FORSENSE
原极科技

Tactical MEMS 6 degrees of freedom inertial sensor

FSS-IMU16460 Product manual

Features

Tactical grade MEMS gyroscope

- 2.0°/hr zero bias instability
- 0.3 Angle random walk°/$\sqrt{hr}$
- 0.03/s temperature drift (-40~85°C, <=1°C/ min@1σ)°

Tactical grade MEMS accelerometer

- 20ug zero bias instability
- 0.0 speed random walk5m/s/$\sqrt{hr}$
- 0.5mg 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

- Independent calibration of each module: sensitivity, zero bias, non-orthogonal error

High strength condition tolerance

- Strong impact tolerance: 2000g (0.5ms, half sine, 3 axis)
- Super strong vibration resistance: 10 g (10 ~ 2 KHZ, 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
- Supports COM and SPI interfaces
- 22.4*24.05*9.0mm, weight 8.6g

Product Overview

FSS-IMU16460 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

- Autonomous driving: vehicle, robot, engineering vehicle, underwater
- Precision measurement: underground, tunnel, vibration, tilt
- Stable platform: PTZ, MTC,
- Automatic control: automatic control system, fixed wing UAV

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

Contents

1. Performance Parameter

1.1 Key indicators of gyroscope

Table 1 Key indicators of gyroscope

Parameter	Test conditions/Remarks	Minimum value	Typical value	Maximum value	Units
Measuring range			＋500		°/s
Zero bias instability	@25 ° C, ALLAN variance, 1 σ		2.0		°/hr
Zero bias stability	National military standard, 10s smooth		5		°/hr
Zero bias repeatability	National Army mark		0.5		°/s
Resolution			0.0076		°/s
g value sensitivity			/		°/h/g
Non-orthogonal between axes			0.02		deg
Internal low-pass cutoff frequency	The software can be adjusted		116		Hz
ODR			1000		Hz
Measuring delay			7		ms
Full temperature range zero deviation variation	-40 ~ 85℃, <=1℃/ min@1σ		0.03		°/s
Random walk X axis	@25 ° C, ALLAN variance, 1 σ		0.4		°/√hr
Random walk Y axis			0.4		°/√hr
Random walk Z axis			0.3		°/√hr
Calibration coefficient error			2.5		‰
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

1.2 accelerometer key indicators

Table 2 Key indicators of accelerometer

Parameter	Test conditions/Remarks	Minimum value	Typical value	Maximum value	Units
Measuring range			Plus or minus 6		g
Zero bias instability	@25 ° C, ALLAN variance, 1 σ		20		Mug
Zero bias stability	National military standard, 10s smooth		40		Mug
Zero bias repeatability	National Army mark		10		mg
Resolution			0.0916		mg
Non-orthogonal between axes			0.02		deg
Internal low-pass cutoff frequency	Software adjustable		116		Hz
ODR			1000		Hz
Measuring delay			7		ms
Full temperature range zero deviation variation	-40 ~ 85℃, <=1℃/ min@1σ		xy: 0.5z : 2		mg
Random Walk	@25 ° C, ALLAN variance, 1 σ		0.05		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 the zero deviation of the total temperature changes by 1σ at 2:1 ℃/ min

