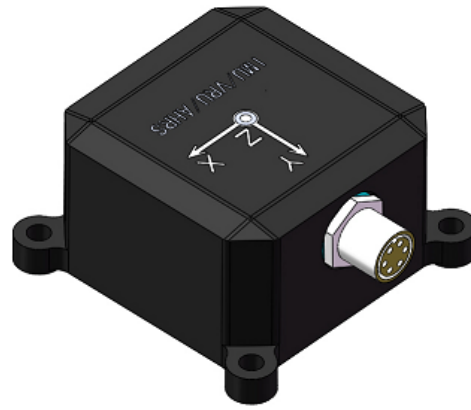


# CH10X Industrial IP68 IMU/VRU/AHRS Datasheet

Applicable to CH10X series RS-232, USB, CAN interface



Products: CH104 & CH108

Attribute: public

Official website: <https://sealandtech.com.tw>

Purchase and support: [sltech@ms28.hinet.net](mailto:sltech@ms28.hinet.net)

## File change history

Version	Date	Remarks
V1.0	2022.07.02	Release the first version of the module manual of the CH10X series
V1.1	2022.08.15	Correct some instructions
V1.2	2024.03.13	Update configuration instructions, applicable to firmware versions after v1.3.7

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# 1. CH10X Introduction

## 1.1. Applications and Advantages

This product series encompasses the CH104 and CH108 Inertial Measurement Units (IMUs), engineered to precisely capture pitch, roll, yaw, and other attitude parameters of mobile devices. These IMUs are adeptly suited for a spectrum of applications spanning land, maritime, and aerial domains. They seamlessly integrate into various systems, complementing navigation solutions such as Laser Radar (Lidar) and Vision (Camera), thereby augmenting device navigation accuracy while reducing reliance on external reference objects.

### Key application scenarios include

- Land: Deployment on smart mobile platforms (e.g., AGV/AMR), unmanned trucks, patrol robots, smart agricultural machinery, building detection systems, and machine monitoring setups.
- Maritime: Utilization in ship navigation and positioning systems, wave detection mechanisms, and orientation detection setups.
- Aerial: Integration into flight navigation and positioning systems, UAV balance systems, and related aerial navigation applications.

### Streamlined Manufacturing Process

- Incorporating automated batch calibration and testing production lines to ensure consistent quality across mass production. Utilizing industrial-grade calibration machinery to address error factors including zero offset, scale factor, cross-axis sensitivity, and temperature variations, all calibrated meticulously at the factory.

### Exceptional Performance Standards

- Demonstrating bias stability of 1.76°/h and an attitude angle accuracy of 0.1°.

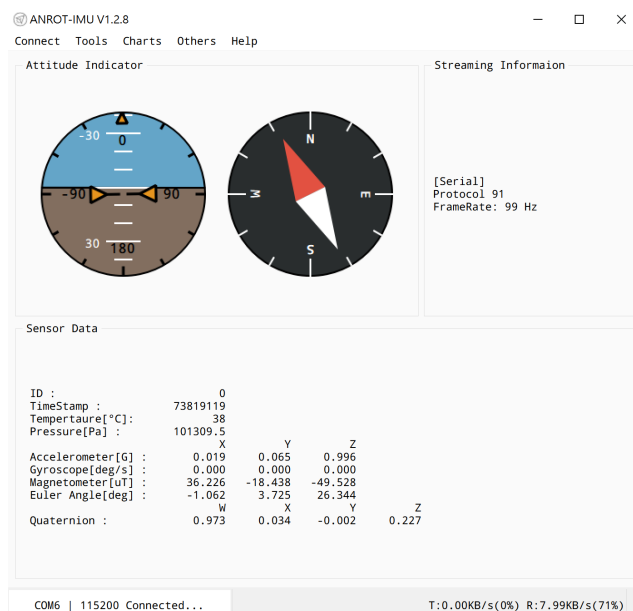
### Versatile Deployment in Varied Environments

- Engineered with an IP68 waterproof design and CE certification, ensuring robustness for high-intensity outdoor automation applications.
- Compact dimensions measuring 48 X 47.2 X 22.5 mm.
- Robust and dependable waterproof plug and cable.

## 1.2. ANROT-IMU UI Assistant

The **ANROT-IMU UI tool** is a PC-side software application developed by our team to facilitate efficient product evaluation. It is compatible with both **Windows** and **Linux** x64 operating systems. This versatile tool provides several essential functions, including:

