

APAC Opto Electronics Inc.

# **AO-1503 / AO-1503A ZigBee to UART Module**

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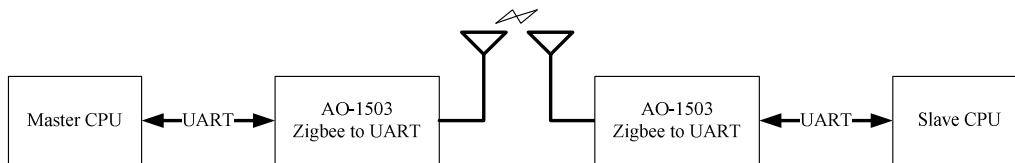
## **Operation Manual**

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## 1. Introduction

Simplicity is the major design issue of this module. Users can set this module by regarding it as the usual UART. Thus, even users who are unfamiliar with RF technology can make use of this product easily.



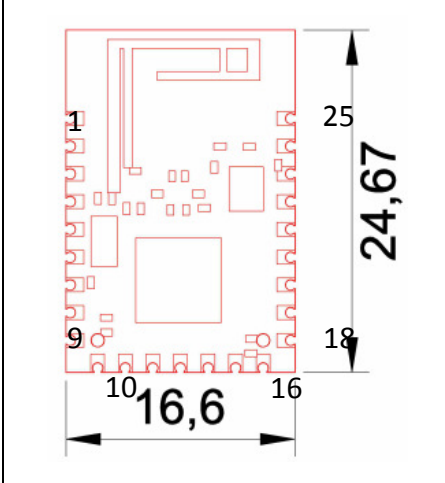
Both AO-1503 / AO-1503A are ZigBee to UART modules that use the advanced TI CC2530 chip. The difference between AO-1503 and AO-1503A is that the former, which has built-in high performance PCB micro strip antenna, is suitable for applications with small dimensions. The AO-1503A, which requires external antenna, is appropriate for industrial applications in adverse environments. It is noted that the AO-1503 / AO-1503A module is an extension of our product AO-1501 ZigBee module. The distinct feature of AO-1503 / AO-1503A is that the application program suitable for UART protocol has been encoded in it. This can simplify the installation and operation of the module. Consequently, the period of design and development for new products can be shortened.

## 2. Features

The major distinct features of AO-1503 / AO-1503A ZigBee to UART module include: (i) easy use; (ii) can be set as the usual UART, thus can be used in conjunction with any microprocessor; (iii) small size; (iv) has built-in high performance PCB antenna, the communication distance is 50 meters in regular environments, and 150 meters in benign environments.

The AO-1503 / AO-1503A module can be used indoors or outdoors. They are suitable for various applications, such as machine-to-machine data transfer, wireless sensor networks, or smart light control. In addition, the module can be used in conjunction with the CC Debugger of TI Encoder. Then, users can encode and compile programs by themselves. This makes the module a valuable assistant for the development of ZigBee systems.

### 3. Dimensions and Pin Assignments

	Pin	Function	Pin	Function	Pin	Function
	1	GND	10	+VDD 3.0-3V	17	P10(NC)
	2	GND	11	GND	18	P07(NC)
	3	REST_N	12	P13 Reserved	19	P06(NC)
	4	P22 (NC)	13	P12 0=C 1=R	20	P05(NC)
	5	P21 (NC)	14	P11 ID Clear	21	P04(NC)
	6	P17 (NC)	15	P03 TX UART0	22	P01(NC)
	7	P16 (NC)	16	P02 RX UART0	23	P00=NET LED
	8	P15 (NC)			24	+VDD 3.0-3V
9	P14 (NC)			25	GND	

P20 is reserved and not connected.

- Note: 1. Connection of Pin 10~16 is required for AO-1503 / AO-1503A ZigBee to UART module, leave the remaining pins open(internal pull high).  
2. Pin assignments are defined by the users if reprogrammed.

