DTS DIGITAL OUTPUT DYNAMIC HIGH SEISMIC INCLINATION SENSOR

Product Manual

V1.1-20260515

Technical Characteristics

- ❖ Dynamic accuracy ±0.1°;
- ❖ Static accuracy ±0.05°;
- ❖ RS485/232/TTL optional;
- ❖ Measuring range (R±180°, P±90°, Y±180°).

Product Introduction

DTS is a high-performance digital MEMS dynamic tilt sensor independently developed by RUICOM Technology. Designed specifically for attitude monitoring of moving vehicles, it can accurately measure three-dimensional attitude parameters such as roll, pitch, and yaw angles, and is particularly suitable for tilt detection under vibration or motion conditions.

This sensor employs a multi-axis MEMS inertial measurement unit (IMU), integrating a three-axis accelerometer and gyroscope, and incorporates an adaptive Kalman filter algorithm to ensure real-time output of high-precision attitude data even in dynamic environments. It supports multiple digital interfaces including RS485, RS232, and TTL, offering strong compatibility and facilitating system integration.

Based on a non-contact measurement principle, the product can achieve real-time attitude calculation without relying on a reference mounting surface. Its built-in high-precision analog-to-digital converter (ADC) and gyroscope compensation unit automatically correct for nonlinear errors, orthogonal coupling, temperature drift, and centrifugal acceleration effects, effectively suppressing measurement deviations caused by motion interference and significantly improving dynamic measurement accuracy, making it suitable for long-term harsh operating conditions.

As a dynamic/static dual-mode sensor, DTS has excellent electromagnetic interference (EMI) immunity and can withstand high-intensity mechanical shock and vibration. It is widely used in attitude measurement and control in harsh environments such as industrial automation, engineering machinery, and rail transportation, making it an ideal solution for industrial-grade high-reliability attitude sensing.

Main Applications

★ Construction equipment leveling
★ High-impact vibration crushing equipmen
★ Agricultural machinery monitoring and control
★ Engineering vehicle equipment monitoring and control
★ Ship attitude monitoring
★ Aircraft attitude control

Performance Parameters

DTS		Parameter
Measurement Range (Initial value after power failure is 0°)		Roll ±180°, Pitch ±90°, Azimuth ±180°
Measurement Axis		X-axis / Y-axis / Z-axis
Roll and Pitch Resolution[1]		0.01°
Roll and Pitch Static Accuracy @25℃		±0.05°
Roll and Pitch Dynamic Accuracy (rms) @25℃		±0.1°
gyroscope	Gyroscope Range	±300°/s
	Oblique Stability (10s Mean)	8.5°/h
	Oblique Instability (allan)	4.5°/h
	Angle Random Walk Coefficient (allan)	0.25°/sqrt(h)
acceleration	Acceleration Range	±4g / ±16g (optional)
	Oblique Stability (10s Mean)	0.02mg
	Oblique Instability (allan)	0.005mg
	Velocity Random Walk Coefficient (allan)	0.005m/s/sqrt(h)
Zero-point temp coefficient[3]@-40～85℃		±0.01°/℃
Sensitivity temp coefficient[4]@-40～85℃		≤100ppm/℃
Power-on startup time		≤3.5S
Response time		0.01S
Communication protocol		RS485/RS232/TTL optional
Electromagnetic compatibility		According to EN61000 and GBT17626
Mean time between failures (MTBF)		≥98000hours/time
Insulation resistance		≥100megaohm
Shock resistance		100g@11ms, triaxial (half-sine wave)
Vibration resistance		10grms、10～1000Hz
Protection class		IP67 / IP68(optional)
Weight		Single connector ≤165g (excluding cable) / Dual connector ≤180g (excluding cable)

1) Resolution: The smallest angular change that the sensor can detect within its effective range, reflecting its ability to monitor minute tilt fluctuations.
2) Accuracy: Calculated by performing multiple repeated measurements (sample size ≥ 16) at a fixed angle under standard ambient temperature (25±5℃), representing the root mean square (RMS) error between the measured and true values, characterizing the sensor's overall measurement deviation.
3) Zero-point temperature coefficient: The ratio of the sensor's output value to temperature change under zero-input conditions, defined as the ratio of the zero-point offset within the rated operating temperature range to the room temperature reference value.
4) Sensitivity temperature coefficient: The stability index of the sensor's full-scale output value with temperature changes, characterizing the drift rate of sensitivity relative to the room temperature reference value within the rated temperature range.

Electrical Parameters

Parameter	Condition	Minimum Value	Typical Value		Maximum Value	Unit
Power supply voltage	Standard	9	12	24	36	V
Operating current	No load		40mA(12V)			mA
Operating temperature		-40			+85	℃
Storage temperature		-40			+85	℃

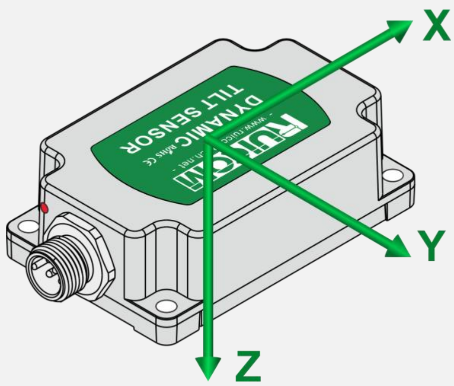
Ordering Information

Model	Package		Signal Output	Protocol		Installation Orientation	Application		Protection level
	3:PCBA Board		232:RS232	BIN:Binary Protocol		H:Horizontal installation	OB:Shipboard application		7:IP67
	6:Standard casing	-	485:RS485	MB:MODBUS Protocol	-	HD:Horizontal downwards	EV:Construction excavator		8:IP68
DTS	9:Corrosion -resistant casing		TTL:UART TTL			V:Vertical installation	EGP:Construction piling	-	
						VL:Vertical to the left	V:In-vehicle applications		
						VR:Vertical to the right	MTI:Mine car slope		

Example: DTS6-232BIN-HOB-7: Standard enclosure / RS232 signal output / binary communication protocol / horizontal mounting / marine application / IP67 protection.

Install axially

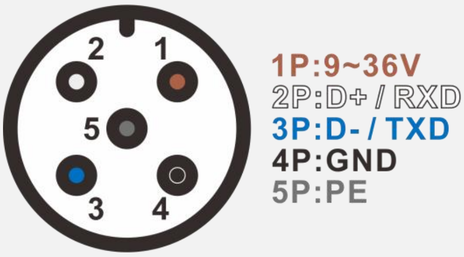
The DTS series products adopt the ENU (East-North-Up) coordinate system and follow the right-hand rule. Attitude angles are defined according to the rotation order of Z / X / Y. When the positive Y-axis points in the direction of the vehicle's forward movement: the angle of rotation around the Z-axis is called the heading angle, the angle of rotation around the X-axis is called the pitch angle, and the angle of rotation around the Y-axis is called the roll angle.



