FORSENSE
原极科技

Tactical MEMS 6 Degrees of freedom (DOF) inertial sensor

FSS-IMU16460-D Product manual

Features

Tactical grade MEMS Gyroscope

- 0.8°/hr Bias instability
- 0.15°/√hr Angle Random Walk
- 0.02°/s temperature drift (-40~85 °C, <=1 ° C/min@1σ)

Tactical MEMS Accelerometer

- 20ug Bias instability
- 0.0 Velocity Random Walk5m/s/$\sqrt{hr}$
- 1mg temperature drift (-40~85 ° C, <=1 ° C/min@1σ)

Large range refined temperature compensation

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

Independent Rotary Table Calibration

- Independently calibrate each module: sensitivity, Bias instability, non-orthogonal error

High strength 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 serial port,
- 22.4*24.05*9.0mm, weight 8.6g

Product Overview

FSS-IMU16460-D is a 6 degrees of freedom (DOF) MEMS inertial sensor module built by Yuanji Technology. Three-axis Gyroscope and acceleration information are provided 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

- Lawn Mower
- Autonomous driving: underwater robots, engineering vehicles
- Precision measurement: downhole, tunnel, vibration, tilt
- Stable platform: PTZ, moving through

On the basis of standard performance and output parameters, Yuanji 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 X axis 1	@25, ALLAN variance, 1σ		5.0		°/hr
Bias instability Y-axis 1			5.0		°/hr
Bias instability Z-axis 1			0.8		°/hr
Non-orthogonal between axes			0.05		deg
Internal low-pass cutoff frequency	Software adjustable		75		Hz
ODR			1000		Hz
Measuring delay			7		ms
The whole temperature range Bias instability change 2	-40 ~ 85 ° C, <=1 ° C/min@1σ		Xy: 0.05 Z: 0.02		°/s
Random Walk X axis 1	@25, ALLAN variance, 1σ		0.7		°/√hr
Random Walk Y-axis			0.7		°/√hr
Random walk Z axis			0.15		°/√hr
Calibration coefficient error			xy:3 Z: 0.8		‰
Scale coefficient nonlinear			200		ppm

Note 1: IEEE standard, Allan variance curve given at static 25 ° C environment

Note 1σ change in total temperature with zero deviation at 2:1 ° C/min

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		g
Zero bias instability X axis 1	@25,ALLAN variance, 1σ		20		Mu g
Zero bias instability Y-axis 1			20		Mu g
Zero bias instability Z axis 1			35		Mu g
Non-orthogonal between axes			0.05		deg
Internal low-pass cutoff frequency	Software adjustable		75		Hz
ODR			1000		Hz
Measuring delay			7		ms
The whole temperature range Bias instability change 2	-40 ~ 85 ° C, <=1 ° C/min@1σ		1.0		mg
Random Walk X axis 1	@25,Allan Variance, 1σ		0.05		m/s/√hr
Random walk Y axis			0.05		m/s/√hr
Random walk Z axis			0.1		m/s/√hr
Calibration coefficient error			0.5		‰

