HI14 Series User Manual

IMU/VRU/AHRS Module, Rev 1.2

applicable to the HI14 series

File：hi14_um_cn

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Property: Public

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HiPNUC

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Document Revision History

Version	Date	Author	Note
V1.0	October 25, 2023	HiPNUC	Initial Version

HI14 Series User Manual

1. Product Introduction

The HI14 series is an attitude sensing system that uses high-performance, compact, industrial-grade MEMS inertial devices to perceive the attitude information of objects. It integrates an Inertial Measurement Unit (IMU), a magnetometer, and a microcontroller with an extended Kalman filter (EKF) fusion algorithm. It can output three-dimensional orientation data based on local geographic coordinates calculated through sensor fusion algorithms, including absolute reference heading, pitch angle, and roll angle. It can also output calibrated raw sensor data. The HI14 series packaging can be conveniently and reliably integrated into the user's system. The HI14 series primarily includes the HI14R1, HI14R2, HI14R3, and HI14R5 . The model information is as follows:

HI14ab-c-def

HI Company	14 Product Line	a Sensor	b TC	c Interface	d Synchronization	e Cable-Typ	f OEM
		R1:2XIMU	N:Without TC	232:RS-232	0:Without SYNC	0:M12 Connector	00: Default
		R2:4XIMU	T:With TC	485:RS-485	1:With SYNC	1:Direct Cable-Type	Others :OEM
		R3:4XIMU+Mag		CAN:CAN 2.0			
		R5:8XIMU+Mag		URT:UART(TTL)			

Mag:Magnetometer TC:Temperature Compensation

> ①Model example: HI14R2N-232-000
> ②The HI14R1 series has no temperature-compensated models.
> ③The RS-485/CAN interface has no hardware synchronization pins.

1.1 Typical applications

The HI14 series can accurately perceive the attitude information of mobile devices, including pitch, roll, and yaw, and is suitable for applications such as autonomous guided vehicles (AGVs), inspection robots, smart agricultural machinery, and more. It can complement navigation solutions such as lidar and vision to enhance navigation accuracy and reduce dependence on external reference objects. Typical application markets include:

- Autonomous Guided Vehicles (AGV/AMR)
- Service Robots
- Exoskeleton Robots
- Smart Agricultural Machinery

1.2 Key Features

1.2.1 Robust Manufacturing System

- Independent development of automated batch calibration and testing production lines to ensure product consistency.
- Compact size, embedded design, excellent product compatibility, and high cost-effectiveness.
- Factory calibration of zero offsets, scale factors, cross-axis, and temperature error factors.

1.2.2 Advanced Software Algorithms

Abundant industry experience, integrating advanced algorithms, results in superior performance in static detection, low-speed detection, rapid startup, real-time zero offset estimation, automatic magnetic field calibration, and resistance to magnetic field interference.

1.2.3 Industrial-Grade MEMS Sensors

- Gyroscope zero offset instability of 1.76°/h
- Accelerometer zero offset instability of 21 micro-g
- Attitude angle accuracy up to 0.1°

1.2.4 IP68 and CE Certification

IP68 waterproof design, along with CE certification, makes it highly suitable for outdoor automation applications.

1.2.5 Convenient Communication Interfaces

In order to seamlessly integrate into user products, the HI14 series employs robust and reliable straight or angled M12 5-pin /8-pin aviation connectors.Support RS-232、RS-485、CAN、UART(TTL)、USB and SYNC IN/OUT

1.2.6 GUI CHCenter

CHCenter is a PC-based software developed by us for users to quickly evaluate our products. It can run freely on both WIN and Linux platforms. CHCenter offers the following features:

- Data display
- Data logging
- Data analysis
- Product parameter configuration
- Firmware updates

1.3 Order

1.3.1 RS-232

P/N	Name	Description
HI14R1N-232-000	IMU/VRU/Module	6DoF 3.6°/h
HI14R2N-232-000	IMU/VRU/Module	6DoF 2.5°/h
HI14R2N-232-010	IMU/VRU/Module	6DoF 2.5°/h
HI14R3N-232-000	IMU/VRU/AHRS/Module	6DoF+Magnetometer 2.5°/h
HI14R3N-232-010	IMU/VRU/AHRS/Module	6DoF+Magnetometer 2.5°/h
HI14R3T-232-000	IMU/VRU/AHRS/Module	6DoF+Magnetometer 2.5°/h Temperature Compensation
HI14R5N-232-000	IMU/VRU/AHRS/Module	6DoF+Magnetometer 1.76°/h
HI14R5N-232-010	IMU/VRU/AHRS/Module	6DoF+Magnetometer 1.76°/h
HI14R5T-232-000	IMU/VRU/AHRS/Module	6DoF+Magnetometer 1.76°/h Temperature Compensation
HI14R2N-232-100	IMU/VRU/Module	6DoF+Magnetometer 2.5°/h Synchronization
HI14R5N-232-100	IMU/VRU/AHRS/Module	6DoF+Magnetometer 1.76°/h Synchronization

1.3.2 UART(TTL)

P/N	Name	Description
HI14R1N-URT-000	IMU/VRU/Module	6DoF 3.6°/h
HI14R2N-URT-000	IMU/VRU/Module	6DoF 2.5°/h
HI14R2N-URT-010	IMU/VRU/Module	6DoF 2.5°/h
HI14R3N-URT-000	IMU/VRU/AHRS/Module	6DoF+Magnetometer 2.5°/h
HI14R3N-URT-010	IMU/VRU/AHRS/Module	6DoF+Magnetometer 2.5°/h
HI14R3T-URT-000	IMU/VRU/AHRS/Module	6DoF+Magnetometer 2.5°/h Temperature Compensation
HI14R5N-URT-000	IMU/VRU/AHRS/Module	6DoF+Magnetometer 1.76°/h
HI14R5N-URT-010	IMU/VRU/AHRS/Module	6DoF+Magnetometer 1.76°/h
HI14R5T-URT-000	IMU/VRU/AHRS/Module	6DoF+Magnetometer 1.76°/h Temperature Compensation
HI14R2N-URT-100	IMU/VRU/Module	6DoF 2.5°/h Synchronization
HI14R5N-URT-100	IMU/VRU/AHRS/Module	6DoF+Magnetometer 1.76°/h Synchronization

> User can optionally select a USB to RS-232 or USB to Serial (TTL) cable to convert the communication interface into a USB interface

1.3.3 RS-485

P/N	Name	Description
HI14R2N-485-000	IMU/VRU/Module	6DoF 2.5°/h
HI14R2N-485-010	IMU/VRU/Module	6DoF 2.5°/h
HI14R3N-485-000	IMU/VRU/AHRS/Module	6DoF+Magnetometer 2.5°/h
HI14R3N-485-010	IMU/VRU/AHRS/Module	6DoF+Magnetometer 2.5°/h
HI14R5N-485-000	IMU/VRU/AHRS/Module	6DoF+Magnetometer 1.76°/h
HI14R5N-485-010	IMU/VRU/AHRS/Module	6DoF+Magnetometer 1.76°/h

1.3.4 CAN

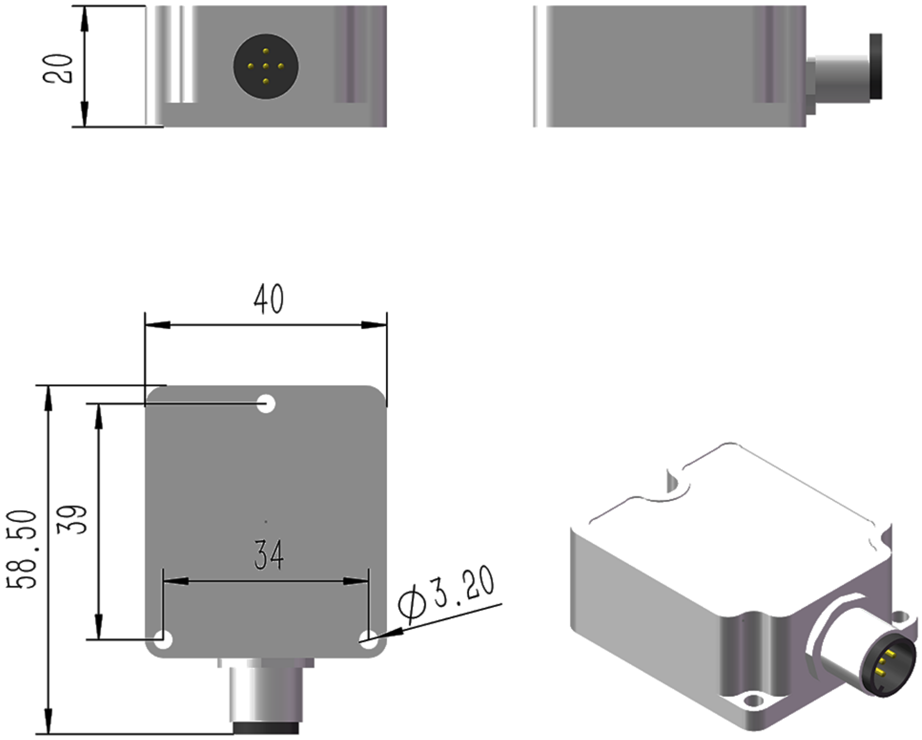
P/N	Name	Description
HI14R2N-CAN-000	IMU/VRU/Module	6DoF 2.5°/h
HI14R2N-CAN-010	IMU/VRU/Module	6DoF 2.5°/h
HI14R5N-CAN-000	IMU/VRU/Module	6DoF 1.76°/h
HI14R5N-CAN-010	IMU/VRU/Module	6DoF 1.76°/h

