Bluetooth[®] Low Energy Protocol Stack Introduction

Rev 1.01 Jan. 29, 2021 R01QS0014EJ0101 Renesas Electronics Corporation





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 <u>under-lined and blue word</u> has a link to web page or document.

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Overview of BLE Protocol Stack



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)



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



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



Application of Host MCU can use BLE communication functionality.



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





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



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

Device Discovery and Connection



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



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)



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.



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
- : switches MCU and RF state to low power consumption mode automatically

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- Bluetooth Device Address Write : writes device address to data flash memory area
- Direct Test Mode

Sleep

- Transmission Power Selection
- RF GPIO Port Control
- Adaptable Mode
- RF Unit Power Control

- : executes RF transmission and reception to evaluate RF characteristic
- : changes RF transmission power
- : controls GPIO ports of RF unit
- : manages RF characteristic dynamically
- : changes RF unit power states



BLE Protocol Stack RWKE (Simple OS)

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

	BI	LE Applica	tion		
	BLE	Protocol	Stack		
GAP	SM	GATT	VS	Profiles	
		RWKE			

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



Development Environment for BLE Application



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)





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)
 - e²studio: 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)



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



Documents for Developing BLE Application



Documents for Developing BLE Application





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 NOT
Bluetooth® Low Energy Protocol Stack	RELANZING LIGHT
Quick Start Guide	Jul 31, 201
Introduction	
This manual describes how to install and operate the Historich low energy software Renewa Electronics Corporation.	
BLE software is a water of software that includes the Blactooth Low Energy protoce conforms to the Blactooth Low Energy specification (Blactooth specification v4.2), designed to work on Blactooth Low Energy microcontrollor R1.PEGED.	i stack (BLE protocol stack) that BLE protocol stack has been
Target Device	
K. 19000	
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12 Evaluation Board	
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4.2 Installing EEPROW Emulation Library	
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5. Writing Program	
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6.2 Elonge Location of Built Program File	
6. Creating Evaluation Environment	
6.1 Usage of Sample Program	
6.2 Usage of Terminal Emulator	
7. Operation	
7.1 Connection by BLE	
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Quick Start Guide

BLE Protocol Stack Quick Start Guide (<u>Download</u>)

- ✓ 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)



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 N
Bluetooth® Low Energy Proto	col Stack REIANISTER
Sample Program	JU 31.
Introduction	
Tais menual describes the installation, configuration and surge Low Zanegy software (the SLZ software).	of sample program, which is included in the Shoet
The BLE software refers to the set of software that includes the model compliant with the Neurosch Low Energy specification insigned to run on the Electron Low Energy microcontroller i	Statistic Low Easing protocol study (the BLE pr Blastoch specification v4.2). The BLE protocol s LIN 01D
Target Device	
RL75/G1D	
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3.2. Installation Procedure	
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5.2. Start the Sample Program In Modern Cont	
5.3. Start the Sample Program in Embedded C	
5.4. Usage of Console-based Sample Program	
5.5. Generic Access Profile (CAP)	
S.G. Security Manager (SM)	
5.7. Generic Attribute Profile (GATT)	
5.8. Find Me Profile (FMP)	
5.5. Proximity Profile (PXP)	
5.10. Health Thermometer Profile (HTP)	
5.11. Diood Pressure Profile (DLP)	
5.12. HID over GATT Profile (HOGP)	
5.13. Scan Parameters Profile (SoPP)	
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Sample Program Application Note

BLE Protocol Stack Sample Program Application Note (<u>Download</u>)

- ✓ 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)

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- ✓ Simple Sample Program (Chapter 6)
- ✓ Direct Test Mode Sample Program (Section 7.7)
- ✓ FW Update Sample Program (Section 7.9)

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	Renesas
	Bluetooth® Low Energy Protocol Stack
	User's Manual
	Renesas MCU Target Device RL78/G1D
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	Renasas Electronics Rev.1.21 Jul 2017

User's Manual

- BLE Protocol Stack User's Manual (<u>Download</u>)
 - ✓ 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)



API Reference Manual API Specification of BLE Protocol Stack

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







API Reference Manual: Profiles

BLE Protocol Stack API Reference Manual: Basics (<u>Download</u>)

- ✓ GAP API (Chapter 5)
- ✓ SM API (Chapter 6)
- ✓ GATT API (Chapter 7)
- ✓ VS API (Chapter 8)
- ✓ RWKE API (Chapter 9)
- 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.

