FORSENSE
原极科技

Tactical Grade MEMS 6-DOF Inertial Sensors

FSS-IMU614E-B Product Sheet

Features

Tactical Grade MEMS Gyroscope

- Bias Instability: 2.5°/hr
- Angle Random Walk: 0.3°/ √hr
- Temperature Drift: 0.03/s (-40°C ~ 85°C, ≤1°C/min @1σ)

Tactical Grade MEMS Accelerometer

- Bias Instability: 25μg
- Velocity Random Walk: 0.05m/s /√hr
- Temperature Drift: 0.5mg (-40°C ~ 85°C, ≤1°C/min @1σ)

Wide and refined temperature compensation

- Temperature Range: -40°C to 85°C
- Precise Temperature Calibration

Independent Rotary table calibration

- Independent Calibration for every module includes: Sensitivity, bias instability, and misalignment

High-intensity Tolerance

- Ultra Shock Resistance: 2000g（0.5ms, Half-sine shock pulse, 3 axis）
- Superb Vibration Resistance: 10g（10~2KHz, 3-axis）
- Full-temperature operating Range: -40°C to 85°C
- 100% Magnetic Shielding

The product provides real-time and flexible digital interface while maintain a small size

- Configurable output sampling rate up to 1KHz
- Supports serial, I^2C, SPI, CAN interfaces.
- 14.7*17*3.2mm, about 2g

Description

FSS-IMU614E-B is a MEMS inertial measurement unit (IMU) module with 6 degrees of freedom (DOF) developed by Forsense (Shanghai) Technology Co., Ltd. It features informations of three-axis gyroscopes and three-axis accelerometers.

High precision and high resolution combine to help capture subtle vibration and tilt. A large number of output parameters enable the perception of motion despite intense shaking. All IMU modules are calibrated independently on a rotary table and adjusted precisely over an ultra-wide temperature range in a temperature chamber before leaving the factory, so that they can deliver stable and consistent performance in most extreme conditions.

Applications

- Autonomous Driving: Passenger vehicles, inspection vehicles, engineering vehicles, and underwater vehicles
- Precision Measurement: Underground environments, tunnels, vibration scenarios, and inclined surfaces
- Stabilized Platforms: Gimbal, satellite communication on the move, and drone
- Automatic Control: large-scale industrial equipment, and automatic control system.

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

Contents

1. Performance Parameters

1.1 Gyroscope Key Metrics

Table 1 Gyroscope Key Metrics

Parameters	Test Conditions/Remarks	Min.	Typ.	Max.	Unit
Measurement Range			±500	±2000[2]	°/s
Bias Instability[1]	@25,ALLAN Variance, 1σ		2.5		°/hr
Bias Stability	GJB: 10s smoothing		5.5		°/hr
Bias Repeatability	GJB		16		°/hr
Resolution			0.0076		°/s
Non-orthogonal between axes			0.02		°
Internal Low-pass Cutoff Frequency	Adjustable Software		116		Hz
ODR			1000		Hz
Measure Delay			7		ms
Offset Error over Temperature[3]	-40 ~ 85°C, ≤1°C/min @1σ		0.03		°/s
Random Walk X-axis[1]	@25, ALLAN Variance, 1σ		0.4		°/√hr
Random Walk Y-axis			0.4		°/√hr
Random Walk Z-axis			0.3		°/√hr
Scale Coefficient Error			2.5		‰
Scale Factor Nonlinear			100		ppm

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

Note 2: Maximum range requires special firmware support.

Note 3: 1σ variation of full-temperature bias at a heating rate of 1°C/min.

1.2 Accelerometer Key Metrics

Table 2 Accelerometer Key Metrics

Parameters	Test Conditions/Remarks	Min.	Typ.	Max.	Unit
Measurement Range			±6	±24 [2]	g
Bias Instability [1]	@25, ALLAN Variance, 1σ		25		μg
Bias Stability	GJB: 10s smoothing		45		μg
Bias Repeatability	GJB		0.6		mg
Resolution			0.0916		mg
Non-orthogonal between axes			0.02		°
Internal Low-pass Cutoff Frequency	Adjustable Software		116		Hz
ODR			1000		Hz
Measure Delay			7		ms
Offset Error over Temperature [3]	-40 ~ 85°C, ≤1°C/min @1σ		XY:0.5 Z:2		mg
Random Walk [1]	@25, ALLAN Variance, 1σ		0.05		m/s/√hr
Scale Coefficient Error			0.5		‰
Scale Factor Nonlinear			200		ppm

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

Note 2: Maximum range requires special firmware support.

Note 3: 1σ variation of full-temperature bias at a heating rate of 1°C/min.