2. Mechanical and Electrical

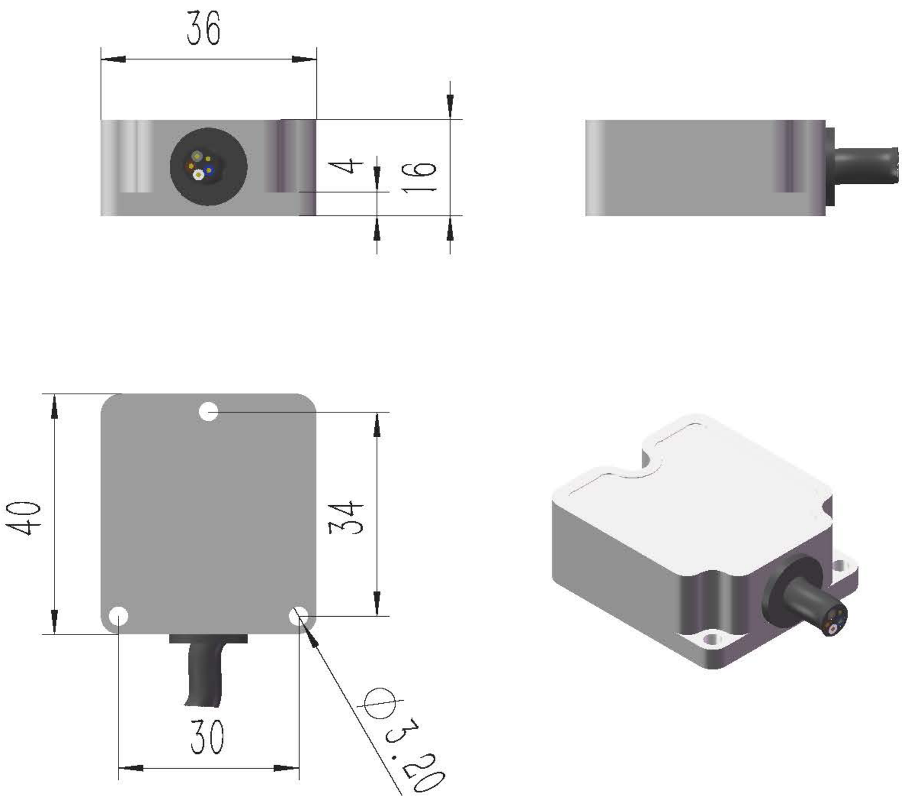
2.1 Dimension

unit: mm

2.1.1 M12 Connector

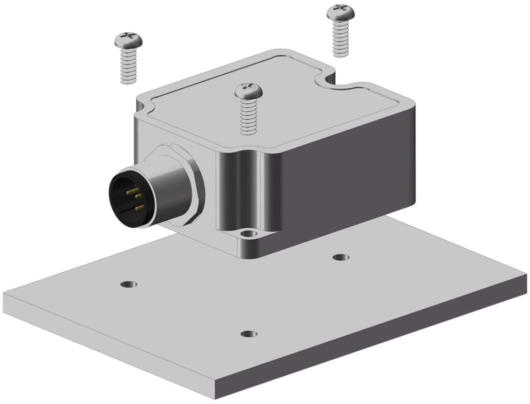


2.1.2 Direct Cable-Type



2.2 Mount

We recommend users to install the module horizontally, as shown in the following diagram:



> If you require an alternative installation method, please refer to the instruction and programming manual coordinate system rotation

2.3 M12 Pin Definitions

2.3.1 RS-232/UART(TTL) Definitions

M12 5 PIN Male

	1	2	3	4	5
	棕(BN)	白(WH)	蓝(BU)	黑(BK)	灰(GY)
UART	SGND	VS	GND	RXD	TXD

M12 8 PIN Male

1	2	3	4	5	6	7	8
白(WH)	棕(BN)	绿(GN)	黄(YL)	灰(GY)	粉(PK)	蓝(BU)	红(RD)
SGND	VS	GND	RXD	TXD	SGND	SIN1	SOUT1

2.3.2 RS-232/UART(TTL) Desciption

NO.	Name	RS-232	UART(TTL)
1	SGND	Signal GND RS-232 GND	Signal GND
2	VS	Power Input	Power Input
3	GND	Power Ground	Power Ground
4	RXD	Serial Receive (RS-232)	Serial Receive (TTL)
5	TXD	Serial Transmit (RS-232)	Serial Transmit (TTL)
6	SGND	Signal Ground RS-232 Ground	Signal Ground
7	SIN1	Synchronous Input	Synchronous Input
8	SOUT1	Synchronous Output	Synchronous Output

2.3.3 RS-485/CAN Definitions

M12 5 PIN Male

	1	2	3	4	5
	棕(BN)	白(WH)	蓝(BU)	黑(BK)	灰(GY)
CAN	CANGND	VS	GND	CAN H	CAN L

M12 5 PIN Male

	1	2	3	4	5
	棕(BN)	白(WH)	蓝(BU)	黑(BK)	灰(GY)
RS-485	485GND	VS	GND	485 A	485 B

2.3.4 RS-485/CAN Desciption

Number	RS-485 Pin Name	RS-485 Interface	CAN Pin Name	CAN Interface
1	485 GND	RS-485 Ground	CAN GND	CAN Ground
2	VS	Power Input	VS	Power Input
3	GND	Power Ground	GND	Power Ground
4	485 A	RS-485 A	CAN H	CAN High
5	485 B	RS-485 B	CAN L	CAN Low

2.4 Direct Cable-Type Pin Definitions

Direct Cable					
5 PIN	1	2	3	4	5
Color	棕(BN)	白(WH)	蓝(BU)	黑(BK)	灰(GY)
UART	SGND	VS	GND	RXD	TXD
RS-485	485 GND	VS	GND	485 A	485 B
CAN	CAN GND	VS	GND	CAN H	CAN L

> The pin definitions described in 2.3 and 2.4 are for the sensor side

2.5 Cable

2.5.1 Introduction

Default Cable	Description
M12A 5-Pin Straight Female to DB9 Female	External power line without synchronization
M12A 8-Pin Straight Female to DB9 Female	External power line with synchronization
M12A 5-Pin Straight Female to DB9 Female	Internal power line
M12A 5-Pin Straight Female to OPEN	Wiring in Loose Form with Line Marking
M12 A 5-Pin Straight Female to USB Male	USB Interface with Internal 232 to USB Chip
M12 A 5-Pin Straight Female to USB Male	USB Interface with Internal Serial to USB Chip
M12 A 8-Pin Straight Female to OPEN	Wiring in Loose Form with Line Marking

> Cable material pur,The default cable length is 3 meters, but cable lengths of 0.5 meters, 1 meter, and 5 meters are also available. It's not recommended to have a cable length longer than 3 meters for UART(TTL) interfaces.
>
> All cables come with M12A angled data cables for ease of use.
>
> M12 A 8-pin cables are only compatible with products that have hardware synchronization pins. For example, HI14R2N-232-100.