FIG. 1 ALLAN variance typical curve of gyroscope

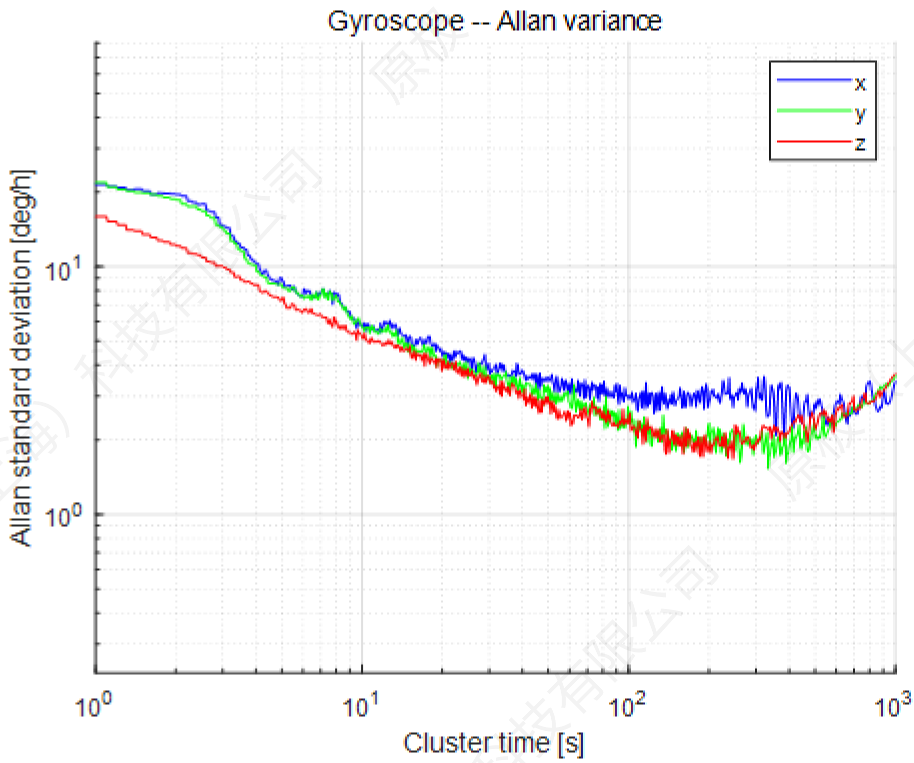
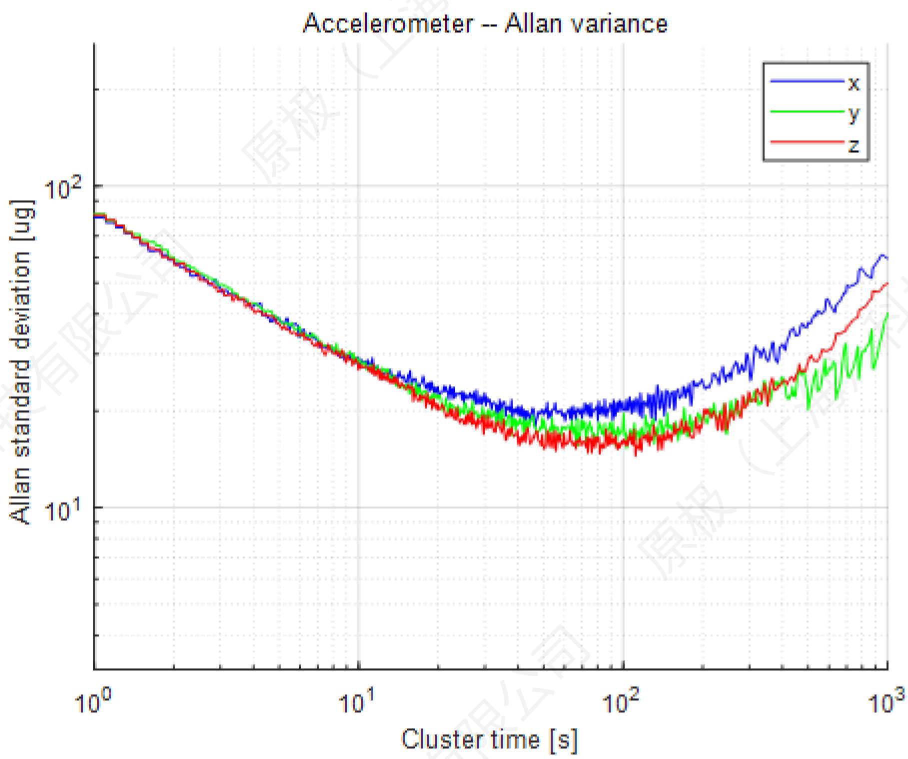
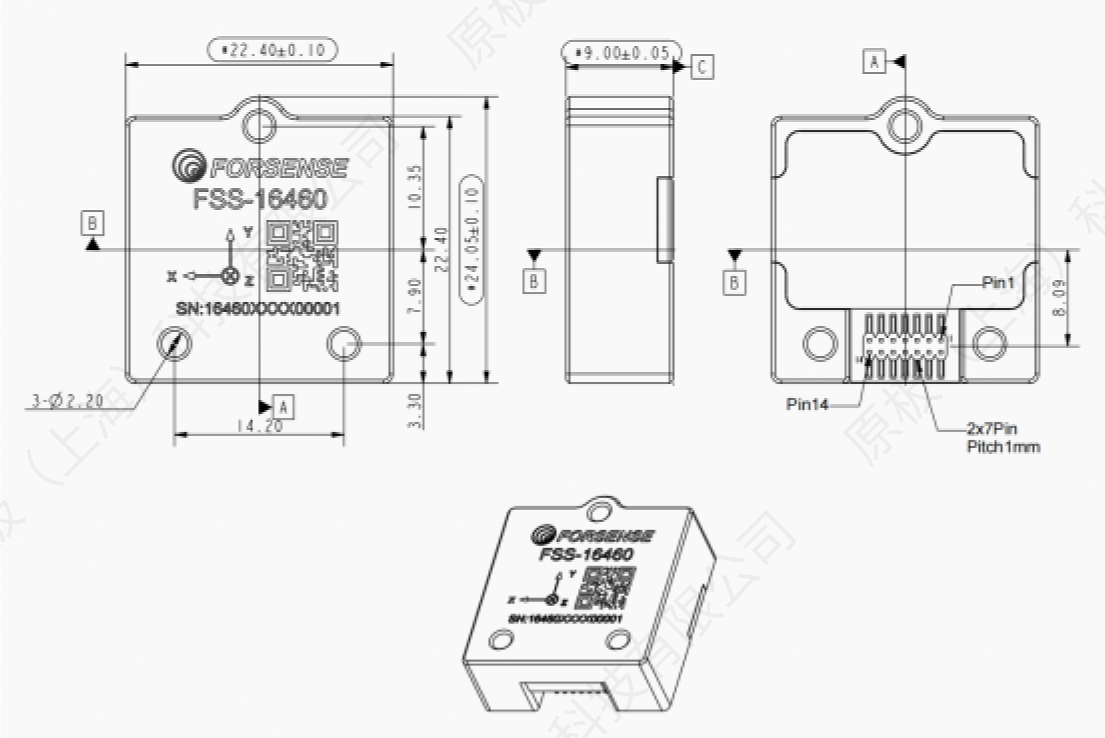


FIG. 2 Typical curve of ALLAN variance for accelerometer



2. External structure

Figure 3 Outline structure and dimensions (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 4.0	V
electrically	GND	-	-
Input pin voltage	Vin	-0.3 to VCC+0.2	V
Use temperature	Tot	-40 to 85	℃
Storage temperature	Tstg	-40 to 85	℃

3.2 Working Conditions

Table 4 Working conditions

Parameters	**Symbols**	**Minimum value**	**Typical value**	**Maximum value**	**Units**
Supply voltage	VCC	3.2	3.3	3.4	V
VCC maximum ripple	Vrpp		+ 40		mV
Power Consumption	P		0.17		W
Use temperature	Tot	-40		85	℃
Storage temperature	Tstg	-40		85	℃

