BS-IC22-4xy-D6EC

Inertial Measurement Unit User Manual

EX2.900.057SM

This instruction manual is the main reference document for the use and operation of BS-IC22-4xy-D6EC, and is mainly prepared in accordance with the Technical Agreement of BS-IC22-4xy-D6EC Inertial Measurement Unit and the Technical Conditions of KTJT-001 Inertial Measurement Unit and Triaxial Gyro Combination.

BS-IC22-4xy-D6EC series inertial measurement unit can be changed according to user requirements. Inertial sensorMeasurement accuracy and measurement range.

1 Product features and technical parameters

1.1 Composition and function

The MEMS inertial measurement unit consists of a three-axis gyroscope, a three-axis acceleration meter, a three-axis inclination angle, a three-axis magnetic sensor, a temperature sensor, a signal processing board, a structure and necessary software, and is used for measuring the three-axis angle of a carrier.Rate, three-axis acceleration, three-axis inclination angle and three-axis magnetic field intensity, and output the gyro, loading table, inclination angle and magnetic field intensity data after error compensation (including temperature compensation, installation misalignment angle compensation, nonlinear compensation, etc.) Through the RS-422 serial port according to the agreed communication protocol.

1.2 Main technical parameters

1.2.1 Gyroscope specifications

Parameter	Unit	BS-IC22-4y-D6EC	BS-IC22-4Ay-D6EC	BS-IC22-4By-D6EC

Measuring range (customizable)	°/s	X：±7200 Y、Z：±300	±300	±400
Zero bias stability (@ Allan Variance)	°/h	X:5 Y、Z:1	0.1	0. 1
Zero bias stability (1s smooth, 1σ, room temperature)	°/h	X：50 Y、Z：10	3	1
Zero bias stability (10 s smooth, 1σ, room temperature)	°/h	X：20 Y、Z：1	0.5	0.2
Zero-bias error over full temperature range	°/h	X：30 Y、Z：20	10	2
Random walk	°/√h	X：2 Y、Z：0.5	0.02	0.015
Zero-bias repeatability	°/h	X：10 Y、Z：5	10	1
Zero bias acceleration sensitivity	°/h/g	1	1	1
Output noise	°/s (unfiltered, RMS)	0.5 0.2	0.1	0.1
Resolution	°/h	X：5 Y、Z：2	1	0.5
Scale factor nonlinearity	ppm	100	100	100
Scale factor repeatability	ppm	100	100	100
Cross coupling	%	0.1	0.1	0.1
Bandwidth	Hz	150	400	250
Delay	ms	2	1	1.5

1.2.2 Add table technical indicators

Parameter	**Unit**	**BS-IC22-4x1-D6EC**	**BS-IC22-4x2-D6EC**	**BS-IC22-4x3-D6EC**
Measuring range (customizable)	g	±15	±20	±40
Zero-bias stability (Allan Variance @ 25 ℃)	mg	0.02	0.05	0.1
Zero-bias stability (1s smoothing)	mg	0.1	0.5	1
Zero-bias stability (10 s smoothing)	mg	0.05	0.2	0.5
Zero-bias error over full temperature range	mg	1	3	5

Random walk	m/s/√h	0.001	0.002	0.005
Zero-bias repeatability	mg	0.1	0.5	1
Scale factor repeatability	ppm	300		
Scale factor nonlinearity	ppm	100		
Bandwidth	Hz	250		

1.2.3 Dip angle specification

Parameter	**Unit**	**BS-IC22-4xy-D6EC**
Measuring range (customizable)	g	±1.7
Zero-bias stability (1s smoothing)	mg	0.5
Random walk	m/s/√h	0.08
Scale factor nonlinearity	ppm	100

1.2.4 Technical specifications of magnetometer

Parameter	**Unit**	**Indicators**
Dynamic measuring range	gauss	±2.5
Sensitivity	mgauss	0.15
Nonlinearity	%FS	0.12

1.2.5 Electrical characteristics

Parameter	**Unit**	**BS-IC22-4xy-D6EC**
Voltage	V	5
Power consumption	W	2
Ripple	mV	100

1.2.6 Environmental adaptability

Parameter	**Unit**	**BS-IC22-4xy-D6EC**
Operating temperature	℃	-45~85
Storage temperature	℃	-55~105
Vibration	--	10~2000Hz，6.06g
Impact	--	1500g,0.1ms

1.2.7 Other

Parameter	Unit	BS-IC22-4xy-D6EC
Weight	g	55±5

2 Space coordinate system

2.1 Right hand rule principle one

The MEMS IMU contains three axial spatial coordinate systems, namely X, Y and Z. The X axis points to the direction of the electrical connection interface, the Y axis points to the left side of the IMU, and the Z axis points to the top surface of the IMU, as shown in Figure 2-1.

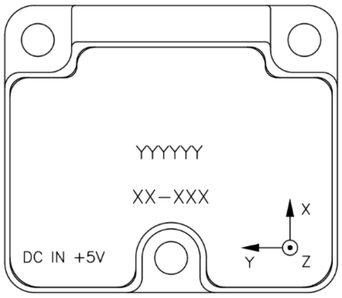

Figure 2-1 IMU Space Coordinate System

The installation of IMU should be matched with the axial direction of the coordinate system, otherwise the measured angular velocity data will be inaccurate. The axis of the coordinate system can be quickly assigned and determined by following the "right-hand rule principle 1". Stretch out the right hand and spread out the thumb, index finger and middle finger respectively. The direction of the thumb is the X axis, the direction of the index finger is the Y axis, and the direction of the middle finger is the Z axis, as shown in Figure 2-2.

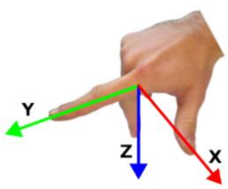

Figure 2-2 Right Hand Rule Principle 1

2.2 Right hand rule principle two

The three-degree-of-freedom gyroscope in the IMU can measure the angular velocity in three directions. The direction of the angular velocity of the axial rotation of the coordinate axis can be quickly determined by following the'right-hand rule principle 2 '. Stretch out the right hand and unfold the thumb. The direction of the thumb is the axial direction, and the direction of the other four fingers is the direction of the angular velocity of the axial rotation of the thumb, as shown in Figure 2-3.

