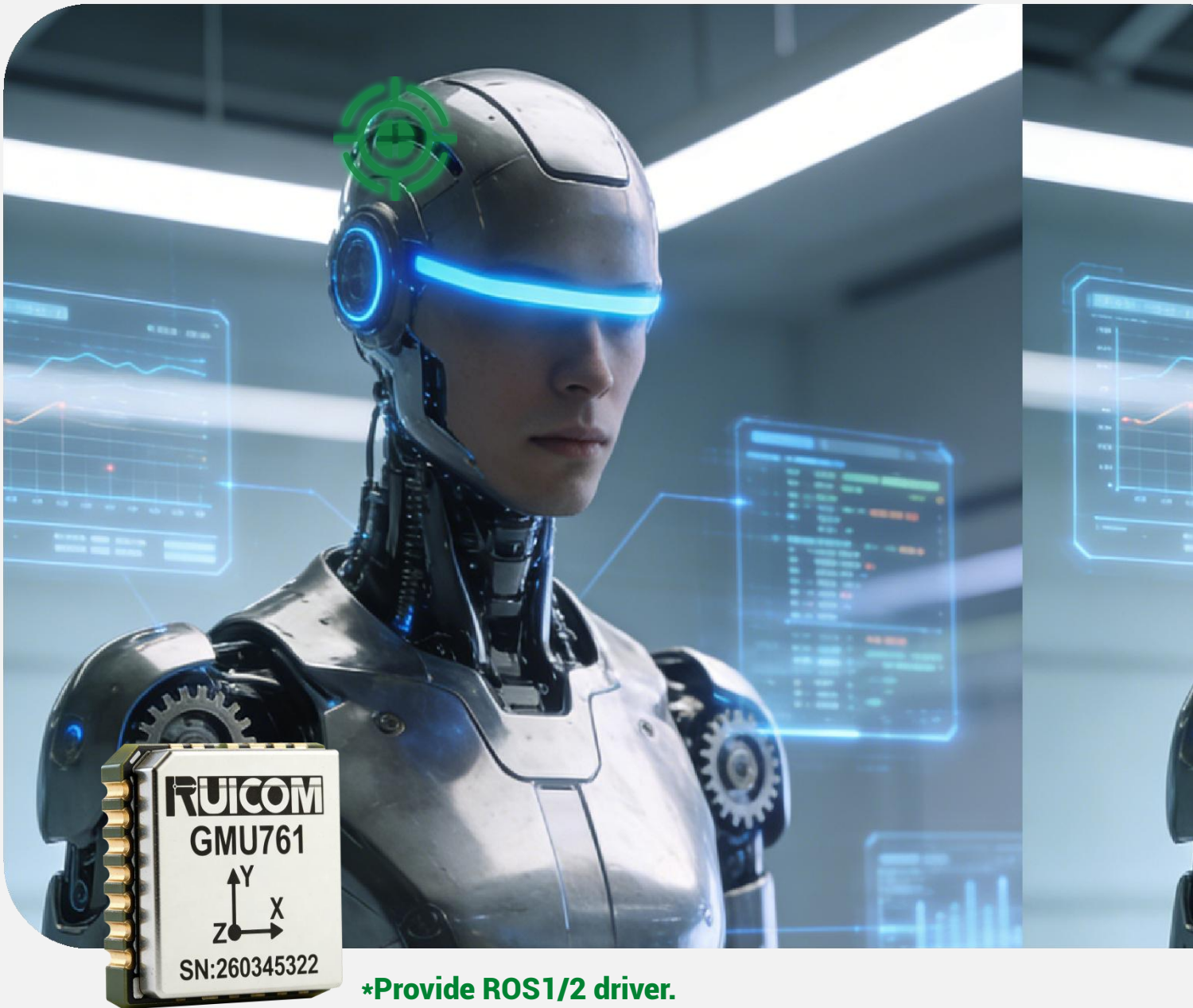




**\*Provide ROS1/2 driver.**

## GMU761 Inertial Measurement Sensor Module

### Product manual

V1.9-20260826

## Technical Characteristics

- ❖ IMU/VRU/AHRS functionality;
- ❖ High dynamic attitude calculation;
- ❖ TTL output;
- ❖ 3.3VDC power supply;
- ❖ Flexible communication and configuration.



## Product Introduction

GMU761 is an inertial measurement module independently developed based on MEMS technology, integrating IMU (Inertial Measurement Unit), VRU (Vertical Reference Unit), and AHRS (Attitude and Heading Reference System) functions into one. The module adopts the adaptive extended Kalman filter algorithm, combined with IMU noise dynamic analysis and carrier motion state recognition technology, which can achieve high-precision attitude output in high dynamic environments and effectively suppress heading angle drift.

Each module has undergone comprehensive error compensation before leaving the factory, covering multiple calibrations such as temperature impact, zero offset, scale factor and cross axis error, to ensure its stability and reliability under various complex working conditions.

GMU761 supports UART and CAN interface communication, and provides flexible user configuration options. If using the CAN interface, users need to integrate the CAN transceiver circuit externally. This module is designed specifically for industrial application scenarios that require high reliability and environmental adaptability.

## Application Field

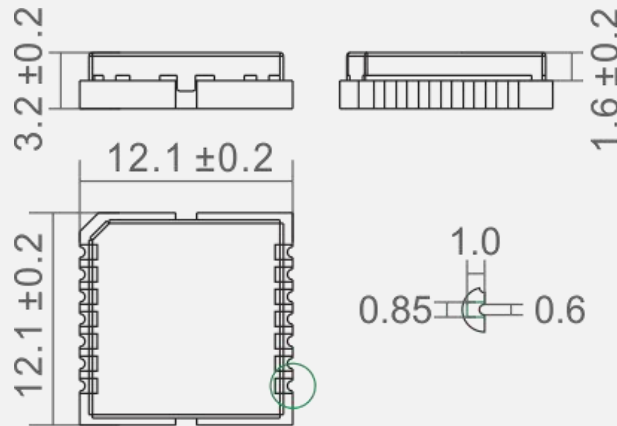
- ❖ Humanoid robot balance stability
- ❖ Precision Measurement and Control of Industrial Robots
- ❖ Stability monitoring of embodied robots
- ❖ Stable measurement and control of quadruped robot