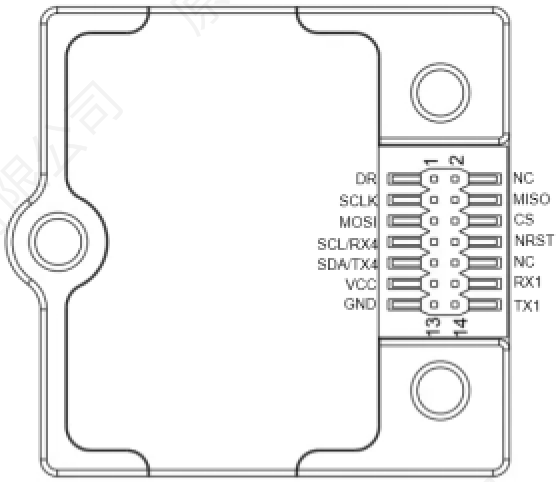
3.3 IO Threshold Characteristics

Table 5 I/O Threshold Characteristics

Parameters	**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

4. Pin definition

Figure 4 Pin schematic



Pin serial number	Pin name	Pin description
1	DRDY	Data Ready
2	NC	Unconnected
3	SCLK	SPI Serial clock
4	MISO	SPI serial data output
5	MOSI	SPI serial data entry
6	CS	SPI slice selection
7	SCL/RX4	I2C clock/receives asynchronous data input
8	NRST	External hardware reset input, internal pull-up (for SPI mode)
9	SDA/TX4	I2C data/Receive asynchronous data output
10	NC	Unconnected
11	VCC	Power input, +3.3V input
12	RX1	Receive asynchronous data input (Data Communication Interface (LVTTL))
13	GND	Power ground
14	TX1	Receiving asynchronous data output (Data Communication Interface (LVTTL))

Note 1: The IMU hardware is reset once using /RST during host initialization

5. Communication protocol

5.1 COM Communication Protocol

Examples of COM protocols based on QT, ROS and STM32:
https://data.forsense-imu.com/page/download.html
COM communication supports two modes: Stream Mode and Command Mode. After the IMU is powered on and initialized, the IMU enters the corresponding mode according to the mode value configured by parameters.
Data flow 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 COM Interface Parameters

Table 7 COM 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	IMU Output frame headers: 0xAA, 0x55 User input frame header: 0x55, 0xAA
1	uint8	Frame header 2	
2	uint16	ID low	The low bit of the frame ID for
3		ID high	The upper byte of the COM frame
4	uint16	Data length low	The lowest byte of the frame length of the COM communication. Length is the number of bytes occupied by the payload, that is, n
5		High data length	The upper byte of the frame length of the COM 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 Headers	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 serial port 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	Base Plate 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

According to the response data, the software version number 211231(1F 39 03 00) and the hardware version number 94053(65 6F 01 00) are parsed.

5.1.5 Command mode GET output — Read 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 Output data format of serial port Parameter

	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 16 Serial port P1 load data format

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 table of COM P1 load parameters

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 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 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 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 instruction

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: 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	Reserved. The default value 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 serial port, 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	Set the serial output baud rate, which is valid in bps value: 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. See Table 24 for the corresponding relation of the orientation of the coordinate system

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 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 22 Reserved parameters Serial port response data format

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

Table 23 Serial user command response data format

	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 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 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

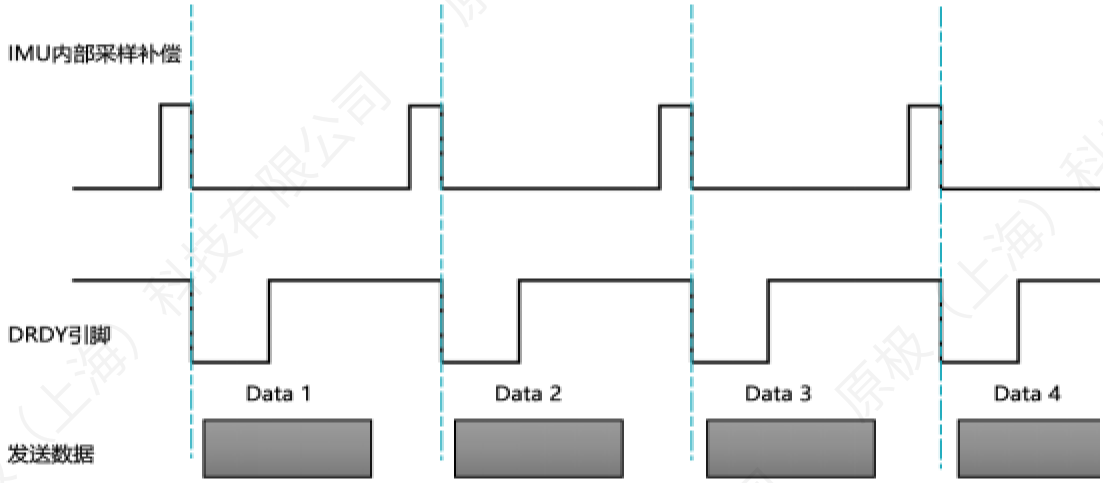
Input data: 55 AA 03 00 18 00 00 00 00 80 3F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 52 D8 8E E8