### 4. Function Selection and Initialization

#### 4.1. Function Selection

P13	P12	Function Description
1	1	Router
1	0	Coordinator

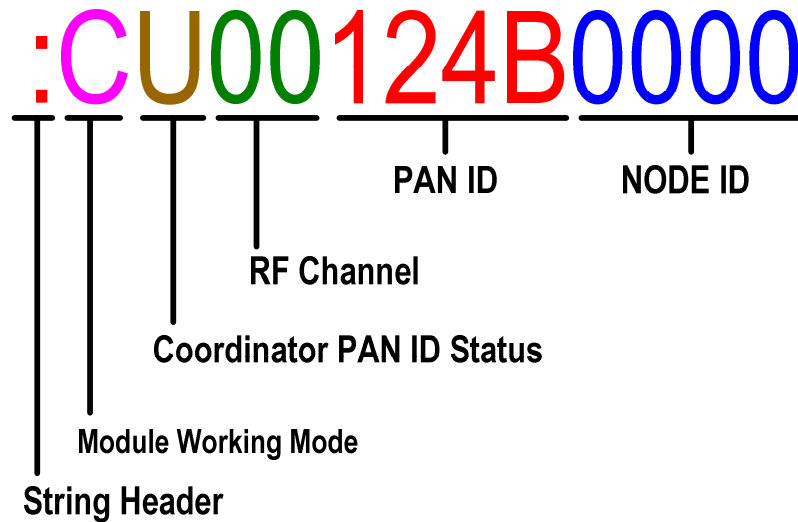
#### 4.2. Initialization

Since the AO-1503 / AO-1503A ZigBee to UART module is produced without setting any PAN ID nor NODE ID, initialization is required before operation. Execute the following steps to initialize the device:

1. Connect AO-1503 / AO-1503A ZigBee to UART module to CPU or PC via UART interface. The CPU activates the UART to receive, or the PC opens the terminal software, preset 9600bps, 8, N, 1.
2. The initialization of a coordinator must be completed prior to that of the router. Furthermore, the coordinator must be in working state when the router is

initialized. Otherwise, the router will not be able to search the PAN ID, and cannot join the network.

- The function mode of the AO-1503 / AO-1503A ZigBee to UART module must be selected before it is powered-on. Please refer to Section 4.1 for the setting of the function mode.
- Format of the responsive message from the AO-1503 / AO-1503A ZigBee to UART module is illustrated below:



**NODE ID:** NODE ID generated by the system, a four-digital HEX code.

**PAN ID:** PAN ID generated by the system, a four-digital HEX code.

**RF Channel:** Normal values lies in [11, 26], 00 means that the ZigBee network is not activated.

**Coordinator PAN ID Status:**

U= Coordinator PAN ID was not written in yet.

S= Coordinator PAN ID has been written in.

**Module Working Mode:**

C=Coordinator

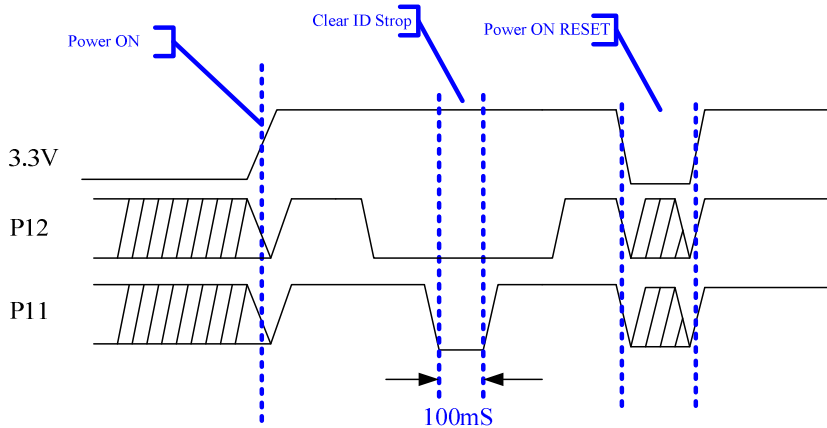
R=Router

- String Header: The symbol is “:”.
- Module working mode: If the module operates as a Coordinator, enter the AT Command mode, use ATPID command to write in the PAN ID, as “AT Command Compilation” described in Section 6.4; if the module works as a Router, the NODE ID can be written into the module automatically, i.e., no action is needed.
- Inquire the status message repeatedly by sending serial data.