Fig. 1 Gyroscope - Typical Allan Variance Curve

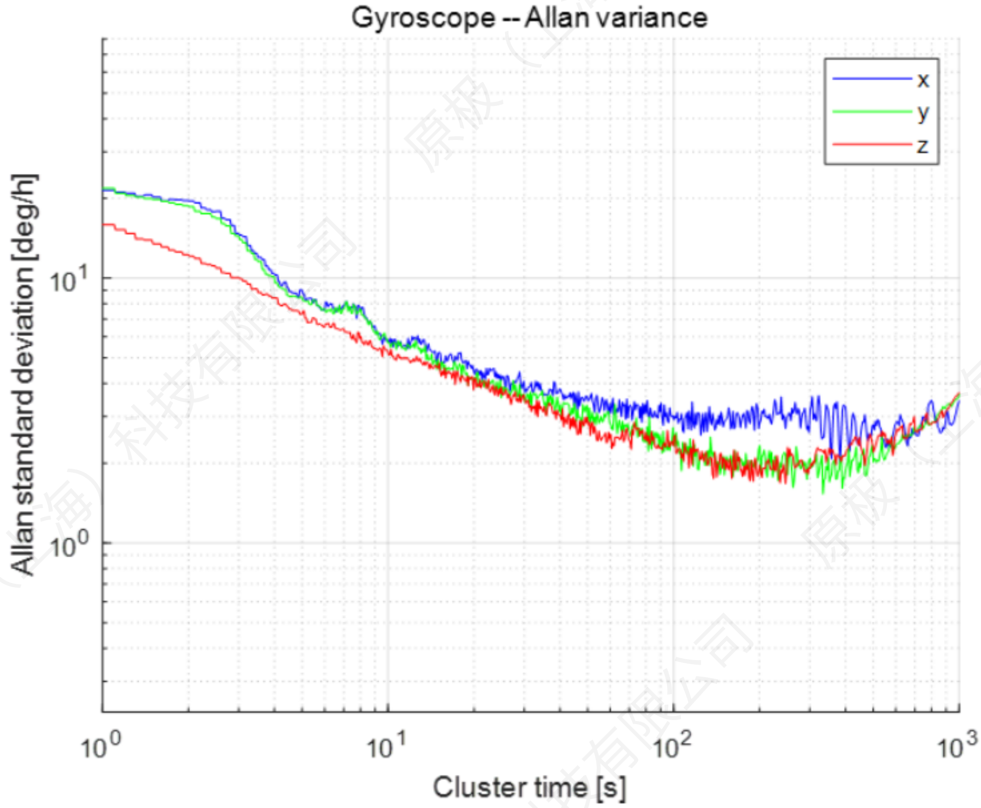
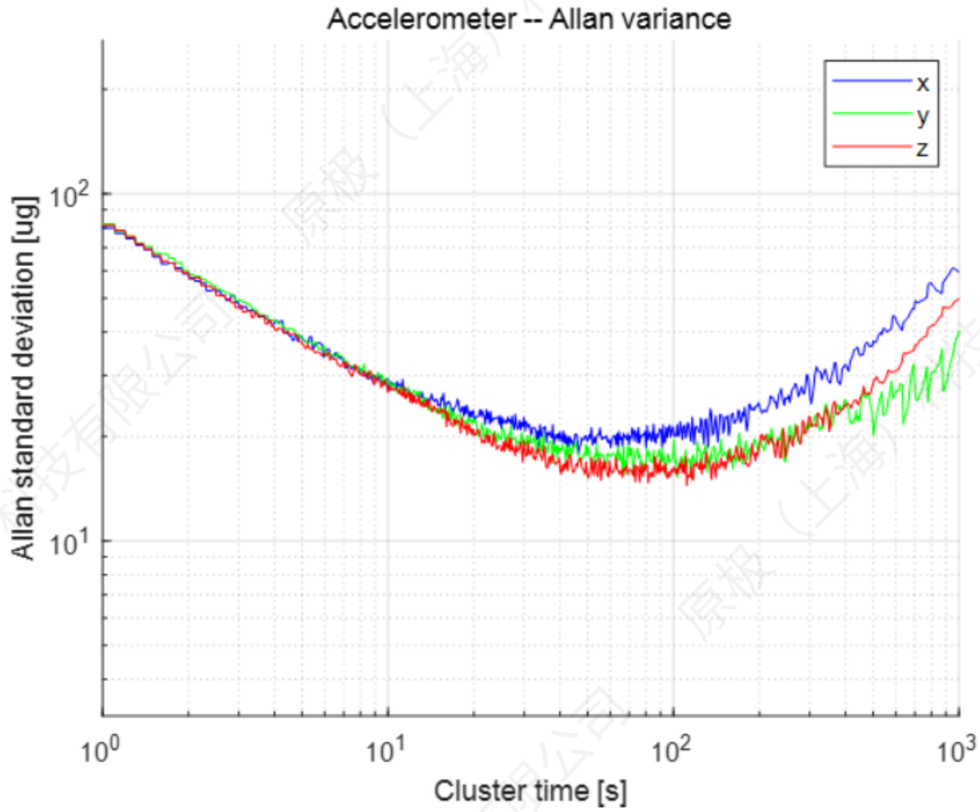
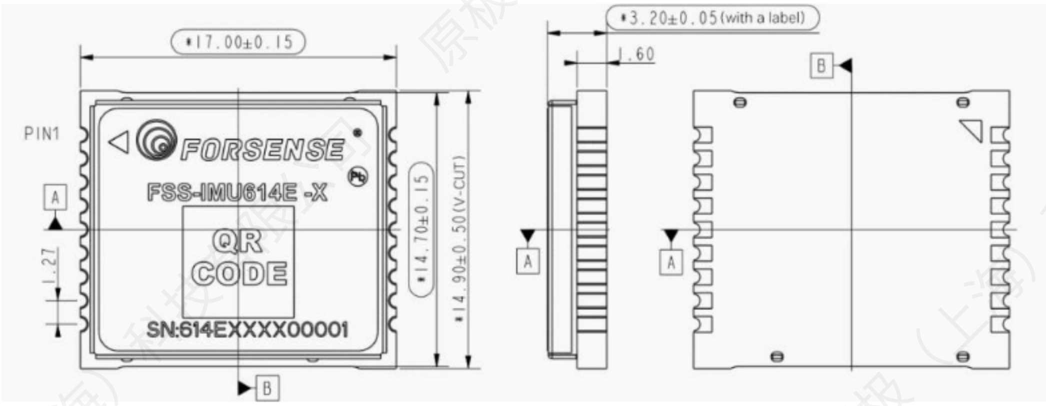


Fig. 2 Accelerometer - Typical Allan Variance Curve

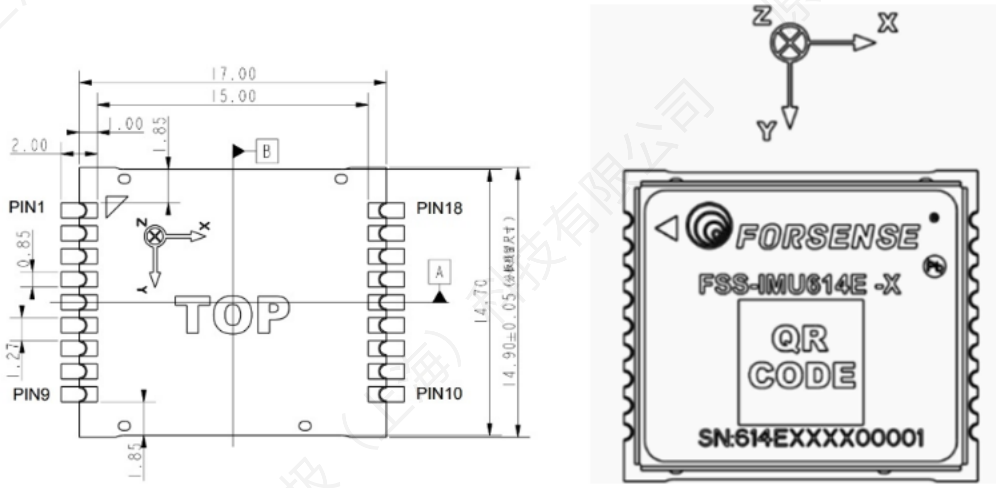


2. External Structure

Fig. 3 Outline Structure and Recommended Pad Size (unit: mm)



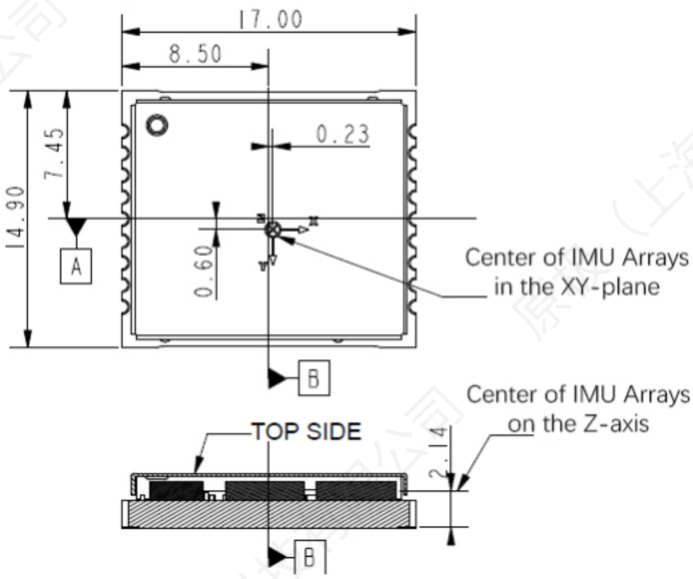
External Size



Recommended Pad Size

Fig. 4 IMU Array Center (unit: mm)

TOP SIDE



IMU Array Center

3. Electrical Properties

3.1 Absolute Maximum Ratings

Table 3 Absolute Maximum Ratings

Parameters	Symbol	Rating	Unit
Voltage for Circuit to Circuit	VCC	-0.3 to 4.0	V
Ground	GND	-	-
Input Pin 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	Symbol	Min.	Typ.	Max.	Unit
Voltage for Circuit to Circuit	VCC	3.2	3.3	3.4	V
VCC Maximum Ripple	Vrpp		±40		mV
Power Consumption	P		0.13		W
Operating Temperature	Tot	-40		85	℃
Storage Temperature	Tstg	-40		85	℃