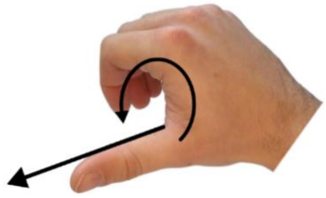

Figure 2-3 Right Hand Rule Principle 2

3 Structural installation

See Figure 3-1 for the outline drawing of BS-IC22-4xy-D6EC IMU.

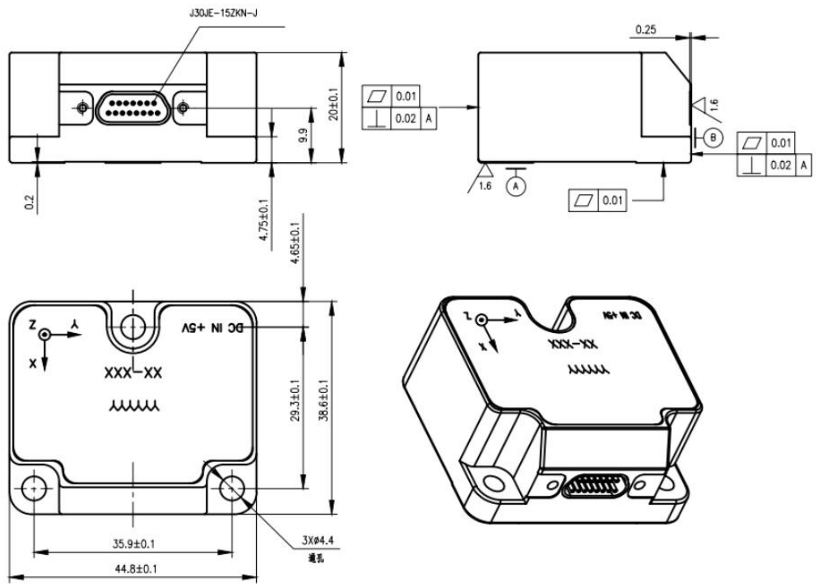

Fig. 3-1 Outline drawing of IMU

"BS-IC22-4xy-D6EC " in the drawing is the product code. According to the product naming rules of the company, "x" in BS-IC22-4xy-D6EC can be "A", "B", "C", etc., or no letter, to distinguish different gyroscope performance index requirements."y" in BS-IC22-4xy-D6EC can be "1", "2", "3", etc., or no number, to distinguish different performance index requirements. "BS-XX-4XX-D6EC" is the product number.

BS-IC22-4xy-D6EC IMU is installed through three Φ4.4 through holes, and three M4 screws (with spring washer and flat washer) are used for installation. When installing the connector, the plug shall be locked with the socket and the cable shall be fixed. EQ \ o \ AC (○, A) in the figure、eq \o\ac(○,B)Is the installation datum plane of the inertia group.

It is recommended that the flatness of the mounting surface opposite to the reference surface shall not be greater than 0.01 mm, the verticality shall not be greater than 0.02 mm, and the surface roughness shall not be greater than 0.8 μm.

4 Electrical characteristics

The electrical connector model of BS-IC22-4xy-D6EC inertia group is J30JE-15-ZKNY-J, and

4.1 Electrical interface

the specific distribution of contacts is shown in Table 4-1 and Figure 4-1.

Table 4-1 J30JE-15ZKNY-J Contact Distribution

Contact number	Pin definition	Type	Explain
1	TxD-	OUTPUT	Product RS422 output interface negative terminal
2	RxD-	INPUT	Product RS422 receiving interface negative terminal
4	TOV	OUTPUT	Sync Signal (1)
5	NRST	INPUT	Reset Signal (2)
8	VSUP	SUPPLY	Positive end of product power supply, DC regulated power supply
9	TxD+	OUTPUT	Product RS422 output interface positive terminal
10	RxD+	INPUT	Product RS422 receiving interface positive terminal
11	ExtTrig	INPUT	External Trigger Source (3)
12、13、15	GND	SUPPLY	Product ground, power ground and serial port ground
3、6~7、14	Reserved by the manufacturer	/	/

Notice

(1) The synchronization signal needs to be specially configured according to the requirements. The default IMU does not have this configuration and needs to be suspended.

(2) The reset signal needs to be specially configured as required. The default IMU does not have this configuration and needs to be suspended.

(3) The external trigger source needs to be specially configured according to the requirements. The default inertia group does not have this configuration and needs to be suspended.

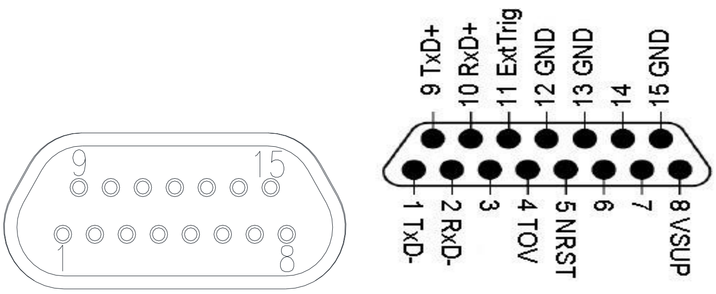

Fig. 4-1 Configuration Diagram of Connector Node (Seen from the Outside of the Product)

4.2 Electrical interface connections

The BS-IC22-4xy-D6EC IMU is very simple to use. If no special additional functions are required, the IMU will send data through the RS422 communication interface protocol about 2 s after power-on. Figure 4-2 shows a simple interconnection diagram for the BS-IC22-4xy-D6EC

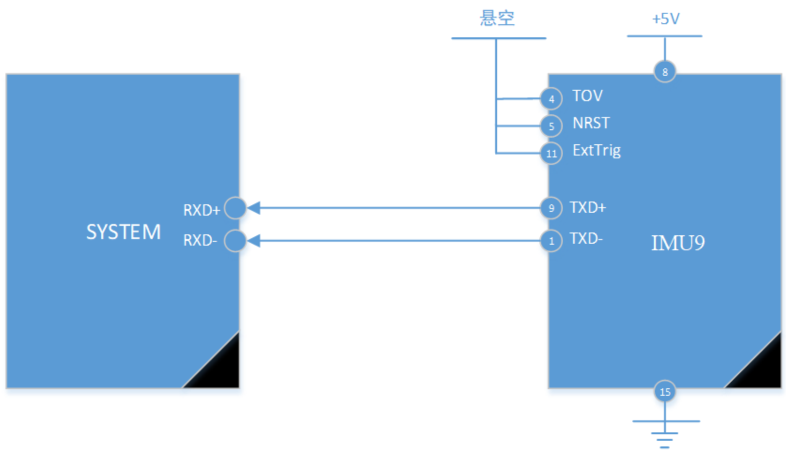

Fig. 4-2 Electrical connection 1

If you want to use all the functions of BS-IC22-4xy-D6EC IMU, you need to connect the IMU to the IMU as shown in Figure 4-3.