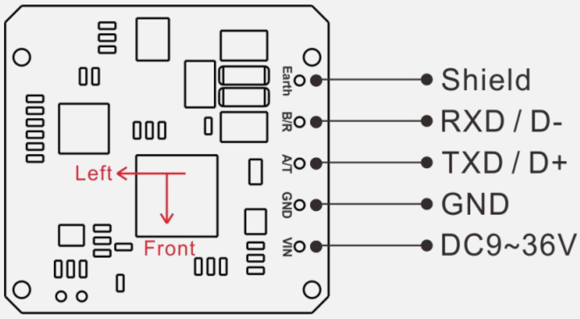
Interface Definition

Pin/Thread Color	Definition	Description
PIN1/Brown	9~36V	Power supply positive terminal
PIN2/White	RS232_RXD/TTL_RXD/485_D+	Signal output
PIN3/Blue	RS232_TXD/TTL_TXD/485_D-	Signal output
PIN4/Black	GND	Power supply negative terminal
PIN5/Gray	PE	Protective ground

Connector pin definition diagram

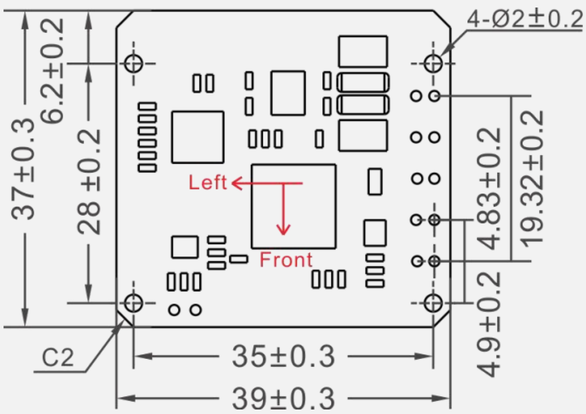


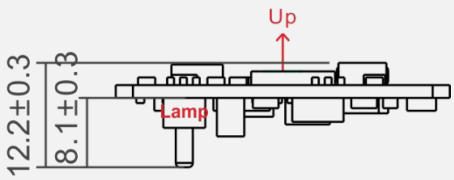
PCBA board wiring definition diagram



Product Dimensions

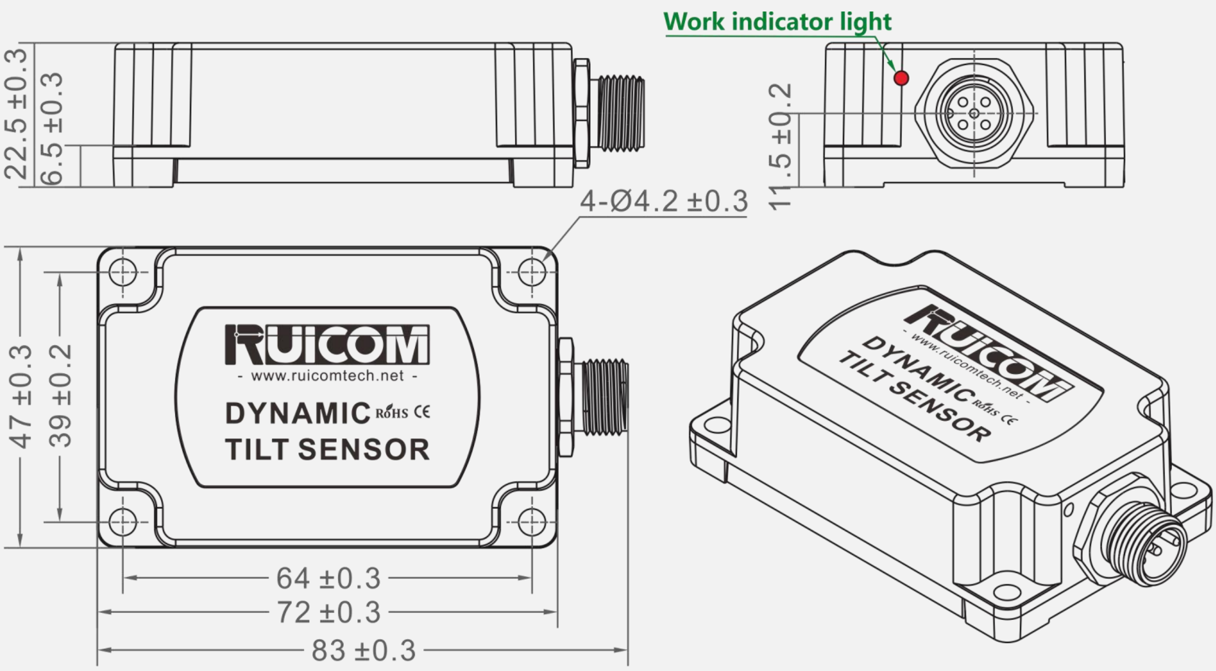
PCBA Dimensions Diagram





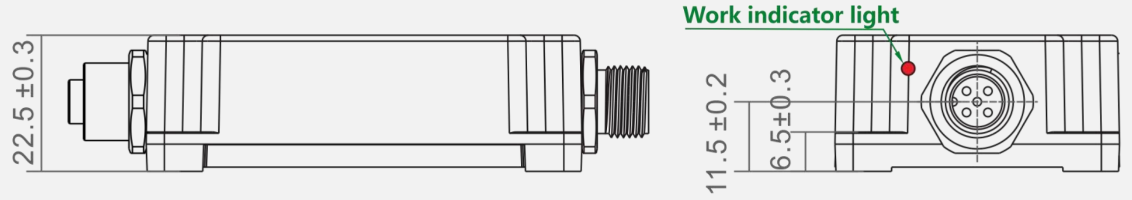
Board size: L39×W37×H12.2mm
Installation size: L35×W28mm

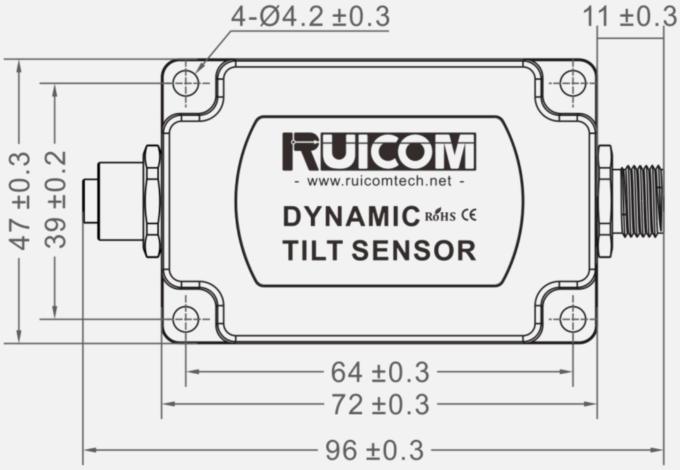
Single-head (male) connector housing dimension drawing

