FORSENSE
原极科技

Tactical MEMS 6 degrees of freedom inertial sensor

FSS-IMUP8 Product manual

Features

Tactical grade MEMS gyroscope

- 0.5°/hr Bias instability instability
- 0.1°/√hr Angle random walk
- 30°/hr temperature drift (-40 ~ 85°C, <=1°C/ min@1σ)

Tactic-grade MEMS accelerometer

- 20μg Bias instability instability
- 0.035m/s/√hr velocity random walk
- 1mg temperature drift (-40 ~ 85°C, <=1°C/ min@1σ)

Large range of fine temperature compensation

- -40°C to 85°C temperature compensation
- Fine temperature calibration

Independent turntable calibration

- Independently calibrate each module: sensitivity, Bias instability, non-orthogonal error
- Provide user calibration installation error interface

High strength working condition tolerance

- Strong impact tolerance: 2000g (0.5ms, half sine, 3 axis)
- Strong vibration tolerance: 10g (10~2KHz, 3 axis)
- Full temperature environment stable operation: -40°C ~ 85°C
- 100% magnetic shielding

Real-time and flexible digital interface, small size

- Configurable output sampling rate up to 1KHz
- Support for serial 422
- 38.6*44.8*21.5mm, weighs about 58g

Product Overview

IMUP8 is a 6-DOF MEMS inertial sensor module built by FORSENSE Technology. It is equipped with three-axis gyroscope and acceleration information as standard.

High precision, high resolution, can capture subtle vibration and tilt. Large range output makes motion perception possible under large dynamics. All modules are equipped with ultra-wide temperature range of fine warming and independent calibration before delivery, so

that each module can play stably in various extreme conditions, while ensuring the performance of all products is highly consistent.

Application field

- Aerial mapping

On the basis of standard performance and output parameters, FORSENSE also provides customized software and LOGO customization services for your special needs, to help you in the product!

Contents

1. Performance parameters

1.1 Key indicators of gyroscope

Table 1 Key indicators of gyroscope

Parameters	Test conditions/Remarks	Minimum value	Typical value	Maximum value	Units
Measuring range			+ 300		°/s
Bias instability instability	@25 ° C, ALLAN variance, 1σ		0.5		°/hr
Bias instability stability	National military standard, 10s smooth		2		°/hr
Bias instability repeatability	National Army mark		3		°/hr
Resolution			0.0041		°/s
Non-orthogonal between axes			0.02		deg
Internal low-pass cutoff frequency	Software adjustable	10	75		Hz
Sampling rate			1000		Hz
Measuring delay			7.2		ms
All temperature range Bias instability change	-40℃ to 85℃ ≤1℃/ min@1σ		30		°/hr
Random Walk	@25 ° C, ALLAN variance, 1σ		0.1		°/√hr
Calibration coefficient error			1.0		‰
Calibration coefficient nonlinearity			50		ppm

Note 1σ change in zero deviation of total temperature at 1:1 ℃/ min

Note 2: IEEE standard, Allan variance curve given at static 25℃ environment

1.2 Key indicators of accelerometer

Table 2 Key indicators of accelerometer

Parameters	Test conditions/Remarks	Minimum value	Typical value	Maximum value	Units
Measuring range			Plus or minus 6	Optional ±20	g
Bias instability instability	@25℃, Allan Variance, 1σ		20		Mu g
Bias instability stability	National military standard, 10s smooth		30		Mu g
Bias instability repeatability	National Army mark		20		Mu g
Resolution			0.0816		mg
Non-orthogonal between axes			0.02		deg
Internal low-pass cutoff frequency	Software adjustable		75		Hz
Sampling rate			1000		Hz
Measuring delay			7.2		ms
Full temperature range zero deviation variation	-40℃ ~ 85℃ ≤1℃/ min@1σ		1.0		mg
Random Walk	@25 ALLAN variance, 1 sigma		0.035		m/s/√hr

Note the total temperature zero deviation change 1σ at 1:1 ℃/ min

Note 2: IEEE standard, Allan variance curve given at static 25℃ environment

FIG. 1 ALLAN variance typical curve of gyroscope

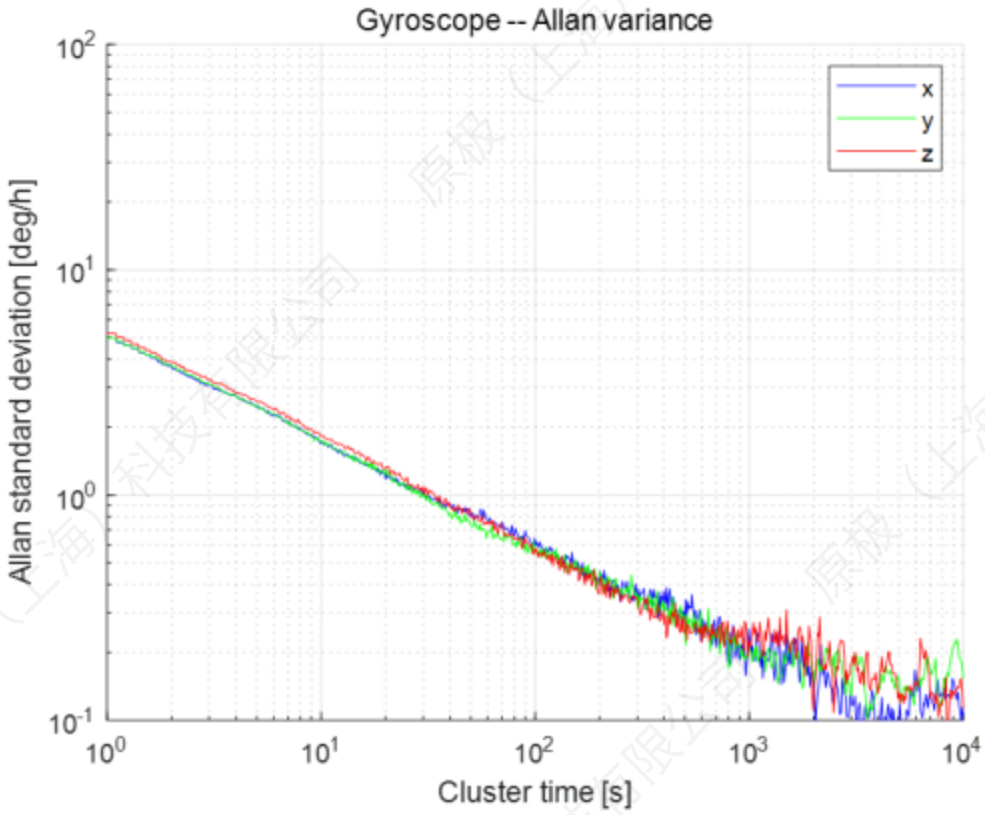
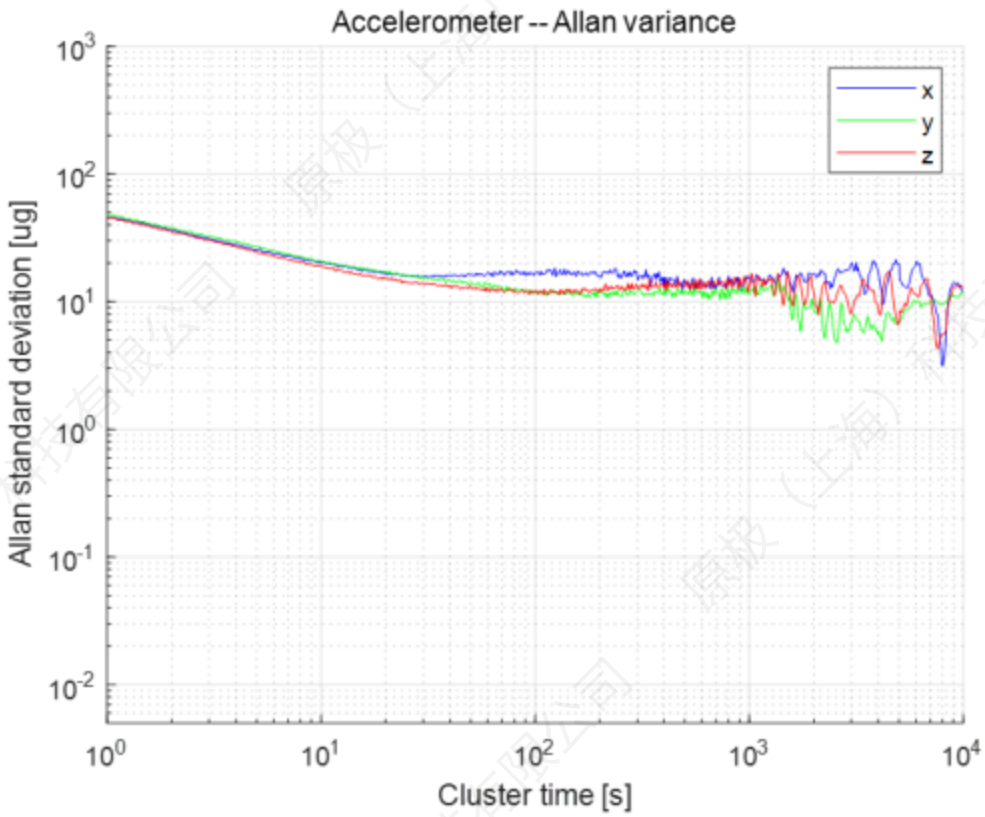


FIG. 2 Typical curve of ALLAN variance for accelerometer



2. External structure

Figure 3 Outline structure and size (unit: mm)