## Specifications

| GMU761                   |                                  |          | condition               | parameter       |
|--------------------------|----------------------------------|----------|-------------------------|-----------------|
| Attitude angle           | Roll angle                       | Accuracy | 1σ RMS                  | 0.15°           |
|                          |                                  | Range    | -                       | ±180°           |
|                          | Pitch angle                      | Accuracy | 1σ RMS                  | 0.15°           |
|                          |                                  | Range    | -                       | ±90°            |
|                          | No reference heading angle       | Accuracy | 1σ RMS                  | 0.2°            |
|                          |                                  | Range    | -                       | ±180°           |
|                          | Magnetic reference heading angle | Accuracy | 1σ RMS                  | 2.5°            |
|                          |                                  | Range    | -                       | ±180°           |
|                          | Angular resolution               |          | -                       | 0.001°          |
| Gyroscope                | Range                            |          | -                       | ±2000°/s        |
|                          | Nonlinearity                     |          | -                       | ±0.05%FS        |
|                          | Noise density                    |          | -                       | 0.015°/s/√Hz    |
|                          | Zero bias instability            |          | @25℃,ALLAN variance,1σ  | 3°/hr           |
|                          | Bandwidth (-3dB)                 |          | -                       | 50Hz            |
|                          | Zero offset                      |          | 1σ RMS                  | ±0.5°/s         |
|                          | Zero temp. drift                 |          | 1σ RMS, -40~85℃         | ±1°/s           |
| Accelerometer            | Range                            |          | -                       | ±16g            |
|                          | Nonlinearity                     |          | -                       | ±0.1%FS         |
|                          | Noise density                    |          | -                       | 100ug/√Hz       |
|                          | Zero bias instability            |          | @25,ALLAN variance,1σ   | 0.03mg          |
|                          | Bandwidth (-3dB)                 |          |                         | 50Hz            |
|                          | Zero offset                      |          | 1σ RMS                  | ±20mg           |
|                          | Zero temp. drift                 |          | 1σ RMS, -40~85℃         | ±10mg           |
| Magnetic sensor          | Range                            |          |                         | ±30Gauss        |
|                          | Nonlinearity                     |          | FS = ±32G               | ±0.5%FS         |
|                          | Resolution                       |          | LBS                     | 1mG             |
|                          | Noise                            |          | RMS                     | 2mGauss         |
| electrical connection    | Input voltage                    |          | -                       | 2.8-5.5VDC      |
|                          | Power consumption                |          | -                       | <160mW          |
|                          | Communication Interface          |          | -                       | UART            |
|                          | Output frequency                 |          | Up to 1KHz              | 1-1KHz          |
| Environmental indicators | Operating Temp.                  |          | -                       | -40~85℃         |
|                          | Storage temp.                    |          | Relative humidity ≤ 65% | -45~85℃         |
|                          | Impact resistance                |          | -                       | 500g            |
|                          | Size                             |          | -                       | 12.1X12.1x3.2mm |
|                          | Weight                           |          | -                       | ≤5g             |

## Product Dimensions



Dimensions: L12.1×W12.1×H3.2mm

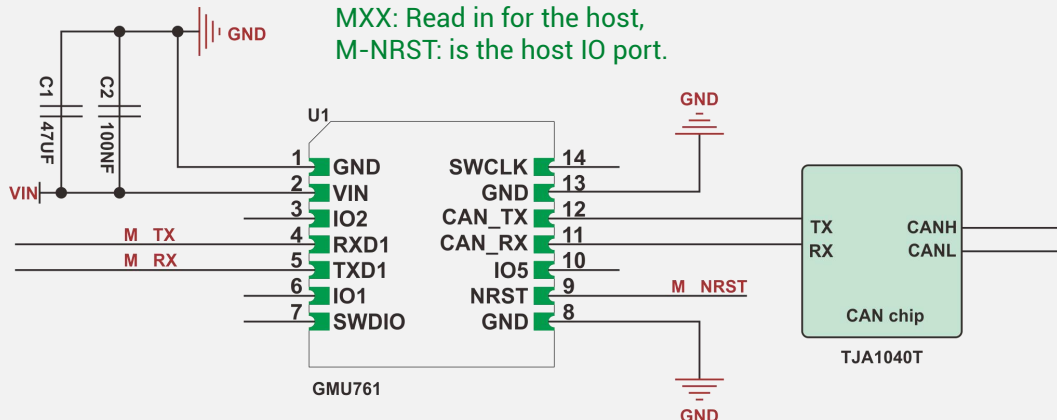
## PIN Definition

| PIN | Pin Definition | Definition Description                                                                                                                                       |
|-----|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | GND            | power ground                                                                                                                                                 |
| 2   | VDD            | Power input 2.8-5.5V                                                                                                                                         |
| 3   | IO2            | SYNC OUT synchronous output pin                                                                                                                              |
| 4   | RXD1           | Module UART1 receiving                                                                                                                                       |
| 5   | TXD1           | Module UART1 sends                                                                                                                                           |
| 6   | IO1            | Sync-IN synchronous input pin (rising edge)                                                                                                                  |
| 7   | SWDIO          | SWDIO functional foot                                                                                                                                        |
| 8   | GND            | power ground                                                                                                                                                 |
| 9   | NRST           | Reset pin, low-level reset module. No external resistors or capacitors are required. It is recommended to connect the GPIO of the host or hang it in the air |
| 10  | IO5            | LED driver pin                                                                                                                                               |
| 11  | CAN_RX         | reserve                                                                                                                                                      |
| 12  | CAN_TX         | reserve                                                                                                                                                      |
| 13  | GND            | power ground                                                                                                                                                 |
| 14  | SWCLK          | SWCLK functional pin                                                                                                                                         |

Note 1: The above IO port has a TTL3.3V level output, compatible with 5V withstand voltage, and a driving current (input/output current) of 5mA. Overloading can easily damage the IO port.

### Recommended Circuit

M-TX: Write for the host,  
MXX: Read in for the host,  
M-NRST: is the host IO port.



## Spatial coordinate system

The carrier system uses the Right Front Up (RFU) coordinate system, while the geographic coordinate system uses the East North Sky (ENU) coordinate system. The acceleration and gyroscope axis are shown in the figure on the right:

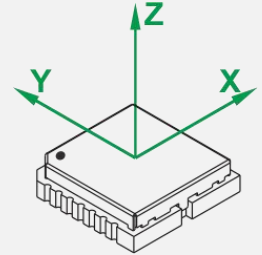
The rotation sequence of Euler angles is East North Tian-312 (first rotate the Z-axis, then the X-axis, and finally the Y-axis). The specific definition is as follows:

Rotation around the Z-axis direction: heading angle \ Yaw \ psi range:  $-180^{\circ}$  -  $180^{\circ}$

Rotation around the X-axis: pitch angle \ pitch \ theta Range:  $-90^{\circ}$  -  $90^{\circ}$

Rotation around the Y-axis direction: roll angle \ Roll \ phi range:  $-180^{\circ}$  -  $180^{\circ}$

If we consider the module as an aircraft. The positive Y-axis direction should be considered as the head direction. When the sensor system coincides with the inertial frame, the ideal output of the Euler angle is: Pitch= $0^{\circ}$ , Roll= $0^{\circ}$ , Yaw= $0^{\circ}$ .



## Multi-point calibration method for magnetic field space

Calibration requirements:

- 1) The accuracy of the product fails to meet the requirements;
- 2) There is magnetic field interference in the installation environment of the product, which is fixed, and the distance between the interference magnetic field and the product will not change after installation (for example, the product is installed on an iron material, because the iron will have magnetic field interference, then it is necessary to rotate and calibrate the iron and the product together, and the iron will not be separated from the product in use. Once separated, it needs to be recalibrated. If the size of this iron is not fixed, or the distance change with this product is not fixed, this interference can not be calibrated, it can only be avoided and installed far away, and the safe distance is controlled above 40 CM).

