RFCOM TECHNOLOGIES

RTBTM01 Bluetooth Module

User Manual

Table of Contents

1. Introduction

1.1 Definitions, Acronyms, and Abbreviations

BLE	Bluetooth Low Energy
DC	Direct Current
MCU	Micro-Controller Unit
UART	Universal asynchronous receiver/transmitter
ESD	Electrostatic discharge
RF	Radio Frequency
UART	Universal Asynchronous Receiver/Transmitter
I2C	Inter-integrated Circuit

1.2 References

A reference is a document to which RFCOM Technologies refers. It could be a customer requirement document; it could be an internal RFCOM document.

RFCOM Technologies commit that the end product will behave as in any of the reference documents or it should explicit be mentioned. The following main documents are used in design:

1. RTBTM01 Bluetooth module software user manual
2. R5F11AG_BLE_Mannual
3. R5F11AG_Datasheet
4. R5F11AG Preliminary User's Manual Evaluation Board
5. R5F11AG Bluetooth Low Energy Protocol Stack User's Manual
6. Renesas rBLE Command Specification

1.3 Naming Rule

RT	**BTM**	**01**	**-**	**X**	**X**	**-**	**X**	**X**

RT - Product Prefix of RFCOM Technologies
BTM – BLE Module Board
01 – Hardware PCB Version Number
XX – Hardware Revision Alphabet (A1 – internal antenna)
XX – Firmware Revision Number (10 – default on-chip firmware)

2. Introduction of RTBTM01 BLE Module Board

RTBTM01 is a Bluetooth low energy module based on Renesas MCU R5F11AG Bluetooth Low Energy Protocol Stack. The R5F11AG is a microcomputer incorporating the R5F11AG core and low power consumption RF transceiver supporting the Bluetooth ver.4.1 (Low Energy Single mode) specifications.

This module has integrated RF Antenna, 32MHz Crystal, DC/DC inductor to make it easy to use in the application product without requesting know-how of sensitive circuitry and RF design technics. Customer can optionally use RF connector, RF pin or RF chip Antenna on module for end-product development.

RTBTM01 is capable to operate either modem (as default) or embedded mode for the sake of cost saving and product size reduction. Embedded firmware is optionally available and in this case, customer may contact RFCOM Technologies for further information.

RTBTM01 BLE module is ROHS, CE, FCC Part 15 and RCM pre-approved module. Customers can directly adopt this module so as to delivery their products to market more efficiently.

2.1 Key features

- 2.4 GHz ISM band, Bluetooth v4.1 compliance
  - Low Energy Single mode Mast & Slave
- Ultra-low power consumption
- Radio capabilities
  - Transmit power: 3.2dBm
  - Receiver sensitivity: -89dBm
  - Line-of-sight range: 10 meters
  - Integrated chip antenna
  - RF connector is optionally available
- Baseband capabilities
  - 10-bit resolution A/D converter
  - Software programmable GPIO: 13
  - Rich and flexible interfaces – CSI/ UART/I2C
  - Communication at different potential 1.8 V/2.5 V
- Operation voltage: 1.6V to 3.6V
- Operation temperature: -30°C to +85°C
- Ultra-form factor: 10.0mm x 14.0mm x 1.9mm
- ROHS, CE, FCC and RCM

2.2 Applications

- Health and fitness gateways
- M2M connectivity
- Personal navigation devices
- Consumer electronics
- Industrial and home automation

2.3 Build-in rich software profiles for rich applications

Come together with RTBTM01-X-XX-X Module, the software package includes the following profiles for rich application:

HID device profiles
- HOGP - HID over GATT profile

Proximity sensing
- FMP - Find me Profile
- PXP - Proximity Profile

Alerts and time profiles
- PASP - Phone alert status Profile
- TIP -Time profile
- ANP - Alert Notification Profile

Health care profiles
- HTP - Heart Thermometer Profile
- GLP - Glucose Profile
- BLP - Blood Pressure Profile

Sports and fitness profiles
- HRP - Heart Rate Profile
- CSCP - Cycling Speed and Cadence Profile
- CPP - Cycling Power Profile
- RSCP - Running Speed and Cadence Profile
- LNP - Location and Navigation Profile

Other profiles
- ScPP - Scan Parameters Profile
- Sample and API for Custom profile

2.4 Bluetooth Core Specification

RTBTM01 Module supports the additional (optional) specification below.

Feature	Version	Support
Limited Discovery Time Changes	v4.0 Addendum	Yes
GAP Connection Parameters Changes	v4.0 Addendum	Yes
GAP Authentication and Lost Bond	v4.0 Addendum	Yes
Fast Advertising Interval	v4.0 Addendum	Yes
32 Bit UUIDs for LE	v4.1	Yes
LE Low Duty Cycle Directed Advertising	v4.1	Yes
LE Privacy (1.1)	v4.1	Yes

Table 2-1 Additional features in RTBTM01 BLE profiles

2.5 Physical Outlook

Figure 2-1 RTBTM01 BLE module

3. Block Diagram

Figure 3-1 Block Diagram of RTBTM01 BLE module shows the overall block diagram of RTBTM01 BLE Module.

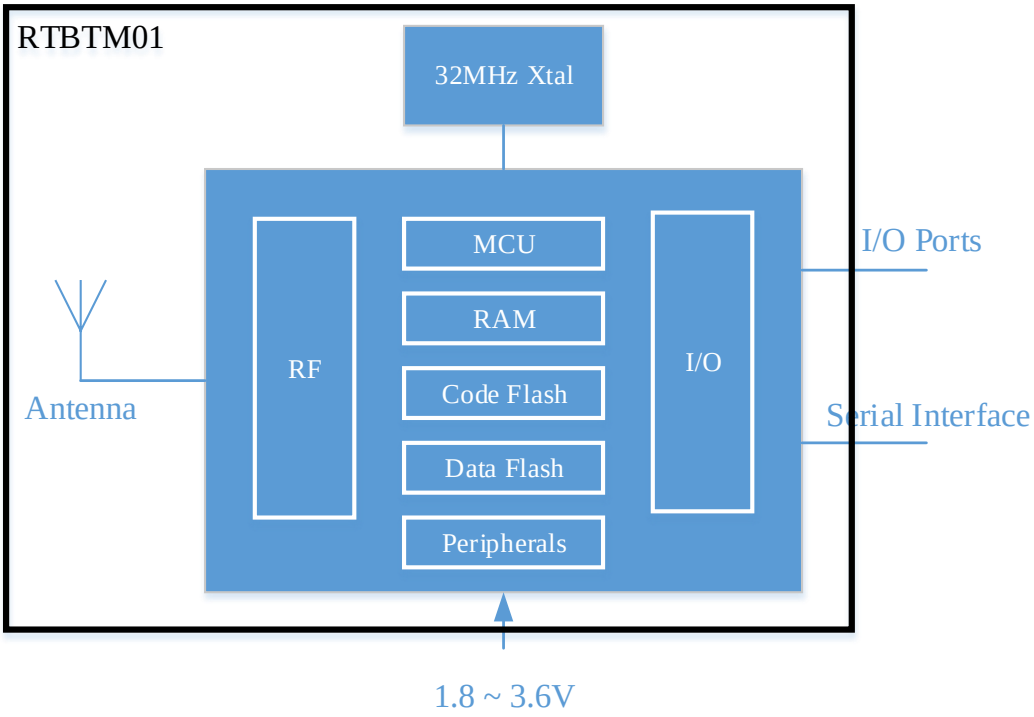


Figure 3-1 Block Diagram of RTBTM01 BLE module

MCU

RTBTM01 is based on R5F CPU core. The chip includes all the functions required for a complaint Bluetooth radio V4.1.

Antenna

Antenna is a ceramic monopole chip antenna as well as optionally configurable RF connectors

32MHz Crystal

The embedded 32MHz crystal is used for generating the internal digital clocks.