2.5.2 Cable Diagrma

M12 5芯直母头-DB9母头电源线外置
注：只适用于RS-232接口，不带同步信号
HI14RXX-232-00X

M12 8芯直母头-DB9母头电源线外置
注：只适用于RS-232接口，带同步信号
HI14RXX-232-10X

M12 5芯直母头-DB9母头电源线内置
注：只适用于RS-232接口，不带同步信号
HI14RXX-232-00X

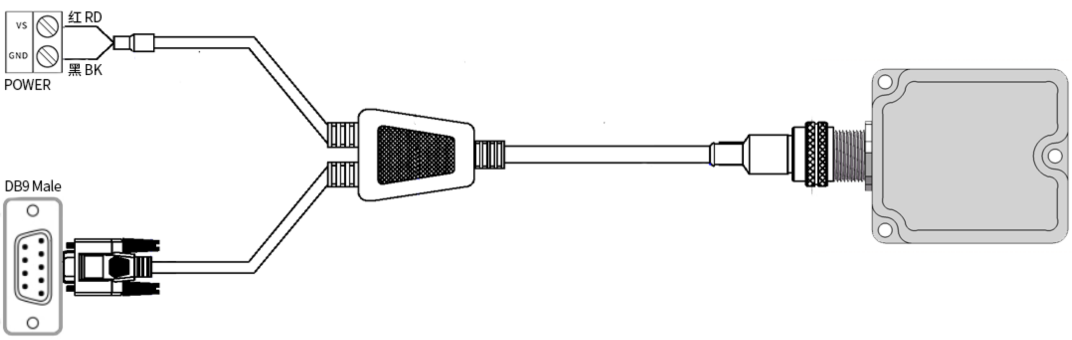
M12 5芯直母头-OPEN
HI14RXX-232-00X
HI14RXX-485-00X
HI14RXX-CAN-00X
HI14RXX-URT-00X

M12 8芯直母头-OPEN
HI14RXX-232-10X
HI14RXX-URT-10X

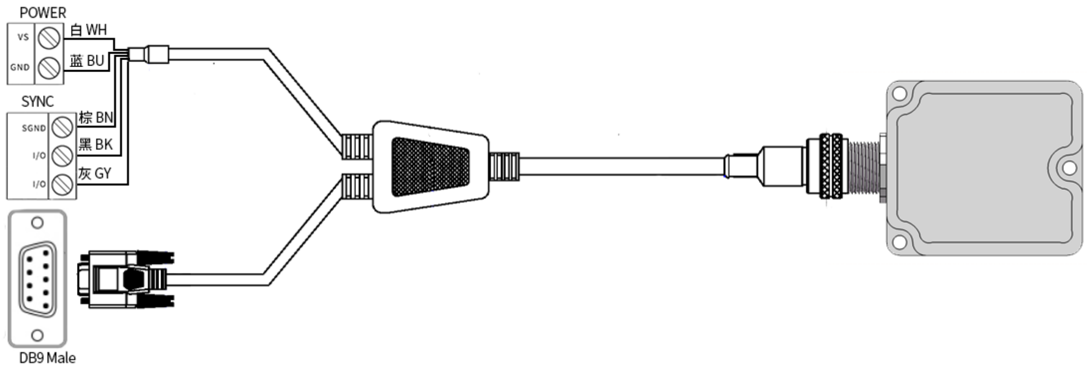
M12 5芯直母头-USB A 公头
注：只适用于UART接口，不带同步信号
HI14RXX-232-00X
HI14RXX-URT-00X

2.6 How to Connect

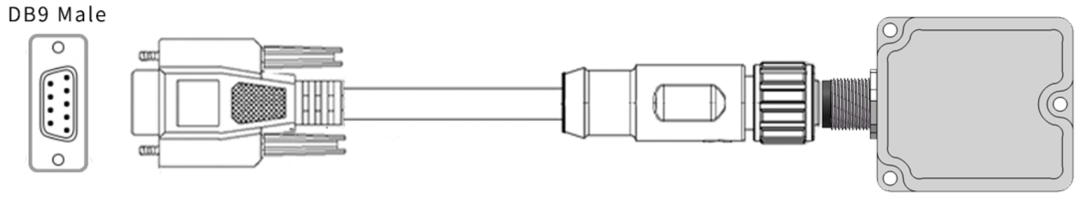
2.6.1 M12A 5-Pin Female to DB9 Female (External Power Line)



2.6.2 M12A 5-Pin Female to DB9 Female (External Power Line With Synchronization)

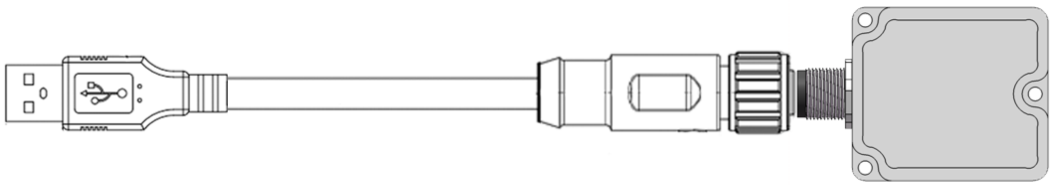


2.6.3 M12A 5-Pin Female to DB9 Female (Internal Power Line)



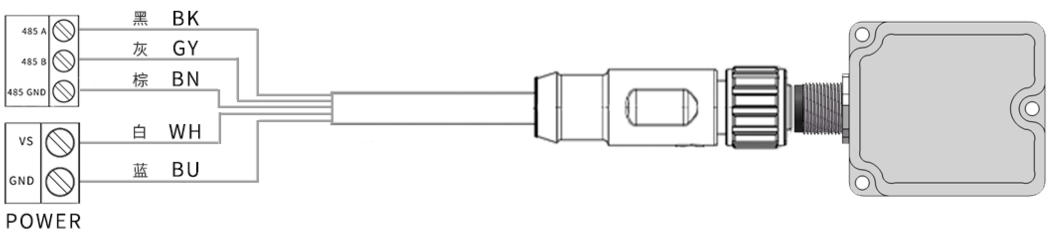
> This type of wiring method requires that PIN 9 of the user's DB9 male connector be the positive power (VS) pin

2.6.4 M12A 5-Pin Female to USB



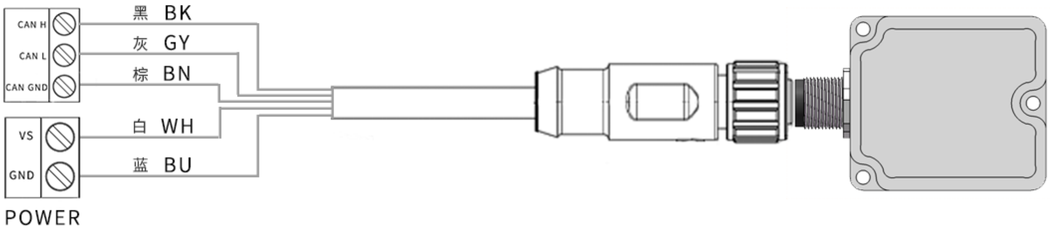
2.6.5 M12A 5-Pin Female to OPEN

2.6.5.1 RS-485



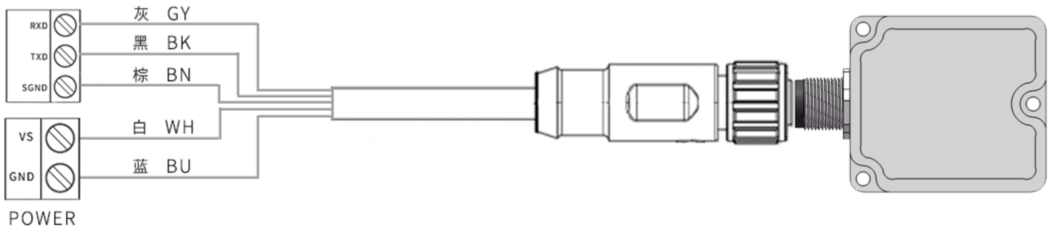
> If the 485 device does not have a 485 GND (brown wire), then the 485 GND can be left unconnected

2.6.5.2 CAN



> If the CAN device does not have a CAN GND (brown wire), then the CAN GND can be left unconnected

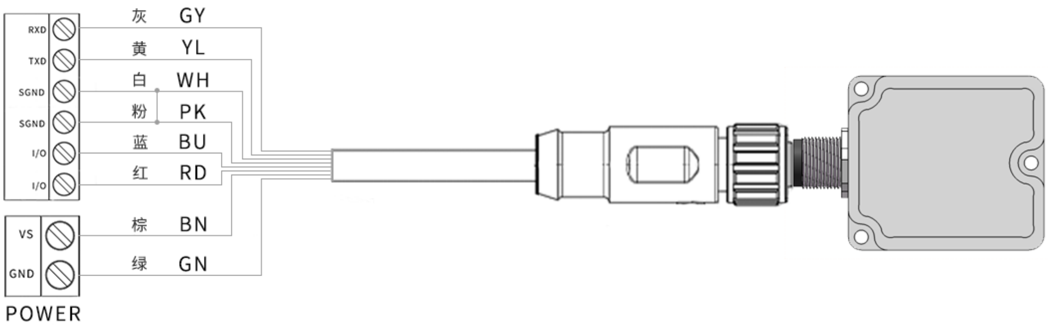
2.6.5.3 UART(RS-232/TTL)



> If the power system and UART system share a common ground reference, then SGND (brown wire) can be left unconnected