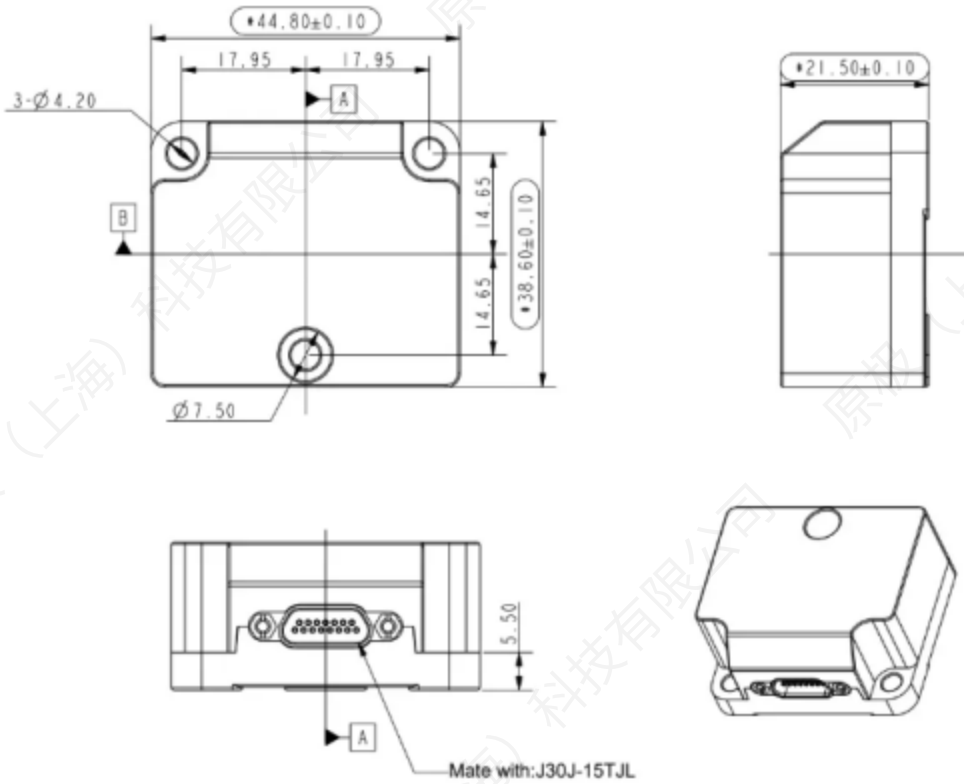
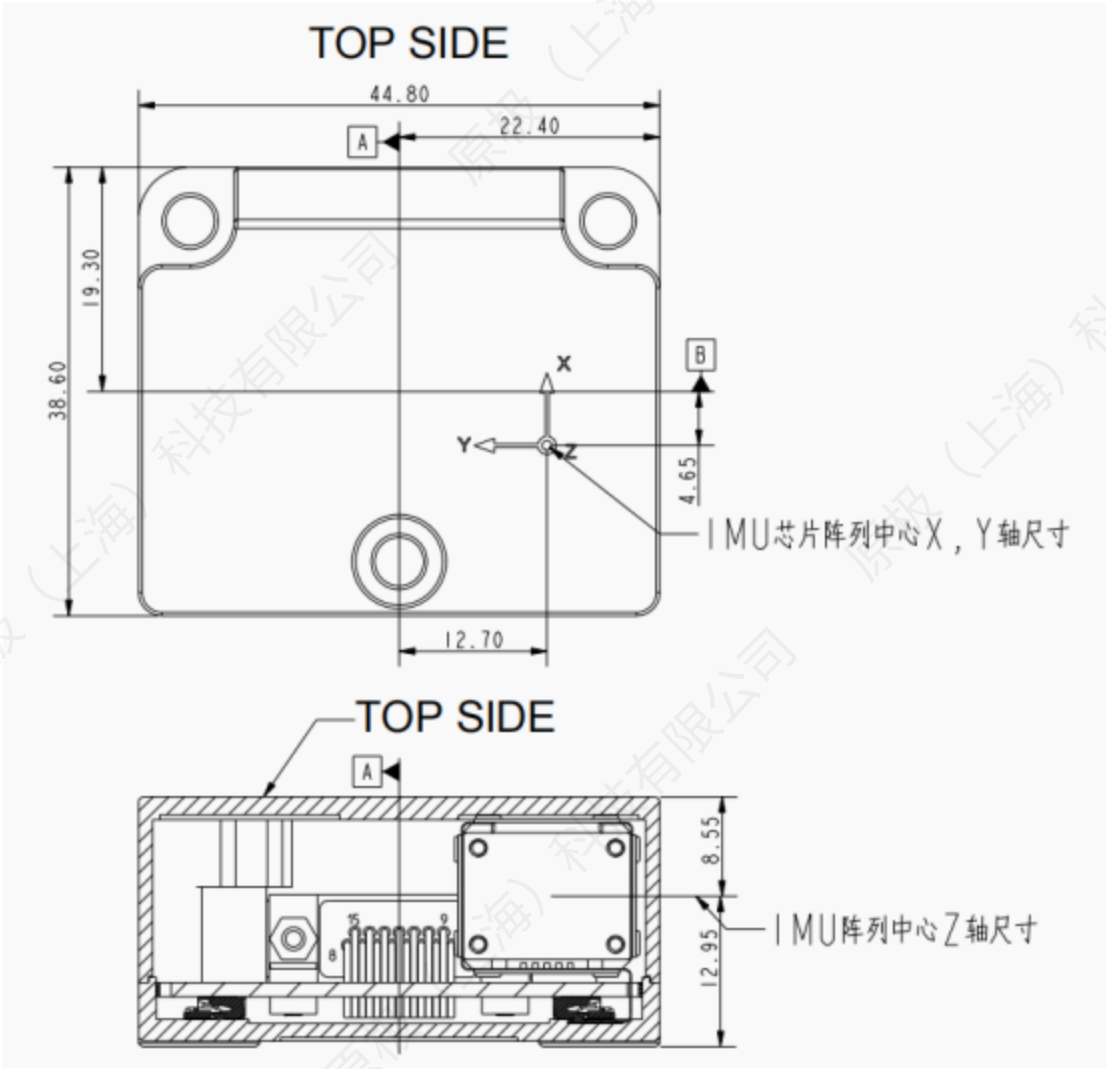


Figure 4 Location of IMU measurement center (unit: mm)



3. Specifications

3.1 Maximum absolute rated value

Table 3 Absolute maximum rating

Parameters	Levels	Remarks
Storage temperature	And 55 ℃ to 90 ℃	
VSUP to GND	- 0.5-6.5 V	
Use temperature	- 40 - + 85 ℃	
RXD+/RXD- to GND	7.5 V to 12.5 V	Match resistance 120Ω
RXD+ to RXD-	±6V	
TXD+/TXD- to GND	7.5 V to 12.5 V	
ExtTrig to GND	0.3 V - 7 V	
NRST to GND	0.3 V - 7 V	
DATA READY to GND	0.3 V - 7 V	

3.2 EMC

Table 4 EMC

Test Items	Test criteria
CE	Comply with EN55032 CISPR 16-2-1
CS	Comply with EN55035 EN(IEC)61000-4-6
EFT	Comply with EN55035 EN(IEC)61000-4-4
RE	Comply with EN55032 CISPR 16-2-3
RS	Meets EN55035 EN(IEC)61000-4-3
ESD	Complies with EN55035 EN(IEC)61000-4-2

3.3 ESD Rating

Table 5 ESD rating

V (ESD) Electrostatic discharge	Test mode	Test Criteria	Test grade
	Contact discharge	Comply with EN(IEC)61000-4-2	±8 KV
	Air discharge		±15 KV

4 Electrical characteristics

Table 6 Electrical characteristics

Parameters	Conditions	Minimum	Typical	Max	Units
Power input		4.5	5	5.5	V
Power			0.7		W
Storage temperature		-55		90	℃
Use temperature		-40		85	℃
RS422 input resistor			120		Ω
RESET (NRST PIN)	High	2.3			V
	Low			0.6	V
NRST Internal pull-up resistor			4.7		K Ω
Data Ready			3.3		V
ExtTrig	High	2.3			V
	Low			0.6	V

Note: When the supply voltage is higher than 6V, the internal voltage protection circuit will cut off the power supply and the device will enter the reset state until the voltage returns to the operating condition and resume work.

5 Pin definition

Figure 5 Pin schematic

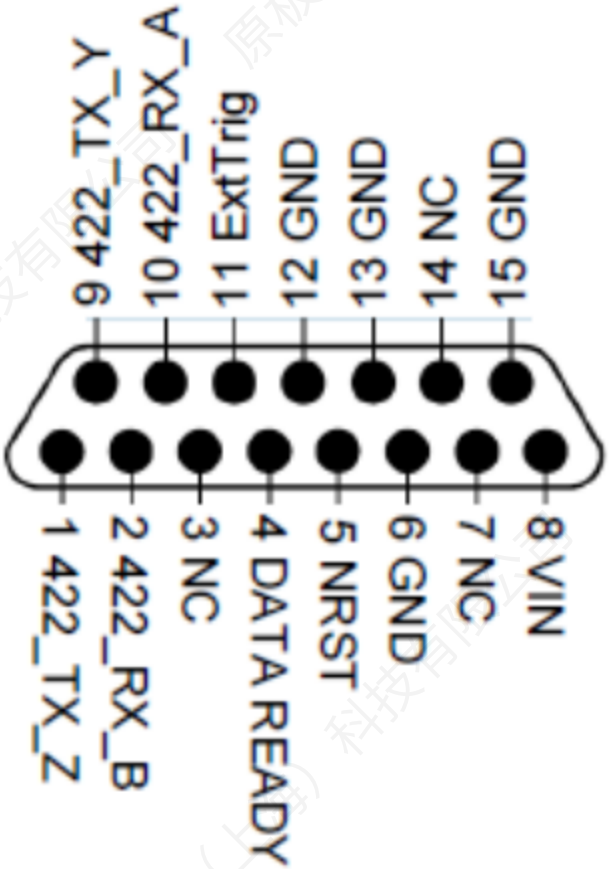


Table 7 Pin definitions

Pin Serial number	Pin name	Pin description
1	422_TX_Z	RS-422,TXD-
2	422_RX_B	RS-422,RXD-
3	NC	Not pick up
4	DATAREADY	Data Ready
5	NRST	External hardware reset input, internal pull-up
6	GND	Signalland
7	NC	Not pick up
8	VIN	Power input, +5V input
9	422_TX_Y	RS-422,TXD+
10	422_RX_A	RS-422,RXD+
11	ExtTrig	External trigger pps
12	GND	Power ground
13	GND	Power ground
14	nc	Not pick up
15	GND	Power ground

6.Recommended connection method

Figure 6 Block diagram of normal acquisition mode

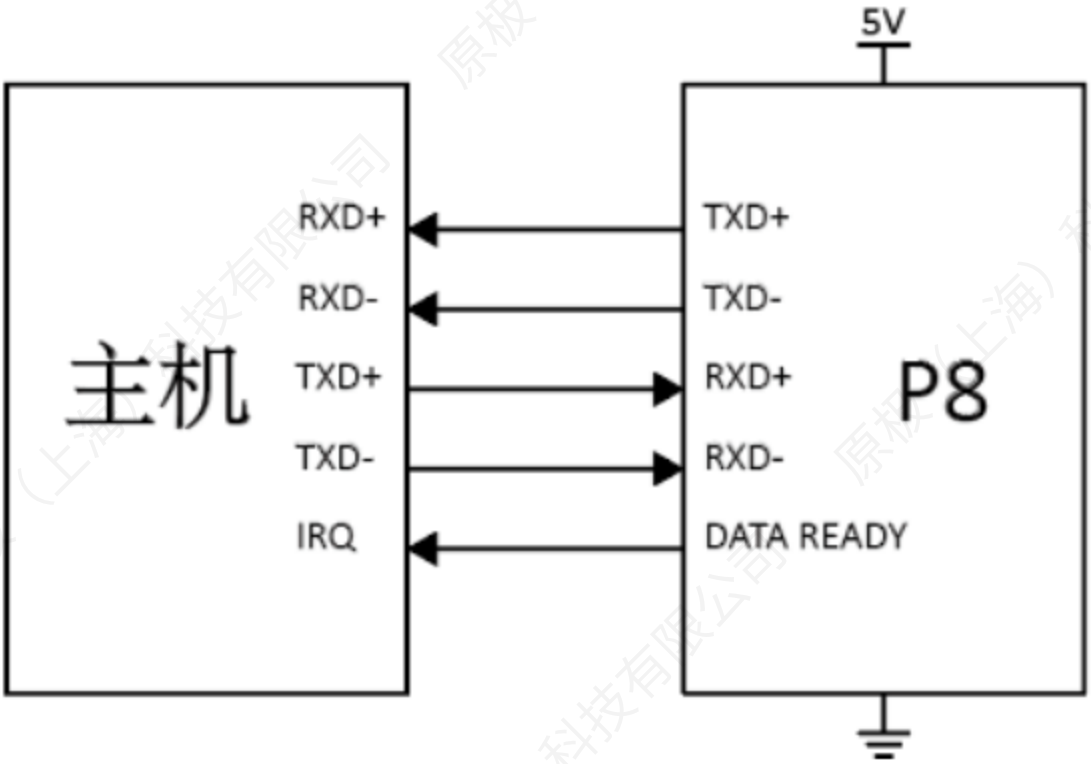
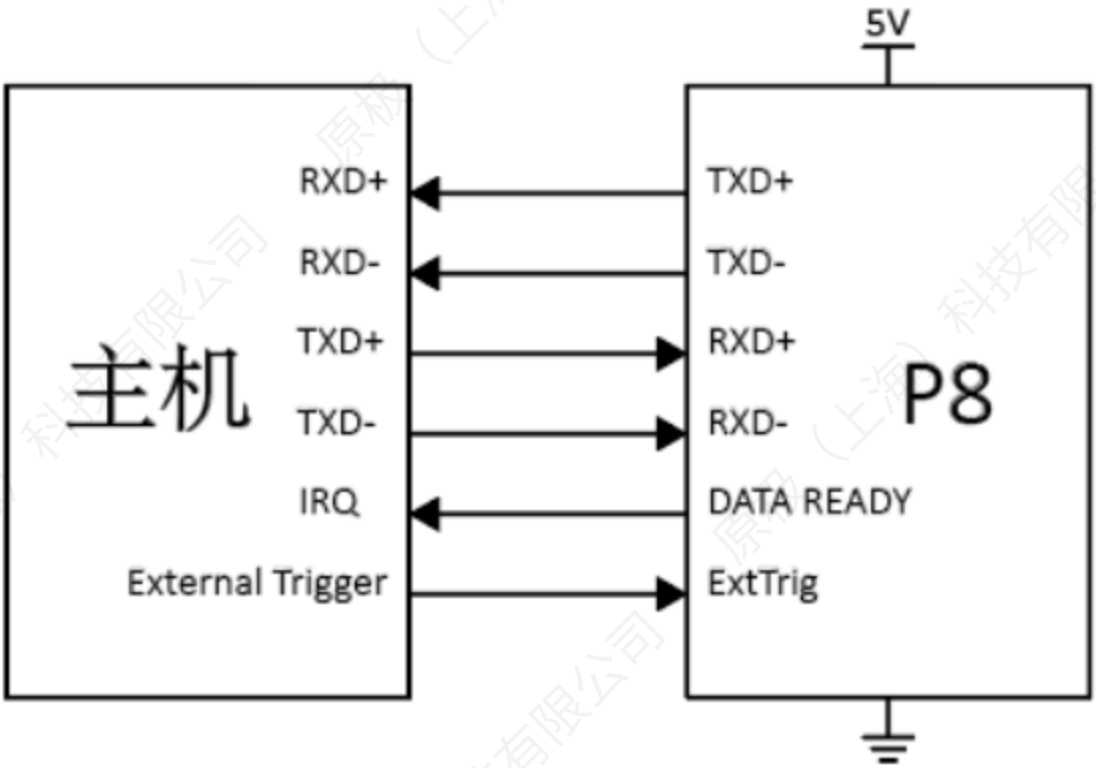