DC-DC converter

The build-in DC-DC convertor enable LV (low-voltage main) mode for ultra-low power current consumption operation

4. RTBTM01 Pin Assignment

4.1 PIN Assignment

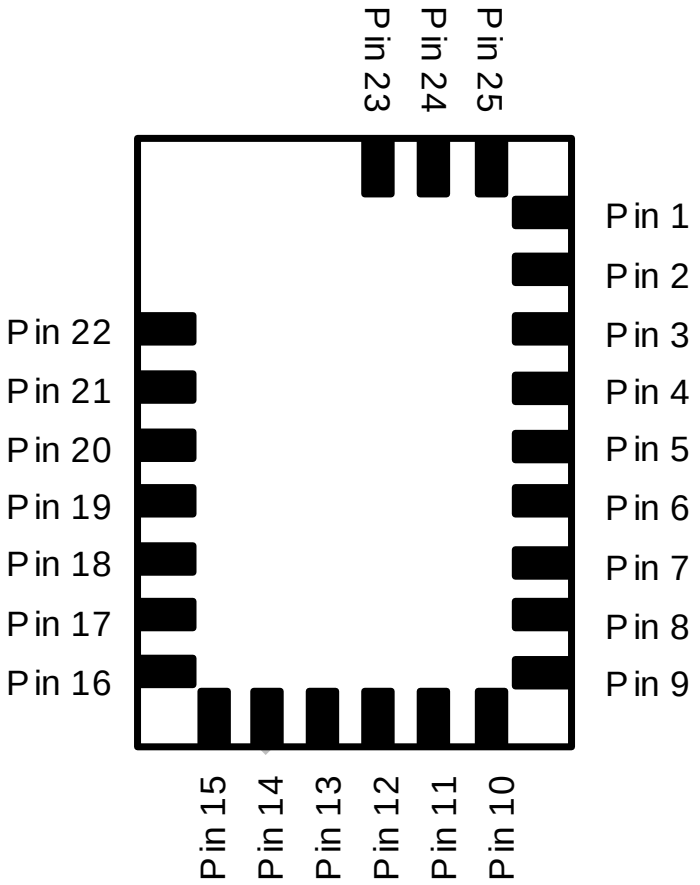


Figure 4-1 RTBTM01 Bottom view

4.2 PIN definition

Pin Number	Pin Signal Name	Default Setting	Alternative Function
1	VSS	GND	GND
2	VSS	GND	GND
3	P1	I/O	External interrupt input /RTC correction clock (1 Hz) output
4	P2	I/O	Serial clock output, Timer Input/output
5	P3	I/O	I/O, Serial data input CSI20
6	P4	I/O	I/O, Serial data output CSI21

7	TxD0	UART Tx Pin	UART0 Transmit Data
8	RxD0	UART Rx Pin	UART0 Receive Data
9	P5	I/O	Serial Clock Output
10	P6	I/O	Analog Input
11	VSS	GND	GND
12	P7	I/O	UART1 Receive Data
13	P8	I/O	UART1 Transmit Data
14	P9	I/O	Analog Input
15	TOOL0	Flash programmer	Data Input/Output for programming
16	nRST	Reset	Reset
17	XT1	N.C.	32.768KH Crystal oscillator (Subsystem)
18	XT2	N.C.	32.768KH Crystal oscillator (Subsystem)
19	SCL0	I2C Clock Signal	Serial Clock Input/Output
20	SDA0	I2C Data Signal	Serial Data Bus line
21	VDD	Power supply (1.6V to 3.6V)	Power supply
22	VSS	GND	GND
23	VSS	GND	GND
24	RF_PAD	RF Output (optional)	RF Output (optional)
25	VSS	GND	GND

Table 4-1 RTBTM01 BLE Module PIN definition

5. Application Schematic

5.1 Adaptor Board Schematic

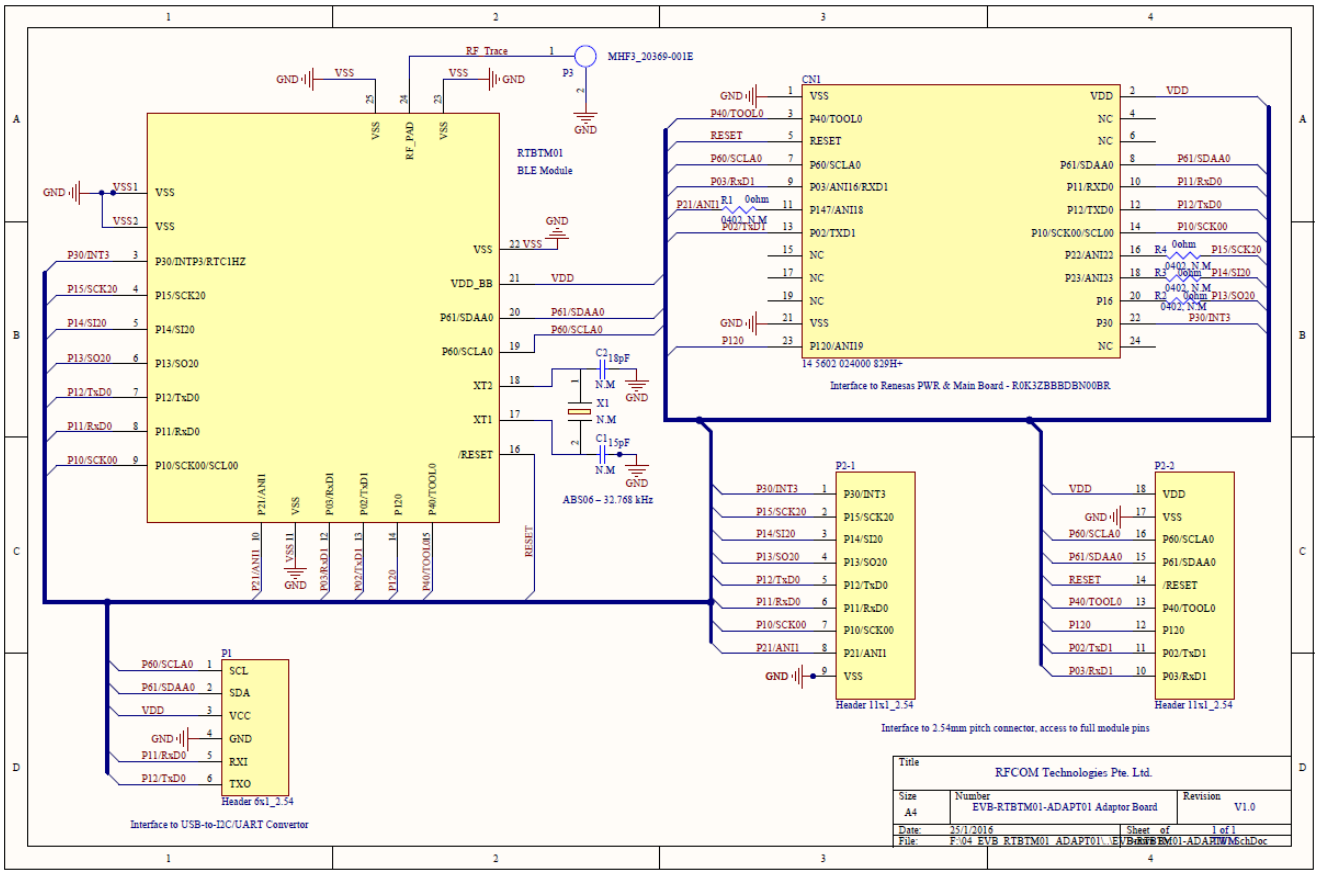


Figure 5-1 RTBTM01 Adaptor Board Schematic

5.2 RF Configuration

RF Configuration	R3	R4	C9	L2	C8
On-module Chip Antenna (Default)	Not Mounted	Not Mounted	2.7nH	0 Ω	3.9nH
RF Connector	0 Ω	Not Mounted			
RF Pad	Not Mounted	0 Ω	Not Mounted		

Table 5-1 RF configuration (optional)

5.3 Application Interface

5.3.1 Communication at same potential (V_{DD})

5.3.1.1 UART interfaces

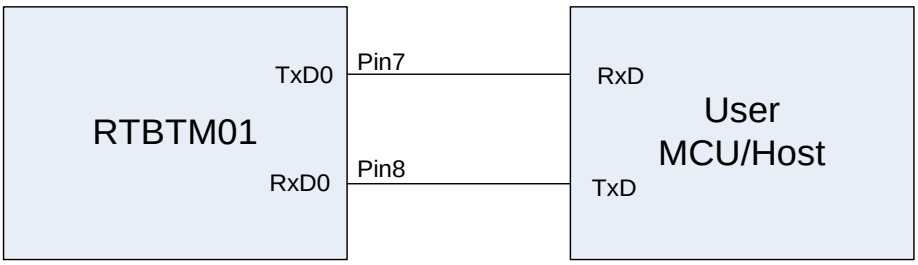


Figure 5-2 UART mode connection diagram at same potential

5.3.1.2 Simplified I2C interface

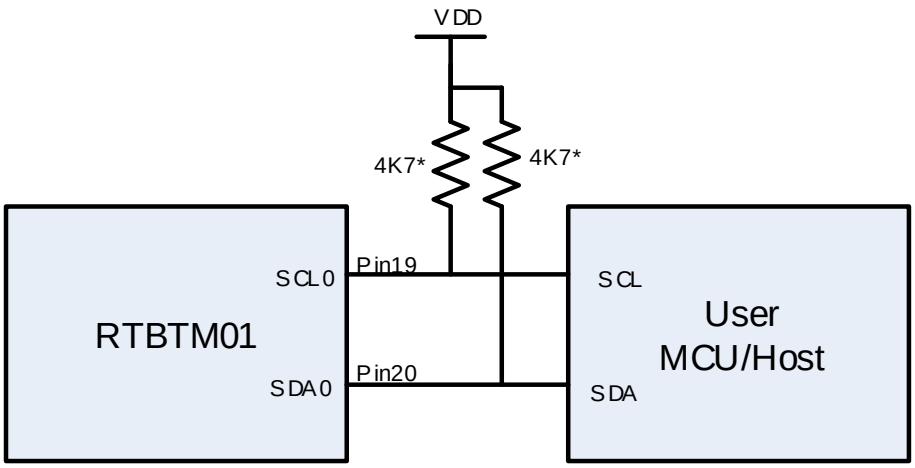


Figure 5-3 Typical pull-up resistor for I2C mode connection at same potential

The recommended typical pull-up resistor value 4.7KΩ varies subject to designed communication line (SDA0, SCL0) load capacitance and operation clock frequency at different speed mode.

