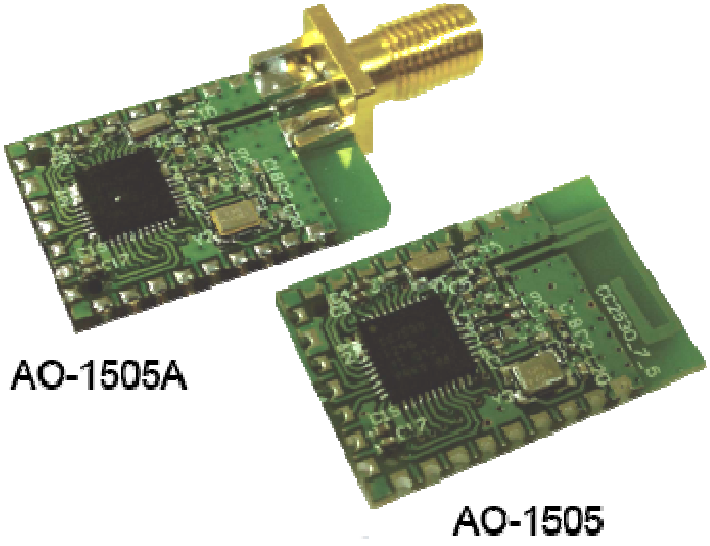
APAC Opto Electronics Inc.

AO-1505 / AO-1505A ZigBee to AIDO Module

Operation Manual



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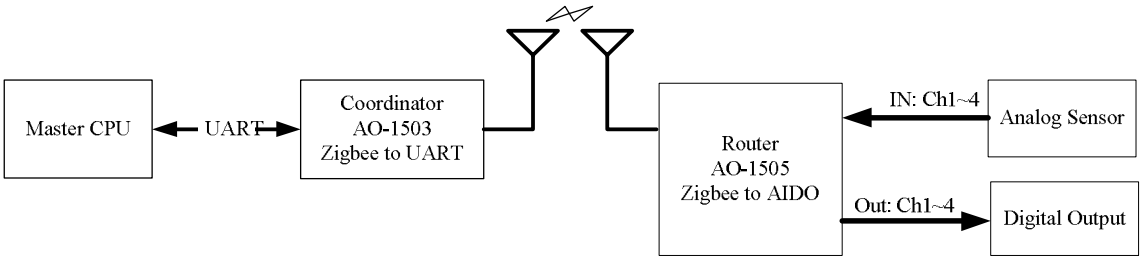
APAC Opto Electronics Inc.
3 Tzu Chiang Road, Hsinchu Industrial Park
Hukow, Hsinchu Hsien, Taiwan 303
TEL: +886-3-5986799
FAX: +886-3-5986655
Website: www.apacoe.com.tw

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. Users only need a general UART Coordinator (AO-1503/AO-1503A) to set. In the router (AO-1505/AO-1505A) side, there are four inputs and four outputs to connect analog input sensors such as temperature and digital output devices such as relay, respectively.



Both AO-1505/AO-1505A are ZigBee to AIDO modules that use the advanced TI CC2530 chip. The difference between AO-1505 and AO-1505A is that the former, which has built-in high performance PCB micro strip antenna, is suitable for applications with small dimensions. The AO-1505A, which requires external antenna, is appropriate for industrial applications in adverse environments. It is noted that the AO-1505/AO-1505A module is an extension of our product AO-1501 ZigBee module.

The distinct feature of AO-1505/AO-1505A is that the application program suitable for simple analog input detection and digital output control. 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

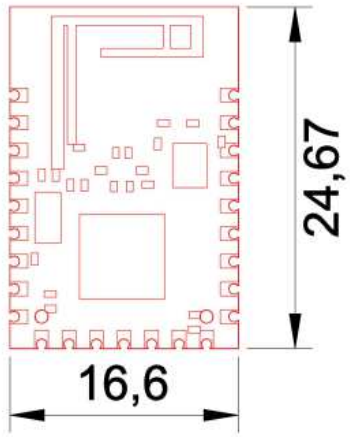
The major distinct features of AO-1505/AO-1505A ZigBee to AIDO module include: (i) easy use; (ii) can be set as the usual UART, thus can be used in conjunction with any microprocessor; (iii) small size; (iv) has built-in high performance PCB antenna, the communication distance is 50 meters in regular environments, and 150 meters in benign environments.

The AO-1505/AO-1505A module can be used indoors or outdoors. They are suitable for various applications, such as machine-to-machine data transfer, wireless sensor networks, or a variety of electrical equipment control applications.

