✓ VS (Section 7.20)
    - ✓ FW Update (Chapter 11)
    - ✓ HCI Packet Monitor (Chapter 12)

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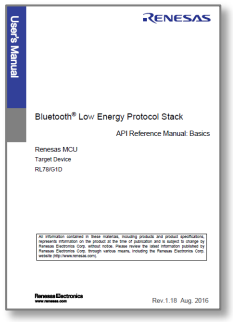
API Reference Manual

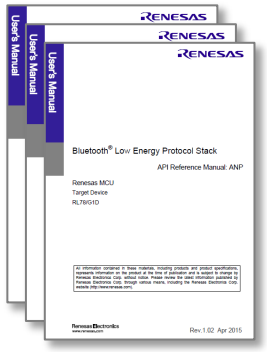
API Specification of BLE Protocol Stack

The API reference manual describes **API specification of BLE Protocol Stack**.



API Reference Manual: Basics

- **BLE Protocol Stack API Reference Manual: Basics** (Download)
  - ✓ GAP API (Chapter 5)
  - ✓ SM API (Chapter 6)
  - ✓ GATT API (Chapter 7)
  - ✓ VS API (Chapter 8)
  - ✓ RWKE API (Chapter 9)



API Reference Manual: Profiles

- **BLE Protocol Stack API Reference Manual: Profiles**

  FMP, PXP, HTP, BLP, HOGP, ScPP, HRP, CSCP, CPP, GLP, TIP, RSCP, ANP, …,etc

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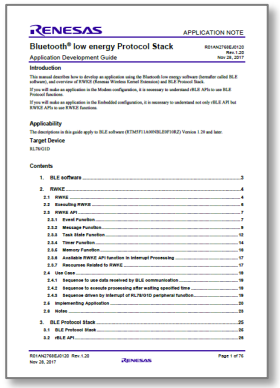
Application Development Guide
How to Implement BLE Application

Application Development Guide shows **how to use API of BLE Protocol Stack**.
This document will help you to understand how to implement BLE Application.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Bluetooth® low energy Protocol Stack

Application Development Guide

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Application Development Guide

- **BLE Protocol Stack Application Development Guide** (Download)
  - ✓ How to use RWKE API (Chapter 2)
  - ✓ How to use rBLE API (Chapter 3)
  - ✓ How to implement Custom Profile (Chapter 4)
  - ✓ Overview of Application Operation (Chapter 5)
  - ✓ Development Tips (Chapter 6)

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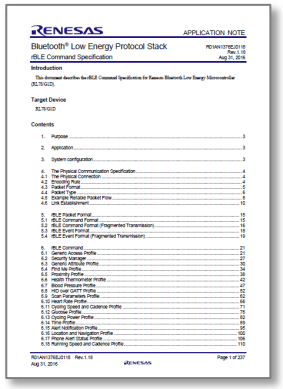
rBLE Command Specification

Specification of RSCIP Communication in Modem Configuration

rBLE Command Specification describes **the specification of RSCIP which is serial communication protocol**. This document will help you to understand serial communication protocol in Modem configuration.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Bluetooth® Low Energy Protocol Stack

rBLE Command Specification

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rBLE Command Specification

- **BLE Protocol Stack rBLE Command Specification** (Download)
  - ✓ RSCIP Communication Protocol Specification (Chapter 4)
  - ✓ rBLE Packet Format Specification (Chapter 5)
  - ✓ rBLE Command Format Details (Chapter 6)
  - ✓ rBLE Event Format Details (Chapter 7)

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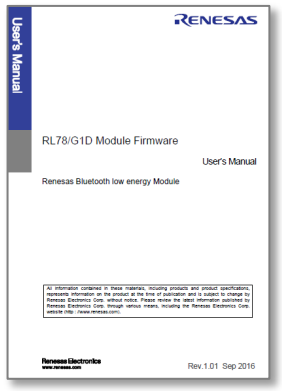
RL78/G1D Module Firmware User's Manual

Specification of RI78/G1D Module Firmware

RL78/G1D Module Firmware User's Manual describes **specification, implemented profiles, and how to re-write the firmware of RL78/G1D Module Firmware**, which is optimized for RL78/G1D Module (RY7011**)**.