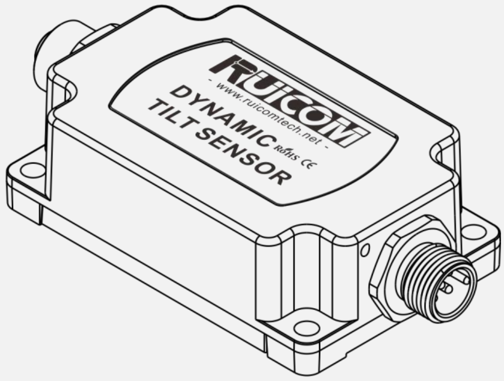


Shell Size: L83×W47×H22.5mm
Recommended screws: 4 M5 screws

head (male and female) connector housing dimension diagram

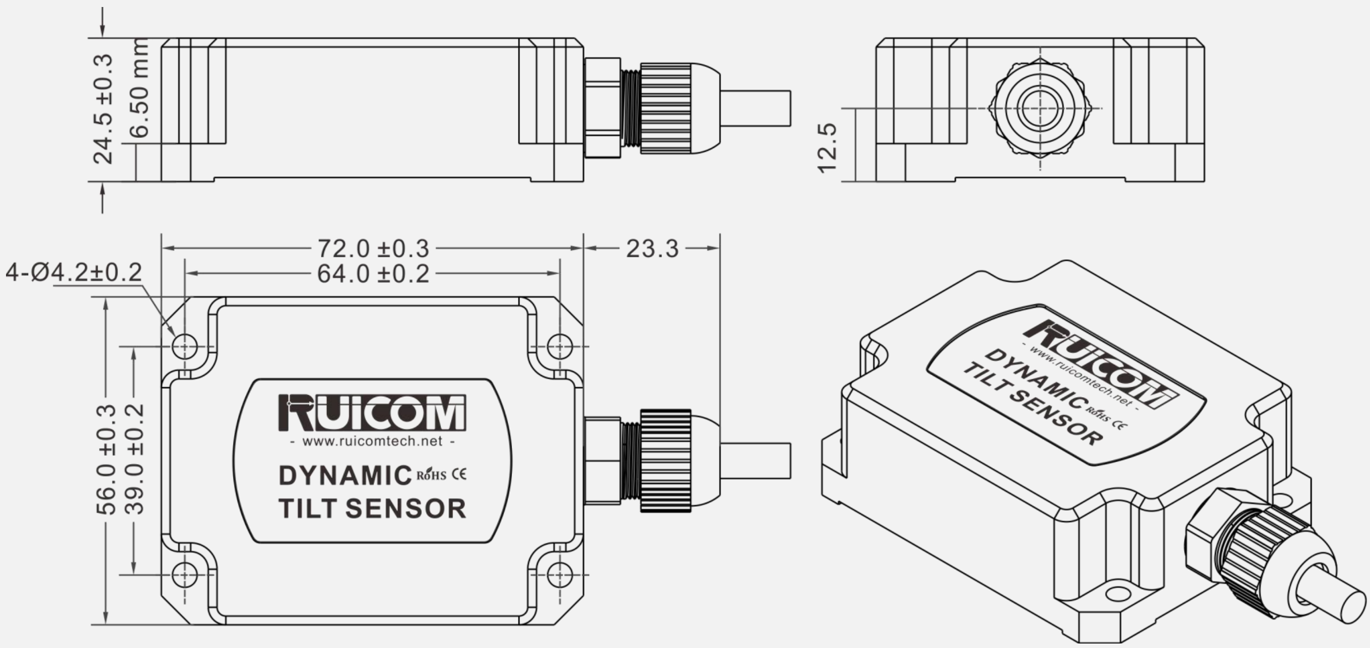






Shell Size: L96×W47×H22.5mm
Recommended screws: 4 M5 screws

Corrosion-resistant shell size diagram



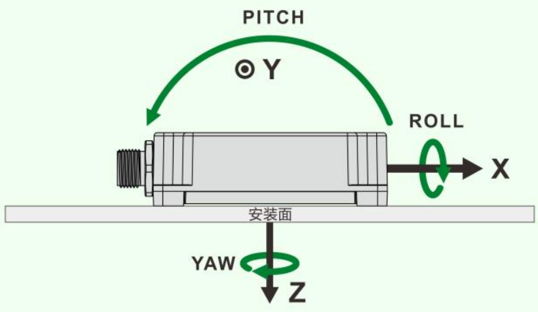
Shell Size: L95.3×W56×H24.5mm

Recommended screws: 4 M5 screws

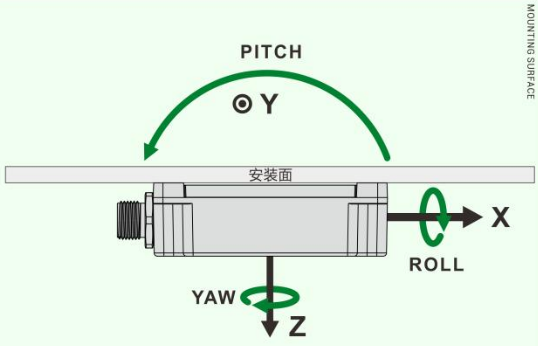
Instructions for use of indicator lights

1. The indicator light flashes after the product is powered on;
2. The indicator light illuminates when the product is transmitting data.

