Tactical Grade MEMS 6-DOF Inertial Sensors

FSS-IMU614E-C Product Sheet

Features

MEMS Gyroscope

- Bias Instability: 1.5°/hr
- Angle Random Walk: 0.1°/$\sqrt{hr}$

MEMS Accelerometer

- Bias Instability: 20μg
- Velocity Random Walk: 0.02m/s/$\sqrt{hr}$

Independent Rotary Table Calibration

- Sensitivity, bias instability, and misalignment
- Temperature Compensation: -40℃ to 85℃

High-intensity Tolerance

- Ultra Shock Resistance: 2000g（0.5ms Half-sine shock pulse，3-axis）
- Superb Vibration Resistance：10g（10~2KHz，3-axis）
- Wide Operating Temperature Range：-40℃ to 85℃
- 100% Magnetic Shielding

Benefits

- Real-time and Flexibility: Configurable output sampling rate up to 1KHz
- Digital Interface: Serial ports, I2C and SPI
- Small Size and Low Weight: 14.7*17.2*3.1mm, about 2g

Description

FSS-IMU614E-C is a MEMS inertial measurement unit (IMU) with 6 degrees of freedom (DOF) developed by Forsense (Shanghai) Technology Co., Ltd. It features three-axis gyroscopes and three-axis accelerometers, measuring angular velocity and linear acceleration respectively.

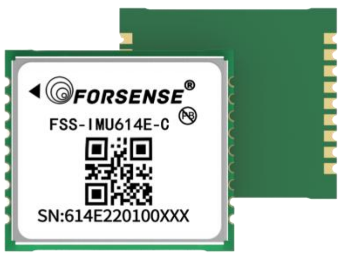
High precision and high resolution combine to help capture subtle vibration and tilt. All IMU modules are calibrated on a rotary table before leaving the factory, so that they can deliver stable and consistent performance in most extreme conditions.

Cost-effective inertial sensors are especially suited for attitude measurement and integrated navigation in self-driving agricultural machinery.

Applications

- Mapping and surveying: SLAM handheld laser scanners and other equipment

Apart from standard performance and output parameters, Forsense also provides **customized services, including software development and LOGO design**, to better your products!



CONTENT

1. Performance Parameters

1.1 Gyroscope Key Metrics

Table 1 Gyroscope Key Metrics

Parameters	Test Conditions/Remarks	Minimum	Typical	Maximum	Unit
Measurement Range			±500		°/s
Bias instability(1)	@,ALLAN Variance,1σ		1.5	2.7	°/hr
Misalignment			0.02	0.05	deg
Internal Low-pass Cutoff Frequency	Adjustable software		41		Hz
ODR			1000		Hz
Measure Delay			5		ms
Offset Error over Temperature	-40 ~ 85℃，<=1℃/min @std		0.04	0.1	
Random Walk X-axis(1)	@,ALLAN Variance，1σ		0.1	0.15	°/ √ hr
Random Walk Y-axis			0.1	0.15	°/ √ hr
Random Walk Z-axis			0.1	0.12	°/ √ hr
Scale Coefficient Error			1.5		‰
Scale Factor Nonlinear	@		200		ppm

Note 1: IEEE standard values acquired from Allan Variance analysis in a static environment (25°C)

1.2 Accelerometer Key Metrics

Table 2 Accelerometer Key Metrics

Parameters	Test Conditions/Remarks	Minimum	Typical	Maximum	Unit
Measurement Range			±8		g
Bias instability(1)	@,ALLAN Variance,1σ		20		μg
Misalignment			0.02	0.05	deg
Internal Low-pass Cutoff Frequency	Adjustable software		41		Hz
ODR			1000		Hz
Measure Delay			5		ms
Offset Error over Temperature	-40 ~ 85°C, <=1°C/min @std		1	1.5	mg
Random Walk X-axis(1)	@,ALLAN Variance,1σ		0.02		m/s/√hr
Random Walk Y-axis			0.02		m/s/√hr
Random Walk Z-axis			0.02		m/s/√hr
Scale Coefficient Error			0.3		‰
Scale Factor Nonlinear	@		100		ppm

Note 1: IEEE standard values acquired from Allan Variance analysis in a static environment (25°C)

Fig. 1 Gyroscope - Typical Allan Variance Curve

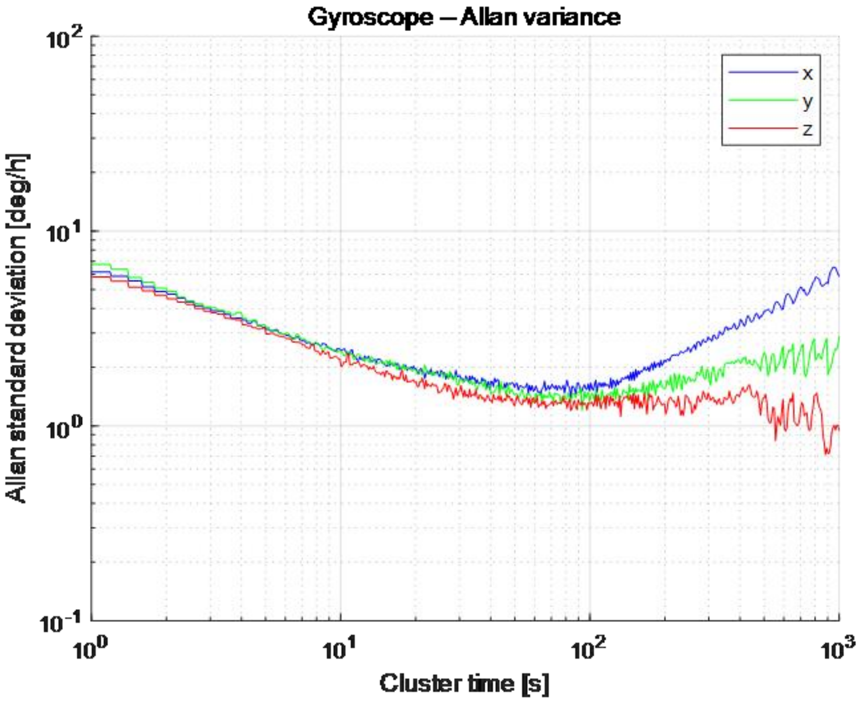
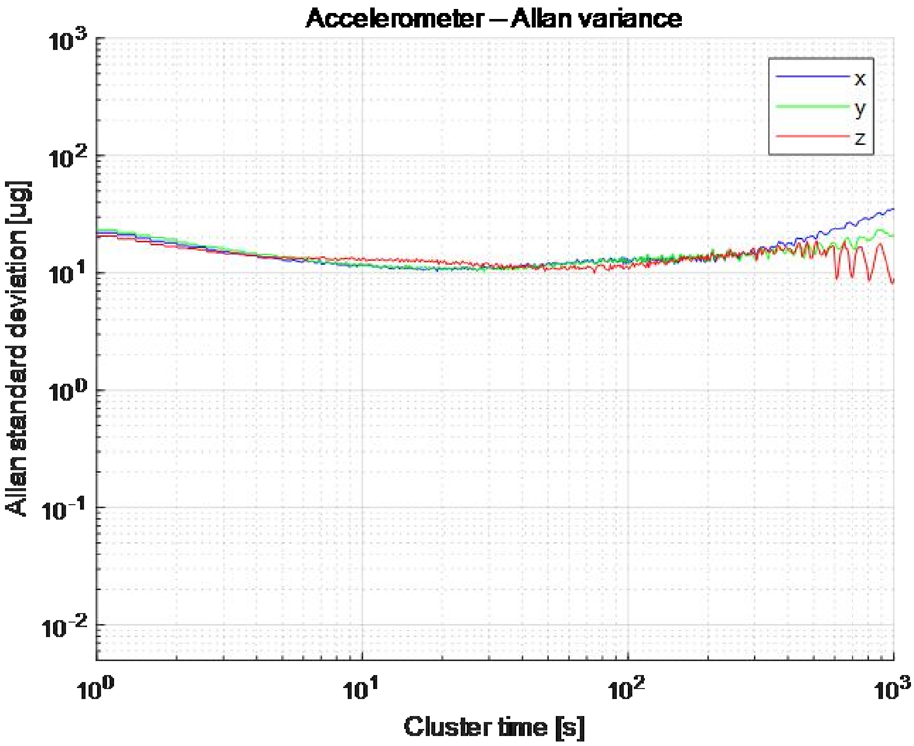


Fig. 2 Accelerometer - Typical Allan Variance Curve



2. External Structure

Fig. 3 Outline Structure and Dimensions (unit: mm)

