BW-AH400 Serials

High precision AHRS

Technical Manual
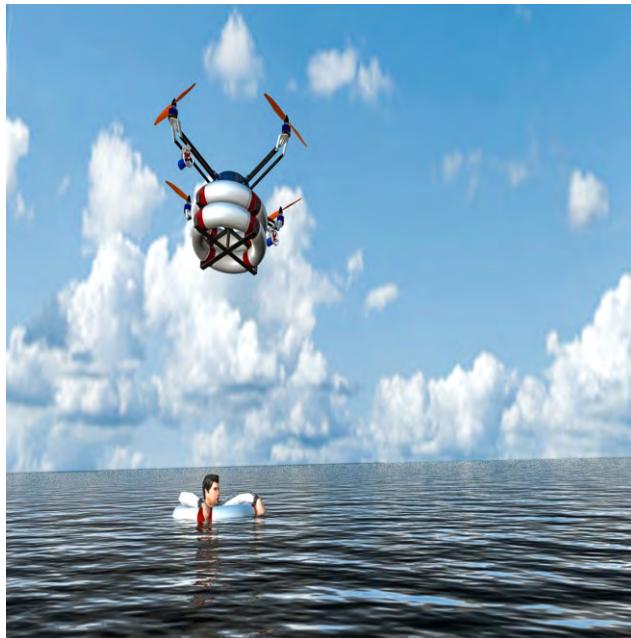
Introduction

BW-AH400 Attitude and Heading Reference System （AHRS） is a high performance, low cost inertial measurement device that measures the attitude parameters (roll and pitch), angular velocity, acceleration information and heading angle of the dynamic carrier.The attitude and angular velocity deviations are estimated by a 6-state Kalman filter with appropriate gain, which is suitable for dynamic measurement of navigation and positioning.The BW-AH400 uses high-quality and reliable MEMS accelerometers, gyroscopes and magnetometers, and guarantees measurement accuracy through algorithms. Meanwhile, the seal design and strict process ensure that the dynamic parameters of the carrier such as the angular velocity、 acceleration and attitude can be accurately measured under harsh conditions. Through various compensations such as nonlinear compensation, quadrature compensation, temperature compensation and drift compensation, the error source of BW-AH400 can be greatly eliminated, and the product accuracy level can be improved.The BW-AH400 is equipped with digital interface that can be easily integrated into the user's system.

Feature

- Nonlinear compensation, quadrature compensation
- Dynamic static measurement
- Special offset tracking algorithm eliminates drift
- Gyro drift compensation
- Heading accuracy 0.5°

- RS232/485/TTL interface output is optional
- temperature range：-40℃~ +85℃,temperature compensation technical
- High performance Kalman filter algorithm
- Product size： L103.8 x W55.4 x H26 （mm）

Application

- Satellite tracking
- High voltage tower monitoring
- Aerial work vehicle
- ROV underwater robot navigation

- Drilling equipment measurement and control
- Ocean Tester
- Robot control
- Unmanned aerial vehicle

Introduction

Electrical Specifications

Voltage	9-35 V DC
Working current	30mA (40mA Max)
Operating temperature	-40~85℃
Storage temperature	-55~100℃

Performance Specifications

Attitude parameters	Pitch Accuracy	0.3° (RMS, dynamic) 0.1° (RMS, Static)
	Roll accuracy	0.3° (RMS, dynamic) 0.1° (RMS, Static)
	Resolution	0.01°
	Slant Range	Pitch ± 90°, Roll ± 180°
Heading parameters	Heading Accuracy	0.5° (Pitch<40°)
		0.7° (Pitch<60°)
		1° (Pitch<80°)
	Resolution	0.01°
Physical characteristics	Size	L103.8 x W55.4 x H26 (mm)
	Weight	150g
	Output form	RS232/RS485/TTL
Interface characteristics	Start Delay	<3s
	Maximum Output Rate	50Hz
	Serial Communication Rate	2400-115200 Baud rate
	Digital Output Format	Binary high performance protocol
Environment	Vibration Resistance	2000g

Resolution: The smallest change in the value that the sensor can detect and resolve within the measurement range.
Accuracy: The root mean square error of the actual angle and the measured angle of the sensor multiple times (≥16 times).

