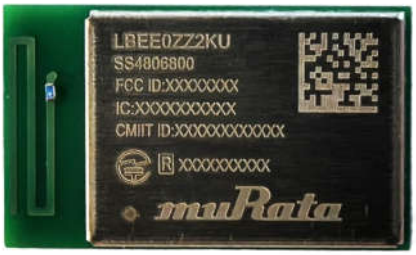
Datasheet

Type 2KU Hostless Wi-Fi® 6 & Bluetooth® 5.4 LE Combo Module

Wi-Fi 6 & BLE MCU for Hostless 802.11 b/g/n/ax and Bluetooth 5.4 Low Energy Combo Module - Rev. E

- Design Name: Type 2KU
- P/N: LBEE0ZZ2KU-001



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About This Document

Type 2KU is Murata's low-cost 2.4 GHz IoT Wi-Fi 6 and Bluetooth LE hostless module, it integrates wireless connectivity and network protocol stacks, offering ultra-low power consumption and making it an ideal choice for IoT applications. This datasheet describes **Type 2KU** module in detail.

Please be aware that an important notice concerning availability, standard warranty and use in critical applications of Murata products and disclaimers thereto appears at the end of this specification sheet.

Audience & Purpose

Intended audience includes any customer looking to integrate this module into their product, specifically RF, hardware, software, and systems engineers.

Document Conventions

Table 1 describes the document conventions.

Table 1: Document Conventions

Conventions	Description
	Warning Note Indicates very important note. Users are strongly recommended to review.
	Info Note Intended for informational purposes. Users should review.
	Menu Reference Indicates menu navigation instructions. **Example**: Insert➔Tables➔Quick Tables➔Save Selection to Gallery
	External Hyperlink This symbol indicates a hyperlink to an external document or website. **Example**: Embedded Artists AB Click on the text to open the external link.
	Internal Hyperlink This symbol indicates a hyperlink within the document. **Example**: Scope Click on the text to open the link.
`Console input/output or code snippet`	**Console I/O or Code Snippet** This text ***Style*** denotes console input/output or a code snippet.
`# Console I/O comment` `// Code snippet comment`	**Console I/O or Code Snippet Comment** This text ***Style*** denotes a console input/output or code snippet comment. • Console I/O comment (preceded by "#") is for informational purposes only and does not denote actual console input/output. • Code Snippet comment (preceded by "//") may exist in the original code.

1 Scope

This product specification is applied to the IEEE 802.11b/g/n/ax and Bluetooth 5.4 Low Energy module used for consumer applications.

2 Key Features

- Wi-Fi & Bluetooth Low Energy MCU at up to 320MHz inside
  - 640 KB RAM
  - 4 MB Flash
- Compliant with IEEE 802.11b/g/n/ax 1x1
- Compliant with Bluetooth 5.4 Low Energy, 1 Mbps, 2 Mbps, and long-range
- Integrates the IoT Platform Security Suite (IPSS) for cryptography and system security control.
- Ultra-low current consumption for active mode RX
- Interface: UART, SPI, I2C, SDIO, GPIOs
- Reference Clock: Internal Xtal
- Antenna: Integrated PCB antenna
- Certification: FCC/ISED/CE/MIC/SRRC/KC/WPC
- Dimensions: 15.0 x 9.0 x 2.2(Max.) mm
- Package: LGA
- MSL: 3
- Weight: 0.5g
- RoHS compliant

This module is delivered with pre-programmed test FW for RF evaluation.

3 Ordering Information

Table 2 shows the part number and composition for **Type 2KU** module.

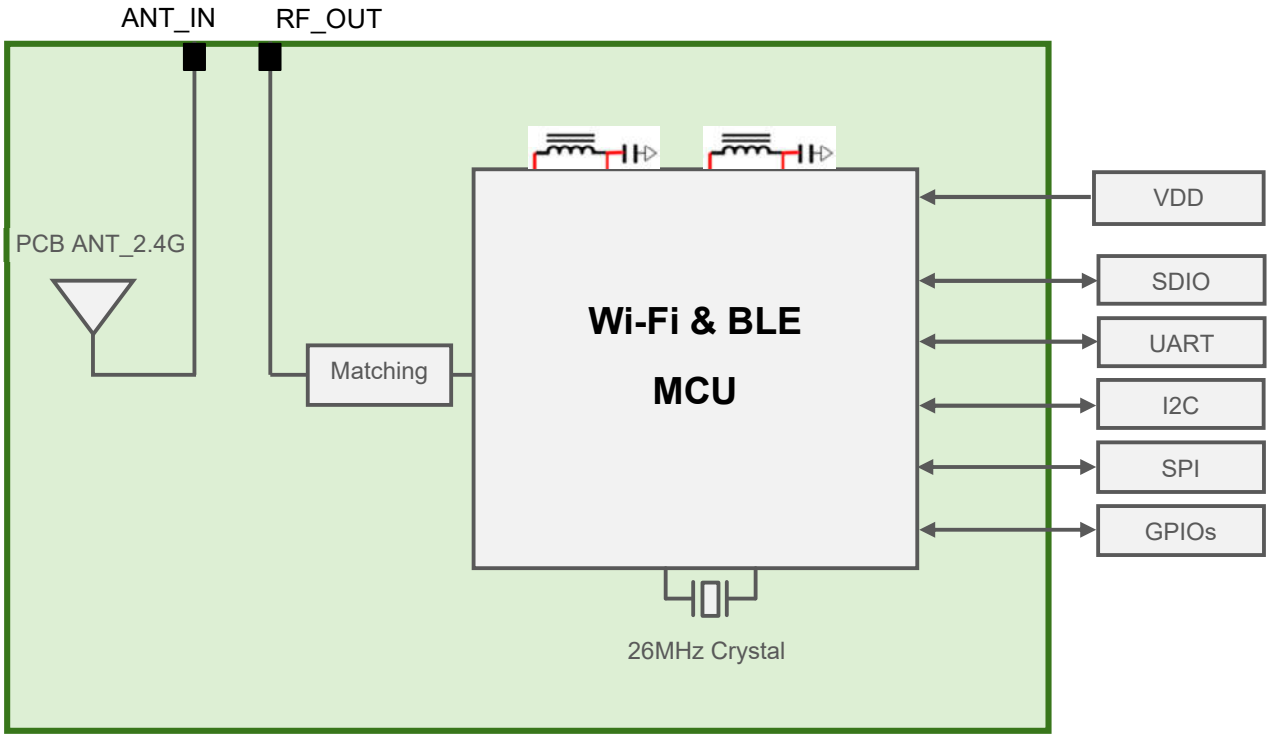
Table 2: Ordering Part Number

Ordering Part Number	Description
LBEE0ZZ2KU-001	Module order
LBEE0ZZ2KU-001SMP	Sample module order (If module samples are not available through distribution, contact Murata referencing this part number)
LBEE0ZZ2KU-001EVB	Murata **Type 2KU** evaluation board (contact Murata as this is special order item)

4 Block Diagram

Figure 1 shows the block diagram.

Figure 1: Block Diagram



5 Certification information

5.1 Radio Certification

Table 3 shows the radio certification information.

Table 3: Radio Certification

Country	ID
USA (FCC)	VPYLBEE0ZZ2KU
Canada (ISED)	772C-LBEE0ZZ2KU
Europe (CE)	N/A
Japan (MIC)	TBD
China (SRRC)	25J99C7RC002
Korea (KC)	TBD
India (WPC)	TBD

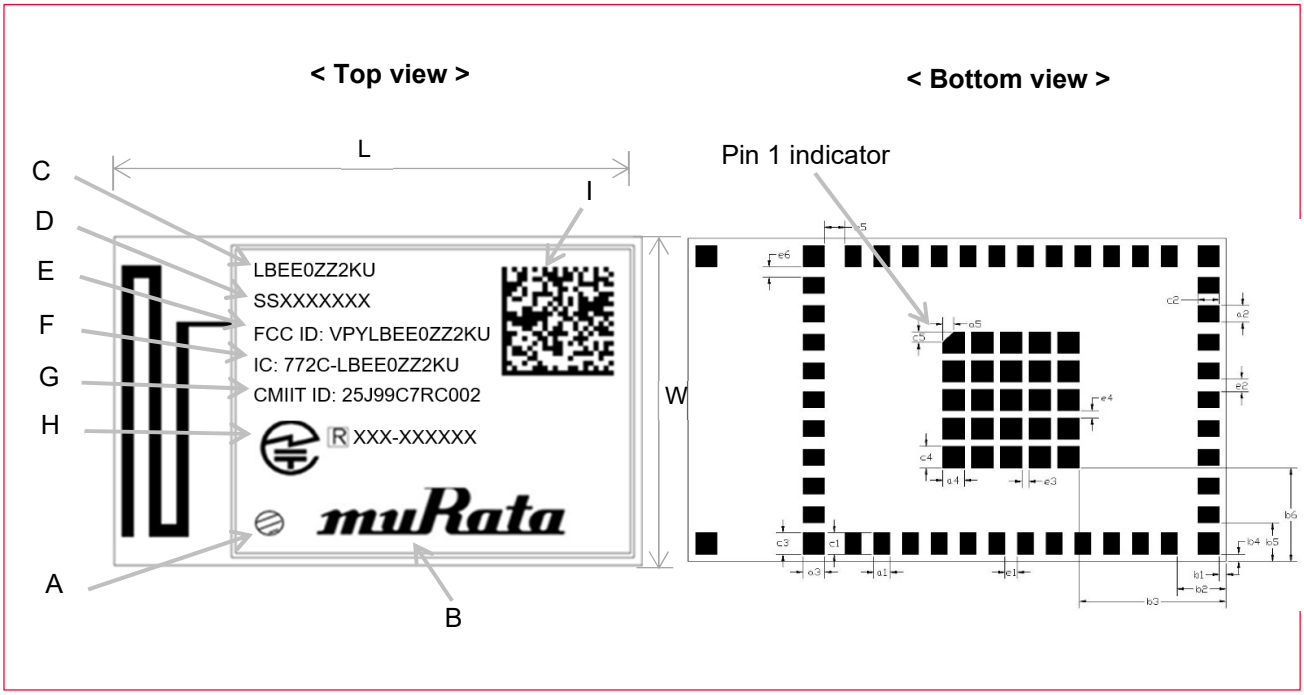
5.2 Bluetooth Qualification

- DN: TBD
- Set Bluetooth Tx Power to Class 1.5.
- For supported Bluetooth functions, refer to Bluetooth SIG site.

6 Dimensions, Marking and Terminal Configurations

This section describes the dimensions, marking and terminal configuration for Type 2KU module as shown in **Figure 2.**

Figure 2: Dimensions, Marking and Terminal Configurations



错误!未找到引用源。 describes the **Type 2KU** dimensions in millimeters (mm).

Table 4: Dimensions

Mark	Dimensions (mm)	Mark	Dimensions (mm)	Mark	Dimensions (mm)	Mark	Dimensions (mm)
L	15.0 ± 0.1	W	9.0 ± 0.1	T	2.2 max	a1	0.45± 0.1
a2	0.45± 0.1	a3	0.6 ± 0.1	a4	0.6 ± 0.1	a5	0.3 ± 0.1
b1	0.2 ± 0.1	b2	1.375 ± 0.1	b3	4.1 ± 0.1	b4	0.2 ± 0.1
b5	1.075 ± 0.1	b6	2.6 ± 0.1	c1	0.6 ± 0.1	c2	0.6 ± 0.1
c3	0.6 ± 0.1	c4	0.6 ± 0.1	c5	0.3 ± 0.1	e1	0.35 ± 0.1
e2	0.35 ± 0.1	e3	0.2 ± 0.1	e4	0.2± 0.1	e5	0.575 ± 0.1
e6	0.275± 0.1						

错误!未找到引用源。 describes the **Type 2KU** markings.

Table 5: Label Markings

Marking	Meaning
A	Pin 1 indicator
B	Murata logo
C	Model Name P/N
D	Inspection code
D	FCC certification ID
E	ISED certification ID
G	SRRC certification ID
H	MIC certification ID
I	2D code

7 Module Pin Descriptions

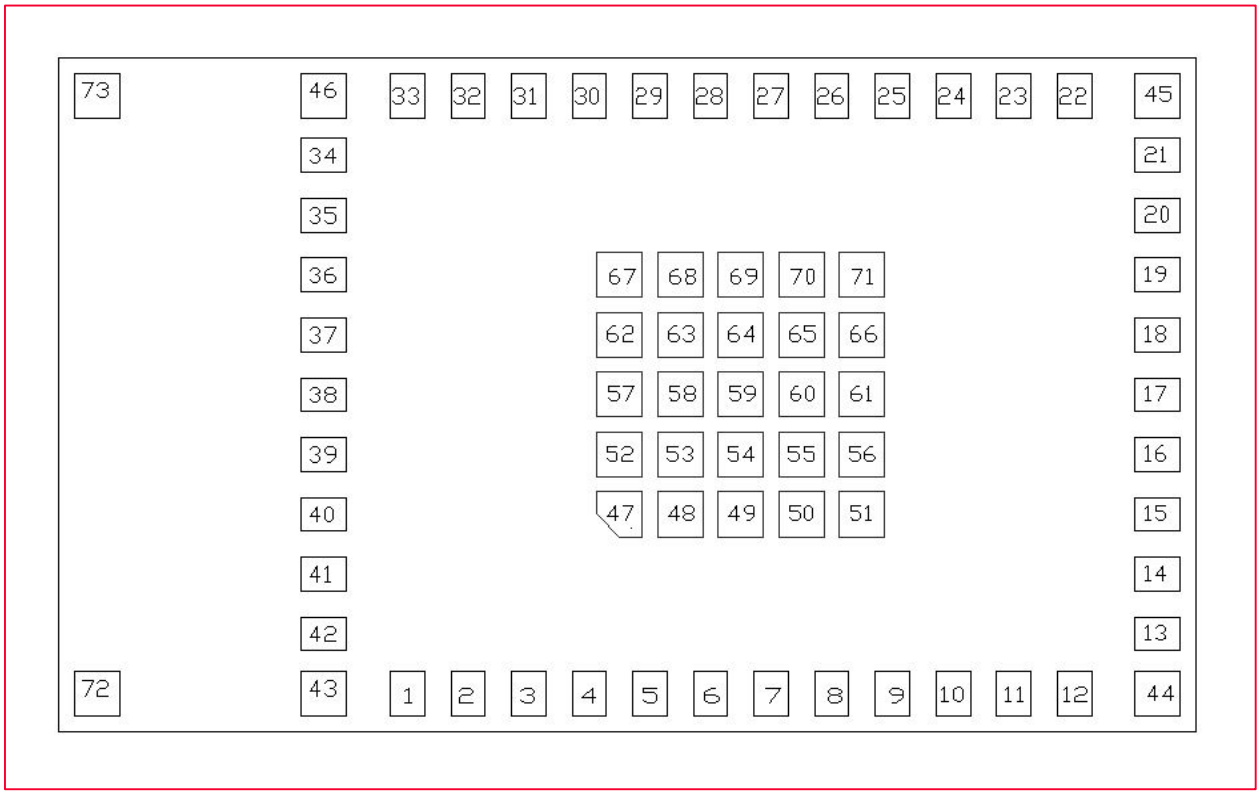
This section has the Pin descriptions of **Type 2KU** and pin assignments layout descriptions.