RL78/G1D Module Firmware User's Manual

- **RL78/G1D Module Firmware User's Manual** (Download)
  - ✓ Firmware Specification (Chapter 5 and Chapter 6)
  - ✓ Profiles (Chapter 7)
  - ✓ How to Re-write Firmware (Chapter 8)

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Other Useful Documents (1/2)

Following useful documents for developing BLE product are published.

Hardware Specification and Evaluation

- RL78/G1D User's Manual: Hardware (Download)
- RL78/G1D User's Manual: Evaluation Board (RTK0EN0001D01001BZ) (Download)
- RL78/G1D Module (RY7011) User's Manual: Hardware (Download)
- RL78/G1D Measurement of Current Consumption Application Note (Download)

Hardware Development

- RL78/G1D Guidelines for RF Board Design (Download)
- Design data of the RL78/G1D Evaluation Module (Download)
- RL78/G1D Design Guidelines for a Pattern Antenna (Download)
- RL78/G1D Design of a Reference Antenna (Download)

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Other Useful Documents (2/2)

Following useful documents for developing BLE product are published.

Certification of the Radio Law

- RL78/G1D Testing for Certification of Compliance with the Radio Law (Japan) (Download)

Certification of Bluetooth SIG

- BLE microcomputer / module Bluetooth qualification acquisition（Download）

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If You Want Help…

KNOWLEDGEBASE(FAQ): https://en-support.renesas.com/knowledgeBase/category/31069

The frequently asked questions are summarized in this web site.

Renesas Rulz: https://renesasrulz.com/

Renesas Rulz is a forum site to discuss technical topics with Renesas users.

Contact Us: https://www.renesas.com/contact/

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Sample Programs and Tools for Developing BLE Application

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Sample Programs

Following sample programs using BLE Protocol Stack are released.
You can use these sample programs as a base program for developing BLE Application.

For Embedded Configuration

- Embedded Configuration Sample Program
- Virtual UART Application

For Modem Configuration (RL78/G1D Module)

- RL78/G1D Module Control Software (Including Module Firmware)

For Modem Configuration (Host MCU)

- Host Sample (RL78/G14 Renesas Starter Kit, RL78/G14 Fast Prototyping Board, RL78/I1E, or RX113)
- Host Sample with Simple API (RL78/G14 or RX113)