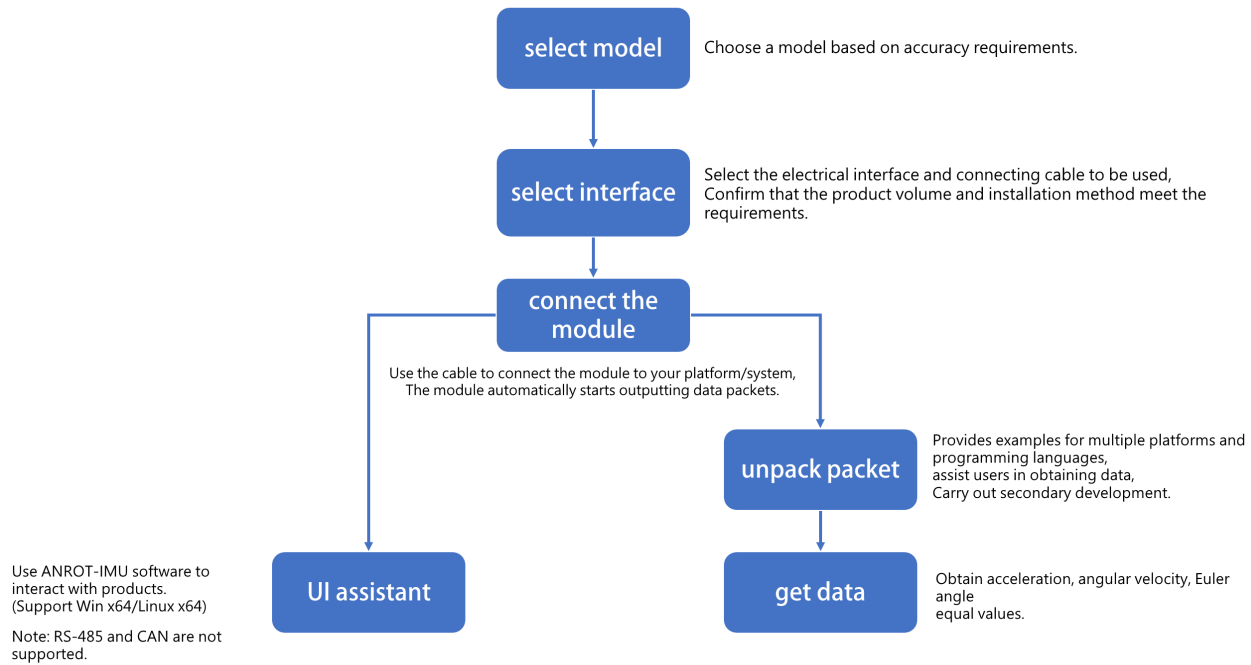
1. **Data Display:** Visualize sensor data in real-time.
2. **Recording:** Capture and store data for further analysis.
3. **Product Parameter Configuration:** Configure IMU parameters to suit specific use cases.



Download and use now: [URL](#)

### 1.3. Product Import Guide

Industry-standard communication protocols can vary significantly among manufacturers, creating a substantial entry barrier for users. To address this challenge, we offer comprehensive guidelines to assist customers across diverse fields. By following these guidelines, you can seamlessly select our product and seamlessly integrate it into your applications.



#### 1.3.1. Select the model

##### Specify your application

Evaluate your application based on the following instructions:

- Evaluate hardware dimensions for your system  
> [Hardware dimensions of CH10X](#)
- Choose RS-232 or USB or CAN electrical interface  
> [Electrical specifications of CH10X series](#)

##### Application Scenarios

The Ch10X series, which includes CH104 and CH108, shares identical design and hardware specifications. The key distinction lies in their fusion performance, which significantly impacts the accuracy of output data.

##### 1. CH104:

- **Accuracy:** Normal
- **Application Scenarios:** Well-suited for machine monitoring, vehicles, agricultural robots, and automatic robots.
- 

##### 2. CH108:

- **Accuracy:** High
- **Application Scenarios:** Ideal for professional precision-level applications, including robot applications, acceleration measurements, and angular velocity measurements that demand stringent specifications. CH108 offers superior accuracy and reduced error compared to CH104.

> [Compare the performance](#)

#### 1.3.2. Purchase

Select your preferred sensor model and connection cable (CH10X series sensors need to select the corresponding connection cable according to the electrical interface), and request a quotation from us.

> [Find CH10X series models](#)

If you need assistance with evaluation and selection, please feel free to ask.

Inquire now: [sltech@ms28.hinet.net](mailto:sltech@ms28.hinet.net)

### 1.3.3. Connection method

Refer to the wiring diagram depending on the electrical interface and cable you choose. Please be careful of your wiring. Although there is power reverse connection protection, incorrectly connecting other pins may still cause damage.

[>View wiring diagram](#)

Once connected, the sensor starts transmitting data.

### 1.3.4. Start using the sensor

#### Quick Start

You can directly download the ANROT-IMU UI tool. As long as you have a Windows/Linux x64 device, you can use it to quickly start recording, observing, and setting sensors.

[>View ANROT-IMU UI tool](#)

#### Platform integration requirements

If you wish to integrate it into platforms like ROS, ROS2, Raspberry Pi, etc., or utilize C and Python languages for receiving and unpacking sensor values across diverse platforms, we offer development examples for your implementation. Please refer directly to the online link provided below:

[> View development SDK](#)

#### Configuration instructions

You can utilize the serial port tool to establish a connection with the COM PORT, enabling you to send commands for configuring sensor functions and receiving packet data from the sensor through the serial port.

Regardless of whether you employ a UI tool or a serial port tool to communicate with the module, you can utilize these configuration commands to adjust the sensor settings to better align with your specific usage scenario.

[> View configuration manual](#)

## 1.4. Order model instruction

Part Number	Name	Specification
CH104	IMU/VRU/AHRS module	6DoF + geomagnetic, 4-array noise reduction, 2.5°/h
CH108	IMU/VRU/AHRS module	6DoF + geomagnetic, 8-array noise reduction, 1.76°/h

You can choose RS232-USB connection cable for the RS-232 output version, which has a built-in conversion chip and can be connected to the product via computer USB.