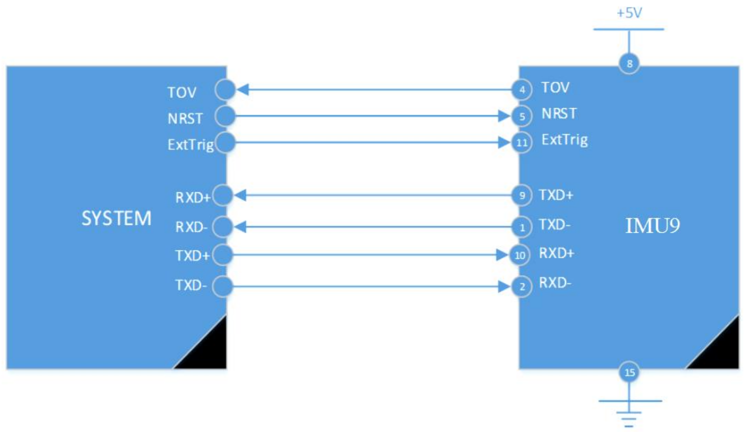

Figure 4-3 Electrical connection 2

4.3 Additional Function 1: Reset

The BS-IC22-4xy-D6EC IMU has a separate digital input pin (NRST) that allows the BS-IC22-4xy-D6EC to be reset without re-powering up if the IMU is configured for a particular configuration. The trigger mode of the NRST signal can be specially defined according to the requirements.

4.4 Additional function 2: external trigger

The BS-IC22-4xy-D6EC IMU has an independent digital input pin (ExtTrig). If the IMU has completed a specific configuration, when it receives an external trigger source signal and generates an interrupt, it can send data through the RS422 communication interface protocol. The frequency of sending data is synchronized with the frequency of the ExtTrig signal. However, there are two special cases where sending data is not affected by an external trigger source:

a) In normal mode, send command 'C' to the IMU to test the RS422 interface. The IMU will transmit the configuration data stream independent of the external trigger source.

b) In the power-on initialization state, the IMU sends the initialization state data without being affected by the external trigger source.

Figure 4-4 is the timing diagram of the external trigger source sending data. The sampling frequency of the IMU is 1000Hz. The external trigger source shall not be higher than the sampling frequency. Latency is the delay of sending trigger data.

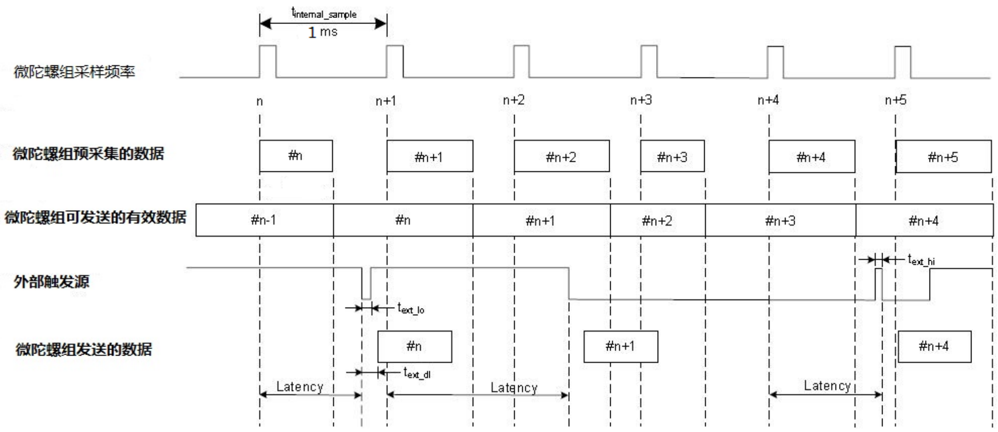

Figure 4-4 External Trigger Timing Diagram

4.5 Additional function 3: synchronization

The BS-IC22-4xy-D6EC IMU has an independent digital output pin (TOV). If the IMU is configured specifically, it can output a signal of a specific frequency and provide a synchronization signal. Figure 4-5 shows the synchronization timing diagram without the external trigger source. Figure 4-6 shows the synchronization timing diagram with the external trigger source. The sampling frequency is 1000 Hz.

