LTE Cat-M1

Multi Band Module

CL5ADAH2Z

Manual

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Application

Restricted to M2M Device. *Not allowed for TELEMATICS use cases.

"M2M Device" hereinto is defined as a complete device that connects to network infrastructure equipment over a wireless network utilizing Wireless Wide-Area Network Standard through the module; utility metering devices, vending machines, cargo containers, ATM machines for electronic payment, remote monitoring systems, digital billboards, portable healthcare monitoring devices, alarm or security systems, portable tracking devices. Telephones and tablet devices are not included in the "M2M Devices".

● Revision History

Revision	Date	Summary of Change
1.0	2020.07.01	New Release
1.1	2020.11.05	Remove a part of RF info.

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● Relation Documents

- Software Application Guide
- AT Commands Manual
- Circuit of EVB (recommended circuit)
- Evaluation Board Manual

1. Introduction

TAIYO YUDEN offers a turnkey solution of CAT-M1 multi band LGA module supporting the following key features:

Module highlights

- Based on Altair Semiconductor ALT1250 chipset
- LTE CAT-M1
- Supporting standard multi band design
  Band2/Band4/Band8/Band12/Band20/Band26
- Small size (module size 15.0mm x 14.0 mm x 1.9 mm)
- Power supply: 2.3-4.2V (VBAT) / 2.85-4.5V (VBAT_FEM)
- Supports ultra-low DRX, eDRX and standby power consumption

LTE features highlights

- LTE CAT-M1 support based on 3GPP release13
- SW upgradable to CAT-M1 based Release14

Features

- LwM2M, TCP/IP, UDP/IP, SMS, Power saving

Interface support

- UART (3)

This document describes the hardware application interfaces and air interfaces that are provided when the module is used.
This document helps you to understand the interface specifications, electrical features and related product information of the module.

2. Overall Description

2.1. Function Overview

Table1 Features

Feature	Description
Physical Features	Dimensions:15.0mm × 14.0mm × 1.9mm
Weight	0.92g
Operating Band	Band2,4, 8, 12, 20, 26
Operating Temperature [1]	–30 to +70°C
Storage Temperature	–40 to +80°C
Power Voltage	VBAT: 2.3V to 4.2V [2] VBAT_FEM: 2.85V to 4.5V [2]
Application Interface (pin)	VSIM pin
	PMU_SHUTDOOWN pin
	VBAT pin
	VBAT_FEM pin
	PMU_WAKEUP pin
	AUX_ADC4 (BOOST_EN) pin
	SC_SWP pin
	UART0 (2wires)
	UART1 (2wires)
	UART2 (4wires)
SMS	Supports formats of PDU (AT command) SMS over SGs
Data Services	Half-Duplex DL: 300kbps (OFDMA) / UL: 375kbps (SC-FDMA) [3]
Operating System	Real Time OS

[1]: When the module works at this temperature, NOT all its RF specifications comply with the 3GPP RF specifications.

[2]: Power voltage of our evaluation board is as follows; VBAT: 3.0 V
VBAT_FEM: 3.3 V

[3]: the maximum value in theory

NOTE

● Use external interface for debugging and rewriting FW.

2.2. Circuit Block Diagram

Figure1 shows the circuit block diagram of the module. The application block diagram and major functional units of the module contain the following parts:

- Radio Frequency (RF) transceiver
- Multi-chip package (MCP) include power management unit
- RF Front End

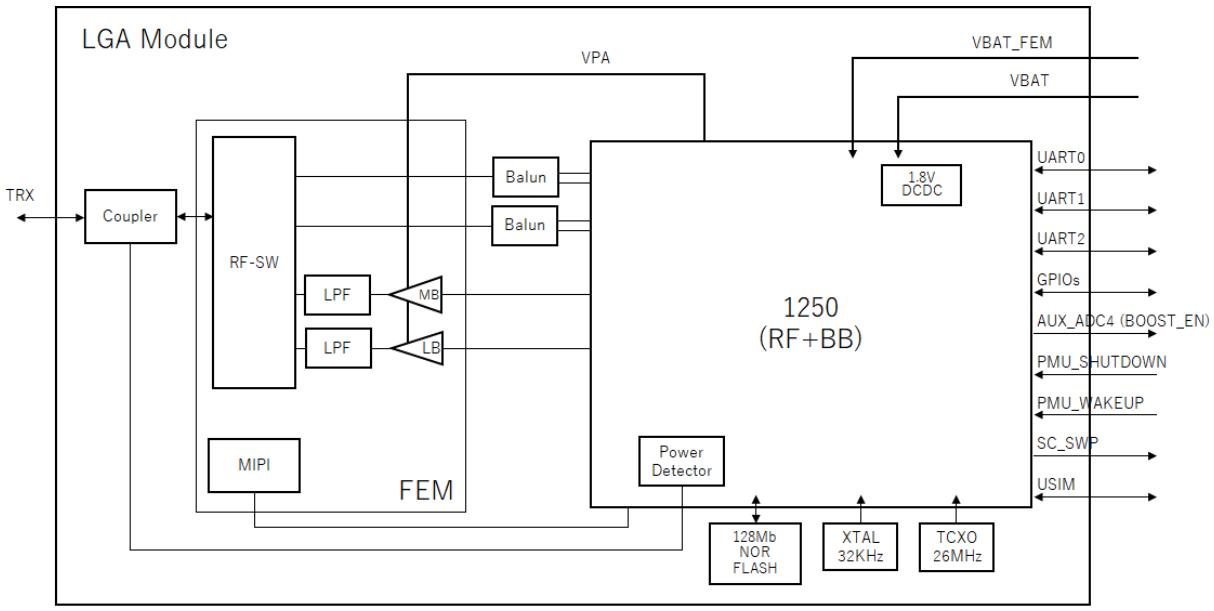


Figure1 circuit block diagram of the module

3. Description of the Application Interfaces

3.1. pin

The module uses pins as its external interfaces.
Figure2 shows an LGA map diagram of this module. Table2 shows definitions of pins on the LGA map.

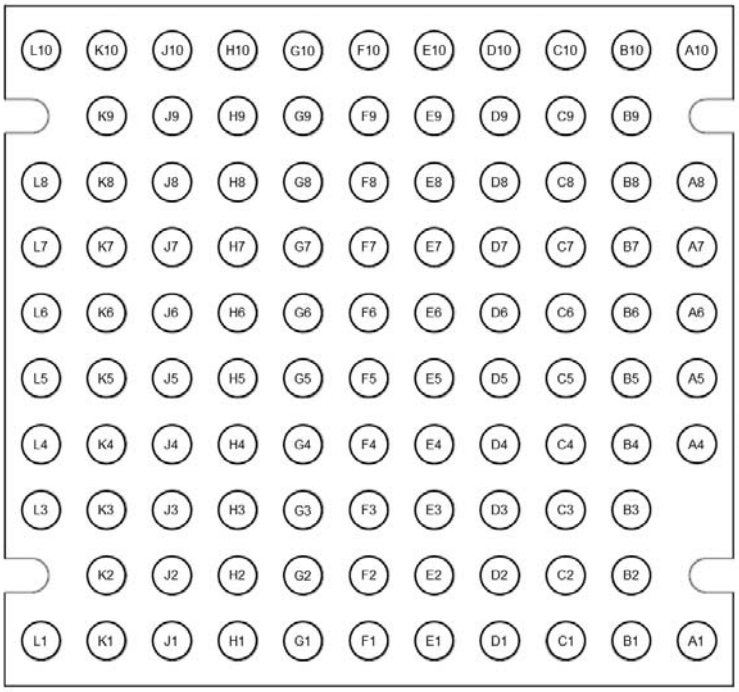


Figure2 LGA map diagram (TOP_THRU_ VIEW)

Table2 Definitions of pins

No.	Pin Name	Direction	Type	Recommendation for Unused pin	Description
A1	GND	-	-	-	Ground
A4	GND	-	-	-	Ground
A5	RF_AUX_OUT1	-	A	Open	Reserved
A6	GND	-	-	-	Ground
A7	RF_RXTX	IO	A	-	RF TXRX Main LTE antenna
A8	GND	-	-	-	Ground
A10	GND	-	-	-	Ground
B1	VBAT_FEM	I	P	-	Module input power supply
B2	VBAT_FEM	I	P	-	Module input power supply
B3	VBAT_FEM	I	P	-	Module input power supply
B4	GND	-	-	-	Ground
B5	GND	-	-	-	Ground
B6	GND	-	-	-	Ground
B7	GND	-	-	-	Ground
B8	GND	-	-	-	Ground
B9	UART2_RX	I	D, PU	Open	UART2 receiving data
B10	UART2_RTS	IO	D, PU	Open	UART2 request to send
C1	GND	-	-	-	Ground
C2	GND	-	-	-	Ground
C3	GND	-	-	-	Ground
C4	GND	-	-	-	Ground
C5	RF_TESTMUX_OUT	-	-	Ground	Reserved
C6	VDD_RF	O	P	-	VDD_RF out
C7	GND	-	-	-	Ground
C8	UART0_RX	I	D, PU	Open	UART0 receiving data
C9	UART2_TX	O	D, PU	-	UART2 transmitting data
C10	UART2_CTS	IO	D, PD	Open	UART2 clear to send
D1	EJ_TRST	IO	D, PD	Pull down (10kΩ)	Reserved
D2	I2C0_SCL	IO	D, PU	Open	Reserved
D3	I2C0_SDA	IO	D, PU	Open	Reserved
D4	PMU_EXT_ALARM	O	A	Open	Reserved
D5	FE_DEBUG	-	-	Ground	Reserved
D6	GND	-	-	-	Ground
D7	GND	-	-	-	Ground

No.	Pin Name	Direction	Type	Recommendation for Unused pin	Description
D8	UART0_TX	O	D, PU	-	UART0 transmitting data
D9	UART0_CTS	IO	D, PU	Open	UART0 clear to send
D10	VDD_XO	O	P	-	VDD_XO out
E1	EJ_TDO	IO	D, PU	Open	Reserved
E2	EJ_TDI	IO	D, PD	Open	Reserved
E3	SC_SWP	IO	D, PD	Open	Host wakeup
E4	PMU_POWER_BUTTON	I	A	PU*	Reserved Internal pull up. *If it is connected to VBAT, it is PU (min: 200kΩ). It is unconnected, it is PU (min:600kΩ). Pull source is VRTC.
E5	DCDC_1v3	O	P	-	DCDC_1v3 out
E6	GND	-	-	-	Ground
E7	GND	-	-	-	Ground
E8	UART0_RTS	IO	D, PU	Open	UART0 request to send
E9	GND	-	-	-	Ground
E10	RESERVED0_USB_DN	-	-	Open	Reserved
F1	EJ_TCK	IO	D, PD	Open	Reserved
F2	EJ_TMS	IO	D, PD	Open	Reserved
F3	VDD_DIG	O	P	-	VDD_DIG out
F4	DEBUG_SEL	IO	D, PD	Open	HW pin for EJTAG chain selection, PD (100kΩ) for MIPS chain, and PU for ARM chain.
F5	TEST	-	-	Ground	Reserved
F6	GND	-	-	-	Ground
F7	GND	-	-	-	Ground
F8	AUX_ADC4 (BOOST_EN)	IO	D, PD	Open	1.8V = enable the external DC-DC for VBAT_FEM power
F9	RESERVED2_USB3V	-	-	Open	Reserved
F10	RESERVED0_USB_DP	-	-	Open	Reserved
G1	GND	-	-	-	Ground
G2	PMU_SHUTDOWN	I	A	PU*	Shutdown active low. HW reset Internal pull up. *If PMU_VBACKUP is connected to VBAT, it is PU (min: 200kΩ). PMU_VBACKUP is unconnected, it is PU (min:600kΩ). Pull source is VRTC.