Cables:

Part Number	Specification	Remark
M8-A to DB9 CAN EX	M8-A Code 6Pin to DB9 and CAN with external power without synchronous.	
M8-A to DB9	M8-A Code 6Pin to DB9 with internal power, Pin 9 = Vcc.	
M8-A to USB	Built-in USB to RS 232 chip or USB to UART (TTL) chip, the chip model is cp2102ncp2102n, users can download the driver by themselves.	

Inquire now: [sltech@ms28.hinet.net](mailto:sltech@ms28.hinet.net)

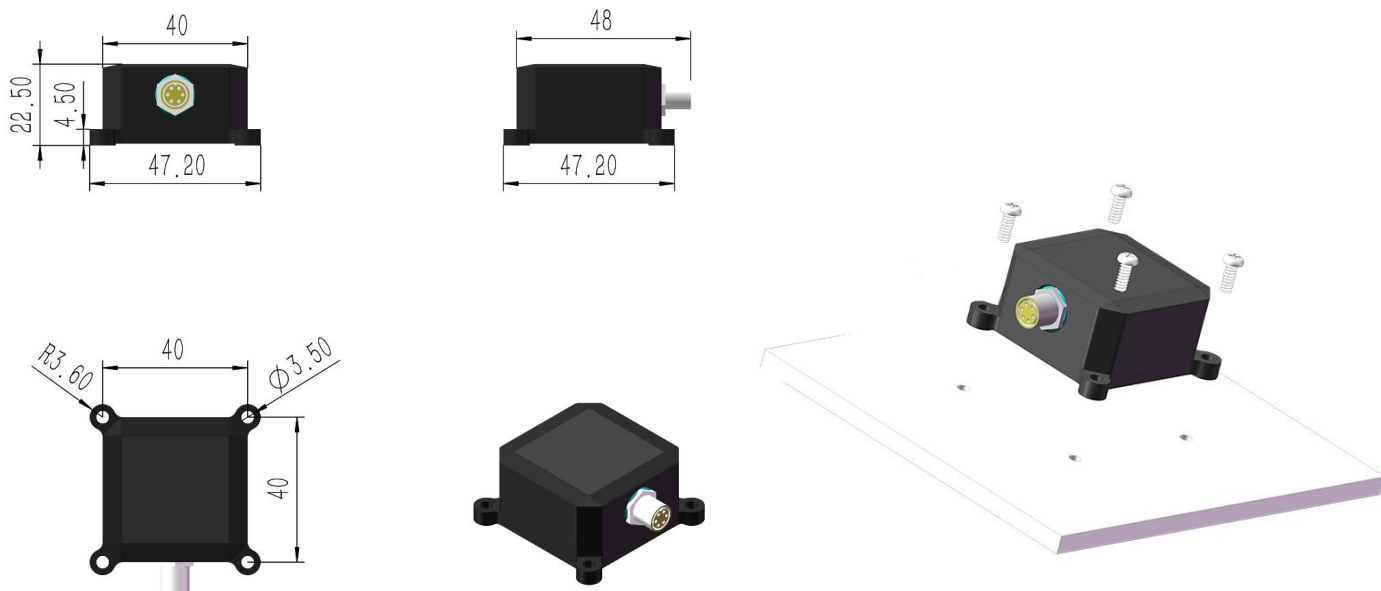
## 2. Specifications and Performance

### 2.1. Hardware Specifications

#### 2.1.1. Dimensions and Installation

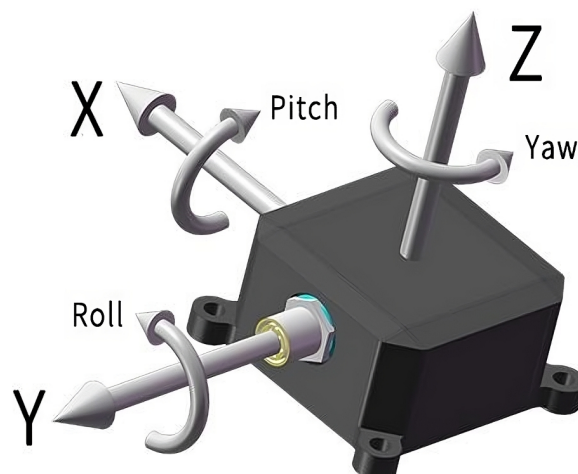
Parameters	CH10X Series
Dimensions	48 X 47.2 X 22.5 mm
Fixing screws	4 X M3 (the screw length needs to be determined according to the user's usage scenario)
Weight	<75g
Shell material	Aluminum
Working temperature	-40-85°C
Storage temperature	-40-85°C
Impact Resistance	2000g
Waterproof rating	IP68

All marking units are in mm. It is recommended that users install the module horizontally and tighten the screws to prevent loosening from affecting the measurement, as shown in the figure below:



For other installation methods, please refer to the "Configuration Manual", "Coordinate System Rotation" chapter

#### Installation coordinate system definition



The installation coordinate system for the CH10X module follows the Euler angle rotation sequence of East-North-Up-312. Let's break down the definition:

**1. Rotation around the Z-axis (Yaw):**

- o Yaw angle ( $\psi$ ) ranges from  $-180^\circ$  to  $180^\circ$ .
- o Represents the rotation about the vertical axis (Z-axis).