Other

- RL78/G1D Beacon Stack

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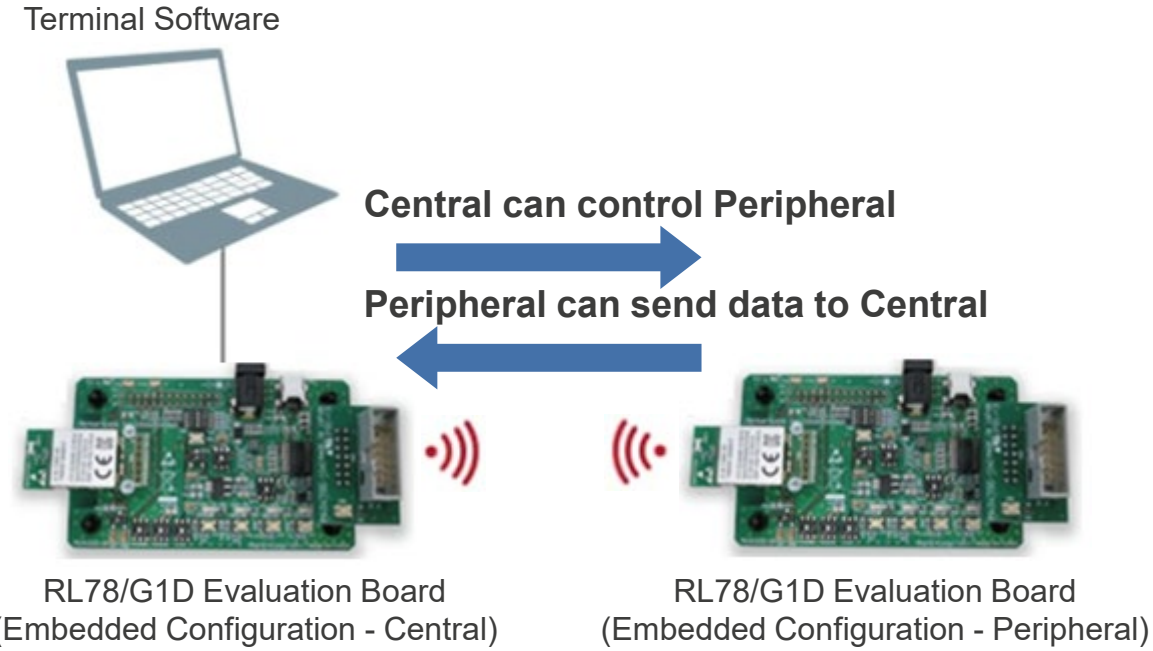
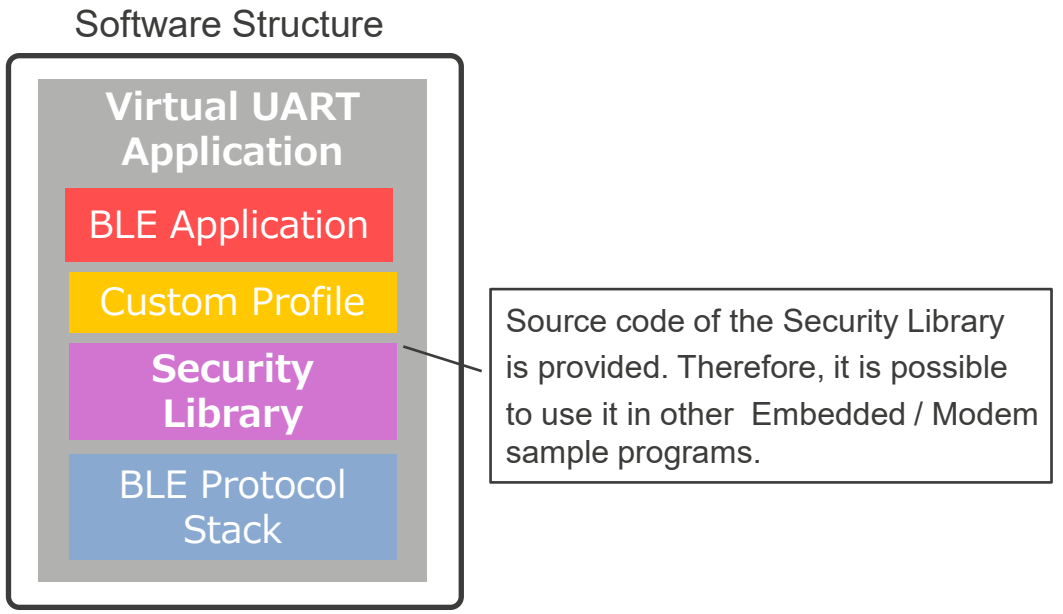
Embedded Configuration Sample Program

Base Program for BLE Application in Embedded Configuration

- **Embedded Configuration Sample Program** (Download)

  This sample program works as Central and Peripheral of Embedded Configuration, and it corresponds to simultaneous connections of Central. You can use it as **a base program for developing various applications**. Furthermore, it includes Security Library to use security function easily.





