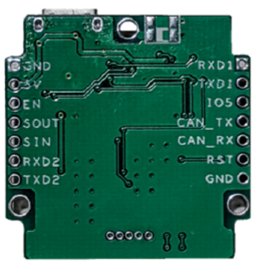
CH100 User Manual

IMU/VRU/AHRS Attitude Measurement Module, Rev 1.0

Chip version

USB Module version



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Introduction

CH100 is an inertial measurement unit (IMU) with high performance, small size and low latency. This product integrates a three-axis accelerometer, a three-axis gyroscope and a microcontroller. It can output the three-dimensional azimuth data based on local geographic coordinates calculated by the sensor fusion algorithm, including the absolute reference heading angle, pitch angle and roll angle. The calibrated raw sensor data can also be output.

CH100 can measure the motion of unmanned vehicle (AGV) and robot chassis, provide inertial positioning reference, improve positioning accuracy and reliability, output real-time measured attitude angle information, and then calculate the spatial position of the chassis. It can complement laser radar or QR code navigation, enhance positioning accuracy in narrow spaces, and reduce dependence on external reference objects.

typical application:

- Robot/AGV DR SLAM application/vehicle measurement attitude detection
- IMU for driverless/integrated navigation

Main Features

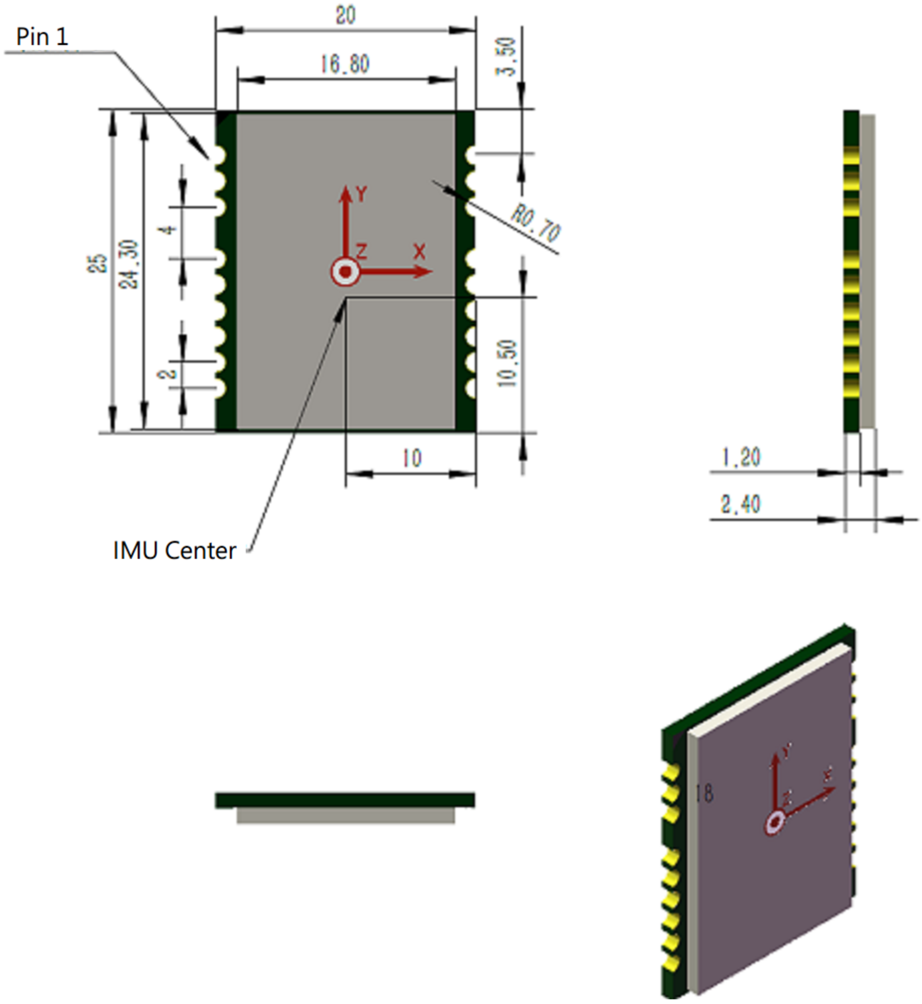
- Small surface mount package: Dimensions: 20 x 25 x 3mm
- On-board sensors: 3-axis gyroscope, 3-axis accelerometer, 3-axis magnetic field sensor, barometric pressure sensor
- Strong anti-vibration performance, no magnetic field interference in 6-axis mode.
- Gyro bias stability: 2.5°/h
- Data output: It can output raw acceleration, angular velocity, attitude angle calculated by the module, quaternion, timestamp and other data. Maximum output frame rate: 400Hz
- Communication interface: TTL serial port, CAN interface (CANopen protocol), multiple parameters can be configured, provide complete Linux/ROS/MCU driver code
- PC-side host computer program, providing real-time data display, waveform, calibration and excel data recording and filter analysis functions

Hardware and interface parameters

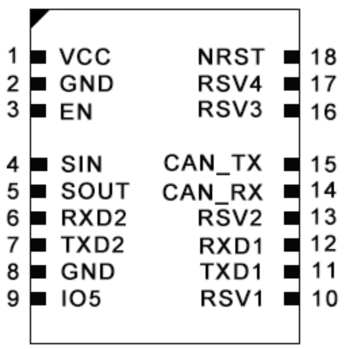
Hardware parameters

Parameters	Description
Output data interface	TTL serial port (1.8V - 5.0V)
Operating Voltage	3.3 - 5V
Working current	<50mA(5V)
Temperature Range	-20℃ - 85℃
Dimensions	20 x 25 x 3mm (W x L x H)

Dimensions and geometric center position



Interface Definition



pin number	name	description
1	VCC	Power 3.3V
2	GND	GND
3	EN	Enable Active high, internal pull-up, can be left floating
4	SYNC_IN	Data input synchronization: Internal pull-up, when the module detects a falling edge, it will output a frame of data. It needs to be suspended when not in use
5	SYNC_OUT	Data output synchronization, internal pull-up, high level (idle) when there is no data output, low level when a frame of data starts to be sent, and return to high level (idle) after a frame of data is sent). It needs to be suspended when not in use
6	RXD2	Reserved, must be left floating
7	TXD2	Reserved, must be left floating
8	GND	GND
9	IO5	Reserved, must be left floating
10	RSV1	Reserved, must be left floating
11	TXD1	Module serial port send UART TXD (connected to MCU's RXD)
12	RXD1	Module serial port receive UART RXD (connect to MCU's TXD)
13	RSV2	Reserved, must be left floating
14	CAN_RX	CAN_RX
15	CAN_TX	CAN_TX
16	RSV3	Reserved, must be left floating
17	RSV4	Reserved, must be left floating
18	NRST	Reset, internal pull-up. >10uS low level reset module. No external resistors and capacitors are required, it is recommended to connect to the GPIO pin of the MCU for software reset

Coordinate system definition

The carrier system uses the right-front-up (RFU) coordinate system, and the geographic coordinate system uses the east-north-sky (ENU) coordinate system.