**2. Rotation around the X-axis (Pitch):**

- o Pitch angle ( $\theta$ ) ranges from  $-90^\circ$  to  $90^\circ$ .
- o Describes the rotation about the lateral axis (X-axis).

**3. Rotation around the Y-axis (Roll):**

- o Roll angle ( $\varphi$ ) ranges from  $-180^\circ$  to  $180^\circ$ .
- o Corresponds to the rotation about the longitudinal axis (Y-axis).

Imagine the module as an aircraft: consider the positive direction of the Y-axis as the orientation of the aircraft's nose. When the sensor frame aligns with the inertial frame, the ideal Euler angle outputs are as follows:

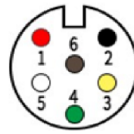
- Pitch =  $0^\circ$
- Roll =  $0^\circ$
- Yaw =  $0^\circ$

**2.1.2. Pin Definitions**

The CH10X module is available in both RS-232 and CAN interfaces. Additionally, we offer a USB version, which comprises the RS-232 module connected via a USB cable. In this configuration, the RS-232 signal is seamlessly converted into a USB signal at the USB interface.

**Important Note:**

- RS-232 and CAN interfaces are **not** compatible with each other due to their distinct electrical characteristics.



Front View

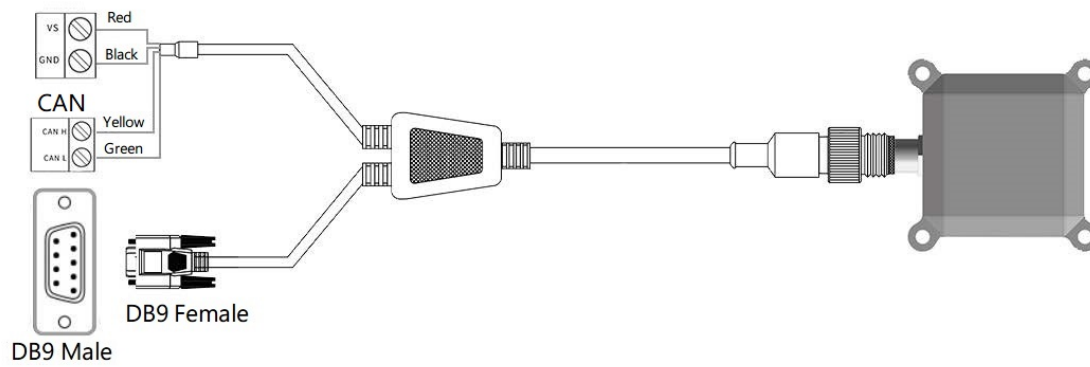
Number	Color	Name	Type	RS-232
1	RED	VCC	Power	Vin+
2	Black	GND	Power	GND
3	Yellow	CAN H	AIO <sub>r</sub>	CAN High
4	Green	CAN L	AIO	CAN Low
5	White	TXD	O	RS-232 signal send
6	Brown	RXD	I	RS-232 signal receive

### 2.1.3. Wiring Diagram

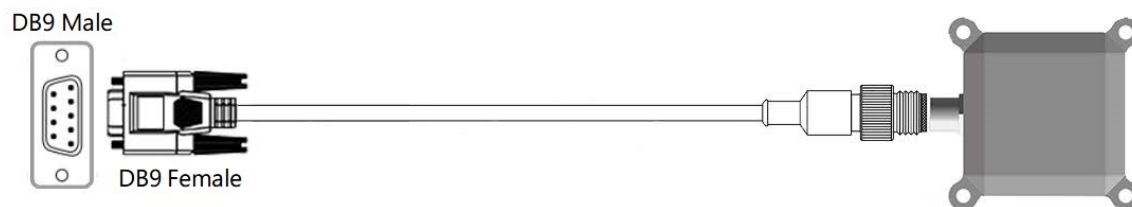
Item	Specification
Material	PUR
Length	1.5 meters

Part Number	Specification
M8-A to DB9 CAN EX	M8-A Code 6Pin to DB9 and CAN with external power without synchronous.
M8-A to DB9	M8-A Code 6Pin to DB9 with internal power, Pin 9 = Vcc.
M8-A to USB	Built-in USB to RS 232 chip, the chip model is cp2102n, users can download the driver by themselves.

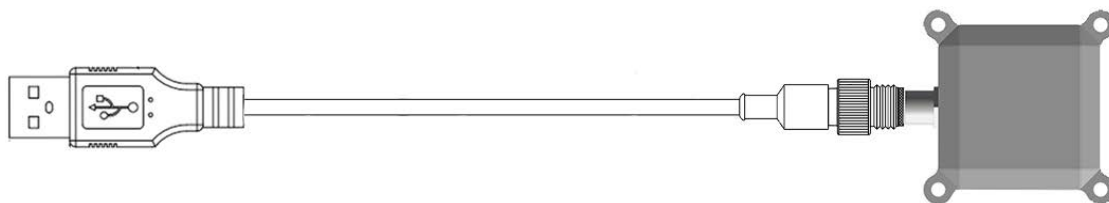
M8-A to DB9 CAN EX



M8-A to DB9, Pin 9 = Vcc



M8-A to USB



## 2.2. Electrical Specifications

### 2.2.1. Common parameters for RS-232 and CAN

Parameter	Condition	Min	Type	Max	Unit	Note
Input voltage	RS-232	5	24	36	V	Compliant with EMC directive 2014/30/EU and equipped with power reverse polarity protection as well as short circuit protection.
	CAN	7	24	36		
	USB	4.9	5	5.5		
Power consumption			<0.6		W	
Operating temperature		-40	25	85	°C	
Startup time				1	s	Startup time denotes the duration from shutdown to when the system begins outputting valid data. The module must remain stationary throughout this period.