5.3.2 Communication at different potential (1.8 V, 2.5 V)

5.3.2.1 UART interfaces

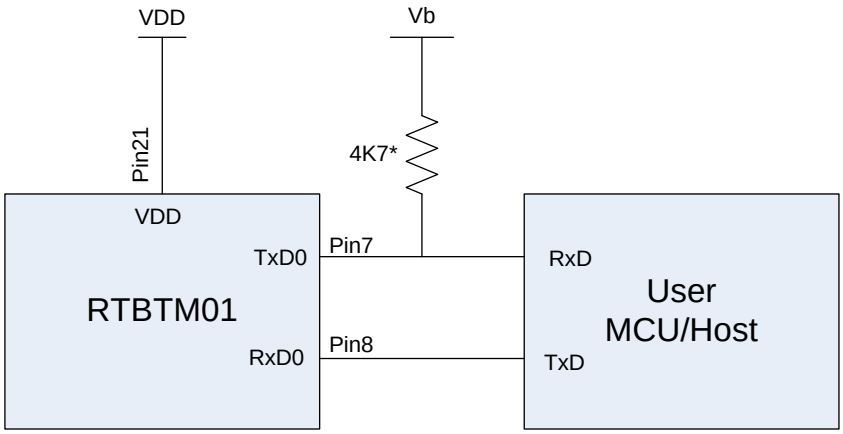


Figure 5-4 UART mode connection diagram at different potential

In this case, VDD ≥ Vb and Vb is either 2.5V (2.3V ~ 2.7V) or 1.8V (1.6V ~ 2.0V). The recommended typical pull-up resistor value 4.7KΩ varies subject to designed communication line (TxD0) load capacitance and operation clock frequency at different speed mode. TTL mode is to be used, please contact RFCOM Technologies for more technical information.

5.3.2.2 Simplified I2C interface

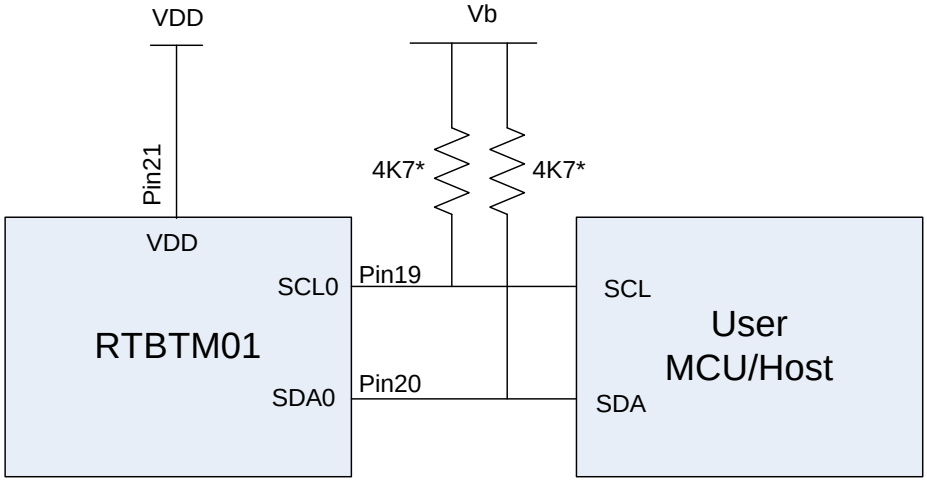


Figure 5-5 Typical pull-up resistor for I2C mode connection at different potential

In this case, VDD ≥ Vb and Vb is either 2.5V (2.3V ~ 2.7V) or 1.8V (1.6V ~ 2.0V). The recommended typical pull-up resistor value 4.7KΩ varies subject to designed communication line (SCL0, SDA0) load capacitance and operation clock frequency at different speed mode. TTL mode is to be used, please contact RFCOM Technologies for more technical information.

6. Electrical Characteristics

6.1 Absolute Maximum Ratings

Parameter	Symbol	Min	Max	Rating	Unit
Power Supply	VDD	-0.5	+4.0		V
	VSS	-0.5	+0.3		V
Input voltage	Per GPIOs	-0.3	VDD+0.3*		V
	RF_PAD	-0.5	+1.4		V
Output voltage	Per GPIOs	-0.3	VDD+0.3*		V
Analog input voltage	P6, P9	-0.3	VDD+0.3*		V
Output current, high	Per Pin			-40	mA
	Total Pins			-170	mA
Output current, high	Per Pin			40	mA
	Total Pins			170	mA
Operating temperature		-30	+85		°C
Storage temperature		-40	+85		°C

*Must be 4.0 V or lower

Figure 6-1 Absolute maximum ratings

6.2 Input & Output Characteristics

Parameter		Condition	Min	Typ.	Max	Unit
Power Supply		VDD	1.6		+3.6	V
Output voltage	High	1.6 V≤ VDD ≤ 3.6 V, I_{OH} = -1.0mA	VDD-0.5			V
	Low	1.6 V≤ VDD ≤ 3.6 V, I_{OL} = 0.3 mA			0.4	V
Input voltage	High	Normal mode (I_{THL} = 1)	0.8VDD		VDD	V
	Low		0		0.2VDD	V
	High (TTL mode)	3.3 V ≤ VDD ≤ 3.6 V	2.0		VDD	V
		1.8 V ≤ VDD ≤ 3.3 V	1.5		VDD	V
	Low (TTL mode)	3.3 V ≤ VDD ≤ 3.6 V	0		0.5	V
		1.8 V ≤ VDD ≤ 3.3 V	0		0.32	V
Current	High	1.6 V≤ VDD ≤ 3.6 V, Per pin			-10	mA
	Low	1.6 V≤ VDD ≤ 3.6 V, Per pin			+20	mA
Clock Speed	HS (High-speed main) mode	VDD = 2.7 to 3.6 V	1		32	MHz
	HS (High-speed main) mode	VDD = 2.4 to 3.6 V	1		16	MHz
	LS (Low-speed main) mode	VDD = 1.8 to 3.6 V	1		8	MHz
	LV (Low-voltage main) mode	VDD = 1.6 to 3.6 V	1		4	MHz

Figure 6-2 Input & Output Characteristics

6.3 Current Consumption

Tx power = 0dBm	Operation Mode	Peak Current	Average Current (DC)	Unit
Normal Voltage (3.0V)	Standby[1]	-	9	μA
	LE Scan (Master Mode)	3.8	see Fig. 6-4[2]	mA
	LE Connected (Slave Mode)	2.5	see Fig. 6-5 [2]	mA
	LE Advertise (Slave Mode)	2.5	see Fig. 6-6 [2]	mA
Remarks: [1] Standby mode: RF unit is power down while MCU is idle mode; [2] LE average current consumption depends on the chosen TX interval and scanning window				

Table 6-1 Current Consumption of RTBTM01 (Tx = 0dBm)