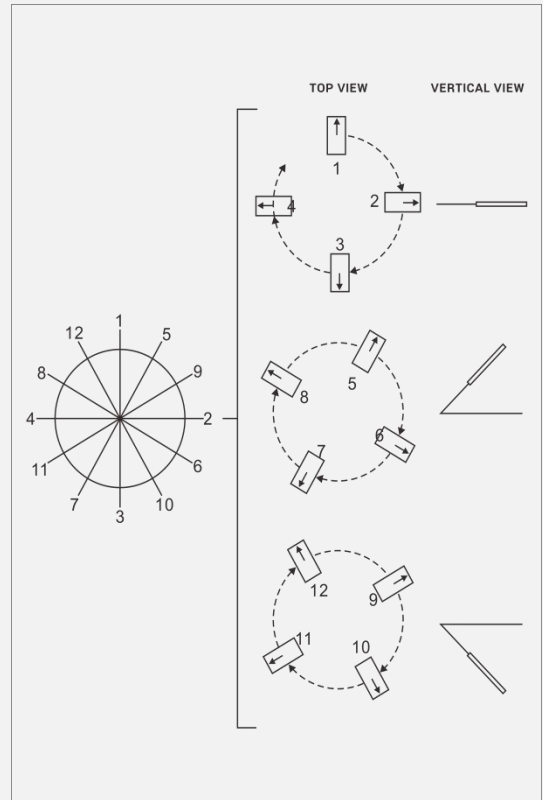
When users use this product, they need to install it on the device for calibration. However, these devices may be affected by ferromagnetic objects that may interfere and affect azimuth accuracy, including iron screws, batteries, speakers, motors, etc. Therefore, after installing this product on the user's device, it needs to be recalibrated to eliminate the impact of these magnetic interferences on the product's azimuth angle. In addition, if there is a significant change in the magnetic field environment on the device where this product is installed, such as replacing batteries on handheld devices, reinstalling batteries, replacing some ferromagnetic objects during major repairs on ships or aircraft, or adding or reducing ferromagnetic objects near the location where this product is installed on large equipment, recalibration should be performed.

This product provides multi-point calibration of magnetic field space and a method of rotating 3 circles in space. The calibration method requires a uniform and stable magnetic field environment in the calibration area. Generally speaking, choosing an open outdoor space with no large magnetic interference objects within 50 meters, such as elevators, generators, cars, reinforced concrete, etc., all meet the calibration requirements. It should be noted that calibration operators should not carry objects such as mobile phones, keys, belts, etc. that may introduce magnetic interference. When placing this product in different postures to collect data, the posture of the product should be kept stable, and shaking and shaking should be avoided as much as possible, which may affect the accuracy of data collection and lead to poor calibration results. During calibration, this product needs to be fixedly installed on the final user device for corresponding calibration, so as to effectively correct the magnetic interference present on the user device, thereby improving the azimuth angle measurement accuracy of this product and maximizing its performance.

Magnetic field multi-point calibration method: The magnetic field multi-point calibration method can effectively correct the magnetic interference present on the user's device. After calibration, it can ensure the azimuth accuracy of this product under various large tilt states. When this product is installed and used on small devices, if there is a matching non-magnetic tripod available for calibration, the magnetic field space multi-point calibration method can be used for calibration. It is generally recommended to use the magnetic field space 12 point calibration method, and users can also increase the number of

sampling points according to the actual situation. The schematic diagram of the 12 point calibration method for magnetic field space is shown in the following figure, and the key points for placing various postures are introduced in the figure on the right:

Attitude 1: Make the azimuth angle of this product point to 0°, pitch angle 0°, and roll angle 0°;  
 Attitude 2: Point the product's azimuth angle at 90°, pitch angle at 0°, and roll angle at 0°;  
 Attitude 3: Point the product's azimuth angle to 180°, pitch angle to 0°, and roll angle to 0°;  
 Attitude 4: Point the product's azimuth angle at 270°, pitch angle at 0°, and roll angle at 0°;  
 Attitude 5: Make the azimuth angle of this product point at 30°, pitch angle at 45°, and roll angle at 0°;  
 Attitude 6: Point the product at an azimuth angle of 120°, pitch angle of 45°, and roll angle of 0°;  
 Attitude 7: Make the azimuth angle of this product point to 210°, pitch angle 45°, and roll angle 0°;  
 Attitude 8: Make the azimuth angle of this product point at 300°, pitch angle at 45°, and roll angle at 0°;  
 Attitude 9: Point the product at an azimuth angle of 60°, pitch angle of -45°, and roll angle of 0°;  
 Attitude 10: Point the product at an azimuth angle of 150°, pitch angle of -45°, and roll angle of 0°;  
 Attitude 11: Point the product at an azimuth angle of 240°, pitch angle of -45°, and roll angle of 0°;  
 Attitude 12: Point the product at an azimuth angle of 330°, pitch angle of -45°, and roll angle of 0°.



The azimuth angle mentioned in the above introduction does not refer to an absolute azimuth angle, but a relative angle. For example, when placed in posture 1, the azimuth angle of this product can point to any angle, such as 42°. However, when placed in posture 2, the azimuth angle of this product needs to be placed at around 132°, and so on. The pitch angle and roll angle refer to absolute angles. However, when placed in posture, the requirements for the accuracy of the azimuth angle, pitch angle, and roll angle are often particularly strict, and the error of each angle is acceptable within  $\pm 5^\circ$ .

Calibration start sending: CONFIG PCAL START. After replying OK, send "CONFIG PCAL SAMPLE" at the 12 o'clock positions above for sampling.

Sensor response:

RX: STAT=1

RX: P\_POINT=1

RX: OK

.....

RX: STAT=1

RX: P\_POINT=12

RX: OK

Resend: CONFIG PCAL STOP to stop, resend: CONFIG PCAL SAVE to save.

Magnetic field space 3-circle rotation calibration method: The magnetic field space 3-circle rotation calibration method can effectively correct the magnetic interference existing on the user's device. After calibration, it can ensure the azimuth accuracy of this product under various large tilt states. The specific method is as follows: first rotate horizontally for one circle, maintain the pitch angle at  $+30^\circ \sim +60^\circ$  degrees for one circle, and maintain the pitch angle at  $-30^\circ \sim -60^\circ$  degrees for one circle. Calibration is completed through automatic point collection. The angular velocity of this product's rotation should be between 10~25 degrees/second, and should not be too fast. The number of automatic point collection points should be greater than 20, and the more points, the better. The maximum number of points is 24.

## Calibration Method for Magnetometer Three Circle Rotation in Space

Calibration premise: 1) The accuracy of this product cannot meet the requirements during testing;

2) The installation environment of this product is subject to magnetic field interference, which is fixed and will not cause any distance changes after installation. For example, if this product is installed on iron material, the iron will have magnetic field interference, so it is necessary to rotate and calibrate it together with this product. When in use, the iron and this product cannot be separated and need to be recalibrated. If the size of the iron is not fixed or the distance change from this product is not fixed, this interference cannot be calibrated and should be kept as far away from installation as possible, with a safe distance controlled at 30cm or more.