APAC Opto Electronics Inc.
3 Tzu Chiang Road, Hsinchu Industrial Park
Hukow, Hsinchu Hsien, Taiwan 303
TEL: +886-3-5986799
FAX: +886-3-5986655
Website: www.apacoe.com.tw

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 3.3V	17	P10 =NET LED
2	GND	11	GND	18	P07 Analog IN #4
3	REST_N	12	P13 Reserved	19	P06 Analog IN #3
4	P22 (NC)	13	P12 0=C 1=R	20	P05 Analog IN #2
5	P21 (NC)	14	P11 ID Clear	21	P04 Analog IN #1
6	P17 Dout#4	15	P03 TX UART0	22	P01(NC)
7	P16 Dout#3	16	P02 RX UART0	23	P00(NC)
8	P15 Dout#2			24	+VDD 3.3V
9	P14 Dout#1			25	GND

P20 is reserved and not connected.

Note: 1. Connection of Pin 10~16 is required for AO-1505/AO-1505A ZigBee to DIDO module, leave the remaining pins open(internal pull high).
2. Pin assignments are defined by the users if reprogrammed.
3. If use AT Command setting, you have to connect via **P03** and **P02** pin of UART.

4. Function Selection and Initialization

4.1 Function Selection

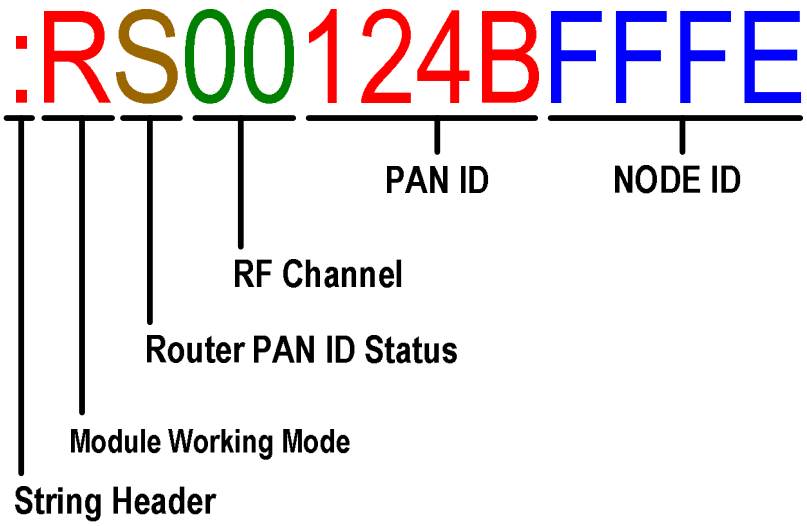
P12	P13	Function Description
1	1	Router (AO-1505/AO-1505A has to set the router device)

4.2 Initialization

Since the AO-1505/AO-1505A ZigBee to AIDO module is produced with setting any neither PAN ID nor NODE ID, initialization is required before operation. Execute the following steps to initialize the device:

APAC Opto Electronics Inc.
3 Tzu Chiang Road, Hsinchu Industrial Park
Hukow, Hsinchu Hsien, Taiwan 303
TEL: +886-3-5986799
FAX: +886-3-5986655
Website: www.apacoe.com.tw

1. Set the order must be completed AO-1503 Coordinator of the set, and then continue to complete the AO-1505/AO-1505A Router setting. The coordinator must remain powered on, otherwise it will not complete to add a new router device into the existed Zigbee network.
2. Connect AO-1505/AO-1505A ZigBee to AIDO module to CPU or PC via UART interface. The CPU activates the UART to receive, or the PC opens the terminal software, and preset 9600bps, 8, N, 1.
3. 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.
4. The function mode of the AO-1505/AO-1505A ZigBee to AIDO module must be selected before it is powered-on. Please refer to Section 4.1 for the setting of the function mode.
5. Format of the responsive message from the AO-1505/AO-1505A ZigBee to AIDO 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.
Router PAN ID Status:
U= not set PAN ID
S= set PAN ID
Module Working Mode:
C=Coordinator