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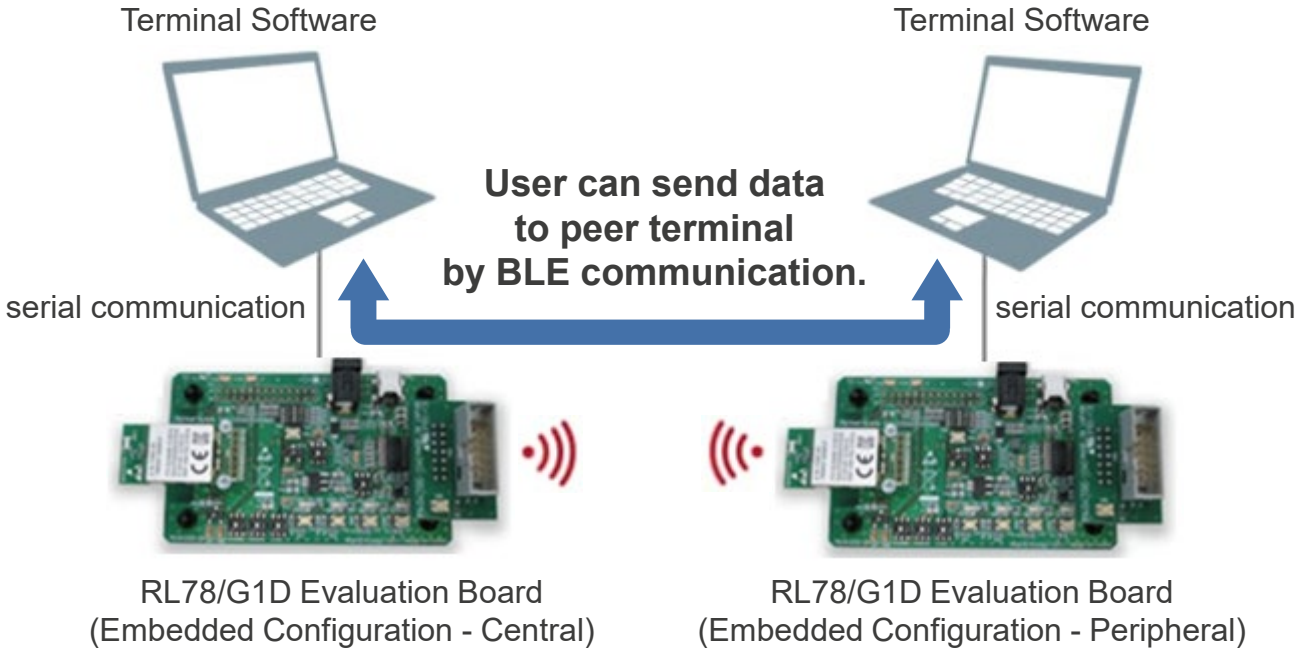
Embedded Configuration Virtual UART Application

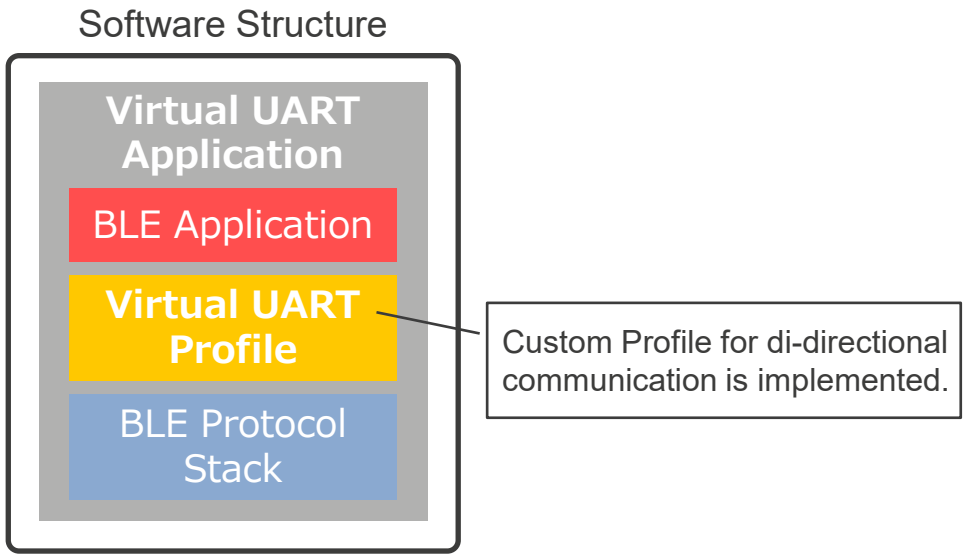
Change from Serial Communication to Wireless Communication by RL78/G1D

- Virtual UART Application (Download)

  This sample program communicates characters di-directionally through terminal software.

  You can use it for **changing wired communication such as UART to wireless communication** by using RL78/G1D.