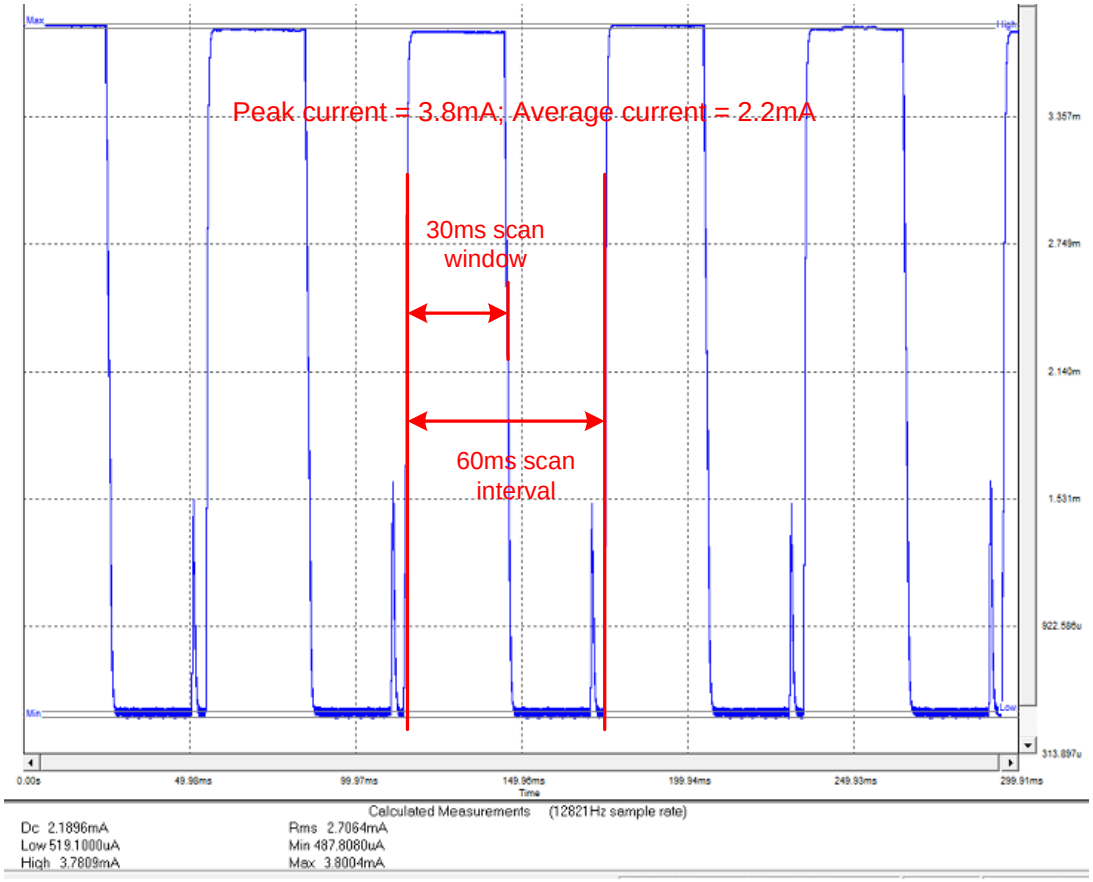


Figure 6-3 LE scanning with 30ms scan window, 60ms scan interval (V_{DD} = 3V)

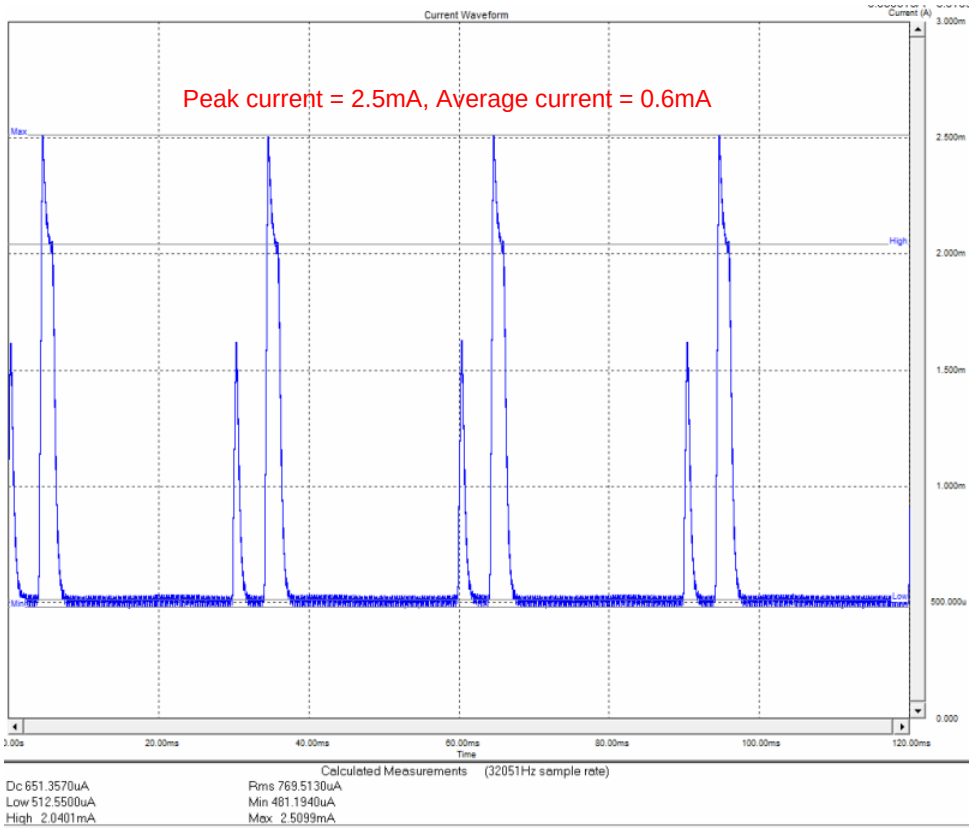


Figure 6-4 LE connected with 70ms interval (V_{DD}= 3V)

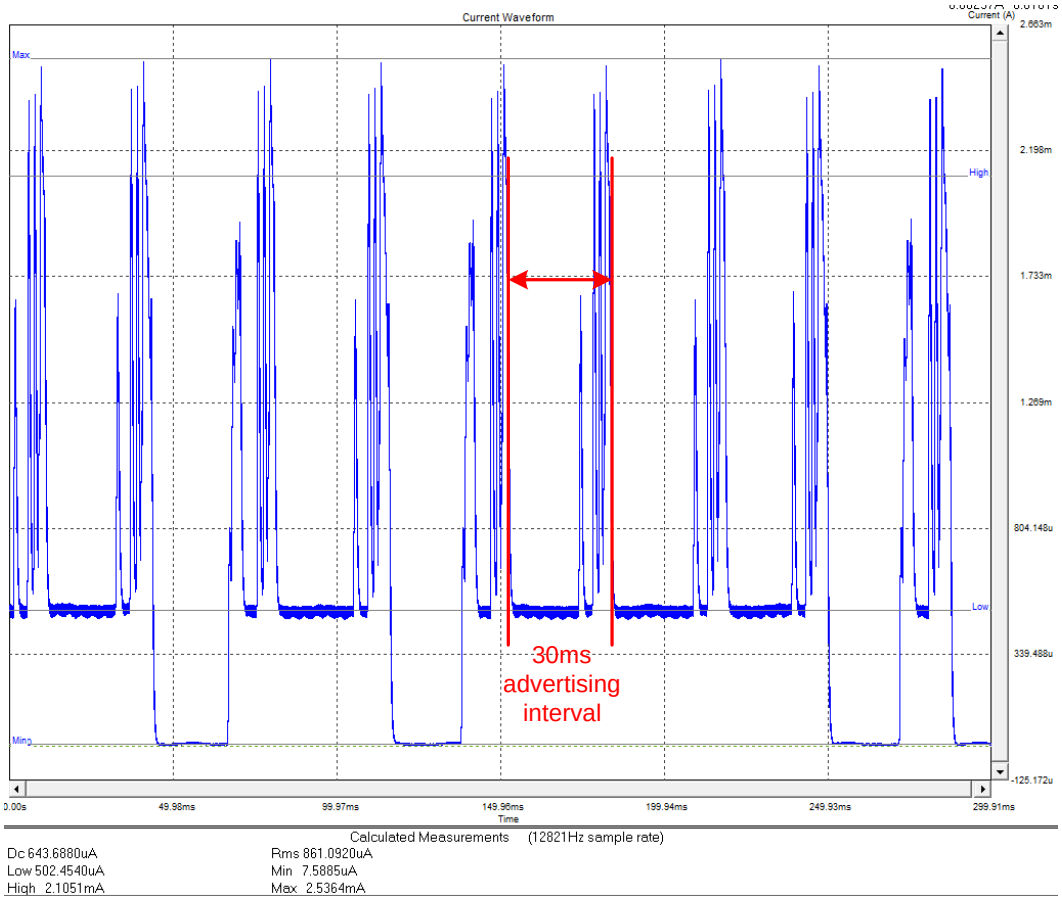


Figure 6-5 LE advertising (3 channels) with 30ms interval (V_{DD}= 3V)