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3 Tzu Chiang Road, Hsinchu Industrial Park
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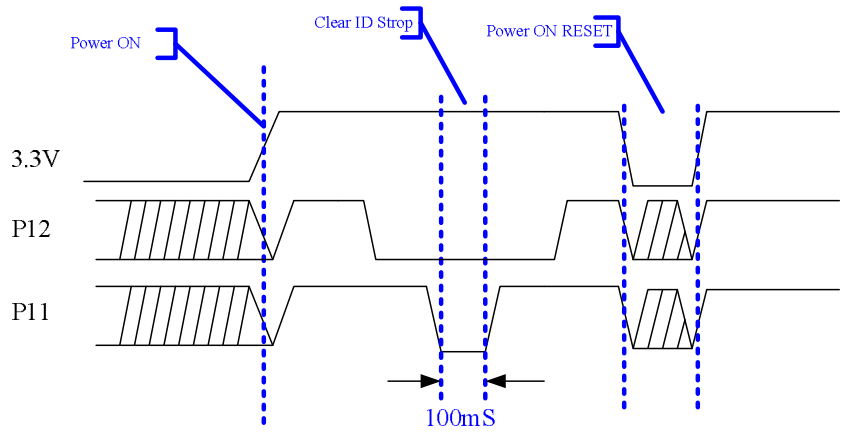
R=Router

String Header: The symbol is " : ".

6. If the module works as a Router, the NODE ID can be written into the module automatically, i.e., no action is needed.
7. Inquire the status message repeatedly by sending serial data.

4.3 ID Clear and Rejoin

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



5. AT Command Compilation

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

5.1 The Inquiry Remoted Output/Input Pin State or Output Pin Setting Instruction

- Direction: Host → Coordinator → Router
- Format : NNNNCCCRSTU

: String header;

NNNN indicates NODE ID of received Router;

CCC indicates an executing action including three commands as follows.

	Action/Function
QDO	Query the current status of assigned Digital Output channel
QDI	Query the current status of Digital Input channel
SDO	Set assigned the current status of Digital Output channel

APAC Opto Electronics Inc.
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RSTU indicates channels of current command, R = Channel 4, S = Channel 3, T = Channel 2, and U = Channel 1. The value for each channel only is 0, 1 or -.

- Example:

  :A247QDO1000 queries the current status of digital output channel 4 at NODE ID=A247.

  :A247QAI1010 queries the current status of analog input channel 2 and 4 at NODE ID=A247.

  :A247SDO10-- sets digital output channel 4=1, channel 3=0 at NODE ID=A247. Both channel 1 and 2 keeps current status.

5.2 AO-1505 Responses Messages to Query Digital Output Pin State

- Direction: Router → Coordinator → Host
- Format : NNNNDCCCC-DDDD #SS

  : String header;

  NNNN indicates NODE ID of sent Router;

  D indicates data port, such as I = Input, O=Output;

  CCCC indicates channels of current command,

  1 represents existed channel position.

  0 represents not existed channel position.

  DDDD indicates data;

  #SS indicates AO-1505 2-byte serial number, and the value is from 00 to FF.

- Example:

  :A247QDO1010 queries the current status of digital output channel 4 and 2 at NODE ID=A247

  :A247O1010-0-1-#22 represents response data from Router NODE ID=A247. The data port is output; data source and content are channel 2=0 and 4=1; other channel 1 and 3 = don't care.

5.3 AO-1505 Responses Messages to Query Analog Input Pin State

- Direction: Router → Coordinator → Host
- Format :NNNNDCCCC-DDDD-V.VVV#SS

  : String header;

  NNNN indicates NODE ID of sent Router;

  D indicates data port, such as I = Input, O=Output;

  CCCC indicates channels of current command,

  1 represents existed channel position.

APAC Opto Electronics Inc.
3 Tzu Chiang Road, Hsinchu Industrial Park
Hukow, Hsinchu Hsien, Taiwan 303
TEL: +886-3-5986799
FAX: +886-3-5986655
Website: www.apacoe.com.tw

0 represents not existed channel position.

DDDD indicates ADC data;

V.VVV indicates analog input voltage; the value is between 0 ~ 3.3V.

#SS indicates AO-1505 2-byte serial number, and the value is from 00 to FF.

- Example:

:A368QAI1010 queries the current status of analog input channel 4 and 2 at NODE ID=A368

:A368I1000-0246-2.331#13 represents response data from Router NODE ID=A368. The data port is input; data source and content are channel 4. The data content is 0x0246 and input voltage is equal to 2.331V.

:A368I0010-0138-1.872#14 represents response data from Router NODE ID=A368. The data port is input; data source and content are channel 2. The data content is 0x0138 and input voltage is equal to 1.872V.

5.4 Remoted Sampling Mode Command

To set sampling mode of all or assigned AO-1505/AO-1505A in the ZigBee network.

- Direction: Host → Coordinator → Router
- Format **SPL=0xC**

0xC represents sampling method. The value has 0, 1, and 2. The default value is 0x2. There are three sampling methods as follows.

0x0: sampling time fixed one second, after sampling auto sending. AO-1505/ AO-1505A reads four channels each time.

0x1: value only for the changed channel, after sampling auto sending.

0x2: polled by host, after sampling auto sending.