Calibration coefficient nonlinearity			200		ppm

Note 1: IEEE standard, Allan variance curve given at static 25 ° C environment

Note 1σ change in total temperature with zero deviation at 2:1 ° C/min

FIG. 1 ALLAN variance typical curve of gyroscope

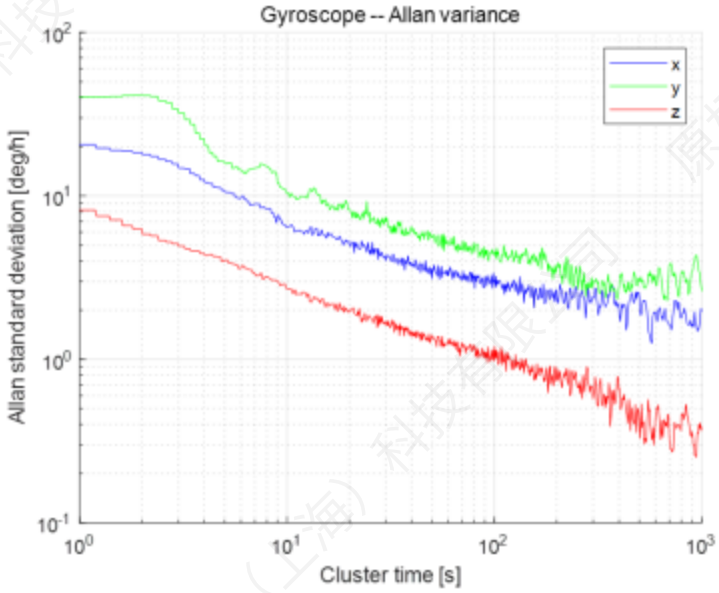
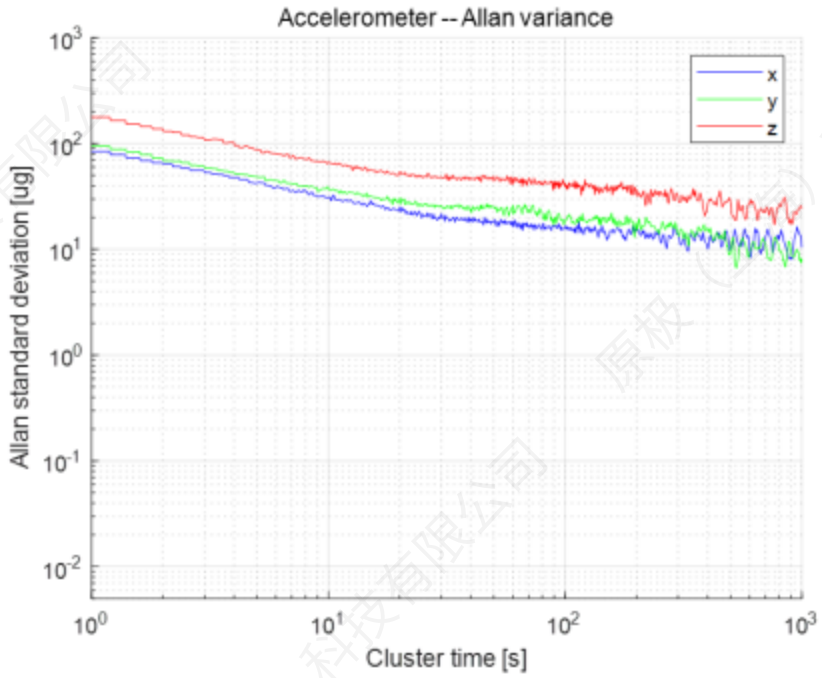
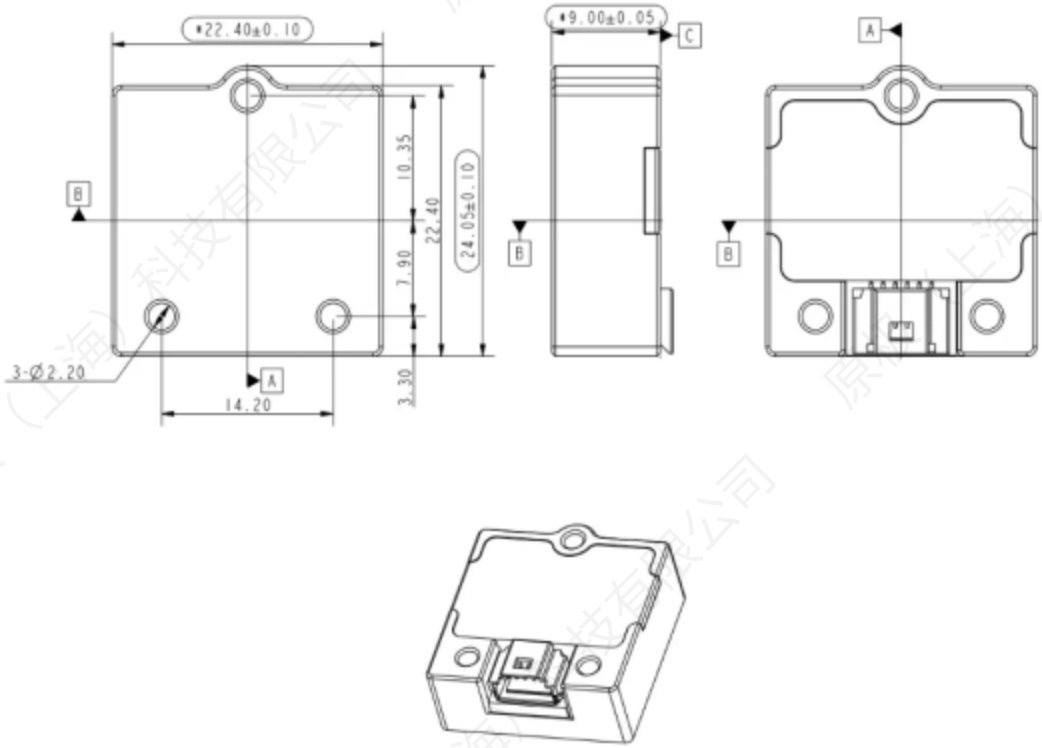