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Modem Configuration RL78/G1D Module Control Software

Sample Program optimized for RL78/G1D Module

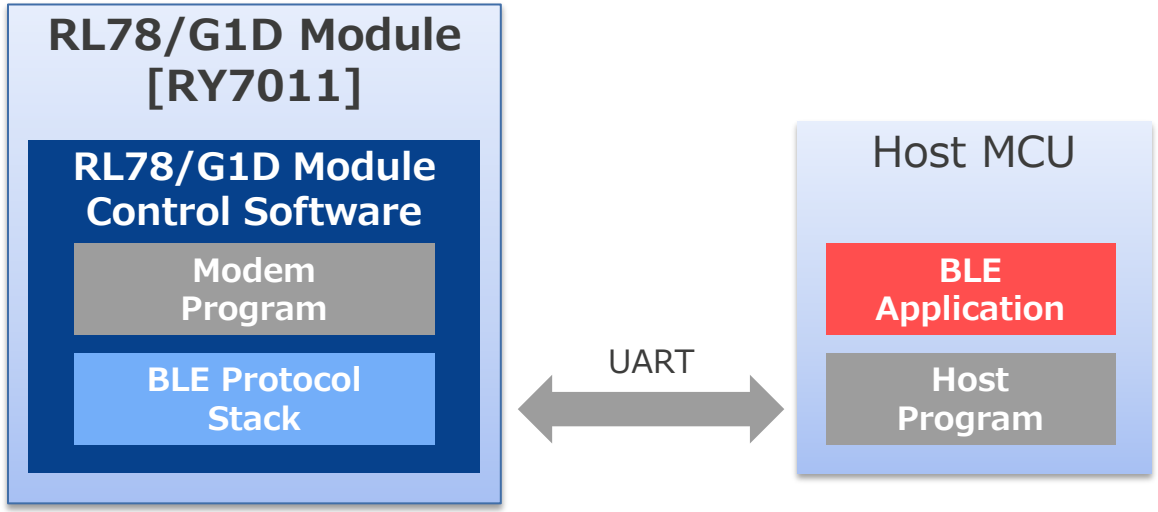
- **RL78/G1D Module Control Software (Including Module Firmware)** (Download)

  This sample program is Modem configuration software optimized for RL78/G1D Module RY7011 (Product Info).
  The following custom profiles are implemented in this sample program.

  - **General Purpose Communication Profile**: for di-directional communication among RL78/G1D and Host MCU
  - **Firmware Update Profile**: for updating application of RL78/G1D

RL78/G1D Module Control Software
- Modem Configuration
- Optimized for RL78/G1D module
- Controlled by Host MCU

RL78/G1D Module [RY7011]



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Modem Configuration Host Sample Program

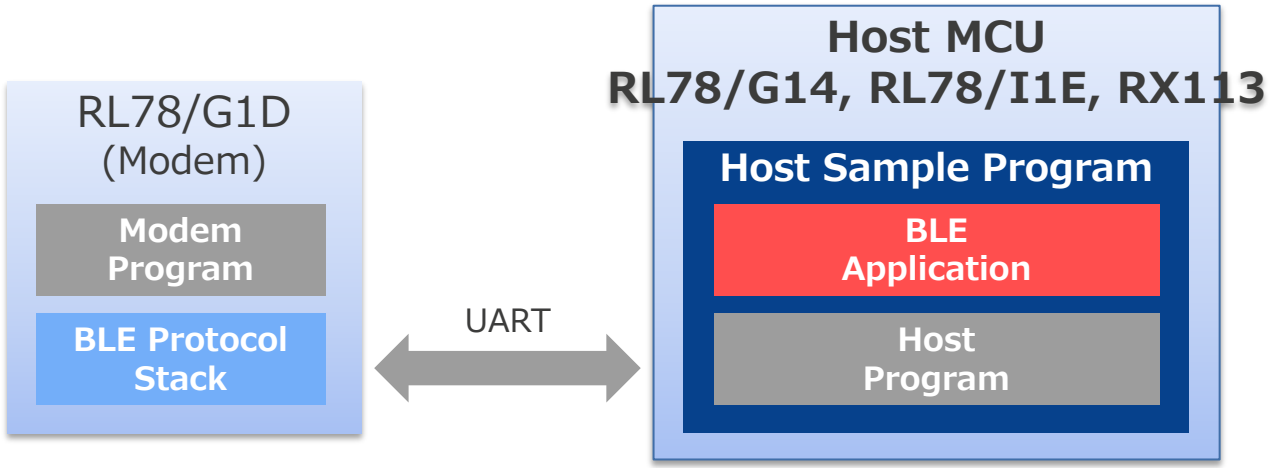
Host Sample Program for RL78/G14 and RX113