Figure 7 Block diagram of trigger acquisition mode



7. Serial communication protocol

Examples of serial port protocols based on QT, ROS, and STM32:

https://data.forsense-imu.com/page/download.html

The serial port communication supports two modes: Stream Mode and Command Mode. The IMU enters the corresponding mode according to the mode value configured by parameters after the initialization is complete.

Stream mode: Periodically output AHRS data at a fixed frequency;

Command mode: In this mode, the periodic output is stopped, the user communicates with the IMU by sending commands, and the sensor data, status, parameters, etc. can be obtained through the GET command, and the parameters of the IMU can also be configured.

7.1 Parameters of serial port interface

Table 8 Serial port parameters

Transmission rate range	115200bps to 1.5Mbps
Default transfer rate	115200bps
Start bit	1 bit
Data bits	8 bits
Stop bits	1 bit
Parity check	There is no

7.2 Packet Format

The packet structure of IMU output and user input is composed as follows:

Table 9 IMU output and user input data structures

Offsets	Data type	Name	Description
0	uint8	Frame Header 1	IMU Output frame headers: 0xAA, 0x55 User input frame header: 0x55, 0xAA
1	uint8	Frame header 2	
2	uint16	ID low	The lower byte of the COM frame ID
3		ID high byte	The upper byte of the COM frame ID
4	uint16	Data length low	The lowest byte of the COM communication frame length, length is the number of bytes carried by payload, that is, n
5		High data length	The high byte of the frame length of the serial port communication, length is the number of bytes carried by the payload, that is, n
6	uint8	Payload (n bytes)	Data load
6+n	Uint32	CRC_CEHCK (32-bit data low byte)	CRC check
7+n		CRC_CEHCK (Low byte in 32-bit data)	
8+n		CRC_CEHCK (High byte in 32-bit data)	
9+n		RC_CEHCK (32-bit data high byte)	

Note 1: Data is transmitted in small-endian format, with low bytes first and high bytes last

Note 2: The initial value of crc32 is 1. CRC calculation does not include all the data of this frame itself. See the end of the document for table lookup calculation

7.3 Data Flow frame -- AHRS data

Table 10 AHRS data format of COM

	Frame Headers	Frame Headers	ID	length	payload	Frame tail
Data type	uint8	uint8	uint16	uint16	A1	uint32
Coding	0xAA	0x55	0x0002	0x002C		crc32

Table 11 COM A1 load data format

offset	Name	Data type	Units	Description
0	timer	uint32	Mu s	Time scale
4	/	/	/	/
8	/	/	/	/
12	/	/	/	/
16	ax	float	g	X-axis acceleration
20	ay	float	g	Y-axis acceleration
24	az	float	g	Z-axis acceleration
28	gx	float	°/s	X axis angular velocity
32	gy	float	°/s	Y-axis angular velocity
36	gz	float	°/s	Z axis angular velocity
40	temp	float	℃	IMU chip temperature

Example: Get AHRS data stream:

AA 55 02 00 2C 00 6D 89 16 05 8F C2 65 40 14 AE 07 BF 5C 0F B2 43 25 06 81 3D BC 74 13 3C 60 E5 80 BF EC 51 38 BD 0A D7 A3 BB CD CC CC BC D7 A3 EE 41 0C BF 84 80

The analysis is as follows:

Table 12 Serial port A1 gets AHRS data stream

Description	Raw Value	Analytic value	Description	Raw Value	Analytic value
ID	0200	02	Y-axis acceleration	BC74133C	0.009 g
Length	2C00	44	Z-axis acceleration	60E580BF	1.007 g
Time scale	6D891605	85363053	X axis angular velocity	EC5138BD	0.045 ° / s
Pitch Angle	8FC26540	3.59 °	Y-axis angular velocity	0AD7A3BB	0.005 ° / s
Roll Angle	14AE07BF	0.53 °	Z axis angular velocity	CDCCCCBC	0.025 ° / s

Heading Angle	5C0FB243	356.12 °	imu chip temperature	D7A3EE41	29.83 ℃
X-axis acceleration	2506813D	0.063 g	crc32 Check	0CBF8480	2156183308

7.4 Command Mode GET Output -- System status

Table 13 COM system status data format

	Frame Headers	Frame header	ID	length	payload	Frame tail
Data type	uint8	uint8	uint16	uint16	S1	uint32
Coding	0xAA	0x55	0x00FF	N		crc32

Note 1: Depending on the IMU model, the length of this frame will vary, all represent the length of S1, need to be confirmed according to the imu model.

Table 14 COM S1 load data format

offset	Name	Data type	Description
0	Software_ver	uint32	Software version number
4	Hardware_ver	uint32	Hardware version number
8	rev	uint16	Reserved bytes
10	sn0	uint32	First SN number
14	sn1	uint32	Second SN
18	sn2	uint32	Third SN
22	Board_version	uint32	Baseboard version number
26	Rev[16]	Uint8	All that follows is reserved bytes

Note 1: Reserved bytes vary based on the imu model. The IMU614E is 16 bytes.

For example, obtain the IMU status

Enter data: 55 AA 01 00 18 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 BD DB 31 34

Response data: AA 55 FF 00 2A 00 1F 39 03 00 65 6F 01 00 50 83 30 33 35 55 34 50 15 FF 8F 5F FF FF 50 83 FF 1F 29 00 00 00 00 E0 00 07 10 17 08 50 D0 37 10 3B 7A C3 00 02

Based on the response data, the resolution yielded software version number 211231(1F 39 03 00) and hardware version number 94053(65 6F 01 00).

7.5 Command mode GET output -- read the parameters

Table 15 Serial port parameters input data format

	Frame header	Frame Headers	ID	length	payload	Frame tail
Data type	uint8	uint8	uint16	uint16	P1	uint32
Coding	0x55	0xAA	0x0006	0x0018		crc32

Table 16 Output data format of serial port parameters

	Frame headers	Frame Headers	ID	length	payload	Frame tail
Data type	uint8	uint8	uint16	uint16	P1	uint32
Coding	0xAA	0x55	0x7530	0x0018		crc32

Note 1: When reading Parameter, the IMU will disable the data stream. After the setting is complete, the data stream needs to be restarted.

Table 17 Load data format of COM P1

offset	Name	Data type	Description
0	Param1	float	Obtained Parameter (input data can be ignored)
4	Param2	float	Keep, default to 0
8	Param3	uint32	Set the Parameter index
12	Param4	uint32	Reserved, the default value is 0
16	Param5	Int32	Keep, default is 0
20	Param6	Int32	Keep, default is 0

Table 18 Index table of Parameter of COM P1 load

Param3	Param1	Units
3	The COM outputs the baud rate. The following baud rates are supported 115200, 230400, 460800, 921600, 1500000	bps
4	Coordinate system orientation (see Table 25 Coordinate System Orientation correspondence table)	
8	X-axis gyro zero bias calibration results, GYRO_X_OFF	°/s
9	Y-axis gyro zero bias calibration results, GYRO_Y_OFF	°/s
10	Z-axis gyro zero bias calibration results, GYRO_Z_OFF	°/s
21	AHRS output frequency, default 100Hz	Hz
31	Internal filter configuration, define the same SPI FILTER_CTRL table	

Example: Get AHRS output frequency

Input data: 55 AA 06 00 18 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 15 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 66 CB 46 AC

Response data: AA 55 30 75 18 00 00 00 00 48 42 00 00 00 00 00 00 00 15 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 31 2F A2 0A

According to the response data, the analysis results in an output frequency of 50hz (00 00 48 42).

7.6 Command Mode SET command

Table 19 Syntax of the COM input command

	Frame header	Frame Headers	ID	length	payload	Frame tail
Data type	uint8	uint8	uint16	uint16	R1	uint32
Coding	0x55	0xAA	CMD	0x0018		crc32

Note 1: For details about the relationship between CMD and R1, see the R1 load Parameter index table

Table 20 Load data format of COM R1

offset	Name	Data type	Description
0	Param1	float	Set Parameter
4	Param2	float	Keep, default to 0
8	Param3	uint32	Set the Parameter index
12	Param4	uint32	Reserved, the default value is 0
16	Param5	Int32	Keep, default is 0
20	Param6	Int32	Keep, default is 0

Table 21 Index of Parameter of the COM R1 load

CMD	Param1	Param3	Description
1	0	0	Trigger to get system status data once
2	0	0	Trigger to obtain AHRS data once
3	<mode>	0	Set output Mode: Mode=1, data stream output AHRS Mode=100 to disable data stream mode and enter COMMAD mode
5	0	0	Save the current Parameter to FLASH
6	0	<value>	Read Parameter, value is the index of the Parameter to be read, that is, P1.index, see the COM response output - Parameter read For example, if you want to read AHRS output frequency (ODR), set value=21 For example, to read the baud rate of the COM, set the value to 3 For example, if you want to read the internal filter, set value=31 For example, if you want to read the coordinate system

			orientation, set value=4
9	0	0	Perform a software restart
14	<value>	3	To set the baud rate of the output of the COM, the valid value in bps value is: 115200,230400,460800,921600,1500000 If value is other values, the default value is 115200bps The baud rate Parameter takes effect only after the system restarts. Procedure for setting the power-off: Set the baud rate, save Parameter to the flash, and reset the software
14	<value>	21	Set the periodic AHRS data output frequency, common values in Hz value are: 1,10,50,100,200,500,1000 Recommended mapping between output frequency and COM baud rate 1000Hz: 921600bps 500Hz: 460,800bps 200Hz: 460800bps 250Hz: 460800bps 100Hz: 115,200 BPS
14	<value>	31	Internal filter configuration, defined as SPI accelerometer and gyro filter configuration, default 0xBB, i.e. 47Hz
14	<value>	4	Set the orientation of the IMU coordinate system. The value ranges from 101 to 124. For details about the orientation of the IMU coordinate system, see Table 25

Note 1: Please note that all values in this table are in decimal

Note 2: The host computer command generator function can be used to generate corresponding commands to send, see the use of the host computer section of this manual

For example, to enable AHRS output:

Enter 3 in CMD ID and 1 in Parameter 1. The generated hexadecimal array can be filled into the COM assistant or program array and sent to the IMU.