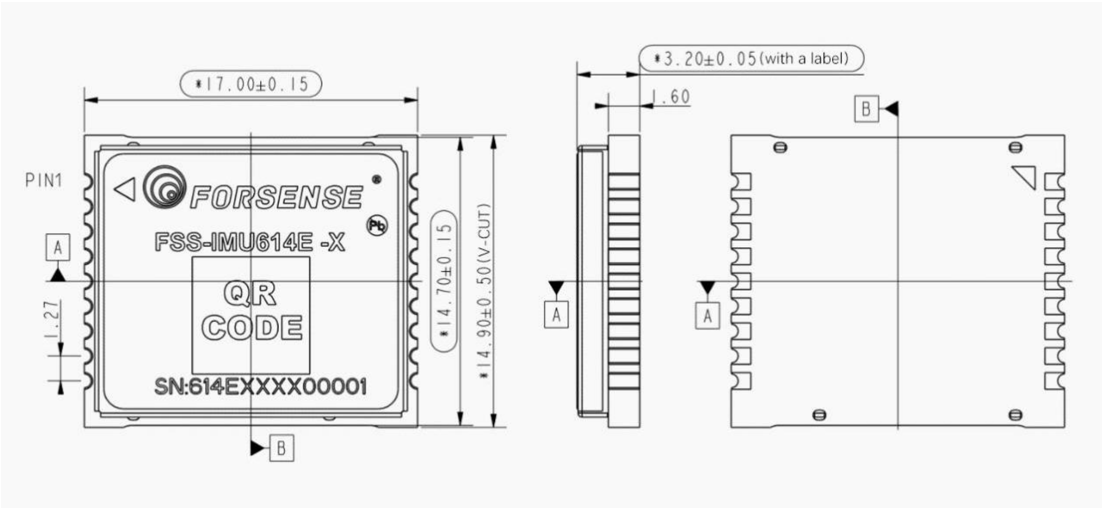
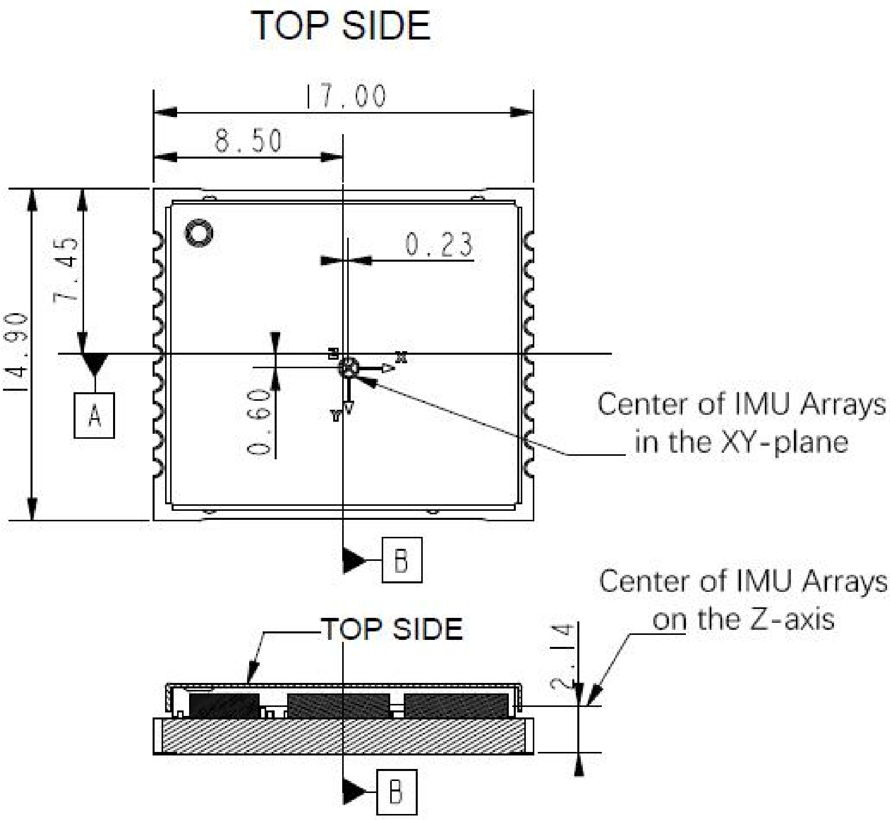


Fig. 4 IMU Coordinate System(unit: mm)



3. Electrical Properties

3.1 Maximum Tolerance Value

Table 3 Absolute Maximum Ratings

Parameters	Abbreviations	Range	Unit
Voltage for Circuit to Circuit	VCC	-0.3 to 4.0	V
Ground	GND	-	-
Input Voltage	Vin	-0.3 to VCC+0.2	V
Operating Temperature	Tot	-40 to 85	℃
Storage Temperature	Tstg	-40 to 85	℃

3.2 Operating Conditions

Table 4 Operating Conditions

Parameters	**Abbreviations**	**Minimum**	**Typical**	**Maximum**	**Unit**
Voltage for Circuit to Circuit	VCC	3.2	3.3	3.4	V
VCC Maximum Ripple	Vrpp		±40		mV
Power Consumption	P		0.08		W
Operating Temperature	T	-40		85	℃
Storage Temperature	T	-40		85	℃

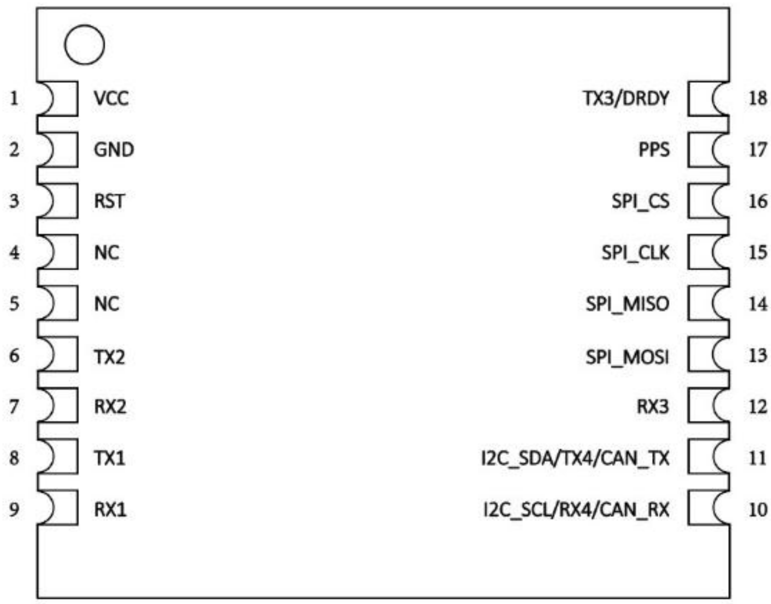
3.3 IO Threshold Characteristics

Table 5 IO Threshold Characteristics

Parameters	Abbreviations	Minimum	Typical	Maximum	Unit
Input Pin Low Voltage	Vin_low	0		VCC*0.2	V
Input Pin High Voltage	Vin_high	VCC*0.7		VCC+0.2	V
Output Pin Low Voltage	Vout_low	0		0.45	V
Output Pin High Voltage	Vout_high	VCC-0.45		VCC	V

4. Pin Definitions

Fig. 4 Pin Diagram



IMU614E-X Pin Layout (Top View)

Table 6 Pin Definitions

<table>
<tr><th>Pin No.</th><th>Pin Name</th><th colspan="3">Description</th></tr>
<tr><td>1</td><td>VCC</td><td colspan="3">Power Input: +3.3V, 40mA, with ripple not exceeding ±40mV</td></tr>
<tr><td>2</td><td>GND</td><td colspan="3">Ground</td></tr>
<tr><td>3</td><td>RST 1</td><td colspan="3">External hardware reset input, internal pull-up (for SPI mode)</td></tr>
<tr><td>4</td><td>NC</td><td colspan="3">No connection</td></tr>
<tr><td>5</td><td>NC</td><td colspan="3">No connection</td></tr>
<tr><td>6</td><td>TX2</td><td colspan="3">Receive asynchronous data output</td></tr>
<tr><td>7</td><td>RX2</td><td colspan="3">Receive asynchronous data input</td></tr>
<tr><td>8</td><td>TX1</td><td colspan="3">Receive asynchronous data output (Data communication interface (LVTTL))</td></tr>
<tr><td>9</td><td>RX1</td><td colspan="3">Receive asynchronous data input (Data communication interface (LVTTL))</td></tr>
<tr><td rowspan="4">10</td><td rowspan="4">CAN RX / RX4 / I2C_SCL</td><td>Mode</td><td>Function</td><td>Description</td></tr>
<tr><td>1</td><td>CAN_RX</td><td>CAN RX pin: reading data from bus and sending them to CAN controller</td></tr>
<tr><td>2</td><td>RX4</td><td>Receive asynchronous data input</td></tr>
<tr><td>3</td><td>I2C_SCL</td><td>I2C Serial Clock</td></tr>
<tr><td>11</td><td>CAN TX / TX4 /</td><td>Mode</td><td>Function</td><td>Description</td></tr>
</table>

	I2C_SDA	1	CAN_TX	CAN TX pin: reading data from CAN controller and sending them to bus driver
		2	TX4	Receive asynchronous data output
		3	I2C_SDA	I2C Serial Data
12	RX3	Receive asynchronous data input		
13	SPI_MOSI	SPI Serial Data Input		
14	SPI_MISO	SPI Serial Data Output		
15	SPI_CLK	SPI Serial Clock		
16	SPI_CS	SPI Chip Select		
17	PPS	Signal to trigger external synchronized sampling; (access to RTK second pulse pin)		
18	TX3/DRDY	Receive asynchronous data output/ available for Data Ready		

Note 1: IMU hardware needs to be reset by triggering /RST before the master initialization.