7.1 Module Pin Layout (Top View)

The pin assignments (Top view) are shown in **Figure 3**.

Figure 3: Pin Assignments

< Top View >



7.2 Pin Descriptions

错误!未找到引用源。 describes **Type 2KU** pins.

Table 6: Pin Descriptions

No.	Pin Name	Description	Type	Connection to IC pin No.	Connected IC Pin Function
1	P48	GPIO48	I/O	10	• GPIO48
2	P24	GPIO24	I/O	11	• GPIO24 • LPO_CLK: 32 kHz clock output • PWMG0_PWM4 • ADC2
3	P25	GPIO25	I/O	12	• GPIO25 • IRDA: infrared data • PWMG0_PWM5 • ADC1
4	P28	GPIO28	I/O	13	• GPIO28 • I2S_MCLK • ADC4 • TOUCH2: touch sensing I/O
5	P32	GPIO32	I/O	14	• GPIO32 • PWMG1_PWM0 • TOUCH6: touch sensing I/O
6	P34	GPIO34	I/O	15	• GPIO34 • PWMG1_PWM2 • TOUCH8: touch sensing I/O
7	P36	GPIO36	I/O	16	• GPIO36 • PWMG1_PWM4 • TOUCH10: touch sensing I/O • SPI0_MISO
8	UART1_RX	UART1 serial input. For communication.	I/O	17	• GPIO1 • UART1_RX • I2C1_SDA • SWDIO • ADC13 • LIN_RXD: receive data input
9	UART1_TX	UART1 serial output. For communication.	I/O	18	• GPIO0 • UART1_TX • I2C1_SCL • SWCLK • ADC12 • LIN_TXD: transmit data output
10	UART0_TX	UART0 serial output. For firmware download and communication	I/O	19	• GPIO11 • DL_UART_TX: UART flash download transmit data output • UART0_TX • SDIO_DATA3
11	UART0_RX	UART0 serial input. For firmware download and communication	I/O	20	• GPIO10 • DL_UART_RX: UART flash download receive data input • UART0_RX • SDIO_DATA2
12	P12	GPIO12	I/O	21	• GPIO12 • UART0_RTS

No.	Pin Name	Description	Type	Connection to IC pin No.	Connected IC Pin Function
					• TOUCH0: touch sensing I/O • ADC14
13	P13	GPIO13	I/O	22	• GPIO13 • UART0_CTS • TOUCH1: touch sensing I/O • ADC15
14	GND	Ground	GND	-	-
15	GND	Ground	GND	-	-
16	GND	Ground	GND	-	-
17	CEN	Enable, active high	Analog input	26	• CEN: Chip enable, active high
18	GND	Ground	GND	-	-
19	GND	Ground	GND	-	-
20	P14	GPIO14	I/O	33	• GPIO14 • SDIO_CLK • SPI0_SCK • BT_ANT0: Bluetooth antenna selection • I2C1_SCL
21	P15	GPIO15	I/O	34	• GPIO15 • SDIO_CMD • SPI0_CSN • BT_ANT1: Bluetooth antenna selection • I2C1_SDA
22	VBAT	Power supply for inside Wi-Fi & BLE MCU chip	Power	31	• Chip power supply
23	GND	Ground	GND	-	-
24	P16	GPIO16	I/O	35	• GPIO16 • SDIO_DATA0 • SPI0_MOSI • BT_ANT2: Bluetooth antenna selection
25	P17	GPIO17	I/O	36	• GPIO17 • SDIO_DATA1 • SPI0_MISO • BT_ANT3: Bluetooth antenna selection
26	P18	GPIO18	I/O	37	• GPIO18 • SDIO_DATA2 • PWMG0_PWM0
27	P19	GPIO19	I/O	38	• GPIO19 • SDIO_DATA3 • PWMG0_PWM1
28	UART2_TX	UART2 serial output	I/O	39	• GPIO41 • UART2_TX • LIN_TXD
29	UART2_RX	UART2 serial input	I/O	40	• GPIO40 • UART2_RX • LIN_RXD
30	GND	Ground	GND	-	-

No.	Pin Name	Description	Type	Connection to IC pin No.	Connected IC Pin Function
31	RF_OUT	2.4GHz RF signal port	RF	4	• ANT: 2.4 GHz RF signal port
32	GND	Ground	GND	-	-
33	ANT_IN	Embedded 2.4GHz PCB antenna port	RF	-	-
34	GND	Ground	GND	-	-
35	GND	Ground	GND	-	-
36	GND	Ground	GND	-	-
37	GND	Ground	GND	-	-
38	GND	Ground	GND	-	-
39	GND	Ground	GND	-	-
40	GND	Ground	GND	-	-
41	GND	Ground	GND	-	-
42	GND	Ground	GND	-	-
43	GND	Ground	GND	-	-
44	GND	Ground	GND	-	-
45	GND	Ground	GND	-	-
46	GND	Ground	GND	-	-
47~71	GND	Center ground plate	GND	-	-
72	NC	No Connection	-	-	-
73	NC	No Connection	-	-	-

8 Absolute Maximum Rating

Figure 14: Reflow Soldering Standard Conditions (Example)shows the absolute maximum ratings of **Type 2KU** module.

Table 7: Absolute Maximum Ratings

Parameter		Minimum	Maximum	Unit
Storage Temperature		-40	125	℃
Supply Voltage	VBAT	-0.3	4.0	V

Stresses in excess of the absolute ratings may cause permanent damage. Functional operation is not implied under these conditions. Exposure to absolute ratings for extended periods of time may adversely affect reliability. No damage assuming only one parameter is set at limit at a time with all other parameters are set within operating condition.

9 Operating Conditions

Table 8: Operating Conditions lists the operating conditions for **Type 2KU**.

Table 8: Operating Conditions

Parameter		Minimum	Typical	Maximum	Unit
Operating Temperature		-40	25	+85	℃
Supply Voltage	VBAT	2.7	3.3	3.6	V

This module is not approved for use when being powered by AC power lines, either directly or indirectly through another device.

10 Power-On Sequence

错误!未找到引用源。 shows the power-on sequence.

Figure 4: Power-On Sequence

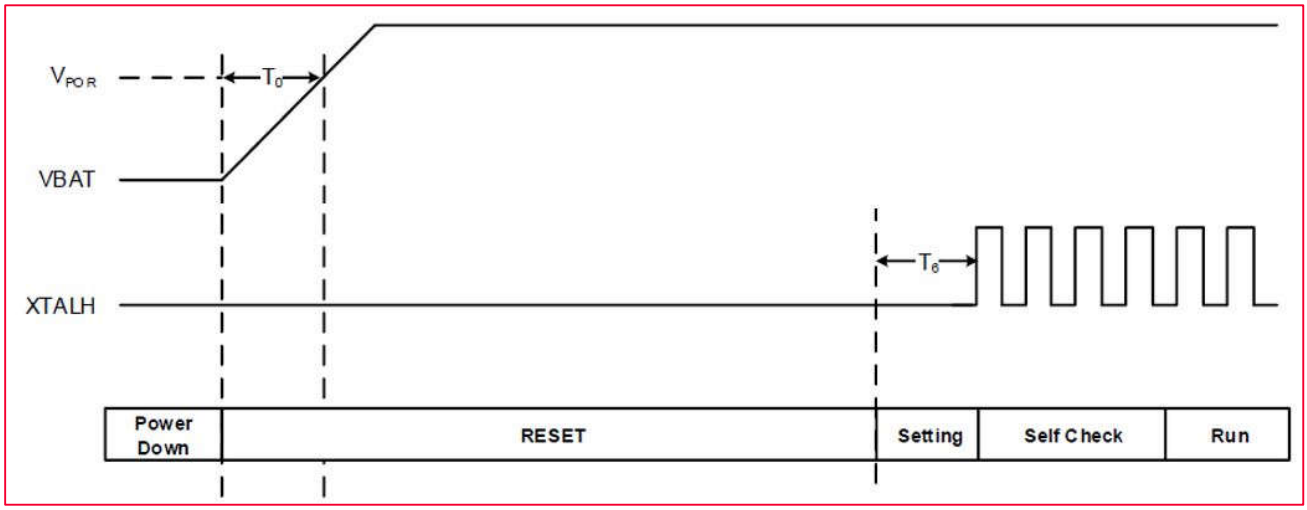


Table 9: Timing Parameters of Power-On Sequence

Parameter	Description	Min.	Typ.	Max.	Unit
V_{POR}	VBAT POR threshold	-	1.95	-	V
T_0	VBAT ready time	200	-	-	µs
T_6	XTALH stable time	-	240	500	µs

11 Functional Description

11.1 Power Management

The Wi-Fi & BLE MCU chip supports three low-power modes except active mode, namely shutdown mode, deep sleep mode, and sleep mode, where shutdown mode has the lowest power consumption.

- **Shutdown Mode:** All circuits are turned off. A high level on the CEN pin will bring the system to active mode.
- **Deep Sleep Mode:** All circuits are powered down except the always-on (AON) logic. GPIO interrupts, RTC interrupts, or interrupts triggered by touch sensing I/O pins can power up the system again. The retention register holds its content.
- **Sleep Mode:** The MCU and all digital logic stop their clocks, and their power supply decreases to a much lower retention voltage, which results in a much lower current. GPIO interrupts, RTC interrupts, interrupts triggered by touch sensing I/O pins, or interrupts triggered by Wi-Fi/Bluetooth MAC low-power counters can bring the system back to active mode with normal voltage.
- **Active Mode:** The MCU is active, and all peripherals are available.

11.2 Clock Management

The primary clock sources available in the Wi-Fi & BLE MCU chip of **Type 2KU** are as follows:

- High-frequency clocks
  - 26 MHz crystal oscillator which derived from a 26MHz crystal inside of module. It outputs clock signal XTALH.
  - 26–360 MHz internal digitally controlled oscillator (DCO): it outputs clock signal CLK_DCO.
  - Digital PLL (DPLL): it generates 320 MHz clock CLK_320M and 480 MHz clock CLK_480M.
- Low-frequency clock
  - 32 kHz internal ring oscillator (ROSC): it outputs clock signal CLK_ROSC.
- Audio clock
  - Audio PLL (APLL): its default frequency is 98.304 MHz, and it outputs clock signal CLK_APLL.

The system generates a low-power clock source LPO_CLK for standby. The LPO_CLK can be selected from the following clocks:

- 32 kHz clock signal derived from 26 MHz crystal oscillator.
- 32 kHz internal oscillator ROSC.

The Wi-Fi & BLE MCU chip of **Type 2KU** also has clock output capability to output clock signals to external components. GPIOs can output the following clock signals:

- LPO_CLK: low-power LPO_CLK clock.
- I2S_MCLK: reference clock for external audio codec, derived from APLL.
- CLK_AUXS: reference clock for external CMOS image sensor (CIS).

11.3 Reset

A reset can be triggered by the following sources:

- Power-on reset
- Brown-out reset
- Watchdog reset
- Wake-up from shutdown mode or deep sleep mode

Power-on reset, brown-out reset, and AON watchdog (AWDT) reset have the same reset effect on all domains, except for the always-on logic. Any of these three resets can reset the whole chip to its initial state. The always-on logic has a 64-bit timer and a 32-bit retention register, which can only be reset to initial values by a power-on reset or brown-out reset. The main domain watchdog (DWDT) reset resets the digital domain and can be configured to reset the analog and AON domains.

Wake-up from shutdown mode triggers the whole system reset, while wake-up from deep sleep mode triggers the reset of the digital domain.

Type 2KU CEN pin is Wi-Fi & BLE MCU chip enable pin which is active high. There is no pull-up resistor for CEN pin inside module, so external pull-up outside module is needed during normal use.. When it goes to low, all circuits are turned off and the chip enter the shutdown mode. A high level on the CEN pin will take the system to active mode.

11.4 General-Purpose I/Os (GPIO)

The inside Wi-Fi & BLE MCU chip has up to 21 GPIOs, which can be configured as either input or output. Most GPIOs are shared with alternate functions.

The main features of GPIOs include:

- Push-pull
- Internal pull-up/down resistors
- Configurable drive strength
- Alternate function
- Interrupt generation:
  - High or low level
  - Rising or falling edge

The requirements are shown in **Table 10.**

Table 10: Digital I/O Requirements

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
VIH	High-level input voltage	-	0.7 VIO	-	VIO + 0.3	V
VIL	Low-level input voltage	-	-0.3	-	0.3 VIO	V
VOH	High-level output voltage	-	0.9 VIO	-	-	V
VOL	Low-level output voltage	-	-	-	0.1 VIO	V
IDRV	I/O output drive strength	-	5	-	20	mA
RPU	Weak pull-up resistor	-	-	40	-	kΩ
RPD	Weak pull-down resistor	-	-	44	-	kΩ

11.5 SPI Interface

The inside Wi-Fi & BLE MCU chip integrates an SPI interface that can operate in master or slave mode. The SPI interface allows a clock frequency up to 40 MHz in both master mode and slave mode.