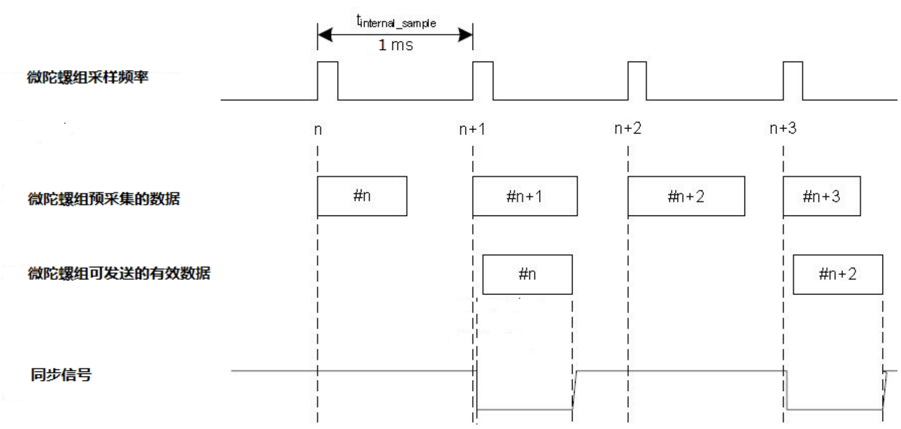

Figure 4-5 Synchronous Signal Timing 1

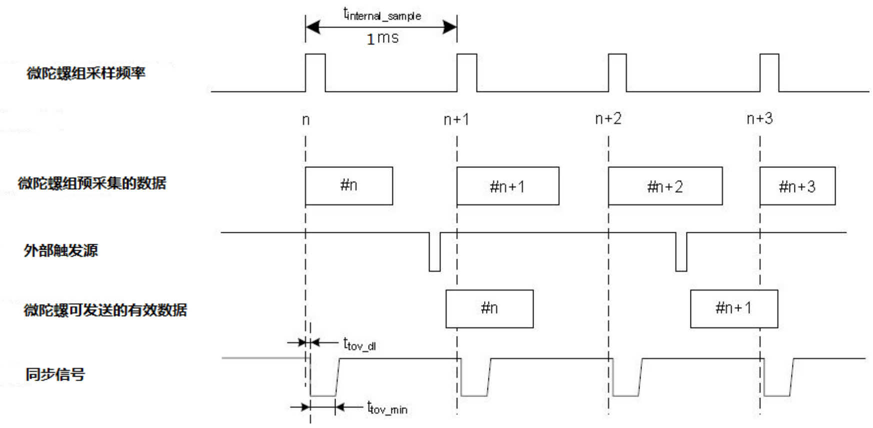

Figure 4-6 Synchronous Signal Timing 2

5 Communication interface

5.1 Configurable parameters

The product communication protocol can be configured through the upper computer software, and the configurable parameters are shown in Table 5-1 below.

Table 5-1 Product Configurable Parameters

<table>
<tr><th>Parameter</th><th colspan="2">Configuration value</th><th>Explain</th></tr>
<tr><td>Data frame</td><td colspan="2">Gyro data frame (ID = 0x90)
'Gyro + Add Table 'data frame (ID = 0x91)
'Gyro + Tilt 'data frame (ID = 0x92)
Data frame of 'gyro + meter + magnetic sensor' (ID = 0 x93)
'Gyro + Temperature 'data frame (ID = 0x94)
'Gyro + plus meter + temperature 'data frame (ID = 0 xA5)
'Gyro + tilt + temperature 'data frame (ID = 0 xA6)
'Gyro + plus meter + tilt + temperature 'data frame (ID = 0 xA7)</td><td>Refer to Section 5.3 for specific data frame format, which can be sent by any one of them.
See Table 5-2 for the relationship between data frame, baud rate and update rate.</td></tr>
<tr><td>RS422 baud rate</td><td colspan="2">460800bps
921600bps</td><td>Refer to Table 5-2 for baud rate limit conditions.</td></tr>
<tr><td>RS422 check digit</td><td colspan="2">NONE (no check)
ODD (odd parity)
EVEN (even parity)</td><td></td></tr>
<tr><td>RS422 stop bit</td><td colspan="2">1 bit
2 bits</td><td></td></tr>
<tr><td rowspan="2">Low-pass filter bandwidth</td><td>-3dB frequency</td><td>Group Delay (ms)</td><td rowspan="2">The filter setting is independent of the data update rate.
The low-pass filter is a second-order IIR.</td></tr>
<tr><td>16Hz
33Hz
66Hz
131Hz
262Hz
400Hz</td><td>23.4
11.7
5.9
3.0
1.6
1.0</td></tr>
<tr><td>Data update rate</td><td colspan="2">125Hz
250Hz
500Hz
1000Hz
2000Hz
4000Hz</td><td>Refer to Table 5-2 for data update rate restrictions.</td></tr>
<tr><td>Restore factory settings</td><td colspan="2">Restore factory settings
Restore factory settings and save</td><td></td></tr>
</table>

5.2 Communication interface

It communicates with the processing circuit unit through the serial communication interface and adopts the RS-422 standard. Both the transmission baud rate and the data update rate can be configured by software. Table 5-2 shows the maximum data update rate corresponding to the transmission baud rate.

In the default state of the product, the communication protocol is: baud rate 921 600bps, 8 data bits, 1stop bit, no check bit, 0x90 data frame, update rate 1000Hz.

Table 5-2 Maximum Data Update Rate

Baud rate / Data frame format	460800 bit/s	921600 bit/s
Gyro data frame (0x90)	2000Hz	4000 Hz
'Gyro + Add Table 'data frame (0 x91)	1000 Hz	1000 Hz
'Gyro + Tilt 'data frame (0x92)	1000 Hz	1000 Hz
'Gyro + plus meter + magnetic field strength 'data frame (0x93)	1000 Hz	1000 Hz
'Gyro + Temperature 'data frame (0x94)	1000 Hz	1000 Hz
'Gyro + plus meter + temperature 'data frame (0 xA5)	500 Hz	1000 Hz
'Gyro +Inclination+ Temperature 'data frame (0 xA6)	500 Hz	1000 Hz
'Gyro + plus meter + tilt + temperature 'data frame (0 xA7)	500 Hz	1000 Hz

5.3 Data frame format

Data frame is sent by IMU in each cycle, and the data format can be configured by referring to the corresponding data frame format in the operating instructions of the supporting upper computer. All formats are shown in the following table.

Table 5-2 Format of Gyro Data Frame (ID = 0x90)

Serial number	Parameter name	Effective range	Byte	Scale	Remark
1	Frame header	0x90	1	——	Packet header
2	X-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
3	Y-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
4	Z-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.

5	Gyro status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
6	Frame counter	[0，255]	1	1	0-255 continuous count
7	Delay		2		Unit: us, first high and then low, the most significant bit of the first byte is the sign bit. See Note 5 for the specific algorithm.
8	CRC32	——	4	——	CRC32 verification, see instruction 6

Table 5-3 Data Frame Format of 'Gyro + Add Table' (ID = 0x91)

Serial number	Parameter name	Effective range	Byte	Scale	Remark
1	Frame header	0x91	1	——	Packet header
2	X-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
3	Y-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
4	Z-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
5	Gyro status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
6	X-axis acceleration	[-15，15]	3	2^{-19}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 2 for the specific algorithm.
		[-20，20]		2^{-18}	
		[-40，40]		2^{-17}	
7	Y-axis acceleration	[-15，15]	3	2^{-19}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 2 for the specific algorithm.
		[-20，20]		2^{-18}	
		[-40，40]		2^{-17}	
8	Z-axis acceleration	[-15，15]	3	2^{-19}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 2 for the specific algorithm.
		[-20，20]		2^{-18}	
		[-40，40]		2^{-17}	
9	Add table status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
10	Frame counter	[0，255]	1	1	0-255 continuous count
11	Delay		2		Unit: us, first high and then low, the most significant bit of the first byte is the sign bit. See Note 5 for the specific algorithm.