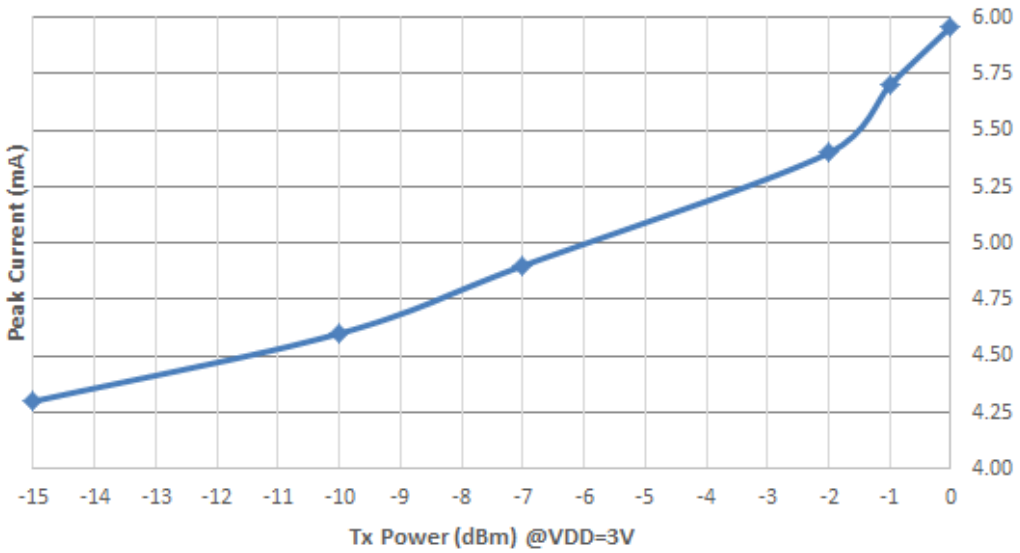


Figure 6-6 Peak Current (mA) vs Tx Power (CW) (V_{DD}= 3V)

7. RF Characteristics

7.1 RF transmission characteristics

Unless specified otherwise, the measurement is performed at normal condition @ TA = +25°C, VDD = 3.0 V.

Parameter	Condition	MIN.	TYP.	MAX.	BLE Specification	Unit
RF frequency range		2402		2480	2400 to 2483.5	MHz
RF Transmit Power	RF normal mode	-3	0	3	20	dBm
Transmitted output power setting	0, -1, -2, -7, -10, -15 dBm	-15		0		dBm
RF Power variation over BLE Channels			2			dB
Spurious radiation	30 to 1000MHz		-74		-36	dBm
	1 to 12.75 GHz		-42		-30	dBm
	1.8 to 1.9 GHz			-70	-47	dBm
	5.15GHz to 5.3GHz			-70	-47	dBm
Harmonics	2nd Harmonics			-40	-30	dBm
	3rd Harmonics			-45	-30	dBm
Drift rate			5		+/-25	KHz
Carrier Frequency Offset			40		150	KHz

Table 7-1 RF transmission characteristics

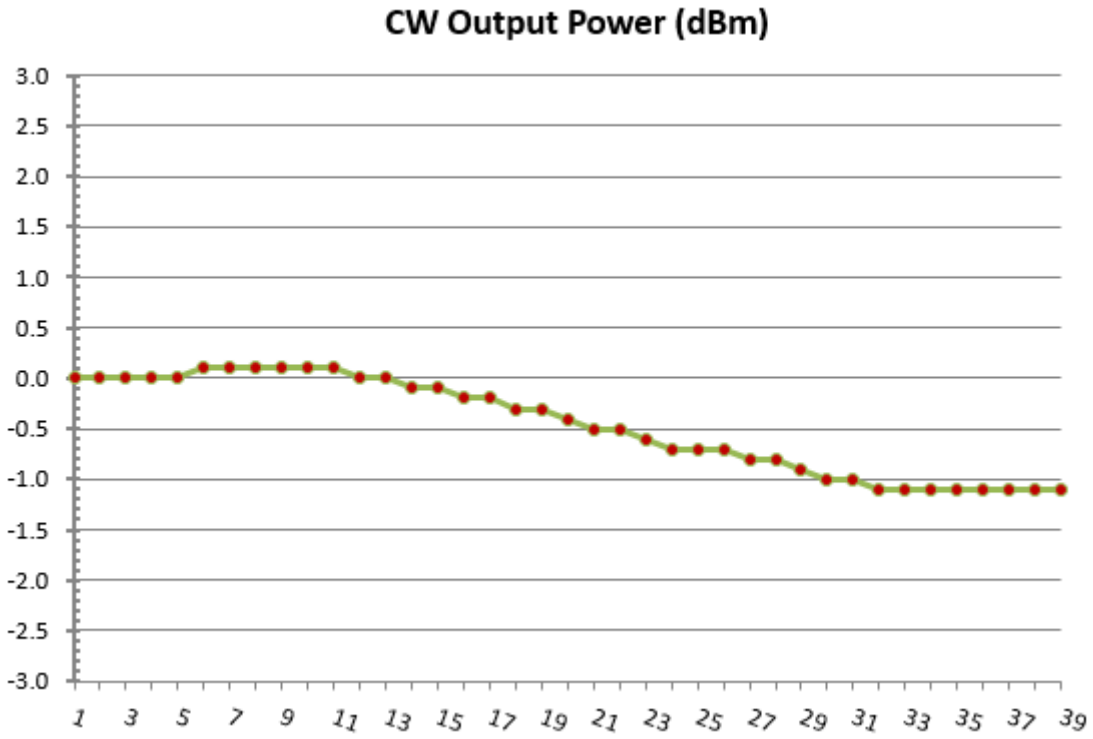


Figure 7-1 CW Output Power (dBm) over channels (0 to 39)

7.2 RF receiver characteristics

Unless specified otherwise, the measurement is performed at normal condition @ TA = +25°C, V_{DD}= 3.0 V.

Parameter	Condition	MIN.	TYP.	MAX.	BLE Specification	Unit
RF frequency range		2402		2480	2400 to 2483.5	MHz
RF sensetivity @ 30.8%	RF normal mode		-89		-70	dBm
RSSI		-3		3		dBm
RF sensetivity variation over BLE Channels	Ch0 to Ch39		2			dB

Table 7-2 RF receiver characteristics

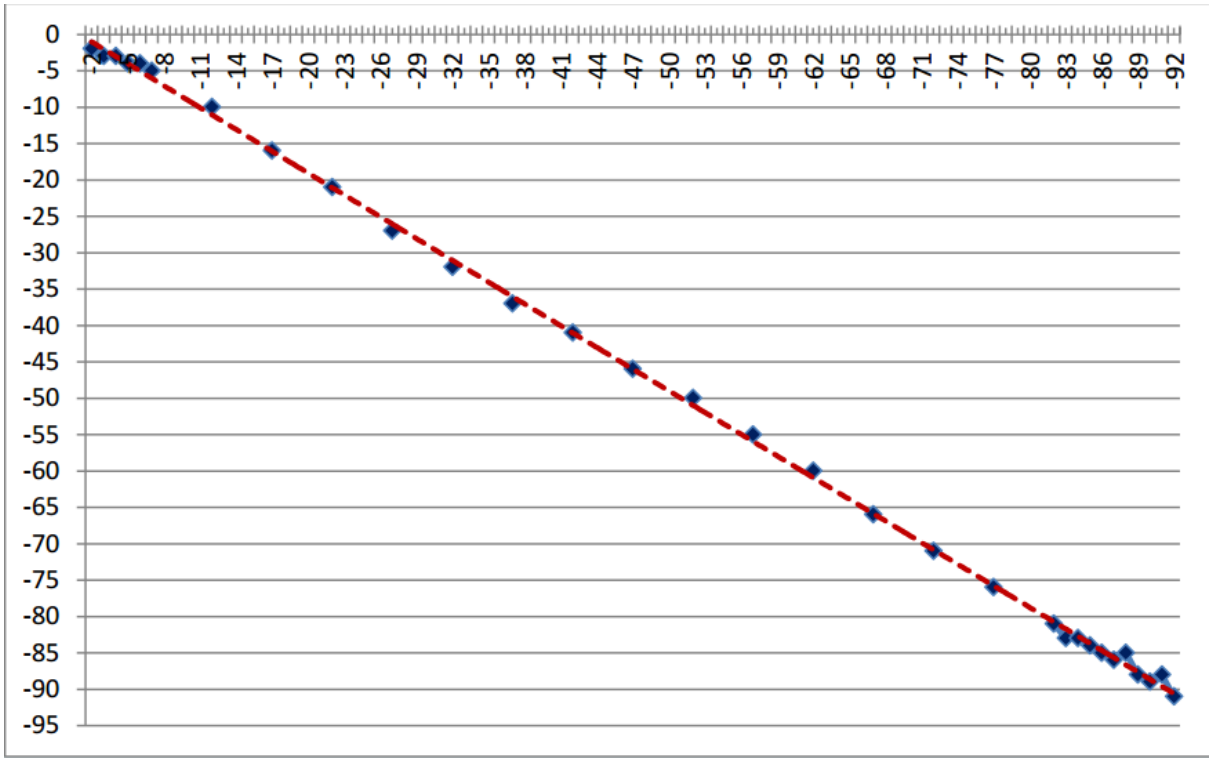
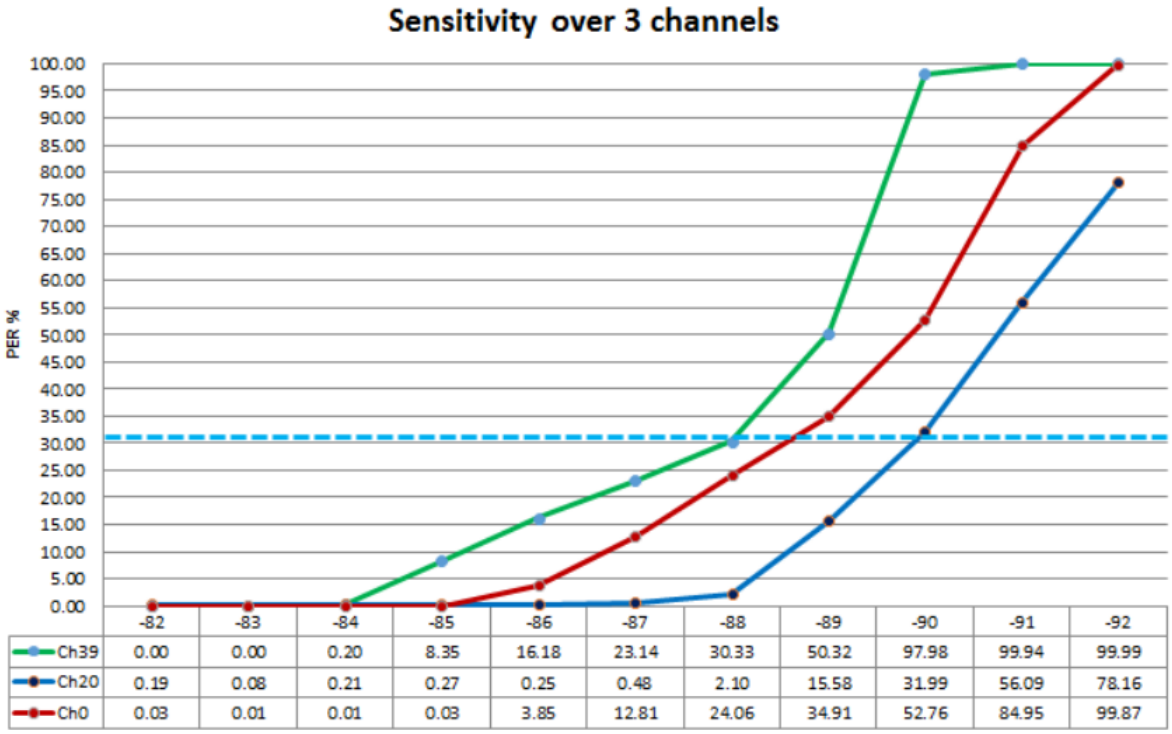