- Example:

:A247SPL=0x0 set sampling time to 1 sec and auto-reply data at NODE ID=A247.
OK Router NODE ID=A247 has received correct command.

SPL=0x2 set sampling stop for all AO-1505/AO-1505A in broadcast mode.
OK Router NODE ID=A247 has received correct command.

5.5 Remoted Broadcast to Query All AO-1505 In/Out Pin State/Value Command

The broadcast is not assigned address. This can query or set states of all AO-1505/ AO-1505A in the ZigBee network.

APAC Opto Electronics Inc.
3 Tzu Chiang Road, Hsinchu Industrial Park
Hukow, Hsinchu Hsien, Taiwan 303
TEL: +886-3-5986799
FAX: +886-3-5986655
Website: www.apacoe.com.tw

- Direction: Host → Coordinator → Router
- Format **CCCRSTU**, **CCC** includes the below three forms.

	Action / Function
QDO	Query the current status for assigned digital output channel
QAI	Query the current status for assigned analog input channel
SDO	Set the current status for digital output channel

RSTU indicates channels of current command, R = Channel 4, S = Channel 3, T = Channel 2, and U = Channel 1. The value for each channel only is 0, 1 or -.

- Example:

  QDO1111 presents inquiry digital output pin status of all AO-1505/AO-1505A at the same PAN network.

  SDO1111 sets digital output pin status of all AO-1505/AO-1505A at the same PAN network.

  QAI1111 presents inquiry analog input pin status of all AO-1505/AO-1505A at the same PAN network.

6. Installation and Operation

6.1 Construction of ZigBee Networks

A ZigBee network must consist of a coordinator, a router, and some end devices. By appropriate pin assignments, the AO-1505/AO-1505A ZigBee to AIDO module can operate in a router mode. 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 interface 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 of AO-1503 user manual.

6.2 Host Queries Data

In a ZigBee network, a coordinator can link up to 65535 devices. Thus, if the host wants to send messages to any router via the AO-1503/AO-1503A module as a coordinator, 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

APAC Opto Electronics Inc.
3 Tzu Chiang Road, Hsinchu Industrial Park
Hukow, Hsinchu Hsien, Taiwan 303
TEL: +886-3-5986799
FAX: +886-3-5986655
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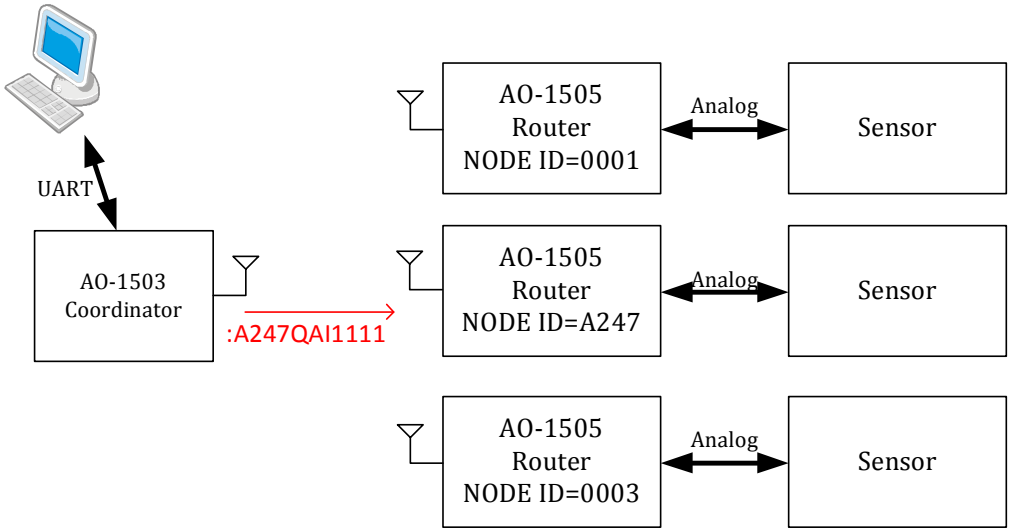
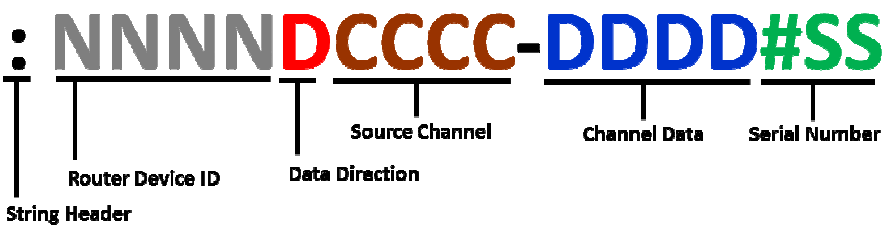
following figure illustrates an example, in which the host wants to query the input status "QDI1111" to the device with "NODE ID=A247". It can be seen that the command sent by the host is ":A247QDI1111", in which ":A247" is the ASCII code with five bytes. Among these routers, only NODE ID=A247 can receive the inquiry message.