命令生成器

55,aa,03,00,18,00,00,00,80,3f,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,52,d8,8e,e8

CMD ID: 3

参数:

1 1 2 0 3 0

4 0 5 0 6 0

生成命令 发送命令

7.7 Command Mode output -- User command response

Table 22 Setting Parameter COM response data format

	Frame header	Frame header	ID	length	ACK	Param3	Frame end
Data type	uint8	uint8	uint16	uint16	uint16	uint16	uint32
Coding	0xAA	0x55	0x753D	0x0004	0x7534	Parameter index	crc32

Table 23 Reserved Parameter serial port response data format

	Frame header	Frame header	ID	length	ACK	result	Frame Tail
Data type	uint8	uint8	uint16	uint16	uint16	uint16	uint32
Coding	0xAA	0x55	0x753D	0x0004	0x0005	0x01	crc32

Table 24 Data format of COM user command response

	Frame header	Frame header	ID	length	command	result	Frame Tail
Data type	uint8	uint8	uint16	uint16	uint16	uint16	uint32
Coding	0xAA	0x55	0x0064	0x0004	Command ID	0x01	crc32

Example: Set the output baud rate of the COM to 115200
Data input: 55, AA, 0 e, 00,18,00,00,00, E1, 47,00,00,00,00,03,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,56,2 B, 4 d, 93
Response data: AA 55 3D 75 04 00 34 75 03 00 A7 98 2A 54

Set the periodic AHRS data output frequency to 100hz
Input data: 55 AA 0E 00 18 00 00 00 00 C8 42 00 00 00 00 00 00 00 00 15 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 0A 2B 2C 8D
Response data: AA 55 3D 75 04 00 34 75 15 00 70 2D B2 48

Save the current parameter to FLASH
Enter data: 55 AA 05 00 18 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 C9 2F E6 32
Response data: AA 55 3D 75 04 00 05 00 01 00 5A CF B1 7C

Set output mode to AHRS data stream
Input data: 55 AA 03 00 18 00 00 00 00 80 3F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 52 D8 8E E8
Response data: AA 55 64 00 04 00 03 00 01 00 E7 87 E3 AD

8. Time synchronization

With time synchronization, you can ensure that the internal clock of the device is consistent with the external time reference, which can eliminate the time deviation due to clock drift;

In a system with multiple devices working together, the time stamps of all devices will be based on the same time benchmark, which helps to ensure data consistency and accuracy.

At present, this module provides two methods of time synchronization:

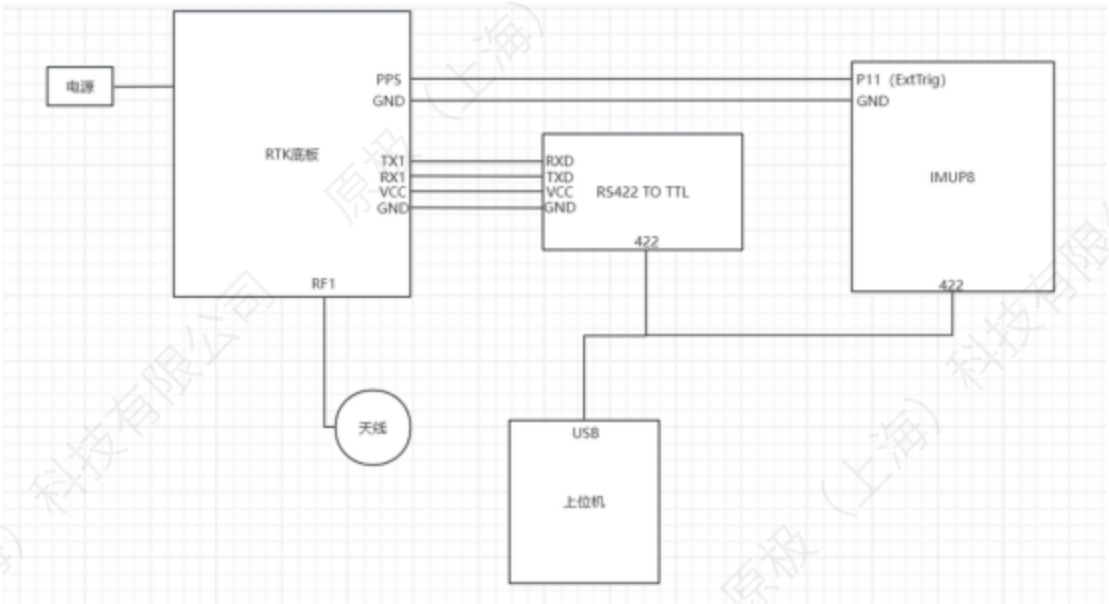
1. Access pps signal +rmc message,

2. Synchronize time on the host using the DRDY signal

8.1 Connecting PPS Signals and GPRMC Packets

8.1.1 Hardware connection

(1) Connect the IMU to the RTK baseboard according to the connection diagram.



P8 Connection diagram

8.1.2 RTK configuration requirements:

GPRMC 10HZ

Disable inertial Navigation Assistance-related functions of the RTK board Turn off other statements.

PPS second pulse: 1s once, rising edge triggered, pulse width 5ms, aligned to UTC time. High level must not be higher than 5v.

Make sure that the baud rate of the RTK serial port is the same as that of the IMU.

Connect the RTK baseboard to the host, open the serial assistant, and enter the instructions successively:

CONFIG (View the baud rate configuration)

config com1 115200 (corresponding to IMU baud rate)

saveconfig (Save parameters)

8.1.3 How to Confirm whether time synchronization is successful:

The steps to confirm are as follows:

Before synchronization, count the value of the IMU itself in ms format

After synchronization, it will become the truth value after UTC conversion in ms, taking the truth value 43767630ms as an example

To convert the given ms value to s:

43,767,630ms= 43,767.63s

To convert s to h, min, and s:

First, divide the number of seconds by 3600 (1h=3600s) to get the number of hours and the number of seconds remaining.

43,767s ÷ 3600 = 12h... 567s (rounded)

Next, divide the number of seconds left by 60 (1min=60s) to get the number of minutes and the number of seconds left.

567s ÷ 60 = 9min... 27s (rounded)

Collate the results:

Combine the h, min, and s from the steps above, along with the initial decimal part, to form the final UTC time representation (hhmmss.sss).

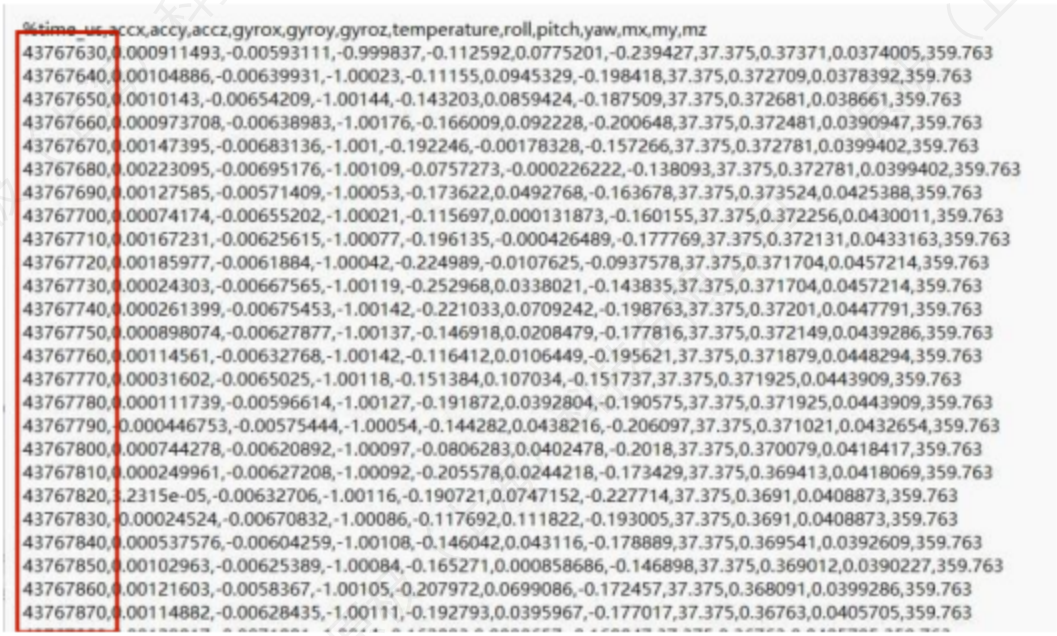
The final UTC time representation is: 120927.63

2. The timestamp interval varies according to the set IMU Update Rate.

For example:

When the IMU Update Rate is 10Hz, the corresponding timestamp interval is 100 ms.

In this case, the timestamps will be sent at a frame interval of every 10 ms to ensure synchronization with the IMU data. The following is an example



```
%time_us,accx,accy,accz,gyrox,gyroy,gyroz,temperature,roll,pitch,yaw,mx,my,mz
43767630,0.000911493,-0.00593111,-0.999837,-0.112592,0.0775201,-0.239427,37.375,0.37371,0.0374005,359.763
43767640,0.00104886,-0.00639931,-1.00023,-0.11155,0.0945329,-0.198418,37.375,0.372709,0.0378392,359.763
43767650,0.0010143,-0.00654209,-1.00144,-0.143203,0.0859424,-0.187509,37.375,0.372681,0.038661,359.763
43767660,0.000973708,-0.00638983,-1.00176,-0.166009,0.092228,-0.200648,37.375,0.372481,0.0390947,359.763
43767670,0.00147395,-0.00683136,-1.001,-0.192246,-0.00178328,-0.157266,37.375,0.372781,0.0399402,359.763
43767680,0.00223095,-0.00695176,-1.00109,-0.0757273,-0.000226222,-0.138093,37.375,0.372781,0.0399402,359.763
43767690,0.00127585,-0.00571409,-1.00053,-0.173622,0.0492768,-0.163678,37.375,0.373524,0.0425388,359.763
43767700,0.00074174,-0.00655202,-1.00021,-0.115697,0.000131873,-0.160155,37.375,0.372256,0.0430011,359.763
43767710,0.00167231,-0.00625615,-1.00077,-0.196135,-0.000426489,-0.177769,37.375,0.372131,0.0433163,359.763
43767720,0.00185977,-0.0061884,-1.00042,-0.224989,-0.0107625,-0.0937578,37.375,0.371704,0.0457214,359.763
43767730,0.0024303,-0.00667565,-1.00119,-0.252968,0.0338021,-0.143835,37.375,0.371704,0.0457214,359.763
43767740,0.000261399,-0.00675453,-1.00142,-0.221033,0.0709242,-0.198763,37.375,0.37201,0.0447791,359.763
43767750,0.000898074,-0.00627877,-1.00137,-0.146918,0.0208479,-0.177816,37.375,0.372149,0.0439286,359.763
43767760,0.00114561,-0.00632768,-1.00142,-0.116412,0.0106449,-0.195621,37.375,0.371879,0.0448294,359.763
43767770,0.00031602,-0.0065025,-1.00118,-0.151384,0.107034,-0.151737,37.375,0.371925,0.0443909,359.763
43767780,0.000111739,-0.00596614,-1.00127,-0.191872,0.0392804,-0.190575,37.375,0.371925,0.0443909,359.763
43767790,-0.000446753,-0.00575444,-1.00054,-0.144282,0.0438216,-0.206097,37.375,0.371021,0.0432654,359.763
43767800,0.000744278,-0.00620892,-1.00097,-0.0806283,0.0402478,-0.2018,37.375,0.370079,0.0418417,359.763
43767810,0.000249961,-0.00627208,-1.00092,-0.205578,0.0244218,-0.173429,37.375,0.369413,0.0418069,359.763
43767820,2.2315e-05,-0.00632706,-1.00116,-0.190721,0.0747152,-0.227714,37.375,0.3691,0.0408873,359.763
43767830,0.00024524,-0.00670832,-1.00086,-0.117692,0.111822,-0.193005,37.375,0.3691,0.0408873,359.763
43767840,0.000537576,-0.00604259,-1.00108,-0.146042,0.043116,-0.178889,37.375,0.369541,0.0392609,359.763
43767850,0.00102963,-0.00625389,-1.00084,-0.165271,0.000858686,-0.146898,37.375,0.369012,0.0390227,359.763
43767860,0.00121603,-0.0058367,-1.00105,-0.207972,0.0699086,-0.172457,37.375,0.368091,0.0399286,359.763
43767870,0.00114882,-0.00628435,-1.00111,-0.192793,0.0395967,-0.177017,37.375,0.36763,0.0405705,359.763
```