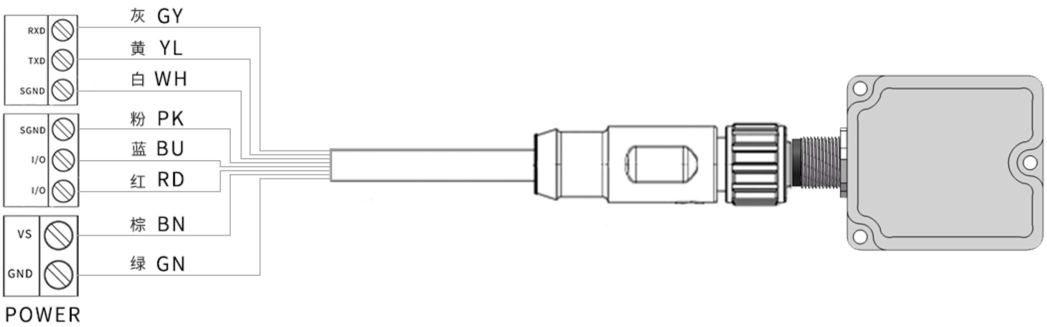
2.6.6 M12A 8-Pin Female to OPEN

- Synchronous input and output share the same system or have a common reference ground with UART



> f the power system and UART system share a common ground reference, then SGND (white or pink wire) can be left unconnected

- Synchronous input and output are not in the same system or have different ground references from UART



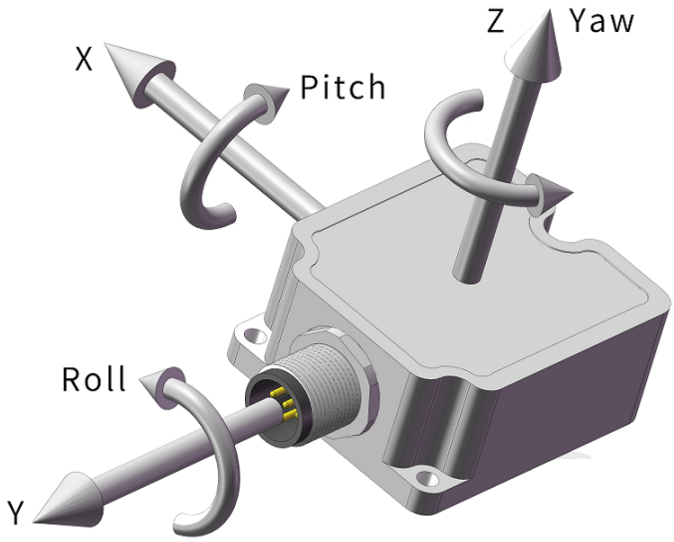
> If the power system and UART system share a common ground reference, then SGND (white wire) can be left unconnected
>
> If the power system and synchronous system share a common ground reference, then SGND (pink wire) can be left unconnected

2.7 HI14 Series Shell Parameters

Parameter	Value	Note
Shell Material	6061 Aluminum Alloy	
Surface Treatment	Matte Anodized	Type II Class 2
Shell Dimensions	58.5X40X20mm	
Mounting Screws	3XM3	Screw length depends on the user's application scenario

3. Coordinate System

In the coordinate system of the object, the right-front-up (RFU) coordinate system is used, while the geographical coordinate system employs the east-north-up (ENU) coordinate system. The directions of acceleration and gyroscope axes are as shown in the following diagram



The Euler angle rotation sequence is East-North-Up-312 (first around the Z-axis, then around the X-axis, and finally around the Y-axis). It is defined as follows:

- Rotation around the Z-axis: Yaw angle (ψ) with a range of -180° to 180°.
- Rotation around the X-axis: Pitch angle (θ) with a range of -90° to 90°.
- Rotation around the Y-axis: Roll angle (ϕ) with a range of -180° to 180°.

If the module is considered as an aircraft, the positive direction of the Y-axis should be considered as the direction of the aircraft's nose. When the sensor frame coincides with the inertial frame, the ideal Euler angle outputs are as follows: Pitch = 0°, Roll = 0°, Yaw = 0°.

4. Technical Specifications

4.1 Fusion Parameters

4.1.1 Attitude Angle Range

Attitude Angle Range	
Pitch	±90°
Roll	±180°
Yaw	±180°

4.1.2 Attitude Angle Accuracy

Model	HI14R1	HI14R2	HI14R3	HI14R45
Pitch/Roll (Static)	0.1°	0.1°	0.1°	0.1°
Pitch/Roll (Dynamic)	0.1°	0.1°	0.1°	0.1°
Yaw Static Drift (6DOF)①	<0.12°/h	<0.12°/h	<0.12°/h	<0.12°/h
Yaw Dynamic Drift Error (6DOF)②	7	5	5	3
Yaw (Magnetometer Assisted)③	-	-	2°	2°
Yaw Rotation Error (6DOF)④	<1°	<1°	<1°	<1°

① Module tested at 25°C, absolutely stationary for 1 hour.

② Module tested on an indoor cleaning robot moving for 1 hour, at 25°C, 1σ.

③ Measured after Magnetometer calibration, in the absence of magnetic field interference at 25°C. Product should be configured in AHRS mode (partially supported).

④ Turntable continuous rotation for 10 turns, Yaw angle cumulative error, at 25°C.