Mechanical Characteristic

Connector	Aviation joint（Line length1.5m)
Protection level	IP67
Shell material	Magnesium alloy oxidation
Installation	Three M4 screws

Package size

Size：L103.8*W55.4*H26（mm)

Φ4 通

86

36

96

104

Top view

86

10

26

4

Aviation joint：116
Metal joint：105
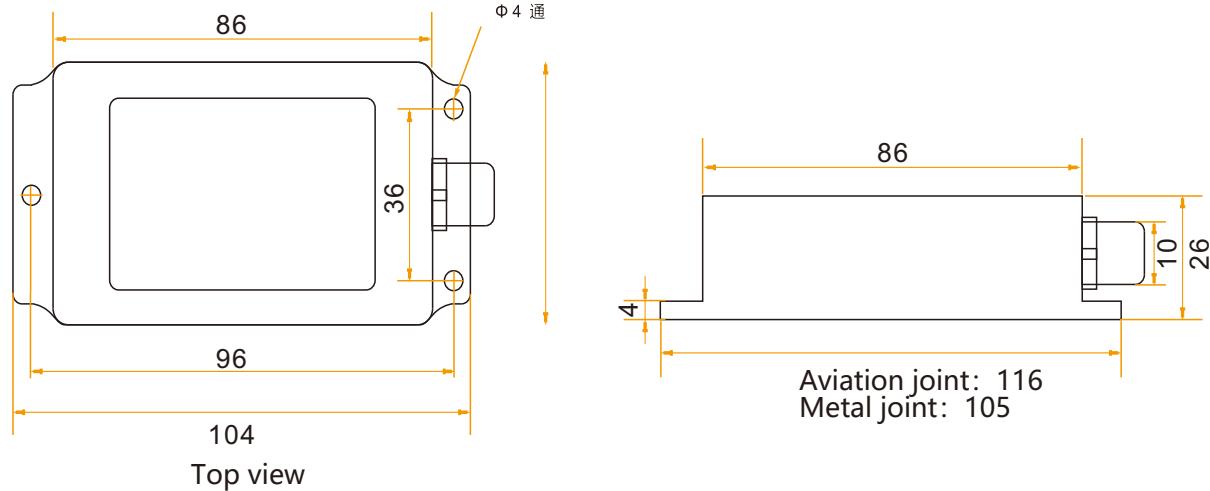
Bare plate product size

Size：L68*W48*H12（mm)
Note: ±1mm error for length and width dimensions, please refer to actual size.

63

孔Φ2mm

43

15

48

5

68
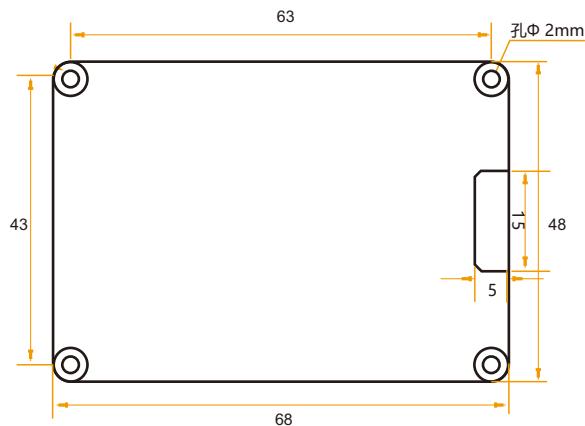
Product installation

The correct installation method can avoid measurement errors, and the following points should be taken when installing the sensor:

First of all, to ensure that the sensor mounting surface is completely close to the measured surface, the measured surface should be as horizontal as possible, and there should be no angle shown in Figure A and Figure C. The correct installation method is shown in Figure B and Figure D.