For more information about IMU hardware design, please refer to the document_ *FSS-IMU614E-XX Hardware Design Manual.*

5. Recommended Welding Furnace Temperature Profile

Fig. 6 Welding Furnace Temperature Profile

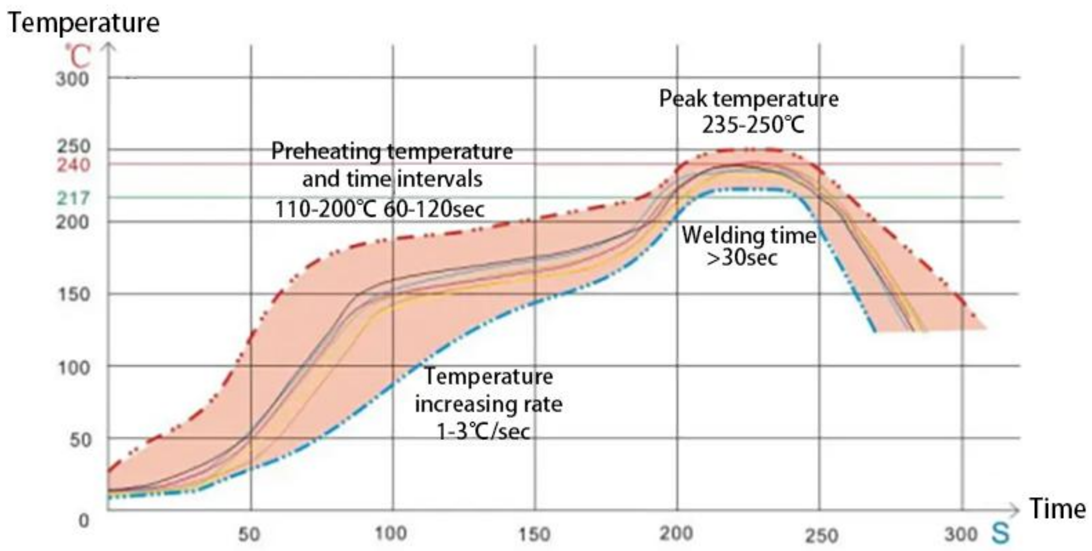


Table 7 Temperature Setting Modes

Indicators	Minimum	Maximum	Unit
Maximum ramp-up rate (target = 0.8) (calculated every 60 seconds)	1	3	Deg/s
Maximum ramp-down rate (calculated every 60 seconds)	-3	-1	Deg/s
Preheating temperature and time intervals	60	120	s
Reflow time (period over 217°C)	40	70	s
Maximum temperature	235	250	°C
Maximum number of reflow		1	Times

For more information about SMT modules, please refer to the document Forsense - LCC Module_SMT Application Guide.

Notes:

1. For modules, it is recommended to use reflow welding equipment with eight or higher temperature zones;
2. The module is a high-precision sensor sensitive to any deformation;

- If the thickness of the PCB board is less than 1.0 mm, it is recommended to use reflow fixtures to prevent the board from getting deformed under high temperature, thereby ensuring the coplanarity of pins;
- We recommend customers to use high TG value boards as PCB main boards to avoid deformation during high temperature reflow, thus reducing the possibility of warping, extrusion, empty soldering, and solder bridging;

3. Due to the sensitive devices inside the module, the maximum temperature of the reflow soldering machine must not exceed 260°C (referring to the the top surface temperature of the package);
4. It is recommended to use lead-free solder paste, including Alpha OM-338 SAC305 Sn96.5Ag3.0Cu0.5;
5. Given sensitive devices in the module, the second reflow should be avoided to ensure proper performance of the module;
6. Cooling;

- Controlled cooling ramp rate can help reduce negative soldering effects (e.g. more brittle solder joints) and mechanical stresses within the product. Controlled cooling contributes to bright soldered surfaces with fine crystalline particles and low contact angles, avoiding the warping of the shielding cap caused by rapid cooling changes.

7. Exterior inspection:

- After the module is soldered, the X-ray and optical magnifying glass are used to test the welding quality. For details, please refer to the IPC-A-610F standards.

8. **Using electric soldering iron requires the temperature to be controlled at 260 °C to 290 °C, the single welding time shall not exceed 3s, and the anti-static treatment shall be done.**

6. ESD Protection

Static electricity may cause intermittent or permanent circuit damage, which is very harmful to electronic products. Most of them are identified as ESD damage;

Therefore, the electrostatic protection of modules is particularly important. The production and transportation process needs to be strictly subject to the following conditions:

- It is prohibited to touch the module, especially the pin position, with bare hands;
- SMT machines, workstations, soldering irons and other equipment need to be grounded;
- Operators wear human anti-static bracelets with grounding wires (cordless static bracelets are not allowed and anti-static gloves are recommended);
- Qualified anti-static packaging and PCB is a must.

7. Communication Protocols

7.1 Serial Communication Protocols

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

https://www.forsense.cn/download/

Serial communication has two modes, Stream Mode and Command Mode. IMU enters a specific mode based on corresponding parameters after the IMU has been powered on and initialized.

Stream Mode: Outputting AHRS data at a fixed frequency;

Command Mode: In this mode, the periodic output is stopped and users communicate with the IMU by sending commands, including the GET command which is used to obtain sensor data, status, parameters and other information and to configure the parameters of the IMU.

7.1.1 Serial Port Parameters

Table 8 Serial Port Parameters

Transmission rate range	115200bps ~ 1.5Mbps
Default transmission rate	115200bps
Start Bit	1 bit
Data Bit	8 bits
Stop Bit	1 bit
Parity Check	/

7.1.2 Packet Format

The IMU output and user input packets consist of the following:

Table 9 IMU Output and User Input Data Structure

Offset	Data type	Name	Description
0	uint8	Frame header 1	IMU output frame header: 0xAA, 0x55 User input frame header: 0x55, 0xAA
1	uint8	Frame header 2	
2	uint16	ID Low Byte	Low byte of serial communication frame ID
3		ID High Byte	High byte of serial communication frame ID
4	uint16	Low Byte of Data Length	The low byte of serial communication frame length, and the length represents the number of bytes occupied by the payload, i.e. n
5		High Byte of Data Length	The high byte of serial communication frame length, and the length represents the number of bytes occupied by the payload, i.e. n
6	uint8	Payload (n bytes)	Data Load
6+n	Uint32	CRC_CEHCK (32-bit data low bytes)	CRC verification
7+n		CRC_CEHCK (32-bit data low middle	
8+n		CRC_CEHCK (32-bit data high middle	
9+n		RC_CEHCK (32-bit data high bytes)	

Note 1: The data is transmitted in small end format, low byte first and high byte second.

Note 2: The initial value of crc32 is 1 and the CRC calculation does not include all the data of the frame itself. Please refer to CRC Look-up Table Calculations at the end of the document.

7.1.3 Stream Frames - AHRS Data

Table 10 Serial AHRS Data Format

	Frame header	Frame header	ID	Length	Payload	Frame trailer
Data type	uint8	uint8	uint16	uint16	A1	uint32
Encoding	0xAA	0x55	0x0002	0x002C		crc32

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

Table 11 Serial A1 Load Data Format

Offset	Name	Data type	Unit	Description
0	timer	uint32	µs	Time scale
4	pitch	float	°	Pitch angle
8	roll	float	°	Roll angle
12	yaw	float	°	Yaw 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

7.1.4 Command Mode GET Output - System Status

Table 12 Serial System Status Data Format

	Frame header	Frame header	ID	Length	Payload	Frame trailer
Data type	uint8	uint8	uint16	uint16	S1	uint32
Encoding	0xAA	0x55	0x00FF	0x002A		crc32

Table 13 Serial 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 number
18	sn2	uint32	Third SN number
22	Board_version	uint32	Base plate version number
26	Rev[n]	Uint8	All subsequent bytes are reserved

7.1.5 Command Mode GET Output - Reading Parameters

Table 14 Serial Port Parameter Input Data Format

	Frame header	Frame header	ID	Length	Payload	Frame trailer
Data type	uint8	uint8	uint16	uint16	P1	uint32
Encoding	0x55	0xAA	0x0006	0x0018		crc32

Table 15 Serial Port Parameter Output Data Format

	Frame	Frame	ID	Length	Payload	Frame
Data type	uint8	uint8	uint16	uint16	P	uint32
Encoding	0xAA	0x55	0x0006	0x0018		crc32

Table 16 Serial P Load Data Format

Offset	Name	Data type	Description
0	Param1	float	Parameters set
4	Param2	float	Reserved, 0 (Default)
8	Param3	uint32	Parameter index set
12	Param4	uint32	Reserved, 0 (Default)
16	Param5	Int32	Reserved, 0 (Default)
20	Param6	Int32	Reserved, 0 (Default)

Table 17 Serial P Load Parameter Index

Param3	Param1	Unit
3	Serial output baud rate, supporting the following baud rates 115200、230400、460800、921600、1500000	bps
4	Coordinate system orientation (referring to table 23 for coordinate system orientation correspondence)	
8	X-axis gyro bias calibration result, GYRO_X_OFF	°/s
9	Y-axis gyro bias calibration result, GYRO_Y_OFF	°/s
10	Z-axis gyro bias calibration result, GYRO_Z_OFF	°/s
21	AHRS output frequency, 100Hz (Default)	Hz
31	Internal filter configuration as defined in SPI's FILTER_CTRL cross reference	

7.1.6 Command Mode SET Instructions

Table 18 Serial Input Command Format

	Frame header	Frame header	ID	Length	Payload	Frame trailer
Data type	uint8	uint8	uint16	uint16	R1	uint32
Encoding	0x55	0xAA	CMD	0x0018		crc32

Note 1: CMD and R1 relationship, seeing R1 Load Parameter Index Table for details.

Table 19 Serial R1 Load Data Format

Offset	Name	Data type	Description
0	Param1	float	Parameters set
4	Param2	float	Reserved, 0 (Default)
8	Param3	uint32	Parameter index set
12	Param4	uint32	Reserved, 0 (Default)
16	Param5	Int32	Reserved, 0 (Default)
20	Param6	Int32	Reserved, 0 (Default)

Table 20 Serial R1 Load Parameter Index

CMD	Param1	Param3	Description
1	0	0	Triggered to acquire system status data once
2	0	0	Triggered to acquire AHRS data once
3	<mode>	0	Setting output mode: Mode=1, outputting AHRS data in a streaming format. Mode=100, disabling Stream Mode and entering COMMAND Mode.
5	0	0	Save current parameters to FLASH
6	0	<value>	Read parameters, and <value> is the parameter index to be read, i.e. P.index. For details, please refer to Serial Port Parameters Output in Response to indexes. Examples: set value=21 to read AHRS output data rate (ODR), set value=3 to read the serial baud rate, set value=31 to read the internal filter, and set value=4 to read the direction of the coordinate system.
9	0	0	Software restart

14	<value>	3	Set the serial output baud rate, and the valid values of the unit BPS are: 115200, 230400, 460800, 921600, 1500000 If <value> is the values other than those mentioned above, the default is 115200bps. Restart the software after setting the baud rate parameters. Setup process without power failure: set baud rate, save parameters to FLASH, and restart the software.
14	<value>	21	Set the frequency of periodic AHRS data output, and the commonly used values for the unit Hz are 1, 10, 50, 100, 200, 500, 1000. Recommended correlation between output frequency and serial baud rate 1000Hz: 921600bps 500Hz: 460800bps 250Hz: 460800bps 200Hz: 460800bps 100Hz: 115200bps
14	<value>	31	Internal filter configuration, the definition of which is the same as that of SPI accelerometer and gyroscope filter configuration. The default is 0xBB, i.e. 47Hz.
14	<value>	4	Set the IMU coordinate system orientation, the value range is 101~124, and see table 23 for the specific coordinate system orientation correspondence.