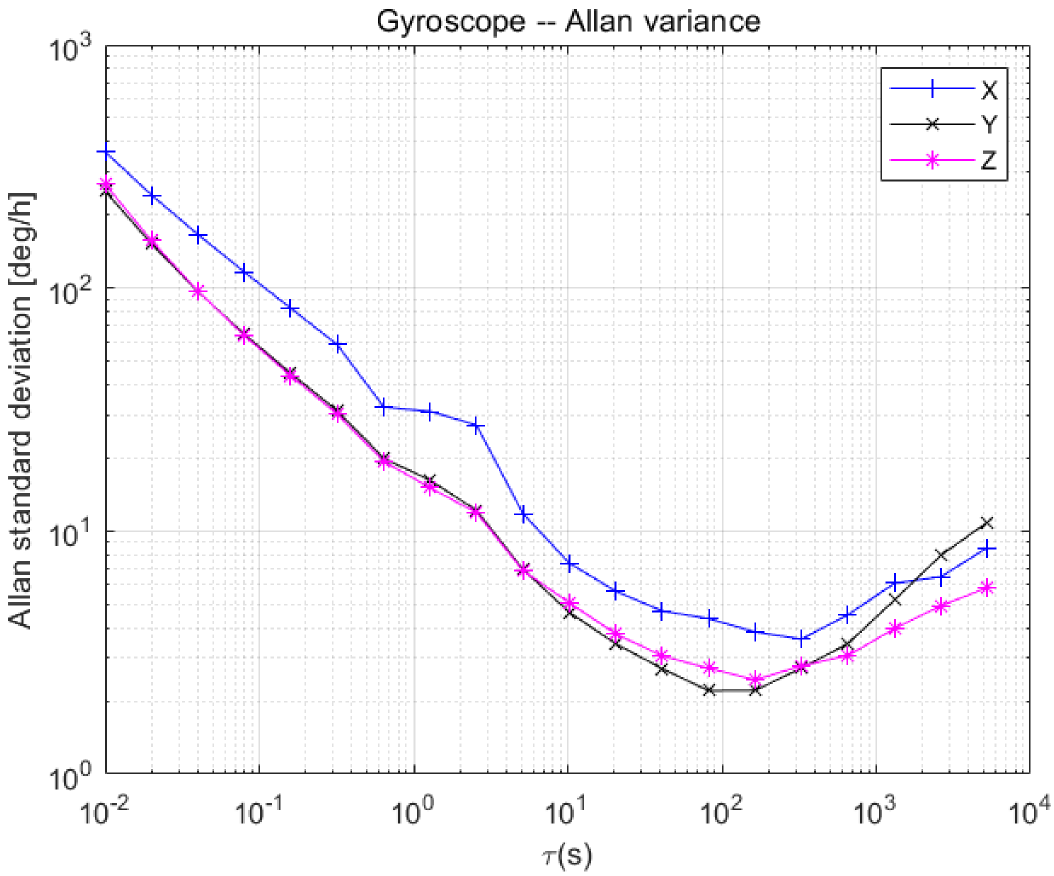
4.2 Sensor Parameters

4.2.1 Gyroscope

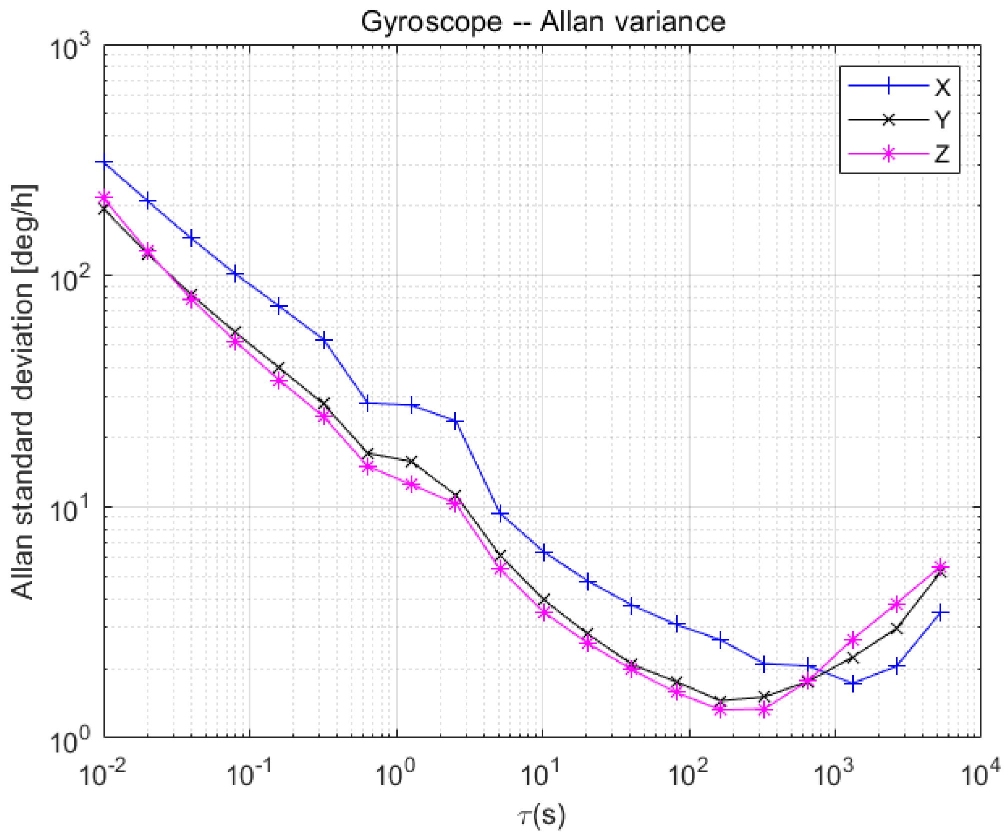
Parameter	HI14R1	HI14R2/HI14R3	HI14R5	Remark
Measurement Range	±2000°/s	±2000°/s	±2000°/s	
Resolution	0.001°/s	0.001°/s	0.001°/s	
3dB Bandwidth	120Hz	120Hz	120Hz	
Zero bias Instability	3.6/h	2.5°/h	1.76°/h	@25°C, 1σ
Zero bias Repeatability	0.09°/s	0.05°/s	0.05°/s	@25°C, 1σ
Non-Orthogonality Error	±0.1%	±0.1%	±0.1%	@25°C, 1σ
Random Walk	0.6°/√hr	0.3°/√hr	0.3°/√hr	@25°C, 1σ
Scale Nonlinearity	±0.1%	±0.1%	±0.1%	Full Scale (Max)
Acceleration Sensitivity	0.1°/s/g	0.1°/s/g	0.1°/s/g	
Z-Axis Zero Offset Change (No Temp. Comp.)①	TBD	TBD	TBD	-40°C to 85°C
Z-Axis Zero Offset Change (With Temp. Comp.)①	-	TBD	TBD	-40°C to 85°C

① Average of test samples.