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

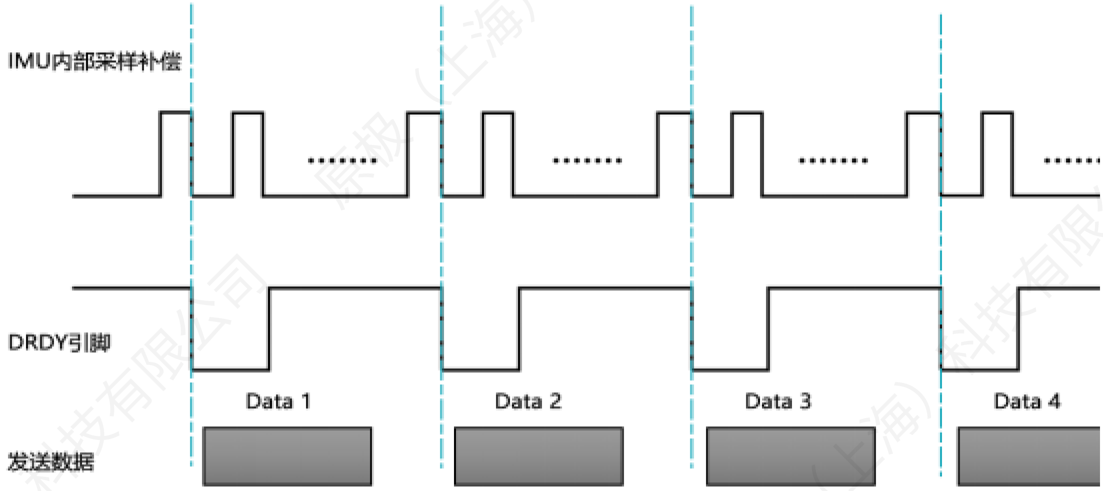
5.1.8 DRDY

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

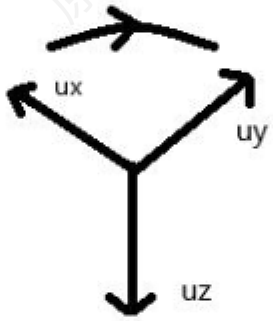


When the serial output frequency is less than the IMU internal sampling frequency, after the imu data sampling compensation is completed, it is determined whether DRDY pin cell is immediately pulled down according to the value youdaoplaceholder3 (maximum ODR/ current ODR). After the DRDY is pulled down, the data frame will be sent from the COM, and the DRDY Pin will be pulled up again in the next IMU sampling period.

5.1.9 Coordinate system setting function

Set the firmware coordinate system and display the corresponding firmware design coordinate system in the Upper computer software

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	

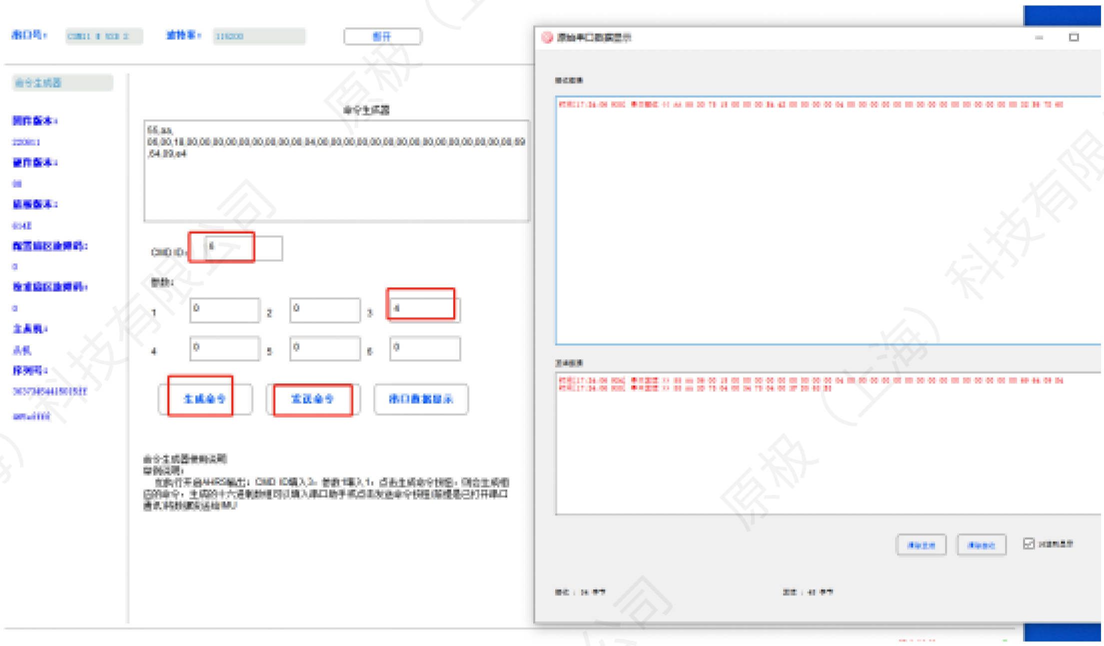
123	-Uz	+Ux	-Uy	
124	+Uz	-Ux	-Uy	

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 in CMD ID and 4 in Parameter 3. The generated hexadecimal array can be filled into the COM assistant or program array and sent to the IMU.