### 4.3. ID Clear and Rejoin

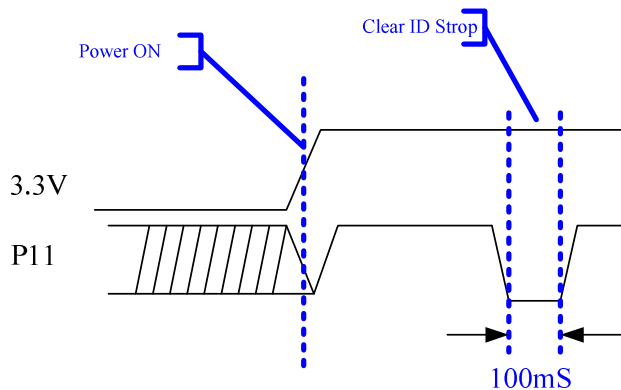
#### 4.3.1 Router:

Power ON, set P12 = 0, press P11, set P12=1, press P11 again, the setting is completed.



#### 4.3.2 Coordinator:

Power ON, press P11.



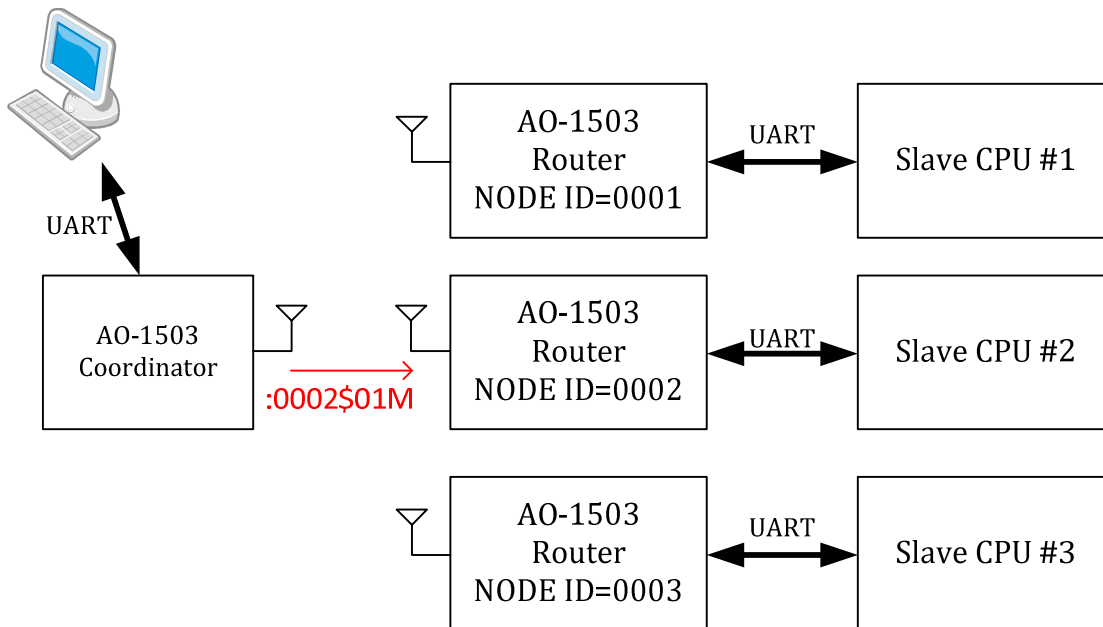
## 5. Installation and Operation

### 5.1. Construction of ZigBee Networks

A ZigBee network must consist of a coordinator, a router, and some end devices. By appropriate pin assignments, the AO-1503 / AO-1503A ZigBee to UART module can operate as a coordinator or a router. Since all elements in a ZigBee network must have the same PAN ID and distinct NODE IDs, setting PAN ID and NODE ID for the module through the UART is required before operation. For details of setting procedures, please refer to “Initialization” described in Section 4.2 and “AT Command Compilation” described in Section 6.