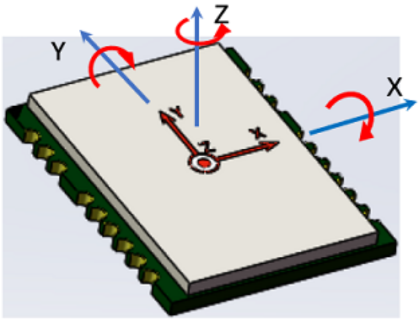
The acceleration and gyroscope axes are shown in the figure below.

The rotation order of Euler angles is east-north-day-312 (the Z axis is rotated first, then the X axis is rotated, and the Y axis is finally rotated). The specific definitions are as follows:

- Rotate around the Z axis: Yaw\Yaw\psi(ψ) Range: -180° - 180°
- Rotate around the X-axis: Pitch\Pitch\theta(θ) Range: -90°-90°

- Rotate around the Y axis: Roll angle\Roll\phi(ϕ) Range: -180°-180°

If you think of the mod as an aircraft. The positive direction of the Y axis should be regarded as the direction of the machine head. When the sensor frame coincides with the inertial frame, the ideal output of Euler angles is: Pitch = 0°, Roll = 0°, Yaw = 0°



Performance metrics

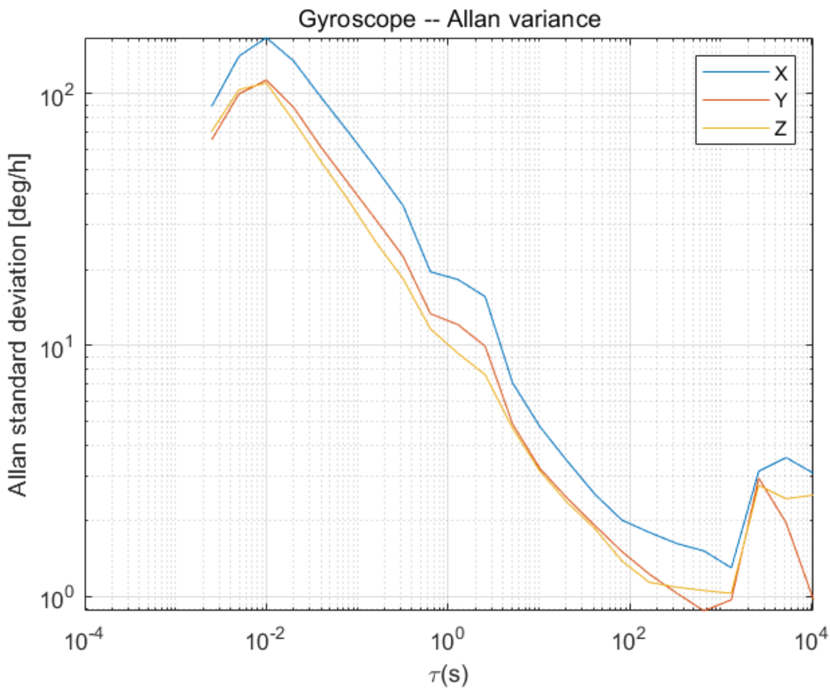
Attitude angle output accuracy

Attitude Angle	Typical	Remarks
Roll\Pitch - Static Error	<0.2°	Static
Roll angle \ pitch angle - dynamic error	<0.8°	Low maneuvering motion, no long acceleration and deceleration behavior
Heading Angle	<1° (within 1h)	Stationary
Heading angle	<8° (within 0.5h)	6-axis mode, low maneuvering motion, no long-term acceleration and deceleration
Heading angle	<2°	9-axis mode, the surrounding magnetic field is clean and geomagnetically calibrated

Gyro

Parameters	Values	Remarks
Measuring range	±500°/s	
Division frequency	0.01°/s	
Internal sampling frequency	1KHz	
Bias stability	2.5°/hr	@25°C,1σ
Zero Bias Repeatability	0.05°/s	@25°C,1σ
Non-orthogonal error	±0.1%	@25°C,1σ
Random walk	$0.3^{\circ}/\sqrt{hr}$	@25°C,1σ
Scale Nonlinearity	±0.1%	at full scale (max)
Scale factor error	±0.4%	After factory calibration
Acceleration Sensitivity	0.1°/s/g	