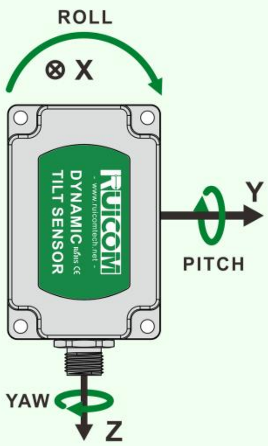
Measurement direction



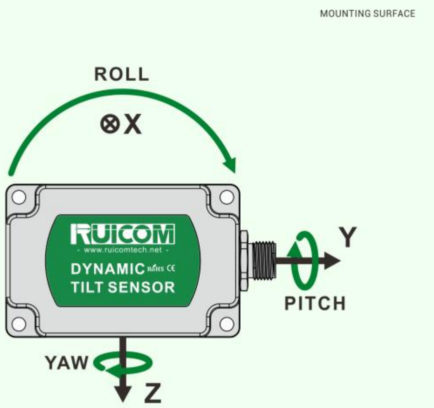
Horizontal Installation



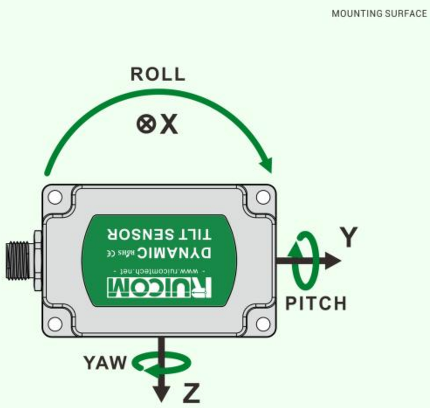
Horizontal-Down Installation



Vertical Installation



Vertical-Left Installation



Vertical-Right Installation

Binary communication frame format

1.0 Communication frame format

Field	Sync	Start	Addr	CMD	LEN	Data Field	CRC	End
NO.r of bytes	1	1	1	1	2	0 to 504	2	1
Description	Sync. byte	Start of byte	Address	Command	Length of the Data	Data	CRC	End of Tx byte
Value	0xFF	0x02	0-FF	-	-	-	-	0x03

Notes:

A. LEN data length field includes the number of bytes in the data field, with the MSB first and the LSB last. A length of 0 indicates no data field. The longest data field length is 504 bytes, and the longest frame length is 512 bytes.

B. CRC calculation starts from ADDR and includes CMD, the length field, and the data field, with the MSB first and the LSB last. The CRC is calculated using the following function:

```
uint16 calcCRC(const uint8 *pBuffer, uint16 bufferSize)
{
	uint16 poly = 0x8408;
	uint16 crc = 0;
	uint8 carry;
	uint8 i_bits;
	uint16 j;

	for (j=0; j<bufferSize;j++)
	{
		crc = crc^pBuffer[j];
		for (i_bits=0; i_bits<8;i_bits++)
		{
			carry = crc & 1;
			crc = crc / 2;
			if (carry)
			{
				crc = crc^poly;
			}
		}
	}
	return crc;
}
```

1.1 Data format and terminal mode

The device outputs data in little-endian mode (such as integers and floating-point numbers, where the low byte comes first and the high byte comes last).

1.2 Serial port default

The default baud rate of the serial port is 115200 bps, with 1 start bit, 1 stop bit, and no parity.

1.3 The default output is automatic, and the output frequency is 10Hz.

1.4 The default address is 0, and the range is 0x00-0xFE, which can be set. 0xFF is a universal address.

2.0 Communication mode

The sensor has two communication modes: query mode (question-and-answer) and continuous output mode (automatically outputting data at a certain frequency). Question-and-answer query operations can also be performed in continuous output mode.

2.1 Detection and inquiry mode

The system employs a question-and-answer (CMA) model. Users send queries or setting commands to the sensor, and the device responds to these commands one-to-one. The device responds to queries in two formats: an answer (CMD=ASK) and a reply (CMD=RET). See the command list in point 4 for details.

2.1.1 Answer

The response frame format is as follows:

Field	Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
NO. of bytes	1	1	1	1	1	1	1	1	1	1
Value	0xFF	0x02	0x00	IMU_ACK (0x01)	0x00	0x01	ERROR CODE	0xXX	0xXX	0x03

The answer, as a reply to the command, uses error codes to reflect the execution status of the instruction. The following error codes determine the device's response to the query command. A list of error codes is provided below;

IMU_Error Code	Value	Description
IMU_NO_ERROR	0x00	Command executed correctly
IMU_ERROR	0x01	Command not executed correctly
IMU_INVALID_FRAME	0x04	Invalid command
IMU_INVALID_PARAMETER	0x09	Invalid parameter
IMU_NOT_READY	0x0A	Sensor not ready

Note: Error codes make up the data field of the ACK frame.

2.1.2 Response

The response is a one-to-one response to the user's command. Different query commands will have different CMD and data fields in the response. Please refer to the command list in point 4.

2.2 Continuous Output Mode

Continuous output mode is an automatic output mode that outputs selected data items at a certain frequency, and the output frequency can be set.

3.0 Output data type

3.1 Output data type

By using `output masks(uint32)` to set the output data items and format, users can select the following data items for output.:

Valid mask	Description	Sequential	Support	Mask value
IMU_OUTPUT_EULER	Attitude angles	1	Support	0x00000001
IMU_OUTPUT_GYROSCOPES	Triaxial angular velocities after calibration	2	Support	0x00000002
IMU_OUTPUT_ACCELEROMETERS	Triaxial acceleration after calibration	3	Support	0x00000004

The sequence indicates the order in which the data is output.

3.2 Data output format

3.2.1 Attitude angles Roll, Pitch, and Yaw are represented using real32 (float), which is 12 bytes long and the unit is radians.

Storage format:

Roll	Pitch	Yaw

3.2.2The angular rates of a three-axis gyroscope, Gx, Gy, and Gz, are represented by real32 (float), which is 12 bytes long and the unit is rad.s^{-1}(radians per second).

Storage format:

Gx	Gy	Gz

3.2.3The triaxial accelerations Ax, Ay, and Az are represented using real32 (float) characters, 12 bytes in size, and the unit is m.S^{-2}。

Storage format:

Ax	Ay	Az

3.3 Output data order

The output masks (uint32) will produce a corresponding output order depending on their value. The default output masks (uint32) = 0x00000007 is as follows: IMU_OUTPUT_EULER|IMU_OUTPUT_GYROSCOPES|IMU_OUTPUT_ACCELEROMETERS (0x00000001|0x00000002|0x00000004). The corresponding output data order and storage format are as follows:

Name	Roll	Pitch	Yaw	Gx	Gy	Gz	Ax	Ay	Az
Size (bytes)	4	4	4	4	4	4	4	4	4
	12			12			12		

Data field parsing follows the storage format described above.
For example, if output masks(uint32) = 0x00000001, then the output data order and storage format for IMU_OUTPUT_EULERS (0x00000001) are as follows::

Name	Roll	Pitch	Yaw
Size (bytes)	4	4	4
	12		

If output masks(uint32) = 0x00000005, then the output data order and storage format are as follows: IMU_OUTPUT_EULER|IMU_OUTPUT_ACCELEROMETERS (0x00000001|0x00000004).

Name	Roll	Pitch	Yaw	Ax	Ay	Az
Size (bytes)	4	4	4	4	4	4
	12			12		

4.0 Command List

4.1 Set automatic data output items

* **IMU_SET_DEFAULT_OUTPUT_MASK------(0x50)**

Function: Used to set the output MASK(output mask(uint32)), i.e., the output data type (Buffer).