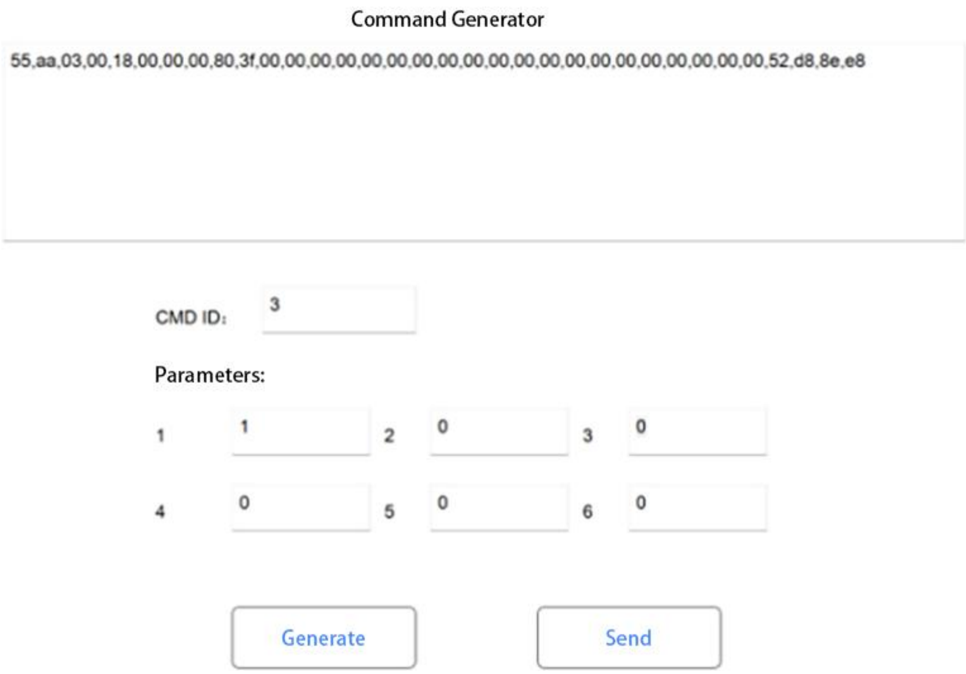
Note 1: Please note that the values in this table are all decimal.

Note 2: You can use the Forsense PC software to generate and send corresponding commands, and the methods of use is shown in the Forsense PC software section of this manual.

If the AHRS output is turned on:

CMD ID is filled with 3, parameter 1 is filled with 1, and the generated hexadecimal array can be added to the serial assistant or program array which will be sent to IMU.

Fig. 7 AHRS output turned on



7.1.7 Command Mode Output - User Command Response

Table 21 Serial Data Format in Response to Adjusted Parameters

	Frame header	Frame header	ID	Length	ACK	Param3	Frame trailer
Data type	uint8	uint8	uint16	uint16	uint16	uint16	uint32
Encoding	0xAA	0x55	0x753D	0x0004	0x7534	Parameter Index	crc32

Table 22 Serial Data Format in Response to Saved Parameters

	Frame header	Frame header	ID	Length	ACK	Result	Frame trailer
Data type	uint8	uint8	uint16	uint16	uint16	uint16	uint32
Encoding	0xAA	0x55	0x753D	0x0004	0x0005	0x01	crc32

Table 23 Serial Data Format in Response to User Commands

	Frame header	Frame header	ID	Length	Command	Result	Frame trailer
Data type	uint8	uint8	uint16	uint16	uint16	uint16	uint32
Encoding	0xAA	0x55	0x0064	0x0004	Command ID	0x01	crc32

Example: Set the serial output baud rate 115200

Input Data:
55,AA,0E,00,18,00,00,00,E1,47,00,00,00,00,03,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,0
0,56,2B,4D,93

Response data: AA 55 3D 75 04 00 34 75 03 00 A7 98 2A 54

Set periodic AHRS data output frequency 100hz

Input Data: 55 AA 0E 00 18 00 00 00 C8 42 00 00 00 00 15 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 current parameters to FLASH

Input 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 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 80 3F 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

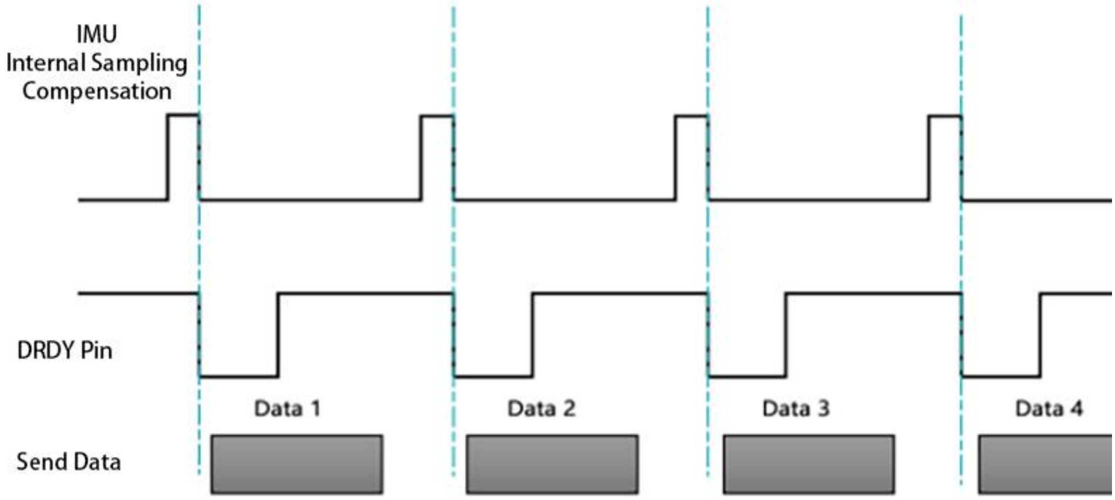
7.1.8 DRDY

The DRDY pin output serves two purposes:

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

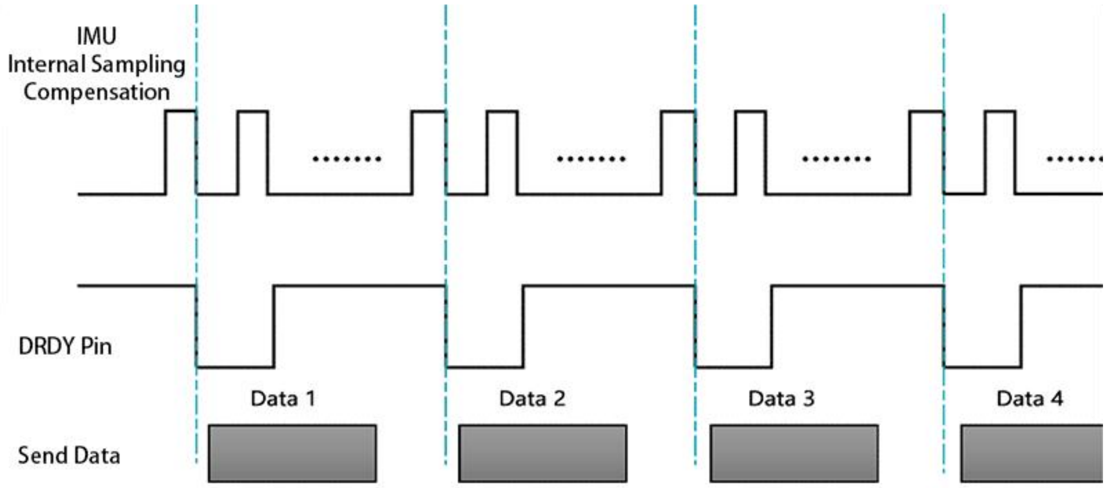
2. to provide a signal to indicate the start of data frame transmission.

Fig. 8 Internal Sampling Frequency Equals Serial Output Frequency



When the IMU internal sampling frequency (maximum ODR) equals the serial output frequency (current ODR), the DRDY pin will always be pulled down immediately after the IMU data sampling compensation is completed. At that time, the data frame will be sent from the serial port, and the DRDY pin will be pulled high again in the next cycle.

Fig. 9 Serial Output Frequency Less Than IMU Internal Sampling Frequency

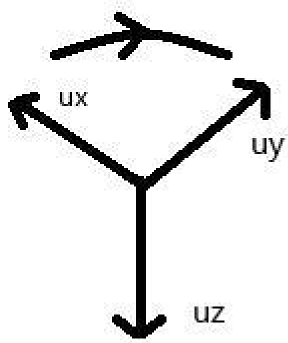


When the serial output frequency is less than the IMU internal sampling frequency, the fractional frequency value (maximum ODR/current ODR) will determine whether the DRDY pin will be pulled down immediately after the IMU data sampling compensation is completed. After DRDY pin is pulled down, the data frame will be sent from the serial port, and the DRDY pin will be pulled up again in the next cycle.