- 1) Connect this product correctly to the signal output interface and turn on the power.
- 2) Send the calibration start command in ASCII format: "CONFIG MCAL START" (click the start button), during which no command is responded to.
- 3) After the upper computer completes the calibration of 24 calibration points, the product rotates three times, horizontally, PITCH+45°, and PITCH -45°, respectively. (Multiple rotations are allowed, but not less, ensuring that the upper computer automatically displays 24 points while completing three rotations.) After completing three rotations, the calibration command "CONFIG MCAL STOP" is sent to stop. At this time, the product pauses for about 1 second, and the internal CPU automatically calculates the sampled data and returns a set of data.
- 4) Save calibration command: Send the command "CONFIG MCAL SAVE" (click the save button), and this product will return a response command. If the save is successful, "OK" will indicate normal operation. If an unsuccessful message is returned, the user will recalibrate the steps.

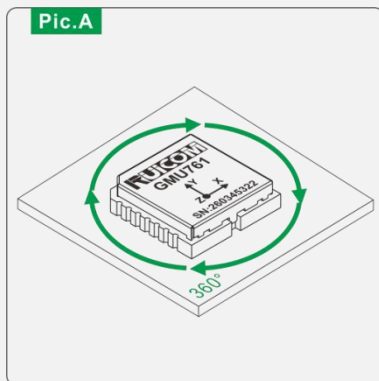
\*When calibrating, if the distance between the magnetic field interference source and the product itself changes, the accuracy will change.

### Magnetometer Space 3 Rotation Calibration Mode:

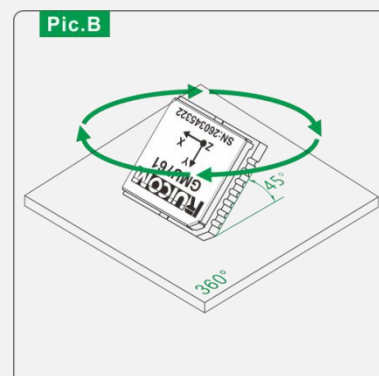
Connect the product correctly to the communication port and turn on the power.

- 1) Rotate horizontally at a constant speed once: as shown in Figure A

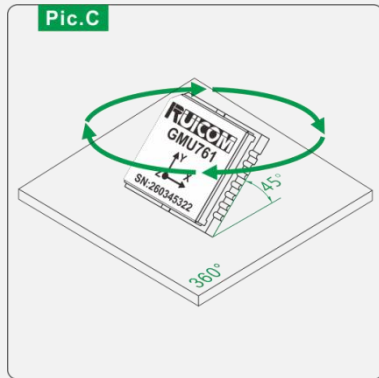
Send calibration start command



TX: CONFIG MCAL START  
Sensor response  
RX: OK  
Then start rotating  
Rotate horizontally at a constant speed for more than 1 turn



- 2) PITCH rotates at a constant speed of 45° once: as shown in Figure B



3) PITCH-45° rotates uniformly once: as shown in Figure C

During the rotation collection process, this product will reply with rotation collection and 24 points, the number of collection points, 24 o'clock sampling response instruction:

```
RX: STAT=1
RX: M_POINT=1
RX: OK
RX: STAT=1
RX: M_POINT=2
RX: OK
RX: STAT=1
RX: M_POINT=3
RX: OK
RX: STAT=1
RX: M_POINT=4
RX: OK
```

```
.....
RX: STAT=1
RX: M_POINT=24
RX: OK
```

Calibration must be completed by collecting at least 20 points and simultaneously rotating them. Horizontal circle, PITCH+45 ° circle, PITCH -45 ° circle,

Then click stop

Send the stop command 'CONFIG MCAL STOP', and the product will pause for about 1 second. The internal CPU will automatically calculate the sampled data and return 'OK',

Save calibration command: Send the command "CONFIG MCAL SAVE" (click the save button).

## Output protocol

**Factory default parameters:**

**Baud rate: 115200bps**

**Output frequency: 100Hz**

**Installation direction: Horizontal installation**

**Application type: VRU mode (robot or agricultural machinery)**

1. Module Configuration Overview

Before using the product, please carefully read this chapter and determine whether user configuration is necessary based on actual usage needs.

1.1 Working mode configuration - AHRS/9-axis mode

**\*Warning: In robot applications and indoor environments, AHRS (9-axis) mode is susceptible to interference from environmental magnetic fields or motor generated magnetic fields, resulting in errors in heading angle.**

In open and non-magnetic environments (such as outdoor drone flight scenes), geomagnetic assist mode can be used. Before use, it is necessary to:

- ① Configure the module to geomagnetic assist mode;
- ② Perform geomagnetic calibration (see "Geomagnetic Calibration" section for details).

## 1.2 Synchronous Input - Sync-IN

The data synchronization of the module depends on the SYNC IN pin, and the main data synchronization is divided into:

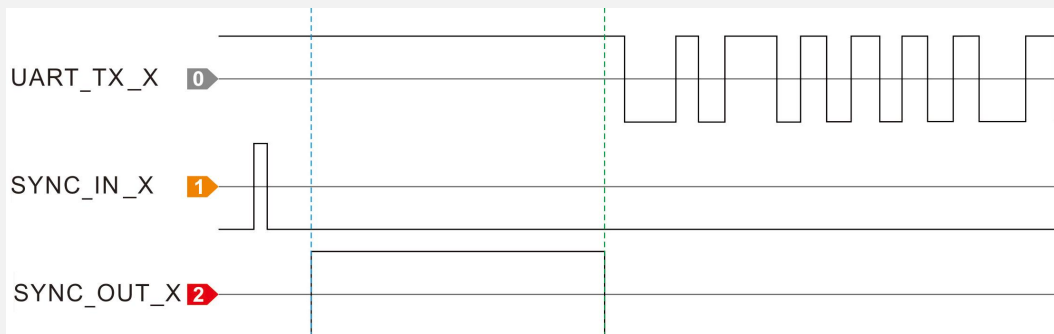
- Sync-IN synchronization data trigger

### 1.2.1 Sync-IN synchronization data trigger

The product is equipped with a synchronous input pin (Sync-IN) for IMU data synchronization. It is recommended to hang or ground it when not in use. Working principle: When the output protocol is configured to ON MARK trigger mode (see LOG instruction for details), the module will output a frame of data after detecting a rising edge at the SYNC IN pin.

Application scenario: Mainly used to receive high-precision square wave pulses generated by the main control to trigger high-frequency synchronized IMU data.

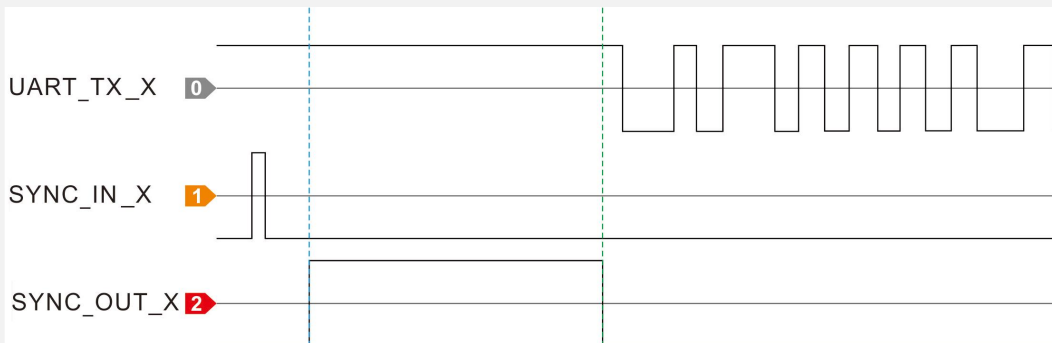
### 1.2.2 SYNC\_IN pin input signal requirements:



- Period: 1ms~1s;
- Trigger: Rising edge;
- Pulse width: 20μs~100ms;
- Level: High level ≤5V (TTL/CMOS compatible).