The SPI interface supports the following features:

- 4-wire or 3-wire full-duplex synchronous communication
- Configurable 8-bit or 16-bit data width
- Programmable clock polarity and phase
- Programmable data order with MSB-first or LSB-first shifting
- Embedded 64-depth RX FIFO and 64-depth TX FIFO with DMA capability

11.6 UART Interfaces

The inside Wi-Fi & BLE MCU chip includes three Universal Asynchronous Receiver/Transmitter (UART) interfaces, which support full-duplex, asynchronous serial communication at a baud rate up to 6 Mbps.

The UART interfaces offer the features below:

- Configurable data length (5, 6, 7, or 8 bit)
- Even, odd, or none parity check
- Programmable stop bits (1 or 2 bits)
- Each UART embeds a 128-byte TX FIFO and a 128-byte RX FIFO. FIFO mode is disabled by default and can be enabled by software.
- Hardware flow control with RTS and CTS signals (UART0)
- Flash download (UART0)
- Programmable digital filter

11.7 SDIO Interface

A secure digital input/output (SDIO) host/slave interface is available on the inside Wi-Fi & BLE MCU chip. It can be used as a host to read external SD cards or used by an external host as a slave to communicate with chips. The SDIO interface allows a maximum clock speed of 80 MHz.

The SDIO features include the following:

- SD memory card specification version 2.0 compliant
- SDIO card specification version 2.0 compliant
- Two data bus modes: 1-bit mode (default) and 4-bit mode
- Data transfer up to 40 Mbyte/s for the host mode and 20 Mbyte/s for the slave mode
- Supports DMA capability, allowing high-speed transfer without CPU load

11.8 I2C Interface

I2C is a popular inter-IC interface that requires only two bus lines, the serial data line (SDA) and the serial clock line (SCL). The inside Wi-Fi & BLE MCU chip embeds an I2C interface, which can operate in master or slave mode.

The features of the I2C interface are listed below:

- Master and slave modes
- Standard mode (up to 100 kbps)
- Fast mode (up to 400 kbps)
- 7-bit and 10-bit addressing
- Bus idle and SCL low timeout condition detection
- Embedded 16-byte TX FIFO and 16-byte RX FIFO

11.9 LIN Controller

The Local Interconnect Network (LIN) controller is a communication controller that performs serial communication. It implements the data link layer of the LIN Protocol Specification. The LIN protocol uses a single master/multiple slave concept for the frame transfer between nodes of the LIN network.

Features of the LIN controller are listed here:

- Support of LIN specification 2.2A
- Backward compatibility to LIN 1.3

- Configurable for support of master or slave functionality
- Programmable data rate between 1 kbit/s and 20 kbit/s (for master)
- Automatic bit rate detection (for slave)
- 8-byte data buffer
- 8-bit host controller interface

11.10 GDMA Controllers

The inside Wi-Fi & BLE MCU chip has two general-purpose DMA controllers (GDMA) with 8 DMA channels each to unload CPU activity. The 8 channels are shared by peripherals that have DMA capabilities.

The GDMA controllers can perform single block transfers and repeated block transfers. Data width for destination and source can be configured as 8 bits (byte), 16 bits (half-word), or 32 bits (word). The GDMA controllers allow peripheral to memory, memory to memory, and memory to peripheral data transfers at a high speed.

The GDMA controllers support channel isolation. The DMA channels can be configured as secure/non-secure and as privileged/unprivileged channels:

- A non-secure channel performs non-secure DMA transfers
- A secure channel can perform secure or non-secure DMA transfers, with
    - Secure or non-secure data read from the source address
    - Secure or non-secure data write to the destination address
    - Via a TrustZone-aware DMA AHB master port
- An unprivileged channel performs unprivileged DMA transfers
- A privileged channel performs privileged DMA transfers

A selection of the peripherals on the inside Wi-Fi & BLE MCU chip have DMA capabilities, including UART0, UART1, UART2, SPI0, SDIO, and AUX ADC.

11.11 PWM Groups (PWMG)

The inside Wi-Fi & BLE MCU chip has two advanced-control PWM groups (PWMG). Each PWMG consists of up to three independent 32-bit auto-reload counters driven by three programmable prescalers. The PWMGs can generate pulse width modulated signals for a variety of purposes, including input capture, pulse edge counting, or generation of output waveforms (output compare).

The features of one PWMG are listed here:

- Three 32-bit up, down, or up-and-down auto-reload counters
  - PWM0 has a counter.
  - PWM1 has a counter (up-counting mode only).
  - PWM2 has a counter.
  - PWM4 and PWM5 share a counter.
- Three 8-bit programmable prescalers capable of dividing the clock frequency of each counter by any factor between 1 and 256
- PWMG0 and PWMG1 both have three independent channels, among which:
  - PWM0/2/4
    - Input capture
    - Pulse edge counting
    - PWM generation (edge or center-aligned modes)
  - PWM1
    - Independent simple waveform generation (up-counting mode)
    - Coupled waveform (reverse or identical) generation when coupled with PWM0
- Channel PWM5 capable of generating coupled waveforms (reverse or identical) when coupled with PWM4
- Complementary outputs with programmable dead-time and configurable dead-time mode
- Synchronization circuit to control the counter with external signals and to interconnect several counters together
- Repetition counter to update the registers only after a given number of cycles of the counter
- Interrupt generation on the following events:
  - Update: counter overflow or underflow, counter initialization (by software or internal/external trigger)
  - Counter start
  - Input capture
  - Output compare
- Change of polarity, duty cycle, and base frequency on every PWM period
- Supports incremental (quadrature) encoder and Hall-sensor circuitry for positioning purposes

Table 11 below provides the description of PWM signals.

Table 11: PWM Signals

GPIO	PWM Pin Name	Signal Type	Description
PWMG0			
GPIO8	PWMG0_PWM0	I/O	PWMG0 channel PWM0
GPIO19	PWMG0_PWM1	I/O	PWMG0 channel PWM1 PWM1 can work independently to generate simple waveforms or couple with PWM0 (with deadtime insertion) to generate reverse or identical waveforms ofPWM0.
GPIO24	PWMG0_PWM4	I/O	PWMG0 channel PWM4
GPIO25	PWMG0_PWM5	I/O	PWMG0 channel PWM5 PWM5 can couple with PWM4 (with deadtime insertion) to generate reverse or identical waveforms of PWM4.
PWMG1			
GPIO32	PWMG1_PWM0	I/O	PWMG1 channel PWM1
GPIO34	PWMG1_PWM2	I/O	PWMG1 channel PWM2
GPIO36	PWMG1_PWM4	I/O	PWMG1 channel PWM4

When PWMG0_PWM4 and PWMG0_PWM5 are enabled simultaneously, they cannot generate waveforms with different duty cycles.

11.12 Auxiliary ADC (AUX ADC)

The auxiliary ADC (AUX ADC) is a 12-bit successive approximation analog-to-digital converter. The AUX ADC has multiple external analog input channels and internal dedicated channels. The AUX ADC supports A/D conversion performed in one-shot, software control, or continuous mode.

The AUX ADC module has the following features:

- Programmable sampling rate from 12.5 kHz to 650 kHz
- 12-bit resolution
- Up to 7 external analog input channels: ADC1/2/4/12/13/14/15
- Five internal dedicated channels:
  - VBAT monitoring channel (VBAT/2, VBAT/3, or VBAT/4), connected to ADC0
  - Internal temperature sensor (TEMP), connected to ADC7
  - TSSIO, connected to ADC8
  - Touch OUT_TD, connected to ADC9
  - Internal debug channel, connected to ADC11
- Conversion modes:

- One-shot mode
- Software control mode
- Continuous mode

11.13 Timer Groups (TIMG)

The inside Wi-Fi & BLE MCU chip includes two general-purpose timer groups (TIMG). Each group has three 32-bit timers. Each group consists of three 32-bit counters driven by a 4-bit prescaler.

Each TIMG module has the following features:

- Three timers (Timer0/1/2)
- Three 32-bit up counters
- 4-bit prescaler, factor between 1 and 16
- Capable of reading the real-time value of the counter

11.14 Watchdog Timers (WDT)

The inside Wi-Fi & BLE MCU chip has two watchdog timers, the main domain watchdog timer (DWDT) and the always-on domain watchdog timer (AWDT). The purpose of the watchdog timers is to detect and recover from failures or malfunctions. The watchdog timers trigger a reset on expiry of a specified time period.

The DWDT runs on the 32 kHz LPO_CLK clock (factor 2/4/8/16) and has a maximum programmable period of up to 32.768 (2^16/2 kHz) seconds. The AWDT runs on the ROSC and has a maximum programmable period of up to 65.536 (2^16/1 kHz) seconds.

11.15 Real-time Counter (RTC)

The real-time counter (RTC) module features a 64-bit counter and a tick event generator. The RTC runs on the 32 kHz LPO_CLK clock. It is used for low-power timing, and it can keep running even when the system is in deep sleep mode.

11.16 IrDA Interface (IrDA)

The inside Wi-Fi & BLE MCU chip embeds a hardware IrDA interface that supports waveform analysis and waveform generation. It monitors the start of infrared signals, records the sequence of infrared waveforms, stores the waveforms in the RX FIFO for software analysis, and writes the waveforms to be sent to the TX FIFO when sending, thereby enabling the analysis and transmission of any infrared protocol.

The IrDA has the following features:

- Single-duplex mode
- Carrier modulation for transmission
- Integrated 512-byte RX FIFO and 512-byte TX FIFO

11.17 Temperature Sensor

The inside Wi-Fi & BLE MCU chip integrates an on-chip temperature sensor that can measure on-chip temperature over -40 to +125 °C with an accuracy of ±5 °C. The digital results can be read from the ADC.

Usually, the software initiates the calibration of a specific module based on the temperature value, narrowing the difference in chip performance at different temperatures. The host can also read the on-chip temperature and decide whether to reduce transmit power or suspend operation at high temperatures.

11.18 Touch Sensor (TOUCH)

The inside Wi-Fi & BLE MCU chip has six capacitive sensing I/Os, which immediately detect capacitance changes induced by touch or proximity of objects.

11.19 Security

The inside Wi-Fi & BLE MCU chip provides state-of-the-art security based on a powerful security architecture. It integrates a total security solution for Internet of Things (IoT), IoT Platform Security Suite (IPSS). The IPSS aims to set up a top-secret execution environment for IoT devices. With the state-of-the-art security technology, it is intended for power/cost/resource sensitive IoT market applications.

The IPSS introduces a fundamental software IP solution for cryptograph and system security control. The key features of the IPSS include:

- Secure boot
- Secure debug
- Secure connection
- Firmware Over-The-Air (FOTA)
- Provisioning
- TEE_M
- TrustEngine

11.19.1 System Architecture

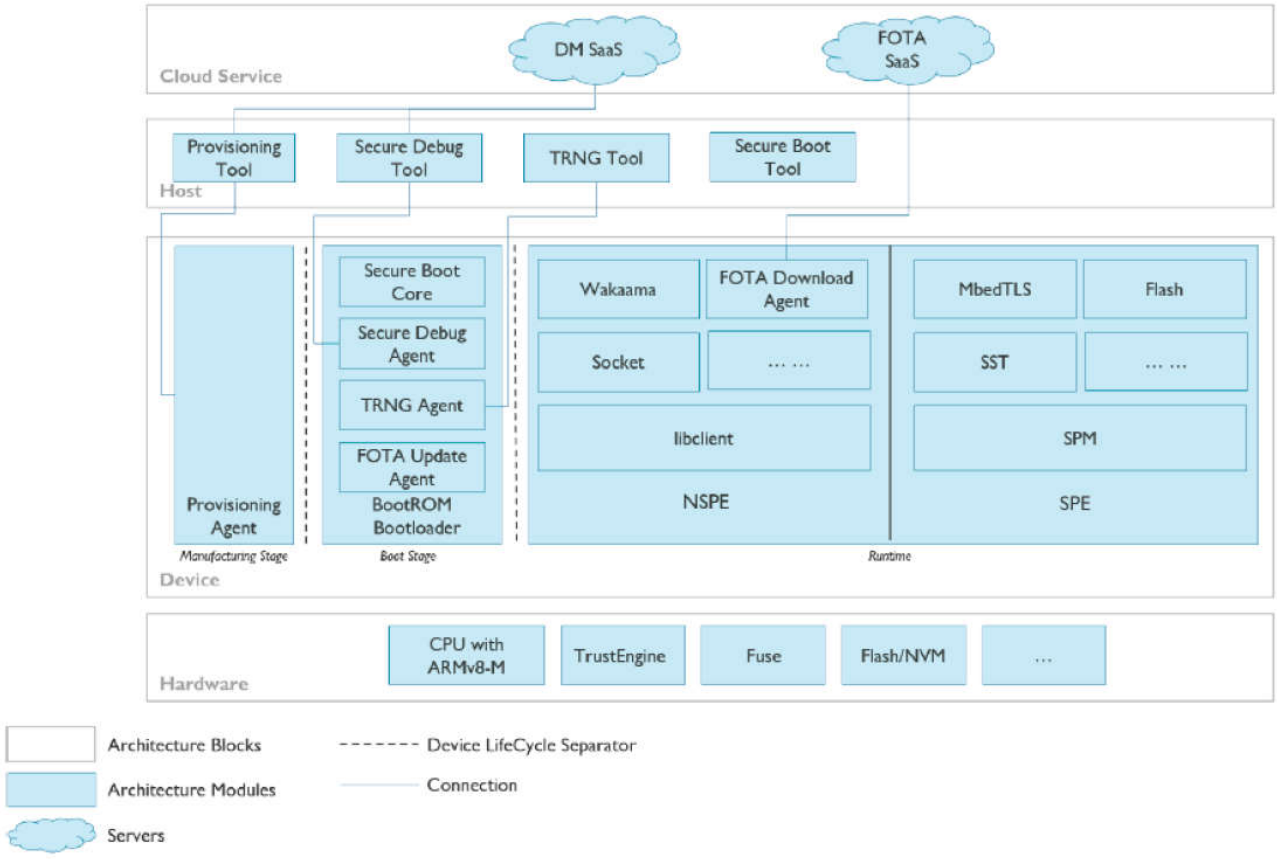
The IPSS software implements an all-round device-to-cloud security architecture, including:

- Provisioning mechanism in the manufacturing stage.
- Secure boot, secure debug, TRNG calibration, and FOTA update in the device boot stage.
- Secure connection and FOTA download in the device run-time stage.