12	CRC32	——	4	——	CRC32 verification, see instruction 6

Table 5-4 Format of 'Gyro + Tilt' Data Frame (ID = 0x92)

Serial number	Parameter name	Effective range	Byte	Scale	Remark
1	Frame header	0x92	1	——	Packet header
2	X-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
3	Y-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
4	Z-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
5	Gyro status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
6	X-axis inclination	[-2.5，2.5]	3	2^{-22}	Unit: Gauss, first high and then low, the most significant bit of the first byte is the sign bit. See Note 3 for the specific algorithm.
7	Y-axis inclination	[-2.5，2.5]	3	2^{-22}	Unit: Gauss, first high and then low, the most significant bit of the first byte is the sign bit. See Note 3 for the specific algorithm.
8	Z-axis inclination	[-2.5，2.5]	3	2^{-22}	Unit: Gauss, first high and then low, the most significant bit of the first byte is the sign bit. See Note 3 for the specific algorithm.
9	Inclination state	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
10	Frame counter	[0，255]	1	1	0-255 continuous count
11	Delay		2		Unit: us, first high and then low, the most significant bit of the first byte is the sign bit. See Note 5 for the specific algorithm.
12	CRC32	——	4	——	CRC32 verification, see instruction 6

Table 5-5 Data Frame Format of 'Gyro + Plus Table + Magnetic Field Intensity' (ID = 0x93)

Serial number	Parameter name	Effective range	Byte	Scale	Remark
1	Frame header	0x93	1	——	Packet header
2	X-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
3	Y-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
4	Z-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
5	Gyro status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
6	X-axis acceleration	[-15，15]	3	2^{-19}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 2 for the specific algorithm.
		[-20，20]		2^{-18}	
		[-40，40]		2^{-17}	
7	Y-axis acceleration	[-15，15]	3	2^{-19}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 2 for the specific algorithm.
		[-20，20]		2^{-18}	
		[-40，40]		2^{-17}	
8	Z-axis acceleration	[-15，15]	3	2^{-19}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 2 for the specific algorithm.
		[-20，20]		2^{-18}	
		[-40，40]		2^{-17}	
9	Add table status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
10	X-axis magnetic field intensity	[-2.5，2.5]	3	2^{-21}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 3 for the specific algorithm.
11	Y-axis magnetic field strength	[-2.5，2.5]	3	2^{-21}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 3 for the specific algorithm.
12	Z-axis magnetic field intensity	[-2.5，2.5]	3	2^{-21}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 3 for the specific algorithm.
13	Status of the magnetometer	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
14	Frame counter	[0，255]	1	1	0-255 continuous count

15	Delay		2		Unit: us, first high and then low, the most significant bit of the first byte is the sign bit. See Note 5 for the specific algorithm.
16	CRC32	——	4	——	CRC32 verification, see instruction 6

Table 5-6 Format of 'Gyro + Temperature' Data Frame (ID = 0x94)

Serial number	Parameter name	Effective range	Byte	Scale	Remark
1	Frame header	0x94	1	——	Packet header
2	X-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
3	Y-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
4	Z-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
5	Gyro status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
6	X-axis gyro temperature	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
7	Y-axis gyro temperature	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
8	Temperature of Z-axis gyroscope	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
9	Gyro Thermometer Status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
10	Frame counter	[0，255]	1	1	0-255 continuous count
11	Delay		2		Unit: us, first high and then low, the most significant bit of the first byte is the sign bit. See Note 5 for the specific algorithm.
12	CRC32	——	4	——	CRC32 verification, see instruction 6

Table 5-7 Data Frame Format of 'Gyro + Add Table + Temperature' (ID = 0xA5)

Serial number	Parameter name	Effective range	Byte	Scale	Remark
1	Frame header	0xA5	1	——	Packet header
2	X-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
3	Y-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
4	Z-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
5	Gyro status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
6	X-axis acceleration	[-15，15]	3	2^{-19}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 2 for the specific algorithm.
		[-20，20]		2^{-18}	
		[-40，40]		2^{-17}	
7	Y-axis acceleration	[-15，15]	3	2^{-19}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 2 for the specific algorithm.
		[-20，20]		2^{-18}	
		[-40，40]		2^{-17}	
8	Z-axis acceleration	[-15，15]	3	2^{-19}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 2 for the specific algorithm.
		[-20，20]		2^{-18}	
		[-40，40]		2^{-17}	
9	Add table status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
10	X-axis gyro temperature	[-128，128]	2	2^{-8}	Unit: ℃, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
11	Y-axis gyro temperature	[-128，128]	2	2^{-8}	Unit: ℃, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
12	Temperature of Z-axis gyroscope	[-128，128]	2	2^{-8}	Unit: ℃, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
13	Gyro Thermometer Status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
14	X-axis plus surface temperature	[-128，128]	2	2^{-8}	Unit: ℃, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.

15	Y-axis plus surface temperature	[-128，128]	2	2^{-8}	Unit: ℃, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
16	Z-axis plus surface temperature	[-128，128]	2	2^{-8}	Unit: ℃, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
17	Add thermometer status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
18	Frame counter	[0，255]	1	1	0-255 continuous count
19	Delay		2		Unit: us, first high and then low, the most significant bit of the first byte is the sign bit. See Note 5 for the specific algorithm.
20	CRC32	——	4	——	CRC32 verification, see instruction 6

Table 5-8 'Gyro + Tilt + Temperature' Data Frame Format (ID = 0 xA6)

Serial number	Parameter name	Effective range	Byte	Scale	Remark
1	Frame header	0xA6	1	——	Packet header
2	X-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
3	Y-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
4	Z-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
5	Gyroscope status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
6	X-axis inclination	[-1.7，1.7]	3	2^{-22}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 3 for the specific algorithm.
7	Y-axis inclination	[-1.7，1.7]	3	2^{-22}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 3 for the specific algorithm.
8	Z-axis inclination	[-1.7，1.7]	3	2^{-22}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 3 for the specific algorithm.