No.	Pin Name	Direction	Type	Recommendation for Unused pin	Description
G3	PMU_ATB	I	-	Open	Debug and testing purposes
G4	PMU_WAKEUP	I	A	PD (100KΩ)	Device wakeup, active high
G5	DEBUG_RSTN	IO	D, PU	Open	Reset pin for the JTAG probe
G6	UART1_RTS	IO	D, PU	Open	UART1 request to send
G7	GND	-	-	-	Ground
G8	SF_nHOLD/IO3	IO	D	Open	Serial flash interface
G9	SPIM0_EN1	IO	D, PU	Open	Reserved
G10	VFLASH	O	P	-	VFLASH out
H1	VBAT	I	P	-	Module input power supply
H2	VDD_EXTRA	O	P	-	VDD_EXTRA out
H3	PMU_AT_OUT	O	A	Open	Anti-tamper output
H4	PMU_VCAP	O	A	Open	Connecting external capacitor as backup for VBAT
H5	VDD_GPM	O	P	-	VDD_GPM out
H6	SPIM1_CLK	IO	D, PD	Open	Reserved
H7	SPIM1_MISO	IO	D, PD	Open	Reserved
H8	GND	-	-	-	Ground
H9	UART1_TX	IO	D, PU	Open	UART1 transmitting data
H10	GND	-	-	-	Ground
J1	VBAT	I	P	-	Module input power supply
J2	SIM_DETECT	I	D, PD	Open	SIM detection If use eSIM, it is NC.
J3	PMU_AT_IN	I	A	Ground	Anti- tamper input
J4	PMU_VBACKUP	I	-	Open	Input from backup battery
J5	CLKOUT	O	D, PU	-	Configurable clock out
J6	SPIM1_EN	IO	D, PU	Open	Reserved
J7	SPIM1_MOSI	IO	D, PD	Open	Reserved
J8	GND	-	-	-	Ground
J9	GND	-	-	-	Ground
J10	UART1_RX	IO	D, PU	Open	UART1 receiving data
K1	GND	-	-	-	Ground
K2	SIMIO	IO	D, PD	Open	SIM data
K3	SIMRST	O	D, PD	-	SIM reset
K4	PMU_VRTC	IO	-	Open	Used for PMU_SHUTDOWN and PMU_POWER_BUTTON pull source
K5	VDDIO_GPM	O	-	-	VDDIO_GPM out
K6	GND	-	-	-	Ground

No.	Pin Name	Direction	Type	Recommendation for Unused pin	Description
K7	GND	-	-	-	Ground
K8	GND	-	-	-	Ground
K9	GND	-	-	-	Ground
K10	UART1_CTS	IO	D, PU	Open	UART1 clear to send
L1	GND	-	-	-	Ground
L3	SIMCLK	O	D, PD	-	SIM clock
L4	VSIM	O	P	-	VSIM out
L5	SF_nWP/IO2	IO	D	Open	Serial flash interface IO2
L6	SF_SO/IO1	IO	D	Open	Serial flash interface IO1
L7	SF_CLK	O	D	-	Serial flash clock
L8	SF_SI/IO0	IO	D	Open	Serial flash interface IO0
L10	GND	-	-	-	Ground

NOTE

- **I:** Input only functionality. **O:** Output only functionality.
  IO: Both input and output functionality.
- **A**: Analog pin. **D**: Digital pin. **PD**: Pull Down. **PU**: Pull Up. **P**: Power
- The internal resistance of digital pin is 13kΩ to 45kΩ.

3.2. Power Supply Interface

3.2.1. Overview

The ALT1250 includes an integrated PMU. The PMU is designed to work directly from both rechargeable and primary batteries. The PMU supplies current to all ALT1250 blocks, the IOs, the External Flash, the TCXO and the UICC.

In addition, the PMU includes a low power RTC.

The power supply part of the module contains:

- RTC (Real Time Clock)
- APC (Advance Power Controller)
- different regulators (LDOs and DC-DC)

Table3 lists the definitions of the pins on the power supply interface

Pin No.	Signal Name	I/O	Description	voltage (V)
B1	VBAT_FEM	I	Module input power supply	2.85-4.5
B2	VBAT_FEM	I		
B3	VBAT_FEM	I		
H1	VBAT	I	Module input power supply	2.3-4.2
H5	VBAT	I		
C6	VDD_RF	O	VDD_RF out	1.9
D10	VDD_XO	O	VDD_XO out	1.9
E5	DCDC_1v3	O	DCDC_1v3 out	1.3
F3	VDD_DIG	O	VDD_DIG	0.9
G10	VFLASH	O	VFLASH out	1.8
H2	VDD_EXTRA	O	VDD_EXTRA out	1.8
H5	VDD_GPM	O	VDD_GPM out	1.1
K5	VDDIO_GPM	O	VDDIO_GPM out	1.8
L4	VSIM	O	VSIM out	1.8

3.2.2. Power Supply VBAT and VBAT_FEM

There are two types of VBAT of module.

(1) VBAT

VBAT is the power supply of RTC and LPDDR.

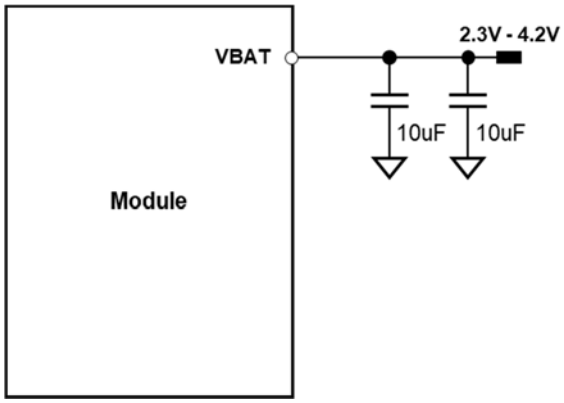


Figure3 VBAT supply block diagram

(2) VBAT_FEM

VBAT_FEM is power supply to be controlled synchronously with the DRX/ eDRX cycle.

See following page for details.

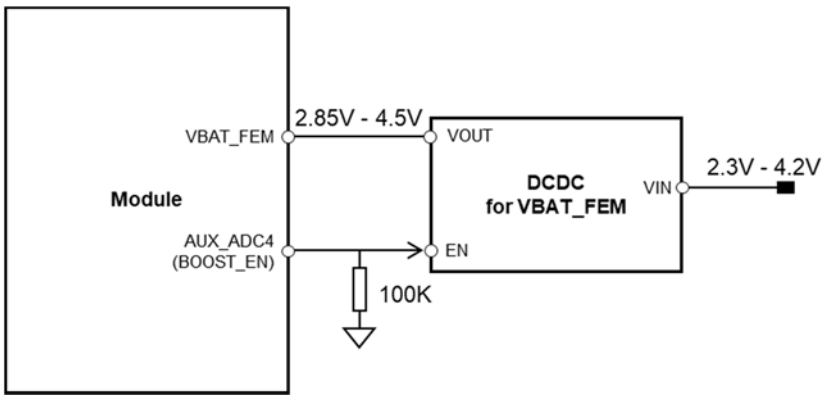


Figure4 VBAT_FEM supply block diagram

When VBAT is 2.3 V (minimum value), must keep 2.3 V or more, during TX.

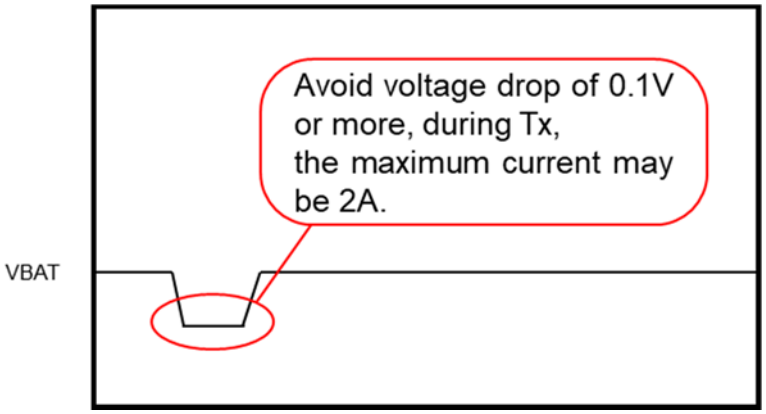


Figure5 drop of power supply voltage (VBAT)

When VBAT_FEM is 2.85 V (minimum value), must keep 2.85 V or more, during TX.

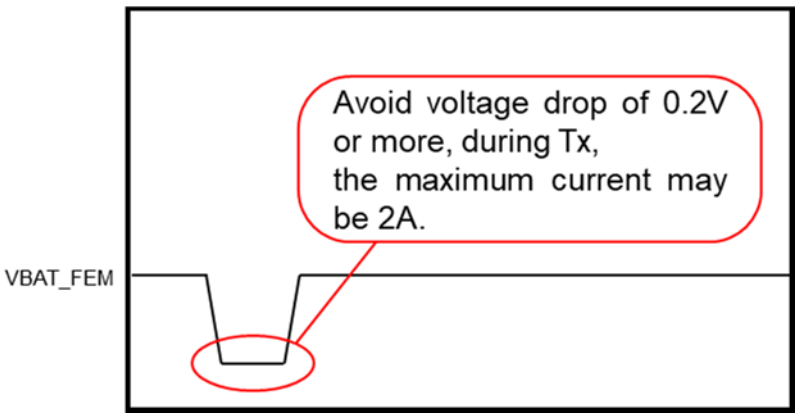


Figure6 drop of power supply voltage (VBAT_FEM)

Figure7 shows reference block diagram of the module.
An external DC-DC converter is required on the VBAT_FEM side of the module.
The reason why the DC-DC converter is necessary is as follows.