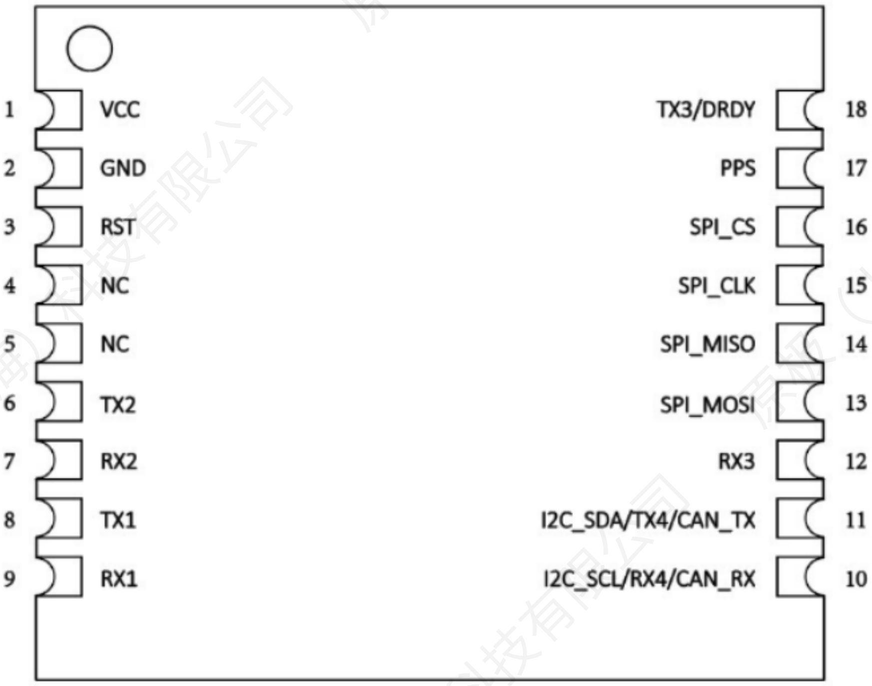
3.3 IO Threshold Characteristics

Table 5 IO Threshold Characteristics

Parameters	Symbol	Min.	Typ.	Max.	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><td>Pin No.</td><td>Pin Name</td><td colspan="3">Description</td></tr>
<tr><td>1</td><td>VCC</td><td colspan="3">Power input, +3.3V input, 40mA, and ripple no more than ±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="2">10</td><td rowspan="2">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>
</table>

		2	RX4	Receive asynchronous data input
		3	I2C_SCL	I2C Serial Clock
11	CAN TX / TX4 / I2C_SDA	Mode	Function	Description
		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 the pulse per second pin of RTK)		
18	TX3/DRDY	Receive asynchronous data output/ available for Data Ready		

Note 1: IMU hardware needs to be reset once by triggering /RST during the host initialization.

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

5. Recommended Welding Furnace Temperature Profile

Fig. 6 Welding Furnace Temperature Profile

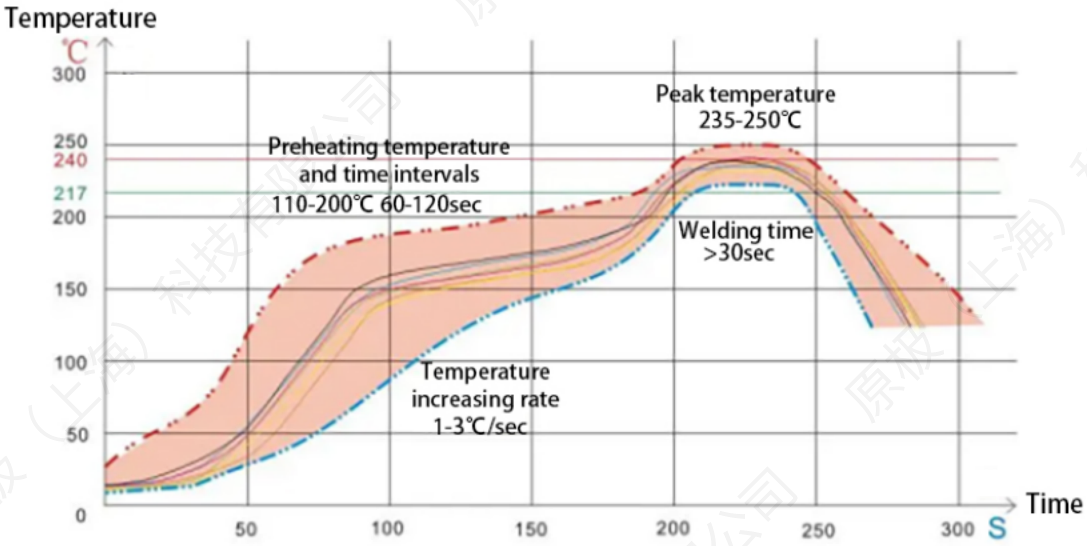


Table 7 Temperature Setting Modes

Parameter	Min.	Max.	Unit
Maximum ramp-up rate (target = 0.8) (calculated every 60 seconds)	1	3	°/s
Maximum ramp-down rate (calculated every 60 seconds)	-3	-1	°/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 reflux 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 reflux 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 the recommended product 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 patch 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);
- Packaging and PCBs must be made of qualified anti-static materials.

7. Communication Protocols

7.1 Serial Communication Protocols

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

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

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, which can be used to obtain sensor data, status, parameters and other information via the GET command 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 bytes)	
8+n		CRC_CEHCK (32-bit data high middle bytes)	
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 Frame - AHRS Data

Table 10 Serial AHRS Data Format

	Frame header	Frame header	ID	length	payload	Frame trailer
Data type	uint8	uint8	uint16	uint16	A1	4'b 1010
Encoding	0xAA	R	0x0002	0x002C		Example:

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	4'b 1010	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	°C	IMU Chip Temperature

Example of AHRS data stream acquired:

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

The analysis is as follows:

Table 12 AHRS data stream acquired by Serial A1

Description	Raw value	Parsed value	Description	Raw value	Parsed value
ID	0200	02	Y-axis acceleration	BC74133C	0.009g
Length	2C00	44	Z-axis acceleration	60E580BF	-1.007g
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
Yaw angle	5C0FB243	356.12°	IMU Chip Temperature	D7A3EE41	29.83°C
X-axis acceleration	2506813D	0.063g	CRC32 verification	0CBF8480	2156183308

7.1.4 Command Mode GET Output - System Status

Table 13 Serial System Status Data Format

	Frame header	Frame header	ID	length	payload	Frame trailer
Data type	uint8	uint8	uint16	uint16	S1	unit32
Encoding	0xAA	0x55	0x00FF	N		crc32

Note 1: The frame length may vary across different IMU models, all representing the length of S1, which required confirmation based on the specific IMU model.

Table 14 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[16]	Uint8	All subsequent bytes are reserved

Note 1: IMU models have different subsequent reserved bytes which need to be further confirmed. IMU614E has 16 bytes.

Example: Acquiring system status

Input 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 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

The response data are analyzed to get the software version number 211231(1F 39 03 00) and hardware version number 94053(65 6F 01 00).

7.1.5 Command Mode GET Output - Reading Parameters

Table 15 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 16 Serial Port Parameter Output Data Format

	Frame header	Frame header	ID	length	payload	Frame trailer
Data type	uint8	uint8	uint16	uint16	P1	uint32
Encoding	0xAA	0x55	0x7530	0x0018		crc32

Note 1: The IMU will turn the data stream off when reading the parameters, and you need to turn the data stream back on after the setup is completed.

Table 17 Serial P1 Load Data Format

offset	Name	Data type	Description
0	Param1	float	Parameters acquired (input data can be ignored)
4	Param2	float	Reserved, 0 (Default)
8	Param3	uint32	Parameter index of setting
12	Param4	uint32	Reserved, 0 (Default)
16	Param5	Int32	Reserved, 0 (Default)
20	Param6	Int32	Reserved, 0 (Default)

Table 18 Serial P1 Load Parameter Index

Param3	Param1	Unit
3	Serial output baud rates, including 115200、230400、460800、921600、1500000	bps
4	Coordinate system orientation (see table 24 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 data rate, 100Hz (Default)	Hz
31	Internal filter configuration as defined in SPI's FILTER_CTRL comparison chart	

Example: Acquiring AHRS output data rate

Input data: 55 AA 06 00 18 00 00 00 00 00 00 00 00 15 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 48 42 00 00 00 00 15 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 31 2F A2 0A

The response data are analyzed to get the output data rate 50hz (00 00 48 42).