7.1.9 Coordinate System Setup

Set the firmware coordinate system and display the corresponding coordinate system in the PC software.

Fig. 10 Original Firmware Coordinate System



According to the rules in the above figure, the z axis is also determined after the x and y axes are determined. The Z-axis is perpendicular to XY-plane.

In total, there are twenty-four orientations for the X/Y/Z axes, as shown in the table below:

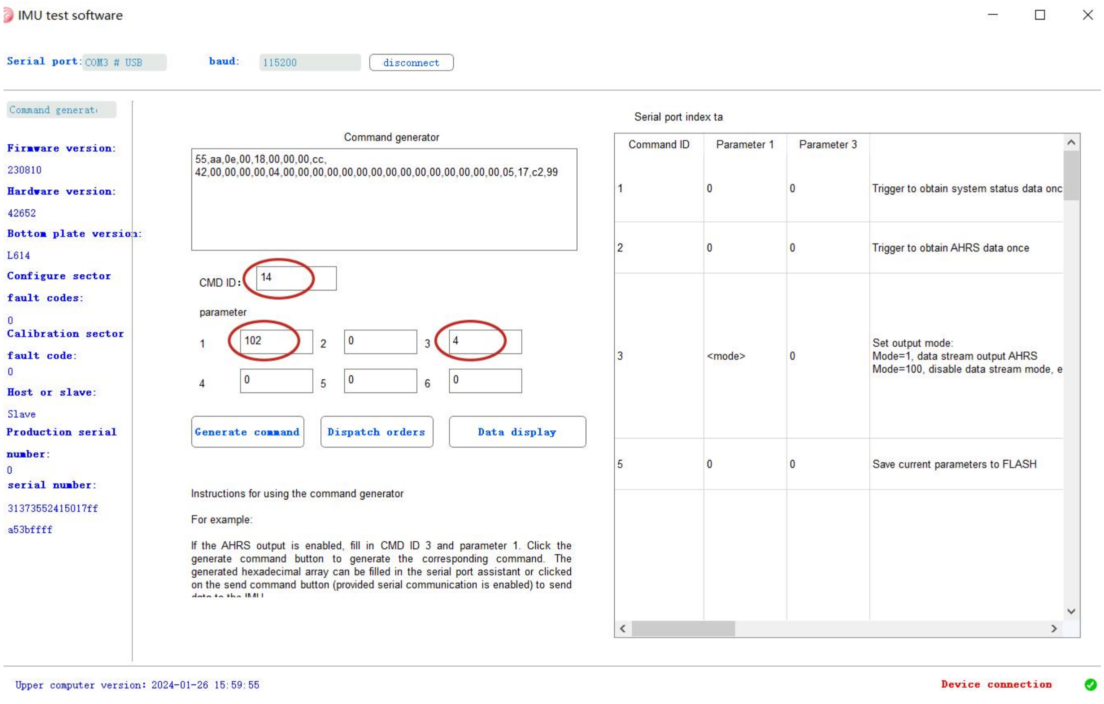
Table 24 Coordinate System Orientation Correspondence

Orientation (value)	XAxis	YAXis	ZAxis	Description
101	+Ux	+Uy	+Uz	Default
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:

CMD ID is filled with 14, parameter 1 is filled with 102, and parameter 3 is filled with 4. The generated hexadecimal array can be added to the serial assistant or program array which will be sent to IMU.

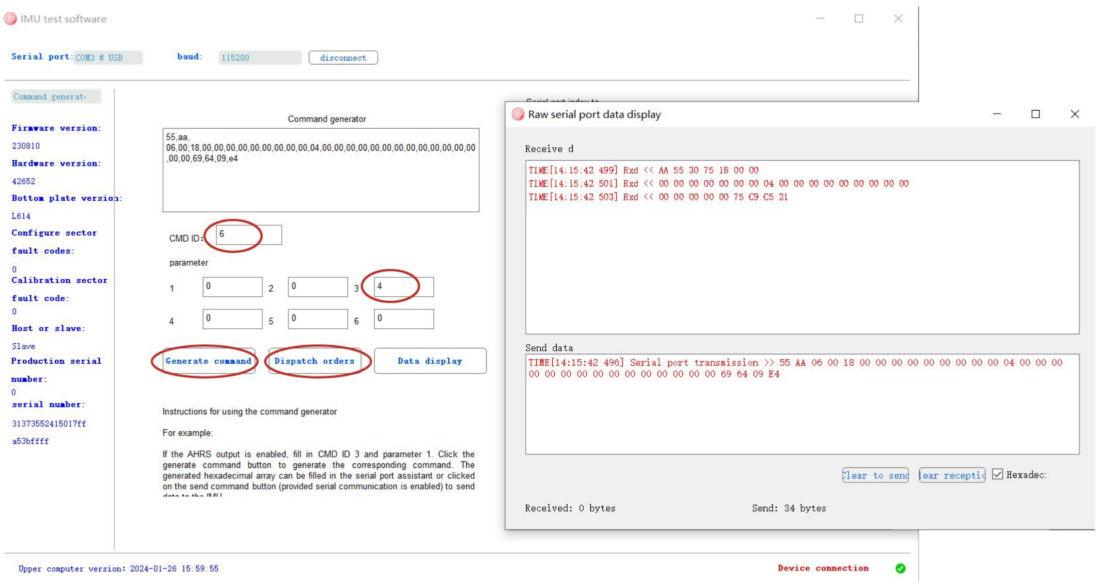
Fig. 11 Changing the coordinate system to 102 orientation



How to read the coordinate system orientation:

CMD ID is filled with 06, parameter 3 is filled with 4, and the generated hexadecimal array can be added to the serial assistant or program array which will be sent to IMU.

Fig. 12 Reading coordinate system orientation



Example: Setting the coordinate system to 115 orientation.

Input Data: 55,aa,0e,00,18,00,00,00,e6,42,00,00,00,00,04,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,46,6a,4e,86

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

Refer to table 20 and get the parameter index 04, then successfully set.

Read the coordinate system:

Input Data: 55 AA 06 00 18 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 69 64 09 E4

Input Data: AA 55 30 75 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 B2 2F 2D 4E

According to Table 14 and Table 15, parameter 1 is 115 (float) and parameter 3 is 04, which means the coordinate system is 115 orientation.

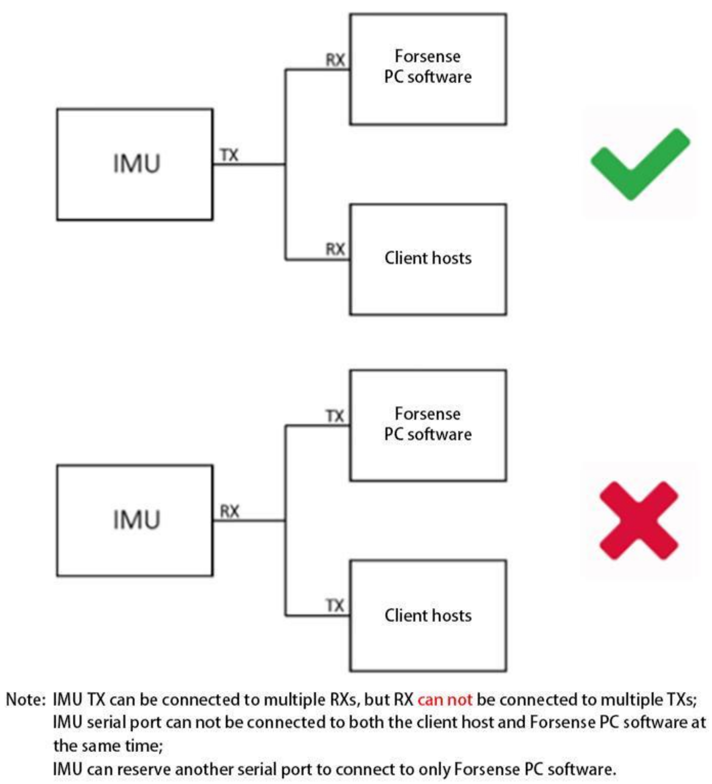
7.1.10 Serial Connection FAQs

1) IMU receiver (RX) can not be connected to 2 host transmitters (TX)

The RX of the serial port can not be connected to the TX of two hosts at the same time. If you need to connect to the Forsense PC software, you shall disconnect its serial communication with the user host, otherwise the PC software can only receive the data and cannot send commands to the IMU.

As shown in the figure below:

Fig. 13 Diagram of Serial Connection Methods



2) Unable to get the version number

Check whether the data is lost, and it is recommended to use the FT232 chip serial cable. CH340 and PL2303 data cables at high baud rate (>115200bps) will lead to data loss.

The serial cable should be connected directly rather than in series. For example, when RS422 interface is connected to the computer, it is recommended to directly use the RS422 to USB converter instead of using the RS422 to RS232 and the RS232Z to USB converters in series.

3) The PC software curve display is stuck

If using FT232 data line, open the PC software by selecting "Run as administrator" and configure the serial delay automatically.

Manually configure the serial delay in the device manager.