- It is synchronizing with eDRX, for power saving.
- The module learns autonomously eDRX cycle.
  AUX_ADC4 (BOOST_EN) synchronizes with eDRX and can control the DC-DC converter.
  (AUX_ADC4 (BOOST_EN) control VBAT_FEM in synchronization with eDRX.)

Figure7 is the recommended circuit. We designed to minimize reduce the current consumption during DH2.

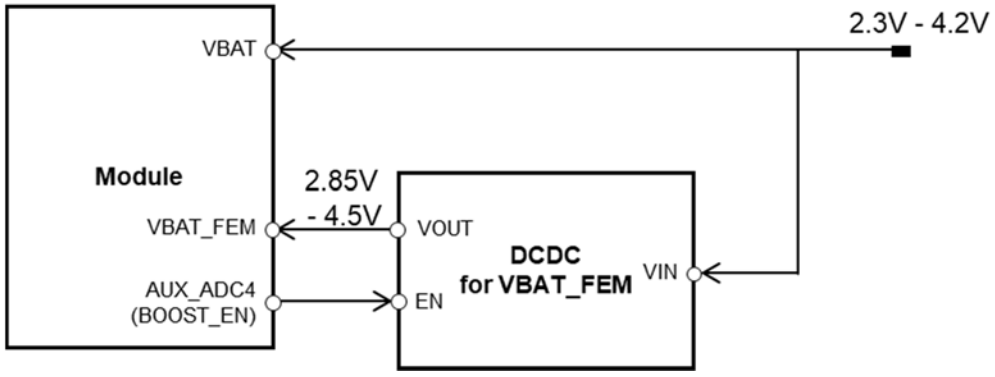


Figure7 reference power block diagram of the module

The external DC-DC converter is TPS61021ADSG.
VBAT_FEM should be supplied by external DC-DC and controlled by ADC_AUX4 (BOOST_EN) pin.
Figure8 shows circuit of the DC-DC. Refer to datasheet of TPS61021ADSG for details.

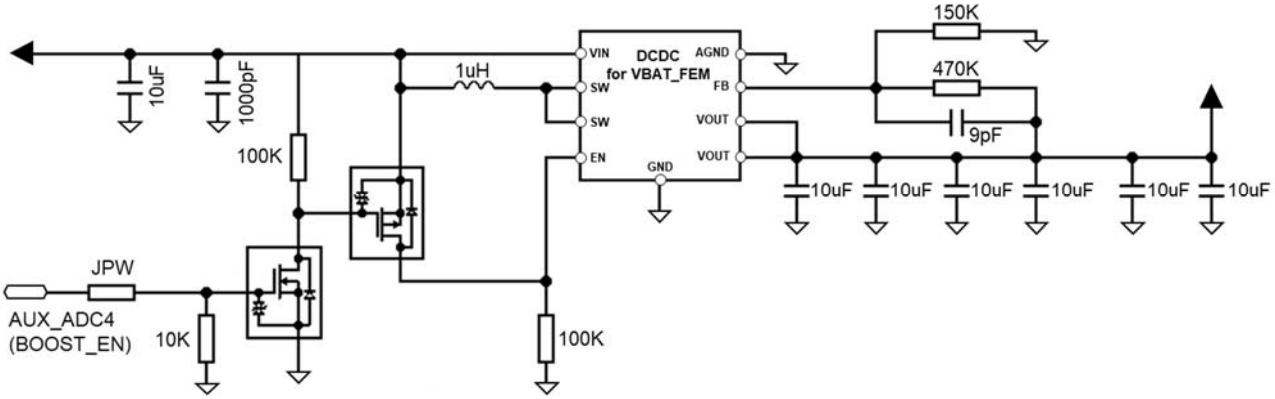


Figure8 reference circuit of the DC-DC

3.2.3. USIM Power Supply VSIM

Through the VSIM power supply interface, 1.8 V power from module can be supplied to USIM card. Special attention should be taken on PCB design at the host side.

3.3. Signal Control Interface

3.3.1. Overview

The signal control part of the interface in the module contains the following:

- SC_SWP pin
- PMU_SHUTDOOWN pin
- PMU_WAKEUP pin
- AUX_ADC4 (BOOST_EN) pin

Table4 Pins on the signal control interface

Pin No.	PIN Name	I/O	Description
E3	SC_SWP	IO	host wakeup
G2	PMU_SHUTDOWN	I	Shutdown, HW reset, active low
G4	PMU_WAKEUP	I	Device wakeup, active high
F8	AUX_ADC4 (BOOST_EN)	IO	1.8V = enable the external DC-DC for VBAT_FEM power

3.3.2. SC_SWP Pin

Table5 Two States of SC_SWP Pin

Item	Pin state	Description
1	High	Interrupt to wakeup HOST. Module wants to send data to host.
2	Low	No interrupt.

3.3.3. PMU_SHUTDOWN Pin

This pin requires an external PU resistor.
This pin has the highest priority compared to other functionalities.
Therefore, it will forcibly hard reset.
Pulling low more than 100ms and then pulling high will reset the module.

Table6 Two States of PMU_SHUTDOWN Pin

Item	Pin state	Description
1	High	active
2	Low	shutdown

3.3.4. PMU_WAKEUP Pin

Table7 Two States of PMU_WAKEUP Pin

Item	Pin state	Description
1	High	Wakeup the module or keep active. Module won't enter DH2 if this signal kept high.
2	Low	Change the state of module Active to DH2. Note: Never set PMU_WAKEUP to low when the host will send data to the module. (See 6.2. Host-Module Mutual Wakeup Interface)

3.3.5. AUX_ADC4 (BOOST_EN) Pin

Output signal to enable the external DCDC for VBAT_FEM power.
When AUX_ADC4 (BOOST_EN) pin is to be high, the external DCDC wakes up.
Then VBAT_FEM also wakes up.

Table8 Two States of AUX_ADC4 (BOOST_EN) Pin

Item	Pin state	Description
1	High	Enable
2	Low	disable

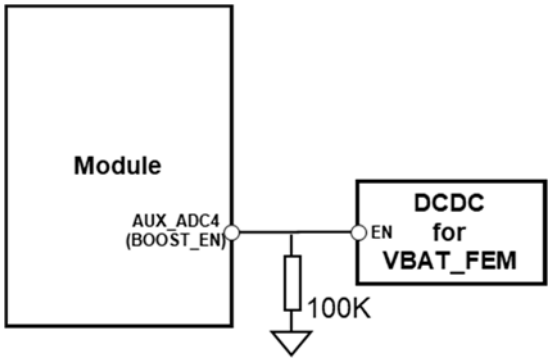


Figure9 connections of the AUX_ADC4 (BOOST_EN) Pin

3.4. UART Interface

The module includes a 4-wire UART interface (UART0 - 2).
The UART is an asynchronous serial interface. The interface is a fully compliant and standard RS-232.
Offers similar functionality to industry-standard 16C550 UART devices.
UART0 is used for AT command or PPP.
* AT command response timeout: max 120s
UART1 is used for debug.
UART2 is used for CLI and firmware version up.

Support baud rates of up to 3Mbps (*). The baud rate can only be changed via AT command. (Refer to Software Application Guide)
The maximum baud rate error is 1.56%.
* Flow control is recommended when the baud rate setting is over 1Mbps.

Default setting is following:
Baud rete: 115200, Data: 8bit, Parity: none, Stop: 1bit, Flow control: none (See Data Format)

Table9 List of UART0 pins

No.	Pin Name	I/O	Description
C8	UART0_RX	I	UART0 receiving data. Active low 0V=active (Data bit=1) 1.8V=not active (Data bit=0)
D8	UART0_TX	O	UART0 transmitting data. Active low 0V=active (Data bit=1) 1.8V=not active (Data bit=0)
D9	UART0_CTS	I	UART0 clear to send. 0V=not active (Data bit=0) 1.8V=active (Data bit=1)
E8	UART0_RTS	O	UART0 ready to send. 0V=not active (Data bit=0) 1.8V=active (Data bit=1)

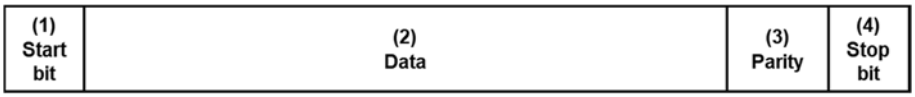
Table10 List of UART1 pins

No.	Pin Name	I/O	Description
J10	UART1_RX	I	UART1 receiving data. Active low 0V=active (Data bit=1) 1.8V=not active (Data bit=0)
H9	UART1_TX	O	UART1 transmitting data. Active low 0V=active (Data bit=1) 1.8V=not active (Data bit=0)
K10	UART1_CTS	I	UART1 clear to send. 0V=not active (Data bit=0) 1.8V=active (Data bit=1)
G6	UART1_RTS	O	UART1 ready to send. 0V=not active (Data bit=0) 1.8V=active (Data bit=1)

Table11 List of UART2 pins

No.	Pin Name	I/O	Description
B9	UART2_RX	I	UART2 receiving data. 0V=active (Data bit=1) 1.8V=not active (Data bit=0)
C9	UART2_TX	O	UART2 transmitting data. 0V=active (Data bit=1) 1.8V=not active (Data bit=0)
C10	UART2_CTS	I	UART2 clear to send. 0V=not active (Data bit=0) 1.8V=active (Data bit=1)
B10	UART2_RTS	O	UART2 ready to send. 0V=not active (Data bit=0) 1.8V=active (Data bit=1)

[Data Format]



(1) Start bit: start frame transmission (1bit)

(2) Data: length of transmission data in one frame (8bit)

(3) Parity: error detecting code (none)

(4) Stop bit: end frame transmission (1bit)

3.5. USIM Card Interface

The USIM interface can be used either for USIM socket, and for eSIM.
The module supports Class C (1.8V).
For 3.0V USIM cards support, an external voltage translator will be required.

To achieve ultra-low power consumption, SIM power will be off during DH2 mode.
The USIM input/output lines are following USIM specifications.