Note: It does not have a power-off save function; a save setting command must be executed to enable the power-off save function.

The frame format is as follows::

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	5	1	1	1
0xFF	0x02	0x00	0x50	0x00	0x05	DATA	0xXX	0xXX	0x03

Among them: DATA section

DATA	
Reserved.Leave to 0(bytes)	Default output mask(uint32)
1	4

Response:

IMU_ACK

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1		1	1	1	1	1	1	1
0xFF	0x02	0x00	0x01	0x00	0x01	ERROR_CODE	0xXX	0xXX	0x03

4. 2 Get the automatically output data items

* **IMU_GET_DEFAULT_OUTPUT_MASK------(0x51)**

Function: Used to read the output MASK (output mask(uint32)) data item for data parsing.
Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	0	1	1	1
0xFF	0x02	0x00	0x51	0x00	0x00	NULL	0xXX	0xXX	0x03

Response: * **IMU_RET_DEFAULT_OUTPUT_MASK------(0x52)**
Function: Returns the output mask;
Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	4	1	1	1
0xFF	0x02	0x00	0x52	0x00	0x04	DATA	0xXX	0xXX	0x03

Among: DATA sections

DATA
Default output mask(uint32)
4

4.3 Continuous data output

* **IMU_CONTINUOUS_DEFAULT_OUTPUT------(0x90)**

Function: Outputs data items continuously.

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	See below	1	1	1
0xFF	0x02	0x00	0x90	0x00	0x24	See below	0xXX	0xXX	0x03

Data sections are as follows(total length: 0x0024):

Name	Roll	Pitch	Yaw	Gx	Gy	Gz	Ax	Ay	Az
Size (bytes)	4	4	4	4	4	4	4	4	4
	12			12			12		

NO. of domain names	real32	float	unit
Roll	BBFF0F9E	-0.007784	radians
Pitch	3C35E11F	0.011101	radians
Yaw	BD2E03F5	-0.042484	radians
Gx	B99D4848	-0.000300	radians/second
Gy	3925ACF1	0.000158	radians/second
Gz	389202DA	0.000070	radians/second
Ax	3DE1E839	0.110306	$m.S^{-2}$
Ay	3D9D7DFA	0.076900	$m.S^{-2}$
Az	C11C1675	-9.755483	$m.S^{-2}$

4.4 Output mode settings

Output operating mode.
There are two modes, as follows:
IMU_QEURY_MODE (Query Mode): 0x00

IMU_CONTINUOUS_MODE (Continuous Output Mode): 0x01
The CONTINUOUS_MODE (Continuous Output Mode) has different Divider values, corresponding to the following different output frequencies:

Divider	OUT(Hz)
0	INVALID
1	200
2	100
4	50
8	25
10	20
20	10
40	5
200	1

Note: The default is IMU_CONTLNUOUS_MODE (continuous output mode), with a frequency of 10Hz.

4.5 Command to set output mode

*** IMU_SET_CONTINUOUS_MODE------(0x53)**

Function: Sets the output mode;
Note: Power-off saving is not supported; the save settings command must be executed to enable power-off saving.
Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	3	1	1	1
0xFF	0x02	0x00	0x53	0x00	0x03	See below	0xXX	0xXX	0x03

Among: DATA sections

DATA		
Reserved.Leave to 0(bytes)	Mode	Divider
1	1	1
0	1	1

Note: Mode = 1 above indicates continuous output; Divider = 1 indicates an output frequency of 200Hz.
Response:
IMU_ACK

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	1	1	1	1
0xFF	0x02	0x00	0x01	0x00	0x01	ERROR_ CODE	0xXX	0xXX	0x03

4.6 Get output mode

*** IMU_GET_CONTINUOUS_MODE------(0x54)**

Function: Used to read the current mode;
Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	0	1	1	1
0xFF	0x02	0x00	0x54	0x00	0x00	NULL	0xXX	0xXX	0x03

Response:

*** IMU_RET_CONTINUOUS_MODE------(0x55)**
Function: Used to return the Mode and Divider;
Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	2	1	1	1
0xFF	0x02	0x00	0x55	0x00	0x02	DATA	0xXX	0xXX	0x03

Among: DATA sections

DATA	
Mode(uint8)	Divider(uint8)
1	1

4.7 Set baud rate
The baud rate is a 32-bit integer, and the valid values are: 9600, 19200, 38400, 57600, 115200, and 256000.
*** IMU_SET_PROTOCOL_MODE-----(0x12)**
Function: Used to set the communication baud rate; (default is 115200)
Note: Power-off saving is not available; a save setting command must be executed to enable power-off saving.
Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	5	1	1	1
0xFF	0x02	0x00	0x12	0x00	0x05	See below	0xXX	0xXX	0x03

Among: DATA sections

DATA	
Reserved.Leave to 0(bytes)	Baud rate(uint32)
1	4
0	115200

Note: Baud rate(uint32) is little-endian, with the least significant byte first and the most significant byte last.
Response:
IMU_ACK

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	1	1	1	1
0xFF	0x02	0x00	0x01	0x00	0x01	ERROR _CODE	0xXX	0xXX	0x03

4.8 Get baud rate
*** IMU_GET_PROTOCOL_MODE------(0x13)**
Function: Used to obtain the communication baud rate;
Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	0	1	1	1
0xFF	0x02	0x00	0x13	0x00	0x00	NULL	0xXX	0xXX	0x03

Response:
***IMU_RET_PROTOCOL_MODE------(0x14)**
Function: Returns the current baud rate;

Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	4	1	1	1
0xFF	0x02	0x00	0x14	0x00	0x04	DATA	0xXX	0xXX	0x03

Among: DATA sections

DATA
Baud rate
4

4.9 Set sensor address

The sensor address is the target address during communication; communication can only be successful if the address field matches the sensor address.

*** IMU_SET_ADDR-----(0x0F)**

Function: Used to set the sensor address; (default is 0x00)

Note: Power-off saving is not supported; a save settings command must be executed to enable power-off saving.

Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	1	1	1	1
0xFF	0x02	0x00	0x0F	0x00	0x01	address	0xXX	0xXX	0x03

Note: ADDR should contain the current sensor address to be changed, and the DATA section should contain the new sensor address to be set.

Response:

IMU_ACK

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	1	1	1	1
0xFF	0x02	0x00	0x01	0x00	0x01	ERROR _CODE	0xXX	0xXX	0x03

Note: The ADDR returned is the previous sensor address.