7.1.6 Command Mode SET Instructions

Table 19 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 20 Serial R1 Load Data Format

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

Table 21 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	Set the output mode: Mode=1, outputting AHRS data in a streaming format. Mode=100, disabling data streaming and initiating 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. P1.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 port 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 software.
14	<value>	21	Set the AHRS output data rate (unit: Hz), and the commonly used values are 1, 10, 50, 100, 200, 500, 1000. Recommended correlation between output data rate and serial port 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 range of <value> is 101 to 124, and see table 24 for the specific coordinate system orientation correspondence.

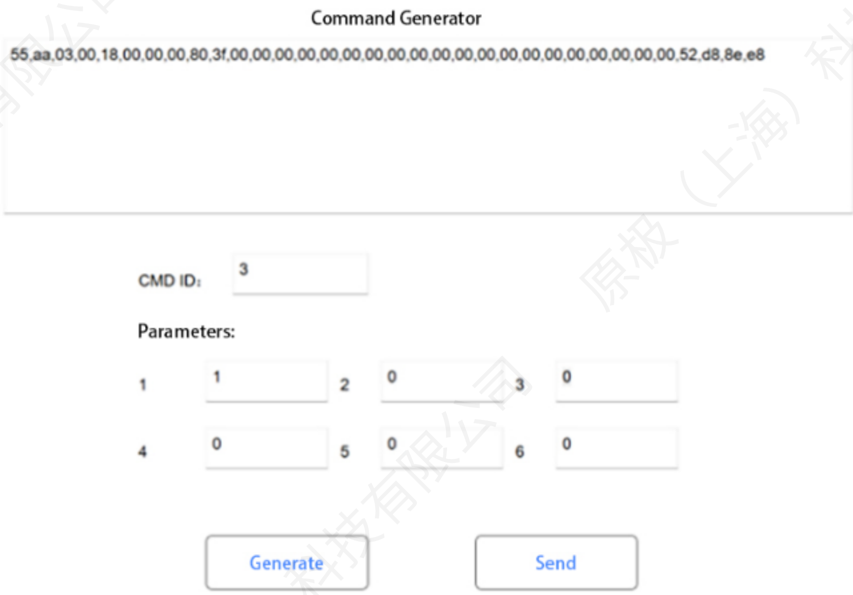
Note 1: Please note that the values in this table are all decimal.

Note 2: You can use the command generator function of the upper computer to generate corresponding commands

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



7.1.7 Command Mode Output - User Command Response

Table 22 Serial Data Format in Response to Setting 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 23 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	crc32	crc32

Table 24 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	crc32	crc32

Example: Set the serial output baud rate 115200
Input data:
55,AA,0E,00,18,00,00,00,E1,47,00,00,00,00,03,00,00,00,00,00,00,00,00,00,00,00,00,00,00,0
0,56,2B,4D,93
Response data: AA 55 3D 75 04 00 34 75 03 00 A7 98 2A 54

Set the AHRS output data rate 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

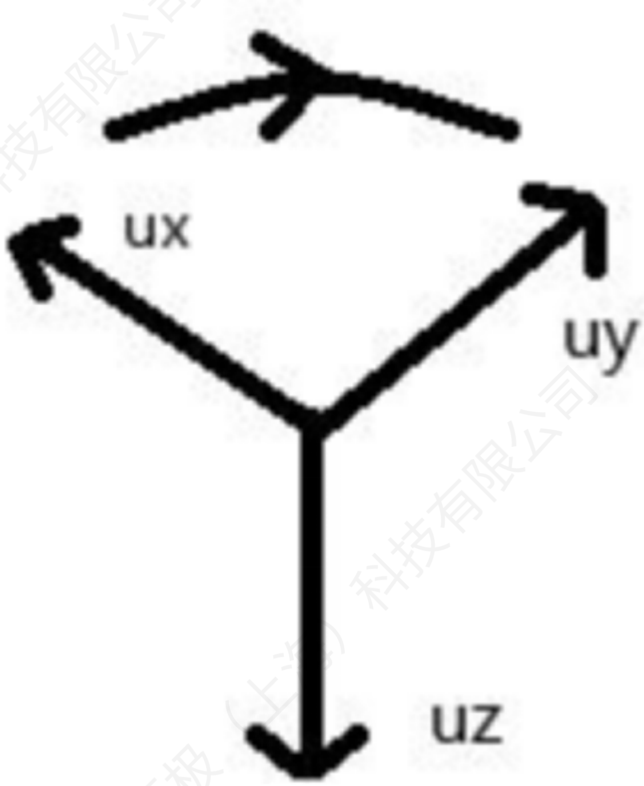
Save current parameters to FLASH
Input data: 55 AA 05 00 18 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 C9 2F E6 32
Response data: AA 55 3D 75 04 00 05 00 01 00 5A CF B1 7C

Set the 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

7.1.9 Coordinate System Setup

Set the firmware coordinate system and display the corresponding coordinate system in the Forsense 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 24 orientations for X, Y and Z axes, as shown in the table below:

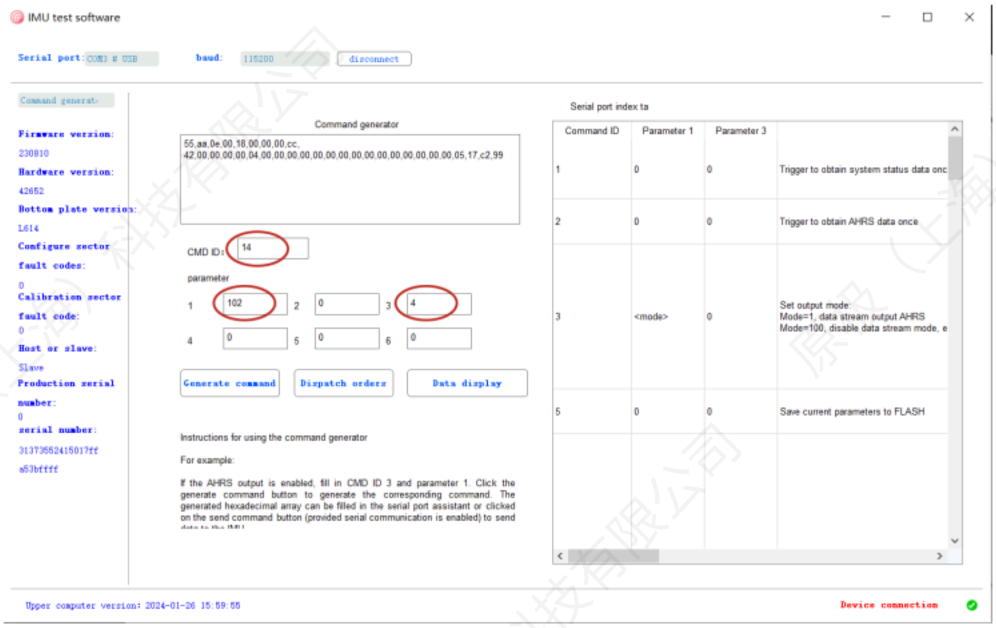
Table 25 Coordinate System Orientation Correspondence