FIG. 2 Typical curve of ALLAN variance for accelerometer



2. External structure

Figure 3 Outline structure and size (unit: mm)



3. Electrical characteristics

3.1 Maximum tolerance value

Table 3 Maximum absolute rating

Parameters	Symbols	Range	Units
Supply voltage	VCC	-0.3 to 6.5	V
Power source	GND	-	-
Input pin voltage	Vin	-0.3 to 5.8	V
Use temperature	Tot	-40 to 85	℃
Storage temperature	Tstg	-40 to 85	℃

3.2 Working Conditions

Table 4 Working conditions

Parameter	Symbols	Minimum value	Typical value	Maximum value	Units
Voltage for Circuit to Circuit (VCC)	VIN	4.5	5	5.5	V
VIN maximum ripple	Vrpp		+ 40		mV
Power Consumption	P		0.2		W
Use temperature	Tot	-40		85	℃
Storage temperature	Tstg	-40		85	℃

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.

3.3 IO Threshold characteristics

Table 5 I/O Threshold Characteristics

Parameter	Symbols	Minimum value	Typical value	Maximum value	Units
Input pin low	Vin_low	0		VCC * 0.2	V
Input pin high	Vin_high	VCC * 0.7		VCC + 0.2	V
Output pin low	Vout_low	0		0.45	V
Output pin high	Vout_high	VCC - 0.45 -		VCC	V

Note: VCC=3.3V

4. Pin definition

Figure 4 Pin schematic

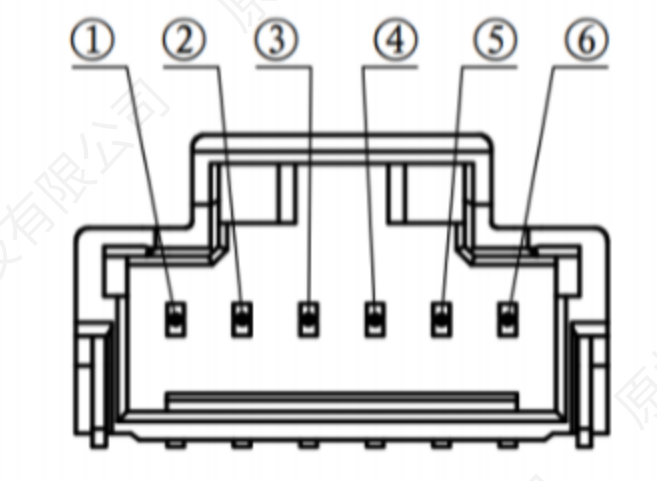


Table 6 Pin definitions

Pin Serial number	Pin name	Pin description
1	VIN	+5V power input
2	GND	Power ground
3	TX	Receive asynchronous data output
4	RX	Receive asynchronous data input
5	NC	Not pick up
6	NC	Not pick up

5 Communication protocol

5.1 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.