7.2 I2C Communication Protocols

Examples of how a STM32-based I2C host reads driver:

http://www.forsense.cn/download/

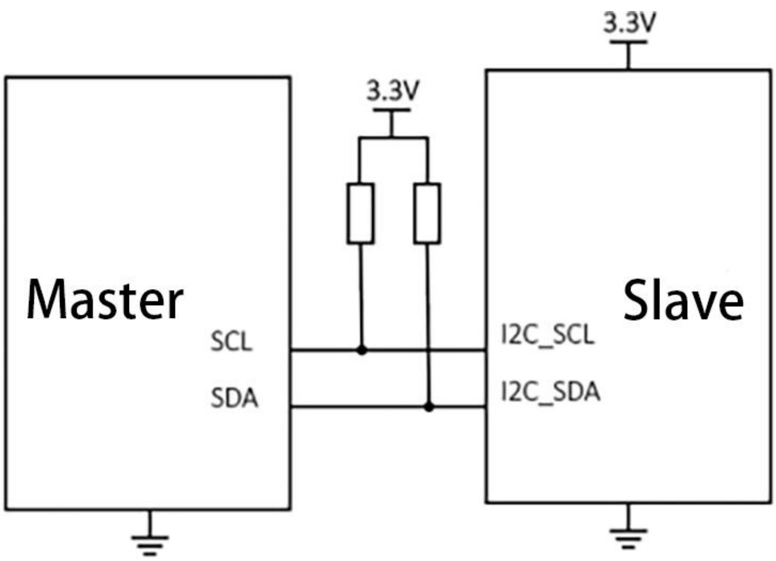
7.2.1 I2C Interface Parameters

Table 25 I2C Interface Parameters

I2C Rate	400KHz
I2C Slave address (7 bits)	0x18

7.2.2 I2C Connection Methods

Fig. 14 I2C Connection Methods



Note: The pull-up resistor value is 4.7KΩ

7.2.3 I2C Register

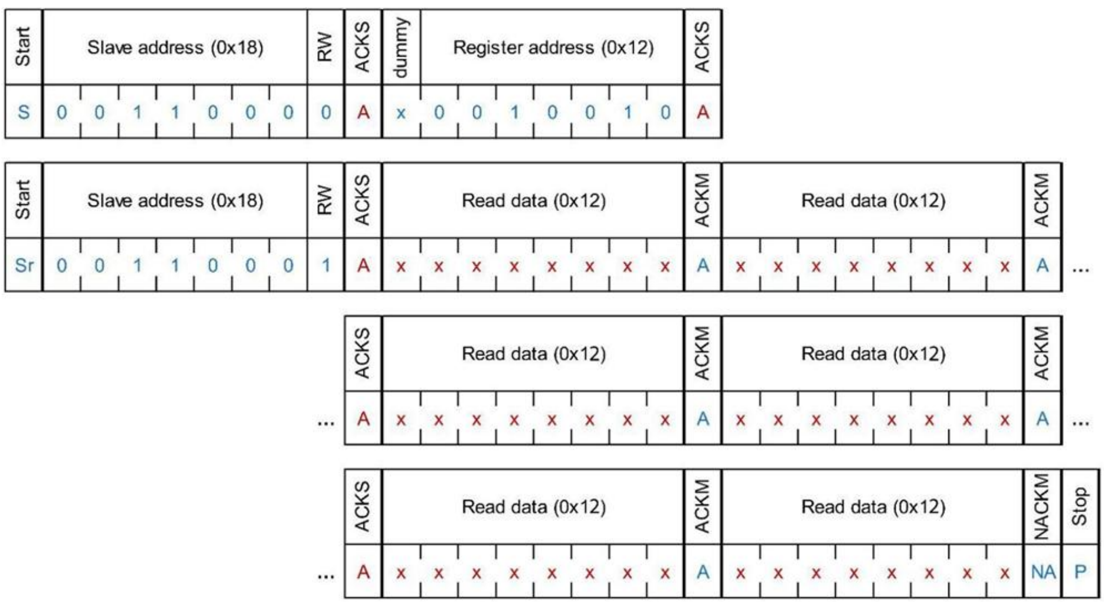
Table 26 I2C Register List

Name	Address	Read/Write	Default Value	Description
BURST	0x12	R		Reading registers continuously
FILTER_CTRL	0x06	RW	0xBB	Filter selection
PROD_ID	0x6A	R		Product name

7.2.3.1 I2C BURST Register

This I2C protocol supports continuous reading of register address 0x12, and the slave automatically accumulates the address and outputs 32 bytes continuously in 8bit mode. The read process is as follows:

Fig. 15 I2C Continuous Reading Mode



The frame definition is as follows:

Table 27 I2C Continuous Read Data Format

Transmit sequence	1	2	3
Data format	uint32_t	float	float
Transmit content	TIME	ACCL_X	ACCL_Y
Transmit sequence	4	5	6
Data format	float	float	float
Transmit content	ACCL_Z	GYRO_X	GYRO_Y
Transmit sequence	7	8	9
Data format	float	float	uint32
Transmit content	GYRO_Z	TEMP	CRC32

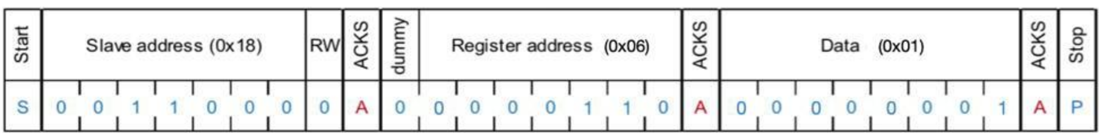
Note 1: The unit of TEMP is °C, the unit of gyroscope output is °/s, the unit of accelerometer output is g, and the unit of attitude output is °.

Note 2: The initial value of crc32 is 1 and the CRC calculation does not include all the data of the frame itself. Please refer to CRC Look-up Table Calculations at the end of the document.

7.2.3.2 I2C FILTER_CTRL Register

FILTER_CTRL register address is 0x06, and the comparison table of filter configuration is the same as that of SPI accelerometer and gyroscope filter configuration. The register read process has the same read method as the I2C BURST, and the register write process is shown in the following figure.

Fig. 16 I2C FILTER_CTRL Register Write Method



7.2.3.3 I2C ID Register

The ID register address is 0x6A and the data content is the character "IMU61B" in ASCII encoded form, and the read process is the same as I2C BURST, as shown in the following table.

Table 27 I2C ID Register Read Mode

Transmit sequence	1	2	3	4
Transmit content	0x00	0x00	0x49	0x4D
Transmit sequence	5	6	7	8
Transmit content	0x55	0x36	0x31	0x*

Note 1: All data are in 8-bit width.

Note 2: 0x* is the product ID, 0x32 is the IMU612, 0x34 is the IMU614, 0x38 is the IMU618, 0x41 is the IMU6132A, and 0x42 is the IMU6132B.

7.3 SPI Communication Protocols

Examples of how a STM32-based SPI host reads driver:

http://www.forsense.cn/download/

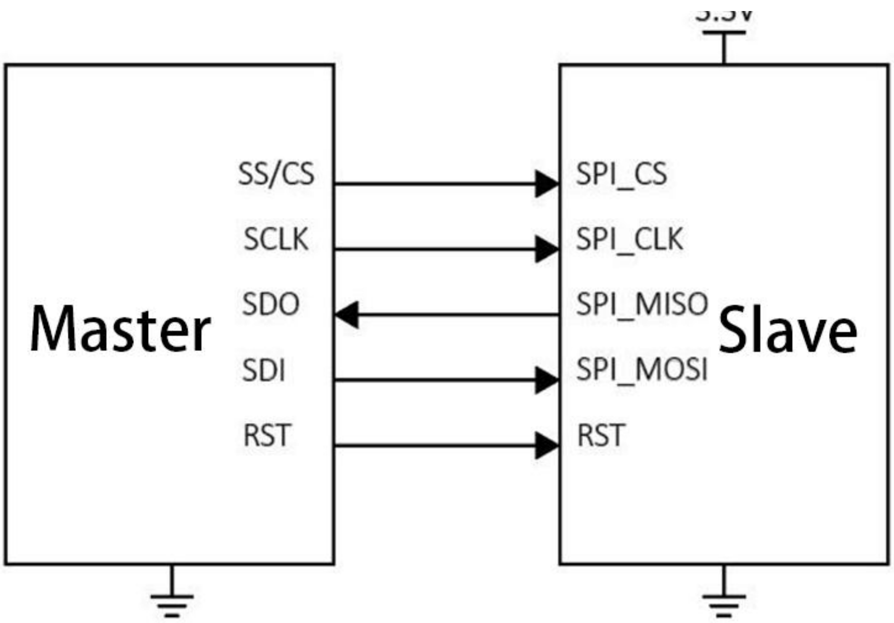
7.3.1 SPI Interface Parameters

Table 28 SPI Interface Parameters

SPI host	This product acts as a slave
SPI rate	0.2~2MHz
SPI word length	16bit
Phase	Rising edge trigger (mode 3, CPHA=1)
Polarity	Idle high state (mode 3, CPOL=1)
Bit sequence	MSB-First

7.3.2 SPI Connection Diagram

Fig. 17 SPI Connection Diagram



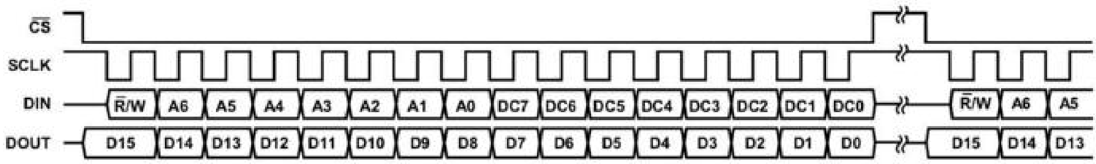
Note 1: Before the host initialization and data reading, reset the IMU and wait for 3s to make it enter normal operating mode.

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

7.3.3 SPI Communication Bit Sequence

The SPI interface supports full-duplex serial communication (simultaneous transmitting and receiving) using the bit sequence shown below.

Fig. 18 SPI Communication Bit Sequence Diagram



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

When /W =1, the DOUT data of this SPI cycle is meaningless.

When /W =0, the DOUT data of this SPI cycle indicates the register output data of the last two cycles, seeing the BURST reading example for details.