As the module is not equipped with an USIM card adapter, you need to place an USIM/eSIM card adapter on the user interface board.
Figure10 is recommended circuit for using USIM card adapter.
Figure11 is recommended circuit for using eSIM. (Refer to eSIM datasheet for detail of circuit.)
If you want to use both USIM card adapter and eSIM, please use switch circuit. (Refer to circuit of EVB for detail.)

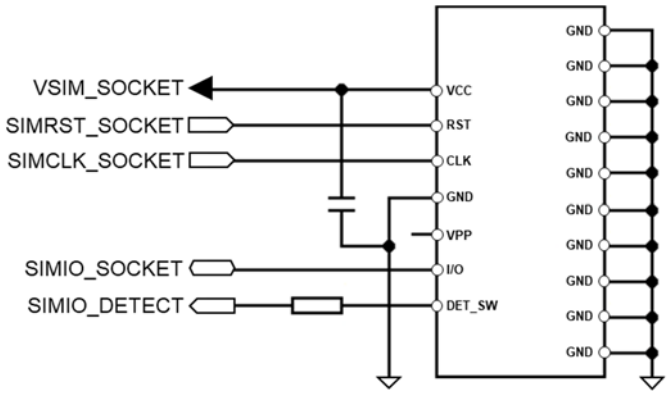


Figure10 recommended circuit for USIM card adapter

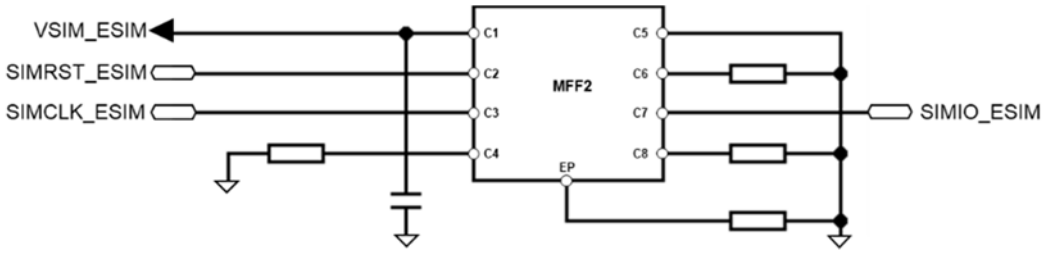


Figure11 recommended circuit for eSIM

3.6. RF Antenna Interface

3.6.1. RF Connector location

This module does not include any antennas. External antennas need to be used for the final products using this module.

NOTE

- You should prepare an external antenna which was certified based on the Radio Type Approval of the module.
- Please optimize impedance matching between RF input/output line and antenna by using a matching circuit.
  The RF input/output line of characteristic impedance in the module is 50Ω.
- For recommended antennas, refer to the antenna list (See attachment).

4. RF Specifications

4.1. Operating Frequencies

Table12 shows the RF bands supported by the module

Operating Band	Tx	Rx	Bandwidth
Band2	1850MHz - 1910MHz	1930MHz－1990MHz	1.4MHz/3MHz/5MHz /10MHz /15MHz/20MHz
Band4	1710MHz - 1755MHz	2110MHz - 2155MHz	1.4MHz/3MHz/5MHz /10MHz /15MHz/20MHz
Band8	880MHz - 915MHz	925MHz - 960MHz	1.4MHz/3MHz/5MHz /10MHz /15MHz/20MHz
Band12	699MHz - 716MHz	729MHz - 746MHz	1.4MHz/3MHz/5MHz /10MHz
Band20	832MHz - 862MHz	791MHz - 821MHz	1.4MHz/3MHz/5MHz /10MHz /15MHz
Band26	814MHz - 849MHz	859MHz - 894MHz	1.4MHz/3MHz/5MHz /10MHz /15MHz

4.2. Conducted RF Measurement

4.2.1. RF Test Environment

RF Test instrument	Rohde & Schwarz CMW500
Power Divider	ANRITSU K240B
Attenuator	Keysight 8493B

NOTE

- The compensation for different frequency bands relates to the cable and the test environment.
- The instrument compensation needs to be set according to the actual cable conditions.

4.2.2. Test Standards

The module meets 3GPP TS 36.521-1 test standards. The module passes strict tests at the factory and thus the quality of the module is guaranteed.

5. Electrical Specifications

5.1. Absolute Maximum Ratings

WARNING

Table26 lists the absolute ratings for the module. Using the module beyond these conditions may result in permanent damage to the module.

Table26 Absolute maximum ratings for the module

Symbol	Parameter	Min.	Max.	Unit
VBAT	VBAT supply pin	-0.2	4.35	V
VBAT_FEM	RF supply pin	-0.5	5.2	V
VDDIO	Voltage on any non-power-supply pin	-0.2	2.0	V

5.2. Operating Conditions

Table27 Operating conditions

Parameter	Min.	Typ.	Max.	Unit	Conditions
Operating temperatures	-10	-	+55	ºC	The module is fully functional (*) in all the temperature range, and it fully meets the 3GPP specification
	-30		+70	ºC	The module is fully functional (*) in all the temperature range
Storage temperatures	-40	-	+80	ºC	-
Module Vin (VBAT)	2.3	-	4.2	V	-
Module Vin (VBAT_FEM)	2.85	-	4.5	V	-
VBAT Rise Time	-	-	50	ms	from power on to 2.3V
VBAT_FEM Rise Time	-	-	1	ms	from power on to 2.85V

* Functional: the module is able to make wireless telecommunication.

Table28 DC Characteristics of pins

Parameter	Min.	Max.	Unit
V_{IH}	0.7 * V_{IO}	-	V
V_{IL}	-	0.3 * V_{IO}	V
V_{OH}	0.8 * V_{IO}	-	V
V_{OL}	-	0.2 * V_{IO}	V
V_{IO}	1.7	1.9	V

5.3. Conducted Electrical Measurement

5.3.1. Electrical Test Environment

Test instrument	Keysight N6705B、Keysight N6781A

5.4. Power Supply

5.4.1. Input Power Supply

Table29 Requirements for input power of the module

Parameter	Min.	Max.	Ripple Max.	Unit
VBAT	2.3	4.2	50mVpp	V
VBAT_FEM	2.85	4.5	50mVpp	V

5.4.2. Power State

Module is optimized to achieve ultra-low power consumption addressing IoT market needs. Power state is supported. (See the following Table 27)

Table30 Power state

Power state	Description	Required supplies	Wake-up options
Shutdown	Module powered off.	-	-
DH2	All digital logic is powered down, a configurable amount of retention memory is retained (64KB granularity), all output IOs are latched while input IOs can be configured to wake up the system, and the RTC is 'On' in this mode. IO Retention, SW state Full Retention, Memory Partially Retention, Timer /Anti Tamper 10 IO's	-	RTC Expiration PMU_WAKEUP PMU_SHUTDOWN Anti-Tamper Interface Any other digital interface configured to wakeup the system A wakeup event initiates a boot flow. This mode enables output IOs to latch and wakeup from digital input.
Active	All system is wake up.	All required power supplies are available.	-

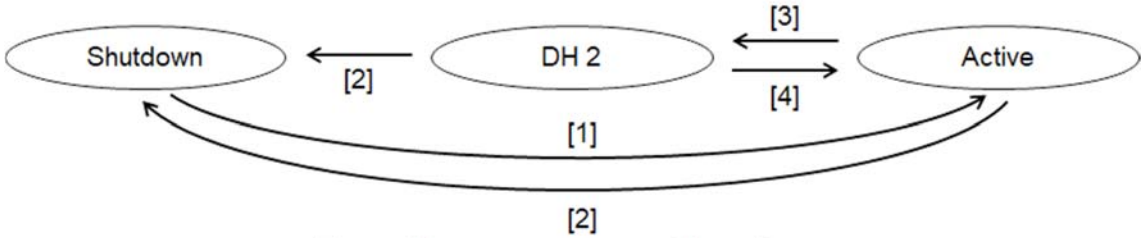


Figure12 power state transition diagram

NOTE

The following part is explained of the Figure10.

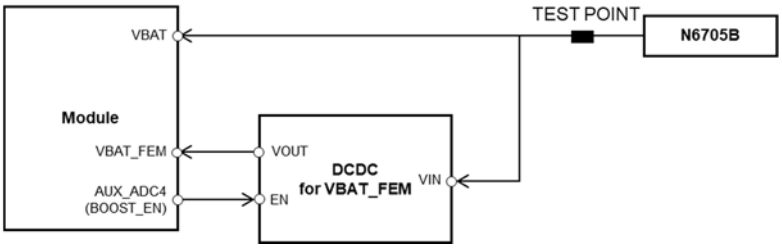
[1] Shutdown --> Active: See 6.1. Power on/off sequence

[2] Active or DH 2 --> Shutdown: See 6.1. Power on/off sequence

[3] Active --> DH 2: See 6.2.3. Close data interface

[4] DH 2 --> Active : See 6.2.1. Open data interface -host to module
6.2.2. Open data interface -module to host

5.4.3. Power Consumption



[conditions]

- measured on our evaluation board at 25ºC indoor
- Band: 1, Band Width: 5MHz
- DRX cycle = 1.28 s
- eDRX cycle = 81.92s, PTW = 1.28 s
- power supply of the module is 3.0V

Table31 Averaged power consumption of the evaluation board

wireless state	power state	Typical values (Avg)	Notes/Condition
RRC CONNECTED	Active	195mA	Tx Power: 0dBm
		233mA	Tx Power: 10dBm
		543mA	Tx Power: 23dBm
RRC IDLE	DH2	1.4mA	DRX [1] (SIM power on)
		50uA	eDRX [2] Average power consumption for 1 hour after shift to eDRX.

* It may be changed because of under development.