A ❌
The mounting surface is uneven and produces an angle

Measured surface

B ✅

Measured surface

C ❌

The mounting surface is uneven and produces an angle

Measured surface

D ✅

Measured surface
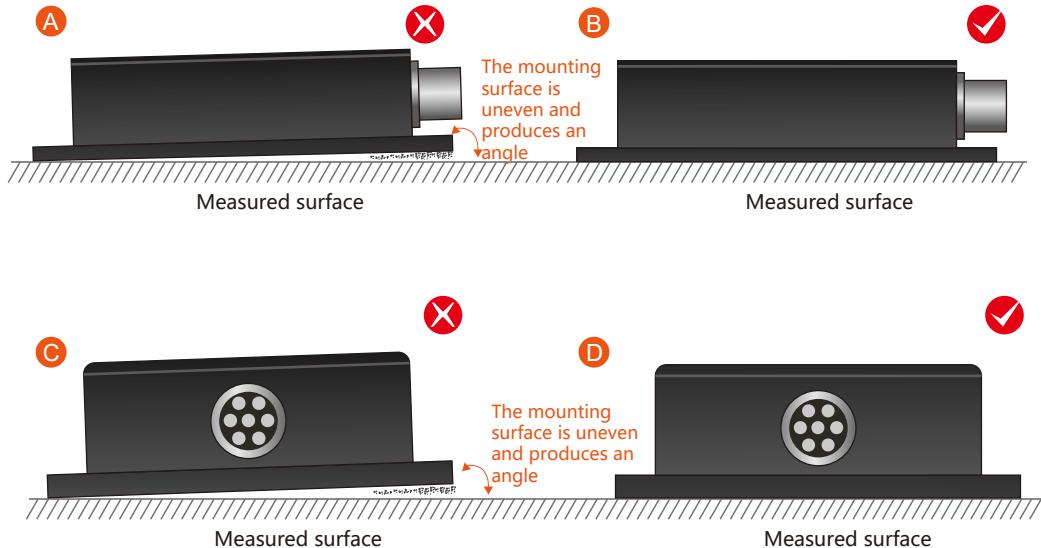
Secondly, the bottom edge of the sensor and the axis of the object to be measured cannot be generated at an angle as shown in Figure E. The bottom edge of the sensor should be kept parallel or orthogonal to the axis of rotation of the object to be measured. This product can be installed horizontally or vertically (vertical installation requires customization), and the correct installation method is shown in Figure F.

E ❌
+Y
轴线A
轴线B
+X

F ✅
平行
平行
+Y
轴线A
轴线B
+X
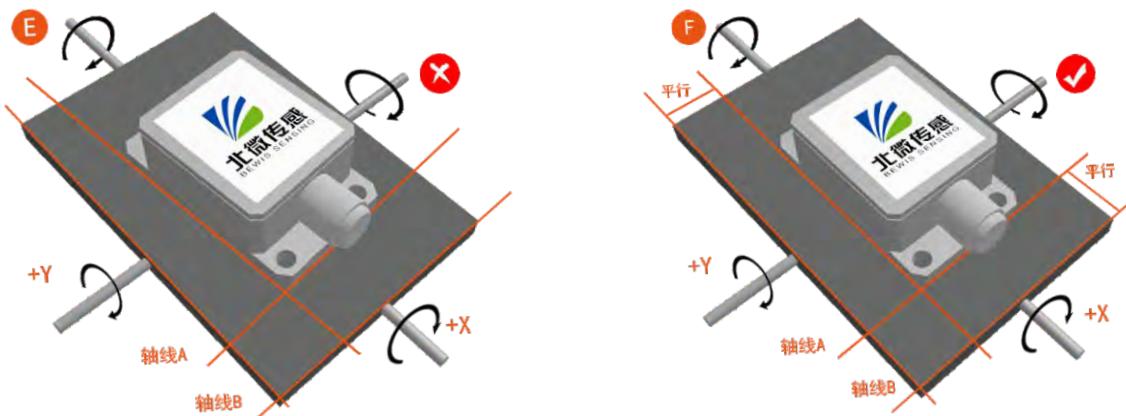
Finally, the mounting surface of the sensor and the surface to be measured must be fixed, the contact is flat, and the rotation is stable. The measurement error caused by acceleration and vibration should be avoided.