7.3.4 SPI Register

Table 29 SPI Register List

Name	Address	Read/	Default	Wind	Description
BURST	0x00	RW		0	Continuous reading
FILTER_CTRL	0x07,0x06	RW	0x00BB	1	Filter selection
PROD_ID1	0x6C	R	0x494d	1	ID No. 1
PROD_ID2	0x6E	R	0x5536	1	ID No. 2
PROD_ID3	0x70	R	0x3132	1	ID No. 3 (IMU612)
			0x3134	1	ID No. 3 (IMU614)
			0x3138	1	ID No. 3 (IMU618)
			0x3141	1	ID No. 3 (IMU6132A)
			0x3142	1	ID No. 3 (IMU6132B)
WIN_CTRL	0x7F,0x7E	RW	0x0000	0, 1	Window ID selection
TEMP_HIGH	0x0E	R	\	0	Temperature high byte

TEMP_LOW	0x10	R	\	0	Temperature low byte
XGYRO_HIGH	0x12	R	\	0	Gyro X-axis high byte
XGYRO_LOW	0x14	R	\	0	Gyro X-axis low byte
YGYRO_HIGH	0x16	R	\	0	Gyro Y-axis high byte
YGYRO_LOW	0x18	R	\	0	Gyro Y-axis low byte
ZGYRO_HIGH	0x1A	R	\	0	Gyro Z-axis high byte
ZGYRO_LOW	0x1C	R	\	0	Gyro Z-axis low byte
XACCEL_HIGH	0x1E	R	\	0	Accel X-axis high byte
XACCEL_LOW	0x20	R	\	0	Accel X-axis low byte
YACCEL_HIGH	0x22	R	\	0	Accel Y-axis high byte
YACCEL_LOW	0x24	R	\	0	Accel Y-axis low byte
ZACCEL_HIGH	0x26	R	\	0	Accel Z-axis high byte
ZACCEL_LOW	0x28	R	\	0	Accel Z-axis low byte

7.3.4.1 SPI BURST Register

BURST is a sequential read register that reads all data in a single stream with no stopping between each 16-bit segment.

Table 30 SPI BURST Register Format

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 BURST read method is as follows: send 0x8000 to set BURST and start reading, then send 0x0000 all the time to receive the data. The output register content is offset by 2 SPI cycles from the reading instructions sent, and the chip select stays low all the time during the reading period.

Fig. 19 SPI BURST Continuous Reading Diagram

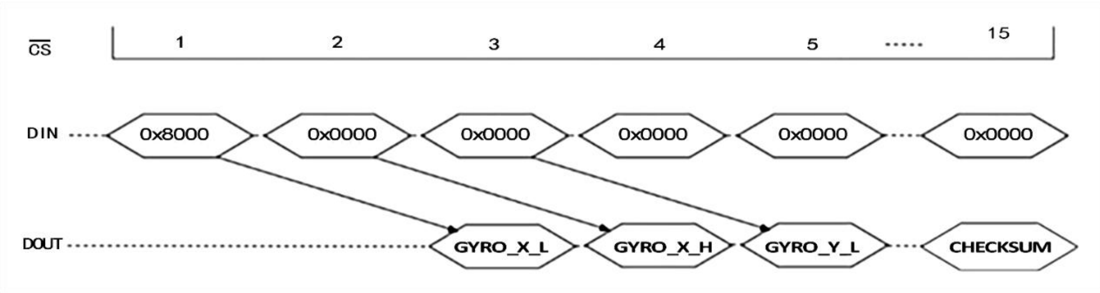


Table 31 SPI BURST Sequential Read Basic Format

Transmit sequence	1	2	3	4	5	6
Transmit content	GYRO_X_L	GYRO_X_H	GYRO_Y_L	GYRO_Y_H	GYRO_Z_L	GYRO_Z_H
Transmit sequence	7	8	9	10	11	12
Transmit content	ACCL_X_L	ACCL_X_H	ACCL_Y_L	ACCL_Y_H	ACCL_Z_L	ACCL_Z_H
Transmit sequence	13					
Transmit content	CHKSM					

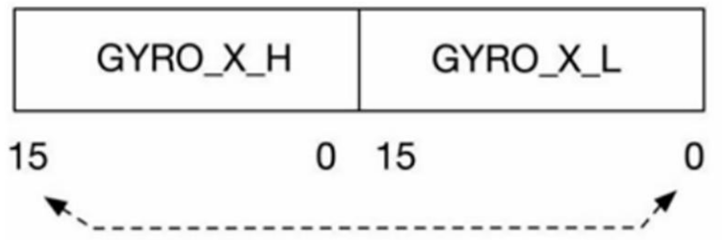
Note 1: All data are in 16-bit width.

Note 2: Gyroscope and accelerometer data are spliced together and represented in the int32 format.

Note 3: CHKSM is CHECKSUM, which is used to confirm data integrity. The calculation method is to sum up all the data before CHECKSUM.

In the BURST continuous reading process, the 32-bit complete data is split into high 16-bit and low 16-bit output respectively, and the output adopts the small end mode, that is, the low byte is output first. Users need to splice these two parts of 16-bit data to restore the complete 32-bit data.

Fig. 20 SPI 32-bit Data Restoration Diagram



32-bit Gyroscope Data Format

After getting the complete 32-bit data, the standard frame user can acquire the information of angular velocity, acceleration, temperature and attitude angle according to the following formulas.

Table 32 Standard Frame SPI 32-bit Data Conversion Formulas

Name	Unit	Formulas	Conditions/Remarks
Angular velocity	°/s	G=SF/65536*GYRO	GYRO is the GYRO data for the X, Y, and Z axes in the table above • Gyro scale factor SF= 0.016
Acceleration	mg	A=SF/65536*ACCL	ACCL is the ACCL data for the X, Y, and Z axes in the table above. • Burst mode, SF = 0.2 • Single register mode, = 0.2/1000
Temperature	℃	T=SF/65536*(TEMP-172621824)+25	TEMP is the TEMP data in the table above. • Temperature scale factor SF=-1/263.4
Attitude angle	°	D=SF/65536*ATT	ATT is the ATT data in the table above • Attitude scale factor SF = 0.00699411

7.3.4.2 SPI FILTER_CTRL Register

The FILTER_CTRL register provides users with the control of digital low-pass filters. This register is readable/writable. The write command is to send 0x86XX and the current SPI cycle setup is valid; the read command is to send 0x0600 and the output register content is offset by 2 SPI cycles from the read command sent.

Table 33 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				Gyroscope filter configuration				RW

Table 34 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 you configure the gyro and accelerometer filters to be 10Hz, write the value 0x8644.

7.3.4.3 SPI ID Register

ID register is a read-only register, the data content is the character "IMU" encoded in ASCII, and the read method is similar to BURST data reading: send 0x6A00~0x7000, and receive data. The output register content is offset by 2 cycles from the read command sent.

Splicing 4 16-bit ID data into ASICII code to obtain the complete ID of the product. The splicing method is the same as that of BURST continuous read data, with PROD_ID1 in the high bit and PROD_ID4 in the low bit.

Table 35 SPI ID Register Format

Address	bit15 ~ bit0	Encoding	Read/Write
0x6C	PROD_ID1	0x494D	R
0X6E	PROD_ID2	0x5536	R
0x70	PROD_ID3 The code content represents the product ID.	0x3132(IMU612)	R
		0x3134(IMU614)	R
		0x3138(IMU618)	R
		0x3141(IMU6132A)	R
		0x3142(IMU6132B)	R

7.3.4.4 SPI WIN_CTRL Register

This register is used to control and switch window ID and it is readable and writable. The window defaults to 0. Writing 0xFE01 toggles it to 1.

Table 36 SPI WIN_CTRL Register Format

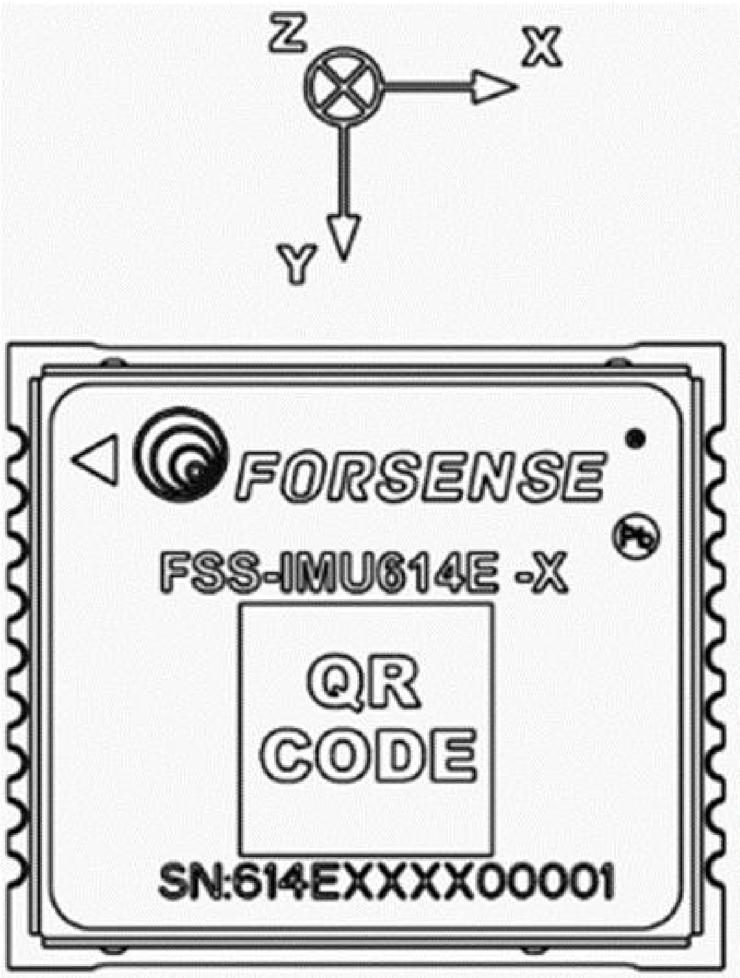
Address	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8	Read/Write
0x7F									RW
Address	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	Read/Write
0x7E	WINDOW_ID								RW