IPSS also introduces a remote management solution to enable users to access, monitor and manage IoT devices in a secure manner. The remote management solution includes FOTA SaaS, Secure Debug SaaS, and Provisioning SaaS.

The following figure shows the architecture of the IPSS system.

Figure 5: Security Architecture of the IPSS System



11.19.2 Secure Boot

The secure boot solution provides the legitimacy and trustworthiness for images running on devices. It ensures that only official images which are published from OEMs are executable.

The secure boot functions include following aspects:

- Image verification

- Image encryption
- Extended program execution
- Image anti-rollback protection

11.19.3 Secure Debug

Secure debug provides a reliable mechanism for enabling the debug feature of a device after the device deployment.

Debug is one of the most commonly-used features in the device. With the debug feature, you can access all the device data, including the device firmware and the device root key.

11.19.4 FOTA

The FOTA solution implements a series of light-weight and trustworthy firmware upgrade interaction between IoT devices and servers, which includes downloading, verification, and installation.

11.19.5 Provisioning

Provisioning is the process to initialize secure credentials onto devices. It is required to happen in a secure environment such as the product line in the manufacturing stage.

The provisioning solution provides a full secure mechanism from the cloud server to devices. It keeps the security and integrity of provisioning materials, such as the device ID, model key, and the secure boot/secure debug public key hash, also keeps the device top secret such as the device root key that occurs only on the device side.

11.19.6 Secure Connection

The secure connection feature uses Mbed TLS to provide connection security in the transport layer over UDP. The key exchange method is Pre-Shared Key (PSK). The PSK's deployment happens in the manufacturing stage.

Mbed TLS provides cryptograph and SSL/TLS capabilities with TLS 1.1 and TLS 1.2.

11.19.7 BootROM

IPSS includes the BootROM reference code which is integrated with the secure boot solution.

There are primary boot and recovery boot paths in the BootROM.

- Primary boot is the main boot path. Normally devices should boot to the primary path.
- Recovery boot is the secondary boot path.

11.19.8 Bootloader

IPSS includes the Bootloader reference code which is integrated with the secure debug, provisioning, TRNG calibration, and FOTA solution.

In the primary bootloader, the secure debug agent, provisioning agent, and TRNG agent are integrated. The primary bootloader boots to the next image—TEE_M.

In the recovery bootloader, both the secure debug agent, TRNG agent, and the FOTA update agent are integrated. The recovery bootloader does not boot to any images.

11.19.9 TEE_M

IPSS introduces TEE_M. TEE_M provides an implementation of secure world software for Armv8-M, which follows Arm Platform Security Architecture (PSA) PSA_Firmware_Framework_1.0-bet0. IPSS TEE_M provides the following services by default:

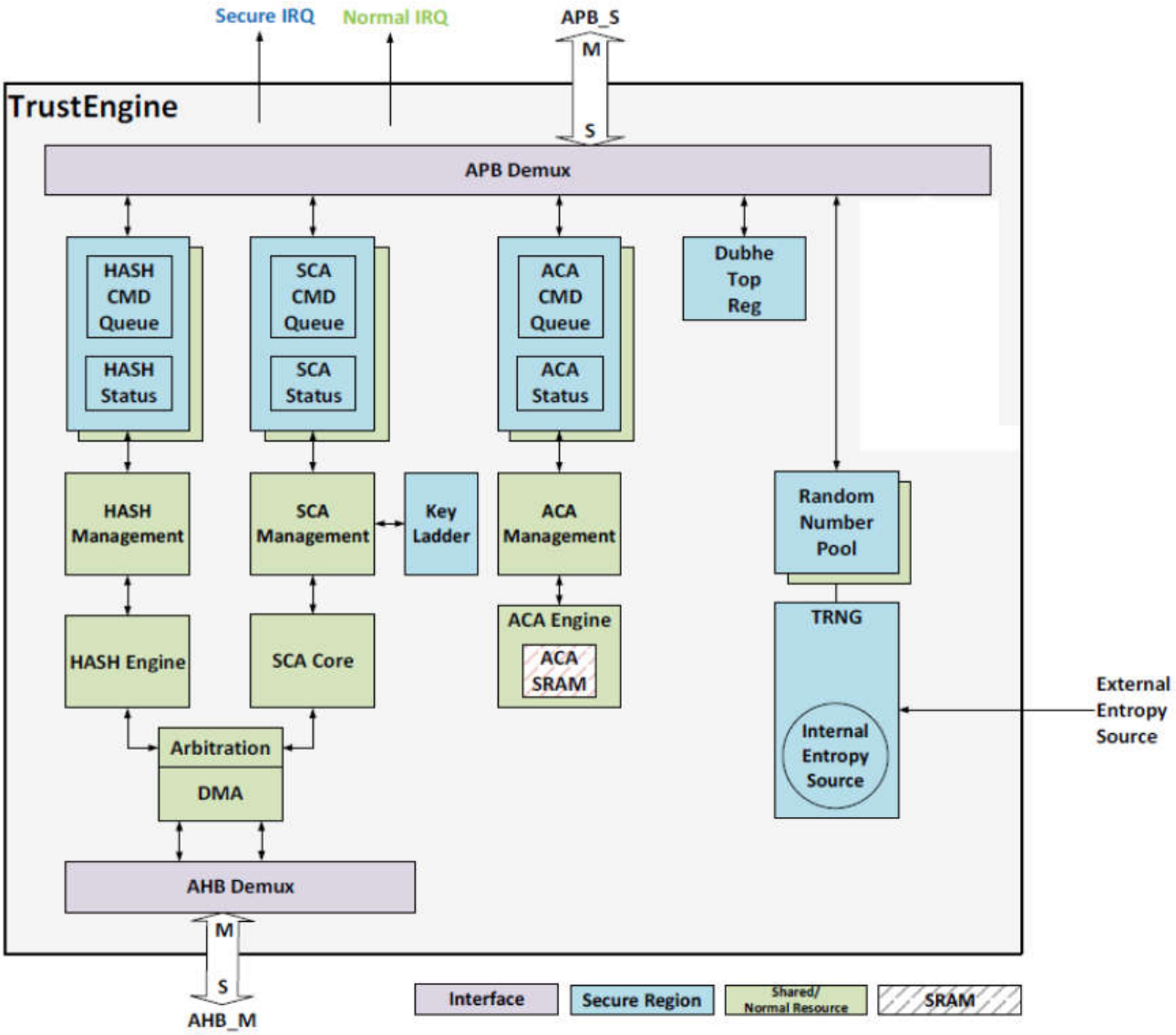
- Secure Storage: The Secure Storage (Only supports Protected Storage) service supports PSA_Storage_API-1.0-bet2 without extended functions.
- Crypto: The Crypto service supports PSA_Cryptography_API_Reference_1.0_bet1.
- DTLS: DTLS (leverages Mbed TLS) is integrated in TEE_M.

11.19.10 TrustEngine

IPSS introduces TrustEngine as a secure component in the system. It provides the following features:

- High security assurance. The crypto engine supports key ladders, lifecycle management and True Random Number Generator (TRNG) which enhance the system security.
- High performance and low power for encryption/decryption operation. This is achieved by TrustEngine internal cryptography engines.
- Reduction of software complicity in security. Some security functions are implemented in TrustEngine hardware, which can reduce the risk of sensitive information leakage to non-secure hosts.
- The following figure shows the TrustEngine top-level architecture.

Figure 6: TrustEngine Top-Level Architecture



11.19.10.1 Features

TrustEngine includes the following features:

- Symmetric schemes, AES-ECB/CBC/CTR/CBC-MAC/CMAC/CCM/GCM (key size 128-bit, 192-bit and 256-bit)
- Symmetric schemes, SM4-ECB/CBC/CTR/CBC-MAC/CMAC/CCM/GCM
- Digest schemes, SHA1/224/256
- Digest scheme, SM3
- Asymmetric schemes, RSA 1024/2048/3072/4096 and ECCP 192/224/256/384/512/521
- Asymmetric scheme, SM2

- Key ladder for key management
- Lifecycle management
- True random number generator

11.19.10.2 Supported Standards and Specifications

TrustEngine is compliant with the following standards:

- FIPS PUB 180-4: Secure Hash Standard (SHS)
- FIPS PUB 197: Advanced Encryption Standard (AES)
- NIST SP 800-38A Recommendation for Block Cipher Modes of Operation-Methods and Techniques
- NIST SP 800-38B Recommendation for Block Cipher Modes of Operation: The CMAC Mode for Authentication
- NIST SP 800-38C Recommendation for Block Cipher Modes of Operation-the CCM Mode for Authentication and Confidentiality
- NIST SP 800-38D, Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC
- NIST SP 800-90B Recommendation for the Entropy Sources Used for Random Bit Generation
- SM2 Public Key Cryptographic Algorithm Based on Elliptic Curves (GB/T 32918-2016)
- SM3 Cryptographic Hash Algorithm (GB/T 32905-2016)
- SM4 Block Cipher Algorithm (GB/T 32907-2016)

11.19.10.3 Components

TrustEngine consists of five major function blocks.

- Symmetric Cryptography Accelerator (SCA)
- Asymmetric Cryptography Accelerator (ACA)
- HASH engine
- One-time programmable storage access controller
- True random number generator

Symmetric Cryptography Accelerator (SCA)

SCA in TrustEngine is responsible for data encryption/decryption using the symmetric cryptography algorithm. The data encryption/decryption operations are performed through the SCA engine by sending special commands to TrustEngine.

Asymmetric Cryptography Accelerator (ACA)

The ACA engine in TrustEngine is responsible for accelerating the asymmetric cryptography, such as:

- Asymmetric encryption and decryption: RSA and ECC
- Digital signature and verification: RSA signatures and ECDSA
- Key exchange: DH (Diffie-Hellman) and ECDH

HASH Accelerator

The HASH engine in TrustEngine is responsible for digest calculation. The digest of certain data can be calculated through the HASH engine by sending special commands to TrustEngine.

True Random Number Generator

The True Random Number Generator (TRNG) generates the random bits using the internal entropy source (ring oscillator inverter chain) or the external entropy source. The random bits are required by both secure and non-secure hosts.

12 DC/RF Characteristics

12.1 DC/RF Characteristics for IEEE 802.11b - 2.4 GHz

Table 12:Characteristics Values for IEEE 802.11b - 2.4 GHz

Items	Contents
Specification	IEEE 802.11b
Mode	DSSS / CCK
Channel Frequency	2412 - 2472 MHz
Data Rate	1, 2, 5.5, 11 Mbps

12.1.1 High-Rate Condition for IEEE 802.11b - 2.4 GHz

Conditions: 25 °C, VBAT = 3.3V, 11 Mbps mode

Table 13: High-Rate Condition for IEEE 802.11b - 2.4 GHz

Items	Contents			
DC Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
DC Current				
• Tx mode (fully occupied)		230		mA
• Rx mode		27.5		mA
Tx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Output Power		19		dBm
Spectrum Mask Margin				
• 1st side lobes (-30 dBr)	0			dB
• 2nd side lobes (-50 dBr)	0			dB
Power-on and Power-down ramp			2.0	µs
RF Carrier Suppression	15			dB
Modulation Accuracy (EVM)			35	%
Frequency Tolerance	-20		20	ppm
Out band Spurious Emissions				
30 Hz ≤ f < 1000 MHz 1000 MHz ≤ f < 12750 MHz 1800 MHz < f ≤ 1900 MHz 5150 MHz < f ≤ 5300 MHz			-36 -30 -47 -47	dBm dBm dBm dBm
Rx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Minimum Input Level Sensitivity		-88	-76	dBm
Maximum Input Level (FER ≤ 8%)	TBD			dBm
Adjacent Channel Rejection (FER ≤ 8%)	35			dB

12.1.2 Low-Rate Condition for IEEE 802.11b - 2.4 GHz

Conditions: 25 °C, VBAT = 3.3V, 1 Mbps mode

Table 14: Low-Rate Condition for IEEE 802.11b - 2.4 GHz

Items	Contents			
DC Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
DC Current				
• Tx mode (fully occupied)		230		mA
• Rx mode		27.5		mA
Tx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Output Power		19		dBm
Spectrum Mask Margin				
• 1st side lobes (-30 dBr)	0			dB
• 2nd side lobes (-50 dBr)	0			dB
Power-on and Power-down Ramp			2.0	µs
RF Carrier Suppression	15			dB
Modulation Accuracy (EVM)			35	%
Frequency Tolerance	-20		20	ppm
Out band Spurious Emissions				
30 Hz ≤ f < 1000 MHz 1000 MHz ≤ f < 12750 MHz 1800 MHz < f ≤ 1900 MHz 5150 MHz < f ≤ 5300 MHz			-36 -30 -47 -47	dBm dBm dBm dBm
Rx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Minimum Input Level Sensitivity		-96	-80	dBm
Maximum Input Level (FER ≤ 8%)	TBD			dBm
Adjacent Channel Rejection (FER ≤ 8%)	35			dB