### 2.2.2. RS-232

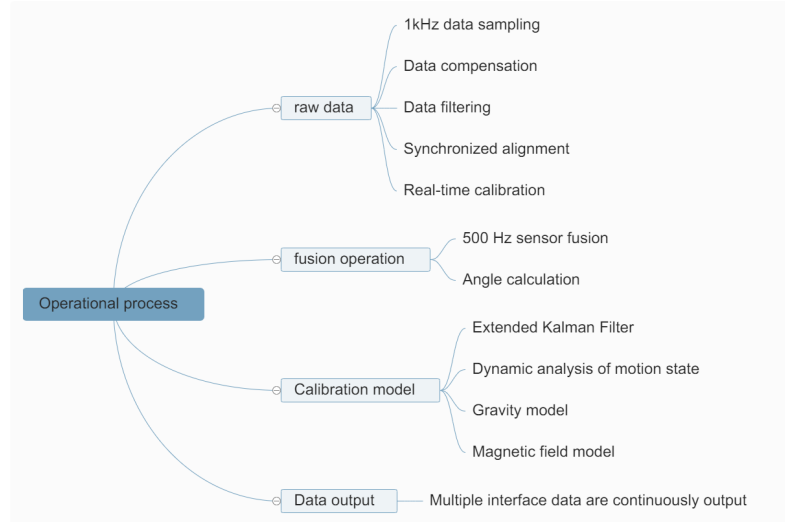
Parameters	Description	Notes
Baud rate	9600/115200/230400/460800/921600 bps (default is 115200)	
Protocol	Private IMU91 Binary Protocol	
Frame rate	5/10/50/100/250/500Hz (default 100)	
Signal input voltage	-15V to 15V	
Signal output voltage	±5.4V	Typical value

### 2.2.3. CAN

Parameters	Description	Remarks
Baud rate	125K/250K/500K/1000K (default 500K)	
Protocol	CANopen	
Frame rate	5/10/50/100/200Hz (default 100)	
Output voltage	CAN H: 2.75 to 4.5V Typical value 3.5V CAN L: 0.5 to 2.25V Typical value 1.5V	
Differential output	1.5 to 3V	
Input voltage	0.9 to 9V	
Differential input threshold	0.5 to 0.9V	
Internal 120Ω resistor	None	

## 2.3. Software Features

We 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.



### Embedded computing system

The sensor subsystem within the CH10X series serves a crucial role in calibrating and compensating raw sensor data, ensuring optimal performance across diverse user scenarios. Here are the key components and functionalities:

#### 1. Raw Data Collection:

- The microcontroller unit (MCU) acquires raw data from the accelerometer, gyroscope, and magnetometer fields at the highest available sampling frequency.

#### 2. Low-Pass Filtering Solutions:

- The CH10X series offers a range of low-pass filtering options to accommodate various user scenarios effectively.

#### 3. Factory Calibration:

- During production, each MEMS IMU (Inertial Measurement Unit) exhibits common errors such as bias, scale factor variations, and cross-axis effects. Additionally, temperature fluctuations impact performance.
- To mitigate these errors, we employ proprietary equipment during manufacturing and testing, ensuring optimal calibration.

#### 4. Coordinate Transformation:

- While we recommend horizontal installation, we recognize that real-world scenarios may require different orientations.
- The sensor's coordinate system can be rotated to align with user-specific installation requirements. Detailed instructions are available in the user configuration section.

#### 5. Online Compensation:

- Upon power-up, users should maintain a static state for one second. During this time, the product automatically collects and calculates the current gyro bias state.
- This compensation enhances gyroscope data accuracy.

#### 6. Geomagnetic Field Real-Time Calibration:

- Our online calibration process supports automatic magnetometer field calibration. Refer to the Magnetometer Calibration section in the Instruction and Programming Manual for specifics.

#### 7. Kalman Fusion Algorithm:

- The processor employs the Extended Kalman Algorithm to perform quaternion-based attitude calculations.
- Using raw data from the accelerometer, gyroscope, and magnetometer, data fusion yields quaternion representations, Euler angles, and other essential fusion information.

Data output type	Data content
Raw data	Acceleration, Angular Velocity, Temperature, ID, etc.
Fusion data	Euler angles (pitch, roll, yaw), Quaternions

#### 8. Dynamic analysis of motion state

- 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.