Measurement installation

Although the AH400 can compensate for magnetic interference, the user should select an environment with minimal magnetic interference for installation and use. Try to keep the AH400 away from iron, nickel, magnets, engines and other magnetic materials.

It is important to strictly avoid the proximity of strong magnetic materials such as magnets and motors to the product, which may cause the measurement accuracy of the product to decrease irreversibly .

Each AH400 is supplied with a 1.5 m cable and the cable length is optional. The magnetic field environment is different for each installation location and the user must evaluate the installation feasibility of the operating environment.

The recommended test method is to mount the AH400 on a vertically erected aluminum (or other non-magnetic material) rod for heading accuracy measurement (the rotating rod is perpendicular to the rotating platform to avoid large external magnetic field interference).

Calibration method

The product has been calibrated at the factory. In places where the influence of the magnetic field environment is small, it is not necessary to perform environmental calibration when using it, and it can be used directly. During actual use, it is recommended to perform calibration.

Azimuth calibration step：

Method 1 - Plane calibration:

1. Connect the product to the system and place the product in a horizontal state;

2. Open the serial port debugging assistant and send 77 04 00 11 15;

3. Rotate the product in the horizontal plane (with the pitch and roll angles within ±5°) around the z-axis (z-axis is vertical) and rotate 2-3 turns, the rotation process is as slow as possible and rotates at a constant speed. The time of one rotation is controlled between 10 seconds and 15 seconds.
4. Rotate the compass around the X or Y axis. The rotation can be performed at a slow speed and near constant speed. Rotate 2-3 turns around each axis. The rotation time is about 15 seconds.
5. Complete the calibration and send 77 04 00 12 16 to save the calibration.

Method 2 - Multi-face calibration:

1. Fix the product in the use environment, and try not to carry magnetic items such as keys and mobile phones during calibration;
2. Place the product in a horizontal state (within ±5°);
3. Send the following calibration command in hexadecimal format: 77 04 00 08 0C, return value 77 05 00 88 00 8D;
4. The product is placed horizontally, face up (pitch and roll are within ±5°), approximate rotates at a uniform speed for one week, and rotation takes more than 10 seconds.
5. The product is placed in a horizontal state with the mounting surface facing up (with a pitch of 0±5 degrees and a horizontal roll of 180±5 degrees),rotate one revolution at a constant speed approximately and use for more than 10 seconds.

6.The product is placed in a vertical state, and the other smooth side of the casing faces downward (the pitch and the roll are both within ±5°), rotate one revolution at a constant speed approximatelyand use for more than 10 seconds.

7.The product is placed in a vertical state, and the other smooth side of the casing faces downward (the pitch and the roll are both within ±5°), rotate one revolution at a constant speed approximately and use for more than 10 seconds.

[Where step 4.5.6.7 can be exchanged];

8.After the four faces have been rotated, send the hexadecimal command 77 04 00 09 0D to save the calibration and return to 77 05 00 89 XX YY. (XX represents the calibration error coefficient, the smaller the value, the better, less than 1 is ideal, FF indicates calibration failure, and YY is the checksum of the command);

9.Calibration completed.