## 1.3 Synchronous output - SOUT

This is an output pin of the module. It is low (idle) when there is no data output. A high pulse is sent before a frame of data is sent. The data is output immediately after the high pulse ends (falling edge). The pulse width is 10-25μs.



## 2. Module configuration commands (ASCII)

Module configuration uses serial port ASCII string command format, **and each command must end with a newline character (\r\n)**. All configuration commands will only take effect after a reset or power-on.

### 2.1 Overview of configuration commands

| Command      | Function                          | Remarks                              |
|--------------|-----------------------------------|--------------------------------------|
| REBOOT       | Reset module                      | Perform software reset on the module |
| SAVECONFIG   | Save all configuration parameters | Effective immediately                |
| SERIALCONFIG | Serial port baud rate settings    | Effective immediately                |

|        |                                                   |                                      |
|--------|---------------------------------------------------|--------------------------------------|
| CONFIG | Configure various module parameters and modes     | Effective after saving and resetting |
| LOG    | Query module information or configure output data | Effective immediately                |
| FRESET | Restore factory settings                          | Effective immediately                |

## 2.2 Command Details

### 2.2.1 REBOOT

Reset module.

Example: REBOOT

### 2.2.2 SAVECONFIG

Save all user configurations to Flash.

Example: SAVECONFIG

### 2.2.3 SERIALCONFIG

Sets the current serial port baud rate. Format: SERIALCONFIG <BAUD>.

Parameter Description: Supported baud rates: 9600, 115200, 230400, 256000, 460800, 921600.

Example: SERIALCONFIG 115200 - Sets the current serial port baud rate to 115200.

#### \*Important Note

This command takes effect immediately. After executing the command, you need to switch to the new baud rate to continue communicating with the module.

### 2.2.4 CONFIG

Used to configure various parameters and operating modes of the module. All configurations must be saved and reset before they take effect.

#### 2.2.4.1 Working mode configuration

Operating mode configuration: 6-axis or 9-axis (geomagnetic assisted) mode, format: CONFIG ATT MODE <VAL>.

| VALUE | Work Mode                                                               | Remarks                                                                                      |
|-------|-------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| 0     | VRU                                                                     | The heading angle is 0 when powered on, and the gyroscope is used to fuse the heading angle. |
| 1     | AHRS                                                                    | The heading angle is a magnetic heading angle.                                               |
| VALUE | Application Type                                                        | Remarks                                                                                      |
| 2     | Applications of construction machinery: Excavators                      | Used for testing excavator boom angle.                                                       |
| 3     | Applications of construction machinery: Tower cranes                    |                                                                                              |
| 4     | Applications of construction machinery: Stone crushing and piling       |                                                                                              |
| 5     | Applications of construction machinery: Vehicle-mounted and AGV-mounted |                                                                                              |
| 6     | Applications of mining trucks                                           |                                                                                              |
| 7     | Applications of marine equipment                                        |                                                                                              |
| 8     | Applications of wind turbines                                           |                                                                                              |
| 9     | Applications of robots or agricultural machinery                        |                                                                                              |
| 10    | Applications of small speedboats                                        |                                                                                              |
| 11    | Wearable applications                                                   |                                                                                              |

Example:

- CONFIG ATT MODE 0 - The module is configured in VRU (6-axis) mode.
- CONFIG ATT MODE 1 - The module is configured in AHRS (9-axis) mode.
- CONFIG ATT MODE 9 - Working mode of robots or agricultural machinery.

#### 2.2.4.2 Attitude User Calibration

Used to set the relative attitude angle, format: CONFIG ATT RST <VAL>. The module must remain stationary when executing this command; otherwise, it may cause significant calibration errors.

Example:

- CONFIG ATT RST 1 - Heading Reset: Resets the heading angle to 0 (for VRU mode, the heading angle is zeroed out).
- CONFIG ATT RST 2 - Set relative zero point: Sets the current pitch and roll angles to zero.
- CONFIG ATT RST 5 - Cancel relative zero point: Sets the current pitch and roll angles to absolute zero point.

#### 2.2.4.3 Coordinate system rotation (vertical installation)

This command is used to modify the module's installation method, such as setting it to vertical installation. After setting, please save the configuration; the changes will take effect after a reset. This command does not need to be sent every time the module is powered on.

Format: CONFIG IMU URFR <C00, C01, C02, C10, C11, C12, C20, C21, C22>

Common rotation configuration examples:

| Serial No. | Installation Method                                                             | Configuration Command                          | Description                             |
|------------|---------------------------------------------------------------------------------|------------------------------------------------|-----------------------------------------|
| 0          | Horizontal, Z-axis upward (default)                                             | CONFIG IMU URFR<br>1, 0, 0, 0, 1, 0, 0, 0, 1   | Factory default                         |
| 1          | Rotate -90° around X-axis (Vertical installation with positive Y-axis downward) | CONFIG IMU URFR<br>1, 0, 0, 0, 0, 1, 0, -1, 0  | Commonly used for vertical IMU mounting |
| 2          | Rotate 90° around X-axis (Vertical installation with positive Y-axis upward)    | CONFIG IMU URFR<br>1, 0, 0, 0, 0, -1, 0, 1, 0  | Commonly used for vertical IMU mounting |
| 3          | Rotate 90° around Y-axis (Vertical installation with positive X-axis upward)    | CONFIG IMU URFR<br>0, 0, -1, 0, 1, 0, 1, 0, 0  | Commonly used for vertical IMU mounting |
| 4          | Rotate -90° around Y-axis (Vertical installation with positive X-axis downward) | CONFIG IMU URFR<br>0, 0, 1, 0, 1, 0, -1, 0, 0  | Commonly used for vertical IMU mounting |
| 5          | Rotate 180° around X-axis                                                       | CONFIG IMU URFR<br>1, 0, 0, 0, -1, 0, 0, 0, -1 | Commonly used for inverted IMU mounting |
| 6          | Rotate 180° around Y-axis                                                       | CONFIG IMU URFR<br>-1, 0, 0, 0, 1, 0, 0, 0, -1 | Commonly used for inverted IMU mounting |
| 7          | Rotate 90° around Z-axis (Combined navigation, -X forward installation)         | CONFIG IMU URFR<br>0, -1, 0, 1, 0, 0, 0, 0, 1  | Commonly used in integrated navigation  |
| 8          | Rotate -90° around Z-axis (Combined navigation, +X forward installation)        | CONFIG IMU URFR<br>0, 1, 0, -1, 0, 0, 0, 0, 1  | Commonly used in integrated navigation  |
| 9          | Rotate 180° around Z-axis (Combined navigation, -Y forward installation)        | CONFIG IMU URFR<br>-1, 0, 0, 0, -1, 0, 0, 0, 1 | Commonly used in integrated navigation  |

Where the transformation matrix:

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

Where:

- $\begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}_U$  SENSOR DATA IN THE ROTATED SENSOR COORDINATE SYSTEM
- $\begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}_B$  SENSOR DATA IN THE ROTATED SENSOR COORDINATE SYSTEM

#### 2.2.4.4 Power-on wait time setting

- 1) CONFIG PWRUP MODE 0 - Used to set the power-on wait time to 0, power -on is outputting data Power-on wait time setting;
- 2) CONFIG PWRUP MODE 1 - This is used to set the power-on waiting time to 5 seconds, and output data after a 5-second pause after power-on. It is mainly used in applications with high heading angle control requirements, such as AGVs, so that the gyroscope can clear the zero bias after a 5-second pause after power-on.