9	Inclination state	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
10	X-axis gyro temperature	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
11	Y-axis gyro temperature	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
12	Temperature of Z-axis gyroscope	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
13	Gyro Thermometer Status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
14	X-axis tilt temperature	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
15	Y-axis tilt temperature	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
16	Z-axis tilt temperature	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
17	Dip Thermometer Status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
18	Frame counter	[0，255]	1	1	0-255 continuous count
19	Delay		2		Unit: us, first high and then low, the most significant bit of the first byte is the sign bit. See Note 5 for the specific algorithm.
20	CRC32	——	4	——	CRC32 verification, see instruction 6

Table 5-9 Data Frame Format of 'Gyro + Add Table + Tilt + Temperature' (ID = 0 xA7)

Serial number	Parameter name	Effective range	Byte	Scale	Remark
1	Frame header	0xA7	1	——	Packet header
2	X-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.

3	Y-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
4	Z-axis angular velocity	[-400，400]	3	2^{-14}	Unit °/s, first high and then low, the most significant bit of the first byte is the sign bit. See Note 1 for the specific algorithm.
5	Gyroscope status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
6	X-axis acceleration	[-15，15]	3	2^{-19}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 2 for the specific algorithm.
		[-20，20]		2^{-18}	
		[-40，40]		2^{-17}	
7	Y-axis acceleration	[-15，15]	3	2^{-19}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 2 for the specific algorithm.
		[-20，20]		2^{-18}	
		[-40，40]		2^{-17}	
8	Z-axis acceleration	[-15，15]	3	2^{-19}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 2 for the specific algorithm.
		[-20，20]		2^{-18}	
		[-40，40]		2^{-17}	
9	Add table status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
10	X-axis inclination	[-1.7，1.7]	3	2^{-22}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 3 for the specific algorithm.
11	Y-axis inclination	[-1.7，1.7]	3	2^{-22}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 3 for the specific algorithm.
12	Z-axis inclination	[-1.7，1.7]	3	2^{-22}	Unit: G, first high and then low, the most significant bit of the first byte is the sign bit. See Note 3 for the specific algorithm.
13	Inclination state	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
14	X-axis gyro temperature	[-128，128]	2	2^{-8}	Unit: ℃, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
15	Y-axis gyro temperature	[-128，128]	2	2^{-8}	Unit: ℃, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
16	Temperature of Z-axis gyroscope	[-128，128]	2	2^{-8}	Unit: ℃, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
17	Gyro Thermometer Status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.

18	X-axis plus surface temperature	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
19	Y-axis plus surface temperature	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
20	Z-axis plus surface temperature	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
21	Add thermometer status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
22	X-axis tilt temperature	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
23	Y-axis tilt temperature	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
24	Z-axis tilt temperature	[-128，128]	2	2^{-8}	Unit: °C, from high to low, the most significant bit of the first byte is the sign bit. See Note 4 for the specific algorithm.
25	Dip Thermometer Status	——	1	——	All zeros are normal. See Table 5-10 for specific definitions.
26	Frame counter	[0，255]	1	1	0-255 continuous count
27	Delay		2		Unit: us, first high and then low, the most significant bit of the first byte is the sign bit. See Note 5 for the specific algorithm.
28	CRC32	——	4	——	CRC32 verification, see instruction 6

Explain

1) Gyro angular velocity output [°/s] $=\dfrac{AR_1 \cdot 2^{16} + AR_2 \cdot 2^{8} + AR_3}{2^{14}}$ See Figure 5-1 for data bit format;

Among AR_1 Outputting the high eight bits of the three bytes for the angular velocity of each axis of the gyroscope;

AR_2 Outputting the middle eight bits of the three bytes for the angular velocity of each axis of the gyroscope;

AR_3 Outputs the lower eight bits of the three bytes for the angular velocity of each axis of the gyro.

AR1								AR2								AR3							
Bit 23	Bit 22	Bit 21	Bit 20	Bit 19	Bit 18	Bit 17	Bit 16	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-5}	2^{-6}	2^{-7}	2^{-8}	2^{-9}	2^{-10}	2^{-11}	2^{-12}	2^{-13}	2^{-14}

Figure 5-1 Converting the Gyro Angular Velocity Output to [°/s]

2) Acceleration speed output [G] $=\frac{AR_1 \cdot 2^{16} + AR_2 \cdot 2^8 + AR_3}{2^X}$;

Among AR_1 Outputs the upper eight bits of the three bytes for the angular velocity of each axis of the accelerometer;

AR_2 Outputs the middle eight bits of the three bytes for the angular velocity of each axis of the accelerometer;

AR_3 Outputs the lower eight bits of the three bytes for the angular velocity of each axis of the accelerometer.

X is the tabulated scale index, and the 10g, 30g, and 50g tabulations correspond to X being the 19,18 and 17.

3) Tilt speed output [G] $=\frac{AR_1 \cdot 2^{16} + AR_2 \cdot 2^8 + AR_3}{2^{22}}$;

Among AR_1 Outputs the upper eight bits of the three bytes for the angular velocity of each axis of the tilt angle;

AR_2 The middle eight bit of that three bytes are output for the angular velocity of each axis of the tilt angle;

AR_3 The lower eight bits of the three bytes are output for the angular velocity of each axis of the tilt angle.

4) Temperature output [°C] $=\frac{T_1 \cdot 2^8 + T_2}{2^8}$? See Figure 5-2 for data bit format.

Among T_1 Outputs the upper eight bits of the two bytes for each axis temperature;

T_2 Outputs the lower eight bits of the two bytes for each axis temperature.

T1								T2							
Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-5}	2^{-6}	2^{-7}	2^{-8}

Figure 5-2 Converting Temperature Output to [°C]

5) Delay time output [us] $= T_1 \cdot 2^8 + T_2$

Wherein, T1 is the high eight bits in the two bytes of the delay time output;

T2 is the lower eight bits of the two bytes of the delay time output.