Figure 7-2 Channel 20 - Input Power (dBm) vs. RSSI reading



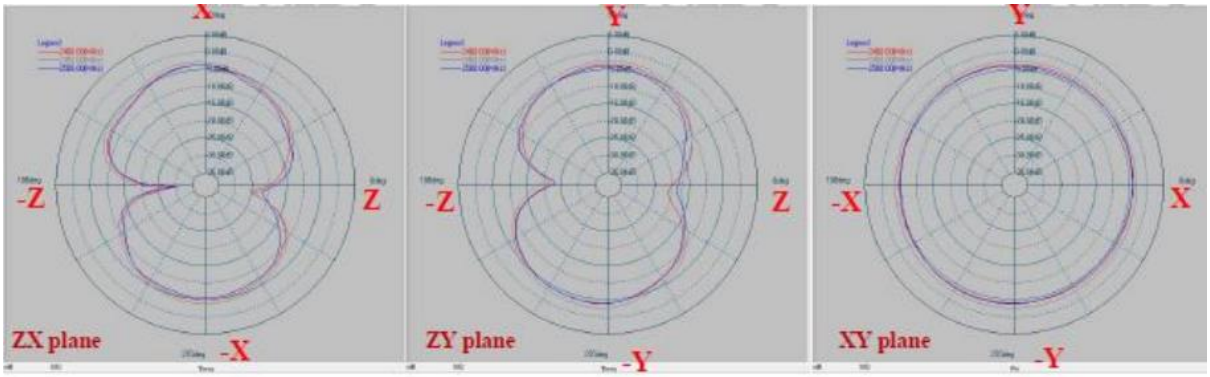
	-82	-83	-84	-85	-86	-87	-88	-89	-90	-91	-92
Ch39	0.00	0.00	0.20	8.35	16.18	23.14	30.33	50.32	97.98	99.94	99.99
Ch20	0.19	0.08	0.21	0.27	0.25	0.48	2.10	15.58	31.99	56.09	78.16
Ch0	0.03	0.01	0.01	0.03	3.85	12.81	24.06	34.91	52.76	84.95	99.87

Figure 7-3 Receiver sensitivity @RF Normal Mode over Low-Mid-High Channels

7.3 Antenna characteristics

The antenna is a standard monopole chip antenna. The radiation pattern is strongly dependent on the layout of end-product board. Typically the maximum radiated efficiency is around 30% subject to end-product board.

The 2-D radiated pattern below is measured on adaptor board, for illustration only.



	ZX plane		ZY plane		XY plane	
Frequency [MHz]	Max Value [dB]	Average [dB]	Max Value [dB]	Average [dB]	Max Value [dB]	Average [dB]
2400	-3.87	-7.56	-3.67	-7.07	-3.67	-4.22
2450	-2.83	-6.57	-2.59	-5.91	-2.62	-3.09
2500	-3.95	-8.00	-3.94	-7.37	-3.88	-4.42

Figure 7-4 2D Radiated Pattern on adaptor board

8. Design Guideline

BLE firmware refers to the set of software that includes the BLE stacks compliant to the Bluetooth Low Energy protocol. RTBTM01 BLE module has pre-loaded configuration software has the application running on a standalone MCU (hereafter referred to as Modem mode) although the alternative configuration - one has integrated the application on R5F11AG (hereafter referred to as Embedded mode) is also possible.

8.1 BLE Firmware Brief

RTBTM01 loads the Modem mode BLE firmware by default. For embedded mode BLE firmware, please contact RFCOM for assistance.