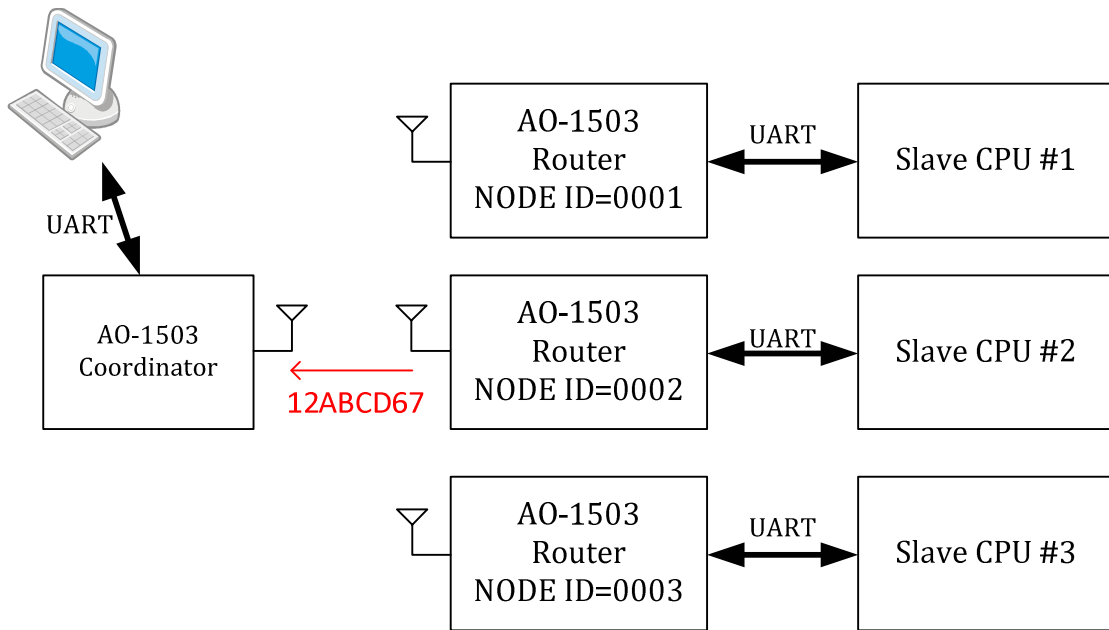
### 5.2. Coordinator Sends Messages

In a ZigBee network, a coordinator can link up to 65535 routers. Thus, if the host wants to send messages to any router via the AO-1503 / AO-1503A module, NODE ID of the destination router must be appended to each message. The AO-1503 / AO-1503A uses ASCII code to define the command. The format of the command is “:xxxx”, in which “:” is the initial code and “xxxx” is the destination NODE ID. The following figure illustrates an example, in which the host wants to send the message ”\$01M” to the device with “NODE ID=0002”. It can be seen that the command sent by the host is “:0002\$01M”, in which “:0002” is the ASCII code with five bytes, but any format can be used for “\$01M”.



### 5.3. Response of a Router

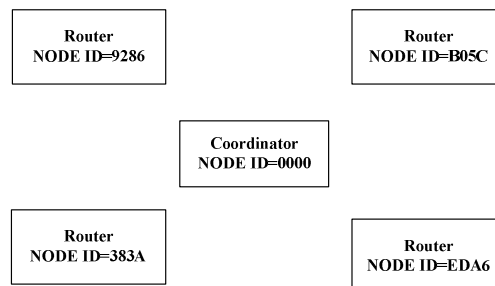
If a router or an End device wants to send messages to the host, since the destination (coordinator with NODE ID=0000) is fixed, no initial code is required, as illustrated in the following figure. It is noted that the size of a message must  $\leq 50$  bytes, no matter it is sent by the coordinator, router, or end device. For a message with exceeding length, a 50-100ms delay must be inserted for every 50 bytes.



#### 5.4. Inquiry of Network Configuration

A ZigBee network can be organized automatically by the coordinator, which is the hub of the network. In a normal condition, users don't need to understand the network configuration. Under certain circumstances, however, if a user needs to recognize the complete network configuration, he/she can inquire about the information by using the "NEATS" command. On receiving the "NEATS" command, every router in the network will respond by sending NODE IDs of itself and its parent node. The format of the responsive command is ":FFFF-NNNN", in which ":" is the initial symbol, "FFFF" is the NODE ID of parent node, and "NNNN" is the corresponding router's NODE ID. Note that if "FFFF=0000", then the parent node is the coordinator.