12.2 DC/RF Characteristics for IEEE802.11g - 2.4GHz

Table 15: Characteristics Values for IEEE 802.11g - 2.4 GHz

Items	Contents
Specification	IEEE 802.11g
Mode	OFDM
Channel Frequency	2412 - 2472 MHz
Data Rate	6, 9, 12, 18, 24, 36, 48, 54 Mbps

12.2.1 High-Rate Condition for IEEE 802.11g - 2.4 GHz

Conditions: 25 °C, VBAT = 3.3V, 54 Mbps mode

Table 16: High-Rate Condition for IEEE 802.11g - 2.4 GHz

Items	Contents			
DC Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
DC Current				
• Tx mode (fully occupied)		180		mA
• Rx mode		27.5		mA
Tx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Output Power		16		dBm
Spectrum Mask Margin				
• 9 MHz to 11 MHz (0 ~ -20 dBr)	0			dB
• 11 MHz to 20 MHz (-20 ~ -28 dBr)	0			dB
• 20 MHz to 30 MHz (-28 ~ -40 dBr)	0			dB
• 30 MHz to 33 MHz (-40 dBr)	0			dB
Constellation Error (EVM)			-25	dB
Frequency Tolerance	-20		20	ppm
Out Band Spurious Emissions				
30 Hz ≤ f < 1000 MHz 1000 MHz ≤ f < 12750 MHz 1800 MHz < f ≤ 1900 MHz 5150 MHz < f ≤ 5300 MHz			-36 -30 -47 -47	dBm dBm dBm dBm
Rx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Minimum Input Level Sensitivity		-75	-65	dBm
Maximum Input Level (PER ≤ 10%)	TBD			dBm
Adjacent Channel Rejection (PER ≤ 10%)	-1			dB

12.2.2 Low-Rate Condition for IEEE 802.11g – 2.4 GHz

Conditions: 25 °C, VBAT = 3.3V, 6 Mbps mode

Table 17: Low-Rate Condition for IEEE 802.11g - 2.4 GHz

Items	Contents			
DC Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
DC Current				
• Tx mode (fully occupied)		205		mA
• Rx mode		27.5		mA
Tx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Output Power		19		dBm
Spectrum Mask Margin				
• 9 MHz to 11 MHz (0 ~ -20 dBr)	0			dB
• 11 MHz to 20 MHz (-20 ~ -28 dBr)	0			dB
• 20 MHz to 30 MHz (-28 ~ -40 dBr)	0			dB
• 30 MHz to 33 MHz (-40 dBr)	0			dB
Constellation Error (EVM)			-5	dB
Frequency Tolerance	-20		20	ppm
Out Band Spurious Emissions				
30 Hz ≤ f < 1000 MHz 1000 MHz ≤ f < 12750 MHz 1800 MHz < f ≤ 1900 MHz 5150 MHz < f ≤ 5300 MHz			-36 -30 -47 -47	dBm dBm dBm dBm
Rx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Minimum Input Level Sensitivity		-90	-82	dBm
Maximum Input Level (PER ≤ 10%)	TBD			dBm
Adjacent Channel Rejection (PER ≤ 10%)	16			dB

12.3 DC/RF Characteristics for IEEE802.11n - 2.4GHz

Table 18: Characteristics Values for IEEE 802.11n - 2.4 GHz

Items	Contents
Specification	IEEE 802.11n
Mode	OFDM
Channel Frequency	2412 - 2472 MHz
Data Rate	HT20 MCS0 – HT20 MCS7

12.3.1 High-Rate Condition for IEEE 802.11n HT20 - 2.4 GHz

Conditions: 25 °C, VBAT = 3.3V, HT20 MCS7

Table 19: High-Rate Condition for IEEE 802.11n HT20 - 2.4 GHz

Items	Contents			
DC Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
DC Current				
• Tx mode (fully occupied)		165		mA
• Rx mode		27.5		mA
Tx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Output Power		15		dBm
Spectrum Mask Margin				
• 9 MHz to 11 MHz (0 ~ -20 dBr)	0			dB
• 11 MHz to 20 MHz (-20 ~ -28 dBr)	0			dB
• 20 MHz to 30 MHz (-28 ~ -45 dBr)	0			dB
• 30 MHz to 33 MHz (-45 dBr)	0			dB
Constellation Error (EVM)			-27	dB
Frequency Tolerance	-20		20	ppm
Out band Spurious Emissions				
30 Hz ≤ f < 1000 MHz 1000 MHz ≤ f < 12750 MHz 1800 MHz < f ≤ 1900 MHz 5150 MHz < f ≤ 5300 MHz			-36 -30 -47 -47	dBm dBm dBm dBm
Rx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Minimum Input Level Sensitivity		-73	-64	dBm
Maximum Input Level (PER ≤ 10%)	TBD			dBm
Adjacent Channel Rejection (PER ≤ 10%)	TBD			dB

12.3.2 Low-Rate Condition for IEEE 802.11n HT20 – 2.4 GHz

Conditions: 25 °C, VBAT = 3.3V, HT20 MCS0

Table 20: Low-Rate Condition for IEEE 802.11n HT20 - 2.4 GHz

Items	Contents			
DC Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
DC Current				
• Tx mode (fully occupied)		195		mA
• Rx mode		27.5		mA
Tx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Output Power		18		dBm
Spectrum Mask Margin				
• 9 MHz to 11 MHz (0 ~ -20 dBr)	0			dB
• 11 MHz to 20 MHz (-20 ~ -28 dBr)	0			dB
• 20 MHz to 30 MHz (-28 ~ -45 dBr)	0			dB
• 30 MHz to 33 MHz (-45 dBr)	0			dB
Constellation Error (EVM)			-5	dB
Frequency Tolerance	-20		20	ppm
Out band Spurious Emissions				
30 Hz ≤ f < 1000 MHz 1000 MHz ≤ f < 12750 MHz 1800 MHz < f ≤ 1900 MHz 5150 MHz < f ≤ 5300 MHz			-36 -30 -47 -47	dBm dBm dBm dBm
Rx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Minimum Input Level Sensitivity		-90	-82	dBm
Maximum Input Level (PER ≤ 10%)	TBD			dBm
Adjacent Channel Rejection (PER ≤ 10%)	16			dB

12.4 DC/RF Characteristics for IEEE 802.11ax - 2.4 GHz

Table 21: Characteristics Values for IEEE 802.11ax HE20 - 2.4 GHz

Items	Contents
Specification	IEEE 802.11ax
Mode	OFDM
Channel Frequency	2412 - 2472 MHz
Data Rate	HE20 MCS0 – HE20 MCS7

12.4.1 High-Rate Condition for IEEE 802.11ax HE20 - 2.4 GHz

Conditions: 25 °C, VBAT = 3.3V, HE20 MCS7

Table 22: High-Rate Condition for IEEE 802.11ax HE20 - 2.4 GHz

Items	Contents			
DC Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
DC Current				
• Tx mode (fully occupied)		165		mA
• Rx mode		27.5		mA
Tx Characteristics 错误!未定义书签。	**Minimum**	**Typical**	**Maximum**	**Unit**
Output Power		15		dBm
Spectrum Mask Margin				
• 9 MHz to 11 MHz (0 ~ -20 dBr)	0			dB
• 11 MHz to 20 MHz (-20 ~ -28 dBr)	0			dB
• 20 MHz to 30 MHz (-28 ~ -45 dBr)	0			dB
• 30 MHz to 33 MHz (-45 dBr)	0			dB
Constellation Error (EVM)			-27	dB
Frequency Tolerance	-20		20	ppm
Out band Spurious Emissions				
30 Hz ≤ f < 1000 MHz 1000 MHz ≤ f < 12750 MHz 1800 MHz < f ≤ 1900 MHz 5150 MHz < f ≤ 5300 MHz			-36 -30 -47 -47	dBm dBm dBm dBm
Rx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Minimum Input Level Sensitivity		-72	-64	dBm
Maximum Input Level (PER ≤ 10%)	TBD			dBm
Adjacent Channel Rejection (PER ≤ 10%)	TBD			dB

12.4.2 Low-Rate Condition for IEEE 802.11ax HE20 – 2.4 GHz

Conditions: 25 °C, VBAT = 3.3V, HE20 MCS0

Table 23: Low-Rate Condition for IEEE 802.11ax HE20 - 2.4 GHz

Items	Contents			
DC Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
DC Current				
• Tx mode (fully occupied)		195		mA
• Rx mode		27.5		mA
Tx Characteristics 错误!未定义书签。	**Minimum**	**Typical**	**Maximum**	**Unit**
Output Power		18		dBm
Spectrum Mask Margin				
• 9 MHz to 11 MHz (0 ~ -20 dBr)	0			dB
• 11 MHz to 20 MHz (-20 ~ -28 dBr)	0			dB
• 20 MHz to 30 MHz (-28 ~ -45 dBr)	0			dB
• 30 MHz to 33 MHz (-45 dBr)	0			dB
Constellation Error (EVM)			-5	dB
Frequency Tolerance	-20		20	ppm
Out band Spurious Emissions				
30 Hz ≤ f < 1000 MHz 1000 MHz ≤ f < 12750 MHz 1800 MHz < f ≤ 1900 MHz 5150 MHz < f ≤ 5300 MHz			-36 -30 -47 -47	dBm dBm dBm dBm
Rx Characteristics	**Minimum**	**Typical**	**Maximum**	**Unit**
Minimum Input Level Sensitivity		-90	-82	dBm
Maximum Input Level (PER ≤ 10%)	TBD			dBm
Adjacent Channel Rejection (PER ≤ 10%)	TBD			dB

12.5 DC/RF Characteristics for Bluetooth Low Energy

Conditions : 25 °C, VBAT = 3.3V

Table 24: DC/RF Characteristics for Bluetooth Low Energy

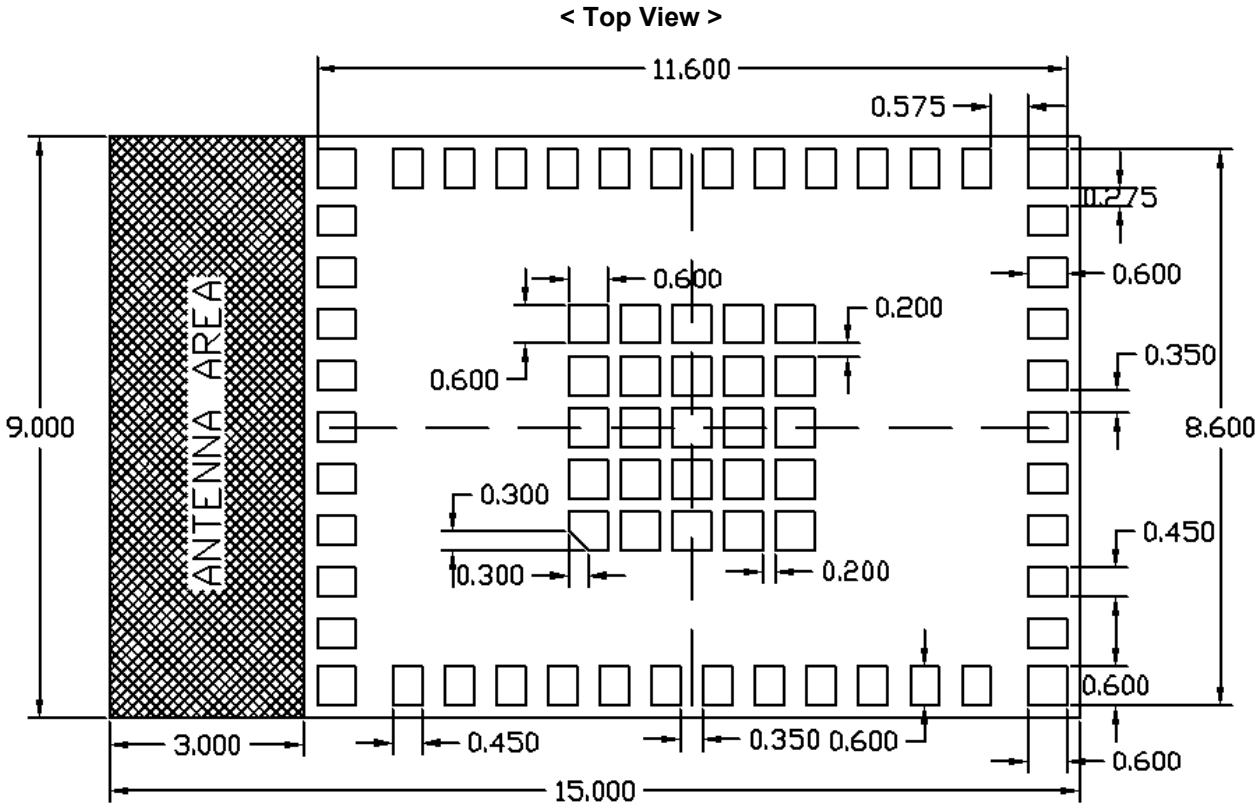
Items	Contents			
Bluetooth Specification (power class)	Version 5.4(LE)			
Channel Frequency (spacing)	2402 to 2480 MHz (2 MHz)			
Number of RF Channel	40			
Bluetooth LE 1 Mbps				
Item / Condition	**Minimum**	**Typical**	**Maximum**	**Unit**
Center Frequency	2402	-	2480	MHz
Channel Spacing	-	2	-	MHz
Number of RF Channel	-	40	-	
Tx Current (fully occupied)		75		mA
Output Power		6		dBm
Modulation Characteristics				
• $\Delta f1_{avg}$	225	-	275	kHz
• $\Delta f2_{max}$ (at 99.9%)	185		-	kHz
• $\Delta f2_{avg} / \Delta f1_{avg}$	0.8	-	-	
Carrier Frequency Offset and Drift				
• Frequency Offset	-	-	150	kHz
• Frequency Drift	-	-	50	kHz
• Drift Rate	-	-	20	kHz
Rx Current		27.5		mA
Receiver Sensitivity (PER < 30.8%)	-	-95	-70	dBm
Maximum Input Signal Level (PER < 30.8%)	TBD	-	-	dBm
PER Report Integrity (-30 dBm input)	50	-	65.4	%
Bluetooth LE 2 Mbps				
Item / Condition	**Minimum**	**Typical**	**Maximum**	**Unit**
Center Frequency	2402	-	2480	MHz
Channel Spacing	-	2	-	MHz
Number of RF Channel	-	40	-	
Tx Current (fully occupied)		75		mA
Output Power		6		dBm
Modulation Characteristics				
• $\Delta f1_{avg}$	450	-	550	kHz
• $\Delta f2_{max}$ (at 99.9%)	370	-	-	kHz
• $\Delta f2_{avg} / \Delta f1_{avg}$	0.8	-	-	
Carrier Frequency Offset and Drift				
• Frequency Offset	-	-	150	kHz
• Frequency Drift	-	-	50	kHz
• Drift Rate	-	-	20	kHz
Rx Current		27.5		mA
Receiver Sensitivity (PER < 30.8%)	-	-92	-70	dBm