#### 2.2.4.5 Gyroscope zero-bias static correction strategy enable setting

- 1) CONFIG GBIAS AUTO ENABLE - This is used to enable the static zero-bias correction strategy for the gyroscope, which will automatically correct the zero bias of the gyroscope when the IMU is at rest.
- 2) CONFIG GBIAS AUTO DISABLE - This is used for zero-bias static correction strategies for de-energized gyroscopes.

It is effective immediately, but there is no power-off save function. To save the settings after a power failure, you must execute the save settings command.

Note: Sometimes, such as when AGV applications involve fine-tuning with very small angular velocities, the gyroscope zero-bias static correction strategy can be enabled and disabled alternately to reduce heading angle errors. For example, disable the gyroscope zero-bias static correction strategy before fine-tuning or running. When the AGV is stopped, the gyroscope zero-bias static correction strategy can be enabled. In this case, the SAVECONFIG command can be omitted to avoid frequent FLASH erasure and writing, which could damage the IMU.

#### 2.2.5 LOG

##### 2.2.5.1 Turn data output on/off

- LOG ENABLE - Global Enable Data Frame Output
- LOG DISABLE - Globally disable data frame output

##### 2.2.5.2 Module version information

- LOG VERSION - Query and print firmware version information

##### 2.2.5.3 Display serial port configuration information

- LOG COMCONFIG - Print serial port and output protocol configuration information

##### 2.2.5.4 Display user configuration information

- LOG USRCONFIG - Print user configuration information

RX: MODBUS\_ID=0x50

RX: PROFILE=0

RX: URFR=1,0,0,0,1,0,0,0,1

RX: QOFS=1.00,0.00,0.00,0.00

RX: OK

##### 2.2.5.5 Set data frame output type and frequency

Format: LOG <MSG> <TYPE> <VALUE>

Parameter Description:

- MSG: Data frame type: HI91, see the "RS232/TTL/USB Data Protocol" section.
- TYPE: ONTIME: Timed trigger, ONMARK: SYNC\_IN pin pulse trigger.
- VALUE: The timing output period, in seconds, can be set to 0.001 (1 kHz) - 1 (1 Hz).

Example:

- LOG HI91 ONTIME 0.01 - Set the current serial port's HI91 data packet output period to 0.01s (100 Hz).
- LOG HI91 ONTIME 0.05 - Set the current serial port's HI91 data packet output period to 0.05s (20 Hz).

- LOG HI91 ONMARK 1 - Configure the current serial port's HI91 data packet to the SYNC\_IN pin pulse trigger mode.
- LOG HI91 ONMARK ONCE - The command manually triggers a data output once, which has the same effect as triggering a SYNC\_IN pulse.

**\*Baud Rate Considerations**

When the output frame rate is set high (e.g., 500 Hz), the default baud rate of 115200 cannot meet the output bandwidth requirements. In this case, the module baud rate needs to be set higher (e.g., 921600) before the module can output data correctly.

#### 2.2.6 FRESET

Restores all configurable parameters to factory default settings, including baud rate, effective immediately. Use with caution.

Example FRESET

#### 2.2.7 Geomagnetic calibration

Geomagnetic calibration is divided into three-circle multi-point calibration (three rotations) and 12-point calibration.

##### 1) Space three-circle multi-point calibration (three rotations)

**A:** Start geomagnetic calibration: Command format CONFIG MCAL START. After sending this command, rotate the dial three times as follows.

Example:

TX: CONFIG MCAL START

RX: OK

**B:** Spatial sampling response: The sensor will send sampling information, as follows::

RX: STAT=1

RX: M\_POINT=1

RX: OK

.....

RX: STAT=1

RX: M\_POINT=24

RX: OK

Rotating slowly and evenly for 3 rounds will yield 20-24 points; the more points, the better.

**C:** Stop geomagnetic calibration: Command format CONFIG MCAL STOP. After sending this command, the sensor calculates the calibration parameters.

Example:

TX: CONFIG MCAL STOP

RX: OK

**D:** Save geomagnetic calibration: Command format CONFIG MCAL SAVE. After sending this command, the sensor saves the calibration parameters.

Example:

TX: CONFIG MCAL SAVE

RX: OK

**E:** Abort geomagnetic calibration: Command format CONFIG MCAL ABANDON. If you encounter problems during the rotation process after starting, send this command to abort the sensor calibration.

Example:

TX: CONFIG MCAL ABANDON

RX: OK

##### 2) Spatial multi-point calibration (default 12 points)

**A:** Start geomagnetic calibration: Command format: CONFIG PCAL START. After sending this command, collect 12 samples using the following method.

Example:

TX: CONFIG PCAL START

RX: OK

**B:** Geomagnetic sampling command: Command format CONFIG PCAL SAMPLE. Once the position is ready and stationary, send this command, and the sensor will reply with the number of sampling points.

Example:

TX: CONFIG PCAL SAMPLE

RX: OK

The sensor immediately sends the sampling point information as follows:

RX: STAT=1

RX: P\_POINT=1

RX: OK

.....

TX: CONFIG PCAL SAMPLE

RX: OK

The sensor immediately sends the sampling point information as follows:

RX: STAT=1

RX: P\_POINT=12

RX: OK

**C:** Stop geomagnetic calibration: Command format CONFIG PCAL STOP. Send this command after collecting 12 data points, and the sensor will calculate the calibration parameters.

Example:

TX: CONFIG PCAL STOP

RX: OK

**D:** Save geomagnetic calibration: Command format CONFIG PCAL SAVE. Sending this command saves the sensor's calibration parameters.

Example:

TX: CONFIG PCAL SAVE

RX: OK

**E:** Abort Geomagnetic Calibration: Command format: CONFIG PCAL ABANDON. If you encounter problems during the calibration process after it has begun, sending this command will abort the sensor calibration.

Example:

TX: CONFIG PCAL ABANDON

RX: OK

### 2.2.8 User-grade gyroscope zero-bias calibration

This command is used to manually calibrate the gyroscope's zero bias. During calibration, the gyroscope remains stationary for 5 seconds. This prevents yaw drift and improves yaw accuracy.

Start calibration command format: CONFIG GBIASCAL START

Example:

TX: CONFIG GBIASCAL START

RX: OK

Query calibration results

TX: CONFIG GBIASCAL STAT

RX: GBIAS STAT=1; 1 indicates in progress, and 0 indicates finished or not started.

RX: OK

Calibration Abort Command Format

If calibration cannot be completed in a long time under some high-vibration working environments, this command can be issued to stop the calibration.