RENESAS	APPLICATION NOT
Bluetooth® low energy Protocol Stack	RO1AN2760EJD1
Application Development Guide	Rev. 1. Nov 28, 20
Introduction	
This manual describes how to develop an application using the Blackcoth low energy subsystem, and converting of RWER (Generate Wireless Konnel Eulersian) and RLE.	p software (hereafter called NLE
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If you will make an application in the Embedded configuration, it is necessary to a KNYCE APIs to use KNYCE functions.	edentand not only rBLE API but
Applicability	
The descriptions in this guide apply to DLE software (RTMSF11A0048LE0F108,	Z) Venice 1.29 and later.
Target Device	
ALTNOID	
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2. RWKE	
21 8975	
2.2 Executing WAYS	
2.3 RWKE AP1	
2.3.1 Event Punction	
2.3.2 Message Pundhon	
2.5.3 Text Male Panelion	
2.3.4 Analiable RWYZ API function in interrupt Processing	
2.4.7 Encourse Existent to EAVE	
24 line Case	
2.4.1 Bequence to use data received by BLE communication	
141 Assume to execute represents after walling specific	
2.4.3 Dequence driven by interrupt of PL/B/01D peripheral 1	under.
2.6 Implementing Application	
2.8 Holes	
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Application Development Guide

BLE Protocol Stack Application Development Guide (<u>Download</u>)

- ✓ 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)



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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Blue	tooth® Low Energy Protocol Stack nowNister
	Command Specification Aug 31, 20
Introd	action
Tak 6 (9175 G	rement dearbas fas (BER Command Specification for Ramon Risatoria Low Energy Microcostrulae (2).
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1.	Partone
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3.	System configuration
4.	The Physical Communication Specification
4.1	The Physical Connection
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	RLE Rockel Formal RLE Command Formal
5.	IELE Packet Pornat
5.4	(ELE Event Format (Fragmented Transmission)
	et g conviored
6.2	Security Manager General Attracter Profile
	Health Themometer Prote
	Bood Pressure Profile HD over GATT Profile
	Soan Parametern Profile
6.1	1 Cycling Speed and Cadence Profile
2.1	
6.1	4 Time Prote
6.1	6 Location and Navigation Profile 1 7 Phone Aleft Litatual Profile 1
6.1	7 Phone Aser status Prote 5 5 Rumming Speed and Cadence Prote 1

rBLE Command Specification

BLE Protocol Stack rBLE Command Specification (<u>Download</u>)

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



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)



Other Useful Documents (1/2)

Following useful documents for developing BLE product are published.

Hardware Specification and Evaluation

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

Hardware Development

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



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) (<u>Download</u>)

Certification of Bluetooth SIG

BLE microcomputer / module Bluetooth qualification acquisition (<u>Download</u>)





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

The frequently asked questions are summarized in this web site.

Renesas Rulz: <u>https://renesasrulz.com/</u>

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

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

This site guides to ask purchase and technical inquiry.





Sample Programs and Tools for Developing BLE Application



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 (<u>Download</u>)

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.



I

Embedded Configuration Virtual UART Application Change from Serial Communication to Wireless Communication by RL78/G1D

Virtual UART Application (<u>Download</u>)

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.





Modem Configuration RL78/G1D Module Control Software Sample Program optimized for RL78/G1D Module

RL78/G1D Module Control Software (Including Module Firmware) (<u>Download</u>)

This sample program is Modem configuration software optimized for RL78/G1D Module RY7011 (<u>Product Info</u>). 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



Modem Configuration Host Sample Program Host Sample Program for RL78/G14 and RX113

Host Sample (<u>RL78/G14 Renesas Starter Kit</u>, <u>RL78/G14 Fast Prototyping Board</u>, <u>RL78/I1E</u>, <u>RX113</u>)

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

Host Sample with Simple API (<u>RL78/G14</u>, <u>RX113</u>)

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.





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 (<u>Download</u>, <u>Document</u>)
- Connecting and Updating Beacon Data Sample Program (<u>Download</u>, <u>Document</u>)





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

<u>GUI Tool</u>: 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

<u>GATTBrowser (iOS or Android)</u>: 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.





GUI Tool Tool for Evaluating Modem Configuration

GUI Tool (<u>Download</u>)

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**.





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**.



GATTBrowser (works on Android device or iOS device)



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