Maximum Input Signal Level (PER < 30.8%)	TBD	-	-	dBm
PER Report Integrity (-30 dBm input)	50	-	65.4	%
Bluetooth LE 125 kbps				
Item / Condition	**Minimum**	**Typical**	**Maximum**	**Unit**
Center Frequency	2402	-	2480	MHz
Channel Spacing	-	2	-	MHz
Number of RF Channel	-	40	-	
Tx Current (fully occupied)		75		mA
Output Power		6		dBm
Modulation Characteristics				
• $\Delta f1_{avg}$	225	-	275	kHz
• $\Delta f2_{max}$ (at 99.9%)	185	-	-	kHz
• $\Delta f2_{avg}$ / $\Delta f1_{avg}$	-	-	-	
Carrier Frequency Offset and Drift				
• Frequency Offset	-	-	150	kHz
• Frequency Drift	-	-	50	kHz
• Drift Rate	-	-	19.2	kHz
Rx Current		27.5		mA
Receiver Sensitivity (PER < 30.8%)		-100	-82	dBm
Maximum Input Signal Level (PER < 30.8%)	TBD	-	-	dBm
PER Report Integrity (-30 dBm input)	50	-	65.4	%
Bluetooth LE 500 kbps				
Item / Condition	**Minimum**	**Typical**	**Maximum**	**Unit**
Center Frequency	2402	-	2480	MHz
Channel Spacing	-	2	-	MHz
Number of RF Channel	-	40	-	
Tx Current (fully occupied)	-	75	-	mA
Output Power	-	6	-	dBm
Modulation Characteristics				
• $\Delta f1_{avg}$	-	-	-	kHz
• $\Delta f2_{max}$ (at 99.9%)	-	-	-	kHz
• $\Delta f2_{avg}$ / $\Delta f1_{avg}$	-	-	-	
Carrier Frequency Offset and Drift				
• Frequency Offset	-	-	-	kHz
• Frequency Drift	-	-	-	kHz
• Drift Rate	-	-	-	kHz
Rx Current		27.5		mA
Receiver Sensitivity (PER < 30.8%)		-97	-75	dBm
Maximum Input Signal Level (PER < 30.8%)	TBD	-	-	dBm
PER Report Integrity (-30 dBm input)	50	-	65.4	%

13 Recommended Land Pattern

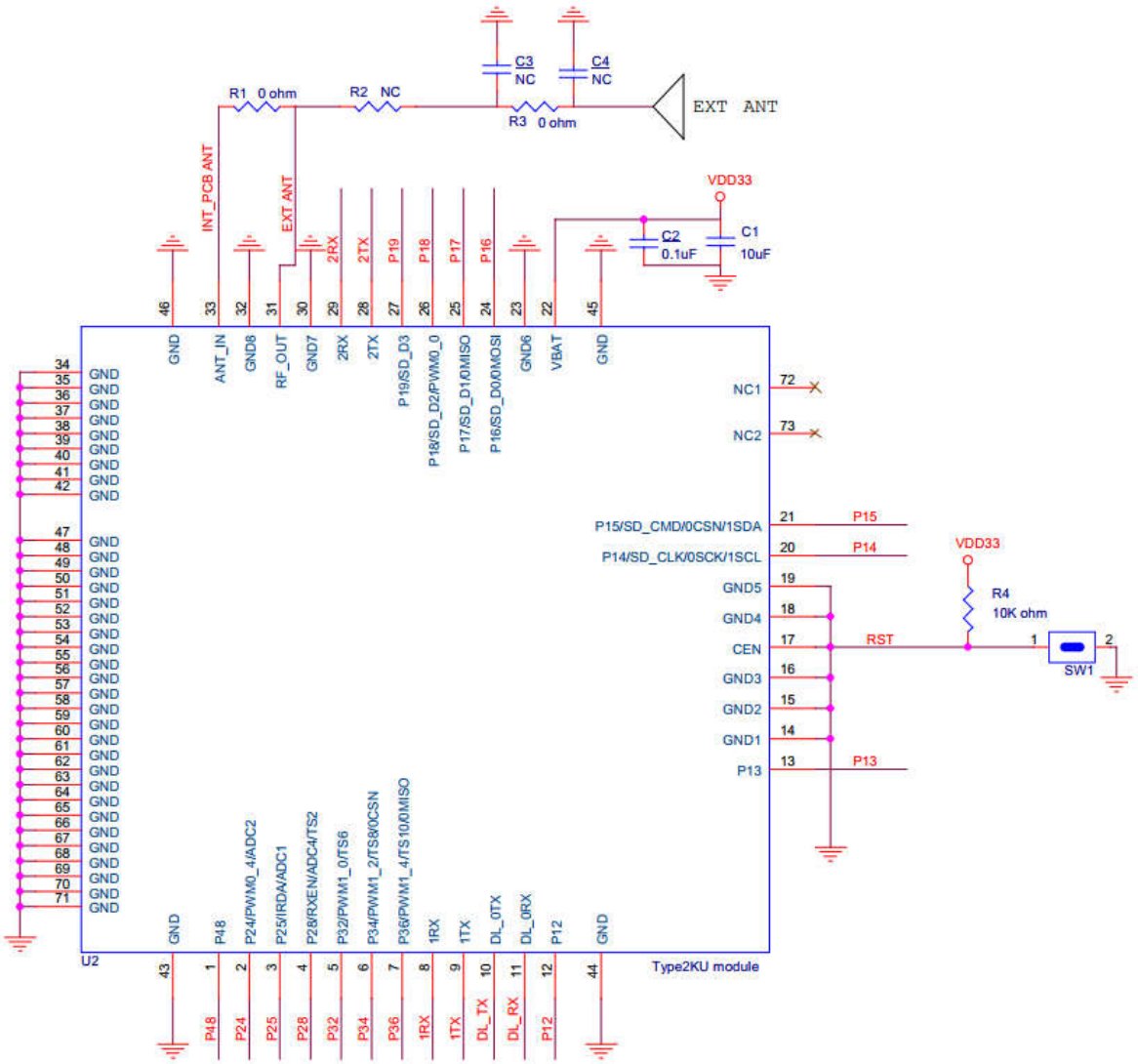
错误!未找到引用源。 shows the recommended land pattern (Top view, unit is mm) for **Type 2KU** module.

Figure 7: Recommended Land Pattern



1. Please use stencil with thickness at least 100um.

14 Reference Design



Antenna selection	R1	R2
Internal PCB antenna	0 ohm	NC
External antenna	NC	0ohm

2. There is no pull-up resistor for CEN inside module. so external pull-up outside module is needed.
3. Customer can use the embedded PCB antenna inside module or external antenna.
4. R3, C3 and C4 are matching circuit for external antenna, the values of them should be tuned based on actual condition

15 PCB Antenna Layout Guidance

15.1 Internal PCB Antenna Layout Guidance

There are 2 ways for antenna area placement:

- Place the antenna area outside the baseboard. This is the recommended way.
- Place the antenna area inside the baseboard. The antenna performance will degrade compare with the recommended way. To get good antenna performance, some guides should be followed:
    - Try to place the antenna area on the corner or edge of the baseboard.
    - No ground, circuit, component under the antenna area, including the reverse side of PCB. If possible, it's better to cut the substrate under PCB antenna area. The clearance area is as large as possible.
    - Metal component should be at least 10 mm away from PCB antenna.
    - Plastic housing should be at least 10 mm away from PCB antenna. If housing is metal, it is recommended to use external antenna.

15.2 External Antenna Layout Guidance

If use external antenna, below points should be noticed to get good RF performance.

- The port impedance of RF_OUT is designed as about 50 ohms. Wen connects RF_OUT to SMA port or external antenna using RF trace, make sure the RF trace impedance is about 50 ohms.
- The RF trace can be stripe-line or co-plane mode. Set the RF path as short as possible to reduce the loss in RF signal transmission. Keep enough asymmetric GND vias around the RF trace.
- It is better to add one PI type matching components on the trace. In case of mismatch, the impedance can be compensated by the matching circuit.
- Routing RF traces on the surface layer which is far away from other high-speed signals trace is recommended. Any right-angle turn-in trace routing should be accomplished with an arc turn.

If use internal PCB antenna, some guides must be followed to get best antenna performance.

1. Place the antenna area on the corner or edge of the main board.

2. No ground, circuit, component under the antenna area, including the reverse side of PCB. No ground area is as large as possible.
3. Metal component should be at least 10 mm away from PCB antenna.
4. Plastic case should be at least 10 mm away from PCB antenna. If it's metal case, it's recommended to use external antenna.

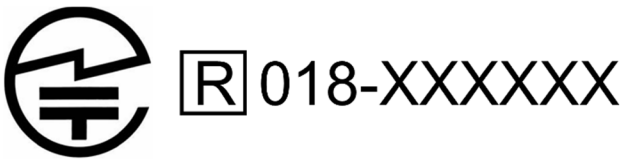
16 Radio Regulatory Certification by Country for LBEE0ZZ2KU-001

This section includes the following regulatory certifications (in plan):

- MIC
- FCC
- ISED
- CE
- KC
- SRRC
- WPC

16.1 MIC

- Manufacturer: Murata Manufacturing Co., Ltd.
- Model: LBEE0ZZ2KU
- This module is certified for "**Construction Design Certification**" pursuant to the Japanese Radio Act.



16.2 FCC

FCC ID: VPYLBEE0ZZ2KU

Model: LBEE0ZZ2KU

This module is not sold to general end users directly. Therefore, there is no user manual of the module. This module should be installed in the host device according to the interface specification (installation procedure).

The OEM integrator has to be aware not to provide information to the end user regarding how to install or remove this module in the end user's manual of the end product which integrates this module. The end user manual shall include all required regulatory information/warnings.

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

FCC CAUTION: Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

This transmitter must not be co-located or operated in conjunction with any other antenna or transmitter.

This device complies with below part 15 of the FCC Rules.

- Part 15 Subpart C

If the FCC ID is not visible when the module is installed inside another device, then the module is installed must also display a label referring to the enclosed module.

The modular transmitter is only FCC authorized for the specific rule parts (i.e., FCC transmitter rules) listed on the grant, and the host product manufacturer is responsible for compliance to any other FCC rules that apply to the host not covered by the modular transmitter grant of certification. The final host product still requires Part 15 Subpart B compliance testing with the modular transmitter installed.

This module is designed for mounting inside of the end product professionally. Therefore, it complies with the antenna and transmission system requirements of §15.203.

16.3 ISED

HVIN: LBEE0ZZ2KU

IC: 772C-LBEE0ZZ2KU

This device contains license-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's license-exempt RSS(s). Operation is subject to the following two conditions:

1. This device may not cause interference ;

2. This device must accept any interference, including interference that may cause undesired operation of the device.

L'émetteur/récepteur exempt de licence contenu dans le présent appareil est conforme aux CNR d'Innovation, Sciences et Développement économique Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes :

1. L'appareil ne doit pas produire de brouillage;

2. L'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

16.4 Europe

Product name: WLAN + Bluetooth LE module

Model: LBEE0ZZ2KU

Manufacturer: Murata Manufacturing Co., Ltd.

When shipping final products with this module to Europe, make a self-declaration that the final product complies with European regulations and apply the CE mark.

The conformity test reports of the following standards are available:

- ETSI EN 300 328 V2.2.2
- EN IEC 62311:2020

16.5 Korea

TBD.

16.6 China

This module is certified the Radio Transmission Equipment Type Approval Certificate as full modular.

Model: LBEE0ZZ2KU

Manufacturer: Murata Manufacturing Co., Ltd.

CMIIT ID: 25J99C7RC002

16.7 India

TBD.

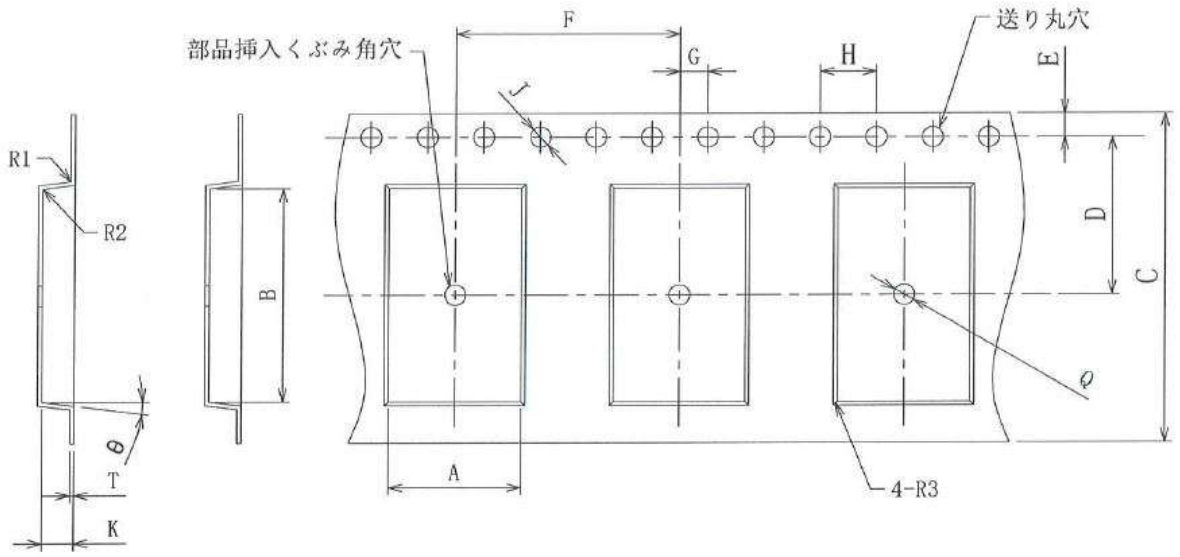
17 Tape And Reel Packing

This section describes the tape and reel packing, i.e., the dimensions of the plastic tape, reel and taping diagrams.