E l e c t r i c a l connections

Wiring definition

Cable color & function	RED	BLUE	BLACK	GREEN	YELLOW
	1	2	3	4	5
	VCC DC 9-35V	NC	GND	RXD (B、D-)	TXD (A、D+)
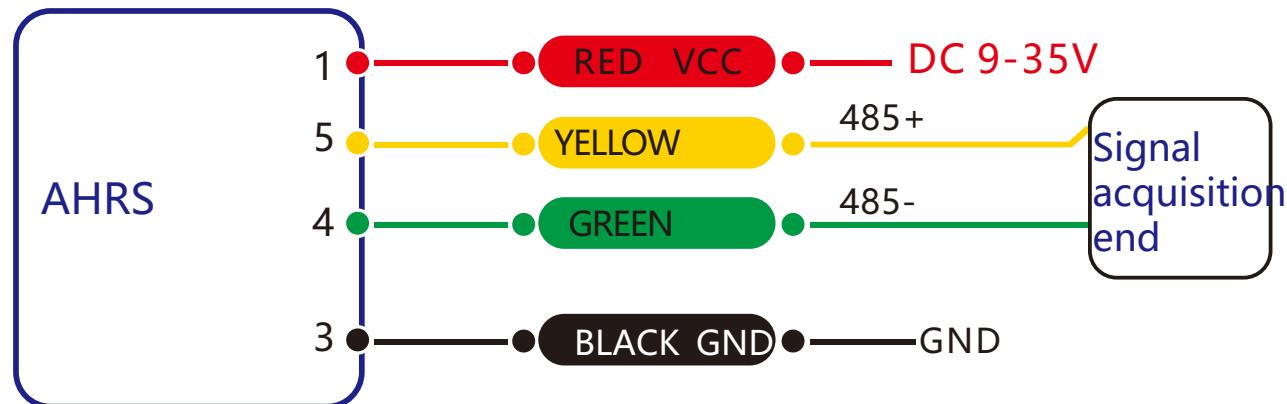
RS485wiring diagram
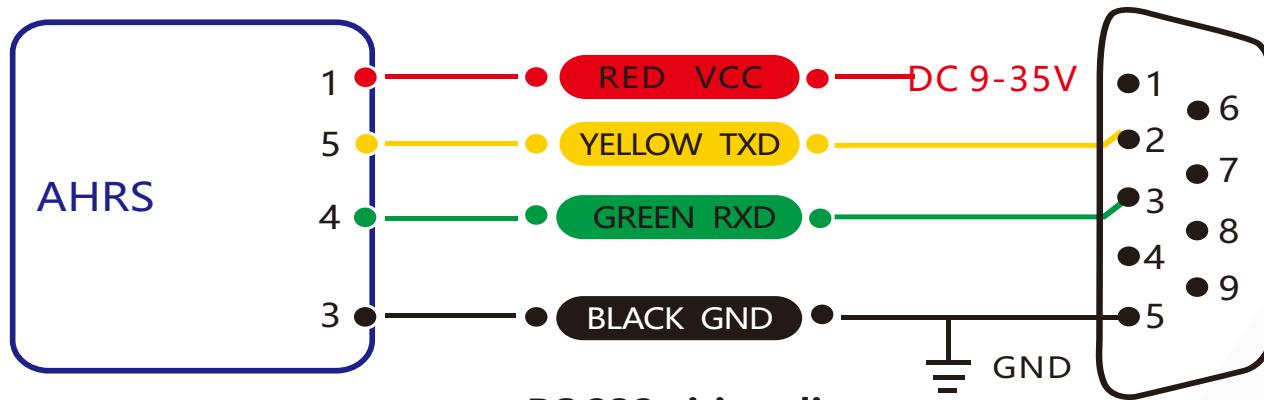
RS 232wiring diagram

The RS232 interface needs to connect the ground wire of the product, the ground wire of the serial device, and the power ground.

Protocol

1 Data Frame Format： (8 data bits，1 stop bit，No parity check，default baud rate 9600)

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (Xbyte)	Checksum (1byte)
0x77					

Data Format: Hexadecimal
Identifier: Fixed to 77
Frame Length: Length from Frame Length to Checksum (included)
Address Code: Address of acquiring module, default 0x00
Data: Content and length variable according to Command
Checksum: The sum of the data length, address code, command word and data field hexadecimal (if there is a carry, only the last two digits are taken).
Note: The checksum will change when the command word or data field changes. Change the checksum accordingly when you change the data field.For the product's change settings, you will need to send the save settings command after the change. Otherwise, if the power is turned back on, the previous setting items will disappear, and the baud rate will not be saved and will take effect immediately after the change.