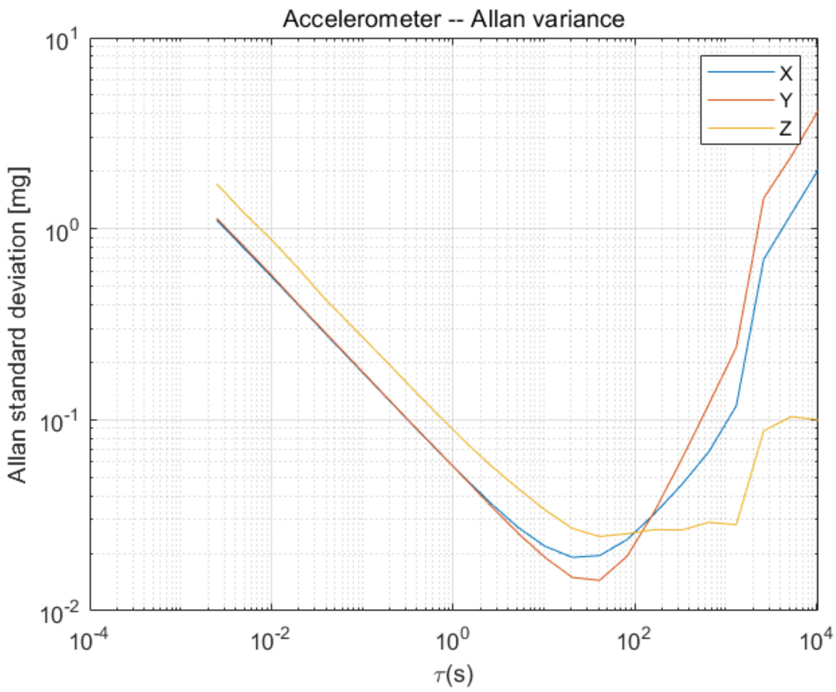
Gyro Allan Variance Curve



Accelerometer

Parameters	Values	Remarks
Measuring range	±8G (1G = 1x gravitational acceleration)	
Resolution	1uG	
Internal sampling frequency	1KHz	
Zero Bias Stability	30uG	@25°C,1σ
Zero Bias Repeatability	1.8mG	@25°C,1σ
Non-orthogonal error	±0.1%	±0.1%
Random walk	0.04$m/s\sqrt{h}$	@25°C,1σ
Scale factor error	±0.3% (at full scale)	After factory calibration
Full temperature range temperature change	2mg	-20 - 85°

Acceleration Allan variance curve



Magnetic sensor parameters

parameter	value
Measuring range	±8G(Gauss)
Nonlinearity	±0.1%
Resolution	0.25mG

Barometer parameters

parameter	value
Measuring range	300 - 1200 hPa
Resolution	± 0.006 hPa (or ±5 cm)
Accuracy	± 0.06 hPa (or ±50 cm)
Internal sampling frequency	64Hz

Module data interface parameters

parameter	value
Serial port output baud rate	9600/115200/460800/921600 optional
Frame output rate	1/50/100/200/400Hz optional
Startup time	<2.5s
Maximum output rate	400Hz raw data (acceleration, gyroscope, attitude angle), 100Hz magnetic field raw data, 64Hz barometer data

Calibration

Factory calibration

Accelerometers and gyroscopes are calibrated at the factory, and these calibrated errors include scale factor, bias, non-quadrature errors, and temperature. Calibration parameters will be written inside the module.

Start calibration

In order to obtain better performance of the module, we also provide users with the function of automatic calibration after power-on, which requires the user to keep the level stationary for 1s during the power-on process, so that more accurate zero-bias parameters can be obtained. Our unique startup algorithm can effectively avoid the power-on bias calculation error of the module, and give full play to the performance of the module.

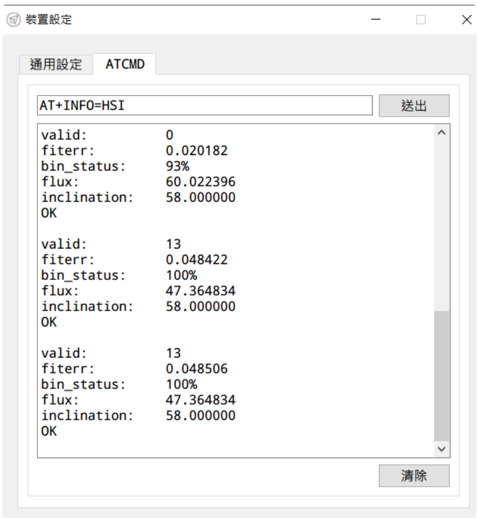
Magnetometer Calibration

The geomagnetic sensor is calibrated by ellipsoid before leaving the factory, but the magnetic sensor is easily disturbed by the magnetic field of the external environment. Generally, the customer needs to recalibrate after getting the product.
The module has its own active geomagnetic calibration system. The system does not require users to send any instructions. The system automatically collects magnetic field data in the background for a period of time, analyzes and compares it, and

eliminates abnormal data. Once the data is sufficient, it will try geomagnetic calibration. Therefore, when using the 9-axis mode, the geomagnetic calibration can be completed without any user intervention. But the module still provides an interface for the user to check the current calibration status. The premise of automatic calibration is that the module needs to have sufficient attitude changes and maintain it for a certain period of time. The internal calibration system can collect geomagnetic field information at different attitudes to complete the calibration. Geomagnetic calibration cannot be performed in a static state.

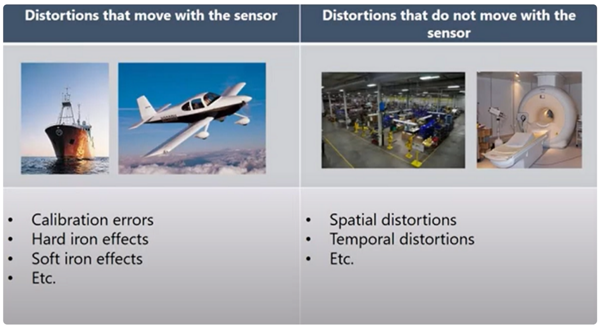
When using the module for the first time and need to use the 9-axis mode, the following calibration operations should be performed:

1. Check whether there is magnetic field interference around: indoor tables and large iron frame structures are common interference areas. It is recommended to take the module to an open space outdoors. Even if there is no condition to take it outdoors, try to keep the module away from (>0.5m) laboratory desks, computers, motors, mobile phones and other objects that are prone to geomagnetic interference.
2. In the smallest possible range (the position does not move, just rotate), slowly rotate the module, and let the module experience as many posture positions as possible (each axis rotates at least 360° for about 1 minute). In general, the calibration can be completed. If the module has not been successfully calibrated, it means that the surrounding geomagnetic field interference is relatively large.
3. The success of the calibration can be checked by AT command: send `AT+INFO=HSI` command, the module will print the current state of the geomagnetic calibration system, as shown in Figure 4-1: here you only need to care about the fiterr item : Below 0.03, the calibration result is good enough. If fiterr is always > 0.1, it means that the geomagnetic interference is very large, and it needs to be calibrated again to get better calibration results. Fit residuals grow slowly over time.
4. Although the geomagnetic parameter estimation can automatically collect data online, the geomagnetic calibration parameters are automatically and dynamically fitted. However, if the surrounding geomagnetic environment changes (for example, it needs to switch to another room or indoor and outdoor, or the module is installed/welded to a new environment), steps 1-3 need to be repeated.
5. Although the geomagnetic calibration does not need to be started or stopped manually, the module automatically runs the system in the background, but the user can still manually control whether the geomagnetic calibration system is turned on or off, use `AT+MCALCTL=0` to close the geomagnetic calibration system, use `AT+MCALCTL=1` to start the geomagnetic calibration system, the command will take effect immediately and will be stored after power-off. The user can use `AT+INFO=HSI` to judge the calibration quality after turning on the geomagnetic calibration. Once the calibration is successfully completed, use `AT+MCALCTL=0` to close the calibration system and lock the calibration value. Under normal circumstances, as long as the calibration is successful once in the non-magnetic area, there is no need to calibrate again later.
6. If the installation location of the customer changes (for example, the last calibration was done with the module alone, but it is installed on the target device when it is used). You will need to recalibrate with the target device.