TX: CONFIG GBIASCAL ABANDON

RX: OK

Save calibration result format

TX: CONFIG GBIASCAL SAVE

RX: OK

### 3. RS-232/TTL/USB Data Protocol (binary)

RS232/serial TTL and USB interfaces (virtual serial ports) are all streaming serial data interfaces, and these interfaces all support custom binary protocols for the super core.

### 3.1 Data Frame Format

| Domain Name | Value  | Length (bytes) | Description                                                                                                                                                                 |
|-------------|--------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SOF         | 5A A5  | 2              | Frame header synchronization flag                                                                                                                                           |
| LEN         | 1-4096 | 2              | Length of the data field in the frame. The LSB (lowest byte first) length indicates the length of the data field (excluding the frame header, frame type, length, and CRC). |
| CRC check   | -      | 2              | 16-bit CRC checksum is performed on the frame header, length, and data field (excluding the CRC field itself).                                                              |
| Data domain | -      | 1-4096         | The data carried in a frame consists of several sub-data packets. Each data packet contains a data packet tag and data. The tag determines the data type and length.        |

### 3.2 Factory default output: Floating-point IMU data frame (HI91) data packet

### 3.3 Data domain content

#### 3.3.1 Floating-point IMU data frames (HI91)

The data field consists of 76 bytes and includes the module ID, temperature, raw IMU data, geomagnetism, air pressure, and fused attitude data.

| Byte Offset | Name         | Data Type | Size (Byte) | Unit  | Scale Factor | Description                                                                                                                                  |
|-------------|--------------|-----------|-------------|-------|--------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| 0           | tag          | uint8_t   | 1           | -     | -            | Data packet tag: 0x91                                                                                                                        |
| 1           | main_status  | uint16_t  | 2           | -     | -            | Status word, see main_status status word description                                                                                         |
| 3           | temperature  | int8_t    | 1           | °C    | 1            | Module average temperature                                                                                                                   |
| 4           | air_pressure | float     | 4           | Pa    | 1            | Air pressure                                                                                                                                 |
| 8           | system_time  | uint32_t  | 4           | ms    | 1            | This data is a local timestamp: accumulated since system startup, increasing by 1 every millisecond                                          |
| 12          | acc_b        | float     | 4×3         | G     | 1            | Factory-calibrated acceleration, in XYZ axis order<br>1G = 1 times standard gravitational acceleration (approximately 9.8 m/s <sup>2</sup> ) |
| 24          | gyr_b        | float     | 4×3         | deg/s | 1            | Factory-calibrated angular velocity, in XYZ axis order                                                                                       |
| 36          | mag_b        | float     | 4×3         | μT    | 1            | Magnetic intensity, in XYZ axis order                                                                                                        |
| 48          | roll         | float     | 4           | deg   | 1            | Roll angle                                                                                                                                   |
| 52          | pitch        | float     | 4           | deg   | 1            | Pitch angle                                                                                                                                  |
| 56          | yaw          | float     | 4           | deg   | 1            | Yaw angle                                                                                                                                    |
| 60          | quat         | float     | 4×4         | -     | -            | Node quaternion set, in WXYZ order                                                                                                           |

#### 3.3.2 MAIN\_STATUS Status word description

| Bit | Name                                  | Description                                                                                                                                                                                                                                                                                                                                                              |
|-----|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0-2 | reserve                               | -                                                                                                                                                                                                                                                                                                                                                                        |
| 3   | Gyroscope zero bias Static correction | 1: Gyroscope zero-bias static correction strategy enabled;<br>0: Gyroscope zero-bias static correction strategy disabled;                                                                                                                                                                                                                                                |
| 4   | MAG_DIST                              | Magnetic field anomaly detection alarm:<br>1: Interference detected in the current ambient magnetic field, or the magnetic sensor is not calibrated, or the hard magnetic environment has changed; heading angle error may be large in 9-axis mode.<br>0: Current geomagnetic environment is good, magnetic heading accuracy converges, or the system is in 6-axis mode. |
| 5-9 | reserve                               | -                                                                                                                                                                                                                                                                                                                                                                        |

|       |            |                                                                                                                                                                                                                                                                           |
|-------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 10    | MAG_AIDING | Magnetic participation in attitude calculation flag:<br>1: Magnetic sensor is participating in heading calculation (9-axis mode)<br>0: Magnetic sensor is not participating in heading calculation (6-axis mode)                                                          |
| 11    | UTC_TIME   | Time synchronization flag:<br>1: Time synchronization not performed; system time is local time.<br>0: UTC time synchronization successful; system_time field aligned to UTC time (in milliseconds per day, starting from midnight).<br><b>Note: This bit is always 1.</b> |
| 12    | SOUT_PULSE | SOUT pulse output flag, used for time synchronization with low-speed sensors: SOUT pulse output<br>1: Current data frame is a SOUT pulse output frame;<br>0: The current data frame has no SOUT pulse output;<br><b>Note: This bit is currently always 1.</b>             |
| 13-15 | reserve    | -                                                                                                                                                                                                                                                                         |

### 3.3 CRC check

The CRC check uses the CRC-16/CCITT format. A C language implementation example is shown below:

```

1  /*
2      currentCrc: previous crc value,  set 0 if it's first section
3      src: source stream data
4      lengthInBytes: length
5  */
   static void crc16_update(uint16_t *currentCrc,    const uint8_t *src,    uint32_t
lengthInBytes)
6  {
7      uint32_t crc = *currentCrc;
8      uint32_t j;
9      for (j=0; j < lengthInBytes; ++j)
10     {
11         uint32_t i;
12         uint32_t byte = src[j];
13         crc ^= byte << 8;
14         for (i = 0; i < 8; ++i)
15         {
16             uint32_t temp = crc << 1;
17             if (crc & 0x8000)
18             {
19                 temp ^= 0x1021;
20             }
21             crc = temp;
22         }
23     }
24     *currentCrc = crc;
25 }

```

### 3.4 Example of a data frame structure (using HI91 as an example)

Using a serial port assistant, sample a data frame (HI91 data frame), totaling 82 bytes. The first 6 bytes are the frame header, length, and CRC checksum, and the remaining 76 bytes are the data field. Assume the data is received in a C language array `buf`, as shown below:

```

1 5A A5 4C 00 14 BB 91 08 15 23 09 A2 C4 47 08 15 1C 00 CC E8 61 BE 9A 35 56 3E 65 EA
72 3F 31 D0 7C BD 75 DD C5 BB 6B D7 24 BC 89 88 FC 40 01 00 6A 41 AB 2A 70 C2 96 D4
50 41 ED 03 43 41 41 F4 F4 C2 CC CA F8 BE 73 6A 19 BE F0 00 1C 3D 8D 37 5C 3F