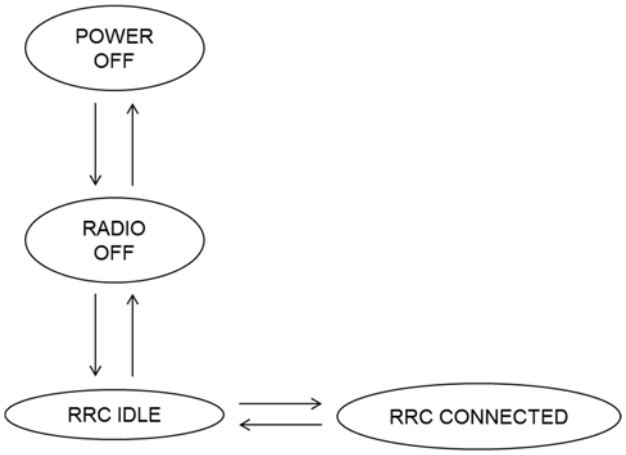


Figure13 wireless state transition diagram

[1] image of current waveform during DRX

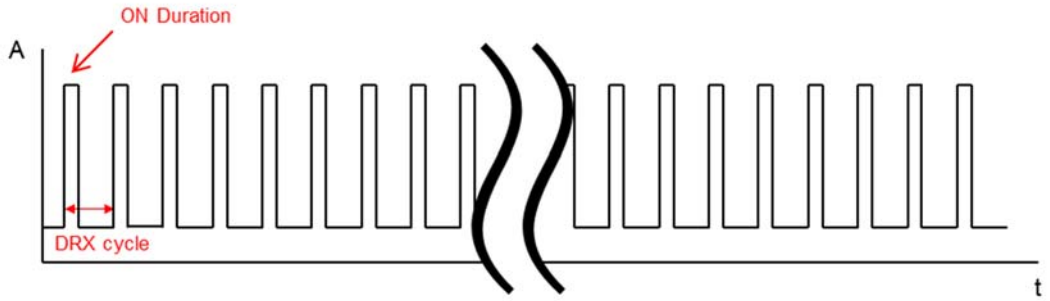


Figure14 image of current waveform during DRX

[2] image of current waveform during eDRX

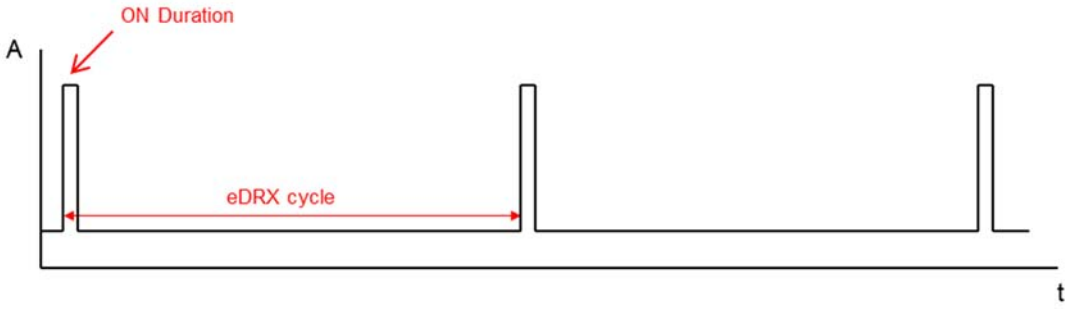


Figure15 image of current waveform during eDRX

6. Function and Features

6.1. Power on/off

6.1.1. Power on

The module is powered on as input triggered by VBAT.
When the module is powered, the PMU_SHUTDOWN pin is PU internally.
*When the PMU_SHUTDOWN pin is connected to an external switch without being connected to the host, the PMU_SHUTDOWN pin is PU internally, so not connecting external PU.
HOST does not need to input a signal to the PMU_SHUTDOWN pin, PMU_SHUTDOWN pin should be opened.

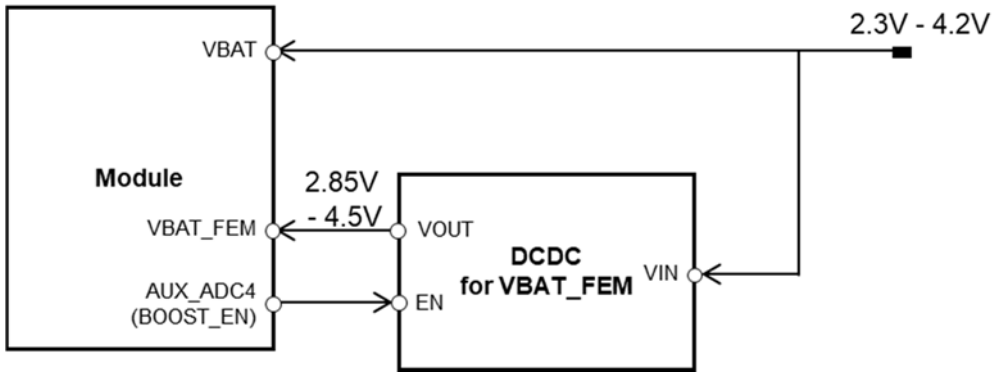


Figure16 reference block diagram of power on

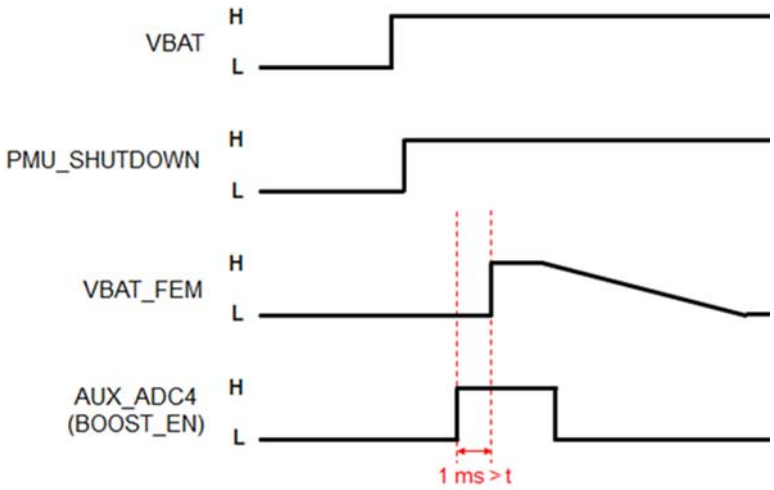
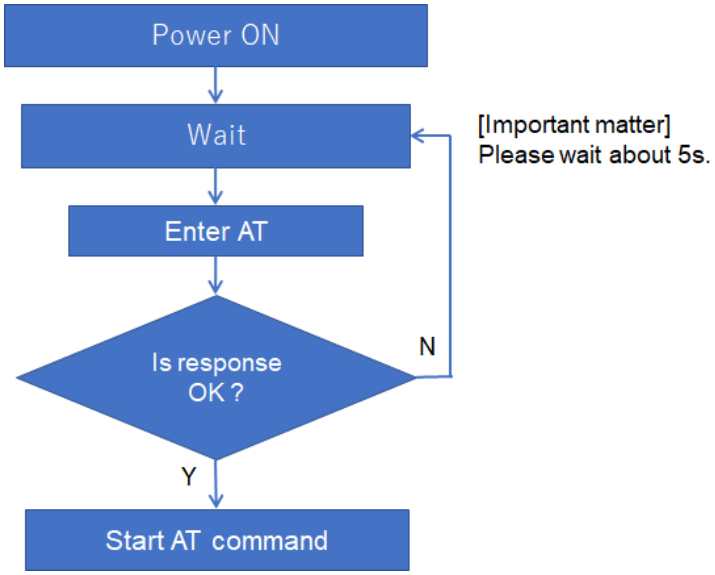


Figure17 power on sequence

● A flowchart showing start AT command.



6.1.2. Power off

The Power-off sequence occurs when either of the following conditions is met:

- VBAT falls below the UVLO power down threshold of 1.8V.
- Shutdown is requested by the PMU_SHUTDOWN pin.

NOTE

- Do not power off during module boot.
  If power off during access to flash, module may break.

6.2. Host-Module Mutual Wakeup Interface

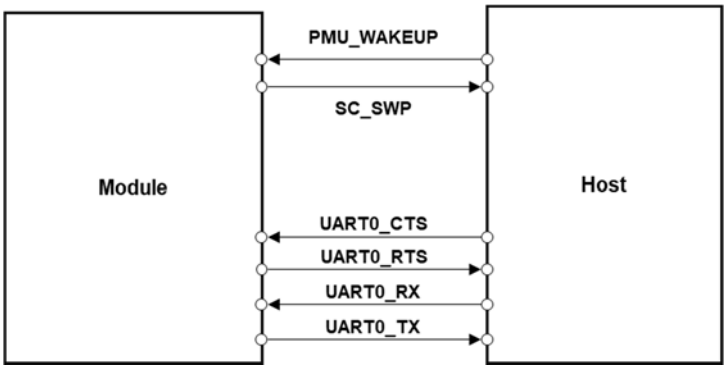


Figure18 Host-Module mutual wakeup

The state of PMU_WAKEUP and SC_SWP

(1) PMU_WAKEUP (Host: Output, Module: Input)

High：When host need to open the data interface and to wake up to module.

Low：When host need to close the data interface.

(2) SC_SWP (Host: Input, Module: Output)

High：Module need to open the data interface.

Therefore, interrupt to wakeup host.

Low：Module do not need to open the data interface.

Table32 the requirements for the external host interface IO

No.	Pin Name	Description
G4	PMU_WAKEUP	host wakes up module
E3	SC_SWP	module wakes up host
D8	UART0_TX	UART0 transmitting data
C8	UART0_RX	UART0 receiving data
E8	UART0_RTS	UART0 ready to send
D9	UART0_CTS	UART0 clear to send
G2	PMU_SHUTDOWN	hardware reset

*: Connect these pins to pins header etc.

6.2.1. Open data interface –host to module

When host wants to send data to module, host should open data interface.
The timing chart is as follows. (See Figure19)

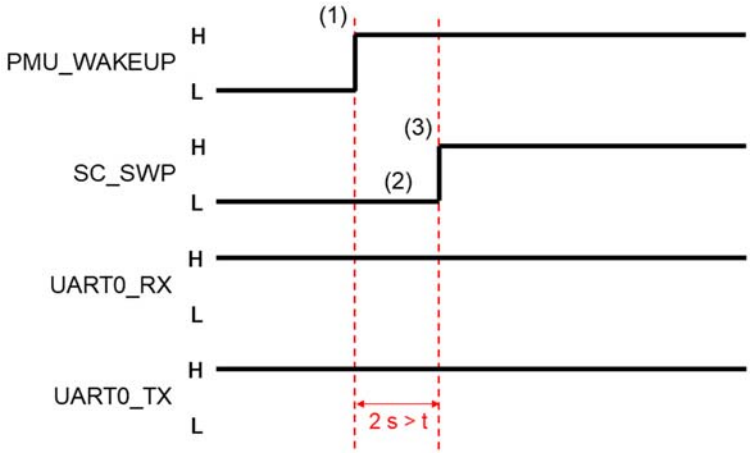


Figure19 open data interface - host to module

First, data interface state is not open.
UART0_RX and UART0_TX are always high.
(1) Host wants to send data to module. Host sets PMU_WAKEUP to high (PMU_WAKEUP = high)
(2) Module is awaking (might also be waking) and module is preparing
(3) Module sets SC_SWP to high (SC_SWP = high)
The data interface is opened and communication can start

6.2.2. Open data interface –module to host

When module wants to send data to host, module opens data interface.