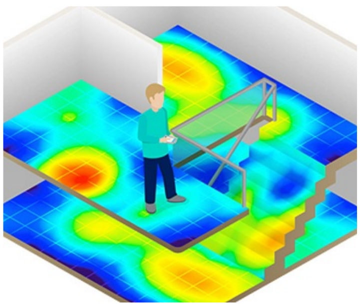
Magnetic Interference Classification

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



Space magnetic field interference (interference does not change with sensor pose changes)

Definition: Magnetic field interference does not move with the movement of the sensor, and is in the world coordinate system
Typical interference sources: various fixed geomagnetic interference sources, furniture, household appliances, cables, reinforced structures in houses, etc. All interference sources that do not move with the movement of the magnetic sensor. The following figure is a typical indoor magnetic field distribution diagram.



Impact on the module: No matter whether the magnetic field sensor is well calibrated or not, the interference of these space magnetic fields (or the uneven environmental magnetic field) will distort the space geomagnetic field. The geomagnetic compensation will be wrong and the correct heading angle cannot be obtained. They are the main reason why indoor geomagnetic fusion is difficult to use. This disturbance cannot be calibrated and can seriously affect the geomagnetic performance. Space magnetic field interference is especially serious

indoors.
Countermeasures: Only try to avoid this source of interference

Interference in the sensor coordinate system (interference changes with the sensor pose)

Definition: The geomagnetic field disturbance source moves with the movement of the sensor
Typical sources of interference: PCB boards, instruments, products, etc. that are fixed with the module. They and the magnetic sensor are regarded as the same rigid body and move with the movement of the magnetic sensor.
Effects on modules: Hard/soft magnetic interference to sensors. These disturbances can be well eliminated by the geomagnetic calibration algorithm.
Countermeasures: Perform geomagnetic calibration on the module.

Geomagnetic usage precautions

In the indoor environment, the spatial magnetic interference is particularly serious, and the spatial magnetic interference cannot be eliminated by calibration. In an indoor environment, although the module has a built-in homogeneous magnetic field detection and shielding mechanism, the accuracy of the heading angle of the 9-axis mode largely depends on the degree of indoor magnetic field distortion. , workshop, underground garage, etc.), even after calibration, the heading angle accuracy of 9-axis may not be as good as that of 6-axis mode or even large angle errors.

The module's automatic geomagnetic calibration system can only deal with the fixed magnetic field interference installed with the module. If there is magnetic field interference in the installation environment, the interference must be fixed, and the distance between the interference magnetic field and the module will not change after installation (for example: the module is installed on an iron material, because iron will have magnetic field interference, At this time, the iron and the module need to be rotated and calibrated together, and the iron will not be separated from the compass during use (relative displacement occurs). Once separated, it needs to be re-calibrated. If the size of the iron is not fixed, or The distance change from the compass is not fixed, and this kind of interference cannot be calibrated. Even if the calibration is successful, the accuracy will be very poor, so it can only be installed away from it, and the safe distance should be controlled at more than 50cm).

case analysis

Assuming that the customer wants to use the 9-axis mode on the mobile robot to obtain an accurate heading angle without drifting, the module is installed on the robot (as a rigid body), due to the metal structure (components, circuits) of the robot itself, there will be a large Hard magnetic interference is equivalent to the "interference in the sensor coordinate system" mentioned above. This part of the disturbance can be calibrated out. Due to the start and stop of the robot's motor and the change of the space magnetic field caused by the magnetic interference of the robot passing through various rooms indoors, the "space magnetic field interference" mentioned above will occur. This part of the disturbance cannot be calibrated. There is a high possibility that the two kinds of disturbances exist at the same time, which poses a great challenge to the 9-axis mode. At this time, it is recommended that customers use the 6-axis mode. If the 9-axis mode must be used, the following points should be done:

1. Calibration: It must be calibrated with the robot (the robot is small enough). It is not correct to take the module off and calibrate it and then install it. The robot and the module must be regarded as a rigid body to be calibrated to get the correct calibration result. For the specific calibration process, please refer to the above. After the calibration is successful, power on (reset) again to take effect.
2. Due to the complex indoor magnetic environment, even if the calibration is completed correctly, there may still be a large route error, especially when the motor starts and stops, and the power changes, which has a huge impact on the magnetic field.

> If the application does not require a geomagnetic sensor, the geomagnetic sensor can be ignored. The product is in 6-axis mode by default, that is, the geomagnetic field does not participate in the calculation. It is not recommended to use a 9-axis attitude sensor in the robot industry.