## 2.4. Output Data Specifications

### Attitude angle range

Attitude angle range	
Pitch	±90°
Roll	±180°
Heading (Yaw)	±180°

Parameter	Specification
Pitch	±90°
Roll	±180°
Heading (Yaw)	±180°
Resolution	0.01°

### Attitude angle accuracy

Parameter	CH104	CH108
Pitch/Roll (static)	0.1°	0.1°
Pitch/Roll (Dynamic)	0.1°	0.1°
Static drift of heading angle (6DOF) <sup>①</sup>	<0.12°/h	<0.12°/h
Dynamic drift error of heading angle (6DOF) <sup>②</sup>	5°	3°
Dynamic drift error of heading angle (with geomagnetic assist, 9-axis mode) <sup>③</sup>	2°	2°
Rotation error of heading angle (6DOF) <sup>④</sup>	<0.8°	<0.8°

① Measured when the module is absolutely stationary at 25°C for 1 hour

② Measured when the module moves on an indoor cleaning robot for 1 hour, room temperature is 25°C, 1 $\sigma$

③ After geomagnetic calibration, measured at room temperature 25°C without magnetic field interference around, the product needs to be configured in 9-axis mode

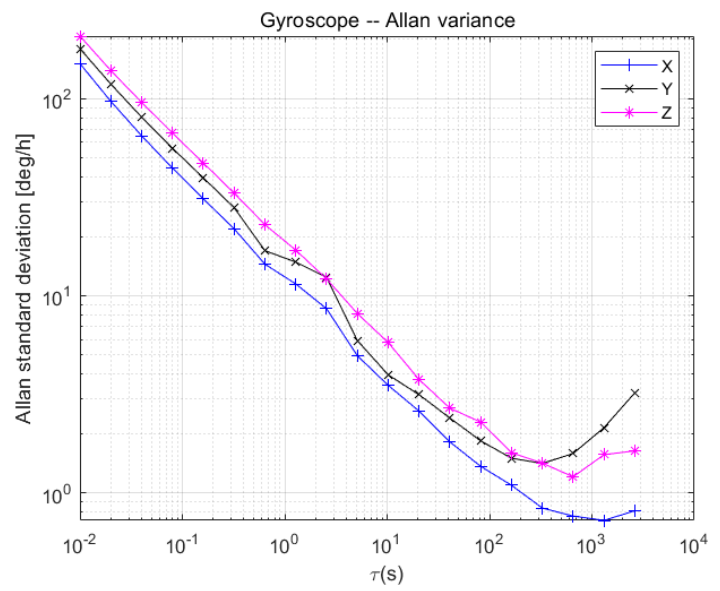
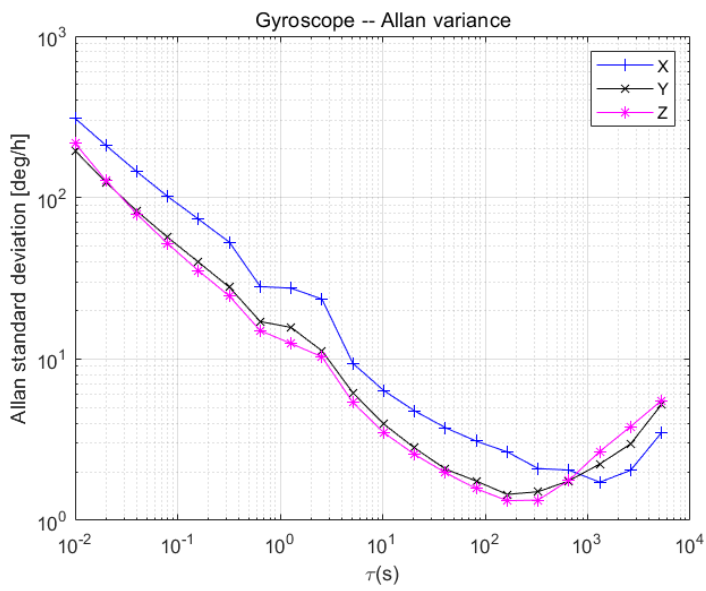
④ The turntable rotates continuously for 10 turns, 100°/s, the cumulative error of the heading angle, room temperature is 25°C

Gyro

Parameter	Condition	Product	Min	Type	Max	Unit	Note
Range				2000		°/s	
Resolution				16bit			
Proportional factor	100°/s	CH104 CH108		<300 <300	350 300	ppm	Rotate on the turntable 10 times, and average the measurement
Nonlinearity	Best-fit straight line Fs=2000°/s		-0.05	-	0.05	%Fs	Maximum deviation from the best-fit straight line within the specified range
3dB bandwidth				116		Hz	
Sampling rate				1000		Hz	
Bias instability	Allan Variance	CH104 CH108		2.5 1.76		°/h	Average value of test sample
Offset repeatability	Allan Variance	CH104 CH108		0.05 0.03		°/s	Test sample average
Angle random walk	Allan Variance	CH104 CH108		0.3 0.21		°/√h	Test sample average
Zero bias within -40 to 85°C	Z Y X			0.015 0.05 0.03	0.035 0.18 0.08	°/s	Measured on the laboratory thermostat turntable, the temperature rise slope is less than 5°C/min

Gyroscope Allan variance.