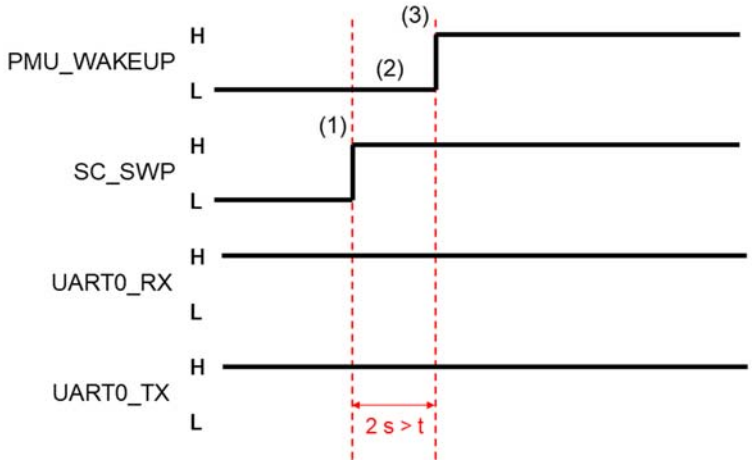


Figure20 open data interface - module to host

First, data interface state is not open.
UART0_RX and UART0_TX are always high.

(1) Module wants to send data to host. Module sets SC_SWP to high (SC_SWP = high)
(2) When host detects module sets SC_SWP to high, host needs to do the processing necessary to receive data
(3) When host is completed the processing on UART, host sets PMU_WAKEUP to high (PMU_WAKEUP = high)

The data interface is opened and communication can start

6.2.3. Close data interface

Host has no send data and wants to close data interface.
Then shift the state of module Active to DH2.

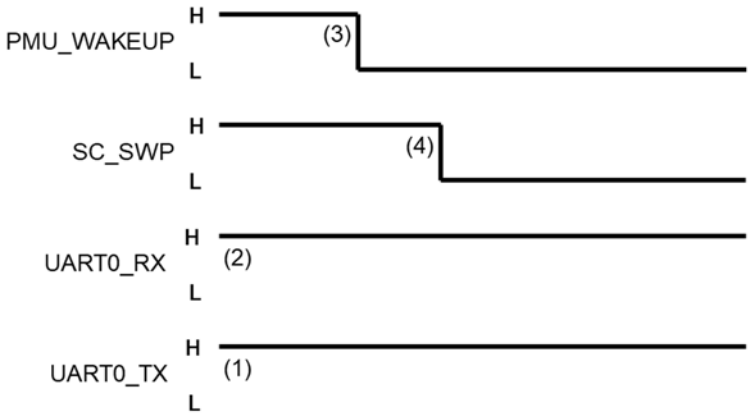


Figure21 close data interface

UART0_RX and UART0_TX are always high.
(1) Host detects that it is sending the last data bit in a session and module is not transmitting any data (UART0_TX = high)
(2) Host will not send any data (UART0_RX = fix = high)
(3) Host sets PMU_WAKEUP to low (PMU_WAKEUP = low)
(4) Module detects PMU_WAKEUP is low, and sets SC_SWP to low (SC_SWP = low)
The point is, the data interface closes and the module will sleep

NOTE

When there are events on the LTE network, Module does not sleep.
(e.g. RRC status is RRC-connected)

In that case, wait for the end of the communication event.
Since it is necessary to receive the output data of the module.
Please resume data connection.

The following figure shows the flowchart of close data interface.

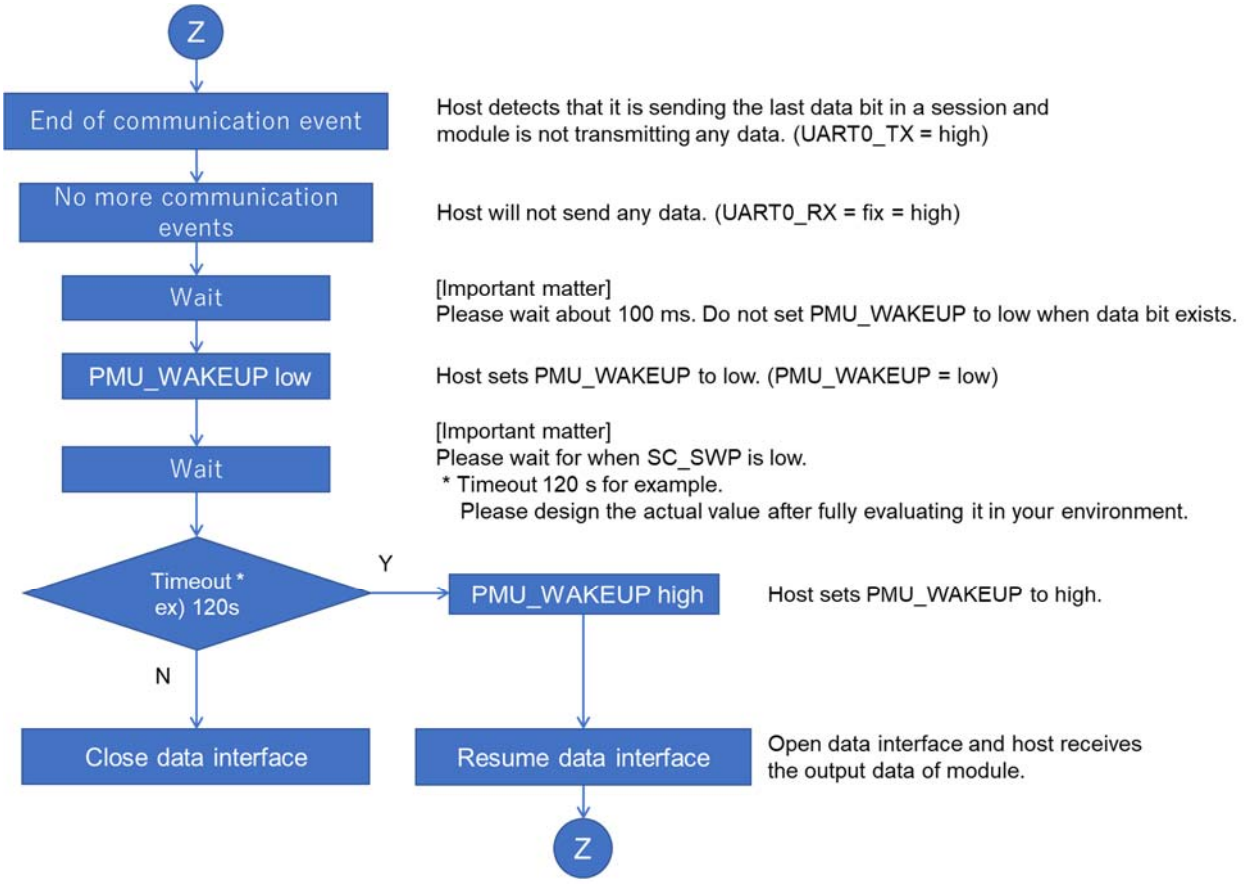


Figure22 flowchart of close data interface

7. Mechanical Specifications

7.1. Dimensions of the module

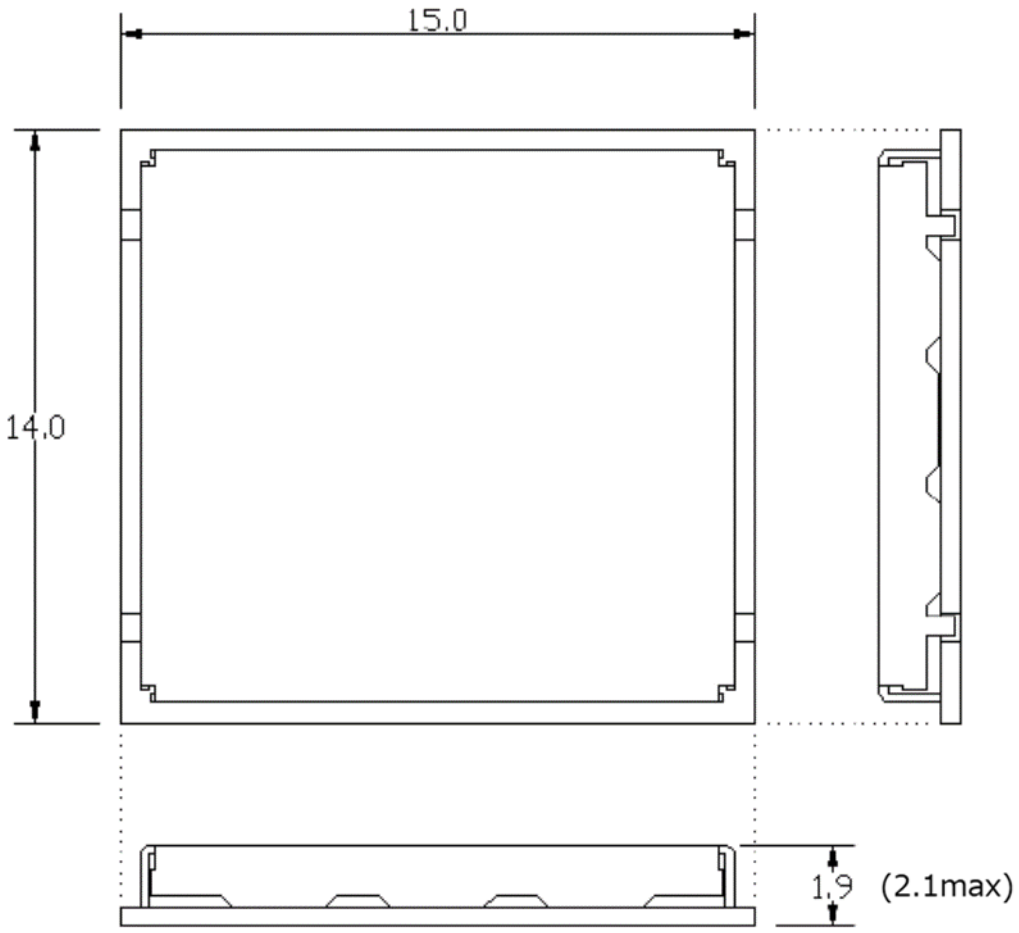


Figure23 dimensions of the module (TOP VIEW) (unit: mm)