Table 37 SPI Register WIN_CTRL.WINDOW_ID Code

Name	Encoding	Description
WINDOW_ID	0x00	Window0, start reading data
	0x01	Window1, enter

8. Definition of Coordinate System

Fig. 21 Definition of Coordinate System



This product is equipped with the Front-Right-Down (FRD) coordinate system, and the range of Euler angles is as follows:

Rotate around Z-axis: Yaw angle range (0° ~ 360°)

Rotate around X-axis: Roll angle range (-180° ~180°)

Rotate around Y-axis: Pitch angle range (-90°~90°)

9. CRC Look-up Table Calculations

```
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;
}
```

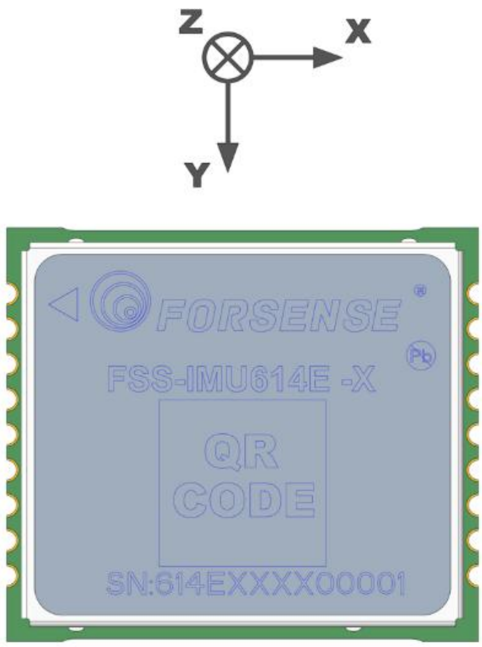
10. Examples of Use

Device Installation

1. The module should be firmly fixed on a rigid plane rather than in a position of high vibration;

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

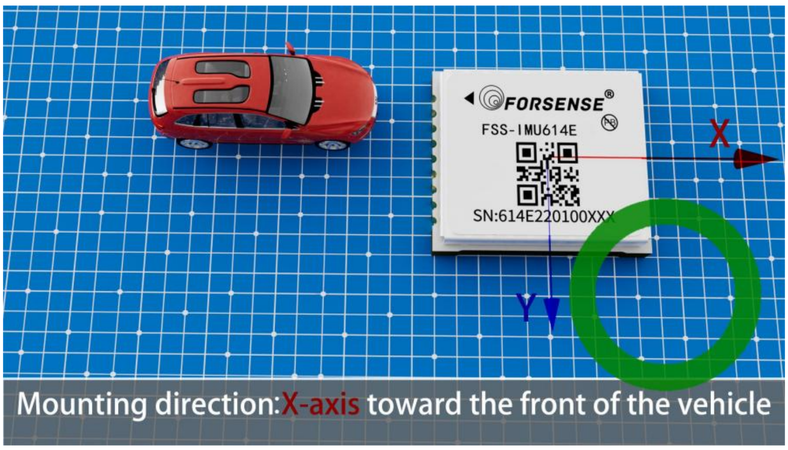
Fig. 22 Module Installation Diagram



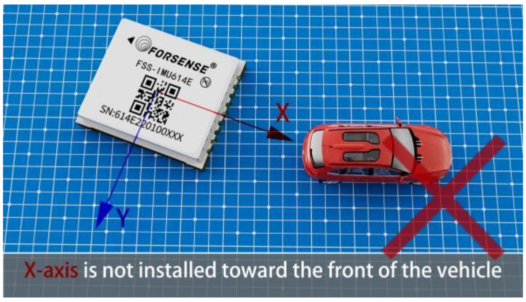
The correct installation method is as follows

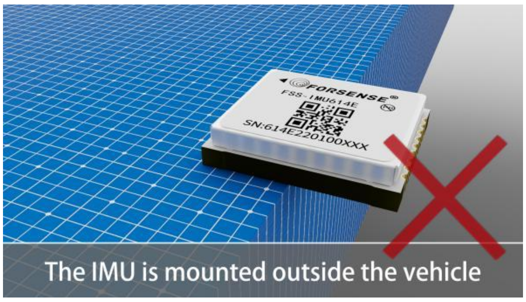
X-axis toward the front of the vehicle

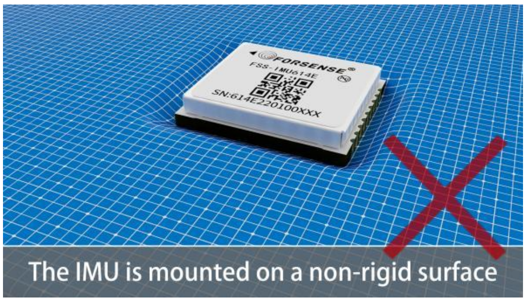
Fig. 23 Correct Installation Method

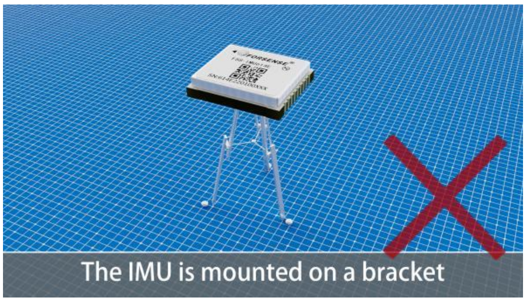


The following mounting methods are incorrect:





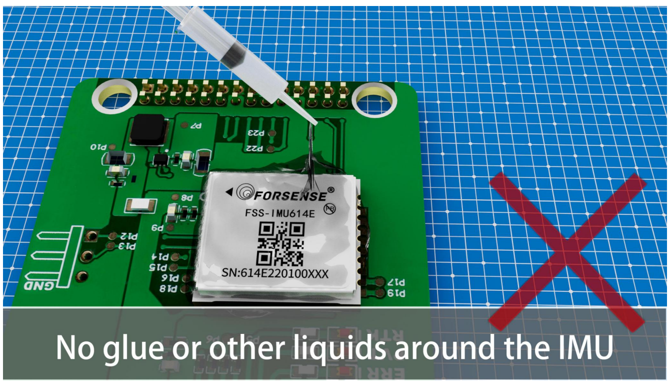




3.IMU Installation Precautions

No glue or other liquids around the IMU to prevent them from flowing into the interior of the IMU through gaps, thus impairing performance of the IMU.

Fig. 24 Wrong Installation Diagram

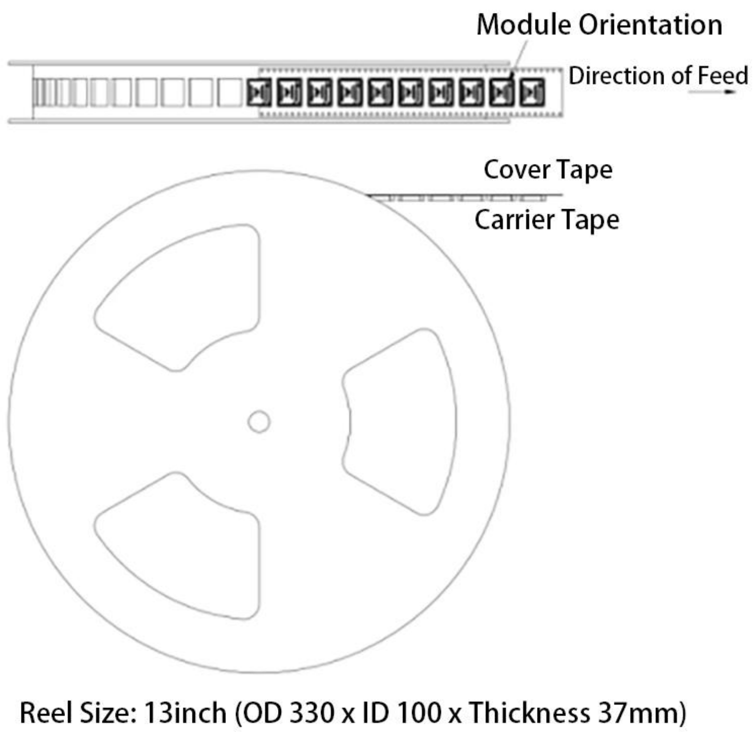


11. Packaging

The IMU614E-C module is packaged in sealed tape and reel, which contributes to efficient production.

11.1 Tape and Reel Packaging

Fig. 25 Tape and Reel Packaging Diagram



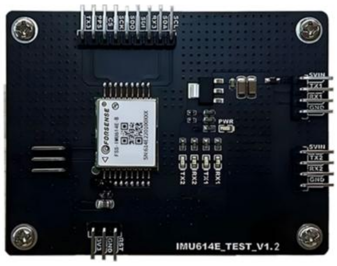
11.2 Carrier Tape

The IMU614E-C module is placed on the carrier tape in the position and orientation shown below before leaving the factory:

Fig. 26 Module Position and Orientation on Carrier Tape

12. Accessories

IMU614E-X Test Base Plate (Old Base Plate)



IMU614E-X Test Base Plate (New Base Plate)

SMD CAN Version IMU614E Series

SMD 485 Version IMU614E Series

SMD TTL Version IMU614E Series

TTL Serial Cable

USB to CAN Module

Type-C Cable

13. Revision History

Version	Date	Status/Notes
Version 1.0	2024.01.03	First release
Version 1.1	2024.02.04	Updated electrical characteristics
Version 1.2	2024.02.27	Updated reflow welding curves and ESD protection issues
Version 1.3	2024.03.26	Updated pin definitions