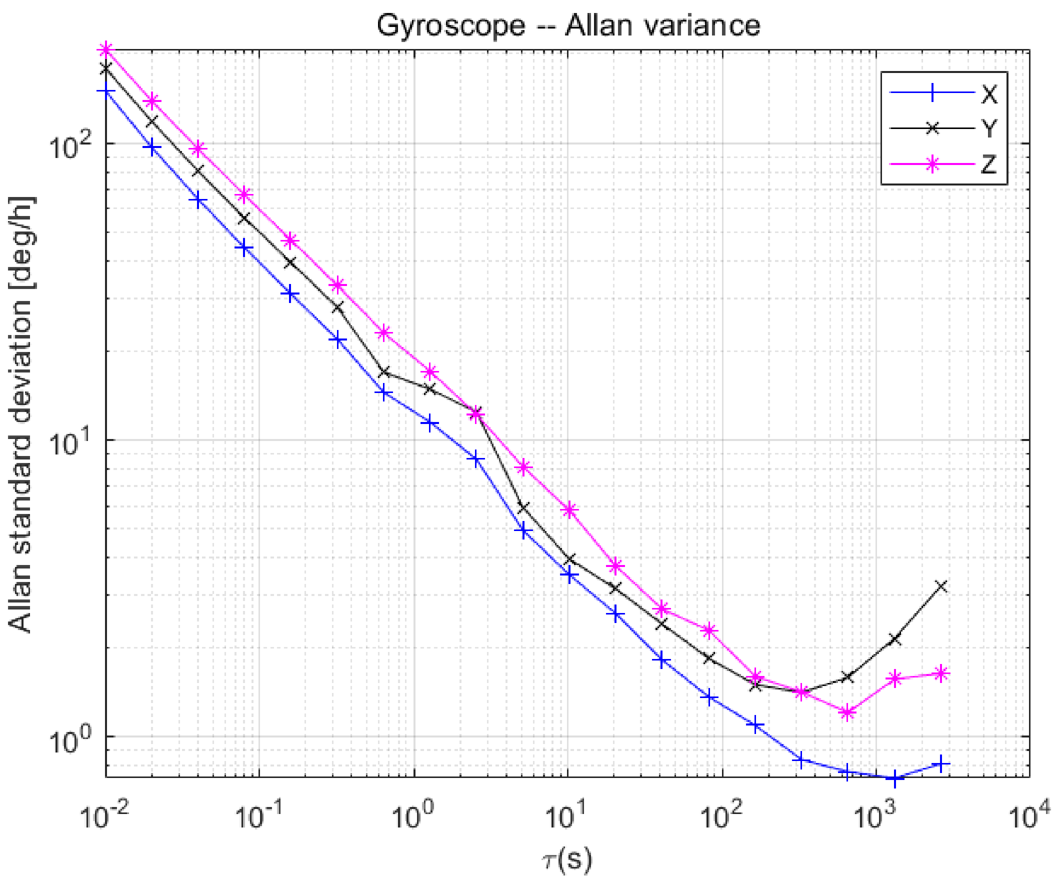
HI14R1 Gyroscope Allan



HI14R2/HI14R3 Gyroscope Allan



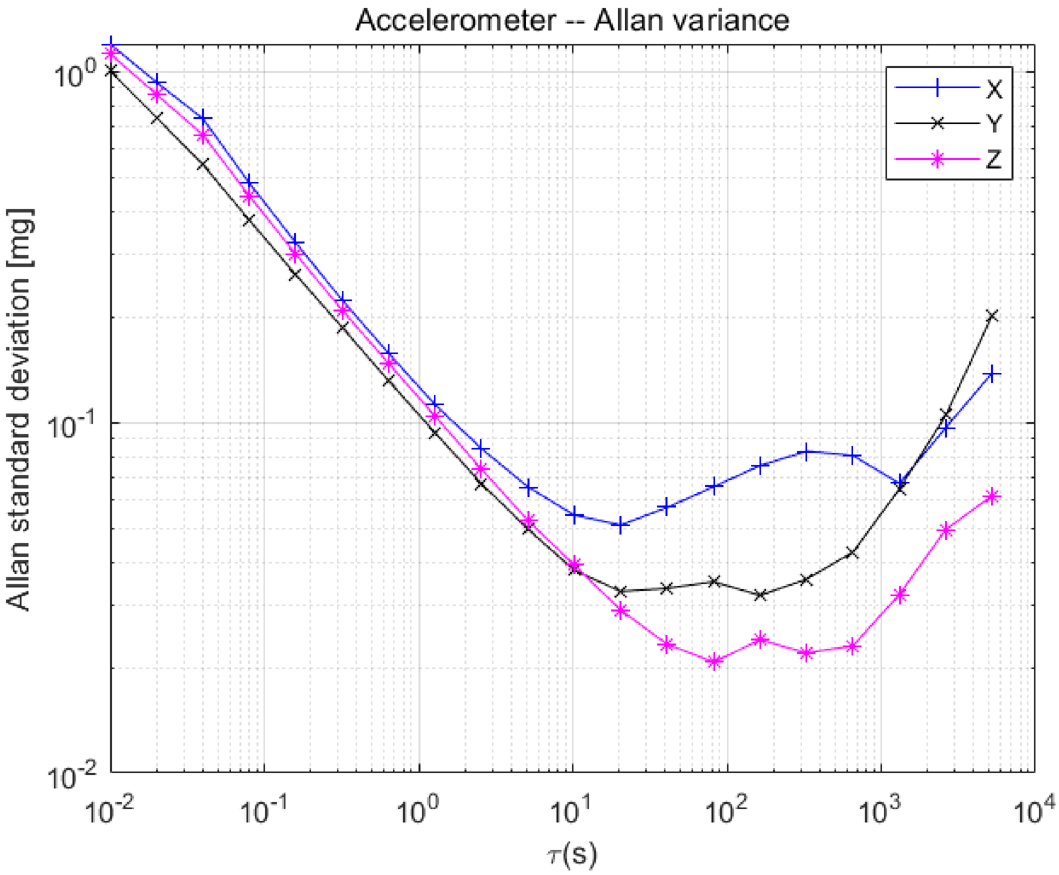
HI14R5 Gyroscope Allan



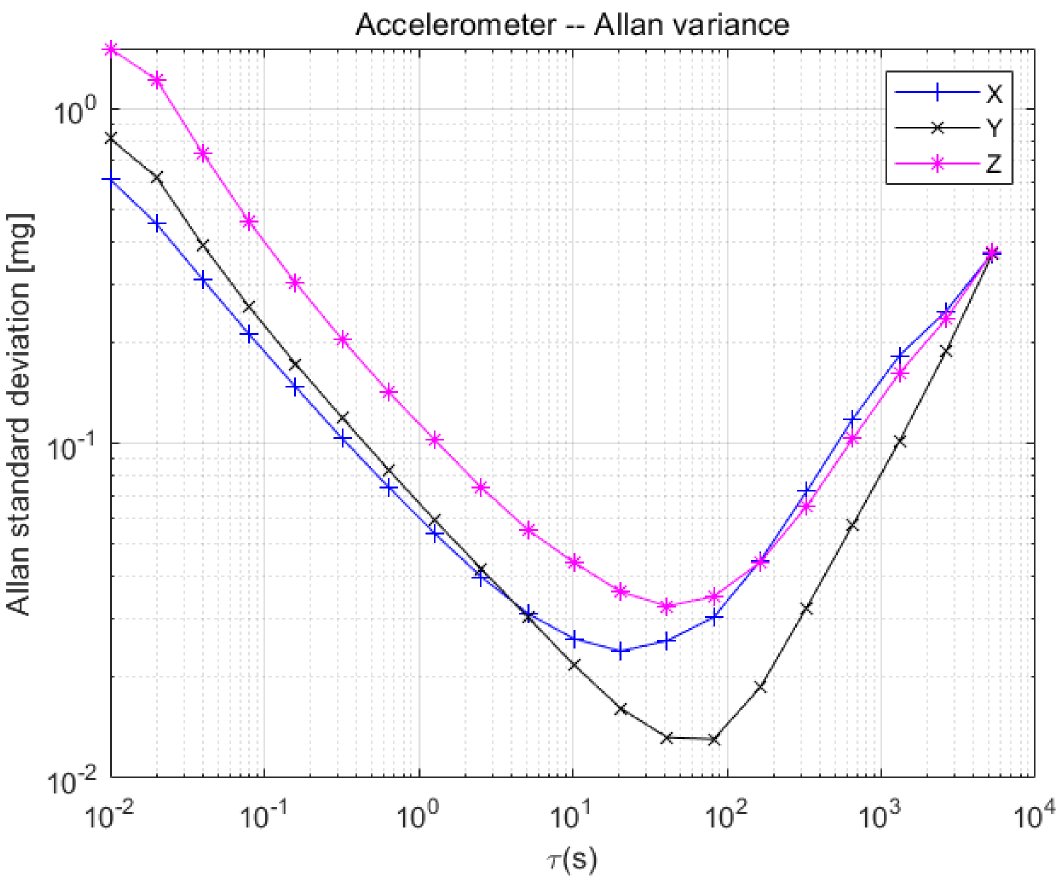
4.2.2 Accelerometer

Parameter	HI14R1	HI14R2/HI14R3	HI14R5	Remark
Measurement Range	±12g	±12g	±12g	1g = 1x gravitational acceleration
Resolution	1ug	1ug	1ug	
3dB Bandwidth	150Hz	150Hz	150Hz	
Zero Offset Instability	60ug	30ug	21ug	@25°C, 1σ
Zero Offset Repeatability	2.52	1.8mg	0.6mg	@25°C, 1σ
Non-Orthogonality Error	±0.1%	±0.1%	±0.1%	@25°C, 1σ
Random Walk	0.08 $m/s\sqrt{h}$	0.04$m/s\sqrt{h}$	0.04 $m/s\sqrt{h}$	@25°C, 1σ
Full Temperature Range Temp. Variation (No Temp. Comp.)	<0.3mg/°C	<0.005mg/°C	<0.005mg/°C	-40°C to 85°C
Full Temperature Range Temp. Variation (With Temp. Comp.)	TBD	TBD	TBD	-40°C to 85°C

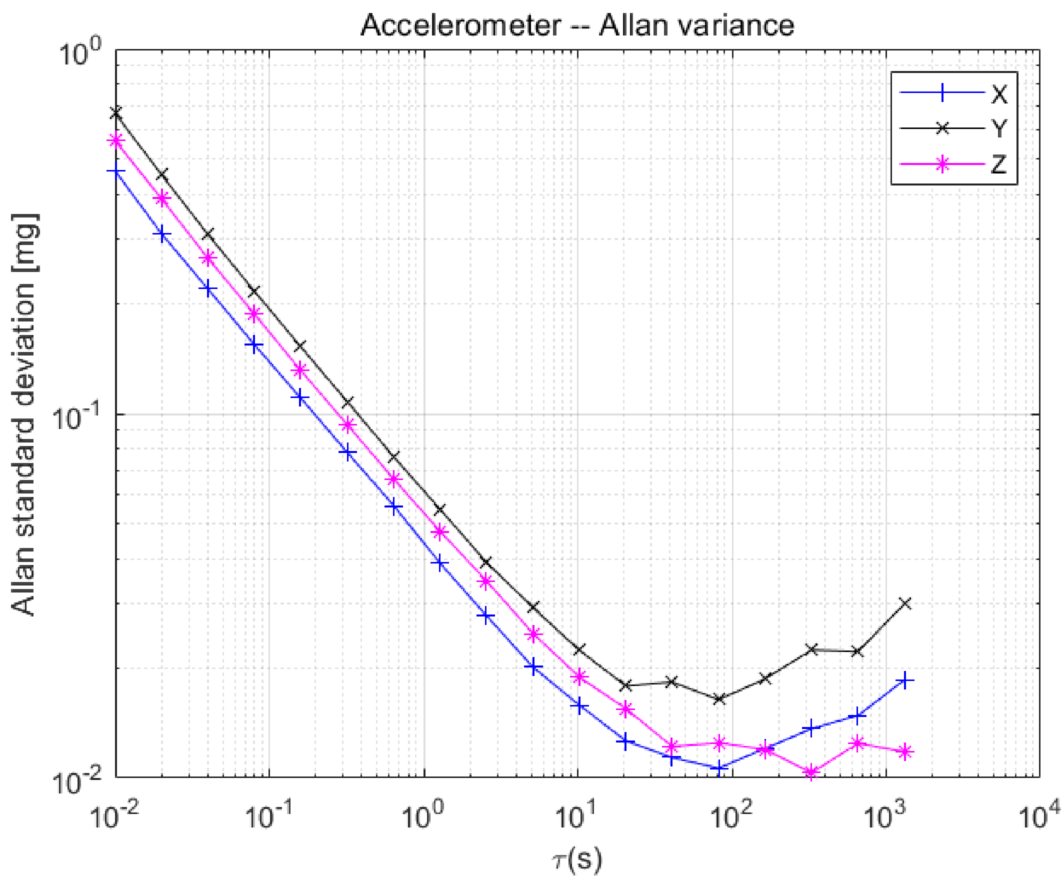
HI14R1 Accelerometer Allan



HI14R2/HI14R3 Accelerometer Allan



HI14R5 Accelerometer Allan



4.2.3 Magnetic Sensor

Parameter	HI14R3/HI14R5
Measurement Range	±8G (Gauss)
Non-linearity	±0.1%
Resolution	0.25mG

4.3 Electrical Parameters

4.3.1 General Electrical Parameters

Parameter	Condition	HI14 Series	Remark
Input Voltage	RS-232/RS-485/UART Interface	5-50V	DC
	CAN Interface	6-50V	DC
Power Consumption	Test Voltage 24V	<350mW	
Reverse Polarity Protection		Supported	
CE Certification		EMC Directive 2014/30/EU	
		RoHS Directive 2011/65/EU	

4.3.2 Interface Parameters

RS-232

RS-232		
Baud Rate		9600/115200/230400/460800/921600bps (default 115200)
Protocol		Binary Protocol
Frame Rate		5/10/50/100/250/500Hz (default 100)
Input Voltage		-15V to 15V
Output Voltage	Typical	±5.4V

UART (TTL)

UART (TTL)	
Baud Rate	9600/115200/230400/460800/921600bps (default 115200)
Protocol	Binary Protocol
Frame Rate	5/10/50/100/250/500Hz (default 100)
Input Voltage	-0.3V to 3.6V
Output Voltage	0-3.3V