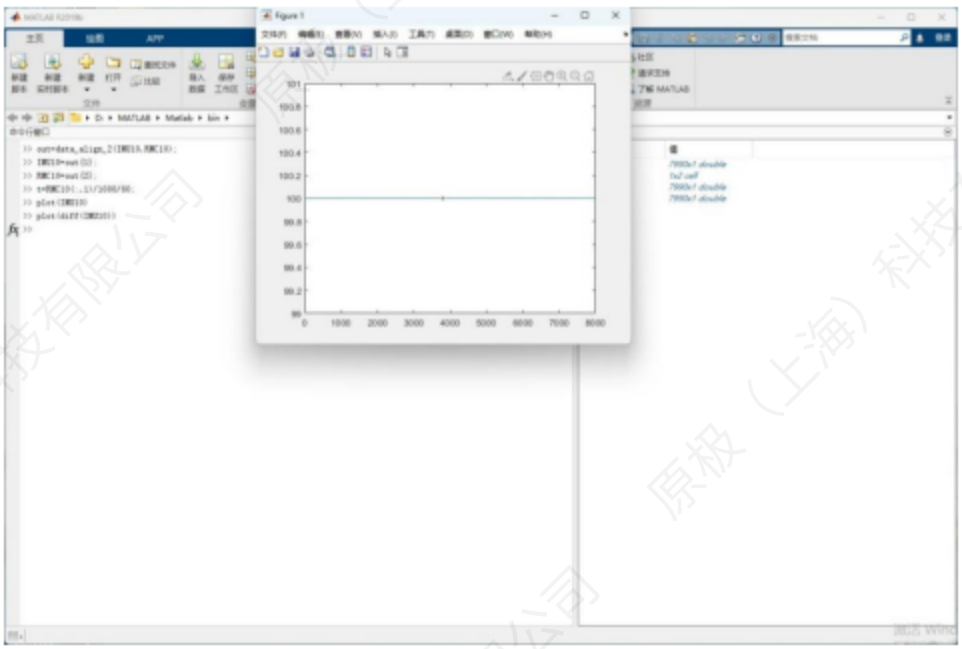
8.1.4 How Do I Verify that the time stamp is Correct After Time synchronization

1. Collect RMC data and AHRS data after time synchronization, and decode it.
2. Convert the two time stamps into the same format, and use matlab and other tools to count the following indicators of the following two groups of corresponding time stamp data

First, the statistical time stamp interval is stable, confirm whether there is packet loss, Judging conditions:

10HZ output: The interval is stable to 100ms

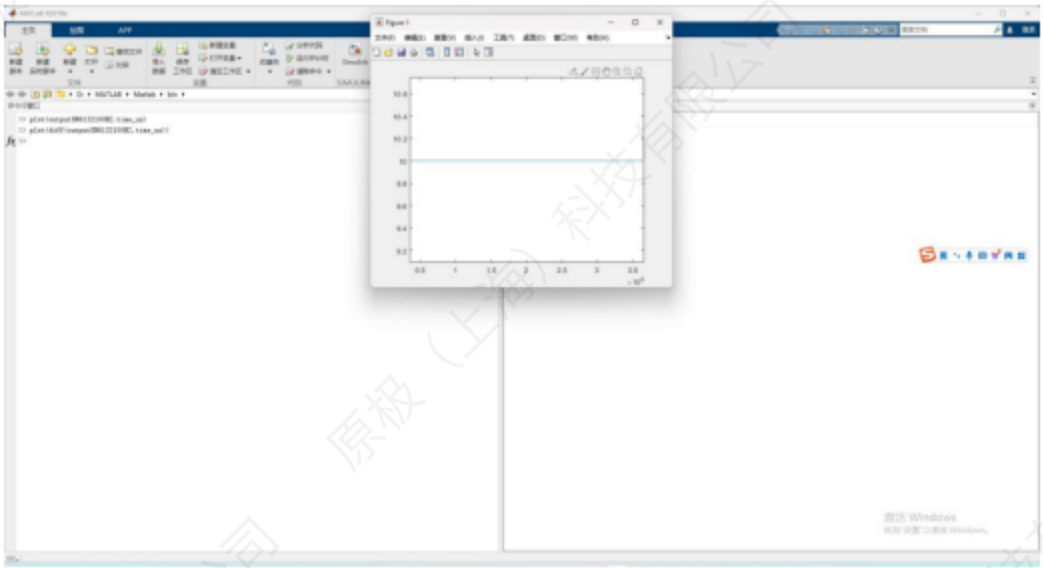
```
%time_us,accx,accy,accz,gyrox,gyroy,gyroz,temperature,roll,pitch,yaw,mx,my,mz
10138100,-0.00785668,0.000511979,-1.00068,0.00577856,0.0224228,-0.170839,43.6992,-0.185733,-0.373024,2.66486
10138200,-0.00548826,-8.32841e-06,-1.00069,0.120156,-0.0394001,0.0182559,43.6992,-0.177175,-0.373694,2.66124
10138300,-0.0177959,-0.0481571,-1.00444,-0.452245,-0.0625247,-6.75837,43.6992,-0.166894,-0.370253,2.60756
10138400,-0.00540888,-0.000368123,-0.999689,0.0587807,0.157406,-0.743163,43.7031,-0.179521,-0.368657,2.35367
10138500,-0.00681769,0.00110348,-1.00052,-0.0118609,-0.0201513,-0.0745728,43.6992,-0.174604,-0.366914,2.32512
10138600,-0.00541474,-2.34533e-05,-1.00088,0.0289074,-0.0428571,0.0164407,43.6992,-0.168918,-0.367043,2.32495
10138700,-0.00661371,0.000592246,-1.00062,0.00993176,-0.000438364,-0.0288885,43.6953,-0.163664,-0.364568,2.3255
10138800,-0.0048226,6.92813e-05,-1.00043,-0.00735649,0.0273419,-0.0158955,43.6992,-0.155855,-0.371403,2.33634
10138900,-0.00664255,0.000866315,-1.00145,0.0919172,-0.0107388,-0.0110982,43.7031,-0.151304,-0.366063,2.33678
10139000,-0.00515508,-0.000483297,-0.999668,-0.00652478,0.114841,-0.00554243,43.6992,-0.147101,-0.370124,2.3664
10139100,-0.00679933,8.07165e-05,-1.00015,0.0193778,-0.00205665,0.000614035,43.6953,-0.141752,-0.363385,2.36672
10139200,-0.00633591,0.000995697,-1.00043,0.0350645,-0.0332949,0.0570056,43.6875,-0.136313,-0.36819,2.37055
10139300,-0.00676747,0.000319971,-1.00062,0.0243442,0.0444976,0.00981862,43.6875,-0.133467,-0.362919,2.37656
10139400,-0.00663674,0.000352815,-1.00029,0.00787024,0.0201864,-0.00876646,43.6953,-0.129017,-0.368695,2.37739
10139500,-0.00679523,0.00118807,-1.00101,-0.00626396,-0.0206355,-0.00567084,43.6953,-0.12762,-0.359295,2.37722
10139600,-0.00583052,8.28852e-05,-0.99977,0.0120336,0.0297521,-0.00074564,43.6992,-0.122915,-0.366905,2.37741
10139700,-0.00690794,0.000215317,-1.00052,0.000730211,-0.0126271,-0.0145498,43.6992,-0.116187,-0.361241,2.37884
10139800,-0.00553715,0.000524005,-1.00127,0.0570455,-0.014946,0.0273024,43.6992,-0.109288,-0.369261,2.37931
10139900,-0.0059149,5.67176e-05,-1.00066,0.00898911,0.0247195,0.0501371,43.7031,-0.100622,-0.362934,2.39978
10140000,-0.00614014,-5.688e-06,-1.0002,-0.121098,0.0651305,-0.00916049,43.707,-0.100607,-0.366901,2.41725
10140100,-0.00616532,-0.000320024,-1.00114,0.0116914,0.00976389,-0.00659498,43.707,-0.0948647,-0.361206,2.41734
10140200,-0.00566859,-0.0003737,-1.00026,-0.00623558,0.013495,0.00671942,43.707,-0.0888662,-0.36321,2.41761
10140300,-0.00680167,-8.83485e-05,-1.00077,-0.100855,0.0120432,-0.00189858,43.707,-0.0788807,-0.362496,2.41875
```



IMU10HZ

100HZ output: The interval is stable at 10ms

```
%time_us,accx,accy,accz,gyrox,gyroy,gyroz,temperature,roll,pitch,yaw,mx,my,mz
12168590,-0.000783923,0.00227535,-0.999381,0.0285426,0.143975,0.0399726,45.8711,-0.261506,-0.0423138,0.597821
12168600,-0.00109725,0.00241267,-1.0014,0.00518191,-0.0503187,-0.0185507,45.8711,-0.260736,-0.0420368,0.598055
12168610,-0.000684899,0.00193684,-1.00129,0.0177225,-0.0174652,-0.00366374,45.875,-0.260757,-0.0421491,0.597998
12168620,-0.00110074,0.00186692,-0.999633,-0.0096959,-0.0503915,-0.0200717,45.8789,-0.259998,-0.0419311,0.597955
12168630,-0.00106939,0.00180071,-0.999801,-0.0493901,0.0672579,0.0065974,45.8789,-0.259534,-0.0427631,0.59775
12168640,-0.0012183,0.00200934,-1.00052,-0.0110379,0.0375103,-0.0019704,45.8789,-0.259273,-0.0431737,0.59775
12168650,-0.0014417,0.00172895,-0.999741,0.00149567,-0.0142063,0.00627559,45.8789,-0.259389,-0.0429253,0.597709
12168660,-0.00050238,0.00208577,-1.00103,-0.0168498,-0.0534377,-0.0177292,45.8789,-0.258919,-0.0438387,0.597691
12168670,-0.000328396,0.0019613,-1.00188,-0.00600252,0.0650926,0.0114503,45.8789,-0.258381,-0.0436349,0.597619
12168680,-0.000636144,0.00222931,-0.99907,-0.0270124,0.0734599,-0.000431323,45.8789,-0.258442,-0.0435879,0.597725
12168690,0.000112191,0.00221846,-1.00066,0.0151018,-0.056569,0.0147384,45.8789,-0.258043,-0.04342,0.597736
12168700,-0.000231573,0.00266871,-1.00237,0.00901595,-0.0218375,0.00337262,45.8789,-0.257449,-0.0417969,0.597825
12168710,8.72014e-05,0.00254247,-0.999538,0.0329301,-0.00658109,0.0136745,45.8789,-0.257216,-0.0417704,0.598
12168720,0.00029099,0.00226171,-1.0001,0.0078541,0.0694334,0.000107848,45.8789,-0.256338,-0.0408185,0.597988
12168730,0.000775636,0.00183092,-1.00108,-0.00733744,-0.0481737,-0.00525246,45.8789,-0.255627,-0.038995,0.597951
12168740,0.000808696,0.00174323,-1.00027,0.0295915,0.00286059,-0.0054113,45.8789,-0.25467,-0.0370789,0.598049
12168750,6.85134e-05,0.00170626,-0.999359,-0.0195651,0.0255302,0.0089159,45.8789,-0.254544,-0.0368456,0.597978
12168760,0.000233264,0.00187571,-1.00239,-0.0111067,0.0395717,-0.0164223,45.8789,-0.2539,-0.0362479,0.597931
12168770,0.000169324,0.00123586,-0.998619,-0.0318644,-0.0207638,0.0203835,45.8789,-0.253344,-0.0350068,0.59792
12168780,0.00034488,0.000749115,-0.999338,-0.0227521,0.00308496,-0.0240282,45.8789,-0.253686,-0.0353146,0.597991
12168790,0.000321285,0.0015652,-1.00105,-0.00523137,0.00901491,-0.0121445,45.8789,-0.253063,-0.0340612,0.597738
12168800,-0.000715598,0.0026208,-1.00151,0.0337185,0.0201632,0.00606421,45.8789,-0.252559,-0.0335472,0.597631
12168810,-0.000791669,0.00262174,-0.999473,0.0266765,0.0124253,-0.00269134,45.8789,-0.25235,-0.0333288,0.597486
```