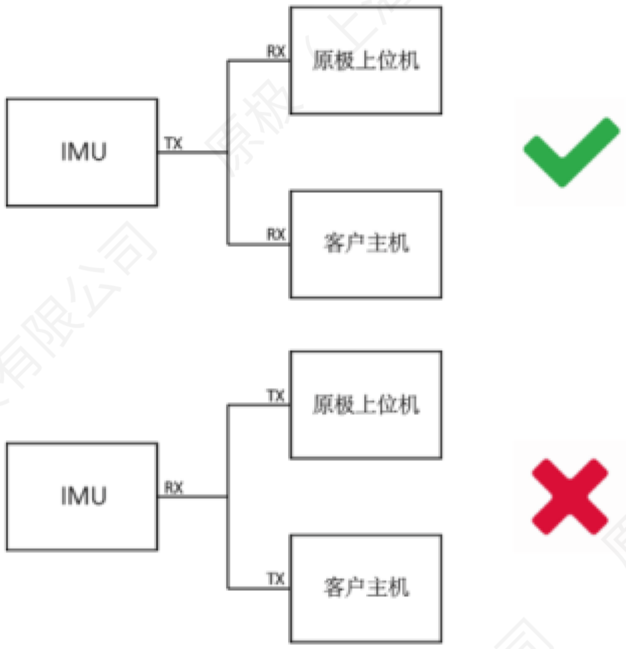


Example: Set the coordinate system to face 115
Data input: 55, aa, 0 e, 00,18,00,00,00, e6,
42,00,00,00,00,04,00,00,00,00,00,00,00,00,00,00,00, 00,00,00,00,46,6 a, 4 e, 86
Response data: AA 55 3D 75 04 00 34 75 04 00 60 0E 6B 1B
According to Table 21, the index of Parameter is 04, and the parameter is set successfully
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 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 B2 2F 2D 4E
According to Table 15 and Table 16, the resolution results in Parameter 1 being 115 (float) and Parameter 3 being 04. 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



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.

5.2 SPI communication protocol

Example of SPI host read driver based on STM32:

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

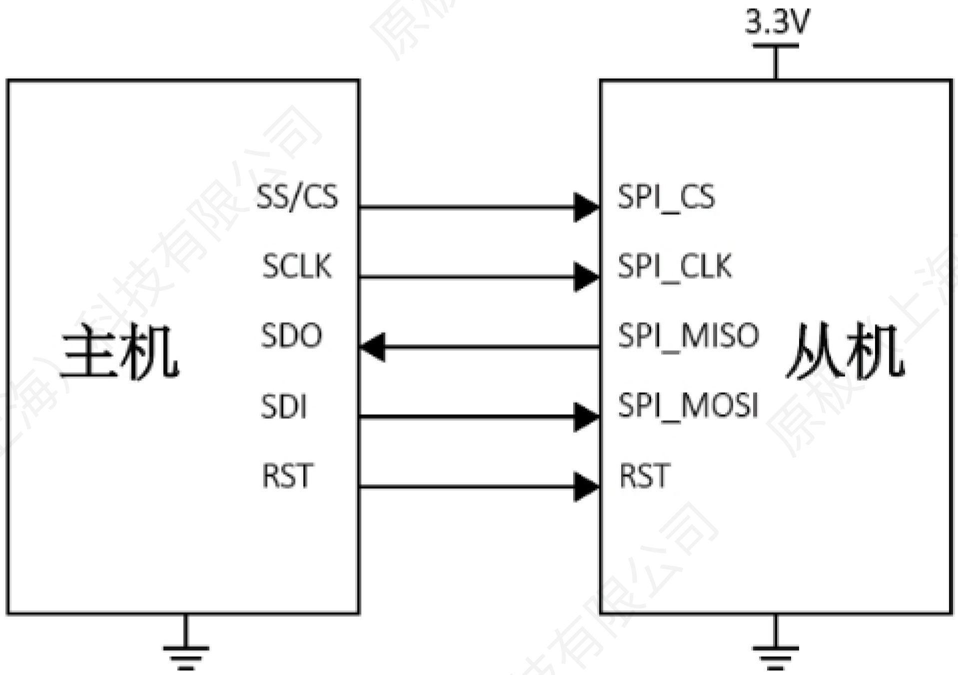
5.2.1 SPI Interface Parameters

Table 29 SPI interface parameters

SPI host	This product acts as slave
SPI rate	0.2 to 2 MHZ
SPI word length	16bit
Phase	Rising edge trigger (Mode 3, CPHA=1)
Polarity	Idle for high (mode 3, CPOL=1)
Bit order	MSB priority

5.2.2 SPI connection diagram

Figure 7 SPI connection diagram



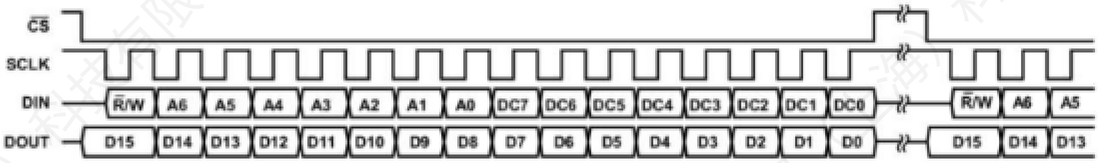
Note 1: Before the initial reading, it is necessary to reset the IMU and wait for 3s to make the IMU enter the normal working state.

Note 2: Refer to the corresponding manual for SPI pins of different IMU models

5.2.3 SPI communication bit order

The SPI interface supports full-duplex serial communication (performing both send and receive at the same time) using the bit order shown in the image below.

Figure 8 Schematic diagram of SPI communication bit order



The highest bit of DIN indicates the read/write operation, [A6:A0] indicates the Register address, and [DC7:DC0] indicates the data written (write operation) or DUMMY data (read operation).

When /W =1, the DOUT data of this SPI cycle is meaningless. $\overline{R}$DOUT data for this SPI cycle when /W =0$\overline{R}$

Represents Register output data for the last two cycles, as shown in the BURST read example.