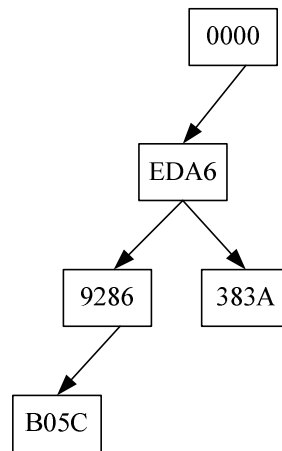
For example, the ZigBee network shown below consists of a coordinator (NODE ID=0000) and four routers (NODE ID=EDA6、9286、383A、B05C, respectively).



As the coordinator sends the "NETAS" command, every router in the network will respond by sending NODE IDs of itself and its parent node. If the responsive commands are ":0000-EDA6, :EDA6-9286, :EDA6-383A, :9286-B05C", then the network configuration



can be interpreted as depicted below.

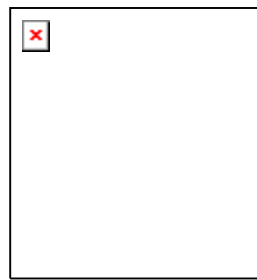


It is noted that based on the ZigBee protocol, all routers as well as their parent nodes are generated automatically when the network is founded. Thus, any network reconstruction will result in different network configurations.

### 5.5. UART Related Products

There are various wired communication specifications based on UART technology. For the two most commonly used specifications RS232 and RS485, we have developed related products AO-1503-232 and AO-1503-485, respectively. These two products have the following major features:

1. Small size and easy use, all system setting commands are similar to that of AO-1503.
2. The user can determine the coordinator or the router, a coordinator can form a network by linking to a number of routers.
3. Can support 2400~115200 bps transmission rate, can take the place of conventional RS-232 or RS485 network, and is suitable for machines equipped with S232/RS485.
4. Have internal flash memory to store network status automatically. This can eliminate the system setting process after power-off.
5. Users can use them as RS232 / RS485, knowledge of ZigBee protocol is not required.



AO-1503-232



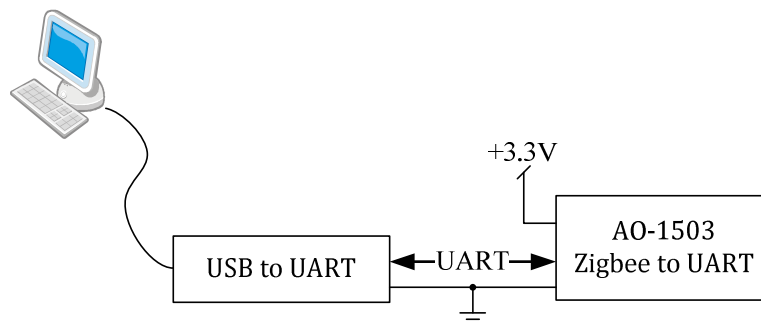
AO-1503-485

## 6. AT Command Compilation

Note: The commands for compilation described in this section are encoded based on ASCII.

### 6.1 Connection to PC

As illustrated in the following figure.

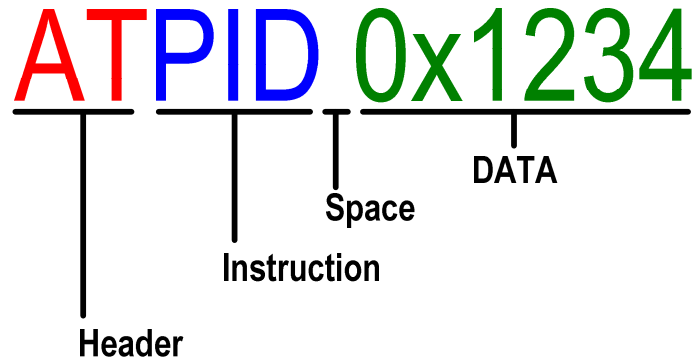


### 6.2 Log into and Quit Compilation

- PC activates the terminal application program.
- Set the com port, the initial values of AO-1503 / AO-1503A are 9600, 8, n, 1.
- Do not send any data within one second.
- Send the data “+++” (ASCII= 0x2B 0x2B 0x2B) within the following one second.
- Do not send any data within the following one second.
- Enter the compilation mode successfully, the AO-1503 / AO-1503A will respond with the word “COMMAND MODE<CR>”.
- Quit the compilation mode by sending “ATBYE<CR>”.
- Quit the compilation mode successfully, the AO-1503 / AO-1503A will respond with the word “OK<CR>”.