*Tolerances unless otherwise specified: ±0.2mm

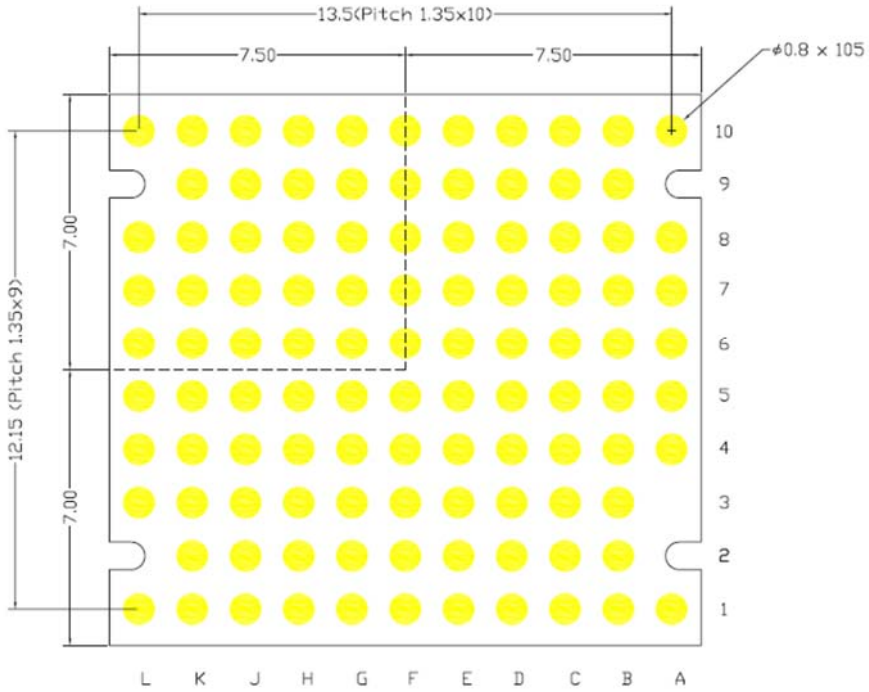
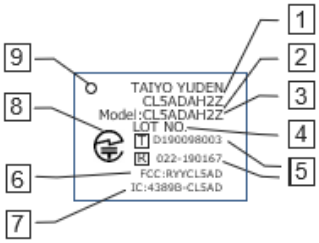


Figure24 Dimensions of the module (TOP THRU VIEW) (unit: mm)

7.2. Label



1:Manufacturer
2:Model Name
3:Part Number
4:Lot Number
5:Japan Technical Conformity Certification
6:FCC ID
7:IC ID
8:Japan Technical Conformity Logo(Φ3.0mm or more)
9:1 Pin Mark (Φ1.0mm)

Figure25 description of label

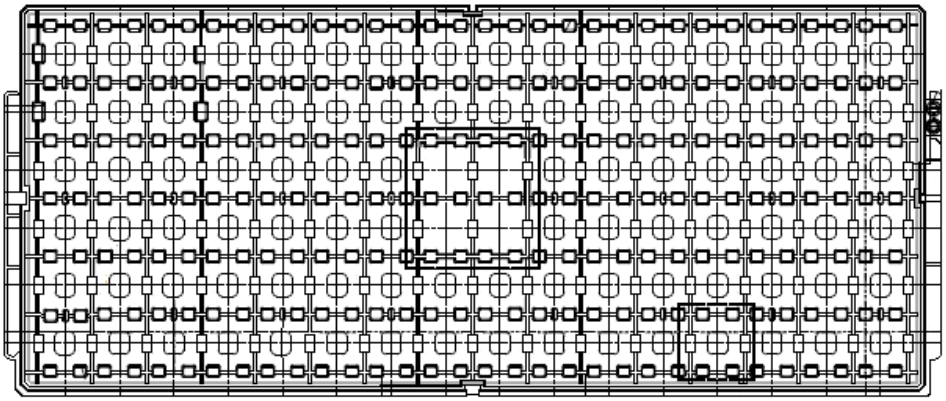
7.3. Packing System

The module package includes the tray, tray(cover), antistatic band, desiccant, and humidity indicator card.

This module is stored in the tray in units of 96 pieces.

- Packaging method: Tray
- Packaging unit: 960

  * It might be providing as tray at sample stage.



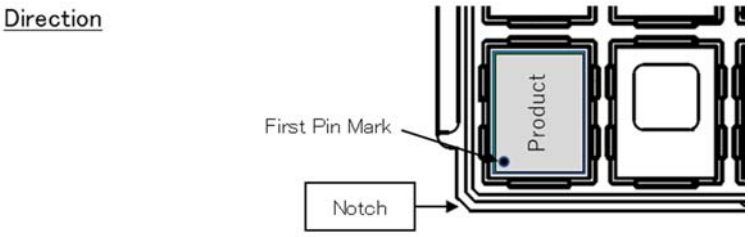


Figure26 packaging Figure

Place 10 trays, place the tray (cover) on it, and place it in an aluminum moisture barrier bag together with desiccant and humidity indicator card.
Both ends of the aluminum moisture barrier bags are sandwiched by buffer corrugated paper and placed in the inner box.
The interior box is packed in an exterior box and shipped.

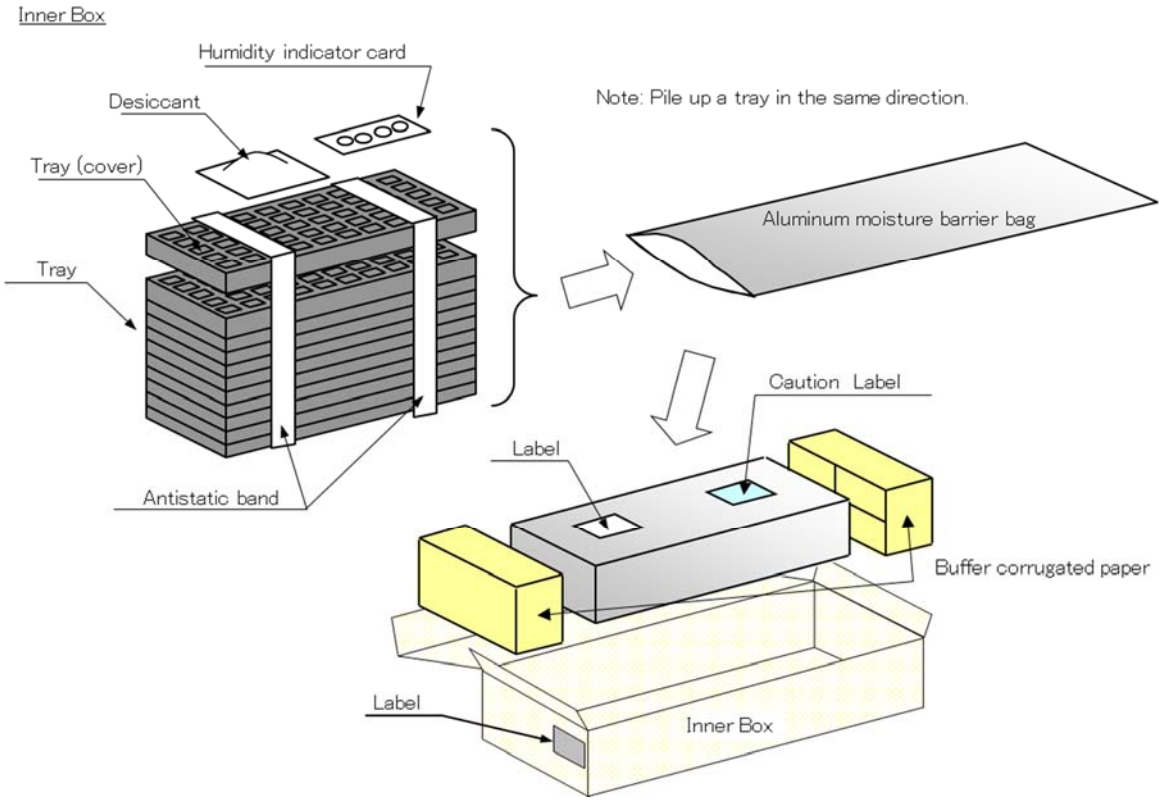


Figure27 package assembly

8. Handling Precautions

8.1. Thermal Management

CLxADAH2Z have high power consumption and due to their very small size, need to be designed properly for heat dissipation.

8.2. Desire and Conditions

This specification describes desire and conditions especially for mounting.

8.2.1. Environment conditions for use and storage

1. Store the components in an environment of < 40°C /90%RH if they are in a moisture barrier bag packed by TAIYO YUDEN.
2. Keep the factory ambient conditions at < 30°C /60%RH .
3. Store the components in an environment of < 25±5°C /10%RH after the bag is opened. (The condition is also applied to a stay in the manufacture process).

8.2.2. Conditions for handling of products

Make sure all of the moisture barrier bags have no holes, cracks or damages at receiving. If an abnormality is found on the bag, its moisture level must be checked in accordance with 2 of 8.2.2. Refer to the label on the bag.

1. All of the surface mounting process (reflow process) must be completed in 12 months from the bag sea date.
2. Make sure humidity in the bag is less than 10%RH immediately after open, using a humidity indicator card sealed with the components.
3. All of the surface mounting process (reflow process including rework process) must be completed in 168 hours after the bag is opened (inclusive of any other processes).
4. If any conditions in 8.2.1. or condition 2 and 3 of 8.2.2. are not met, bake the components in accordance with the conditions at 125°C 24h.
5. As a rule, baking the components in accordance with conditions 4 of 8.2.2. shall be once.
6. Since semi-conductors are inside of the components, they must be free from static electricity while handled. (<100V) Use ESD protective floor mats, wrist straps, ESD protective footwear, air ionizers etc., if necessary.
7. Please make sure that there are lessen mechanical vibration and shock for this module, and do not drop it.
8. Please recognize pads of back side at surface mount.
9. This module should not be cleaned.

10. Please perform temperature conditions of module at reflow within the limits of the following.
Please give the number of times of reflow as a maximum of 2 times.