6-axis mode and 9-axis mode

Modes	Use Environment	Typical Applications	Advantages	Disadvantages
6-axis	No need to consider the influence of magnetic field	Unmanned Inclination detection	Attitude angle output stability Good and completely free from magnetic field interference	The heading angle drifts slowly with time without external reference
9-axis	Need to consider the influence of the magnetic field	Compass Northing system	The heading angle will not drift with time Once the geomagnetic field is detected, the heading angle can be quickly corrected Northing	Any magnetic disturbance will degrade the heading angle accuracy. In the case of severe interference, the heading angle cannot point to the correct direction. Sensors need to be calibrated before use
 10-axis supports both 6-axis and 9-axis modes, and can provide users with additional air pressure data

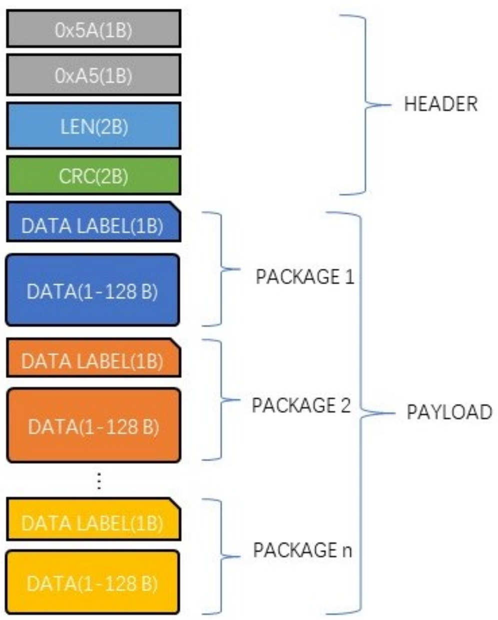
> Products that support geomagnetism will output geomagnetism information no matter what mode it is in. Geomagnetism in 6-axis mode will not participate in the calculation, and geomagnetism in 9-axis mode will participate in the calculation.

Serial port protocol

After the module is powered on, it is preset to output frame data at the factory frame rate (usually 100). The frame format is as follows:

```
Serial port data frame structure:
<frame header (0x5A)><frame type (0xA5)><length><CRC check><data field>
```

field name	value	length (bytes)	description
Frame header	0x5A	1	fixed at 0x5A
Frame Type	0xA5	1	Fixed to 0xA5
length	1-512	2	The length of the data field in the frame, low byte first. Length indicates the length of the data field (excluding frame header，frame type，length，CRC)
CRC Check	-	2	16-bit CRC checksum of all fields (frame header, frame type, length, data field) except the CRC itself. LSB (low byte first)
Data Field	-	1-512	Data carried in one frame. It consists of several **sub-packets**. Each packet contains a packet label and data. The label determines the type and length of the data.



CRC implementation function:

```c
/*
currectCrc: previous crc value, set 0 if it's first section
src: source stream data
lengthInBytes: length
*/
static void crc16_update(uint16_t *currectCrc, const uint8_t *src, uint32_t lengthInBytes)
{
    uint32_t crc = *currectCrc;
    uint32_t j;
    for (j=0; j < lengthInBytes; ++j)
    {
        uint32_t i;
        uint32_t byte = src[j];
        crc ^= byte << 8;
        for (i = 0; i < 8; ++i)
        {
            uint32_t temp = crc << 1;
            if (crc & 0x8000)
            {
                temp ^= 0x1021;
            }
            crc = temp;
        }
    }
    *currectCrc = crc;
}
```

serial port packets

Packet Overview

Packet label	Packet length (including label 1 byte)	Name	Remarks
0x91	76	IMUSOL (IMU data set)	

Product Support Package List

0X91 (IMUSOL)

A total of 76 bytes. Integrate the sensor raw output of the IMU and the attitude solution data.

Byte Offset	Type	Size	Unit	Description
0	uint8_t	1	-	Packet label: 0x91
1	uint8_t	1	-	ID
2	-	2	-	Reserved
4	float	4	Pa	Air pressure (supported by some models)
8	uint32_t	4	ms	Node local timestamp information, accumulated since the system is powered on, increments by 1 every millisecond
12	float	12	1G (1G = 1 gravitational acceleration)	Acceleration after factory calibration, the order is: XYZ
24	float	12	deg/s	Angular velocity after factory calibration, the order is: XYZ
36	float	12	uT	Magnetic strength, order: XYZ
48	float	12	deg	Node Euler angle order is: roll angle (Roll, -180°~180°), pitch angle (Pitch, -90°~90°), heading angle (Yaw, -180 °~180°)
60	float	16	-	Node quaternion set, in order WXYZ

Factory Preset Packets

The factory default definition of packet data carried in a frame is as follows:

Products	Preset Output Packages
CH100	91
CH110	91

Example of data frame structure

The data frame is configured as 0x91 packets

Use the serial port assistant to sample a frame of data, a total of 82 bytes, the first 6 bytes are the frame header, length and CRC check value. The remaining 76 bytes are data fields. Suppose the data is received into the C array `buf`. As follows:

5A A5 4C 00 6C 51 **91** 00 A0 3B 01 A8 02 97 BD BB 04 00 9C A0 65 3E A2 26 45 3F 5C E7 30 3F E2 D4 5A C2 E5 9D A0 C1 EB 23 EE C2 78 77 99 41 AB AA D1 C1 AB 2A 0A C2 8D E1 42 42 8F 1D A8 C1 1E 0C 36 C2 E6 E5 5A 3F C1 94 9E 3E B8 C0 9E BE BE DF 8D BE

- The first step: judge the frame header, get the data field length and frame CRC:

Frame header: 5A A5

Frame data field length: 4C 00: (0x00<<8) + 0x4C = 76

Frame CRC check value: 6C 51: (0x51<<8) + 0x6C = 0x516C

- Step 2: Check CRC

```
    uint16_t payload_len;
    uint16_t crc;

    crc = 0;
    payload_len = buf[2] + (buf[3] << 8);

    /* calulate 5A A5 and LEN filed crc */
    crc16_update(&crc, buf, 4);

    /* calulate payload crc */
    crc16_update(&crc, buf + 6, payload_len);
```

The obtained CRC value is 0x516C, which is the same as the CRC value carried in the frame, and the frame CRC check is passed.