5.1.1 Parameters of serial port interface

Table 7 Serial port interface 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

5.1.2 Packet Format

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

Table 8 IMU output and user input data structures

Offsets	Data type	Name	Description
0	uint8	Frame Header 1	The IMU output Frame header: 0xAA, 0x55 The user enters Frame header: 0x55, 0xAA
1	uint8	Frame header 2	
2	uint16	ID low	The low bit of the frame ID for serial communication
3		ID high byte	The high byte of the serial port frame ID
4	uint16	Data length low	The lowest byte of the frame length of the serial port communication. Length is the number of bytes carried by the payload, that is, n
5		High data length	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

5.1.3 Data Flow frame — AHRS data

Table 9 Serial AHRS data format

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

Note 1: Maximum output update rate is not greater than 200Hz@115200bps

Table 10 Serial port A1 load data format

offset	Name	Data type	Units	Description
0	timer	uint32	Mu s	Time scale
4	pitch	float	°	Pitch Angle
8	roll	float	°	Roll Angle
12	yaw	float	°	Heading Angle
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 11 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

5.1.4 Command Mode GET Output -- System status

Table 12 COM system status data format

	Frame Headers	Frame Headers	ID	length	payload	Frame tail
Data type	uint8	uint8	uint16	uint16	S1	uint32
Coding	0xAA	0x55	0x00FF	0x002A		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 13 Serial port 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	The remaining bytes are reserved

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 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).

5.1.5 Command Mode GET output -- Read the Parameter

Table 14 COM Parameter Input data format

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

Table 15 COM Parameter output data format

	Frame header	Frame header	ID	length	payload	Frame end

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 16 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 17 Index 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 24 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 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 66 CB 46 AC

Response data: AA 55 30 75 18 00 00 00 00 48 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 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).

5.1.6 Command mode SET command

Table 18 COM Input command formats

	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 19 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 20 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	< mode > Set the output mode: Mode=1, data stream output AHRS Mode=100 disables data stream mode and enters 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 output baud rate of the serial port, the valid value in bps value is: 115200,230400,460800,921600,1500000 If value is other values, the default value is 115200bps After setting the baud rate parameter, you need to restart it for it to take effect. Procedure for setting the baud rate without power supply: Set the baud rate, save the 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 correspondence between the output frequency and the baud rate of the serial port 1000Hz: 921600bps 500Hz: 460,800bps 250Hz: 460800bps 200Hz: 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 24

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.

5.1.7 Command Mode Output — User command response

Table 21 Setting parameters COM response data format

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

Table 22 Reserved parameters COM 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 23 Data format of COM user command response

	Frame Headers	Frame Headers	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 serial output baud rate 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 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 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 00 52 D8 8E E8

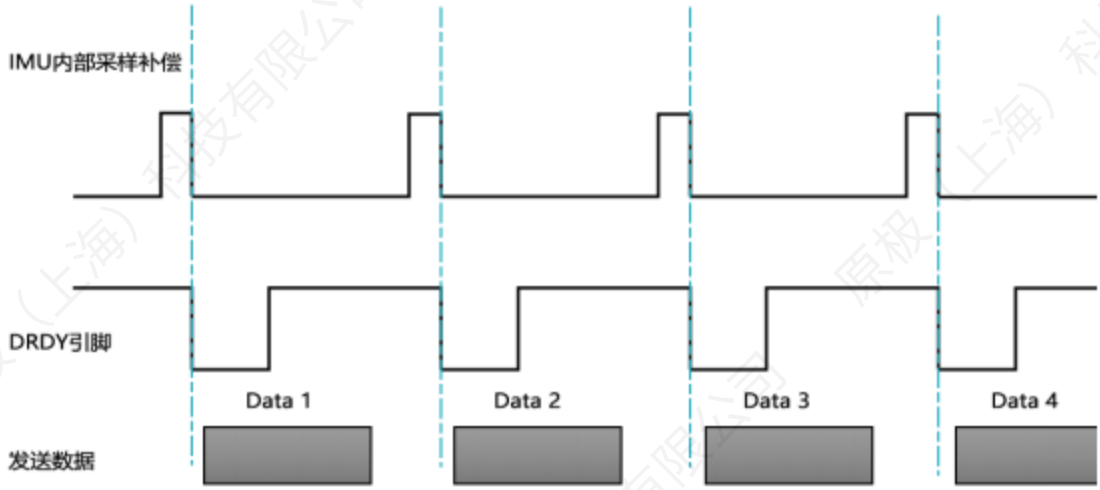
Response data: AA 55 64 00 04 00 03 00 01 00 E7 87 E3 AD