IMU100HZ

2. Check whether the time difference is 0 under the same output frequency of the two sets of corresponding timestamp data (in the case of good satellite condition)

The following is a statistical example:

4	10147500	10147500	0
5	10147600	10147600	0
6	10147700	10147700	0
7	10147800	10147800	0
8	10147900	10147900	0
9	10148000	10148000	0
10	10148100	10148100	0
11	10148200	10148200	0
12	10148300	10148300	0
13	10148400	10148400	0
14	10148500	10148500	0
15	10148600	10148600	0
16	10148700	10148700	0
17	10148800	10148800	0
18	10148900	10148900	0
19	10149000	10149000	0
20	10149100	10149100	0
21	10149200	10149200	0
22	10149300	10149300	0
23	10149400	10149400	0
24	10149500	10149500	0
25	10149600	10149600	0
26	10149700	10149700	0

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	12174500	12174500	0
	12174600	12174600	0
	12174700	12174700	0
	12174800	12174800	0
	12174900	12174900	0
	12175000	12175000	0
	12175100	12175100	0
	12175200	12175200	0
	12175300	12175300	0
0	12175400	12175400	0
1	12175500	12175500	0
2	12175600	12175600	0
3	12175700	12175700	0
4	12175800	12175800	0
5	12175900	12175900	0
6	12176000	12176000	0
7	12176100	12176100	0
8	12176200	12176200	0
9	12176300	12176300	0
0	12176400	12176400	0
1	12176500	12176500	0
2	12176600	12176600	0
3	12176700	12176700	0

IMU100HZ

8.2 Do time synchronization on the host using DRDY signal signals

8.2.1 DRDY Signal Function

In an IMU, the DRDY (Data Ready) signal is an important status marker or interrupt signal used to indicate that the IMU's data is ready and can be read. When the IMU has completed a round of data acquisition and processing, the DRDY signal will change to a valid state (usually low), which indicates that the new acceleration, angular velocity, and other data are ready and can be read.

After the Master is connected to the IMU, it can determine the exact moment when the data is ready by detecting the clock synchronization signal from inside the IMU provided by the DRDY, and add a time stamp and parse the data at that moment. This means that whenever the DRDY signal changes, the Master knows that the data is ready and can record the time at this time as a timestamp for that data.

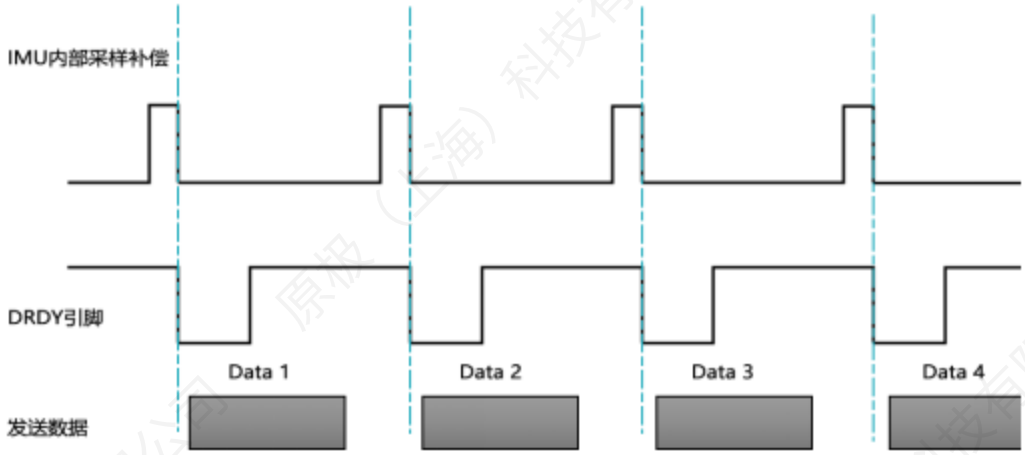
8.2.2 DRDY Signal

DRDY pin output serves two purposes:

1. to provide a clock synchronization signal from inside the IMU; How to

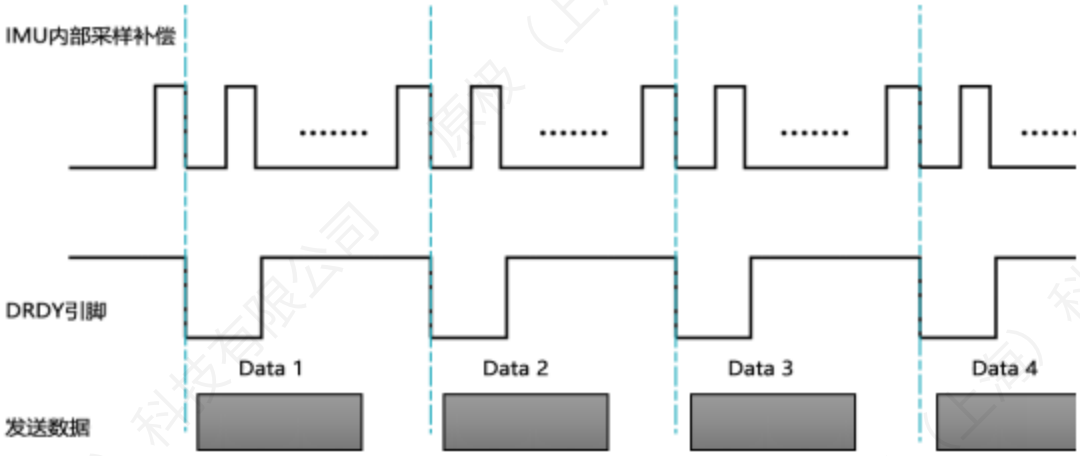
2 Provide a signal to start transmitting data frames.

FIG. 21 Internal sampling frequency is consistent with the output frequency of COM



When the IMU internal sampling frequency (maximum ODR) is consistent with the output frequency of the COM (current ODR), the DRDY pin will be pulled down immediately after the imu data sampling compensation is completed. At this time, the data frame will be sent from the COM. The DRDY pin will be pulled up again in the next cycle.

Figure 22 The output frequency of the COM is less than the internal sampling frequency of the IMU



9. Common AT instructions

9.1.1 Stop the current data stream output

Instruction: AT+SETNO\r\n

Answer: OK\r\n

You can stop the current data flow (without changing the Parameter of the data flow). If the response is OK, the next operation can be performed.

If there is no response, you can continue to send AT+SETNO\r\n command until the response is OK.

9.1.2 Querying the Version Number

Instruction: AT+VERSION\r\n

Answer: SW_VERSION Firmware version
HW_VERSION Hardware version
BOARD_VERSION Backboard version

9.1.3 Querying Parameter of a User

Instruction: AT+CONFIG\r\n
Reply: BAUD_RATE Baud rate of
the COM ORIENT current coordinate system
IMU_ODR Output frequency of the current IMU
STREAM_MODE1 Data flow mode of COM 1
STREAM_MODE2 Data flow mode of COM 2
STREAM_MODE3 Data flow mode of COM 3
LP_CONFIG_REG Filtering of the current IMU

9.1.4 Setting and Querying the ODR

Example: Set the output frequency ODR to 50hz

Command: AT+SET_ODR=50
Answer: IMU_ODR:50
Query the ODR command of the IMU
: AT+GET_ODR

Answer: IMU_ODR:

9.1.5 Set and query the coordinate system

Example: Set the IMU coordinate system to top right front

Instruction: AT+SET_ORIENT=101\r\n

Answer: orientation:101

Query the current IMU coordinate system

Instruction: AT+GET_ORIENT\r\n

Answer: orientation:

9.1.6 Set and query baud rate

Example: Set the baud rate of the IMU to 115200

Instruction: AT+SET_BAUD=115200\r\n

Answer: OK

Example Query the current baud rate of the IMU

Instruction: AT+GET_BAUD\r\n

Answer: BAUD_RATE:

9.1.7 Setting and querying filters

Example: Set the filter of the IMU to 20hz

Instruction: AT+SET_LPF=20\r\n

Answer: LP_CONFIG_REG:20

Query the IMU current filter

Instruction: AT+GET_LPF\r\n

Answer: LP_CONFIG_REG:

9.1.8 Saving Parameter

Instruction: AT+SAVE\r\n

Answer: OK

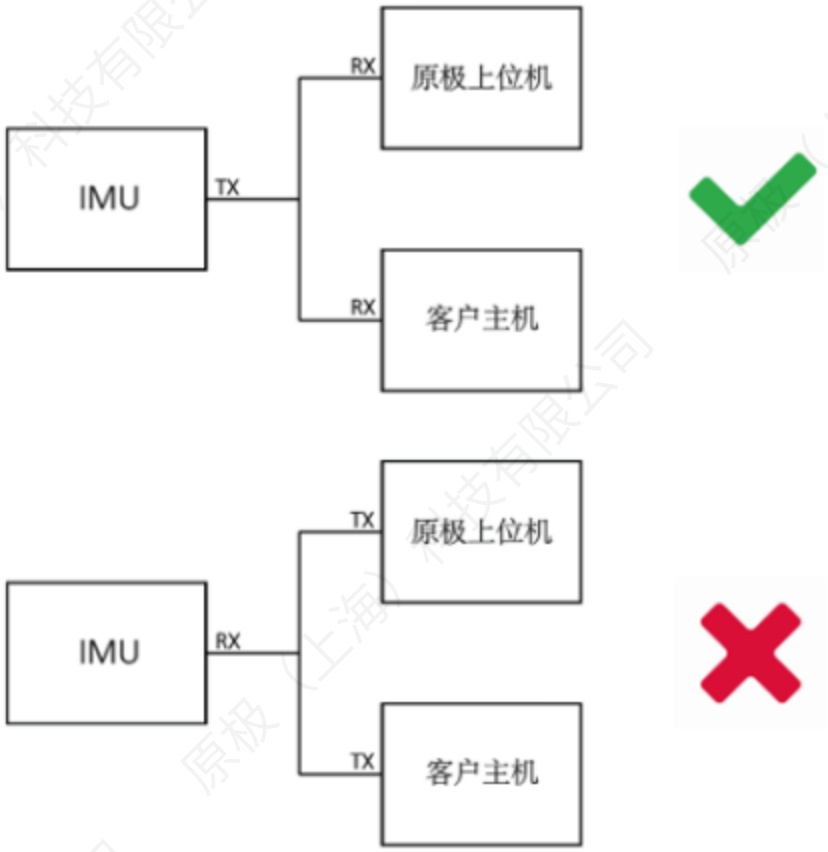
9.2 Common Problems of COM Connection

1) The RX of the IMU cannot connect to 2 host TXS

The RX of the COM cannot be connected to two TX at the same time. Therefore, if the primary host needs to be connected to the RX, disconnect the communication between it and the COM of the user host. Otherwise, the Upper computer software can only receive data but cannot send commands to the IMU.