6) CRC check method

All data before the CRC check byte in the data frame is checked (excluding the

CRC check byte itself). The CRC uses the standard CRC-32 polynomial:

$$x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^{8} + x^{7} + x^{5} + x^{4} + x^{2} + x + 1$$

seed = 0xFFFFFFFF

See Appendix B for a list of table and table lookup function codes generated from this polynomial.

5.4 Self-check function and real-time output function of working status

The product has the functions of self-checking and real-time output of working status. The data frame contains a byte indicating the status, and the real-time output of the working status information of the product is started after the power-on start is completed. The status bits are defined in Table 5-10.

Table 5-10 Product Status Bit Definitions

Bit	Definition
7	0 = normal, 1 = system-wide abnormal
6	0 = normal, 1 = starting
5	0 = normal, 1 = abnormal external environment
4	0 = normal, 1 = three axes out of service condition
3	0 = normal, 1 = error in three-axis output
2	0 = OK, 1 = Z axis out of use condition or error
1	0 = OK, 1 = Y axis out of use condition or error
0	0 = OK, 1 = X axis out of use condition or error

6 Functional testing

6.1 Test equipment and instrumentation required

The equipment and instruments required in the test include: DC regulated power supply, computer, turntable, test tooling and test cable.

6.2 Functional testing

The product is in a static state, and the DC regulated power supply is used to supply power to the product. The power supply requirements meet the requirements of 1.2. The specific connection mode of the product is shown in Figure 6-1. Data is received according to the communication protocol, and the angular velocity output of the product is received and displayed by the upper computer receiving software.

Rotate the gyro assembly in the X, Y and Z directions respectively (if conditions permit, the gyro assembly can be input by the turntable; if conditions do not permit, the gyro assembly can be rotated by hand), and the angular velocity output of the corresponding axis can be monitored as the positive angular velocity. Rotate the product reversely around X, Y and Z respectively, and the angular velocity output of the corresponding axis can be monitored to be a negative angular velocity. It indicates that the angular velocity output polarity of the product is correct. The three angular rate values at the output of the product shall be in the vicinity of 0 deg/s under stationary conditions.

The acceleration output of the corresponding axis can be monitored to be 1G by overtaking X, Y and Z in the forward direction respectively. Under static conditions, the acceleration of the product is about 0 G at the output of two axes and about 1 G at the output of the third axis.

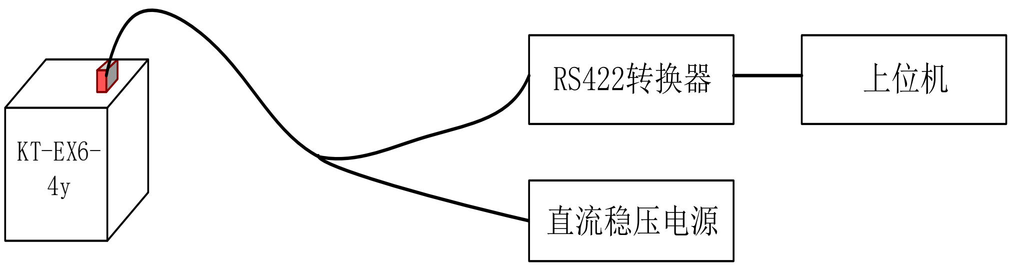

Fig. 6-1 Schematic diagram of IMU test connection

7 Use and maintenance requirements

Before use, the installation position of the system must be checked to ensure correct installation. Carefully check the connection of each signal line to ensure that the connection is correct.

Before power-on, check the cable network contact and power supply value, and the polarity of power supply shall not be reversed.

In use, the mechanical grounding of the system shall be well grounded.

This product contains precision instruments. Knocking and falling are prohibited.

This product should be stored in a well-ventilated warehouse with a temperature of (15 ~ 35) ℃, a relative humidity of not more than 75%, and free of acid, alkali and corrosive gases.

Appendix A Packing List

BS-IC22-4xy-D6EC Inertial Measurement Unit Product Matching Table

Serial number	Name	Quantity	Unit	Remark
1	BS-IC22-4xy-D6EC Products	1	Taiwan	
2	Product certificate	1	Share	
3	Instructions for use	1	Share	
4	Packing list	1	Share	
5	Product packing box	1	A	