4.10 Get sensor address

*** IMU_GET_ADDR------(0x0D)**

Function: Used to obtain the sensor address;

Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	0	1	1	1
0xFF	0x02	0x00	0x0D	0x00	0x00	NULL	0xXX	0xXX	0x03

Response:

***IMU_RET_ADDR------(0x0E)**

Function: Returns the sensor address;

The frame format is as follows::

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	1	1	1	1
0xFF	0x02	0x00	0x0E	0x00	0x01	ADDR	0xXX	0xXX	0x03

Among: DATA sections

DATA
ADDR
1

4.11 Set the measurement installation method(five installation methods: horizontal, horizontal downward, vertical upward, vertical left, and vertical right)

*** IMU_SET_FIXED_MODE-----(0x20)**

Function: Used to set the sensor's installation method; (default is 0x00, horizontal orientation)

Note: Power-off saving is not supported; a save settings command must be executed to enable this function.

Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	1	1	1	1
0xFF	0x02	0x00	0x20	0x00	0x01	Fixed_ Mode	0xXX	0xXX	0x03

Note: Fixed_Mode: 0x00: Horizontal mode, 0x01: Vertical upward, 0x02: Vertical left, 0x03: Vertical right, 0x04: Horizontal downward.

Response: IMU_ACK

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	1	1	1	1
0xFF	0x02	0x00	0x01	0x00	0x01	ERROR _CODE	0xXX	0xXX	0x03

4.12 Obtain measurement and installation methods

*** IMU_GET_FIXED_MODE------(0x21)**

Function: Used to obtain information about the sensor's installation method;

Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	0	1	1	1
0xFF	0x02	0x00	0x21	0x00	0x00	NULL	0xXX	0xXX	0x03

Response:

***IMU_RET_FIXED_MODE------(0x22)**

Function: Returns information on the sensor's installation method;

Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	1	1	1	1
0xFF	0x02	0x00	0x22	0x00	0x01	Fixed_ Mode	0xXX	0xXX	0x03

Among: DATA sections

DATA
Fixed_Mode
1

4.13 Set absolute/relative zero point

The zero point of a sensor is divided into: absolute zero point and relative zero point. When set to absolute zero point, the reference plane for the sensor output tilt angle is the geographical horizontal plane. When set to relative zero point, the reference plane for the sensor output tilt angle is relative to the mounting plane. When there is an error between the sensor's mounting measurement plane and the horizontal plane, the relative zero point can be set to clear the current angle (roll angle and pitch angle) to zero. At this time, the angle change output by the sensor is relative to the mounting plane.

*** IMU_SET_OFFSET_MODE-----(0x25)**

Function: Used to set the sensor's zero point; (default is 0x00, absolute zero)

Note: Power-off saving is not supported; a save setting command must be executed to enable power-off saving.

Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	1	1	1	1
0xFF	0x02	0x00	0x25	0x00	0x01	Offset_ Mode	0xXX	0xXX	0x03

Note: Offset_Mode: 0x00: Absolute zero; 01: Relative zero.

Response: IMU_ACK

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	1	1	1	1
0xFF	0x02	0x00	0x01	0x00	0x01	ERROR_ CODE	0xXX	0xXX	0x03

4.14 Get Zero Point Type

*** IMU_GET_OFFSET_MODE------(0x26)**

Function: Used to obtain the current zero-point type of the sensor;

Frame format is as follows::

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	0	1	1	1
0xFF	0x02	0x00	0x26	0x00	0x00	NULL	0xXX	0xXX	0x03

Response:

***IMU_RET_OFFSET_MODE------(0x27)**

Function: Returns information on the sensor's installation method;

Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	1	1	1	1
0xFF	0x02	0x00	0x27	0x00	0x01	OFFSET_ Mode	0xXX	0xXX	0x03

Among: DATA sections

DATA
OFFSET_Mode
1

Offset_Mode: 0x00: Absolute zero point;   01: Relative zero point

4.15 Set gravity level

*** IMU_SET_GRAVITY_MAGNITUDE------(0xB1)**

Function: Sets the current gravity level;

Note: Power-off saving is not available; the save settings command must be executed to enable power-off saving.

Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	5	1	1	1
0xFF	0x02	0x00	0xB1	0x00	0x05	DATA	0xXX	0xXX	0x03

Among: DATA sections

DATA	
Reserved.Leave to 0(bytes)	magnitude(real32)
1	4

Magnitude: This represents the magnitude of a heavy force. It is a floating-point type, little-endian.
Response:
IMU_ACK

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	1	1	1	1
0xFF	0x02	0x00	0x01	0x00	0x01	ERROR_ CODE	0xXX	0xXX	0x03

4.16 Obtain Gravity
*** IMU_GET_GRAVITY_MAGNITUDE------(0xB2)**
Function: To obtain the current gravity level;
Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	0	1	1	1
0xFF	0x02	0x00	0xB2	0x00	0x00	NULL	0xXX	0xXX	0x03

Response:
*** IMU_RET_GRAVITY_MAGNITUDE------(0xB3)**
Function: Returns the current gravity level;
Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	4	1	1	1
0xFF	0x02	0x00	0xB3	0x00	0x04	DATA	0xXX	0xXX	0x03

Among: DATA sections

DATA
magnitude(real32)
4

4.17 Set save command
The settings do not have a power-off retention function. After changing the settings, you must execute the settings save command to save the updated settings.
*** IMU_SAVE_SETTINGS------(0x24)**
Function: Used to save all setting parameters to EEPROM, with power-down saving function. There is no data field, the frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	0	1	1	1
0xFF	0x02	0x00	0x24	0x00	0x00	NULL	0xXX	0xXX	0x03

Response:
IMU_ACK

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	1	1	1	1
0xFF	0x02	0x00	0x01	0x00	0x01	ERROR _CODE	0xXX	0xXX	0x03

Note: Refer to section 6 for EEROR CODE;

4.18 Default data query command (when output mode Mode = 0, question-and-answer mode)

*** IMU_GET_DEFAULT_OUTPUT------(0x56)**

Function: Retrieves the current default output data item.

Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	0	1	1	1
0xFF	0x02	0x00	0x56	0x00	0x00	NULL	0xXX	0xXX	0x03

Response:

***IMU_RET_DEFAULT_OUTPUT------(0x57)**

Function: Returns the default data items for output.

When the continuously automatically outputting outputmask = 0x00000007j, the Data section is as follows:

The frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	24	1	1	1
0xFF	0x02	0x00	0x57	0x00	0x24	See below	0xXX	0xXX	0x03

Data sections are as follows(total length: 0x0024):

Name	Roll	Pitch	Yaw	Gx	Gy	Gz	Ax	Ay	Az
Size (bytes)	4	4	4	4	4	4	4	4	4
	12			12			12		

4.19 Get the output of specially specified data items

*** IMU_GET_SPECIFIC_OUTPUT------(0x58)**

Function: Retrieves a specifically specified MASK data item.

Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	4	1	1	1
0xFF	0x02	0x00	0x58	0x00	0x04	DATA	0xXX	0xXX	0x03

Among: DATA sections

DATA
Output masks(uint32)
4

The specified data item Output masks is any of the following specified data items: Any one or more combinations of IMU_OUTPUT_EULER|IMU_OUTPUT_GYROSCOPES|IMU_OUTPUT_ACCELEROMETERS.

Response:

*** IMU_RET_SPECIFIC_OUTPUT------(0x59)**

Function: Returns the output of a specifically specified data item.

Frame format is as follows:

Sync	Start	ADDR	CMD	LEN (MSB)	LEN (LSB)	DATA	CRC (MSB)	CRC (LSB)	End
1	1	1	1	1	1	0x24	1	1	1
0xFF	0x02	0x00	0x59	0x00	0x24	DATA	0xXX	0xXX	0x03

DATA sections are as follows(total length: 0x0024):

Name	Roll	Pitch	Yaw	Gx	Gy	Gz	Ax	Ay	Az

Size (bytes)	4	4	4	4	4	4	4	4	4
	12			12			12		

Output masks(uint32) = 0x00000007
IMU_OUTPUT_EULER|IMU_OUTPUT_GYROSCOPES|IMU_OUTPUT_ACCELEROMETERS;

MODBUS Communication Protocol

1. Data Frame Format:
RTU mode;
Communication parameters: Baud rate 9600 bps (factory default);
Data frame: 1 start bit, 8 data bits, even parity, 1 stop bit.

Please carefully read the following items before use:

1> According to the MODBUS communication protocol specification, the time interval between adjacent data frames should not be less than 3.5 character transmission times (taking a baud rate of 9600bps as an example, this interval is 3.5 × (11 bits/character) ÷ 9600 ≈ 4ms). To ensure communication reliability, this sensor adopts a stricter time interval standard, increasing the minimum inter-frame interval to 5ms. It is recommended that users ensure that the transmission interval between adjacent data frames is not less than 5ms in actual applications to guarantee communication stability and data integrity.
Master sends command -- 5ms idle -- Slave replies with command -- 5ms idle -- Master sends command...

2> The MODBUS protocol specifies the broadcast address ---- 0. This sensor can also receive broadcast address content, but will not reply (except for the address code reading function). Therefore, broadcast address 0 can be used for the following purposes, for reference only:
1. Set the address of all tilt sensors of this model connected to the bus to a specific address.
2. Set all tilt sensors of this model connected to the bus to relative/absolute zero.
3. Test all sensors of this model on the entire bus. The master sends an address 0 query angle command to the bus; if the communication indicator light flashes, communication is normal.

3> To improve system reliability, the address setting command, absolute/relative setting command, baud rate setting command, output frequency setting command, and parity setting command must all be sent twice consecutively to be effective. "Sent twice consecutively" means both commands are successfully sent (the slave responds each time), and the two responses must be consecutive. The master cannot insert other data frames between the two responses; otherwise, the command will be locked. The setting process is as follows: Send the address setting command -- wait for the slave to send a successful setting command -- (no other commands can appear) Send the address setting command again -- wait for the slave to send a successful setting command -- modification successful.

4> The communication indicator light will flash once after a certain number of successful communications.

2. Read angle data: Modbus Function code 03H

Host query command:		Slave Response:		
Sensor Address	01H	Sensor Address	01H	
Function Code	03H	Function Code	03H	
Register Start Address	00H	Data length 14 bytes	0EH	
	02H	Data word 1 lower 8 bits	C4H	Roll angle
Data Length 4 words	00H	Data word 1 higher 8 bits	96H	
	07H	Data word 2 lower 8 bits	03H	
CRC	A5C8H	Data word 2 higher 8 bits	00H	
		Data word 3 lower 8 bits	F8H	Pitch angle
		Data word 3 higher 8 bits	9BH	

		Data word 4 lower 8 bits	01H	
		Data word 4 higher 8 bits	00H	
		Data word 5 lower 8 bits	6BH	Azimuth angle
		Data word 5 higher 8 bits	54H	
		Data word 6 lower 8 bits	02H	
		Data word 6 higher 8 bits	00H	
		Data word 7 higher 8 bits	03	Temperature
		Data word 7 lower 8 bits	06	
		CRC	C40CH	

Example of using the command to read measurement data:									
Host sends		01H	03H	00H	02H	00H	07H	A5H	C8H
Slave Response									
01H	03H	0EH	C4H	96H	03H	00H	F8H	9BH	01H
00H	6BH	54H	02H	00H	03H	06H	C4H	0CH	

Note: The data field of the slave response frame are C4H, 96H, 03H, 00H, F8H, 9BH, 01H, 00H, 6BH, 54H, 02H, 00H, 03H, 06H

The roll angle (±180º) is represented by bytes 1-4 of the data field, the pitch angle (±90º) by bytes 5-8, and the azimuth angle (±180º) by bytes 9-12, with the low byte first and the high byte last. Bytes 13-14 contain the temperature. Angles are represented using a point-count method, where one point corresponds to 0.001º. 0.001 × (number of points - offset) equals the angle. For example, if the measurement range is ±90º and the offset is 90,000, the total number of points is 180,000. Therefore, 0 corresponds to -90º, 180,000 corresponds to +90º, and 90,000 corresponds to 0º. Similarly, if the measurement range is ±180º and the offset is 180,000, the total number of points is 360,000. Therefore, 0 corresponds to -180º, 180,000 corresponds to 0º, and 360,000 corresponds to 180º.

Taking the above data frame as an example: the angle conversion process is as follows:

1) Obtain the current angle points, note that the least significant byte comes first. The roll angle is 000396C4H, the pitch angle is 00019BF8H, and the azimuth angle is 0002546BH.

2) Convert to decimal: Roll angle: 396C4H → 235204, Pitch angle: 19BF8H → 105464, Azimuth angle: 2546BH → 152683.

3) Subtract the offset of 180000 from the roll angle (Note: This value is related to the measurement range; multiply the measurement range value by 1000. For example, the offset for a measurement range of ±180° is 180*1000, and the offset for a measurement range of ±90° is 90*1000). Roll angle: 235204 - 180000 = 55204, Pitch angle: 105464 - 90000 = 15464, Azimuth angle: 152683 - 180000 = -27317.

4) Obtain the final angles: Roll angle: 55204 × 0.001 = 55.204°, Pitch angle: 15464 × 0.001 = 15.464°, Azimuth angle: -27317 * 0.001 = -27.317°.

The temperature is represented by bytes 13-14 of the data field.