如果要查詢網路中所有 AO-1505 / AO-1505A 的狀態，則直接發送查詢命令，例如 QAI1111，而不需要加上指定位址，網路中所有的 AO-1505 / AO-1505A 收到查詢命令後均會回應。但當 Router 數量龐大時，所有 Router 可能會同時回應，此時防碰撞機制將會依據 ZigBee 協議自動執行，因此在 Coordinator 端收到訊息的時間可能會相對延長。

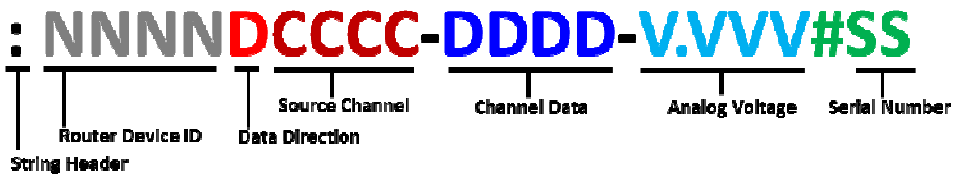
6.3 Response of a Router

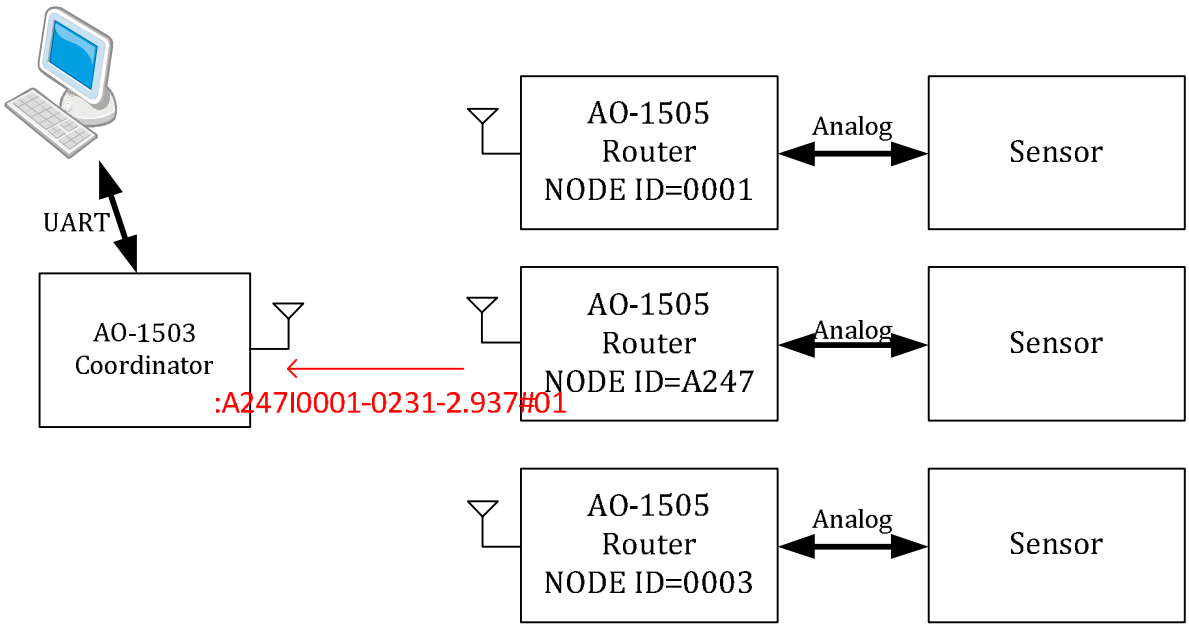
If a router device wants to send messages to the host, since the destination (coordinator with NODE ID=0000) is fixed, no initial code is required, as illustrated in the following figure. The following format is response message from a router device. It consists of a string header, router ID, data direction, source channel, channel data, and serial number. The following figure shows the format of the AO-1505/AO-1505A response when querying digit output pin status.



APAC Opto Electronics Inc.
3 Tzu Chiang Road, Hsinchu Industrial Park
Hukow, Hsinchu Hsien, Taiwan 303
TEL: +886-3-5986799
FAX: +886-3-5986655
Website: www.apacoe.com.tw

The following figure shows the format of the AO-1505/AO-1505A response when querying analog input pin status.