RS-485

RS-485		
Baud Rate		9600/115200/230400/460800bps (default 115200)
Protocol		Modbus/Binary Protocol
Frame Rate		5/10/50/100/250/500Hz (default 100)
Differential Output		2V-5V
Common Mode Output	Typical	2.5V
Differential Input Threshold		-200mV to 200mV

CAN

CAN		
Baud Rate		125K/250K/500K/1000K (default 500K)
Protocol		CANopen/J1939
Frame Rate		5/10/50/100/200Hz (default 100)
Output Voltage	CAN H	2.75-4.5V (Typical 3.5V)
	CAN L	0.5-2.25V (Typical 1.5V)
Input Voltage		0.9-9V
Differential Input Threshold		0.5-0.9V

SIN1 Synchronization Input

SIN1	
Input Voltage	-0.5-3.6V
Input Frequency	0-500Hz

SOUT1 Synchronization Output

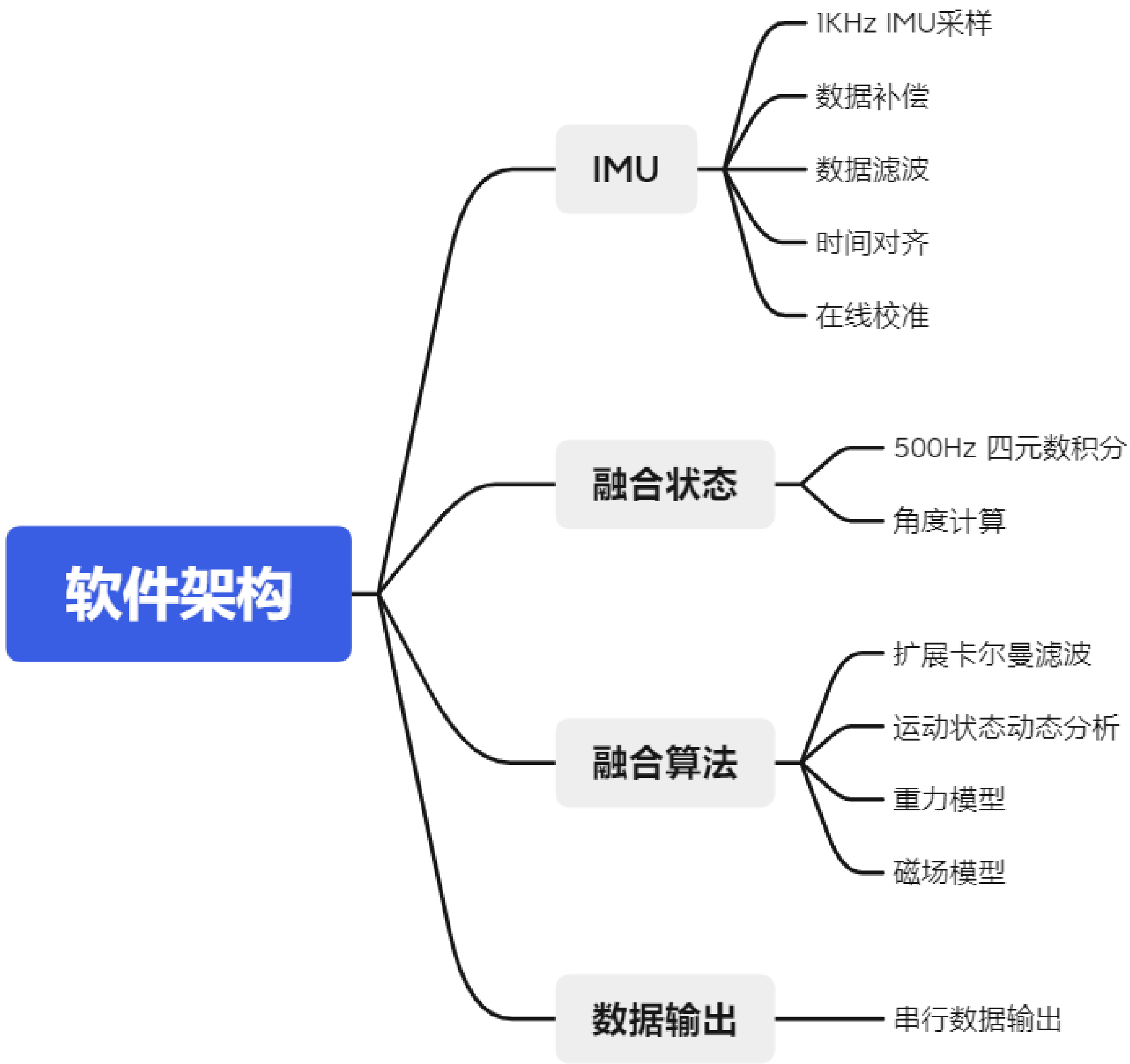
SOUT1	
Output Voltage	0-3.3V
Output Frequency	0-500Hz

4.4 Mechanical and Environmental Parameters

Parameter	HI14 Series
Dimensions	58.5X40X20mm
Weight	<75g
Housing Material	Aluminum Alloy Type II Class 2
Operating Temperature	-40-85°C
Storage Temperature	-40-85°C
Shock Resistance	2000g
Waterproof Rating	IP68

5. Software Architecture

The HI14 series utilizes in-house developed Extended Kalman Filtering (EKF) and IMU noise dynamic analysis techniques to achieve high-precision attitude angles even under high-dynamic conditions, reducing yaw angle drift. The algorithm architecture primarily comprises four main components: IMU, Fusion State, Fusion Algorithm, and Data Output.

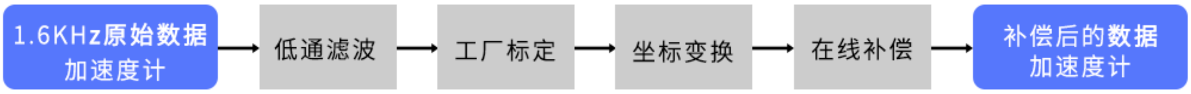


5.1 Sensor Subsystem

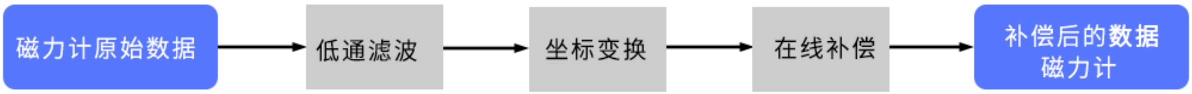
The primary function of the sensor subsystem is to calibrate and compensate for raw sensor data, allowing the sensor data to better meet various user scenarios.

5.1.1 Gyroscope Data Processing

5.1.2 Accelerometer Data Processing



5.1.3 Magnetic Data Processing



5.2 Raw Data

The MCU collects raw data from the accelerometer, gyroscope, and the magnetometer field at the highest sampling frequency.

5.3 Low-Pass Filtering

The HI14 series provides various low-pass filtering solutions for users (refer to Chapter 6, User Configuration - Bandwidth Configuration) to meet a wide range of user applications.

5.4 Factory Calibration

During the production process, every MEMS IMU exhibits common errors such as bias, scale factor, cross-axis errors, and is also affected by temperature variations. Therefore, we employ proprietary equipment in the manufacturing and testing processes to minimize the impact of these errors.

5.5 Coordinate Transformation

While we recommend users to install the product in a horizontal orientation, we understand that user scenarios may necessitate the installation of the module in different positions. Thus, we support the rotation of the sensor's coordinate system to better meet user installation requirements. Coordinate transformation instructions can be found in the user configuration section.

5.6 Online Compensation

Users should maintain a static state for 1 second when powering up, allowing the product to automatically collect and calculate the current gyro bias state for better compensation of gyroscope data.

5.7 Online Calibration of the Magnetometer Field

Online calibration of the magnetometer field supports automatic calibration. For specific details, refer to the Magnetometer Calibration section in the Instruction and Programming Manual.

5.8 Data Fusion

5.8.1 Kalman Fusion Algorithm

The processor utilizes the Extended Kalman Algorithm to perform quaternion-based attitude calculation at a fixed frequency (default is 500Hz) using raw data from the accelerometer, gyroscope, and magnetometer. Data fusion provides quaternion, Euler angle, and other fusion information. It can also estimate sensor biases, such as the gyroscope and accelerometer biases, which is crucial for systems relying on low-latency, low-jitter attitude information as a control input.

Fusion Data Output
Euler Angles (Pitch, Roll, Yaw)
Quaternions

5.8.2 Dynamic Analysis of Motion States

Based on the information provided by sensors like the accelerometer and gyroscope, it is possible to indirectly analyze the current motion state of the carrier, which can be used to adjust the Kalman fusion state for optimal module performance.