### 6.3 Format of Command

All commands are started with AT with the format shown below:



### 6.4 Table of AT Commands

All commands are described by ASCII codes using capital letters.

Command	Function	Values	Example
PID	Set or inquire PAN ID	0x0000~0xFFFFB, preset value is 0xFFFF, assigned automatically.	“ATPID<CR>” to inquire PAN ID, AO-1503 / AO-1503A will respond “PANID=0x5680<CR>”. “ATPID 0x1234<CR>” to set PAN ID=0x1234, AO-1503 / AO-1503A will respond “OK<CR>”.
NID	Set or inquire NODE ID	0x0001~0xFFFFB, preset value is generated automatically.	“ATNID<CR>” to inquire NODE ID, AO-1503 / AO-1503A will respond “NODEID=0x6AB6<CR>”. “ATNID 0x000F<CR>” to set NODE ID=0x000F, AO-1503 / AO-1503A will respond “OK<CR>”.
CHL	Set or inquire RF channel	0x0B~0x1A (ch11~ch26), Preset value is 0x1A (ch26).	“ATCHL<CR>” to inquire RF channel, AO-1503 / AO-1503A will respond “Channel=26<CR>”. “ATCHL 0x0C<CR>” to set RF channel=ch12, AO-1503 / AO-1503A will respond “OK<CR>”.
OPW	Set or inquire RF output power	0x00~0x0F, Preset value is 0x03	“ATPOW<CR>” to inquire RF output power, AO-1503 / AO-1503A will

	(Note 1)	( -0.5dBm ).	respond “Output Power=0x03 <CR>”. “ATPOW 0x00<CR>” to set RF output power=0dBm, AO-1503 / AO-1503A will respond “OK<CR>”.
RES	Reset to the original value (Note 2)	POWER=0 dbm, RF Channel=26, Baud rate =9600bps, Clear PAN ID and NODE ID, (P11=0 CLEAR ID)	“ATRES<CR>” to reset to the original value, AO-1503 / AO-1503A will clear all settings. Restart the module and reports the working status.
MAC	Inquire 64bit MAC address (Note 2)	Preset value is generated automatically.	“ATMAC<CR>” to inquire 64bit MAC address, AO-1503 / AO-1503A will respond “MAC= 00:12:4B:00:01:36:8A:4A <CR>”. “ATMAC 1122334455667788<CR>” to set the MAC address = 1122334455667788 (8 bytes in total), AO-1503 / AO-1503A will respond “OK<CR>”.
BPS	Set or inquire the baud rate (Note 3)	0x01~0x07, Preset value is 0x03.	“ATBPS<CR>” to inquire baud rate, AO-1503 / AO-1503A will respond “Baud=9600 bps <CR>”. “ATBPS 0x04<CR>” to set the baud rate=14400bps, AO-1503 / AO-1503A will respond “OK<CR>”.
TYE	Set the working status by software (Note 4)	Coordinator=0x00 Router=0x01.	“ATTYE<CR>” to inquire working status, AO-1503 / AO-1503A will respond “Coordinator or Router<CR>”. “ATTYE 0x01<CR>” to set the working status as a router, AO-1503 / AO-1503A will quit the “COMMAND MODE”, reset and respond with the report of starting-up. If a change is made from the coordinator to the router, the module will search the coordinator when restarts. If there is no coordinator

			available, no report about working status will be generated. In this case, the command “inquiry” can be used.
RST	Software RESET	Not available.	Quit the compilation mode, AO-1503 / AO-1503A will respond with the report of starting-up.
PAR	Inquire or set the parent node	A coordinator can inquire only. A router can inquire and set.	“ATPAR<CR>” to inquire the parent node, AO-1503 / AO-1503A will respond “Parent ID=0x0000<CR>”. “ATPAR 0xNNNN<CR>” to set the router with parent NODE ID =NNNN, AO-1503 / AO-1503A will respond “OK<CR>”.
BYE	Quit the compilation mode.	Not available.	“ATBYE<CR>” to quit the compilation mode, AO-1503 / AO-1503A will respond “EXIT COMMAND MODE<CR>”.
VER	Inquire the firmware version	Not available.	“ATVER<CR>” to inquire the firmware version, AO-1503 / AO-1503A will respond “Firmware version = 1.2.17<CR>”.