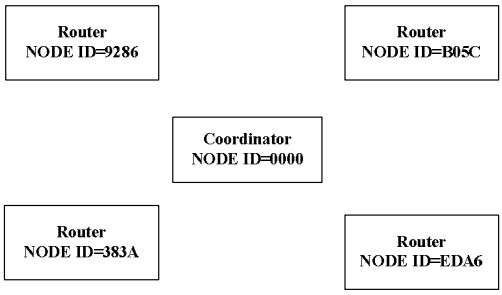


6.4 Inquiry of Network Configuration

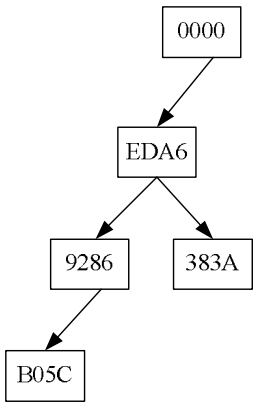
A ZigBee network can be organized automatically by the coordinator, which is the hub of the network. In a normal condition, users don't need to understand the network configuration. Under certain circumstances, however, if a user needs to recognize the complete network configuration, he/she can inquire 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).

APAC Opto Electronics Inc.
3 Tzu Chiang Road, Hsinchu Industrial Park
Hukow, Hsinchu Hsien, Taiwan 303
TEL: +886-3-5986799
FAX: +886-3-5986655
Website: www.apacoe.com.tw



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.



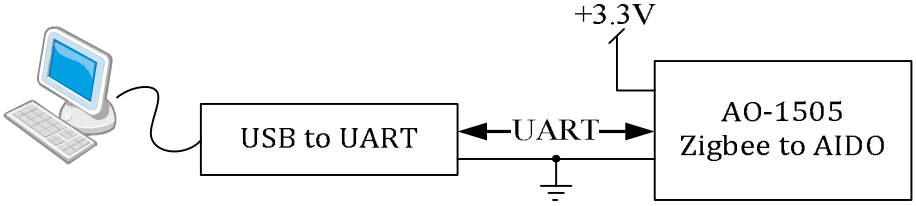
It is noted that based on the ZigBee protocol, all routers as well as their parent nodes are generated automatically when the network is founded. Thus, any network reconstruction will result in different network configurations.

7. AT Commands

Note that the all setting commands described in this section are coded in ASCII.

7.1 PC Connection

The connection is as the following figure.



APAC Opto Electronics Inc.
3 Tzu Chiang Road, Hsinchu Industrial Park
Hukow, Hsinchu Hsien, Taiwan 303
TEL: +886-3-5986799
FAX: +886-3-5986655
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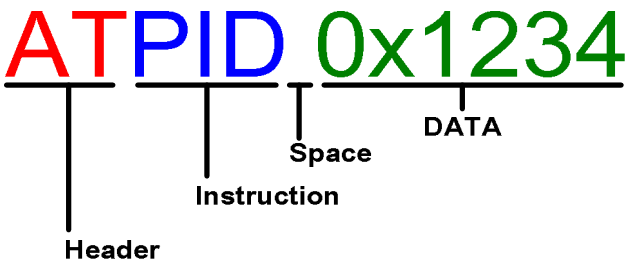
7.2 Enter and Quit Command Mode

- Open "Terminal" application program in PC.
- Set the com port, 9600bps, 8-bit data, no parity check, and 1 stop bit.
- Do not send any message within 1 second.
- Within 1 second sent string +++ (ASCII= 0x2B 0x2B 0x2B)
- Do not send any message within 1 second.
- Enter command mode, then AO-1505/AO-1505A replies the string "COMMAND MODE<CR>".
- Quit command mode, send ATBYE<CR>.
- Successfully exit the command mode, then AO-1505/AO-1505A replies OK<CR>.

7.3 Format

All command strings start with AT, and the format is as follows.



7.4 AT Command Table

Note that all commands are limited to uppercase ASCII.

CMD	FUNC	Value Range	Examples
PID	Set or Query PAN ID	0x0000~0xFFFB Default: 0xFFFF (Auto specified)	Send: ATPID<CR> Query PAN ID Response: PAN ID=0x5680<CR> Send: ATPID 0x1234<CR> Response: OK<CR>
NID	Set or Query NODE ID	0x0001~0xFFFB Default=Auto specified	Send: ATNID<CR> Response: NODE ID=0x6AB6<CR> Send: ATNID 0x000F<CR> Response: OK<CR>
CHL	Set or Query RF Channel	0x0B~0x1A (ch11~ch26) Default=0x1A (ch26)	Send: ATCHL<CR> Response: Channel=26<CR> Send: ATCHL 0x0C<CR> Response: OK<CR>
OPW	Set or Query	0x00~0x0F	Send: ATPOW<CR>