5.9 Data Output

Different data interfaces have different output protocols, as shown in the table below:

Data Interface	Protocol
RS-232/UART(TTL)	Binary Protocol (Protocol 91)
RS-485	Modbus
CAN	CANopen

6. Initial Configuration

The HI14 series is designed with the intent of minimal user configuration to cover the majority of application scenarios. The default configuration is sufficient for many working conditions, but additional configuration options are provided to cater to special situations.

6.1 Interfaces

6.1.1 Initial Configuration for UART (RS-232/TTL) Interface

Configuration	Parameter
Protocol	Custom Binary Protocol (91)
Baud Rate	115200
Data Rate	100Hz
Coordinate System	Refer to the Coordinate System Definition Section

6.1.2 Initial Configuration for RS-485 Interface

Configuration	Parameter
Protocol	Modbus
Baud Rate	115200
Data Rate	100Hz
Coordinate System	Refer to the Coordinate System Definition Section

6.1.3 Initial Configuration for CAN Interface

Configuration	Parameter
Protocol	CANopen
Baud Rate	500K
120-ohm Termination Resistor	None
Data Rate	100Hz
Coordinate System	Refer to the Coordinate System Definition Section

6.2 Inertial Sensors

Configuration	Parameter
Gyroscope Range	±2000°/s
Accelerometer Range	±12g
Mode	6DoF
Gyroscope Minimum Detectable Angular Velocity	0.15°/s
Gyroscope Bandwidth (3dB)	120Hz
Accelerometer Bandwidth (3dB)	150Hz

7. Magnetometer Calibration

7.1 Magnetometer Calibration Procedure

Calibration Prerequisites:

- The current testing results show that the heading angle accuracy does not meet the requirements.
- The module installation environment is subject to magnetic field interference, and this interference is fixed. Additionally, this interfering magnetic field does not change its distance after module installation. For example, if the module is installed on a piece of iron material, and this iron remains in proximity to the module without varying the distance. If the size of the iron is not constant, or its distance from the module changes unpredictably, calibration is not possible, and it's better to avoid such installations, maintaining a safe distance of at least 40cm.

The module features an internal, active Magnetometer calibration system. This system does not require user input, as it operates automatically in the background. The system gathers Magnetometer field data over a period of time, performs analysis and comparison, and eliminates outliers. When enough data is collected, the system attempts Magnetometer calibration. Therefore, when using Magnetometer-assisted (9-axis) mode, no user intervention is required for Magnetometer calibration. However, the module still provides an interface for users to check the current calibration status. The premise for automatic calibration is that the module experiences sufficient changes in orientation and **maintains these changes for a certain duration**. This allows the internal calibration system to collect Magnetometer field data at different orientations and complete the calibration. Calibration cannot be performed when the module is in a stationary state.

If you are using the module for the first time and need to employ AHRS (9-axis) mode, follow these calibration steps:

1.Check for magnetic field interference in the surroundings. Common sources of interference include lab tables containing iron or iron-containing objects such as computers, motors, and mobile phones. It is recommended to take the module to an open outdoor area to minimize interference. If outdoor conditions are not available, keep the module as far away from potential interference sources as possible.

2.Within a limited range (try not to move the module; only rotate it), slowly rotate the module to allow it to go through as many different orientations as possible. Each axis should be rotated at least 360°, and this should be done for about 1 minute. This calibration process is considered complete once this is achieved. If you are unable to calibrate the module successfully, it indicates that there is significant magnetic field interference in the vicinity.

3.If the installation location changes (for instance, if you initially calibrated the module by holding it separately and later mounted it on the target device), you will need to recalibrate the module while it's attached to the target device.

4.Use the command ==LOG MAGCONFIG== to check the Magnetometer calibration parameters:

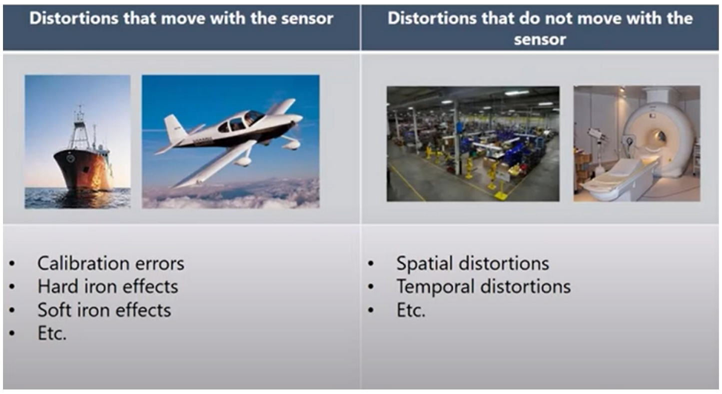
```
pythonCopy code...

MAG BIS:
  0.029
 -22.062
 11.926
```

If ==MAG BIS==consists of three numbers that are not all zeros, it means that Magnetometer calibration has been successful. If ==MAG BIS== is all zeros, it means that Magnetometer calibration has not been successful. In this case, return to step 1 and restart the calibration procedure.

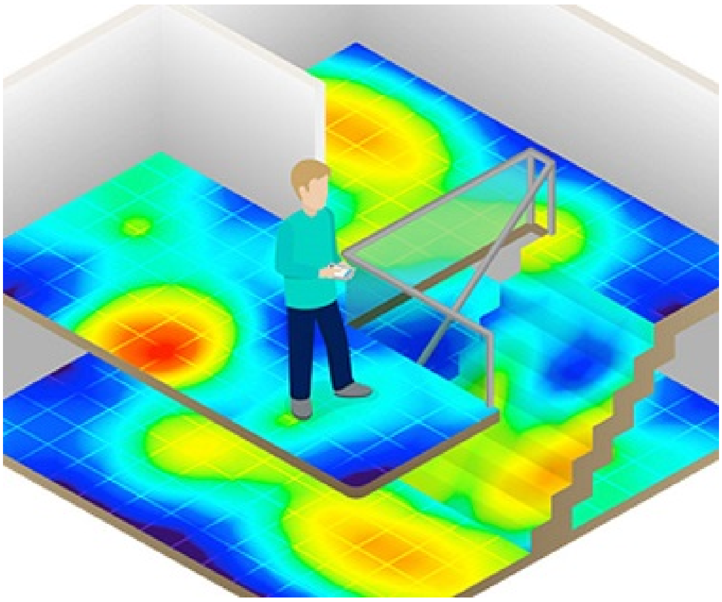
7.2 Understanding Magnetic Interference

Magnetic interference for Magnetometers can be categorized into spatial magnetic field interference and magnetic field interference in the sensor's coordinate system, as illustrated in the diagram below:



7.2.1 Spatial Magnetic Field Interference

Definition: Magnetic field interference does not change with the movement of the sensor and exists in the world coordinate system. Typical sources of interference: Various fixed Magnetometer interference sources, furniture, household appliances, cables, steel structures inside buildings, etc. Anything that does not move with the magnetic sensor's movement is considered a static interference source. The figure below shows a typical indoor magnetic field distribution.



7.2.2 Impact on the Module:

Whether the Magnetometer sensor is well calibrated or not, spatial magnetic field interference (or non-uniform environmental magnetic fields) will distort the spatial Magnetometer field. Magnetometer compensation will be inaccurate, and the correct heading angle cannot be obtained. These are the main reasons for the difficulty of using indoor Magnetometer fusion. Such interference cannot be calibrated and severely affects Magnetometer performance. Spatial magnetic field interference is particularly severe indoors.

Countermeasures: The only measure is to try to avoid such sources of interference.

7.2.3 Interference in the Sensor Coordinate System

Definition: Magnetometer field interference sources move with the sensor.

Typical interference sources: PCB boards fixed to the module, instruments, and equipment that are considered the same rigid body as the magnetic sensor and move with it.

Impact on the Module: Causes hard magnetic/soft magnetic interference on the sensor. These interferences can be effectively eliminated through the Magnetometer calibration algorithm.

Countermeasures: Calibrate the module with the Magnetometer.

7.3 Precautions for Magnetometer Use

In indoor environments, spatial magnetic field interference can be particularly severe, and this type of interference cannot be eliminated through calibration. In indoor environments, even though the module has a built-in homogeneous magnetic field detection and shielding mechanism, the accuracy of the heading angle in Magnetometer-assisted (9-axis) mode largely depends on the degree of magnetic field distortion indoors. If the indoor magnetic field environment is poor (such as near a computer room, laboratory, workshop, underground garage, etc.), the heading angle accuracy after calibration may not be better than the 6-axis mode, and significant angular errors may occur.

The module's automatic Magnetometer calibration system can only handle fixed magnetic field interference associated with the module's installation. If the installation environment has magnetic field interference, this interference must be fixed and should not change its position relative to the module after installation (e.g., if the module is mounted on a metal material like a robot, and the metal material causes magnetic field interference, you need to calibrate the robot and the module together. Once they separate or have relative displacement, you need to recalibrate).

8. Technical Support

New product and material information can be obtained through the website and the official public account.