As shown in the following picture:

Figure 9 COM connection



注：IMU TX 可接多路 RX，RX 不可接多路 TX；
IMU串口不可同时连接客户主机和原极上位机；
IMU可以预留另外一路串口专门连接原极上位机。

2) The version number cannot be obtained

You are advised to use the COM of the FT232 chip. CH340 and PL2303 data cables may lose packets when the baud rate is high (>115200bps)

It is recommended that COM be connected directly, and it is not recommended to be connected in series. If the interface of RS422 is connected to the computer, directly use RS422 to USB cable, and do not use RS422 to RS232+RS232Z to USB cable in series.

3) Upper computer software curve display lag

If it is an FT232 data line, use the system administrator to open the Upper computer software and automatically configure the COM delay

Manually configure COM delay in Device Manager.

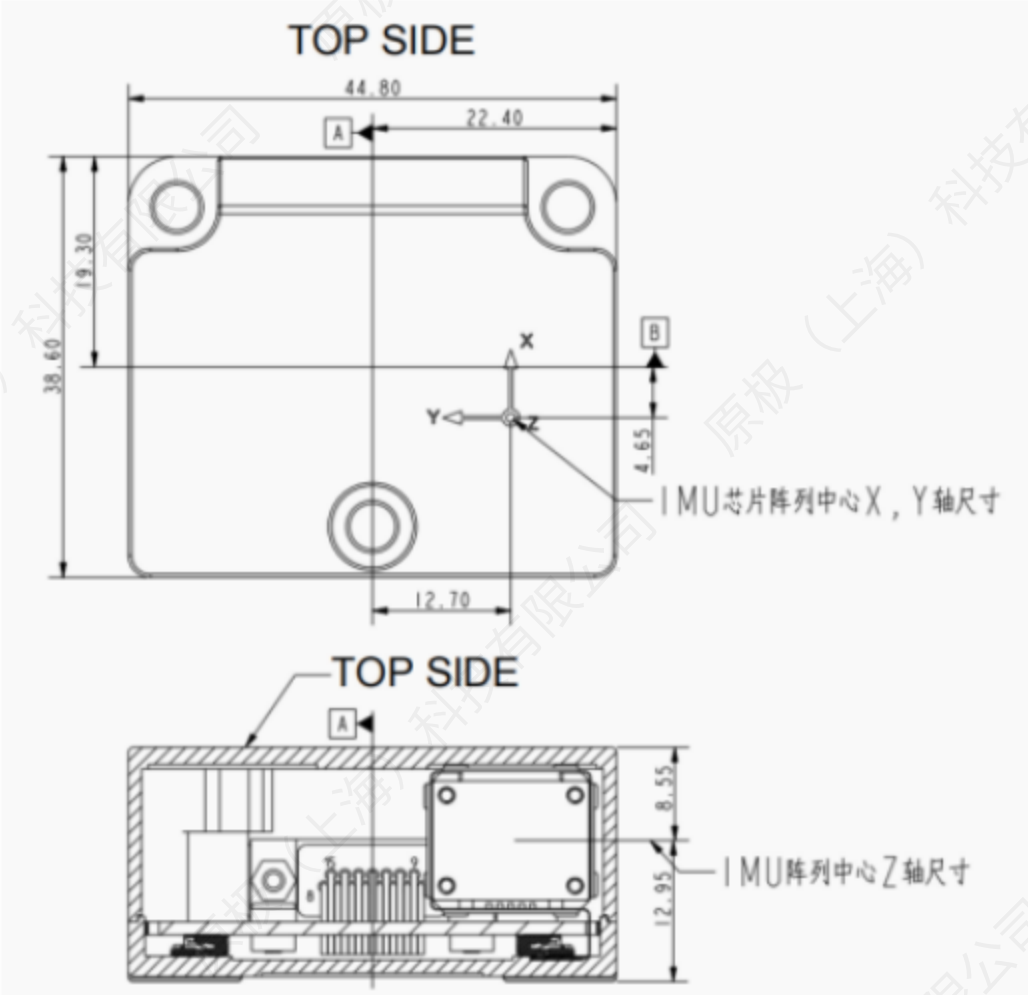
10. Precautions for post-processing use

1. Confirm whether all filters are no filter (screenshots are retained), and the Update Rate is generally SET to 500hz, which can be confirmed by the Upper computer software or queried by command. For specific commands, refer to the 7.6 command mode set instruction or the common AT instruction in chapter 7.10

2. P8 data output has 7.2ms delay, which needs to be subtracted when stamping!!!

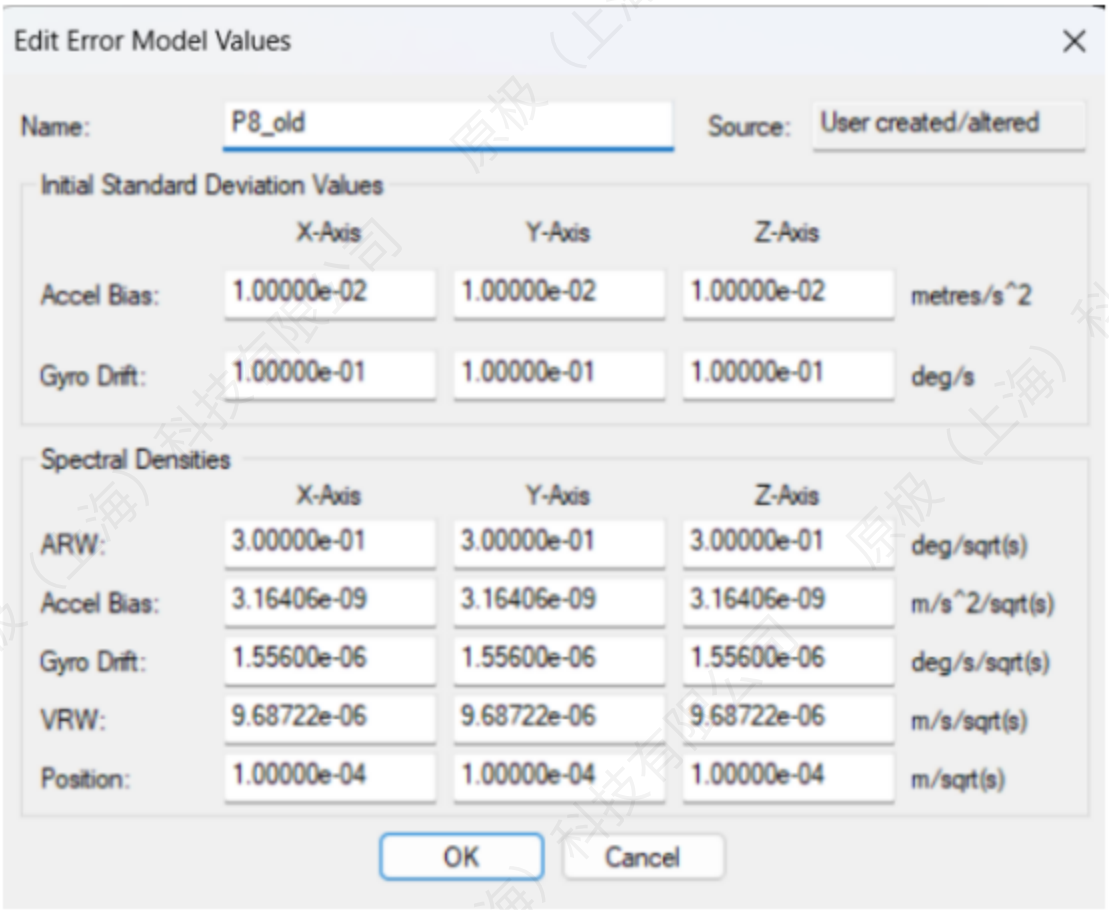
3, the rod arm configuration

Note that the physical center point of the P8 IMU is shown in the figure below, and attention should be paid to the configuration of the rod arm