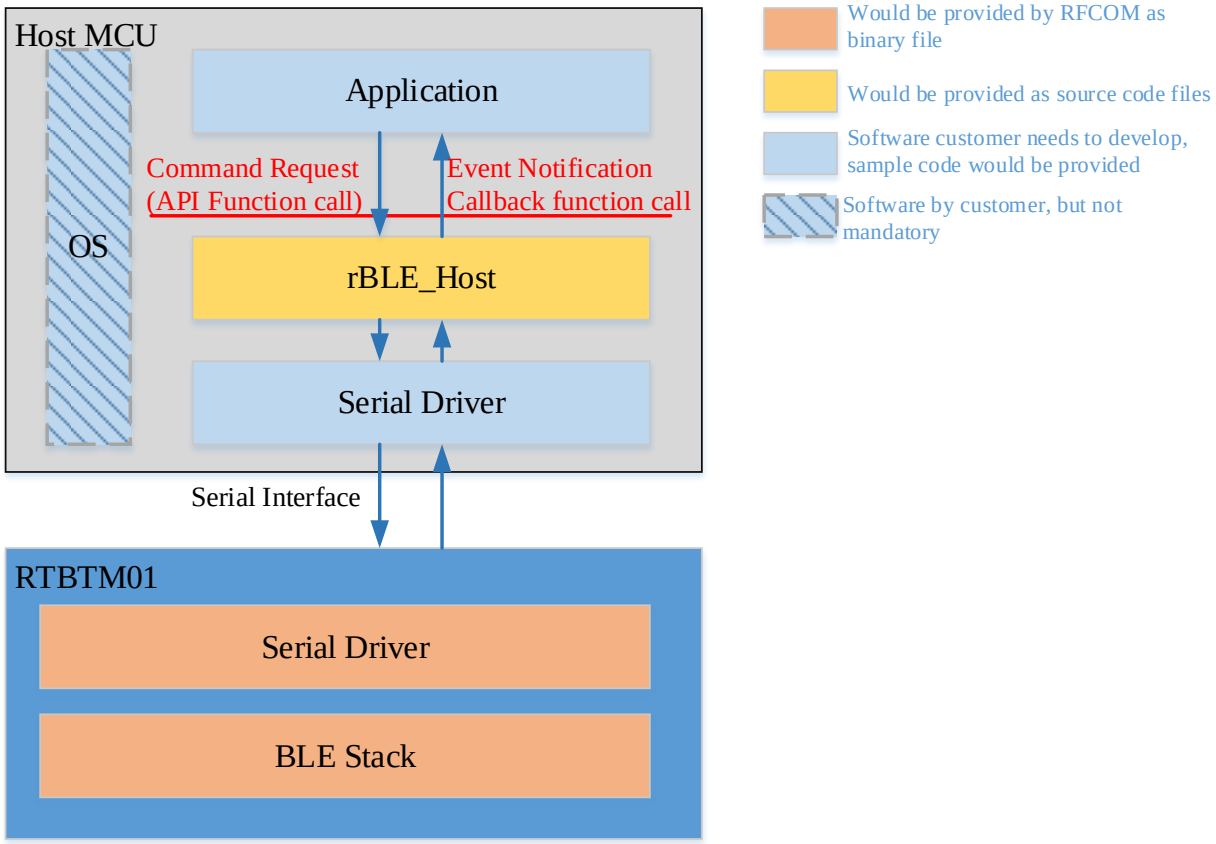


Figure 8-1 RTBTM01 and Host MCU

Figure 8-1 RTBTM01 and Host MCU demonstrates the use case of RTBTM01 module. Host MCU connects to RTBTM01 through serial interface. As promised, rBLE_Host source code would be provided to customer and together comes with sample code of the application. To have full control of the RTBTM01, customer just need customize the application, call rBLE API and handle the event notification reported from rBLE_Host. This could significantly reduce the development cost and speed to market.

For more software details, please refer to *"RTBTM01 Bluetooth module software user manual"*.

8.2 Serial Communication with RTBTM01

Software in Modem mode runs on two MCUS, the R5F11AG on RTBTM01 module and the host MCU. Host MCU and RTBTM01 communicates via serial interface (UART). The exchange data is encapsulated based on the RSCIP (Renesas Serial Communication Interface Protocol). The RSCIP is based on the SLIP (Serial Line Internet Protocol) defined in RFC 1055, and is extended. The RSCIP ensures the reliability and robustness of the data communication using error recovery capabilities by retransmission.

The RSCIP driver performs protocol processing and control of the serial driver. It's a part of the rBLE_Host software, whose source code would be provided to customer, refer to Figure 8-1 RTBTM01 and Host MCU.

For instruction how to use rBLE_Host, Refer to the Application Note*: Renesas rBLE Command Specification* for more details.

UART could be configured as follows, as shown in Figure 8-2 Settings of UART

.

Setting	Setting Value
Baud Rate	4,800bps ~ 250kbps[1]
Data length	8bit
Parity	None
Stop bit	1 bit
Flow control	None

Figure 8-2 Settings of UART

In UART connection, the Host MCU and the RTBTM01 communicate using two signal lines (TxD and RxD). If the baud rate is greater than 4800bps, the Sleep function is disabled to reduce power consumption. There is no handshake operation.

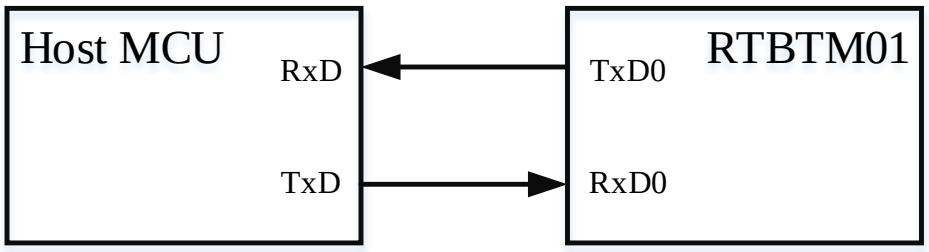


Figure 8-3 2-wire UART Connection

RTBTM01 Pin Name	Direction	Function
TxD0	BLE -> Host	Serial output data signal
RxD0	Host -> BLE	Serial input data signal

[1] If you select the UART connection method and set the baud rate greater than 4,800 bps, the Sleep function is disabled. The Sleep function is always enabled in other connection method. The Sleep function realizes the low current consumption of BLE MCU

Figure 8-4 2-wire UART Pin Function

9. Mounting Requirements & Parameters

9.1 Mounting Requirement

RTBTM01 is a sensitive RF module. While using default on-module antenna, it'd better to be mounted at the corner of the application board and reserve some keep out space to the components on the application board. The RTBTM01 antenna is optimized for application board thickness of 1.0 mm. Do not place any metal (traces, components, battery etc.) on all layers within the keep-out area of the antenna. Connect all the GND pins directly to a solid GND plane and punch the GND vias on application board as close to the module GND pins as possible. Use good layout practices to avoid any excessive noise coupling to signal lines or supply voltage lines.

The figure below illustrates how to mount the RTBTM01 module. **Improper mounting will decrease the RF performance dramatically.**