Note 1: Table of RF output power (dBm)

Set value	Output power	Set value	Output power	Set value	Output power	Set value	Output power
0x00	4.5	0x04	-1.5	0x08	-8	0x0C	-16
0x01	2.5	0x05	-3	0x09	-10	0x0D	-18
0x02	1	0x06	-4	0x0A	-12	0x0E	-20
0x03	-0.5	0x07	-6	0x0B	-14	0x0F	-22

0dbm=1mW, dBm=10\*log(Power/1mW).

Preset value=0x03, -0.5dBm nearly corresponds to 0.895mW.

Note 2: The command “RES”, which resets to the original value, will not restore the 64bit MAC address.

Note 3: Table of baud rate (bps)

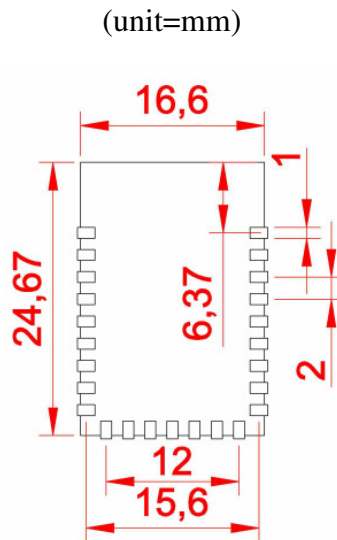
Set value	Baud rate	Set value	Baud rate
---	---	0x04	19200
0x01	2400	0x05	38400
0x02	4800	0x06	57600
0x03	9600	0x07	115200

Note 4: When you use the “ATTYE” command to set the working status by software, make sure to set P13=0 before the 3.3V power supply is activated (start up).

### 7. Antenna Characteristics and Installation Notes

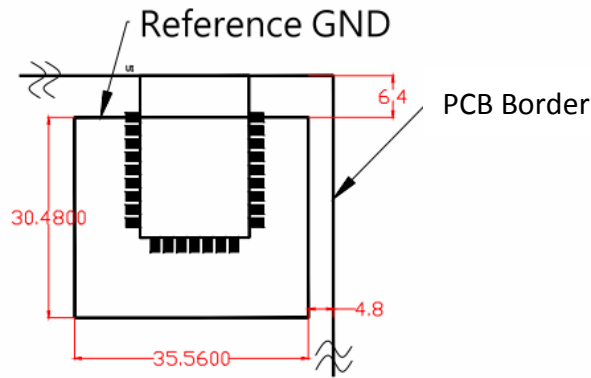
To ensure optimum Tx/Rx efficiency for the antenna, users of the AO-1503 / AO-1503A should follow the following notes:

- Don't encapsulate the AO-1503 module in a metallic box. This does not apply to the AO-1503A, which has external antenna.
- Install the module in an erect posture to ensure good antenna radiation pattern.
- Don't put any inductive element within 30mm distance of the module.
- Refrain from condensation of damp or dew.
- To ensure the PCB antenna efficiency of the module, you are advised to layout the PCB based on the following illustration.