5.2.4 SPI Register

Table 30 List of SPI Register

Names	Address	Read/Write	Default	Window ID	Description
MSC_CTRL	0x32	RW	0x00C1	1	Other controls
FILTER_CTRL	0x38	RW	0x00BB	1	Filter selection
BURST	0x3E	RW	\	0	Continuous reads
PROD_ID1	0x6A	R	0x4653	1	ID Number 1
PROD_ID2	0x6C	R	0x2D31	1	ID Number 2
PROD_ID3	0x6E	R	0x3634	1	ID Number 3
PROD_ID4	0x70	R	0x3630	1	ID Number 4
WIN_CTRL	0x7F, 0x7E	RW	0x0000	0, 1	Window ID selection
XGYRO_LOW	0x04	R	\	0	Gyro X axis low byte
XGYRO_HIGH	0x06	R	\	0	Gyro X axis height bytes
YGYRO_LOW	0x08	R	\	0	Gyro Y axis low byte
YGYRO_HIGH	0x0A	R	\	0	Gyro Y-axis height bytes
ZGYRO_LOW	0x0C	R	\	0	Gyro Z axis low byte
ZGYRO_HIGH	0x0E	R	\	0	Gyro z-axis height bytes
XACCEL_LOW	0x10	R	\	0	Add table X axis low byte
XACCEL_HIGH	0x12	R	\	0	Add table X axis height bytes
YACCEL_LOW	0x14	R	\	0	Add table Y-axis low byte
YACCEL_HIGH	0x16	R	\	0	Add table Y-axis height bytes
ZACCEL_LOW	0x18	R	\	0	Add table Z axis low byte
ZACCEL_HIGH	0x1A	R	\	0	Add table Z-axis height bytes
TEMP	0x1E	R	\	0	Temperature

5.2.4.1 SPI BURST Register

BURST reads Register continuously, reading all data in a single data stream without stopping between 16-bit segments.

Table 31 Format of SPI BURST Register

Address	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8	Read/Write
0x01									RW

Address	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Read/Write
0x00	BURST_CMD								RW

The method of reading BURST is: sending 0x3E00 before reading means setting BURST and starting reading, and then sending 0x0000 and receiving data all the time, the output register content is offset by 2 SPI cycles compared with the sending of reading instruction, and the chip selection low level is kept during reading.

FIG. 9 Schematic diagram of continuous reading of SPI BURST

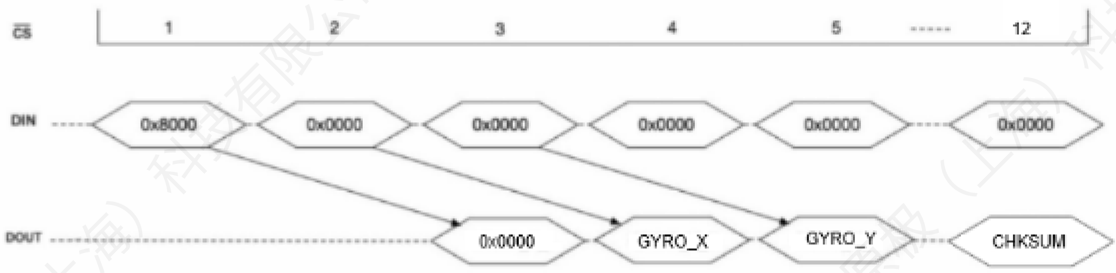


Table 32 Basic format of continuous reading by SPI BURST

Sending sequence	1	2	3	4	5	6
What to send	0x00	GYRO_X	GYRO_Y	GYRO_Z	ACCL_X	ACCL_Y
Send order	7	8	9	10		
What to send	ACCL_Z	TEMP	0x00	CHKSM		

Note 1: All data are 16-bit widths

Note 2: CHKSM stands for CHECKSUM, which is used to confirm data integrity. It is calculated by summing all the data before the CHECKSUM

In the process of reading a single Register, the 32-bit complete data is split into high 16 bits and low 16 bits respectively for output, and the output adopts the small-endian mode, that is, the low byte is output first. The user needs to concatenate the two parts of the 16-bit data to restore the complete 32-bit data.

FIG. 10 Schematic diagram of SPI32-bit data restoration

After getting the complete 32-bit data, the standard frame user can convert it into angular velocity, acceleration, temperature and attitude Angle information according to the following formula.

Table 33 Standard frame SPI 32-bit data conversion formula

Name	Units	Formula	Conditions/Notes
Angular Speed	°/s	G=SF*GYRO	GYRO is the GYRO data for the X/Y/Z axis in the table above ● □ = 0.016 for Burst mode ● In single Register mode, SF=0.016*65536
Acceleration	g	A=SF*ACCL	ACCL is the ACCL data for the X/Y/Z axis in the table above ● For Burst mode, □ = 0.2/1000 ● In single-register mode, SF=0.2/1000*65536
Temperature	°C	T=SF*(TEMP-2634)+25	TEMP is the TEMP data in the table above ● Temperature scale factor □ =-1/263.4
Attitude Angle	°	D=SF/65536*ATT	ATT is the ATT data in the table above ● Attitude scale factor □ = 0.00699411

5.2.4.2 SPI FILTER_CTRL register

The FILTER_CTRL register provides the user with control over the digital low-pass filter. This register is read/write register, write command is send 0xB8XX, and the current SPI cycle setting is valid; The read command is sent 0x3800, and the output register content is offset by 2 SPI cycles than the read instruction is sent.

Table 34 SPI FILTER_CTRL register format

Address	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8	Read/Write
0x07									RW
Address	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Read/Write
0x06	Accelerometer filter configuration				Gyro filter configuration				RW

Table 35 Filter configuration

	Encoding	Description
Accelerometer/gyroscope filter configuration	4'b 0000	IIR filter fc=1 Hz
	4'b 0001	IIR filter fc=1 Hz
	4'b 0010	IIR filter fc=2 Hz
	4'b 0011	IIR filter fc=5 Hz
	4'b 0100	IIR filter fc=10 Hz

	4'b 0101	IIR filter fc=15 Hz
	4'b 0110	IIR filter fc=20 Hz
	4'b 0111	IIR filter fc=25 Hz
	4'b 1000	IIR filter fc=30 Hz
	4'b 1001	IIR filter fc=35 Hz
	4'b 1010	IIR filter fc=40 Hz
	4'b 1011	no filter

Note: For example, if the gyro is configured and the accelerometer filter is 10Hz, the value 0xB844 is written.