5.1.8 DRDY

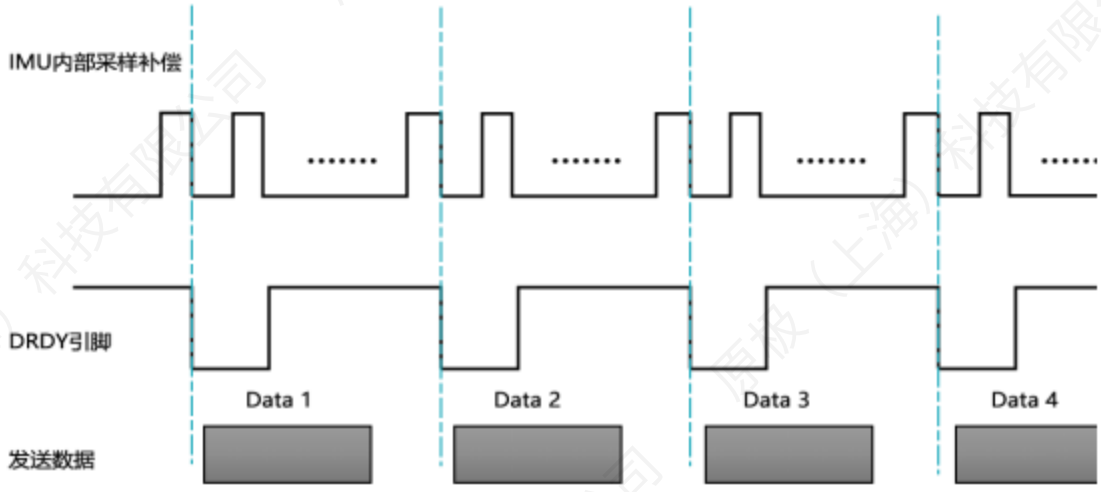
DRDY pin output serves two purposes:

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

2. Provide a signal to signal the start of transmitting data frames.



When the IMU internal sampling frequency (maximum ODR) is consistent with the serial port output frequency (current ODR), whenever the imu data sampling compensation is completed, the DRDY pin will be immediately pulled down, at which time the data frame will be sent from the serial port, and the DRDY pin will be pulled up again in the next cycle.



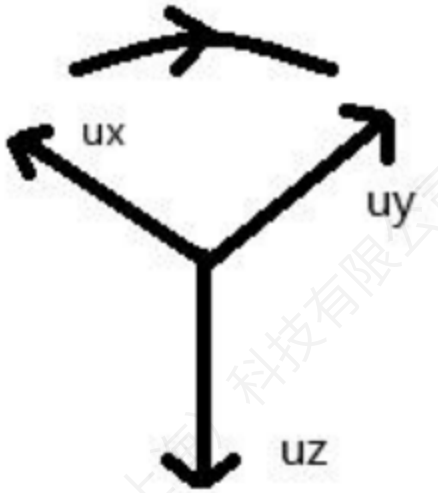
When the output frequency of the serial port is less than the internal sampling frequency of the IMU, the DRDY pin will be immediately pulled down according to the frequency divider value (maximum ODR/ current ODR) whenever the imu data

sampling compensation is completed. After the DRDY is pulled down, the data frame will be sent from the serial port, and the DRDY pin will be pulled up again in the next IMU sampling cycle.