APAC Opto Electronics Inc.
3 Tzu Chiang Road, Hsinchu Industrial Park
Hukow, Hsinchu Hsien, Taiwan 303
TEL: +886-3-5986799
FAX: +886-3-5986655
Website: www.apacoe.com.tw

	RF output power[*1]	Default=0x03 (1dBm)	Response: Output Power=0x03 <CR> Send: ATPOW 0x00<CR> Response: OK<CR>
RES	Restore Factory Settings[*2]	POWER=0dbm, RF Channel=26, Baud rate=9600bps, Clear PAN and NODE ID (P11=0 CLEAR ID)	Send: ATRES<CR> Response: Clear setting and system reset.
MAC	Query 64-bit MAC address	Default=Auto specified	Send: ATMAC<CR> Response: MAC=00:12:4B:00:01:36:8A:4A <CR> Send: ATMAC 1122334455667788<CR> Response: OK<CR>
BPS	Set or Query Serial Baud rate[*3]	0x00~0x09 Default=0x03	Send: ATBPS<CR> Response: Baud=9600 bps <CR> Send: ATBPS 0x04<CR> Response: OK<CR>
TYE	Set or Query Working Status [*4]	Coordinator=0x00 Router=0x01	Send: ATTYE<CR> Response: Coordinator or Router<CR> Send: ATTYE 0x01<CR> Response: quit “COMMAND MODE” and system reset
RST	Software RESET	None	Send: ATRST<CR> Response: System reset
PAR	Set or Query Parent Node	For Coordinator, query only For Router, query or set	Send: ATPAR<CR> Response: Parent ID=0x0000<CR> Send: ATPAR 0xNNNN<CR> Response: OK<CR>
BYE	Quit Command Mode	None	Send: ATBYE<CR> Response: EXIT COMMAND MODE<CR>
VER	Query Firmware Version	None	Send: ATVER<CR> Response: Firmware version=1.2.17<CR>
SPL	Set Sampling Time (Auto-reply)	0x0: interval time 1 sec 0x1: if changed, reply 0x2: stop auto-reply	Send: ATSPL 0x0<CR> Response: OK<CR>

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Hukow, Hsinchu Hsien, Taiwan 303
TEL: +886-3-5986799
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*1 RF output power corresponding table(dBm)

Setting	Power	Setting	Power	Setting	Power	Setting	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)

Default=0x03 -0.5dBm is about 0.895mW

*2 The "RES" instruction cannot restore 64-bit MAC address.

*3 Baud rate corresponding table(bps)

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

*4 Using the “ATTYE” instruction, it is necessary to set P13 to 0 before power on.

8. ADC Self-correction Function

AO-1505/AO-1505A has built-in a set of 12-bit high precision analog / digital converter (ADC). This ADC input voltage range is between 0V and 3.3V. If the voltage beyond the rated input range, it will cause permanent damage to the module. Due to different batch of wafer, ADC characteristics will be slightly different. Hence, the AO-1505/AO-1505A module has built-in self-correction program. Users only need to provide three 100K precision resistors (refer to circuit application R2, R3, and R4) outside the series as a reference voltage source in order to get accurate voltage output data. Refer to Section 5.3 AO-1505 response analog input status for the voltage output format.

9. Antenna Characteristics and Installation Notes

To ensure optimum Tx/Rx efficiency for the antenna, users of the AO-1505/AO-1505A should follow the following notes:

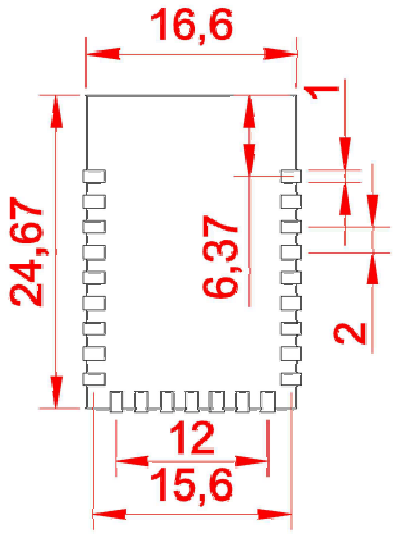
- Don’t encapsulate the AO-1505 module in a metallic box. This does not apply to the

APAC Opto Electronics Inc.
3 Tzu Chiang Road, Hsinchu Industrial Park
Hukow, Hsinchu Hsien, Taiwan 303
TEL: +886-3-5986799
FAX: +886-3-5986655
Website: www.apacoe.com.tw

AO-1505A, which has external antenna.