2 Command Format：

2.1 Read PITCH angle Command：77 04 00 01 05

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x01		

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (3byte)	Checksum (1byte)
0x77	0x07		0x81	SXXX.YY	

Note: Data represents 4 byte angle value in format of compressed BCD code. S is the sign bit (0 means positive, 1 means negative), XXX is the three digit integer part, YY is the fractional part. The Data of other axis is the same format. For example, 10 26 87 means -026.87 °.

2.2 Read ROLL roll angle command:77 04 00 02 06

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	04		0x02		

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (3byte)	Checksum (1byte)
0x77	0x07		0x82	SXXX.YY	

2.3 Read Heading azimuth angle Command: 77 04 00 03 07

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x03		

Command response:

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (3byte)	Checksum (1byte)
0x77	0x07		0x83	SXXX.YY	

2.4 Read PITCH,ROLL,HEADING axis angle Command: 77 04 00 04 08

| Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x04		

Command response:

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (9byte)	Checksum (1byte)
0x77	0x0D		0x84	3 groups SXXX.YY	

The data field consists of 9 bytes, which are Pitch, Roll and Heading angle values. The compressed BCD code is a group of every three bytes. For example, the return command is 77 0D 00 84. 10 26 80 00 33 65 03 13 71 66, where Pitch is 10 26 80 and Roll is 00 33 65,Heading is 03 13 71. For the three bytes of the return value for each angle, the format is SX XX YY, S is the sign bit (0 positive, 1 negative), XXX is the three-digit integer value, and YY is the decimal value. The corresponding three angle readings for this example are: -26.8°, 33.65°, 313.71°.

Command parsing:

Send command: 77 04 00 04 08

77   04   00   04   08

Identifier; fixed as 77

04 indicates the length of the byte, 04, 00, 04, 08 total 4 bytes

Indicates the default address of the product, which can be modified

Indicates the function code for reading the three-axis angle

For the checksum, add the sum in hexadecimal (only the last two digits) 08=04+00+04

Receiving resolution：

77 0D 00 84 10 26 80 00 33 65 03 13 71 66

Identifier；

Frame Length

indicates the default address of the product, which can be modified

Indicates the function code for reading the three-axis angle

10 26 80 indicates pitch angle -26.8°

00 33 65 means Roll angle +33.65°

03 13 71 indicates azimuth angle +313.71°

66 is the checksum, and the cumulative sum in hexadecimal (only the last two digits) 66=0D +00+84+ 10+26+80+00+33+65 +03+13+71=266 (after taking 2 digits)

2.5 Set the communication rate   send command：77 05 00 0B 02 12

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x0B	XX	

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x8B		

Note: The data field XX sent is the baud rate option:
00indicates2400,
01 indicates4800 ,
02indicates9600,
03indicates19200,
04indicates115200,
05indicates38400,
06indicates7600,
Changing the baud rate does not require a save command to be sent and takes effect immediately.

2.6 Set the magnetic declination send command：77 06 00 06 02 08 16

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (2byte)	Checksum (1byte)
0x77	0x06		0x06	SX XY	

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (2byte)	Checksum (1byte)
0x77	0x06		0x86	00	

Note: S indicates a symbol, 0 is positive 1 is negative, XX is a two-digit integer, and Y is 1 decimal. For example, 02 08 is +20.8°.
    The magnetic declination indicates the angle between the azimuth and the geomagnetism, which is also equivalent to setting the magnetic declination angle + the measured azimuth = product output azimuth.