Left:CH104 / Right:CH0108

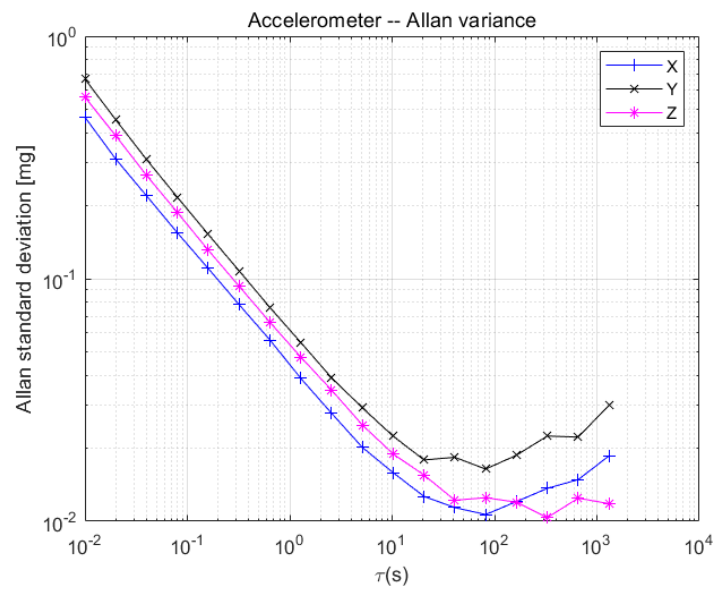
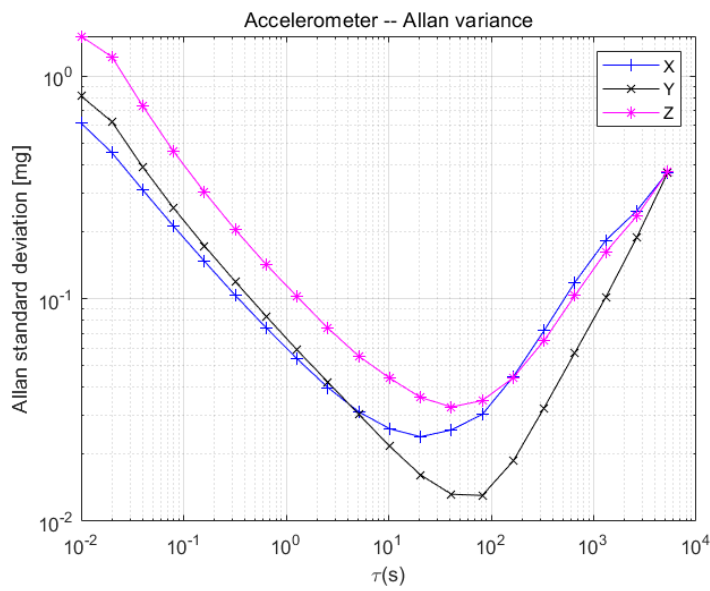


**Accelerometer Parameters**

Parameter	Condition	Product	Min	Type	Max	Unit	Note
Measuring range				12		g	1g = 1x gravity
Resolution				16bit			
Initial zero offset					10	mg	
Nonlinearity	Best-fit straight line Fs=3g			0.5		%Fs	Maximum deviation from the best-fit straight line within the specified range
3dB bandwidth				145		Hz	
Sampling rate				1600		Hz	
Zero bias stability	Allan Variance	CH104 CH108	30 21			ug	Average value of test samples
Zero bias repeatability	Allan Variance	CH104 CH108	1.5 0.6			mg	Average value of test samples
Random walk	Allan Variance	CH104 CH108	0.04 0.028			m/svh	Average value of test samples
Zero bias within -40 to 85°C				1	2.5	mg	Measured on the laboratory thermostat turntable, the temperature rise slope is less than 5°C/min

**Accelerometer Allan variance**

Left:CH104 / Right:CH0108



**Magnetic sensor parameters**

Parameters	CH104/CH108
Measuring range	±8G(Gauss)
Nonlinearity	±0.1%
Resolution	0.25mG

## 3. Other Functions

### 3.1. Geomagnetic Calibration Algorithm (Only used in 9-axis mode)

#### 3.1.1. Architecture

The **CH10X module** incorporates an active geomagnetic calibration system that operates seamlessly without user operation. Here's how it works:

##### 1. Automatic Data Collection:

- In the background, the system continuously collects geomagnetic field data over time.
- It analyzes and compares this data, eliminating any abnormal readings.
- Once sufficient data is acquired, the system attempts geomagnetic calibration.

##### 2. User Intervention Not Required:

- When using the **geomagnetic assist (9-axis) mode**, calibration occurs automatically.
- However, the module provides an interface for users to check the current calibration status.

##### 3. Calibration Premise:

- The module must undergo sufficient attitude changes and maintain these positions for a specific duration.
- This allows the internal calibration system to collect geomagnetic field information across different postures.

##### 4. Avoid Static State:

- Geomagnetic calibration cannot be performed when the module remains static.

#### 3.1.2. Initial Calibration Operations:

##### 1. Check for Interference:

- Assess the surroundings for magnetic field interference.
- Common sources include iron-containing tables, computers, motors, and mobile phones.
- Ideally, take the module outdoors. If not possible, keep it at least **0.5 meters away** from interference sources.