```

**Data analysis table:**

| Field Name        | Type     | Raw Value   | Parsed Value       | Description                                                  |
|-------------------|----------|-------------|--------------------|--------------------------------------------------------------|
| Frame header      | -        | 5A A5       | -                  | Frame Header                                                 |
| Data field length | -        | 4C 00       | 0x004C = 76        | Data Field Length = 76 bytes                                 |
| CRC               | -        | 14 BB       | 0xBB14             | CRC Checksum                                                 |
| tag               | -        | 91          | 0x91               | 0x91 Data Packet (Payload data field begins from this field) |
| main_status       | uint16_t | 10 1C       | 0x1C10             | Status Word                                                  |
| temperature       | int8_t   | 23          | 0x23=35            | Temperature: °C                                              |
| air_pressure      | float    | 09 A2 C4 47 | 100676             | Air Pressure, Pa                                             |
| system_time       | uint32_t | 08 15 1C 00 | 0x001C1508=1840392 | Timestamp, ms                                                |
| acc_b_x           | float    | CC E8 61 BE | -0.220615          | Acceleration X-axis, G                                       |
| acc_b_y           | float    | 9A 35 56 3E | 0.209189           | Acceleration Y-axis, G                                       |
| acc_b_z           | float    | 65 EA 72 3F | 0.948889           | Acceleration Z-axis, G                                       |
| gyr_b_x           | float    | 31 D0 7C BD | -0.061722          | Angular Velocity X-axis, deg/s                               |
| gyr_b_y           | float    | 75 DD C5 BB | -0.00603836        | Angular Velocity Y-axis, deg/s                               |
| gyr_b_z           | float    | 6B D7 24 BC | -0.0100611         | Angular Velocity Z-axis, deg/s                               |
| mag_b_x           | float    | 89 88 FC 40 | 7.89167            | Magnetic Field X-axis, $\mu$ T                               |
| mag_b_y           | float    | 01 00 6A 41 | 14.625             | Magnetic Field Y-axis, $\mu$ T                               |
| mag_b_z           | float    | AB 2A 70 C2 | -60.0417           | Magnetic Field Z-axis, $\mu$ T                               |
| roll              | float    | 96 D4 50 41 | 13.0519            | Roll Angle, deg                                              |
| pitch             | float    | ED 03 43 41 | 12.1885            | Pitch Angle, deg                                             |
| yaw               | float    | 41 F4 F4 C2 | -122.477           | Head Angle, deg                                              |
| q_w               | float    | CC CA F8 BE | -0.485922          | Quaternion W                                                 |
| q_x               | float    | 73 6A 19 BE | -0.14982           | Quaternion X                                                 |
| q_y               | float    | F0 00 1C 3D | 0.0380868          | Quaternion Y                                                 |
| q_z               | float    | 8D 37 5C 3F | 0.860223           | Quaternion Z                                                 |

### 3.5 C language parsing code example (using HI91 as an example)

Please refer to the official C language examples.

```

1  int16_t payload_len;
2  uint16_t crc;
3  crc = 0;
4  payload_len = buf[2] + (buf[3] << 8);
5
6  /* Calculate 5A A5 and LEN field crc */
7  crc16_update(&crc, buf, 4);
8
9  /* Calculate payload crc */
10 crc16_update(&crc, buf + 6, payload_len);

```

The calculated CRC value is 0xBB14, which is the same as the CRC field value in the data frame, so the CRC check passes.

### 3.5.1 Define data receiving structure

Starting from 0x91, the data field of the data packet is defined, including data structures and commonly used conversion macros.:

```
1  #include "stdio.h"
2  #include "string.h"
3
4  /* Common type conversion */
5  #define U1(p) (*((uint8_t *) (p)))
6  #define I1(p) (*((int8_t *) (p)))
7  #define I2(p) (*((int16_t *) (p))) 8
9  static uint16_t U2(uint8_t *p) {uint16_t u; memcpy(&u, p, 2); return u;}
10 static uint32_t U4(uint8_t *p) {uint32_t u; memcpy(&u, p, 4); return u;}
11 static int32_t I4(uint8_t *p) {int32_t u; memcpy(&u, p, 4); return u;}
12 static float R4(uint8_t *p) {float r; memcpy(&r, p, 4); return r;} 13
14 typedef struct
15 {
16     uint8_t tag; /* Item tag: 0x91 */
17     float acc[3]; /* Acceleration */
18     float gyr[3]; /* Angular velocity */
19     float mag[3]; /* Magnetic field */
20     float eul[3]; /* Attitude: Euler angle */
21     float quat[4]; /* Attitude: quaternion */
22     float pressure; /* Air pressure */
23     uint32_t timestamp; /* Timestamp */
24 }imu_data_t;
```

### 3.5.2 Receive data

The payload portion begins at buf[6]=0x91:

```
1  imu_data_t i0x91 = {0};
2  int offset = 6; /* Payload start at buf[6] */
3
4  i0x91.tag = U1(buf+offset+0);
5  i0x91.pressure = R4(buf+offset+4);
6  i0x91.timestamp = U4(buf+offset+8);
7  i0x91.acc[0] = R4(buf+offset+12);
8  i0x91.acc[1] = R4(buf+offset+16);
9  i0x91.acc[2] = R4(buf+offset+20);
10 i0x91.gyr[0] = R4(buf+offset+24);
11 i0x91.gyr[1] = R4(buf+offset+28);
12 i0x91.gyr[2] = R4(buf+offset+32);
13 i0x91.mag[0] = R4(buf+offset+36);
14 i0x91.mag[1] = R4(buf+offset+40);
15 i0x91.mag[2] = R4(buf+offset+44);
16 i0x91.eul[0] = R4(buf+offset+48);
17 i0x91.eul[1] = R4(buf+offset+52);
18 i0x91.eul[2] = R4(buf+offset+56);
19 i0x91.quat[0] = R4(buf+offset+60);
20 i0x91.quat[1] = R4(buf+offset+64);
21 i0x91.quat[2] = R4(buf+offset+68);
22 i0x91.quat[3] = R4(buf+offset+72);
```

### 3.5.3 Print the received data

```
1  printf("%-16s0x%X\r\n", "tag:", i0x91.tag);
2  printf("%-16s%8.4f %8.4f %8.4f\r\n", "acc(G):", i0x91.acc[0],
i0x91.acc[1], i0x91.acc[2]);
3  printf("%-16s%8.3f %8.3f %8.3f\r\n", "gyr(deg/s):", i0x91.gyr[0],
i0x91.gyr[1], i0x91.gyr[2]);
4  printf("%-16s%8.3f %8.3f %8.3f\r\n", "mag(uT):", i0x91.mag[0],
i0x91.mag[1], i0x91.mag[2]);
```

```
5   printf("%-16s%8.3f %8.3f %8.3f\r\n",    "eul(deg):",    i0x91.eul[0],  
i0x91.eul[1],    i0x91.eul[2]);  
6   printf("%-16s%8.3f %8.3f %8.3f %8.3f\r\n",    "quat:",    i0x91.quat[0],  
i0x91.quat[1],    i0x91.quat[2],    i0x91.quat[3]);  
7   printf("%-16s%8.3f\r\n",                    "pressure(pa):",    i0x91.pressure);  
8   printf("%-16s%d\r\n",                        "timestamp(ms):",  
i0x91.timestamp);
```

### 3.6 Maximum transmission rate

| Protocol | byte count | 9600bps | 115200bps | 230400bps | 256000bps | 460800bps | 921600bps |
|----------|------------|---------|-----------|-----------|-----------|-----------|-----------|
| 91       | 76         | 10Hz    | 100Hz     | 250Hz     | 250Hz     | 500Hz     | 1000Hz    |