5.1.9 Coordinate system setting function

Set the firmware coordinate system and display the corresponding firmware design coordinate system in the upper computer

Figure 5 Original firmware coordinate system



According to the above rule, after x and y axes are determined, z axis is determined. The Z axis is perpendicular to the plane from the X to the Y axis.

There are a total of twenty-four orientations for the X/Y/Z triaxial axis, as shown in the table below:

Table 24 coordinates are oriented towards the corresponding table

Orientation (value)	XAxis	YAXis	ZAxis	Instructions
101	+Ux	+Uy	+Uz	Default orientation
102	-Ux	-Uy	+Uz	
103	-Uy	+Ux	+Uz	
104	+Uy	-Ux	+Uz	
105	-Ux	+Uy	-Uz	

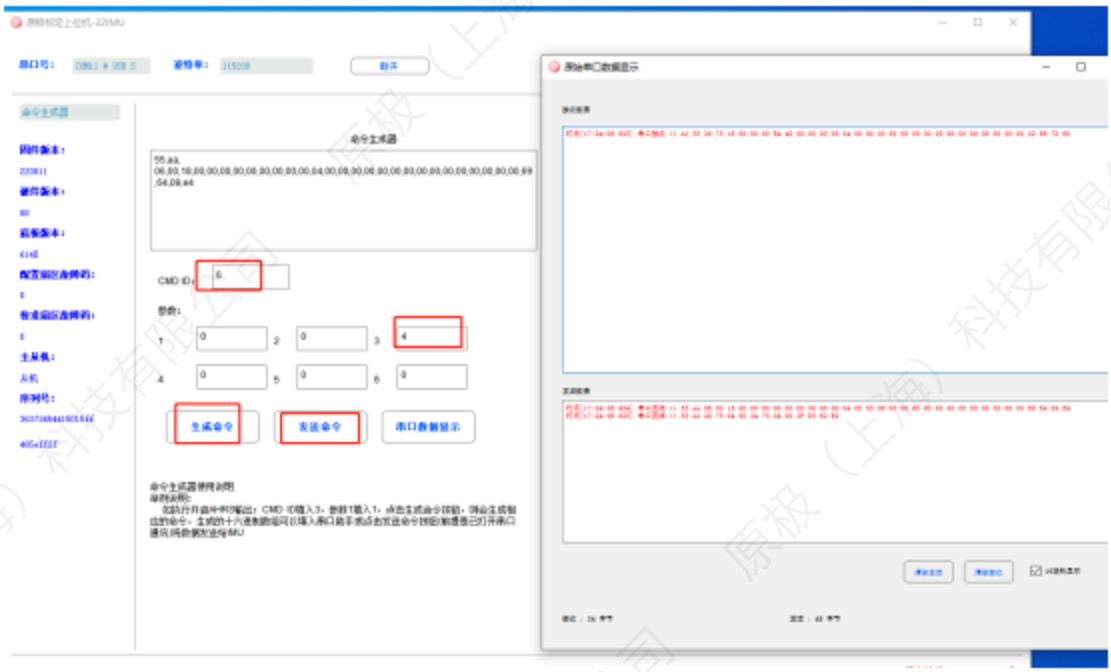
106	+Ux	-Uy	-Uz	
107	+Uy	+Ux	-Uz	
108	-Uy	-Ux	-Uz	
109	-Uz	+Uy	+Ux	
110	+Uz	-Uy	+Ux	
111	+Uy	+Uz	+Ux	
112	-Uy	-Uz	+Ux	
113	+Uz	+Uy	-Ux	
114	-Uz	-Uy	-Ux	
115	-Uy	+Uz	-Ux	
116	+Uy	-Uz	-Ux	
117	-Ux	+Uz	+Uy	
118	+Ux	-Uz	+Uy	
119	+Uz	+Ux	+Uy	
120	-Uz	-Ux	+Uy	
121	+Ux	+Uz	-Uy	
122	-Ux	-Uz	-Uy	
123	-Uz	+Ux	-Uy	
124	+Uz	-Ux	-Uy	