- **Host Sample** (RL78/G14 Renesas Starter Kit, RL78/G14 Fast Prototyping Board, RL78/I1E, RX113)

  This sample program works on Host MCU to control Modem configuration RL78/G1D.

- **Host Sample with Simple API** (RL78/G14, RX113)

  This is Host Sample that Simple API is added to above sample program.
  General Purpose communication Profile and Firmware Update Profile are implemented in this sample.



Host Sample Program
- Controls Modem Configuration RL78/G1D
- Works on RL78/G14, RL78/I1E, or RX113

Simple API
API to execute BLE communication easily

initialize()	whitelist()	scan()
advertise()	connect()	disconnect()
get_event()	send_data()	receive_data()

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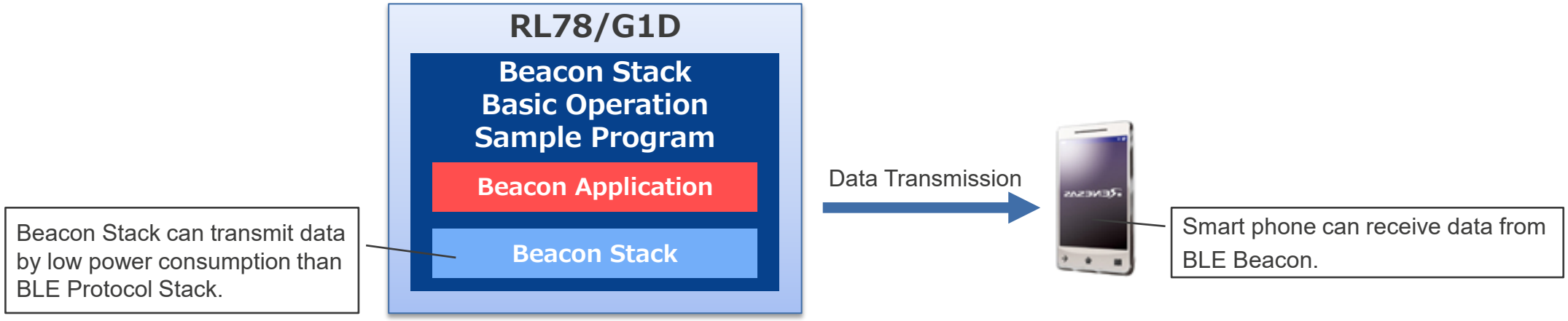
RL78/G1D Beacon Stack

Software Stack optimized for BLE Beacon

- **RL78/G1D Beacon Stack** (Document)

  RL78/G1D Beacon Stack is a software stack for RL78/G1D device as a BLE Beacon.

  Library of the Beacon Stack is included in the following samples.
- **Basic Operation Sample Program** (Download, Document)
- **Connecting and Updating Beacon Data Sample Program** (Download, Document)



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Tools

The following tools to generate source code or execute BLE wireless communication are released.
You can use these tools for developing or evaluating BLE Application of RL78/G1D.

Tool for evaluating Modem Configuration

- GUI Tool : tool for controlling BLE communication of Modem configuration RL78/G1D by GUI

  You can use for initial evaluation of BLE communication and confirmation of API sequence.

BLE Communication Tool for smart phone

- GATTBrowser (iOS or Android) : smart phone application for executing GATT-based communication

  You can use smart phone as a peer device in evaluating the sample program or debugging BLE application.