2.7 Read magnetic declination send command：77 04 00 07 0B

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x07		

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (2byte)	Checksum (1byte)
0x77	0x06		0x87	SX XY	

2.8 Set module address send command：77 05 00 0F 01 15

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05	Pre-modification address	0x0F	new address	

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05	new address	0x8F	00	

Note: For example, sending the following command "77 05 00 0F 0A 1E" means changing the product address from hexadecimal address 00 to 0A.

2.9 Query current address send command：77 04 00 1F 23

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04	0x00	0x1F		23

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05	new address	0x1F	new address	

Note: The Query Address command is a fixed command.

2.10 Set the output frequency send command：77 05 00 0C 00 11

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x0C	XX	

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x8C	00	

Note: The data field XX sent is the automatic output frequency option: 00 indicates the answer mode.,

01 means 5Hz automatic output corresponding data type parameter
02 means 10Hz automatic output corresponding data type parameter
03 means 20Hz automatic output corresponding data type parameter
04 means 25Hz automatic output corresponding data type parameter
05 means 50Hz automatic output corresponding data type parameter

1. When the automatic output frequency setting is high, the baud rate needs to be set to a high baud rate;
2. The automatic output data type parameter is determined according to the following data type selection command. The default is the automatic output angle.

2.11 Query gravitational acceleration g value   send command：77 04 00 54 58

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x54		

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (9byte)	Checksum (1byte)
0x77	0x0D		0x54	3 groups SXYYYY	

Note: The data field is the value of the g value of pitch, roll, Z axis (perpendicular to the horizontal plane), consisting of 1 bit sign bit + 1 bit integer bit + 4 decimal places
For example, the return value is 77 0D 00 54 10 01 51 00 04 47 11 05 00 24 respectively: -0.0151g, 0.0447g, -1.05g.

2.12 Query magnetic field value send command：77 04 00 55 59

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x55		

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (9byte)	Checksum (1byte)
0x77	0x0D		0x55	3groups SYYYYY	

Note: The data field is the pitch, roll, Z axis (perpendicular to the horizontal plane), the 1-bit sign + 5 decimal places, the unit is Gauss。

For example, the return value is 77 0D 00 55 11 55 25 00 34 52 13 46 16 E2 respectively: -0.15525, 0.03452, -0.34616.

2.13 Query angular velocity send command：77 04 00 50 54

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x50		

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (9byte)	Checksum (1byte)
0x77	0x0D		0x50	3 groups SXXXYY	

Note: The data field is the angular velocity of the pitch, roll, and Z axis (perpendicular to the horizontal plane). It consists of 1 sign bit + 3 integer bits + 2 decimal places.

For example, the return value is 77 0D 00 50 01 13 92 04 99 52 10 21 78 9B , then the data field parts are respectively represented Pitch angular velocity: +113.92°/s, roll angular velocity +499.52°/s, Z-axis angular velocity: -21.78°/s.

2.14 Save Settings   send command：77 04 00 0A 0E

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x0A		

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x8A	0x00	

Note: 1. For parameter modification settings, you need to send the save command again. If the save setup command is not sent after the setup is completed, these settings will disappear after power off.

2.Except for the baud rate setting, the rest will send a save command.

2.15 Clear magnetic calibration data   send command：77 04 00 10 14

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x10		

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x90	0x00	

Note: This command is to clear the magnetic calibration data made by the user.

2.16 Quaternion   send command： 77 04 00 57 5B

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x57		

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (16byte)	Checksum (1byte)
0x77	0x14		0x57	4 groups SXYYYYYY	

Note: The data field contains 16 bytes, 4 bytes are a group, respectively quaternary q0, q1, q2, q3, which is a compressed BCD code, the format is SX YY YY YY,

   S is a 1-bit sign bit (0 positive, 1 negative), X is a 1-bit integer bit, and YYYYYY is a 6-digit decimal place.For example, if the return command 77 14 00 57 00 99 99 96 00 00 02 90 10 00 26 73 10 00 00 01 7F, the quaternion data is: where q0 is 00 99 99 96, which means 0.999996

   Q1 is 00 00 02 90, which means 0.000290
   q2 is 10 00 26 73, which means -0.002673
   q3 is 10 00 00 01, which means -0.000001