Appendix B CRC Lookup Table and Lookup Function

Lookup table for B1 CRC32

```
static Uint32 crc_table[256]={
0x00000000, 0x04c11db7, 0x09823b6e, 0x0d4326d9, 0x130476dc, 0x17c56b6b, 0x1a864db2,
0x1e475005, 0x2608edb8, 0x22c9f00f,  0x2f8ad6d6, 0x2b4bcb61, 0x350c9b64, 0x31cd86d3,
0x3c8ea00a, 0x384fbdbd,0x4c11db70, 0x48d0c6c7, 0x4593e01e, 0x4152fda9,  0x5f15adac,
0x5bd4b01b, 0x569796c2, 0x52568b75, 0x6a1936c8, 0x6ed82b7f, 0x639b0da6, 0x675a1011,
0x791d4014, 0x7ddc5da3,  0x709f7b7a, 0x745e66cd,0x9823b6e0, 0x9ce2ab57, 0x91a18d8e,
0x95609039, 0x8b27c03c, 0x8fe6dd8b, 0x82a5fb52, 0x8664e6e5,  0xbe2b5b58, 0xbaea46ef,
0xb7a96036, 0xb3687d81, 0xad2f2d84, 0xa9ee3033, 0xa4ad16ea, 0xa06c0b5d, 0xd4326d90,
0xd0f37027,  0xddb056fe, 0xd9714b49, 0xc7361b4c, 0xc3f706fb, 0xceb42022, 0xca753d95,
0xf23a8028, 0xf6fb9d9f, 0xfbb8bb46, 0xff79a6f1,  0xe13ef6f4, 0xe5ffeb43, 0xe8bccd9a,
0xec7dd02d,0x34867077, 0x30476dc0, 0x3d044b19, 0x39c556ae, 0x278206ab, 0x23431b1c,
0x2e003dc5, 0x2ac12072, 0x128e9dcf, 0x164f8078, 0x1b0ca6a1, 0x1fcdbb16, 0x018aeb13,
0x054bf6a4, 0x0808d07d, 0x0cc9cdca,  0x7897ab07, 0x7c56b6b0, 0x71159069, 0x75d48dde,
0x6b93dddb, 0x6f52c06c, 0x6211e6b5, 0x66d0fb02, 0x5e9f46bf, 0x5a5e5b08,  0x571d7dd1,
0x53dc6066, 0x4d9b3063, 0x495a2dd4, 0x44190b0d, 0x40d816ba,0xaca5c697, 0xa864db20,
0xa527fdf9, 0xa1e6e04e,  0xbfa1b04b, 0xbb60adfc, 0xb6238b25, 0xb2e29692, 0x8aad2b2f,
0x8e6c3698, 0x832f1041, 0x87ee0df6, 0x99a95df3, 0x9d684044,  0x902b669d, 0x94ea7b2a,
0xe0b41de7, 0xe4750050, 0xe9362689, 0xedf73b3e, 0xf3b06b3b, 0xf771768c, 0xfa325055,
0xfef34de2,  0xc6bcf05f, 0xc27dede8, 0xcf3ecb31, 0xcbffd686, 0xd5b88683, 0xd1799b34,
0xdc3abded, 0xd8fba05a,0x690ce0ee, 0x6dcdfd59,  0x608edb80, 0x644fc637, 0x7a089632,
0x7ec98b85, 0x738aad5c, 0x774bb0eb, 0x4f040d56, 0x4bc510e1, 0x46863638, 0x42472b8f,
0x5c007b8a, 0x58c1663d, 0x558240e4, 0x51435d53,0x251d3b9e, 0x21dc2629, 0x2c9f00f0,
0x285e1d47, 0x36194d42, 0x32d850f5,  0x3f9b762c, 0x3b5a6b9b, 0x0315d626, 0x07d4cb91,
0x0a97ed48, 0x0e56f0ff, 0x1011a0fa, 0x14d0bd4d, 0x19939b94, 0x1d528623,  0xf12f560e,
0xf5ee4bb9, 0xf8ad6d60, 0xfc6c70d7, 0xe22b20d2, 0xe6ea3d65, 0xeba91bbc, 0xef68060b,
0xd727bbb6, 0xd3e6a601,  0xdea580d8, 0xda649d6f, 0xc423cd6a, 0xc0e2d0dd, 0xcda1f604,
0xc960ebb3,0xbd3e8d7e, 0xb9ff90c9, 0xb4bcb610, 0xb07daba7,  0xae3afba2, 0xaafbe615,
0xa7b8c0cc, 0xa379dd7b, 0x9b3660c6, 0x9ff77d71, 0x92b45ba8, 0x9675461f, 0x8832161a,
0x8cf30bad,  0x81b02d74, 0x857130c3, 0x5d8a9099, 0x594b8d2e, 0x5408abf7, 0x50c9b640,
0x4e8ee645, 0x4a4ffbf2, 0x470cdd2b, 0x43cdc09c,  0x7b827d21, 0x7f436096, 0x7200464f,
0x76c15bf8, 0x68860bfd, 0x6c47164a, 0x61043093, 0x65c52d24,0x119b4be9, 0x155a565e,
0x18197087, 0x1cd86d30, 0x029f3d35, 0x065e2082, 0x0b1d065b, 0x0fdc1bec, 0x3793a651,
0x3352bbe6, 0x3e119d3f, 0x3ad08088,  0x2497d08d, 0x2056cd3a, 0x2d15ebe3, 0x29d4f654,
```

```
0xc5a92679, 0xc1683bce, 0xcc2b1d17, 0xc8ea00a0, 0xd6ad50a5, 0xd26c4d12,   0xdf2f6bcb,
0xdbee767c, 0xe3a1cbc1, 0xe760d676, 0xea23f0af, 0xeee2ed18, 0xf0a5bd1d, 0xf464a0aa,
0xf9278673, 0xfde69bc4, 0x89b8fd09, 0x8d79e0be, 0x803ac667, 0x84fbdbd0, 0x9abc8bd5,
0x9e7d9662, 0x933eb0bb, 0x97ffad0c, 0xafb010b1, 0xab710d06,   0xa6322bdf, 0xa2f33668,
0xbcb4666d, 0xb8757bda, 0xb5365d03, 0xb1f740b4
    };
```

B2 Table lookup function

```
void CRC32(Uint16 *pch,int len)
{
UInt32 reg = 0xFFFFFFFF; //initial value
   int i;
    int res=0;
    if((len%4)! = 0 UNK1//If the data frame length is not a multiple of 4, add 0x00 to make the parity check length a multiple of 4
    {
        res = 4 - len % 4;
     }
   for( i = 0; i < len; i++)
    {
      reg = (reg<<8) ^ crc_table32[(((reg>>24)&0xFF) ^ pch[i])];
    }
   for (i = 0; i < res; i++)
    {
      reg = (reg << 8) ^ crc_table32[(((reg >> 24) & 0xFF) ^ 0x00)];
    }
   crc_data[0] = (byte)((reg>>24) & 0xFF);
   crc_data[1] = (byte)((reg>>16) & 0xFF);
   crc_data[2] = (byte)((reg>>8) & 0xFF);
   crc_data[3] = (byte)(reg & 0xFF);
   return;
}
```

The CRC _ data [4] returned through the global variable is the CRC32 check value.

Appendix C Product Naming Rules

The product type spectrum is designed according to the requirements of standardization. KT stands for the development company, EX stands for the meaning of Exploit in English, and the subsequent numbers represent serialization. Specific product spectrum naming rules are as follows:

BS-IC22-4xy-D6EC

BLITZ Sensor

Series number: IC22

x: gyro perfomance
- blank: X: ±7200 deg/s; Y, Z: ±300 deg/s
- A: X, Y, Z: ±300 deg/s
- B: X, Y, Z: ±400 deg/s

y: accelerometer perfomance
- 1: ±15 g
- 2: ±20 g
- 3: ±40 g

Digital output
6 axec
Encapsulated
Connector