5.2.4.3 SPI ID register

The ID register is a read-only register, and the data content is the character "FS-16460" in ASCII encoding form. The reading method is similar to that of BURST data reading: sending 0x6A00~0x7000 when reading, and receiving data. The output register content is offset by 2 cycles compared with the read instruction.

The complete ID of the product can be obtained by concatenating 4 16-bit ID data into ASICII code. The splicing method is the same as the splicing of data read continuously by BURST, with PROD_ID1 in the high position and PROD_ID4 in the low position.

Table 36 Format of SPI ID register

Address	bit15 ~ bit0	Encoding	Read/Write
0x6A	PROD_ID1	0x4653	R
0x6C	PROD_ID2	0x2D31	R
0x6E	PROD_ID3	0x3634	R
0x70	PROD_ID4	0x3630	R

5.2.4.4 SPI WIN_CTRL register

This register is used to control the switch window ID and can be read and written. The window default is 0, write 0xFE01, then switch to 1.

Table 37 SPI WIN_CTRL register format

Address	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8	Read/Write
0x7F									RW
Address	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Read/Write
0x7E	WINDOW_ID								RW

Table 38 SPI register WIN_CTRL.WINDOW_ID encoding

Name	Code	Description
WINDOW_ID	0x00	window0, start reading data

	0x01	window1, go to Configuration

5.2.4.5 SPI MSC_CTRL register

This register is used to control SYNC and DATA READY pin patterns and polarity, and defaults to 0xC1.

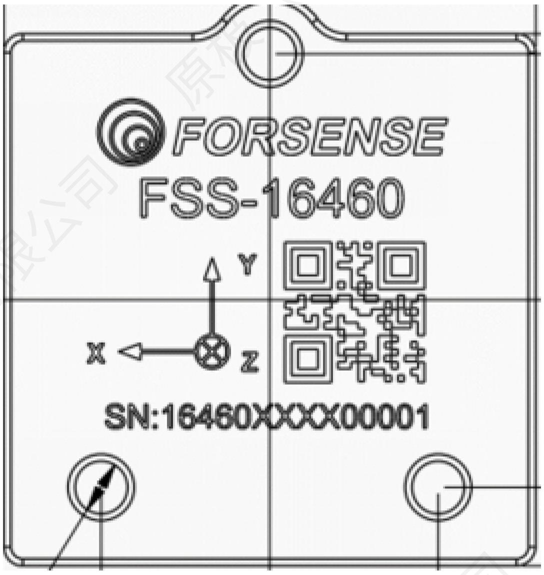
Table 39 SPI MSC_CTRL register format

Address	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8	Read/Write
0x32									RW
Address	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Read/Write
0x33					SYNC function Settings		SYNC Polarity	DR Polarity	RW

Table 40 SPI register MSC_CTRL encoding

name	Code	Description
DR Polarity	0x00	Low active (when data is active)
	0x01	High active (when data is active)
SYNC polarity	0x00	Rising edge triggers sampling
	0x01	Falling edge triggers sampling
SYNC function Settings	0x00	Disable (Internal sampling clock)
	0x01	Direct Sampling Control (input)

6. Coordinate system definition



This product coordinate system uses the front - right - down (FRD) coordinate system, Euler Angle range is as follows:

Rotation around the Z axis: Yaw angle Yaw range: 0° ~360°;

Rotation around the X axis: Roll angle roll range: -180°~180°;

Rotation around the Y axis: Pitch angle pitch range: -90°~90°.

Roll, pitch, course Angle diagram is as follows:

FIG. 21 Schematic diagram of roll, pitch and Yaw angle

7. CRC table lookup method calculation

```
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;
}
```

8. Examples of use

8.1 Device Installation

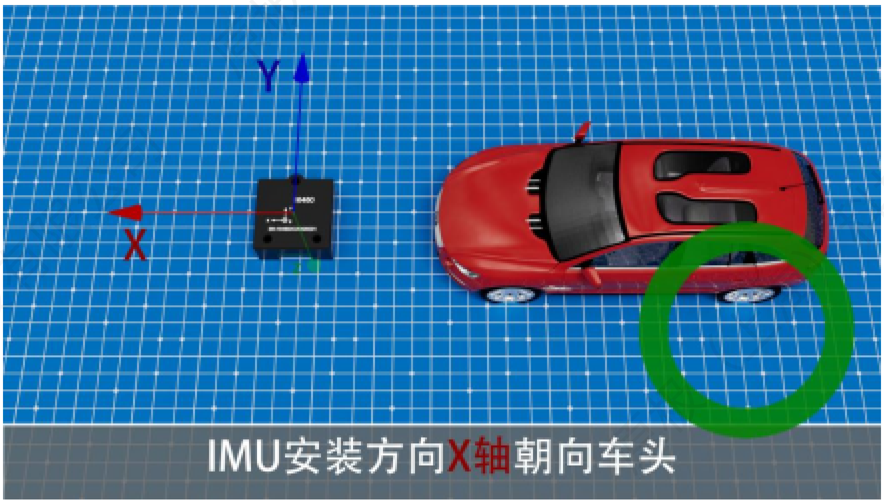
1. The module should be firmly fixed on a rigid plane to avoid being installed in a position with large vibration.
2. The module should be installed in the same direction as the front.