Explanation:

The high four bits of byte 13 are the sign bit (0: positive temperature, 1: negative temperature), and the low four bits are the tens digit.

The high four bits of byte 14 are the units digit, and the low four bits are the tenths digit.

For example, if the slave device replies with 03H or 06H, the temperature is 30.6℃.

3. Set the sensor's relative/absolute zero point:

Modbus Function Code 06H

Command to set relative/absolute zero point:		Slave Response:	
Sensor Address	01H	Sensor Address	01H
Function Code	06H	Function Code	06H
Access Register Start Address	00H	Register Address	00H
	10H		10H

If this word is non-zero, it indicates a relative zero; if it is zero, it indicates an absolute zero	00 H FFH / 00H Relative / Absolute	If this word is non-zero, it indicates a relative zero; if it is zero, it indicates an absolute zero	00H FFH / 00H Relative / Absolute
CRC	C84FH/ 880FH	CRC	C84FH/ 880FH

Commands must be sent twice consecutively to be effective, and no other commands can be sent in between.

Example of using the command to set relative/absolute zero point:								
Host sends	01H	06H	00H	10H	00H	FFH	C8H	4FH
Slave response								
01H	06H	00H	10H	00H	FFH	C8H	4FH	

Note: 0010 is the register address, which controls whether the sensor output is a relative zero or an absolute zero. If it is non-zero (as in the example above, it is written with 00FFH), the output is a relative zero. Conversely, if it is zero (by changing bytes 5 and 6 to 00H), it is an absolute zero. The last two bytes are the CRC checksum.

4. Set sensor address: (The sensor address is set to 1 by default at the factory)

Command to set sensor address code:		Slave Response:	
Sensor Address	01H	Sensor Address	01H
Function Code	06H	Function Code	06H
Register Address	00H	Register Address	00H
	11H		11H
New Address of Sensor	00H	New Address of Sensor	00H
	04H		04H
CRC	D80C	CRC	D80C

Commands must be sent twice consecutively to be effective, and no other commands can be sent in between.

Example of using the command to set the sensor address:								
Host sends	01H	06H	00H	11H	00H	04H	D8H	0CH
Slave Response								
01H	06H	00H	11H	00H	04H	D8H	0CH	

Note: 0011H is the register address, which controls the sensor address. In the example above, the sensor address has been changed to 0004H, and the last two bytes are the CRC checksum.

5. Set the sensor baud rate: (The factory default is 9600bps)

Command to set sensor baud rate:		Slave Response:	
Sensor Address	01H	Sensor Address	01H
Function Code	06H	Function Code	06H
Register Address	00H	Register Address	00H
	12H		12H
Sensor Baud Rate	00H	Sensor Baud Rate	00H
	XX		XX
CRC	CRC LH	CRC	CRC LH

XX : A0H:4800 A1H:9600 A2H:19200 A3H:38400 A4H:115200

Commands must be sent twice consecutively to be effective, and no other commands can be sent in between.

Example of using the command to set the sensor baud rate:								
Host sends	01H	06H	00H	12H	00H	A2H	A8H	76H
Slave Response								
	01H	06H	00H	12H	00H	A2H	A8H	76H

Note: 0012H is the register address, which controls the sensor baud rate. In the example above, the sensor baud rate is set to 19200, and the last two bytes are the CRC checksum.

6. Read sensor address code:

command to read sensor address code:		Slave Response:	
Sensor Address	00H	Sensor Address	01H
Function Code	42H	Function Code	42H
Register Address	00H	Return Data Length	02H
	11H		
Data Length	00H	Sensor Address	01H
	01H		01H
CRC	CRC LH	CRC	CRC LH

Example of using the command to read sensor address:								
Host sends	00H	42H	00H	11H	00H	01H	E9H	D1H
Slave Response								
	01H	42H	02H	01H	01H	6CH	28H	

7. Configure the sensor communication character format: (The factory default is even parity)

Command to set sensor communication character format:		Slave Response:	
Sensor Address	01H	Sensor Address	01H
Function Code	06H	Function Code	06H
Register Address	00H	Register Address	00H
	09H		09H
New Format for Sensors	00H	New Format for Sensors	00H
	00H		00H
CRC	59 C8	CRC	59 C8

Note: Commands must be sent twice consecutively to be effective, and no other commands can be sent in between. Powering on again will make the command effective.

Example of setting sensor communication character format application:								
Host sends	01H	06H	00H	09H	00H	00H	59H	C8H
Slave Response								
	01H	06H	00H	09H	00H	00H	59H	C8H

The above example sets the byte format to: one start bit + 8 data bits, no parity, + 1 stop bit, which takes effect after power-on; the factory default is one start bit + 8 data bits, even parity, + 1 stop bit.

Note: 0009 is the register address, which controls the sensor communication character format.

0000H: One start bit + 8 data bits, no parity, +1 stop bit.

0001H: One start bit + 8 data bits, odd parity, +1 stop bit.

0002H: One start bit + 8 data bits, even parity, +1 stop bit.

8. Set the sensor's automatic output frequency: (The factory default is 0Hz, check the settings)

Set sensor automatic output frequency command:		Slave Response:	
Sensor Address	01H	Sensor Address	01H
Function Code	06H	Function Code	06H
Register Address	00H	Register Address	00H
	13H		09H
Sensor Output Frequency	00H	Sensor Output Frequency	00H
	XXH		XXH
CRC	CRC LH	CRC	CRC LH

XXH:
00H: 0Hz(Search methods);01H: 5Hz;02H: 10Hz;03H: 20Hz; 04H: 25Hz;05H: 50Hz;06H: 100Hz;

Note: Commands must be sent twice consecutively to be effective, and no other commands can be sent in between.

Example of setting the sensor's automatic output frequency command::								
Host sends	01H	06H	00H	13H	00H	04H	79H	CCH
Slave Response	01 H	06 H	00 H	13 H	00 H	04H	79 H	CCH

The example above sets the byte format to: automatic output frequency: 25Hz.

9. The example above sets the byte format to: automatic output frequency: 25Hz:

Sensor heading angle zeroing command:		Slave Response:	
Sensor Address	01H	Sensor Address	01H
Function Code	06H	Function Code	06H
Register Address	00H	Register Address	00H
	15H		15H
Sensor Zeroing Command	00H	Sensor Zeroing Command	00H
	FFH		FFH
CRC	D8 4E	CRC	D8 4E

Examples of sensor heading angle zeroing applications:								
Host sends	01H	06H	00H	15H	00H	FFH	D8H	4EH
Slave Response	01H	06H	00H	15H	00H	FFH	D8H	4EH

The above example demonstrates how to reset the current heading angle to zero.