##### 2. Rotation Procedure:

- Rotate the module within a small range (no specific position, just rotation).
- Ensure each axis completes at least **360° of rotation**.
- This process typically completes the calibration.
- If calibration fails, it indicates significant geomagnetic interference in the vicinity.

##### 3. Installation Location Change:

- If the customer relocates the module after the initial calibration (for instance, if it was calibrated separately but is now installed on the target device), recalibration is necessary.
- Ensure that the target device accompanies you during recalibration to account for the new installation context.

##### 4. Viewing Geomagnetic Calibration Parameters:



- Send **LOG MAGCONFIG** command to access and review the geomagnetic calibration parameters. This command provides essential information related to the calibration process.

```
1 | MAG BIS:
2 | 0.029
3 | -22.062
4 | 11.926
```

If MAG BIS is a 3x1 vector that is not all 0, it means that the geomagnetic calibration is successful. If MAG BIS is all 0, it means that the geomagnetic calibration is unsuccessful. Please return to 1 and start the calibration step again.

#### 3.1.3. Common Geomagnetic Interference Classification

Geomagnetic interference can be divided into space magnetic field interference and magnetic field interference in the sensor coordinate system, as shown in the following figure:

Distortions that move with the sensor	Distortions that do not move with the sensor
	
<ul style="list-style-type: none"> <li>• Calibration errors</li> <li>• Hard iron effects</li> <li>• Soft iron effects</li> <li>• Etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Spatial distortions</li> <li>• Temporal distortions</li> <li>• Etc.</li> </ul>

### Space Magnetic Field Interference: Understanding Fixed Geomagnetic Disturbances

Space magnetic field interference remains constant in the world coordinate system and does not vary with the sensor's posture. Let's delve into the details:

#### 1. Interference Sources:

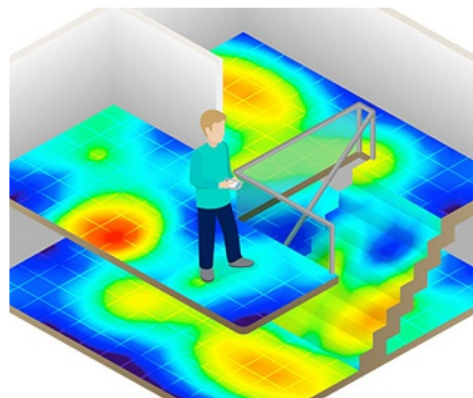
- These sources are fixed and do not move alongside the sensor.
- Examples include:
  - Fixed geomagnetic interference sources.
  - Furniture.
  - Household appliances.
  - Connecting wires.
  - Steel structures within buildings.

#### 2. Impact:

- Space magnetic field interference affects the sensor's accuracy.
- These disturbances persist regardless of the sensor's orientation.

#### 3. Indoor Scenario:

- In typical indoor environments, various fixed interference sources contribute to the overall magnetic field distribution.
- The accuracy of geomagnetic measurements depends on the degree of distortion caused by these fixed sources.



### 3.1.4. Geomagnetic Interference and Countermeasures

#### 1. Space Magnetic Field Interference (Uneven Environmental Fields):

- Impact
  - Regardless of sensor calibration, spatial magnetic fields (including uneven environmental fields) cause distortion in the geomagnetic field.
  - Incorrect geomagnetic compensation results in inaccurate heading angles.
  - This challenge is particularly pronounced in indoor environments.
- Countermeasure
  - **Avoidance:** Efforts should focus on minimizing exposure to such interference sources.

#### 2. Interference in Sensor Coordinate System (Posture-Dependent Interference):

- Definition
  - Interference sources move in tandem with the sensor's motion.
  - These sources (e.g., PCB boards, instruments) are fixed alongside the module and behave as part of the same rigid body as the magnetic sensor.
- Impact
  - Such interference introduces hard magnetic or soft magnetic effects to the sensor.
  - These effects can disrupt accurate geomagnetic measurements.
- Countermeasure

- Geomagnetic Calibration
  - Perform calibration specifically to address this type of interference.
  - Calibration algorithms effectively eliminate unwanted effects caused by fixed interference sources.

### 3.1.5. Precautions for Using Geomagnetism

When operating in indoor environments, magnetic interference becomes particularly pronounced. Unfortunately, space magnetic interference cannot be entirely eliminated through calibration. Although the module incorporates a built-in homogeneous magnetic field detection and shielding mechanism for indoor use, the accuracy of the **geomagnetic assist (9-axis) mode** heading angle heavily relies on the degree of indoor magnetic field distortion.

Here are some key considerations:

#### 1. Indoor Magnetic Field Environment:

- If the indoor magnetic field environment is unfavorable (e.g., near computers, laboratories, workshops, or underground garages), even after calibration, the heading angle accuracy may not match that of the 6-axis mode. Large angle errors could occur.

#### 2. Fixed Magnetic Field Interference:

- The module's automatic geomagnetic calibration system effectively handles fixed magnetic field interference that is present during installation.
- However, if magnetic field interference exists in the installation environment, it must be addressed:
  - Fix the interference source.
  - Ensure that the distance between the interference magnetic field and the module remains constant post-installation.
  - Example: If the module is installed on a metallic robot, both the robot and the module should be rotated and calibrated together.
  - Avoid separating the module from the robot during use to prevent relative displacement. If separation occurs, recalibration is necessary.