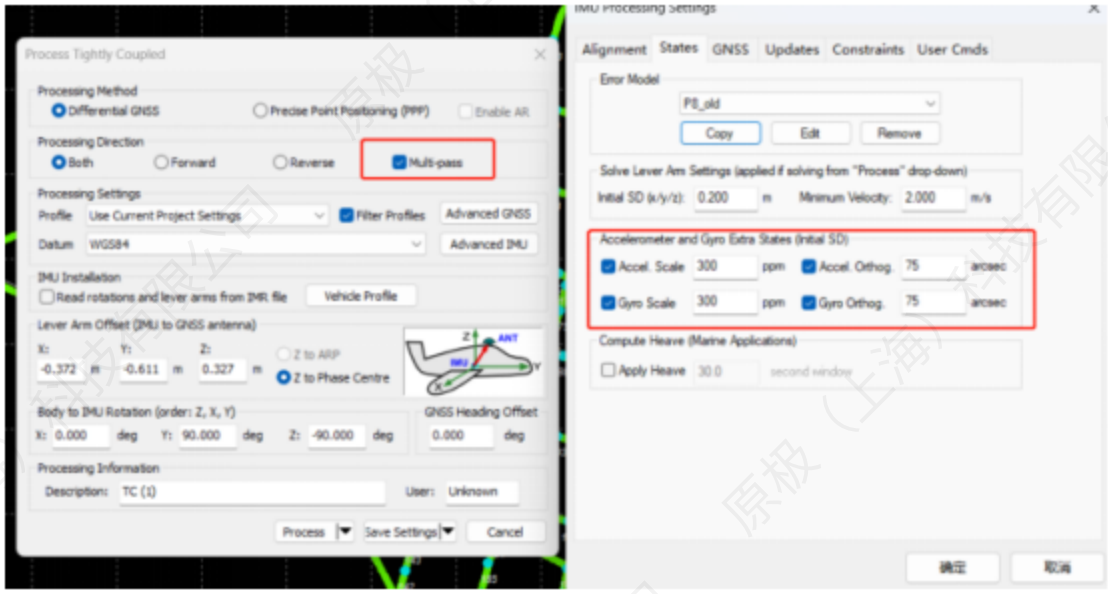


4. Data processing

① Use the following Parameter for P8



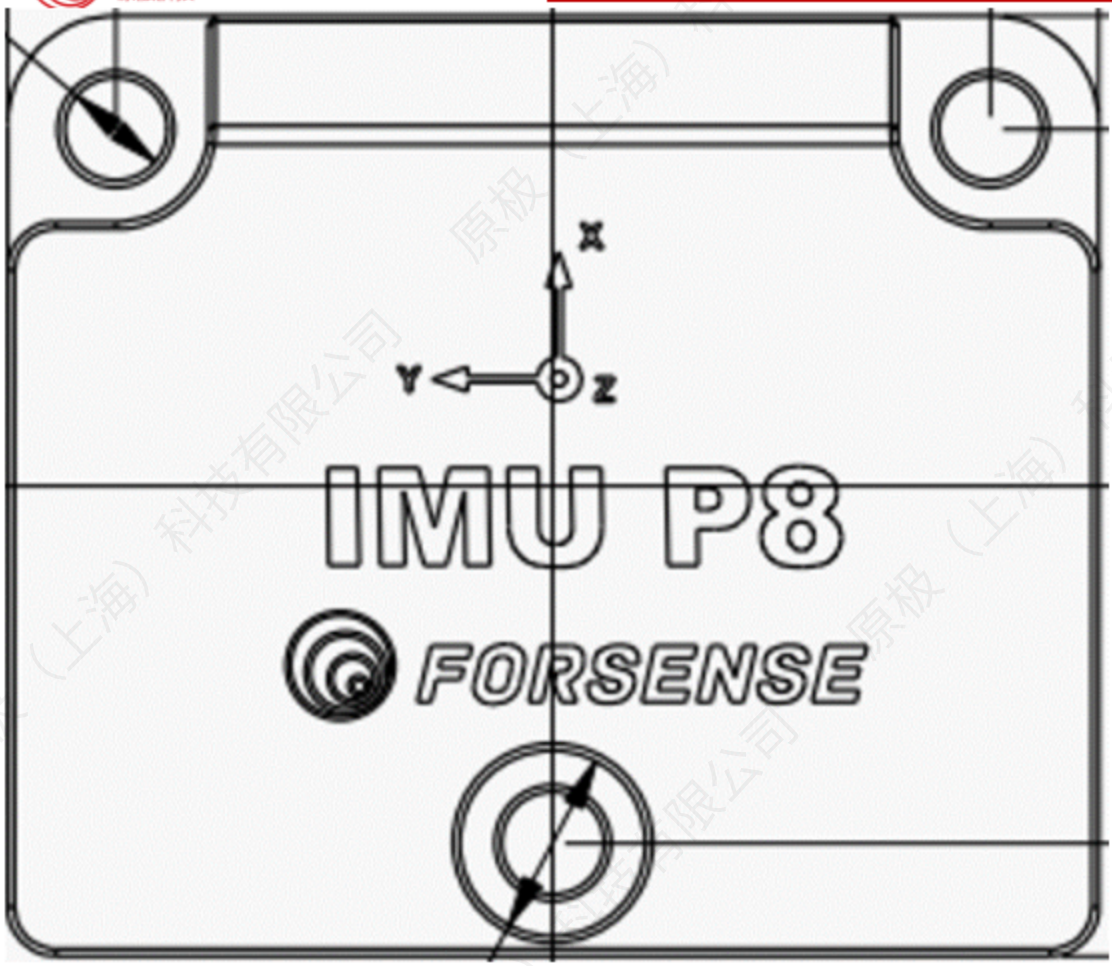
② Select the Settings shown in the following figure when processing IE



5. Recommended flight mode

Stop before takeoff, circle back and forth, and stop after landing on the ground

11. Definition of coordinate system



The product coordinate system uses the right-front-top (FRD) coordinate system.

12. CRC table lookup method

It is recommended to refer directly to the example code.

Note 1: Data is transmitted in small-endian format, with low bytes first and high bytes last

Note 2: The initial value of crc32 is 1, and CRC calculations do not include all the data in this frame itself

```
Cstatic
   const  uint32_t  crc32_tab [ ]  =  {
 0x00000000, 0x77073096, 0xee0e612c, 0x990951ba, 0x076dc419, None
706Af48F
 ,0xe963a535, 0x9e6495a3, 0x0edb8832, 0x79dcb8a4, 0xe0d5e91e,
0x97d2d988
 ,0x09b64c2b, 0x7eb17cbd, 0xe7b82d07, 0x90bf1d91, 0x1db71064,
0x6ab020f2
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0x56b3c423
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0xb10be924
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0x270241aa
 ,0xbe0b1010,  0xc90c2086,  0x5768b525,  0x206f85b3,  0xb966d409,
0xce61e49f
 ,0x5edef90e,  0x29d9c998, 0xb0d09822, 0xc7d7a8b4, 0x59b33d17,
0x2eb40d81
 ,0xb7bd5c3b, 0xc0ba6cad, 0xedb88320, 0x9abfb3b6, 0x03b6e20c,
0x74b1d29a
 ,0xead54739, 0x9dd277af, 0x04db2615, 0x73dc1683, 0xe3630b12,
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0x7d079eb1
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0x67dd4acc
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0xa867df55
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0xb2bd0b28
 ,0x2bb45a92, 0x5cb36a04, 0xc2d7ffa7, 0xb5d0cf31, 0x2cd99e8b,
0x5bdeae1d
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0x18b74777,0x88085ae6
 , 0xff0f6a70, 0x66063bca, 0x11010b5c, 0x8f659eff,
0xf862ae69,0x616bffd3
 , 0x166ccf45, 0xa00ae278, 0xd70dd2ee, 0x4e048354, 0x3903b3c2
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0xd9d65adc,0x40df0b66
 ,  0x37d83bf0,  0xa9bcae53,  0xdebb9ec5,  0x47b2cf7f,
0x30b5ffe9,0xbdbdf21c
 , 0xcabac28a, 0x53b39330, 0x24b4a3a6, 0xbad03605,
0xcdd70693,0x54de5729
 , 0x23d967bf, 0xb3667a2e, 0xc4614ab8, 0x5d681b02,
0x2a6f2b94,0xb40bbe37
 , 0xc30c8ea1, 0x5a05df1b,   0x2d02ef8d
 ,}
  uint32_t  crc_crc32 (uint32_t  crc,  const  uint8_t  *buf,
uint32_t size ) {for   (uint32_t
   i=0;  i<size ;  i++)  {crc
 =  crc32_tab [ (crc  ^  buf [i ] )  &  0xff]  ^   (crc  >>  8 ) ;
 }
 return crc;
 }
```

13 Use examples

13.1 Device Installation

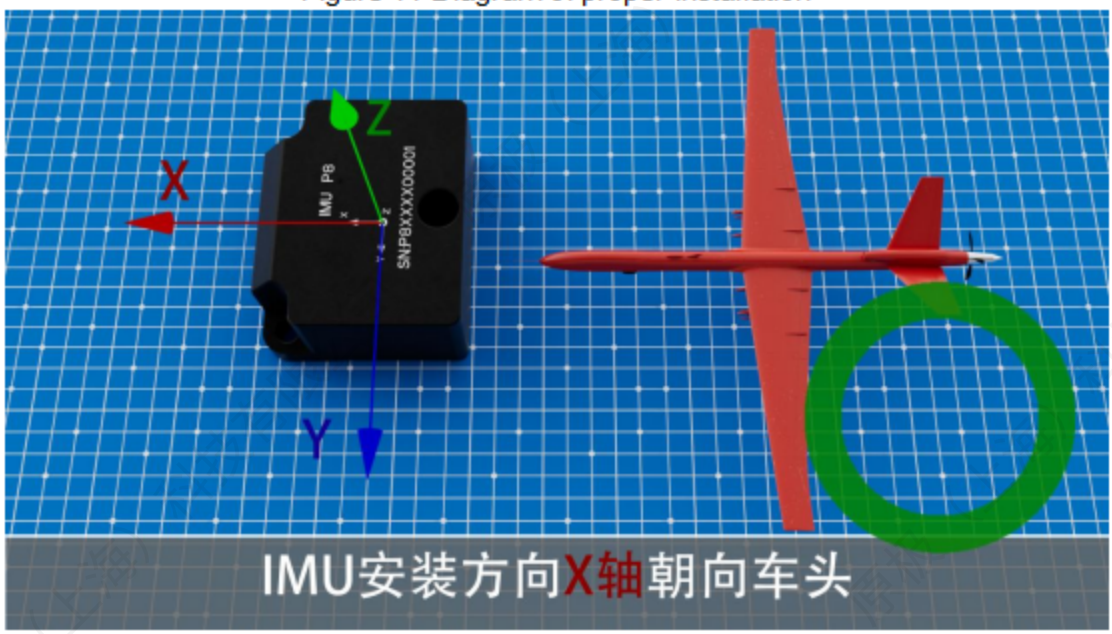
1. The module should be firmly fixed on a rigid plane and avoid being installed in a position with large vibration.

2. The module should be installed in the same direction as the front.

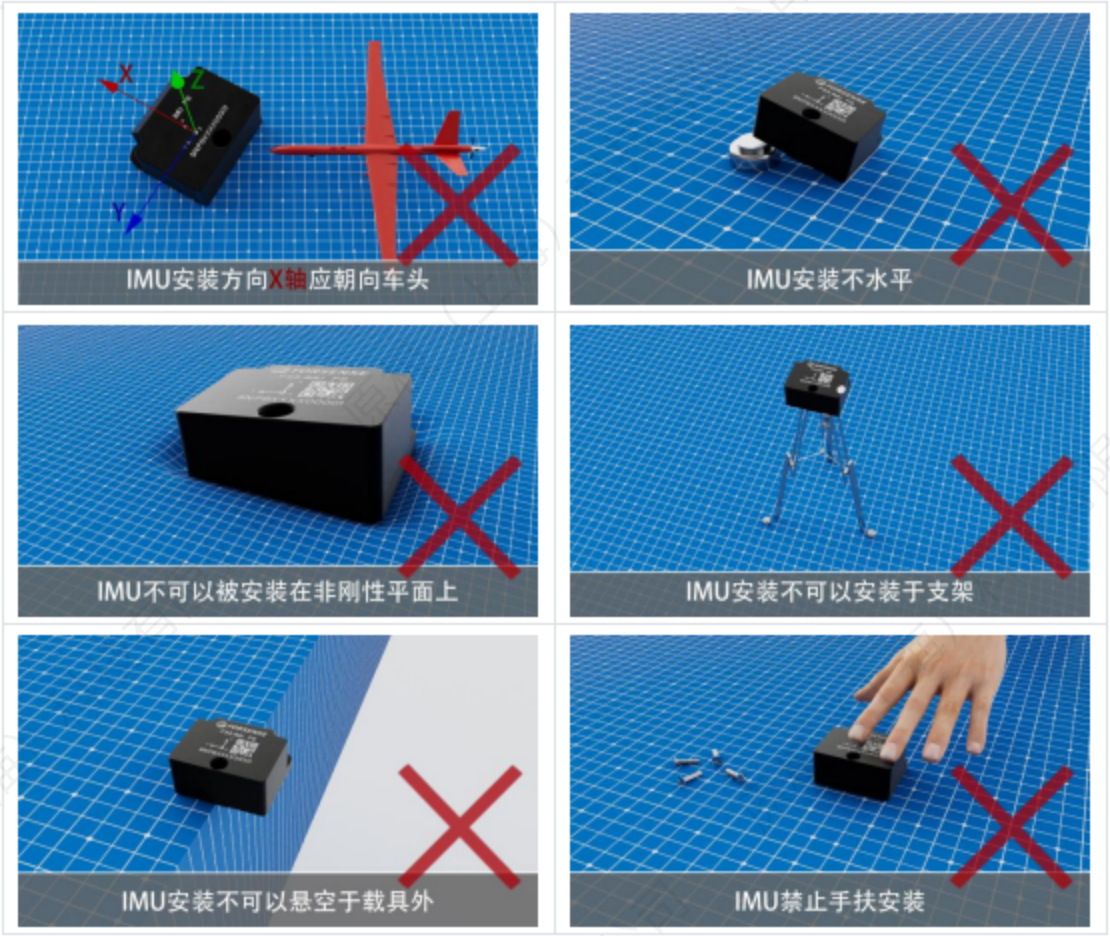
Figure 10 Schematic diagram of module installation

The correct installation diagram is as follows
The X axis faces the front of the car

Figure 11 Diagram of proper installation



The following installation methods are all wrong installation



14. Select accessories

422 COM (harness Forsense modified with 5V power supply)

422 and P8 signal adapter cable

15. Update the record

Versions	Dates	Status/Comments
Version 1.0	2023.08.30	First Issue
Version 1.1	2023.10.07	Update coordinate system definition
Version 1.2	2023.12.14	Add attachments
Version 1.3	2024.03.26	Add common AT instructions
Version 1.4	2024.05.14	Added notes for post-processing use
Version 1.5	2024.08.01	Adjusting Content structure
Version 1.6	2024.09.19	Added time synchronization step