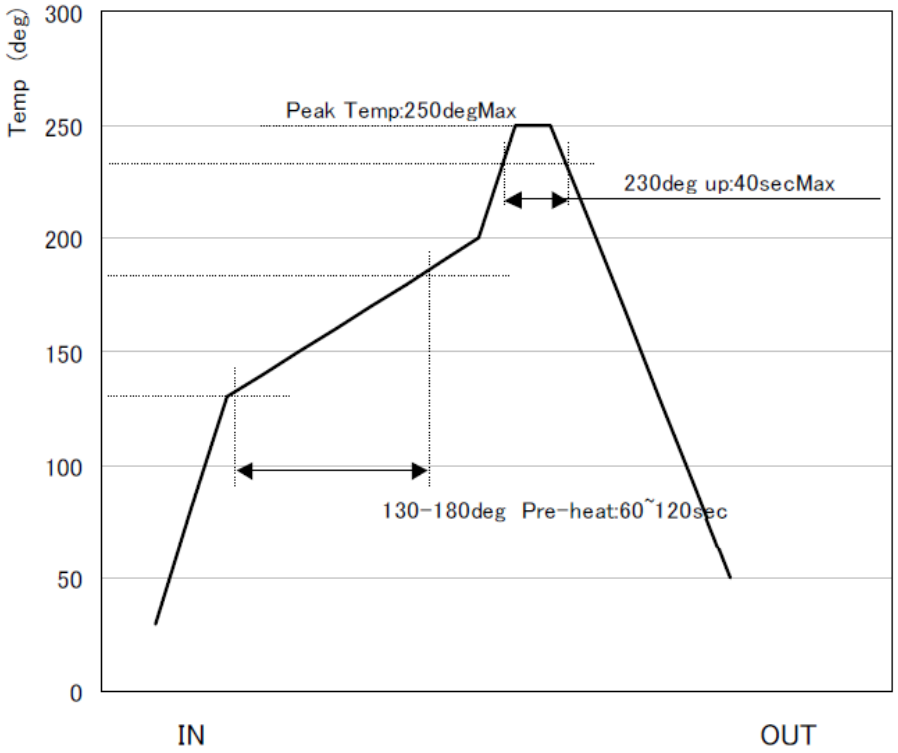


Figure28 temperature conditions of module at reflow

9. Certifications

9.1. Certifications

Table34 shows the certificate obtained by the module.

Table34 Product certifications

Certification	Model Name
	CL5ADAH2Z
FCC/IC	✔
CE	✔
Japan Technical Conformity Certification	✔

10. Safety Information

Read the safety information carefully to ensure the correct and safe use of module. Applicable safety information must be observed.

10.1. Interference

Communication between this product and other might not be established nor maintained depending upon radio environment or operating condition of this product and other products with wireless technology.

This product operates in the licensed band at 2GHz/800MHz. In case this product is used around the other wireless devices which operate in same frequency band of this product, there is a possibility that interference occurs between this product and such other devices. If such interference occurs, please stop the operation of other devices or relocate this product before using this product or do not use this product around the other wireless devices.

Power off module if using the device is prohibited. Do not use the module when it causes danger or interference with electric devices.

10.2. Medical Device

- Power off module and follow the rules and regulations set forth by the hospitals and health care facilities.
- Some module may affect the performance of the hearing aids. For any such problems, consult your service provider.
- Pacemaker manufacturers recommend that a minimum distance of 15 cm be maintained between the module and a pacemaker to prevent potential interference with the pacemaker. If you are using an electronic medical device, consult the doctor or device manufacturer to confirm whether the radio wave affects the operation of this module.

10.3. Area with Inflammables and Explosives

To prevent explosions and fires in areas that are stored with inflammable and explosive devices, power off module and observe the rules. Areas stored with inflammables and explosives include but are not limited to the following:

- Gas station
- Fuel depot (such as the bunk below the deck of a ship)
- Container/Vehicle for storing or transporting fuels or chemical products
- Area where the air contains chemical substances and particles (such as granule, dust, or metal powder)
- Area indicated with the "Explosives" sign

● Area indicated with the "Power off bi-direction wireless equipment" sign
● Area where you are generally suggested to stop the engine of a vehicle

10.4. Airline Security

Observe the rules and regulations of airline companies. When boarding or approaching a plane, power off module. Otherwise, the radio signal of the module may interfere with the plane control signals.

10.5. Safety of Children

Do not allow children to use the module without guidance. Small and sharp components of the module may cause danger to children or cause suffocation if children swallow the components.

10.6. Environment Protection

Observe the local regulations regarding the disposal of your packaging materials, used module, and promote their recycling.

10.7. RoHS Approval

The module is in compliance with the restriction of the use of certain hazardous substances in electrical and electronic equipment Directive 2011/65/EU (RoHS Directive).

10.8. Laws and Regulations Observance

Observe laws and regulations when using module. Respect the privacy and legal rights of the others.

10.9. Care and Maintenance

It is normal that module gets hot when you use or charge it. Before you clean or maintain the module, stop all applications and power off the module.

● Use module with care and in clean environment. Keep the module from a fire or a lit cigarette.
● Protect module from water and vapor and keep it dry.
● Do not drop, throw or bend module.
● Clean module with a piece of damp and soft antistatic cloth. Do not use any chemical agents (such as alcohol and benzene), chemical detergent, or powder to clean it.
● Do not leave module in a place with a considerably low or high temperature.
● Do not dismantle the module. Otherwise, the module is not covered by the warranty.

10.10. Emergency Call

This module functions through receiving and transmitting radio signals.
Therefore, the connection cannot be guaranteed in all conditions. In an emergency, module cannot be used.

10.11. FCC & ISED Notice

Required End Product Labeling

Any device incorporating this module must include an external, visible, permanent marking or label which states: “Contains FCC ID: RYYCL5AD” and “Contains IC: 4389B-CL5AD”

Obligation d'étiquetage du produit final:

Tout dispositif intégrant ce module doit comporter un externe, visible, marquage permanent ou une étiquette qui dit: "Contient IC : 4389B-CL5AD”

Additional testing, Part 15 Subpart B disclaimer

The CL5ADAH2Z modular transmitter is only FCC authorized for the specific rule parts (i.e., FCC transmitter rules) listed on the grant, and that 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.

FCC

This module has been tested and found to comply with the following requirements for Modular Approval.

- Part 22H – Cellular radiotelephone service
- Part 24E – Broadband PCS
- Part 27C – Technical standards
- Part 90S – Regulations governing licensing and use of frequencies in the 806-824, 851-869, 896-901, and 935-940 MHz Bands, 851-869, 896-901, and 935-940 MHz Bands
- Part 2.1046 – Measurements required: RF power output

Antennas

This radio transmitter CL5ADAH2Z has been approved by the FCC and ISED to operate with the maximum permissible gain indicated below.

Modulation	Frequency (MHz)	Maximum permissible gain approved by the FCC (dBi)	Maximum permissible gain approved by the ISED (dBi)
LTE Band 2	1850 ~ 1910	8.00	8.00
LTE Band 4	1710 ~ 1755	5.00	5.00
LTE Band 12	699 ~ 716	8.70	5.63
LTE Band 26	824 ~ 849	9.41	6.12
LTE Band 26 (Part 90S)	814 ~ 824	9.36	N/A

Test Modes

Taiyo Yuden Co., Ltd. uses various test mode programs for test set up which operate separate from production firmware. Host integrators should contact Taiyo Yuden Co., Ltd. for assistance with test modes needed for module/host compliance test requirements.

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

In the end product, the antenna(s) used with this transmitter must not be co-located or operation in conjunction with any other antenna or transmitter except in accordance with FCC multi-transmitter product procedures. User and installers must be provided with antenna installation instructions and transmitter operating conditions for satisfying the RF exposure compliance.

Federal Communications Commission (FCC) Statement

15.21

You are cautioned that changes or modifications not expressly approved by the part responsible for compliance could void the user's authority to operate the equipment.

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 of the device.

FCC RF Radiation Exposure Statement:

1. This Transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.
2. This equipment complies with RF radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with a minimum distance of 20 cm between the radiator and your body.

ISED

Canadian Notice

This device contains licence-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's licence-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.*

Avis Canadien

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.*

Caution: Exposure to Radio Frequency Radiation.

1. To comply with the Canadian RF exposure compliance requirements, this device and its antenna must not be co-located or operating in conjunction with any other antenna or transmitter.
2. To comply with RSS 102 RF exposure compliance requirements, a separation distance of at least 20 cm must be maintained between the antenna of this device and all persons.

Attention: exposition au rayonnement radiofréquence.

1. Pour se conformer aux exigences de conformité RF canadienne l'exposition, cet appareil et son antenne ne doivent pas être co-localisés ou fonctionnant en conjonction avec une autre antenne ou transmetteur.
2. Pour se conformer aux exigences de conformité CNR 102 RF exposition, une distance de séparation d'au moins 20 cm doit être maintenue entre l'antenne de cet appareil et toutes les personnes.

10.12. CE Notice

Hereby, Taiyo Yuden Co., Ltd. declares that the radio equipment type CatM1 Module is in compliance with Directive 2014/53/EU

The full text of the EU declaration of conformity is available at the following internet address:
https:www.yuden.co.jp

Radio Type / Description		Transmitter Frequency (MHz)	Maximum Output Power
LTE	FDD 8	880.7 ~ 914.3	23 dBm
	FDD 20	834.5 ~ 859.5	23 dBm

11. Appendix Acronyms and Abbreviations

Term	Definition
ADC	Analog-to-Digital Converter
AUX	auxiliary
DC	Direct Current
DH	Deep Hibernation
DRX	Discontinuous Reception
eDRX	Extended DRX
EJTAG	Embedded Joint Test Action Group
ESD	Electro-Static Discharge
EU	European Union
EUTRA	Evolved Universal Terrestrial Radio Access
FDD	Frequency Division Duplex
I2C	Inter-Integrated Circuit
JTAG	Joint Test Action Group
LGA	Land Grid Array
LPDDR	Low Power DDR
LPF	Low-pass filter
LTE	Long Term Evolution
LwM2M	Lightweight machine-to-machine
MCP	Multi-chip Package
MISO	Master In Slave Out
MOSI	Master Out Slave In
NC	Not Connected
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PCB	Printed Circuit Board
PMU	Power Management Unit
PTW	Paging Transmission Window
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RoHS	Restriction of the Use of Certain Hazardous Substances
RRC	Radio Resource Control
RTC	Real Time Clock
Rx	Receive

SC-FDMA	Single-Carrier Frequency Division Multiple Access
SMS	Short Message Service
SPI	Serial Peripheral Interface
TCP	Transmission Control Protocol
TCXO	Temperature Compensated Crystal Oscillator
Tx	Transmit
UART	Universal Asynchronous Receiver Transmitter
UDP	User Datagram protocol
UICC	Universal Integrated Circuit Card
USB	Universal Serial Bus
USIM	Universal Subscriber Identity Module
UTRA	Universal Terrestrial Radio Access
XO	Crystal Oscillator. Typically used to indicate a Crystal connection to the IC (utilizing internal Oscillator)