How to change the coordinate system to 102 orientation:

Enter 14 in CMD ID, 102 in parameter 1, and 4 in parameter 3. The generated hexadecimal array can be filled into the COM assistant or program array and sent to the IMU.

How to read the coordinate system orientation:

Enter 06 for CMD ID and 4 for parameter 3. The generated hexadecimal array can be filled into the COM assistant or program array and sent to the IMU.



Example: Set the coordinate system to face 115

Data input: 55, aa, 0 e, 00,18,00,00,00, e6,
42,00,00,00,00,04,00,00,00,00,00,00,00,00,00,00,00, 00,00,00,00,46,6 a, 4 e,

86

Response data: AA 55 3D 75 04 00 34 75 04 00 60 0E 6B 1B

Refer to Table 21 to parse the parameter index as 04, and the setting is successful

Read the coordinate system:

Input data: 55 AA 06 00 18 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 04 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 69 64 09 E4

Response data: AA 55 30 75 18 00 00 00 00 E6 42 00 00 00 00 00 00 00 00 00 04 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 B2 2F 2D 4E

According to Table 15 and Table 16, the parsing results in 115 for parameter 1 (float) and 04 for parameter 3. That is, the coordinate system is 115 orientation.

5.1.9 Common Problems of COM Connection

1) The RX of the IMU cannot connect to two Master TX

The RX of the COM cannot be connected to two TX at the same time. Therefore, if the Forsense upper machine needs to be connected, it needs to disconnect the communication with the COM of the user's host. Otherwise, the upper computer cell can only receive data and cannot send commands to the IMU.

As shown in the following picture:

Figure 6 Schematic diagram of COM connection

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.