- Step 3: Receive data

The data field of the packet starts from 0x91. In C language, you can define a structure to easily read data:

Define the 0x91 packet structure as follows:

```
__packed typedef struct
{
    uint8_t tag; /* data tag: 0x91 */
    uint8_t id; /* module ID */
    uint8_t rev[2];
    float prs; /* air pressure */
    uint32_t ts; /* timestamp */
    float acc[3]; /* acceleration */
    float gyr[3]; /* angular velocity */
    float mag[3]; /* geomagnetism */
    float eul[3]; /* Euler angles: Roll,Pitch,Yaw */
    float quat[4]; /* Quaternion */
}id0x91_t;
```

`__packed` is a compiler keyword (under Keil), indicating that the structure is tightly aligned by bytes, and each element of the structure corresponds to the structure definition of the 0x91 data packet. When receiving data, you can directly memcpy the received array to the structure: (note that the structure must be aligned with 4 bytes), where `buf` points to the frame header, and `buf[6]` points to the data field in the frame.

```
    /* Receive data and interpret data using 0x91 packet structure definition */
    __align(4) id0x91_t dat; /* struct must be 4 byte aligned */
    memcpy(&dat, &buf[6], sizeof(id0x91_t));
```

Finally get the dat data result:

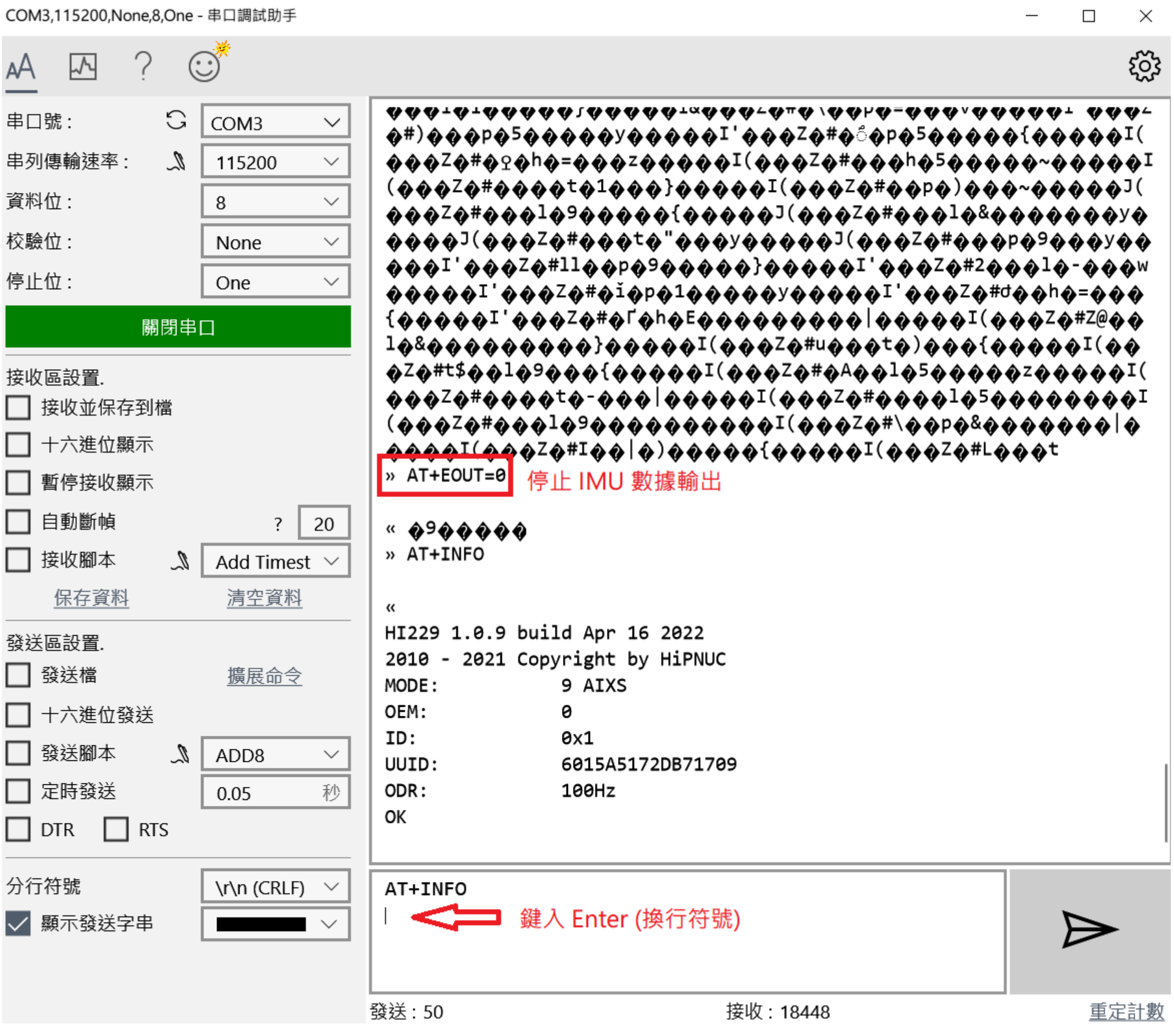
```
id : 0
timestamp : 310205
acc : 0.224 0.770 0.691
gyr : -54.708 -20.077 -119.070
mag : 19.183 -26.208 -34.542
eul(R/P/Y) : 48.720 -21.014 -45.512
quat : 0.855 0.310 -0.310 -0.277
```

AT command

When using the serial port to communicate with the module, the module supports the AT command set to configure/view the module parameters. AT commands always start with the ASCII code `AT`, followed by control characters, and the last end with a carriage return line feed `\r\n`.

Use the host computer to input AT commands:

Use the serial port tuning assistant to test:



General module AT commands are as follows

Command	Function	Power-off storage (Y) Power-off no storage (N)	Immediately effective (Y) Reset effective (R)	Remarks
AT+ID	Set module user ID	Y	R	
AT+INFO	Print Module Information	N	Y	
AT+ODR	Set the module serial port output frame frequency	Y	R	
AT+BAUD	Set serial port baud rate	Y	R	
AT+EOUT	Data output switch	N	Y	
AT+RST	Reset module	N	Y	
AT+TRG	Single output trigger	N	Y	Some models support
AT+SETPTL	Set output packet	Y	Y	Some models support
AT+MODE	Set the working mode of the module	Y	R	Some models support
AT+GWID	Set wireless gateway ID	Y	R	Some models support

AT+ID

Set mod user ID

Example `AT+ID=1`

AT+INFO

Print module information, including product model, version, firmware release date, etc.

AT+ODR

Set the module serial port output rate. Power-off storage, reset the module to take effect

Example Set the serial port output rate to 100Hz: `AT+ODR=100`

Note: When the ODR is set to a relatively high value (such as 200), the preset 115200 baud rate may not meet the output bandwidth requirements. At this time, the module needs to be set to a high baud rate (such as 921600) before the module can press The set ODR output data frame. The output frame rate can be 1, 2, 5, 10, 20, 50, 100, 200, 400Hz.