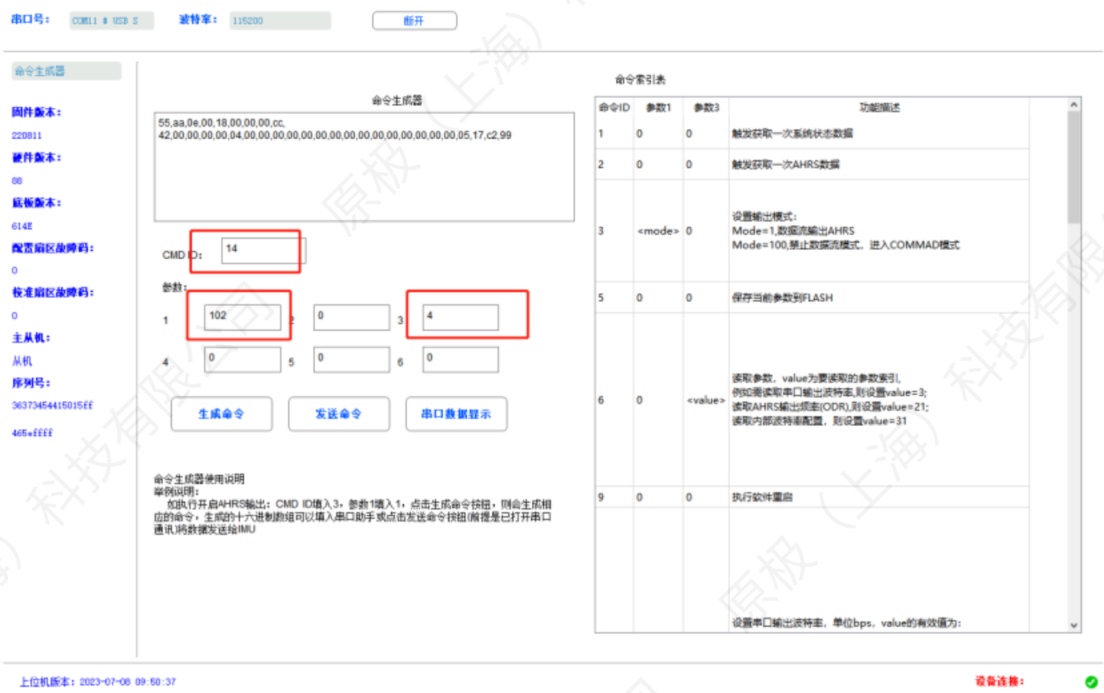
Orientation (value)	XAxis	YAXis	ZAxis	Description	Example
101	+Ux	-Uy	+Uz	Default orientation	
102	-Ux	-Uy	+Uz		
103	-Uy	+Ux	+Uz		
104	-Uy	-Ux	+Uz		

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:

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.





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 Original Firmware Coordinate System

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, 00,00,00,00,46,6a,4e,86

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

Refer to table 21 and acquire 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

Response 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 tables 15 and 16, parameter 1 is 115 (float) and parameter 3 is 04, which means the orientation of coordinate system is 115. Setting the coordinate system to 115 orientation.

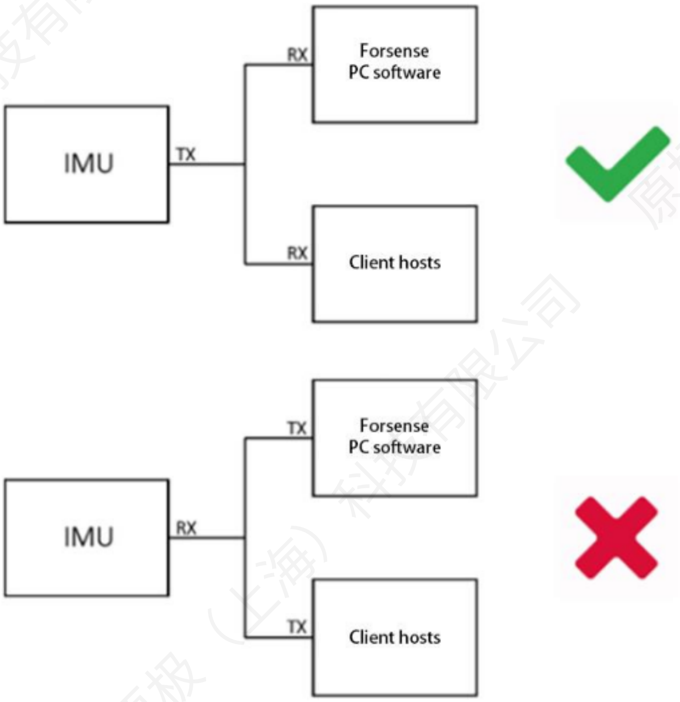
7.1.10 Serial Connection FAQs

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 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 Serial Connection Methods



Note: IMU TX can be connected to multiple RXs, but RX can not be connected to multiple TXs;
IMU serial port can not be connected to both the client host and Forsense PC software at the same time;
IMU can reserve another serial port to connect to only Forsense PC software.

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 cable, open the Forsense 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:
https://data.forsense-imu.com/page/download.html

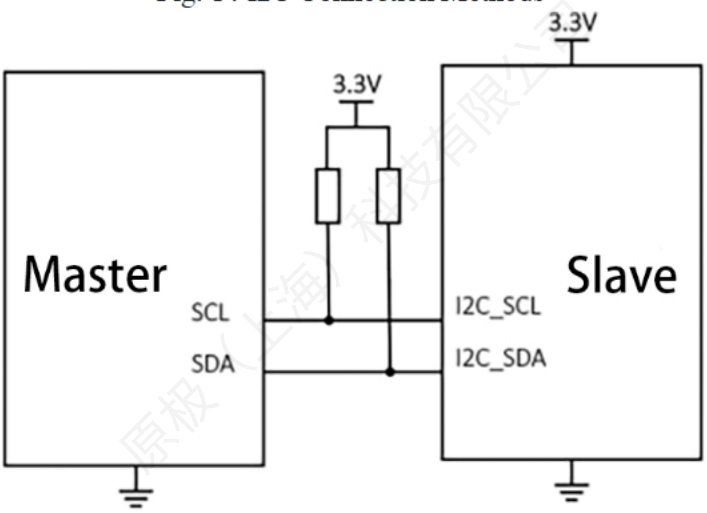
7.2.1 I2C Interface Parameters

Table 26 I2C Interface Parameters

I2C Rate	Conditions/Remarks
I2C Slave address (7 bits)	°/s

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

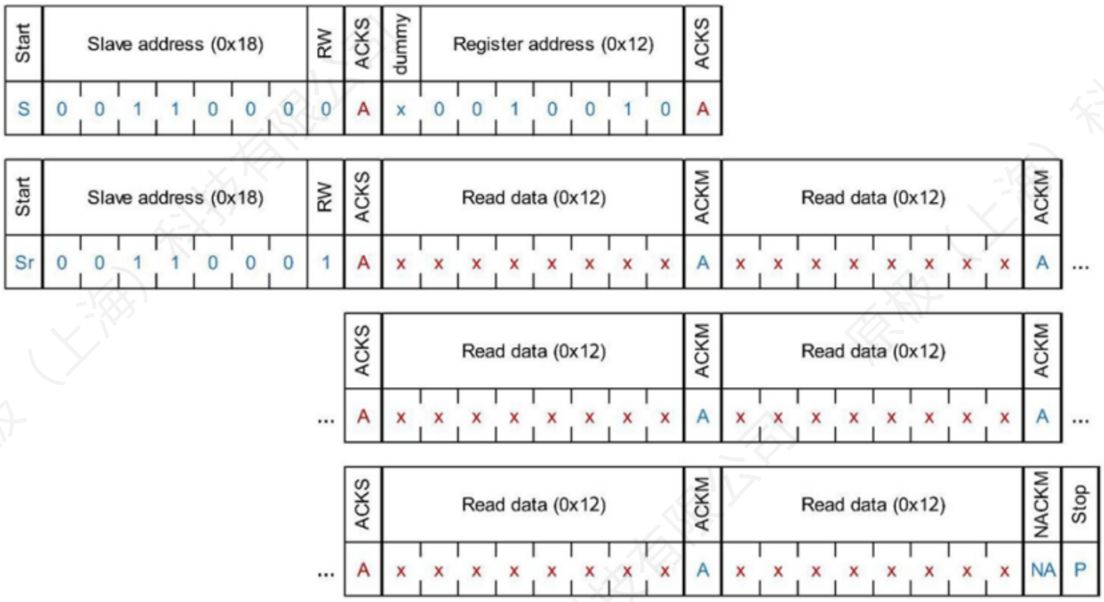
Table 27 I2C Register List

Name	Address	Read/Write	Default Value	Description
BURST	Attitude angle	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 48 bytes continuously in 8bit mode. The read process is as follows:

Fig. 15 I2C Continuous Reading Mode



The frame definition is as follows:

Table 28 I2C Continuous Data Format Reading

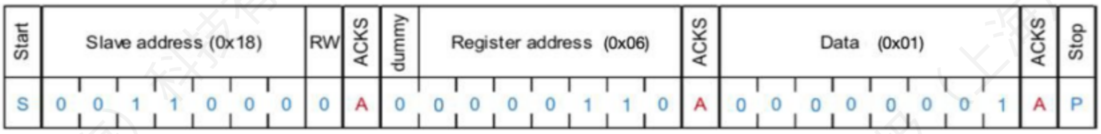
Transmit sequence	1	2	3
Data format	uint32_t	float	float
Transmit content	TIME	ACCL_X	ACCL_Y
Transmit sequence	4	5	6
Data format	float	float	float
Transmit content	ACCL_Z	GYRO_X	GYRO_Y
Transmit sequence	7	8	9
Data format	float	float	float
Transmit content	GYRO_Z	TEMP	ROLL
Transmit sequence	10	11	12
Data format	float	float	uint32
Transmit content	PITCH	YAW	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 Appendix 1.

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" encoded in ASCII, and the read process is the same as I2C BURST, as shown in the following table.

Table 29 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:

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

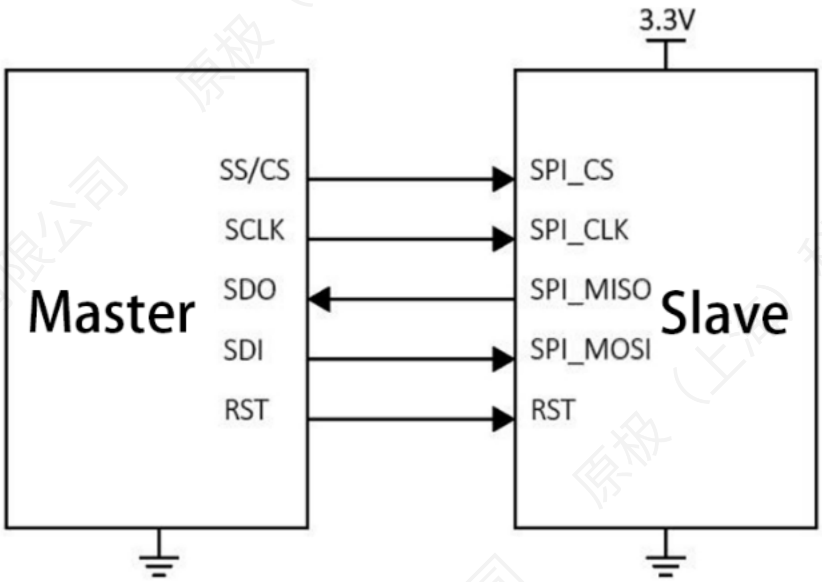
7.3.1 SPI Interface Parameters

Table 30 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



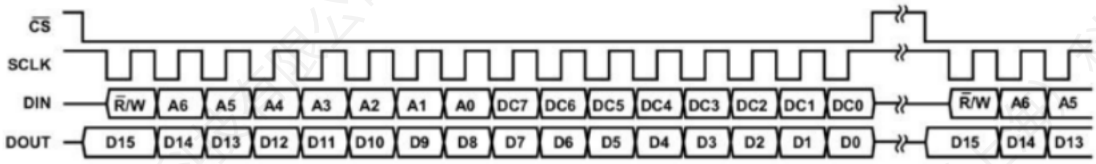
Note 1: Before the host initialization and data reading, reset the IMU and wait for 3s to make it enter normal operating mode.

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

Name	Address	Read/Write	Default Value	Window ID	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

Table 31 SPI Register List

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 32 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

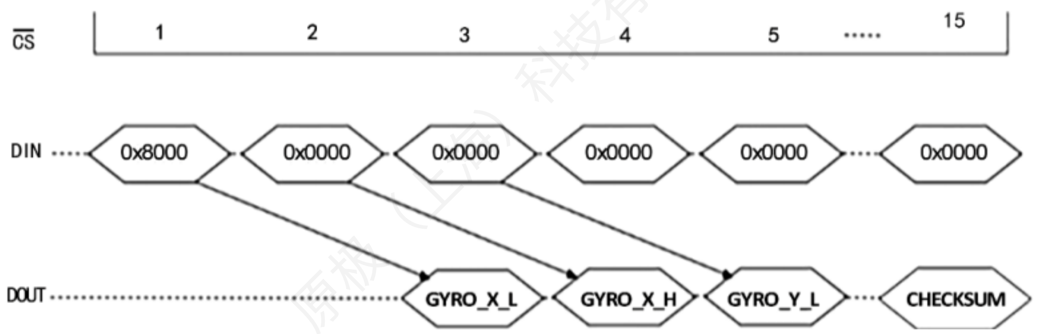


Table 33 SPI BURST Sequential Read Basic Format

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					

SPI BURST Sequential Read Basic Format

Before the output of mode 2， you need to first write 0x02 to registers 0x8D

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	14	15	16	17	18
Transmit content	TEMP_L	TEMP_H	PITCH_L	PITCH_H	ROLL_L	ROLL_H
Transmit sequence	19	20	21	22	23	24
Transmit content	YAW_L	YAW_H	Reserved	Reserved	CHECK_L	CHECK_H

SPI BURST3Sequential Read Basic Format

Before the output of mode 3， you need to first write 0x03to registers 0x8D

Transmit sequence	1	2	3	4	5	6
Transmit content	TIME	STATUS	GYRO_X_L	GYRO_X_H	GYRO_Y_L	GYRO_Y_H
Transmit sequence	7	8	9	10	11	12
Transmit content	GYRO_Z_L	GYRO_Z_H	ACCL_X_L	ACCL_X_H	ACCL_Y_L	ACCL_Y_H
Transmit sequence	13	14	15	16	17	18
Transmit content	ACCL_Z_L	ACCL_Z_H	PITCH_L	PITCH_H	ROLL_L	ROLL_H
Transmit sequence	19	20	21	22	23	24
Transmit content	YAW_L	YAW_H	TEMP_L	TEMP_H	Q0_L	Q0_H
Transmit sequence	25	26	27	28	29	30
Transmit content	Q1_L	Q1_H	Q2_L	Q2_H	Q3_L	Q3_H
Transmit	31	32				

sequence						
Transmit content	CHECK_L	CHECK_H				

Instruction for BURST3:

Time description: The counting time after the arrival of PPS is cleared to zero every full second.

STATUS Description:

Bit0: Accelerometer Sensor Ready Status, 0 = not ready, 1 = ready.

Bit1： Gyroscope Sensor Ready Status, 0 = not ready, 1 = ready.

Bit2： IMU Calibration Status: 0 = not implemented, 1 = calibration in progress

Bit3： IMU Calibration Success Status: 0 = failed, 1 = success

Bit4-Bit6：Gyroscope GX， GY， GZ If the range is exceeded, it will be set to 1 in the corresponding position, otherwise it will return to 0.