2.17 read Three-Axis Gyro Three-Axis Accelerometer Three-Axis Magnetometer   command： 77 04 00 60 64

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (0byte)	Checksum (1byte)
0x77	0x04		0x60		

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (36byte)	Checksum (1byte)
0x77	0x28		0x84	*	

*The above output format is as follows:

77 28 00 84 10 41 07 00 02 44 01 22 18 10 65 20 00 03 19 10 74 33 10 00 15 00 00 13 00 00 02 11 55 25 00 34 52 13 46 16 A7
among them：

10 41 07 00 02 44 01 22 18:
Three-axis attitude compression BCD code (SXXXYY): S is a sign bit, XXX three-digit integer bit, YY two decimal places
pitch：-41.07 roll：2.44 yaw：122.18

10 65 20 00 03 19 10 74 33:
Three-axis accelerometer (SXYYYY): S is a sign bit, X is an integer bit, and YYYY is four decimal places.
AX：-0.6520 AY：0.0319 AZ：-0.7433

10 00 15 00 00 13 00 00 02:
Three-axis gyroscope (SXXXYY): S is a sign bit, XXX three-digit integer bit, YY two decimal places
GX：-0.15 GY：0.13 GZ：0.02

11 55 25 00 34 52 13 46 16 (SXYYYY)：
S is a sign bit, X is an integer bit, and YYYY is four decimal places.
MX:-0.15525 MY:0.03452 MZ:-0.34616

A7:
Checksum: the sum of all data from length 28 to checksum

2.18 Automatic output data type setting send command：77 05 00 56 00 5B

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x56	XX	

Command response：

Identifier (1byte)	Frame Length (1byte)	Address Code (1byte)	Command (1byte)	Data (1byte)	Checksum (1byte)
0x77	0x05		0x56	00	

*Note: Data field XX corresponds to the output data type:

0x00: Automatically output three-axis attitude data, output format reference read three-axis angle 2.4

0x01: Automatic output three-axis accelerometer, output format reference reading accelerometer data 2.11

0x02: automatic output three-axis gyroscope data, output format reference reading gyroscope data 2.13

0x03: automatic output three-axis magnetometer data, output format reference reading magnetic Data 2.12

0x04: Automatically output all data, including (three-axis attitude, accelerometer, gyroscope, magnetometer),

output format reference read nine-axis data 2.17

Ordering Information

Product number	way of communication	Package condition
BW-AH400-232	RS232	IP67 package / aviation connector
BW-AH400-485	RS485	IP67 package / aviation connector
BW-AH400-TTL	TTL	IP67 package / aviation connector

Executive standard

- Enterprise Quality System Standard: ISO9001:2008 Standard (Certificate No.:10114Q16846ROS)
- CE certification (certificate number: 3854210814)
- ROHS (certificate number: SO81426003)
- GB/T 191 SJ 20873-2003 General specifications for tiltmeters and spirit levels
- GBT 18459-2001 sensor main static performance index calculation method
- JF 1059-1999 Evaluation and Expression of Measurement Uncertainty
- GBT 14412-2005 mechanical vibration and shock mechanical installation of accelerometer
- General requirements for GJB 450A-2004 equipment reliability
- Quality control of key parts and important parts of GJB 909A
- GJB 899 Reliability Qualification and Acceptance Test
- GJB 150-3A high temperature test
- GJB 150-4A low temperature test
- GJB 150-8A rain test
- GJB 150-12A dust test
- GJB 150-16A vibration test
- GJB 150-18A impact test
- GJB 150-23A Tilt and Swing Test
- GB/T 17626-3A RF electromagnetic radiation immunity test
- GB/T 17626-5A surge (hit) impulse immunity test
- GB/T 17626-8A power frequency magnetic field immunity test
- GB/T 17626-11A voltage dips, short interruptions and voltage changes immunity

BW-AH400

High precision AHRS

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