17.1 Dimensions of Tape

错误!未找到引用源。 shows the dimensions of the plastic tape.

Figure 8: Dimensions of Tape (Plastic Tape)



記号	A	B	K ⚠	D	E	F
寸法	9.4±0.05	15.5±0.05	2.3±0.1	11.5±0.1	1.75±0.1	16.0±0.1

記号	G	H	J	C	Q	T
寸法	2.0±0.1	4.0±0.1	$1.5^{+0.1}_{-0}$	24.0±0.3	$1.5^{+0.1}_{-0}$	0.3±0.05

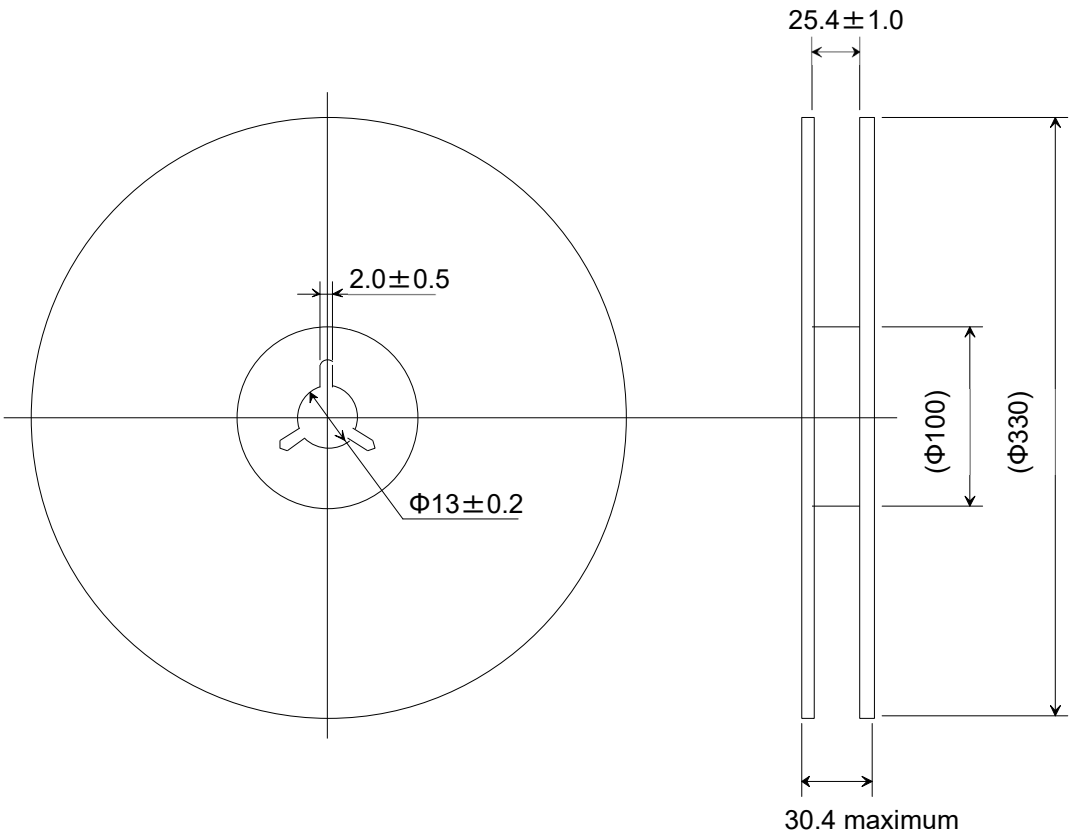
記号	R1	R2	R3	θ
寸法	0.3MAX	0.3MAX	0.3MAX	7° MAX

[単位:mm]

17.2 Dimensions of Reel

Figure 9 shows the reel dimensions.

Figure 9: Dimensions of Reel (Unit: mm)



17.3 Taping Diagrams

Figure 10 shows the tapings diagrams.

Figure 10: Taping Diagrams

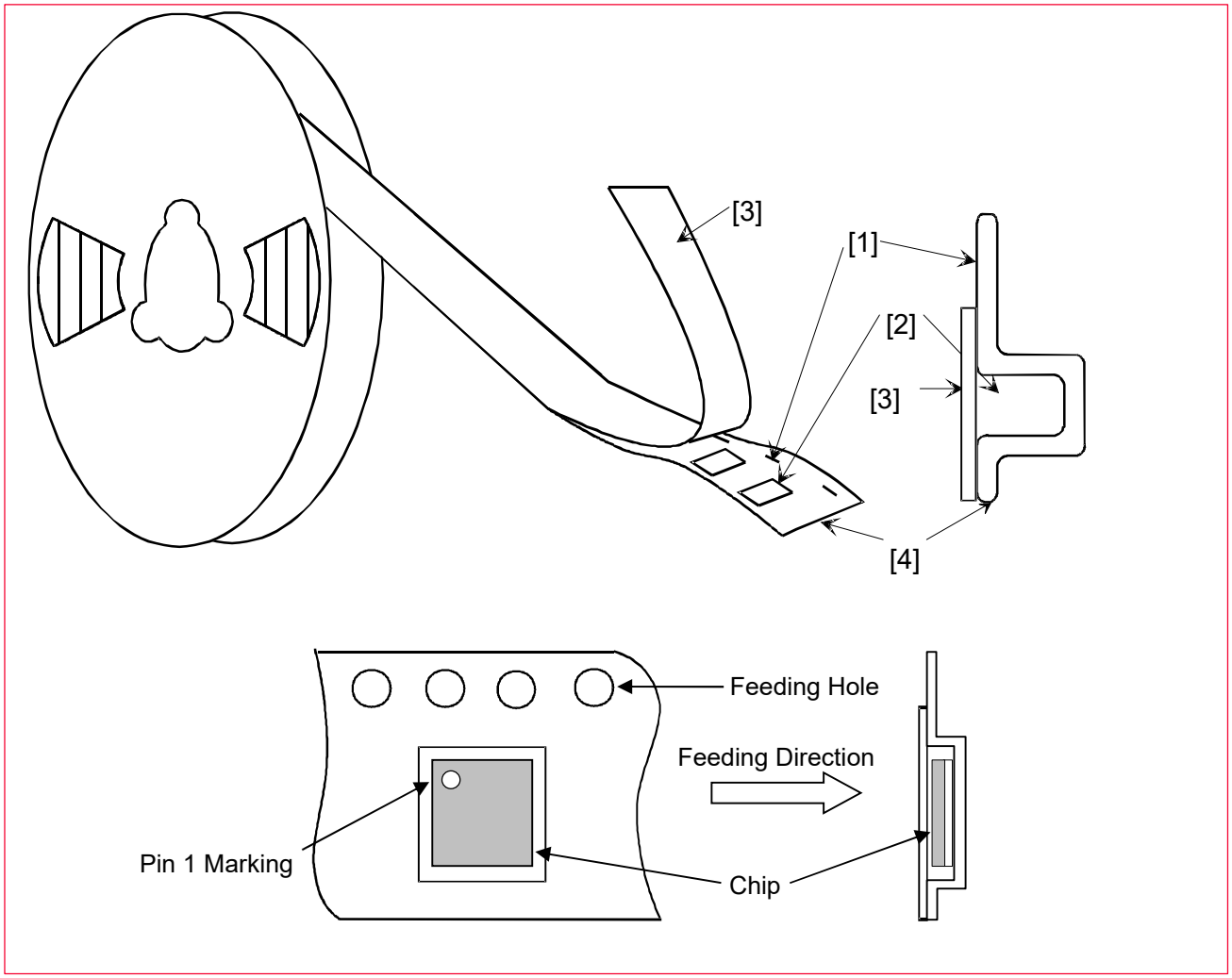


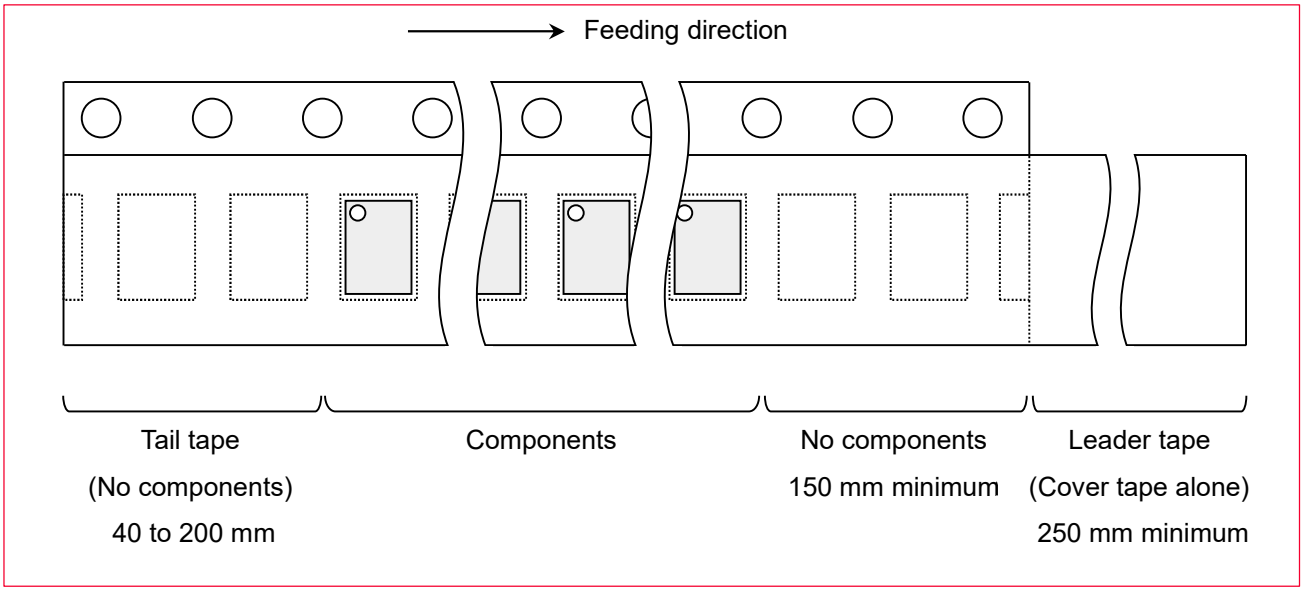
Table 25: Taping Specifications

Mark	Description
1	Feeding hole. As specified in Dimensions of Tape (Plastic tape).
2	Hole for Chip. As specified in Dimensions of Tape (Plastic tape).
3	Cover tape. 62 µm in thickness.
4	Base tape. As specified in Dimensions of Tape (Plastic tape).

17.4 Leader and Tail Tape

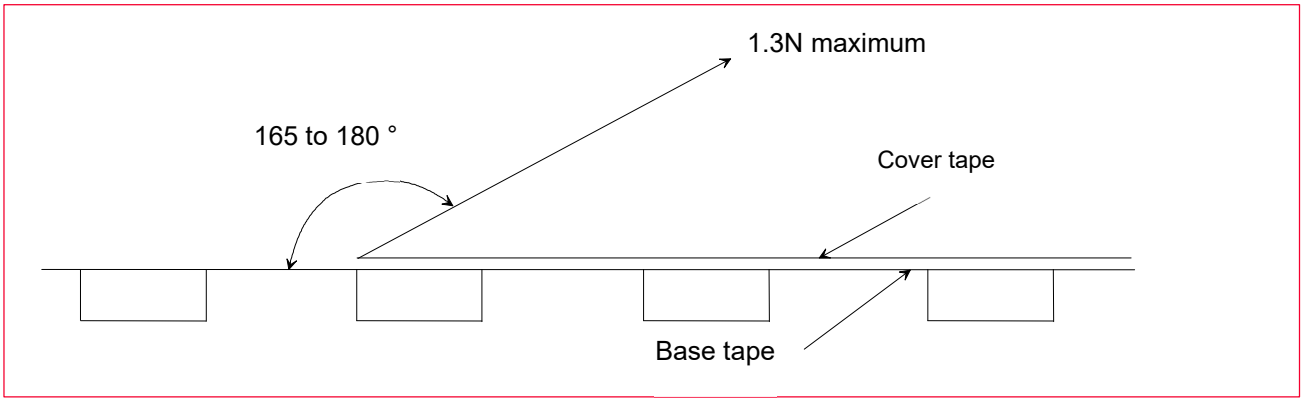
The leader and tail tape are shown in **Figure 11**.

Figure 11: Leader and Tail Tape



- The tape for chips is wound clockwise, the feeding holes to the right side as the tape is pulled toward the user.
- The cover tape and base tape are not adhered at no components area for 250 mm minimum.
- Tear off strength against pulling of cover tape: 5 N minimum.
- Packaging unit: 1000 pcs. / Reel
- Tape material:
  - Base tape: Plastic
  - Reel: Plastic
  - Cover tape, cavity tape and reel are made the anti-static processing.
- Peeling off force: 1.3 N maximum in the direction of peeling as shown in **Figure 12**.