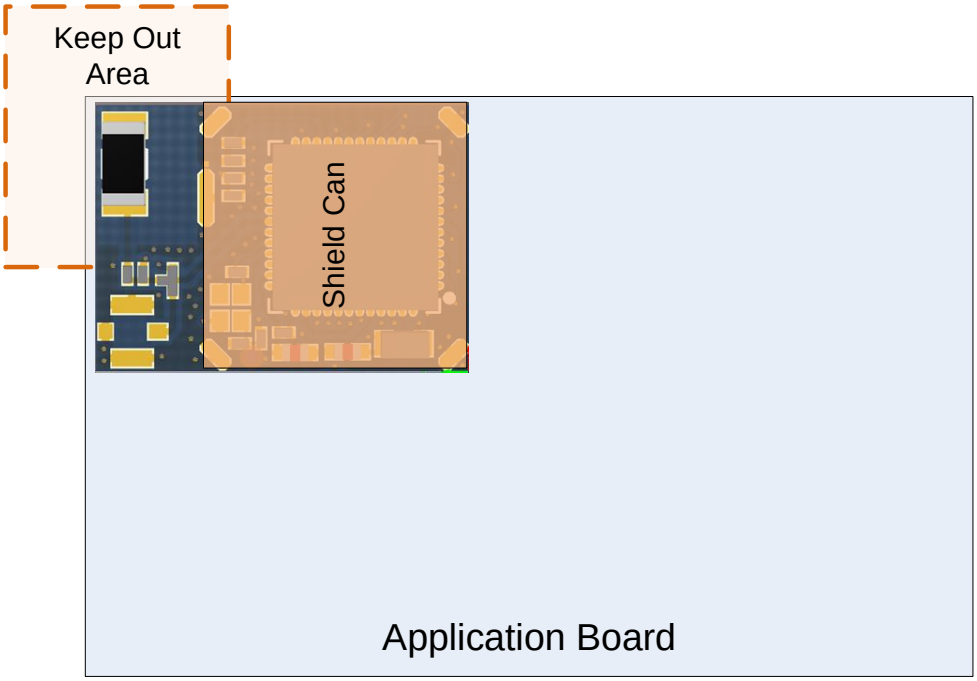


Figure 9-1 RTBTM01 Mounting on Application Board

9.2 RTBTM01 Physical Dimension

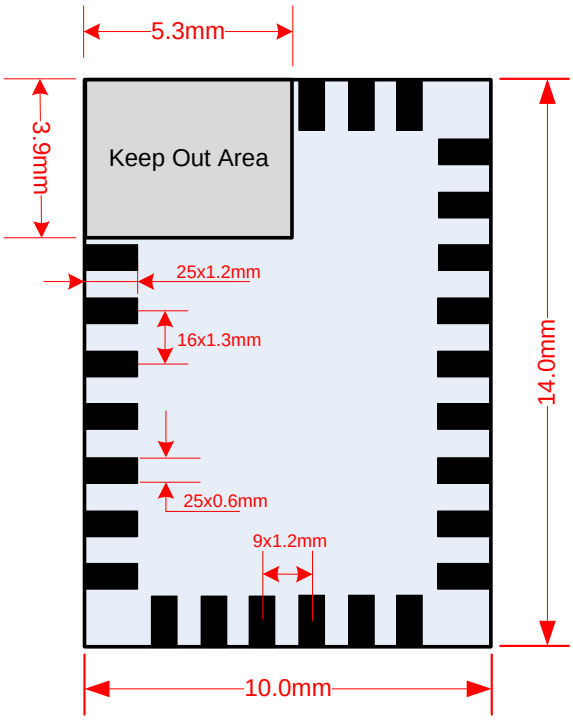


Figure 9-2 RTBTM01 Bottom View

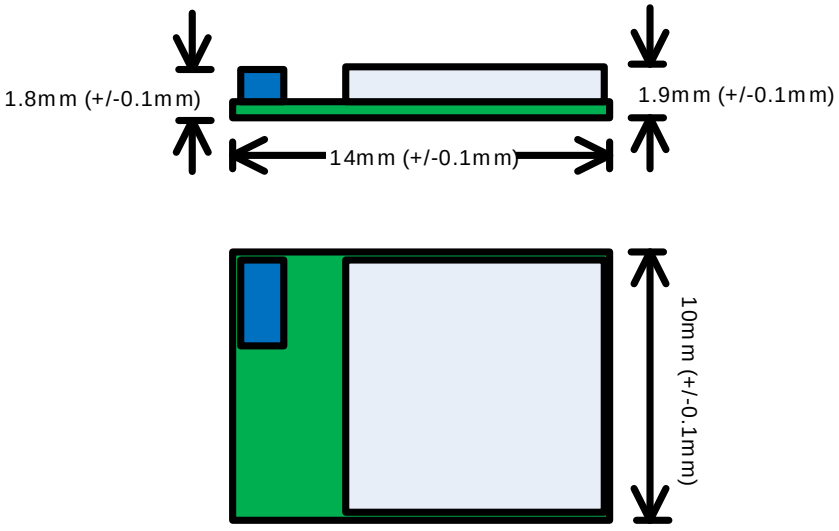


Figure 9-3 External Dimension

9.3 Recommended Land Pattern

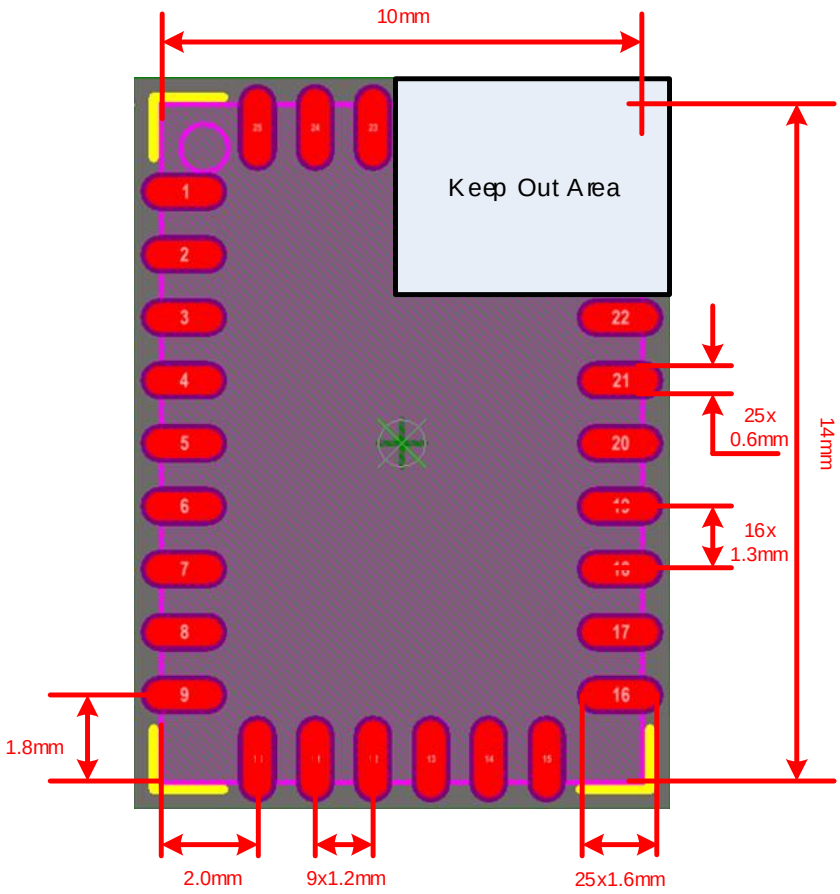


Figure 9-4 RTBTM01 Recommended Land Pattern

9.4 Soldering Profile

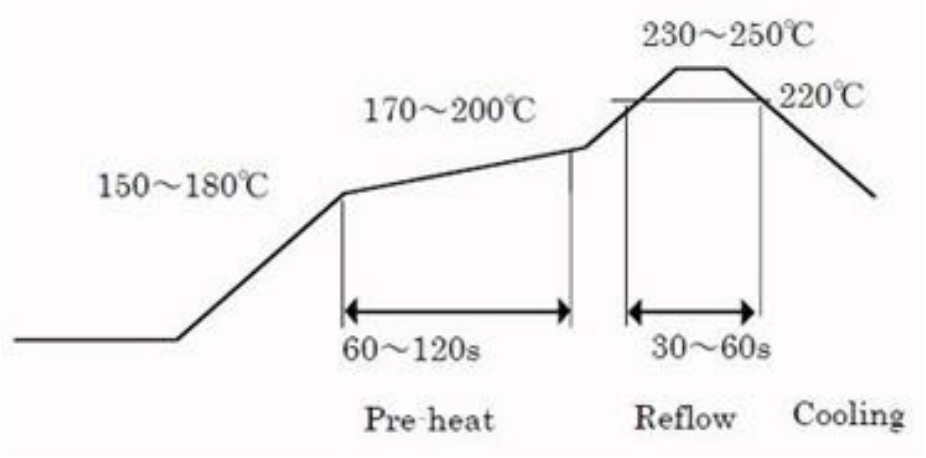
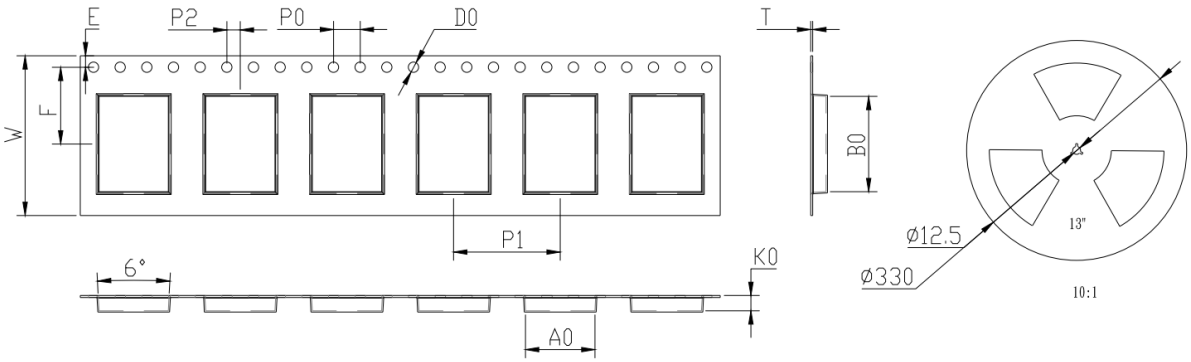


Figure 9-5 Recommendable Reflow Profile

	Standard soldering profile	Time
Pre-heating	150°C to 180°C	60s to 120s
Heating	220°C above	30s to 60s
Peak temperature	235°C to 245°C, Absolute max reflow temperature is 260ºC	5s
Remark	Please keep the temperature of the re-flow soldering as specified. (Please do not add temperature of more than 260℃)	

10. Tape and Reel Packaging

The reel is 330mm in diameter and each reel contains 500/1900 modules.



未標公差均為±0.1mm

						D_0 ⓑ	D_1 ⓑ	P_0 Ⓐ	P_2 Ⓐ	E Ⓐ
						$1.50^{+0.10}_{-0.00}$	$1.52^{+0.10}_{-0.00}$	$4.00^{+0.10}_{-0.10}$	$2.00^{+0.10}_{-0.10}$	$1.75^{+0.10}_{-0.10}$
ITEM	W ⓑ	A_0 Ⓐ	A_1 Ⓐ	B_0 Ⓐ	B_1 Ⓐ	K_0 ⓒ	K_1 ⓒ	P_1 Ⓐ	F ⓘ	T ⓑ
DIM	$24.0^{+0.30}_{-0.30}$	10.4±0.1	±0.1	14.3±0.1	±0.1	2.30±0.1	±0.1	16.0 ±0.1	11.50±0.1	$0.30^{+0.05}_{-0.05}$
ALTERNATE										

Figure 10-1 Taper and Reel Specification

11. Certification

11.1 FCC

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

(1) this device may not cause harmful interference, and

(2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications to this unit not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
—Reorient or relocate the receiving antenna.
—Increase the separation between the equipment and receiver.
—Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
—Consult the dealer or an experienced radio/TV technician for help.

Integrator is reminded to assure that these installation instructions will not be made available to the end-user of the final host device.

The final host device, into which this RF Module is integrated" has to be labelled with an auxilliary lable stating the FCC ID of the RF Module, such as "Contains FCC ID: 2AHUYBM01".

the Integrator will be responsible to satisfy SAR/ RF Exposure requirements

12. Ordering Information

Number Code	Hardware Revision			On-chip Firmware
RTBTM01-A1-10	Antenna	Flash Memory	Data Flash Memory	default modem firmware
	internal	256KB	8 KB	

13. Contact Information

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