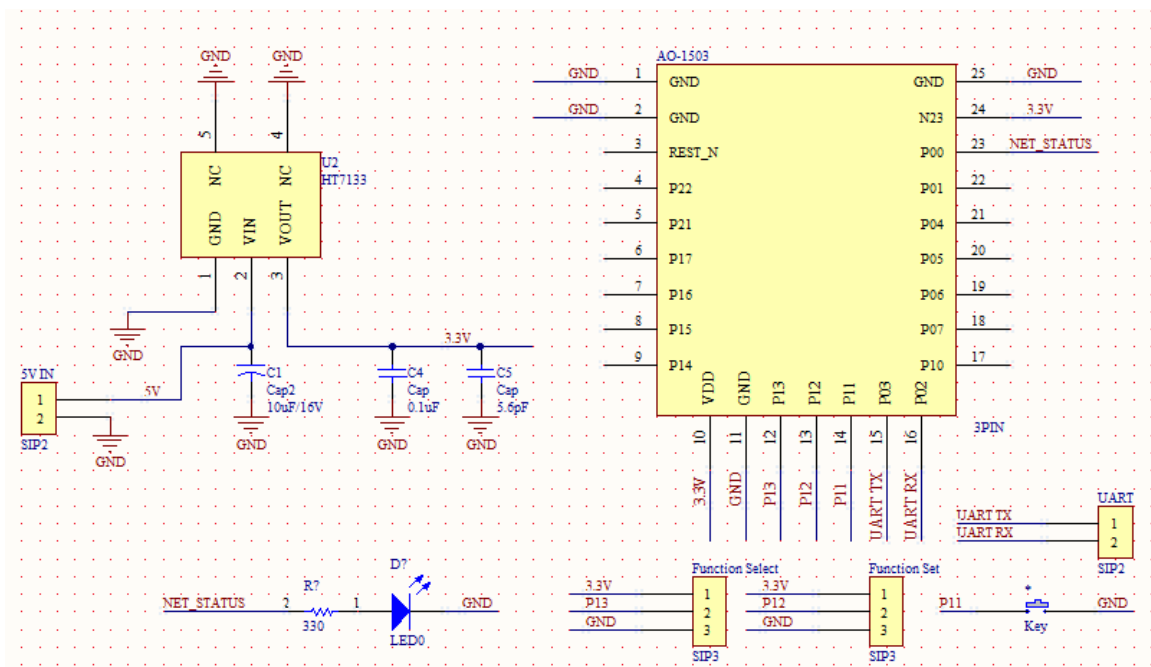


- For clearance around the module and reference ground of the antenna radiation (Reference GND), please refer to and follow the illustration displayed below. In addition, the material for the major board must be FR4 1.6mm.

(unit=mm)



- Refer to the figures and illustrations shown below for basic electronic circuit application.



Note:

P11 = GND will enforce clear of ID setting.

P12=3.3V, the working mode is Router; P12=GND, the working mode is Coordinator.

P13=3.3V, the working mode is determined by P12; P13=GND, then P12 is ignored and the working mode is to be set through UART by software.

P00 is the LED which indicates the network status.

## 8. Technical Specifications

Item	parameter			
	Min value	Typical value	Max value	Unit
Electrical characteristics (25°C )				

Voltage	3.0	3.3	3.6	V
Tx current 1		35.4	39.6	mA
Rx current 2		24.1	29.6	mA
Power mode 03		5	8.9	mA
Power mode 14		0.2	0.3	mA
Power mode 25		1	2	uA
Power mode 36		0.3	1	uA
Communication characteristics (with internal PCB antenna)				
Frequency	2.405(CH11)		2.480(CH26)	GHz
Tx power	-22	0	4.5	dBm
Rx sensivity		-97	-92	dBm
Transmission range			150	m
Transmission rate		250		Kbps
Interface characteristics				
Interface voltage level	-0.3		VCC+0.3 ≤3.6	V
Interface rate	2400	9600	115200	bps
General characteristics				
Working temperature	0		80	°C
Dimensions	23.3(L)x16.2(W)x.5(H)			mm

1. 32-MHz XOSC running, radio in TX mode, 4.5-dBm output consumption power, no active peripherals, and CPU idle.
2. 32-MHz XOSC running, radio in RX mode, waiting for signal, no active peripherals, and CPU idle.
3. 32-MHz XOSC running, no active radio or peripherals, CPU idel, no flash and RAM access.
4. 16-MHz RCOSC and 32-MHz crystal oscillator off, 32.768-kHz XOSC, CPU idle, RAM and register retention.
5. 32-MHz RCOSC oscillator off, 32.768-kHz XOSC, CPU idle, RAM and register retention.
6. No clocks (32-MHz RCOSC oscillator off and 32.768-kHz XOSC crystal off), CPU idle, RAM and register retention.