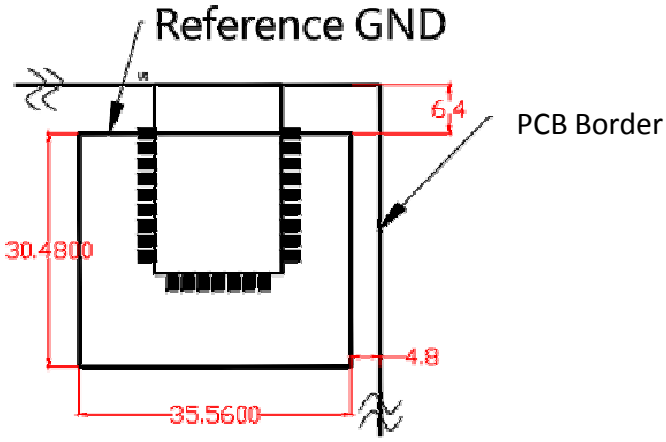
- Install the module in an erect posture to ensure good antenna radiation pattern.
- Don't put any inductive element within 30mm distance of the module.
- Refrain from condensation of damp or dew.

To ensure the PCB antenna efficiency of the module, you are advised to layout the PCB based on the following illustration.



(units: mm)

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



(units: mm)

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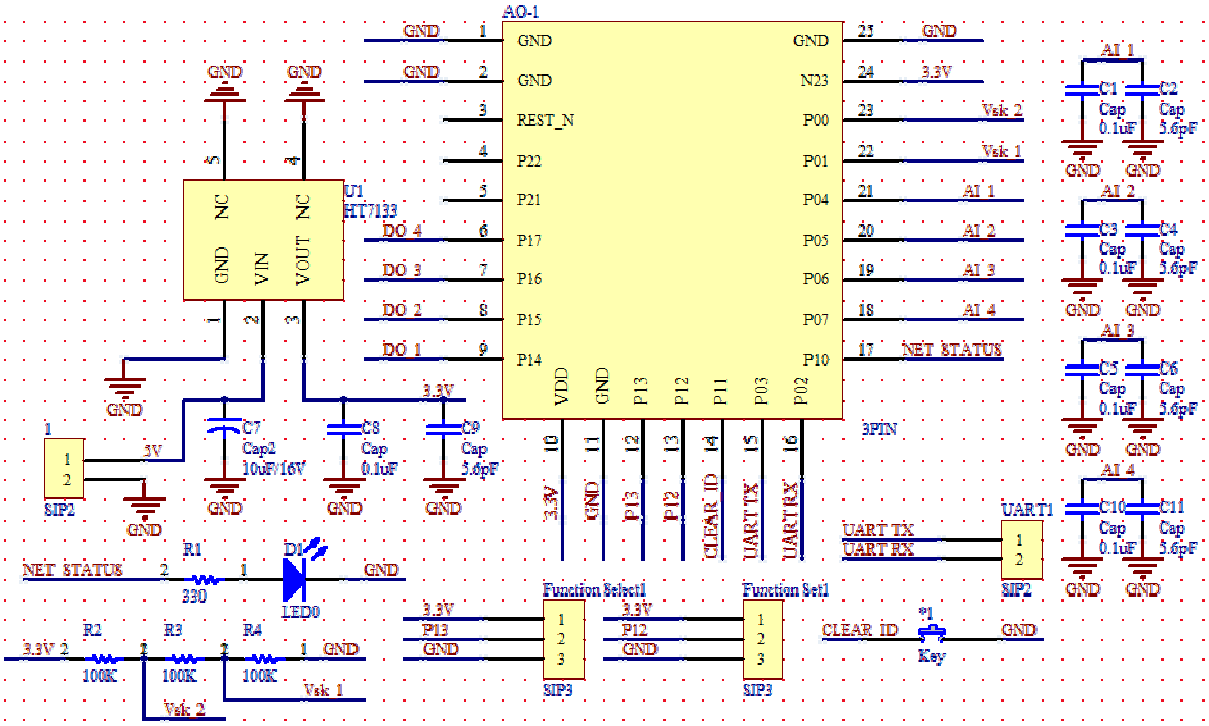
- Refer to the figures and illustrations shown below for basic electronic circuit application.



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.

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10. Technical Specifications

Item	Parameter			
	Min	Typical	Max	Unit
Electrical characteristics (25℃)				
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 0		5	8.9	mA
Power mode 1		0.2	0.3	mA
Power mode 2		1	2	uA
Power mode 3		0.3	1	uA
Communicationcharacteristics (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	℃
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.

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