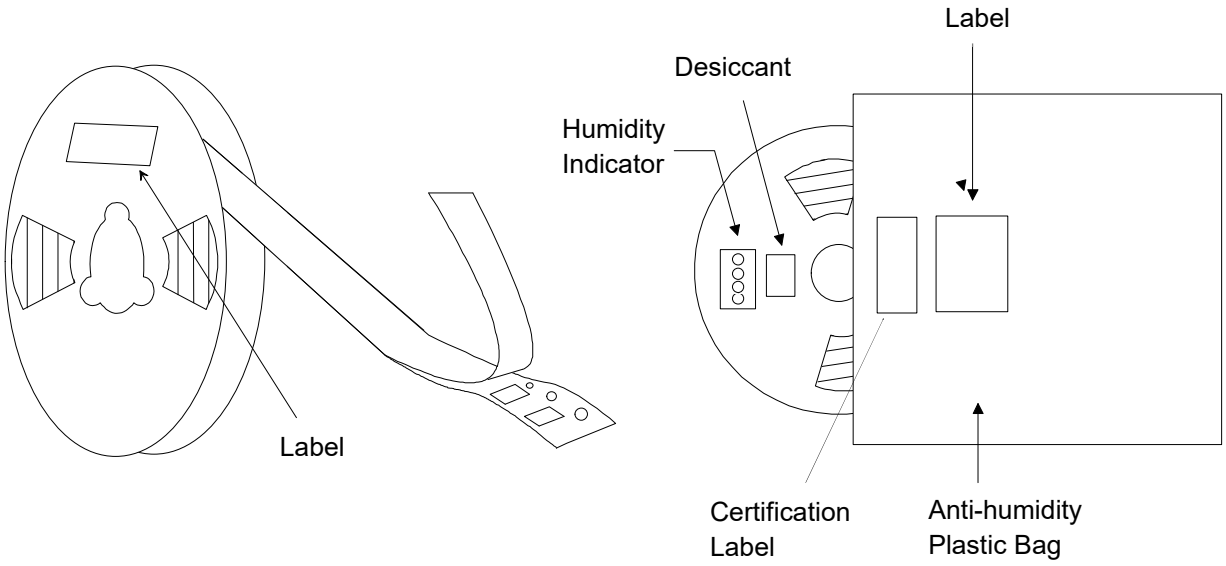
Figure 12: Peeling Force



17.5 Packaging (Humidity Proof Packing)

Figure 13 shows the humidity proof packaging.

Figure 13: Humidity Proof Packaging



Tape and reel must be sealed with the anti-humidity plastic bag. The bag contains the desiccant and the humidity indicator.

18 Notice

18.1 Storage Conditions

- Please use this product within 6 months after receipt.
  - The product shall be stored without opening the packing under the ambient temperature from 5 to 35 °C and humidity from 20 ~ 70 %RH (Packing materials may be deformed at the temperature over 40 °C).
  - The product left more than 6 months after reception; it needs to be confirmed the solderability before used.
  - The product shall be stored in noncorrosive gas (Cl_2, NH_3, SO_2, NO_X, etc.).
  - Any excess mechanical shock including, but not limited to, sticking the packing materials by sharp object and dropping the product, shall not be applied in order not to damage the packing materials.
- This product is applicable to MSL3 (Based on IPC/JEDEC J-STD-020)
  - After the packing opened, the product shall be stored at <30 °C / <60 %RH and the product shall be used within 168 hours.
  - When the color of the indicator in the packing changed, the product shall be baked before soldering.
- Baking condition: 125 +5/-0 °C, 24 hours, 1 time
- The products shall be baked on the heat-resistant tray because the material is not heat-resistant.

18.2 Handling Conditions

- Be careful in handling or transporting products because excessive stress or mechanical shock may break products.
- Handle with care if products may have cracks or damages on their terminals, the characteristics of products may change. Do not touch products with bear hands that may result in poor solderability.

18.3 Standard PCB Design (Land Pattern and Dimensions)

- All the ground terminals should be connected to the ground patterns. Furthermore, the ground pattern should be provided between IN and OUT terminals. Please refer to the specifications for the standard land dimensions.
- The recommended land pattern and dimensions is as Murata's standard. The characteristics of products may vary depending on the pattern drawing method, grounding method, land dimensions, land forming method of the NC terminals and the PCB material and thickness. Therefore, be sure to verify the characteristics in the actual set. When using non-standard lands, contact Murata beforehand.

18.4 Notice for Chip Placer

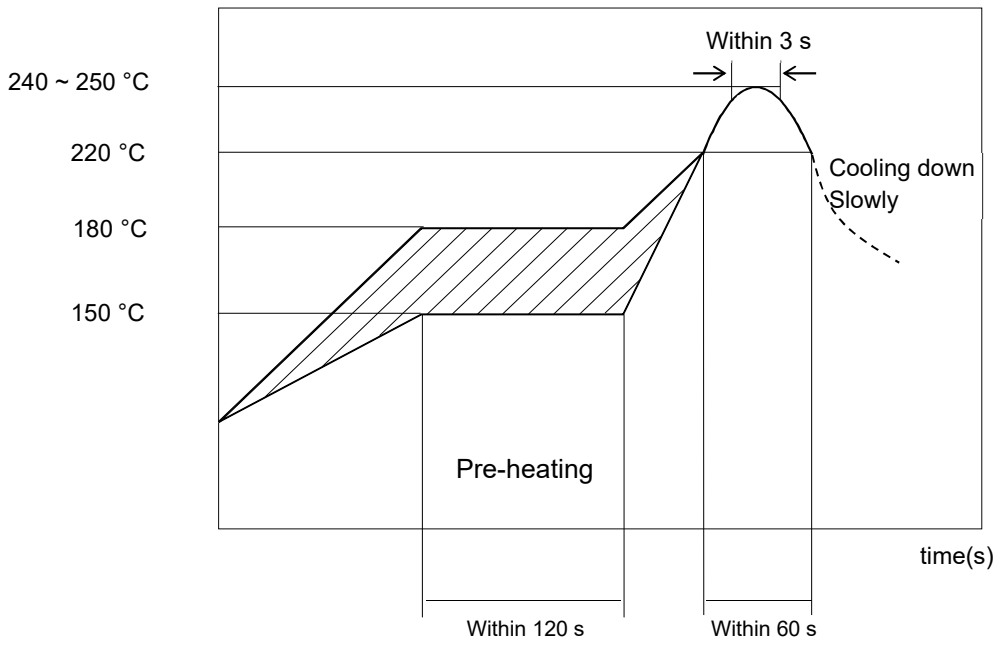
When placing products on the PCB, products may be stressed and broken by uneven forces from a worn-out chucking locating claw or a suction nozzle. To prevent products from damages, be sure to follow the specifications for the maintenance of the chip placer being used. For the positioning of products on the PCB, be aware that mechanical chucking may damage products.

18.5 Soldering Conditions

The recommended reflow soldering conditions of soldering are shown in Figure 14: Reflow Soldering Standard Conditions (Example).

When products are immersed in solvent after mounting, pay special attention to maintain the temperature difference within 100 °C. Soldering must be carried out by the above-mentioned conditions to prevent products from damage. Set up the highest temperature of reflow within 260 °C. Contact Murata before use if concerning other soldering conditions.

Figure 14: Reflow Soldering Standard Conditions (Example)



Please use the reflow within 2 times.

Use rosin type flux or weakly active flux with a chlorine content of 0.2 wt % or less.

18.6 Cleaning

Since this Product is Moisture Sensitive, any cleaning is not permitted. If any cleaning process is done the customer is responsible for any issues or failures caused by such process.

18.7 Operational Environment Conditions

Products are designed to work for electronic products under normal environmental conditions (ambient temperature, humidity and pressure). Therefore, products have no problems to be used under the similar conditions to the above-mentioned. However, if products are used under the following circumstances, it may damage products and leakage of electricity and abnormal temperature may occur.

- In an atmosphere containing corrosive gas (Cl_2, NH_3, SO_X, NO_X, etc.).
- In an atmosphere containing combustible and volatile gases.
- Dusty place.
- Direct sunlight place.
- Water splashing place.
- Humid place where water condenses.
- Freezing place.

If there are possibilities for products to be used under the preceding clause, consult with Murata before actual use.

Do not apply static electricity or excessive voltage while assembling and measuring, as it might be a cause of degradation or destruction to apply static electricity to products.

18.8 Input Power Capacity

Products shall be used in the input power capacity as specified in these specifications.

Inform Murata beforehand, in case that the components are used beyond such input power capacity range.

19 Preconditions to Use Our Products

PLEASE READ THIS NOTICE BEFORE USING OUR PRODUCTS.

Please make sure that your product has been evaluated and confirmed from the aspect of the fitness for the specifications of our product when our product is mounted to your product.

All the items and parameters in this product specification/datasheet/catalog have been prescribed on the premise that our product is used for the purpose, under the condition and in the environment specified in this specification. You are requested not to use our product deviating from the condition and the environment specified in this specification.

Please note that the only warranty that we provide regarding the products is its conformance to the specifications provided herein. Accordingly, we shall not be responsible for any defects in products or equipment incorporating such products, which are caused under the conditions other than those specified in this specification.

WE HEREBY DISCLAIMS ALL OTHER WARRANTIES REGARDING THE PRODUCTS, EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE, THAT THEY ARE DEFECT-FREE, OR AGAINST INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS.

You agree that you will use any and all software or program code (including but not limited to hcd, firmware, nvram, and blob) we may provide or to be embedded into our product (“Software”) provided that you use the Software bundled with our product. YOU AGREE THAT THE SOFTWARE SHALL BE PROVIDED TO YOU “AS IS” BASIS, MURATA MAKES NO REPRESENTATIONS OR WARRANTIES THAT THE SOFTWARE IS ERROR-FREE OR WILL OPERATE WITHOUT INTERRUPTION. AND MORE, MURATA MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED WITH RESPECT TO THE SOFTWARE. MURATA EXPRESSLY DISCLAIM ANY AND ALL WARRANTIES OR CONDITIONS OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE NOR THE WARRANTY OF TITLE OR NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS.

You shall indemnify and hold harmless us, our affiliates, and our licensor from and against any and all claims, costs, expenses and liabilities (including attorney’s fees), which arise in connection with the using the Software.

The product shall not be used in any application listed below which requires especially high reliability for the prevention of such defect as may directly cause damage to the third party's life, body or property. You acknowledge and agree that, if you use our products in such applications, we will not be responsible for any failure to meet such requirements.

Furthermore, YOU AGREE TO INDEMNIFY AND DEFEND US AND OUR AFFILIATES AGAINST ALL CLAIMS, DAMAGES, COSTS, AND EXPENSES THAT MAY BE INCURRED, INCLUDING WITHOUT LIMITATION, ATTORNEY FEES AND COSTS, DUE TO THE USE OF OUR PRODUCTS IN SUCH APPLICATIONS.

- Aircraft equipment.
- Aerospace equipment
- Undersea equipment.
- Power plant control equipment

- Medical equipment.
- Transportation equipment (vehicles, trains, ships, elevator, etc.).
- Traffic signal equipment.
- Disaster prevention / crime prevention equipment.
- Burning / explosion control equipment
- Application of similar complexity and/ or reliability requirements to the applications listed in the above.

Even in the unlikely event that an abnormality or malfunction occurs in this product under operating conditions that conform to the specifications, be sure to add an appropriate fail-safe function to the system to prevent secondary accidents.

We expressly prohibit you from analyzing, breaking, Reverse-Engineering, remodeling altering, and reproducing our product. Our product cannot be used for the product which is prohibited from being manufactured, used, and sold by the regulations and laws in the world.

We do not warrant or represent that any license, either express or implied, is granted under any our patent right, copyright, mask work right, or our other intellectual property right relating to any combination, machine, or process in which our products or services are used. Information provided by us regarding third-party products or services does not constitute a license from us to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from us under our patents or other intellectual property.

Please do not use our products, our technical information and other data provided by us for the purpose of developing of mass-destruction weapons and the purpose of military use.

Moreover, you must comply with "foreign exchange and foreign trade law", the "U.S. export administration regulations", etc.

Please note that we may discontinue the manufacture of our products, due to reasons such as end of supply of materials and/or components from our suppliers.

Customer acknowledges that Murata will, if requested by you, conduct a failure analysis for defect or alleged defect of Products only at the level required for consumer grade Products, and thus such analysis may not always be available or be in accordance with your request (for example, in cases where the defect was caused by components in Products supplied to Murata from a third party).

By signing on specification sheet or approval sheet, you acknowledge that you are the legal representative for your company and that you understand and accept the validity of the contents herein.

When you are not able to return the signed version of specification sheet or approval sheet within 90 days from receiving date of specification sheet or approval sheet, it shall be deemed to be your consent on the content of specification sheet or approval sheet.

Customer acknowledges that engineering samples may deviate from specifications and may contain defects due to their development status.

We reject any liability or product warranty for engineering samples.

In particular we disclaim liability for damages caused by

- the use of the engineering sample other than for evaluation purposes, particularly the installation or integration in the product to be sold by you,
- deviation or lapse in function of engineering sample,
- improper use of engineering samples.

We disclaims any liability for consequential and incidental damages.

This Precondition to Use Our Products stipulated in this datasheet can only be modified, amended or altered by documents that explicitly reflect the mutual consent of both parties (including instances where one party explicitly indicates its acceptance of terms provided by the other party through click-through agreements).

If you can’t agree the above contents, you should inquire our sales.

Revision History

Revision	Date	Changed Item	Comment
-	2024/05/08	Initial release	
A	2024/12/09	Update the key features, dimension, label marking, recommended Land Pattern, reference circuit, function description, Wi-Fi & BLE performance, Regulatory certification.	
B	2024/12/30	Update product weight and picture.	
C	2025/02/24	Update the reference circuit design. Update the pin descriptions.	
D	2025/03/18	Added the note for stencil thickness	
E	2025/06/24	Update FCC ID, ISED ID and Korea certification mark.