AT+BAUD

Set serial port baud rate, optional value: 9600/115200/460800/921600`

Example `AT+BAUD=115200`

Notice

- Special attention should be paid to using this command. Entering the wrong baud rate will result in the inability to communicate with the module
- After the baud rate parameter is set, it will be stored after power-off, and the reset module will take effect. The baud rate of the host computer should also be modified accordingly.
- When upgrading firmware, you need to switch back to 115200 baud rate.

AT+EOUT

Serial port output switch

Example Open serial port output `AT+EOUT=1` Close serial port output `AT+EOUT=0`

AT+RST

reset module

Example `AT+RST`

AT+SETYAW

Set the heading angle, the format is `AT+SETYAW=<MODE>,<VAL>`

- MODE=0 Absolute mode: Set the heading angle directly to the value of VAL. For example, `AT+SETYAW=0,90` will directly set the heading angle to 90°
- MODE=1 Relative mode: increment the original heading angle by VAL value. For example, `AT+SETYAW=1,-10.5` increases the heading angle by -10.5°, if the original is 30°, the heading angle becomes 19.5° after sending the command.

AT+MODE

Set the module working mode

example

- Set the module to work in 6-axis mode (non-magnetic calibration) `AT+MODE=0`
- Set the module to work in 9-axis mode (geomagnetic field sensor participates in heading angle correction) `AT+MODE=1`

AT+URFR

This command provides an interface to rotate the sensor XYZ axis, which can be used for vertical installation at any angle.

`AT+URFR=C00,C01,C02,C10,C11,C12,C20,C21,C22`

Where

$$C_{nn} \tag{1}$$

supports floating point numbers

$$\begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}_U = \begin{bmatrix} C00 & C01 & C02 \\ C10 & C11 & C12 \\ C20 & C21 & C22 \end{bmatrix} \cdot \begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}_B \tag{2}$$

Where $\begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}_U$ is the rotated sensor coordinate system Lower sensor data, $\begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}_B$ is the pre-rotation sense Sensor data in the detector coordinate system

Here are some examples of common rotations:

- The coordinate system of the new sensor is rotated 90° around the X axis of the original coordinate system (for vertical installation: the positive direction of the Y axis is downward), enter the command: `AT+URFR=1,0,0,0,0,1 ,0,-1,0`
- The coordinate system of the new sensor is to rotate -90° around the X-axis of the original coordinate system (for vertical installation: the positive direction of the Y-axis is upward), enter the command: `AT+URFR=1,0,0,0,0, -1,0,1,0`
- The coordinate system of the new sensor is rotated 180° around the X axis of the original coordinate system, and input the command: `AT+URFR=1,0,0,0,-1,0,0,0,-1`
- The coordinate system of the new sensor is rotated 90° around the Y-axis of the original coordinate system (for vertical installation: the positive direction of the X-axis is upward), enter the command: `AT+URFR=0,0,-1,0,1, 0,1,0,0`
- The coordinate system of the new sensor is to rotate -90° around the Y-axis of the original coordinate system (for vertical installation: the positive direction of the X-axis is downward), enter the command: `AT+URFR=0,0,1,0,1, 0,-1,0,0`
- The coordinate system of the new sensor is rotated 180° around the Y-axis of the original coordinate system. Input the command: `AT+URFR=-1,0,0,0,1,0,0,0,-1`
- The coordinate system of the new sensor is rotated 90° around the Z axis of the original coordinate system, and input the command: `AT+URFR=0,-1,0,1,0,0,0,0,1`
- The coordinate system of the new sensor is to rotate -90° around the Z axis of the original coordinate system, and enter the command: `AT+URFR=0,1,0,-1,0,0,0,0,1`
- Restore factory defaults: `AT+URFR=1,0,0,0,1,0,0,0,1`

CAN communication protocol

The CAN interface of this product complies with the following standards:

- The CAN interface conforms to the CANopen protocol, all communications use standard data frames, only use PTO1-4 to transmit data, all transmissions use standard data frames, and do not receive remote frames and extended data frames
- All PTOs use asynchronous timing trigger mode.

CANopen Default Settings

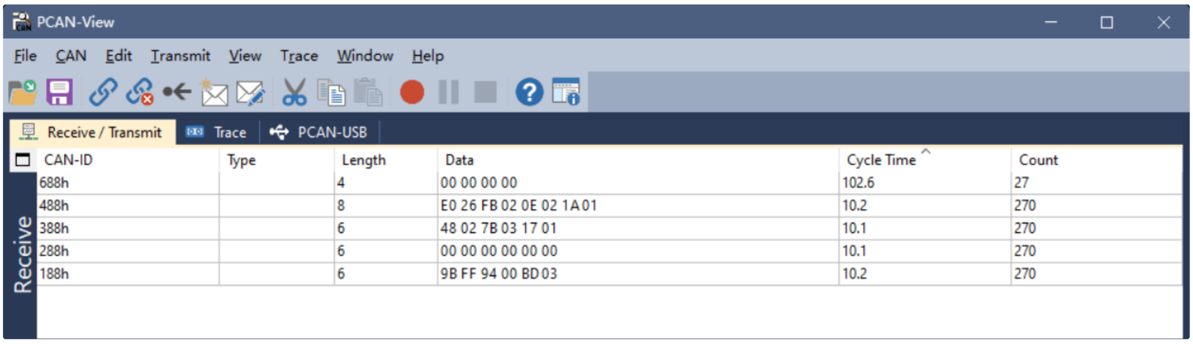
CANopen Default Configuration	Values
CAN Baud Rate	500KHz
CANopen Node ID	8
Initialization State	Operational
Heartbeat Pack	None
TPDO output rate	10Hz - 200Hz (per TPDO)