6. CRC table lookup method calculation

```
C++
static const uint32_t crc32_tab[] = {
0x00000000, 0x77073096, 0xee0e612c, 0x990951ba, 0x076dc419, 0x706af48f,
0xe963a535, 0x9e6495a3, 0x0edb8832, 0x79dcb8a4, 0xe0d5e91e, 0x97d2d988,
0x09b64c2b, 0x7eb17cbd, 0xe7b82d07, 0x90bf1d91, 0x1db71064, 0x6ab020f2,
0xf3b97148, 0x84be41de, 0x1adad47d, 0x6ddde4eb, 0xf4d4b551, 0x83d385c7,
0x136c9856, 0x646ba8c0, 0xfd62f97a, 0x8a65c9ec, 0x14015c4f, 0x63066cd9,
0xfa0f3d63, 0x8d080df5, 0x3b6e20c8, 0x4c69105e, 0xd56041e4, 0xa2677172,
0x3c03e4d1, 0x4b04d447, 0xd20d85fd, 0xa50ab56b, 0x35b5a8fa, 0x42b2986c,
0xdbbbc9d6, 0xacbcf940, 0x32d86ce3, 0x45df5c75, 0xdcd60dcf, 0xabd13d59,
0x26d930ac, 0x51de003a, 0xc8d75180, 0xbfd06116, 0x21b4f4b5, 0x56b3c423,
0xcfba9599, 0xb8bda50f, 0x2802b89e, 0x5f058808, 0xc60cd9b2, 0xb10be924,
0x2f6f7c87, 0x58684c11, 0xc1611dab, 0xb6662d3d, 0x76dc4190, 0x01db7106,
0x98d220bc, 0xefd5102a, 0x71b18589, 0x06b6b51f, 0x9fbfe4a5, 0xe8b8d433,
0x7807c9a2, 0x0f00f934, 0x9609a88e, 0xe10e9818, 0x7f6a0dbb, 0x086d3d2d,
0x91646c97, 0xe6635c01, 0x6b6b51f4, 0x1c6c6162, 0x856530d8, 0xf262004e,
0x6c0695ed, 0x1b01a57b, 0x8208f4c1, 0xf50fc457, 0x65b0d9c6, 0x12b7e950,
0x8bbeb8ea, 0xfcb9887c, 0x62dd1ddf, 0x15da2d49, 0x8cd37cf3, 0xfbd44c65,
0x4db26158, 0x3ab551ce, 0xa3bc0074, 0xd4bb30e2, 0x4adfa541, 0x3dd895d7,
0xa4d1c46d, 0xd3d6f4fb, 0x4369e96a, 0x346ed9fc, 0xad678846, 0xda60b8d0,
0x44042d73, 0x33031de5, 0xaa0a4c5f, 0xdd0d7cc9, 0x5005713c, 0x270241aa,
0xbe0b1010, 0xc90c2086, 0x5768b525, 0x206f85b3, 0xb966d409, 0xce61e49f,
0x5edef90e, 0x29d9c998, 0xb0d09822, 0xc7d7a8b4, 0x59b33d17, 0x2eb40d81,
0xb7bd5c3b, 0xc0ba6cad, 0xedb88320, 0x9abfb3b6, 0x03b6e20c, 0x74b1d29a,
0xead54739, 0x9dd277af, 0x04db2615, 0x73dc1683, 0xe3630b12, 0x94643b84,
```

```
0x0d6d6a3e, 0x7a6a5aa8, 0xe40ecf0b, 0x9309ff9d, 0x0a00ae27, 0x7d079eb1,
0xf00f9344, 0x8708a3d2, 0x1e01f268, 0x6906c2fe, 0xf762575d, 0x806567cb,
0x196c3671, 0x6e6b06e7, 0xfed41b76, 0x89d32be0, 0x10da7a5a, 0x67dd4acc,
0xf9b9df6f, 0x8ebeeff9, 0x17b7be43, 0x60b08ed5, 0xd6d6a3e8, 0xa1d1937e,
0x38d8c2c4, 0x4fdff252, 0xd1bb67f1, 0xa6bc5767, 0x3fb506dd, 0x48b2364b,
0xd80d2bda, 0xaf0a1b4c, 0x36034af6, 0x41047a60, 0xdf60efc3, 0xa867df55,
0x316e8eef, 0x4669be79, 0xcb61b38c, 0xbc66831a, 0x256fd2a0, 0x5268e236,
0xcc0c7795, 0xbb0b4703, 0x220216b9, 0x5505262f, 0xc5ba3bbe, 0xb2bd0b28,
0x2bb45a92, 0x5cb36a04, 0xc2d7ffa7, 0xb5d0cf31, 0x2cd99e8b, 0x5bdeae1d,
0x9b64c2b0, 0xec63f226, 0x756aa39c, 0x026d930a, 0x9c0906a9, 0xeb0e363f,
0x72076785, 0x05005713, 0x95bf4a82, 0xe2b87a14, 0x7bb12bae, 0x0cb61b38,
0x92d28e9b, 0xe5d5be0d, 0x7cdcefb7, 0x0bdbdf21, 0x86d3d2d4, 0xf1d4e242,
0x68ddb3f8, 0x1fda836e, 0x81be16cd, 0xf6b9265b, 0x6fb077e1, 0x18b74777,
0x88085ae6, 0xff0f6a70, 0x66063bca, 0x11010b5c, 0x8f659eff, 0xf862ae69,
0x616bffd3, 0x166ccf45, 0xa00ae278, 0xd70dd2ee, 0x4e048354, 0x3903b3c2,
0xa7672661, 0xd06016f7, 0x4969474d, 0x3e6e77db, 0xaed16a4a, 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;
}
```

7 Update the record

Versions	Dates	Status/Comments
Version 1.0	2024.05.16	First Draft