Figure 11 Schematic diagram of module installation

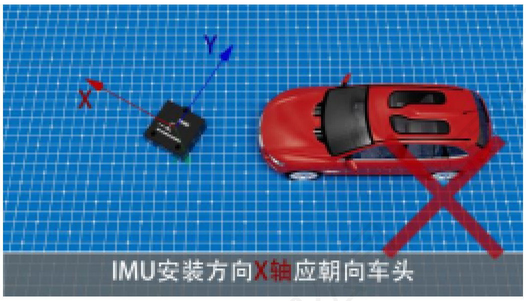
The correct installation diagram is as follows

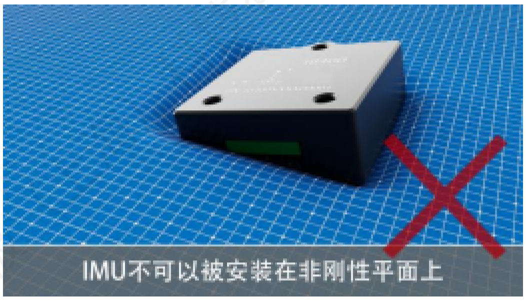
The X axis faces the front of the car

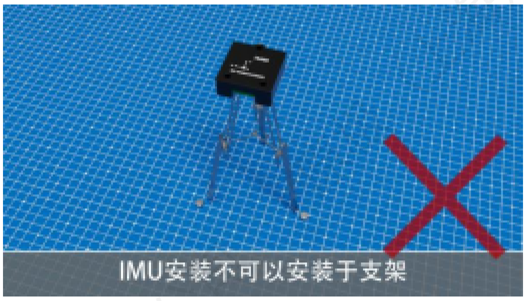
Figure 12 Diagram of proper installation

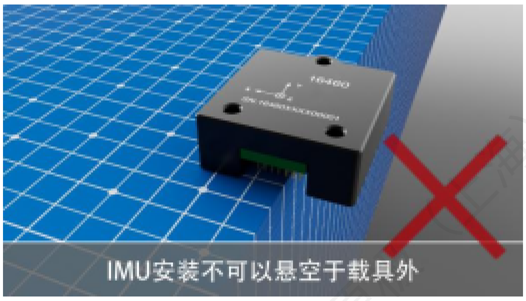


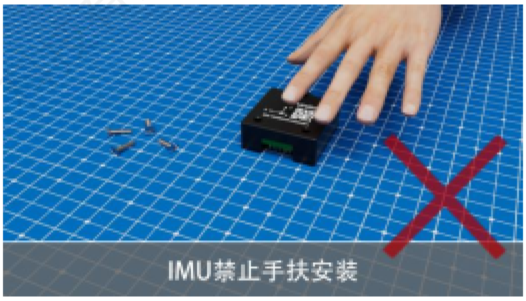
The following installation methods are incorrect installation











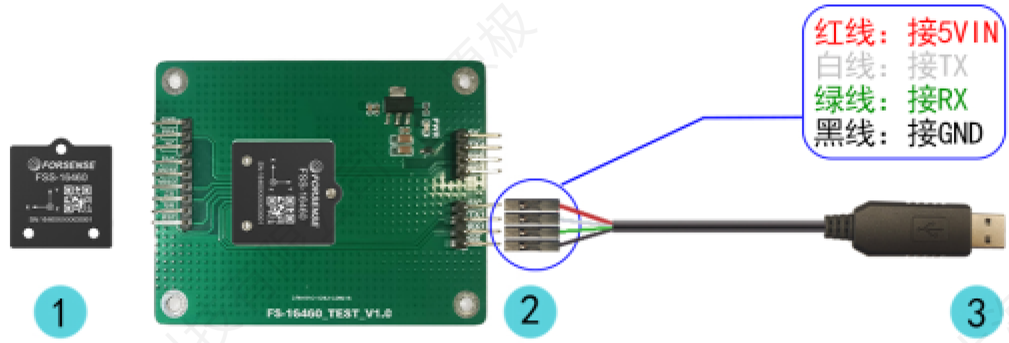
3. Precautions for IMU installation

Do not use glue or other flowing liquid around the IMU to prevent liquid from flowing into the IMU through gaps and affecting the IMU performance.

Figure 19 Schematic diagram of incorrect installation

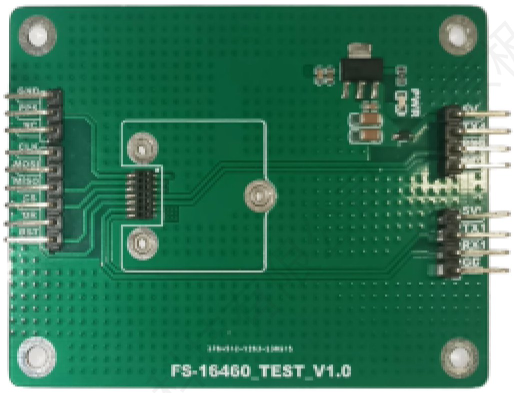
8.2 Example for Connecting a Upper computer software

FIG. 20 Schematic diagram of module connecting to Upper computer software



	名称	数量
1	IMU16460	1个
	附件名称	数量
2	16460测试底板	1个
3	TTL串口线	1个

9. Select accessories



IMU16460 Test mainboard

TTL serial cable

10 Update the record

Versions	Dates	Status/Comments
Version 1.0	2023.09.15	First issue
Version 1.1	2023.10.07	Update coordinate system definition
Version 1.2	2023.12.14	Add attachments
Version 1.3	2024.04.11	Update electrical features
Version 1.4	2024.05.10	Add Upper computer software connection diagram