CANopen TPDO

PTO Channel	PTO Frame ID	Length (DLC)	PTO Transmission Mode	Asynchronous Output Frequency (Hz)	Send Data	Description
TPDO1	0x180+ID	6	Asynchronous timing (0xFE)	100	Acceleration	The data type is (int16, low byte first, 2 bytes per axis, 6 bytes in total), respectively X, Y, Z axis acceleration, the unit is mG (0.001 gravitational acceleration)
TPDO2	0x280+ID	6	Asynchronous timing (0xFE)	100	Angular velocity	Data type is (int16, low byte first, 2 bytes per axis, 6 bytes in total), respectively X, Y, Z axis angular velocity, the unit is 0.1DPS (°/s)
TPDO3	0x380+ID	6	Asynchronous timing (0xFE)	100	Euler angle	The data type is (int16, low byte first, 2 bytes per axis, 6 bytes in total), The order is Roll: Roll, Pitch: Pitch, Yaw: Yaw. The unit is 0.01°
TPDO4	0x480+ID	8	Asynchronous timing (0xFE)	100	Quaternion	q_w q_x q_y q_z respectively. The result after the unit quaternion is expanded by a factor of 10,000. For example, when the quaternion is 1,0,0,0, output 10000,0,0,0.
TPDO5	0x680+ID	4	Asynchronous timing (0xFE)	20	Air pressure	Unit Pa

Use the host computer to connect the CAN device

Using the PCAN-View tool and PCAN-USB, the received CAN message and frame rate can be displayed in the receiving box (Rx Message), as shown in the following figure:



Examples of common commands in CANOpen interface

1. Enable data output (open asynchronous trigger)

To send standard CANopen protocol frames, use the NMT: Start Remote Node command:

ID=0x000,DLC=2,DATA=0x01,0x08

Where 0x01 is the Start Remote Node command, 0x08 is the node ID

2. Configure CAN baud rate, output rate and output frame information

The following location of the data dictionary stores the manufacturer's parameter configuration data, which can be modified by sending fast SDO commands through CANopen, **save when power off, and take effect after power on again.**

data dictionary location	suboffset	name	value type	default value	description
0x2100	0	CAN_BAUD	INTEGER32	500000	CAN bus baud rate
0x2101	0	NodeID	INTEGER32	8	Node ID

The above configuration operations all use fast SDO to write the data dictionary, where the TPDO channel and its corresponding parameter index are:

PTO channel	PTO frame ID	TPDO parameter index address (default definition of CANopen protocol)
TPDO1	0x180+ID	0x1800
TPDO2	0x280+ID	0x1801
TPDO3	0x380+ID	0x1802
TPDO4	0x480+ID	0x1803
TPDO5	0x680+ID	0x1804

Modify CAN baud rate

1. Modify the baud rate:

Modify the CAN baud rate to 125K, then send:

ID=0x608 ,DLC=8,DATA=23,00,21,00,48,E8,01,00(ID=0x608, standard data frame of length 8)

- ID=0x608 is the fast write SDO address, of which 8 is the default node ID. After modifying the node ID, make corresponding changes. For example, after CANopenID is changed to 9, ID=0x609.
- 0x23 write four byte instruction for SDO
- 0x00, 0x21 is write 0x2100 index
- 0x00 sub-index position, default 0
- (4-7)0x00, 0x01, 0xE8, 0x48 = (0x00<<24) + (0x01<<16) + (0xE8<<8) + 0x48 = 125000

Modify the CAN baud rate to 250K, send:

23,00,21,00,90,D0,03,00

Modify the CAN baud rate to 1M and send:

23 00 21 00 40 42 0F 00

2. Re-power on to take effect

Modify Node ID

1. If the device CANopen node ID is changed to 9, send:

ID=0x608 ,DLC=8,DATA=23,01,21,00,09,00,00,00

- 0x23 write four byte instruction for SDO
- 0x01, 0x21 is write 0x2101 index
- 0x09 0x00, 0x00, 0x00 = (0x00<<24) + (0x00<<16) + (0x00<<8) + 0x09 = 9

2. Re-power on to take effect
3. Note: ID modification range: 1-64, after it takes effect, send start node command (for example, node start command data becomes 01 09) and SDO command (send CAN frame ID becomes 0x609), pay attention to the new address

Modify/On/Off data output rate

1. Send the standard CANopen protocol frame and use the standard fast SDO command: (This configuration takes effect immediately)

Modify the output rate of TPDO3 (Eulerian angle) to 20Hz (output every 50ms):

ID=0x608 ,DLC=8,DATA=2B,02,18,05,32,00,00,00

in

- 0x2B write two byte instruction for SDO
- 0x02, 0x18 is to write 0x1802 index,
- 0x05 is the sub-index
- 0x00, 0x32= (0x00<<8) + 0x32 = 50 (unit is ms), add 0 if it is missing.

Modify the TPDO1 (acceleration) output rate to 10Hz (output every 100ms):

2B 00 18 05 64 00 00 00

Modify the TPDO2 (angular velocity) output rate to 5Hz (output every 200ms):

2B 01 18 05 C8 00 00 00

The TPDO output can also be turned off by modifying the output rate (output every 0ms means turning off):

Set the timing output of TPDO2 (angular velocity) to 0

2B,01,18,05,00,00,00,00

Set TPDO1 (acceleration) output rate to 0

2B 00 18 05 00 00 00 00

Set TPDO3 (Eulerian angles) output rate to 0

2B 02 18 05 00 00 00 00

Set TPDO4 (quaternion) output rate to 0

2B 03 18 05 00 00 00 00

2. Re-power on to take effect

Turn on/off site

Nodes can be turned on and off using the NMT commands StartRemoteNode and StopRemoteNode:

- Open node: ID:0,DLC:2,DATA:01 08 where 01 is the command to open the node, 08 is the node ID (factory default is 8)
- Shutdown node: ID:0,DLC:2,DATA:02 08 where 02 is the shutdown node command, 08 is the node ID (factory default is 8)

Configure TPDO to sync mode
First close all TPDOs (set the TPDO output rate to 0) as in Example 4, and then send CANopen synchronization frames:

CANopen sync frame: ID:80 DLC:0, DATA:null

Appendix A - Firmware Upgrade and Factory Reset

This product supports firmware upgrade, and you do not need to upgrade the firmware by yourself under normal use.
Firmware upgrade steps:

- Connect the module, open the host computer, set the baud rate of both the module and the host computer to 115200, and open the firmware update window
- Click the connection button, if the module connection information appears. It means that the upgrade system is ready, click "Open" to select the firmware with the file name .hex, and then click "Write".
- After completion, it will prompt completion, close the serial port at this time, power on the module again, and the module upgrade is complete.