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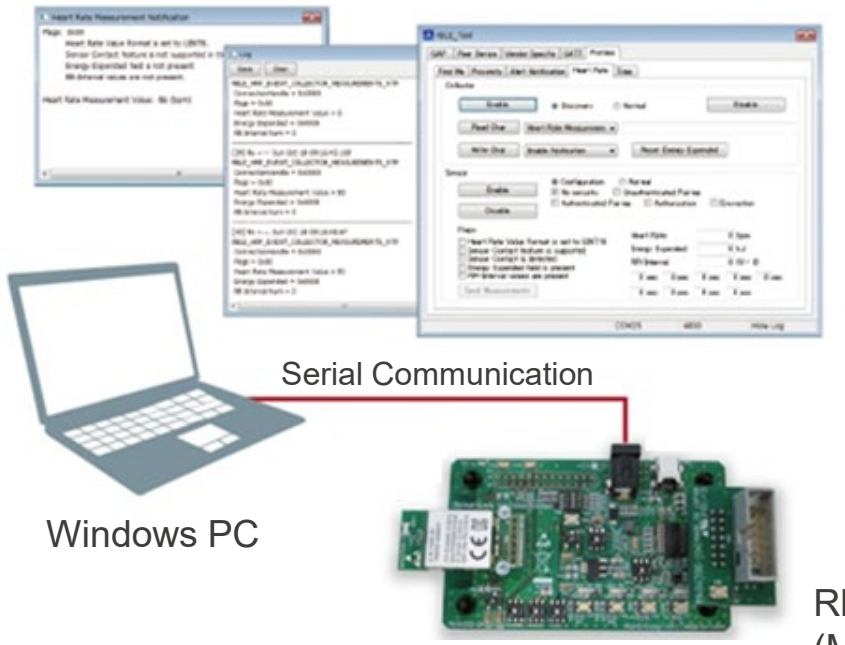
GUI Tool

Tool for Evaluating Modem Configuration

- **GUI Tool** (Download)
  This tool works on PC and controls BLE communication of Modem configuration RL78/G1D by GUI.
  You can use for initial evaluation of BLE communication and confirmation of API sequence.



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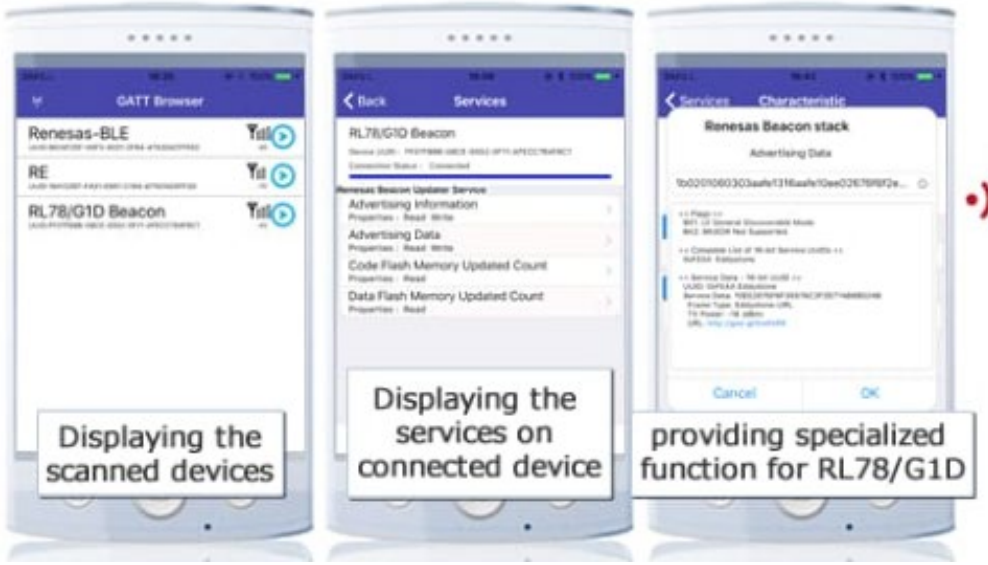
GATTBrowser

Application to BLE-Communicate by Using Smart Phone

- **GATTBrowser** (iOS, Android)
  This tool works on smart phone and communicates with BLE device by GATT-based.
  When evaluate functionality of the sample programs or debug BLE Application in development,
  you can use smart phone as a peer device of RL78/G1D.



RL78/G1D Evaluation Board
(Embedded and Modem configuration)

GATTBrowser (works on Android device or iOS device)

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