Bit7: Reserved

Bit8： Geomagnetic Sensor Ready Status, 0=not ready, 1=ready, please be noted that this bit is invalid for those without geomagnetism

Bit9-Bit15：Reserved

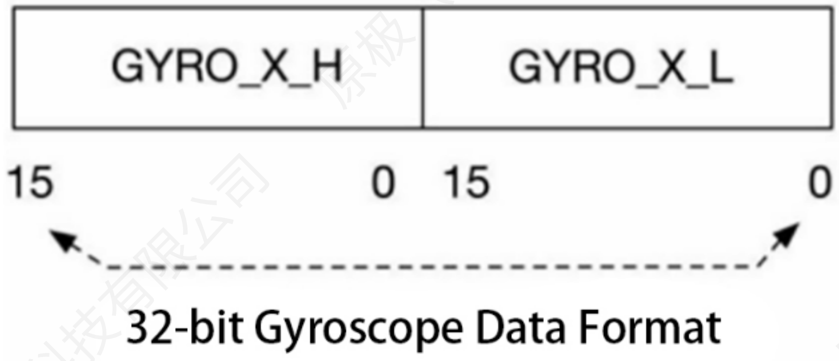
Note 1: All data in BURST, BURST2, BURST3 are in 16-bit width.

Note 2: The data from the gyroscope, accelerometer, attitude, and quaternion data in BURST, BURST2, BURST3 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



After acquiring the complete 32-bit data, standard frame users can get the information of angular velocity, acceleration, temperature and attitude angle by applying the following formulas.

Table 34 Standard Frame SPI 32-bit Data Conversion Formulas

Name	Unit	Formulas	Conditions/Remarks
Angular velocity	°/s	G=SF/65536*GYRO	GYRO represents the GYRO data for the X/Y/Z axis in the table above Gyro scale factor SF= 0.016
Acceleration	mg	A=SF/65536*ACCL	ACCL represents the ACCL data for the X, Y, and Z axes in the table above. Burst mode, SF = 0.2 Single Register mode, SF = 0.2/1000
Temperature	°C	T=SF/65536*TEMP-172621824+25	TEMP represents the TEMP data in the table above. Temperature scale factor SF=-1/263.4
Attitude angle	°	D=SF/65536*ATT	ATT represents 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 35 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 36 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 gyroscope 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 0x6C00~0x7000 when reading, 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 37 SPI ID Register Format

Name	Address	Read/ Write	Default	Window ID	Descriptions
BURST	0x00	RW		0	Continuos 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	0x000A	1	ID No. 3 (A6-PRO)
			0x000E	1	ID No. 3 (IMU614-B)
			0x001B	1	ID No. 3 (IMU614-Q)
			0x0015	1	ID No. 3 (IMU618-A)
			0x0016	1	ID No. 3 (IMU618-C)
			0x001A	1	ID No. 3 (A6-H)
			0x001F	1	ID No. 3 (A6-B)
			0x0023	1	ID No. 3 (IMU618-H)
			0x002A	1	ID No. 3 (IMU614-G)
			0x0032	1	ID No. 3 (IMU614-C)
			0x0025	1	ID No. 3 (IMU6132)

Name	Address	Read/ Write	Default	Window ID	Descriptions
			0x0026	1	ID No. 3 (IMU6132-D)
			0x0046	1	ID No. 3 (IMU6132-T)
			0x0048	1	ID No. 3 (IMU618-T)
			0x0032	1	ID No. 3 (IMU614-S)
			0x0034	1	ID No. 3 (IMU614-UAV)
			0x0035	1	ID No. 3 (NH1T-X)
WIN_CTRL	0x7F,0x7E	RW	0x0000	0，1	Wimdow ID Selection
TEMP_HIGH	0x0E	R	\	0	High temperature byte
TEMP_LOW	0x10	R	\	0	Low temperature byte
XGYRO_HIGH	0x12	R	\	0	Gyroscope X-Axis High Byte
XGYRO_LOW	0x14	R	\	0	Gyroscope X-Axis Low Byte
YGYRO_HIGH	0x16	R	\	0	Gyroscope Y-Axis High Byte
YGYRO_LOW	0x18	R	\	0	Gyroscope Y-Axis Low Byte
ZGYRO_HIGH	0x1A	R	\	0	Gyroscope Z-Axis High Byte
ZGYRO_LOW	0x1C	R	\	0	Gyroscope 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 ZAxisLow Byte

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. Switch window ID to 1 if writing 0xFE01.

Table 38 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 39 SPI Register WIN_CTRL.WINDOW_ID Encoding

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

7.4 CAN Communication Protocols

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

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

7.4.1 Communication Parameters

Interface type: CAN, standard frame

CAN rate: 250Kbps~1Mbps (configurable)

7.4.2 Standard Frame Format

Table 40 CAN Standard Frame Format 101

Standard Frame ID	1	2	3	4	5	6	7	8
65+ nodes	ROLL				PITCH			

Table 41 CAN Standard Frame Format 102

Standard Frame ID	1	2	3	4	5	6	7	8
66	YAW				Gx			

Table 42 CAN Standard Frame Format 103

Standard Frame ID	1	2	3	4	5	6	7	8
67+ nodes	Gy				Gz			

Table 43 CAN Standard Frame Format 104

Standard Frame ID	1	2	3	4	5	6	7	8
68+nodes	Ax				Ay			

Table 44 CAN Standard Frame Format 105

Standard Frame ID	1	2	3	4	5	6	7	8
69+ nodes	Az				TEMP		INDEX	

Note 1: The data of attitude angle, gyroscope, and accelerometer are expressed as float, while the data of temperature and count value are expressed as int16.

Note 2: The unit of TEMP is 100*°C, the unit of gyroscope output is °/s, the unit of accelerometer output is g, and the unit of attitude output is °.

7.4.2 CAN Parameters Configuration

7.4.2.1 Setting CAN's Baud Rate

Setting Can's Baud Rate, Command:
ID=0x619，DATA=0x20 0x21 0x22 0x23 0xXX 0x00 0x00 0x00
IMU responds as follows:
ID=0x519，DATA=0xXX 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF
Query CAN's current baud rate, command:
ID=0x619，DATA=0x20 0x21 0x22 0x23 0x0A 0x00 0x00 0x00
IMU responds as follows:
ID=0x519，DATA= 0xXX 0x0A 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF
In which:
When XX=01; Baud Rate=250 Kbps
When XX=02; Baud Rate=500 Kbps
When XX=03; Baud Rate=1000 Kbps

7.4.2.2 Setting Nodes ID

The default node is 100,set the node ID to 0X0102, command:
ID=0x61A，DATA=0x30 0x31 0x32 0x33 0x01 0x02 0x00 0x00
IMU respnds as follows:
ID=0x51A，DATA=0x01 0x02 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF

7.4.2.3 Querying Version Numbers

Command:
ID=0x618，DATA=0x10 0x11 0x12 0x13 0x00 0x00 0x00 0x00
IMU responds as follows:
ID=0x518，DATA=0x00 0x03 0x12 0x0E 0xFF 0xFF 0xFF 0xFF
Version Number: 0X0003120E, i.e. firmware version number: 201230

7.4.2.4 Querying / Setting Terminal Resistance

Without Terminal Resistance, command:
ID=0x61B，DATA=0x10 0x11 0x12 0x13 0x01 0xFF 0xFF 0xFF
IMU responds as follows:
ID=0x51B，DATA=0x01 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF
With Terminal Resistance, command:
ID=0x61B，DATA=0x10 0x11 0x12 0x13 0x02 0xFF 0xFF 0xFF
IMU responds as follows:
ID=0x51B，DATA=0x02 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF

7.4.2.5 Setting Output Frequency

Setting output frequency, command:
ID=0x61C，DATA=0x10 0x11 0x12 0x13 0xXX 0xFF 0xFF 0xFF
IMU responds as follows:
ID=0x51C，DATA=0xXX 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF

Querying output frequency, command:
ID=0x61C，DATA=0x10 0x11 0x12 0x13 0x0A 0xFF 0xFF 0xFF
IMU responds as follows:
ID=0x51C，DATA=0xXX 0x0A 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF
In which:
When XX=01, output frequency = 1HZ
When XX=02, output frequency = 10HZ
When XX=03, output frequency = 50HZ
When XX=04, output frequency =100HZ
When XX=05, output frequency = 200HZ

7.4.2.6 Setting and Querying The Reverse Raw&Pitch

Setting reverse raw&pitch, command:
ID=0X61D,DATA=0X10 0X11 0X12 0X13 XXXX 0XFF 0XFF 0XFF
IMU responds as follows:
ID=0X51D,DATA=XXXX 0XFF 0XFF 0XFF 0XFF 0XFF 0XFF 0XFF

Querying the status of reverse raw&pitch, command:
ID=0X61D,DATA=0X10 0X11 0X12 0X13 0X0A 0XFF 0XFF 0XFF
IMU responds as follows:
ID=0X51D,DATA=XXXX 0X0A 0XFF 0XFF 0XFF 0XFF 0XFF 0XFF
In which:
When XXXX=0X00, roll and pitch angles are not reversed.
When XXXX=0X01, roll and pitch angles are not reversed.
When XXXX=0X10, roll angle is not reversed while pitch angle is reversed
When XXXX=0X11, roll angle is reversed while pitch angle is not reversed

7.4.2.7 Setting and Querying Filter Cut-off Frequency

Setting Filter Cut-off Frequency, command:
ID=0X61E,DATA=0X20 0X21 0X22 0X23 XXXX 0XFF 0XFF 0XFF
IMU responds as follows:
ID=0X51E,DATA=XXXX 0XFF 0XFF 0XFF 0XFF 0XFF 0XFF 0XFF

Querying the status of Filter Cut-off Frequency, command:
ID=0X61E,DATA=0X20 0X21 0X22 0X0A 0XFF 0XFF 0XFF 0XFF
IMU responds as follows:
ID=0X51E,DATA=XXXX 0X0A 0XFF 0XFF 0XFF 0XFF 0XFF 0XFF
In which:
XXXX=0X44, cut-off frequency is 10HZ
XXXX=0X66, cut-off frequency is 20HZ
XXXX=0XAA, cut-off frequency is 40HZ
XXXX=0XBB, cut-off frequency is 47HZ

7.4.2.8 Setting and Querying the Coordinate System

Setting the coordinate system, command:

ID=61F,DATA=0X30 0X31 0X32 0X33 XXXX 0XFF 0XFF 0XFF

IMU responds as follows:

ID=0x51F,DATA= XXXX 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF

Querying orientation, command:

ID=0x61F，DATA=0x30 0x31 0x32 0x0A 0xFF 0xFF 0xFF 0xFF

IMU responds as follows:

ID=0x51F，DATA=XXXX 0x0A 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF

In which:

When XXXX=0X65, default orientation

CAN is configured in hexadecimal, while chapter 8 shows decimal. Please go to chapter 8 for specific orientation settings

7.4.2.9 Closing and Deducting Attitude Angle

Setting to deduct the misalignment of the attitude angle, command:

ID=0x620，DATA=0x10 0x11 0x12 0x13 XXXX 0xFF 0xFF 0xFF

IMU responds as follows:

ID=0x520，DATA=XXXX 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF

Querying whether the attitude angle setting is deducted, command:

ID=0x620，DATA=0x10 0x11 0x12 0x0A 0xFF 0xFF 0xFF 0xFF

IMU responds as follows:

ID=0x520，DATA=XXXX 0x0A 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF

In which:

When XXXX=0X01, the attitude angle is deducted;

When XXXX=0X00, the attitude angle is not deducted.

7.4.2.10 Save Commands

Sent command:

ID=0x6FF，DATA=0x10 0x11 0x12 0x13 0xFF 0xFF 0xFF 0xF

IMU responds as follows:

ID=0x5FF，DATA=0xFF 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF

The message will be returned only after the saving is completed, and taken effect after rebooting.

7.5 Common AT Commands

7.5.1 Stopping the Current Data Stream Output

Command: AT+SETNO\r\n

Response: OK

You can stop the current data flow (without changing the parameters) and output OK to indicate that you can proceed to the next step.

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

Enable data stream output:

Command: AT+SETYES\r\n

7.5.2 Querying Version Numbers

Command: AT+VERSION\r\n

Response: SW_VERSION Firmware version HW_VERSION Hardware version BOARD_VERSION Baseboard Version

Firmware version

HW_VERSION Hardware version

BOARD_VERSION Base plate version

OK

7.5.3 Querying User ParametersCommand:

Command: AT+CONFIG\r\n

Response: BAUD_RATE Current serial port baud rate

ORIENT Current coordinate system

IMU_ODR Current IMU output frequency

STREAM_MODE1 Current data flow mode of serial port 1

STREAM_MODE2 Current data flow mode of serial port 2

STREAM_MODE3 Current data flow mode of serial port 3

LP_CONFIG_REG Current IMU filtering

OK

7.5.4 Setting and Querying the ODRs

Example: Set the output frequency ODR to 50HZ
Command: AT+SET_ODR=50\r\n
Response: IMU_ODR:50
OK
Query the ODR of the IMU Command: AT+GET_ODR\r\n
Response: IMU_ODR:
OK

7.5.5 Setting and Querying the Coordinate System

Example: Set the IMU coordinate system to Front-Right-Up
Command: AT+SET_ORIENT=101\r\n
Response: orientation:101
OK
Query IMU's current coordinate system
Command: AT+GET_ORIENT\r\n
Response: orientation:

7.5.6 Setting and Querying Baud Rates

Example: Set the IMU's baud rate 115200
Command: AT+SET_BAUD=115200\r\n
Response: OK
Query IMU's current baud rate
Command: AT+GET_BAUD\r\n
Response: BAUD_RATE:
OK

7.5.7 Setting the Reverse Roll and Pitch

If AT+SET_ATT_ORIENTATION=00\r\n, then roll and pitch angles are not reversed.
If AT+SET_ATT_ORIENTATION=01\r\n, then roll angle is reversed while pitch angle is not reversed.
If AT+SET_ATT_ORIENTATION=10\r\n, then roll angle is not reversed while pitch angle is reversed.
If AT+SET_ATT_ORIENTATION=11\r\n, then roll and pitch angles are reversed.

7.5.8 Setting and Querying Filters

Example: Set the IMU's filtering to 20Hz
Command: AT+SET_LPF=102\r\n
Response: LP_CONFIG_REG:102
OK
Query the IMU's current filtering
Command: AT+GET_LPF\r\n
Response: LP_CONFIG_REG:
OK

Table 45 Low-pass filter value and corresponding value of AT command

No.	IMU Low-pass filter value	Corresponding value of AT command
1	1	17
2	2	34
3	5	51
4	10	68
4	15	85
5	20	102
6	25	119
7	30	136
8	35	153
9	40	170
10	47 (without filter value)	187

7.5.9 Setting Initial Yaw angle

Example: Setting the initial Yaw angle at 180 degrees (integer only)
Command: AT+SET_ORIENT=180\r\n
Response: AT+SET_HEADING=180

7.5.10 Save Parameters

Command: AT+SAVE\r\nResponse: OK

8. Time Synchronization

Through time synchronization, the device's internal clock is aligned with an external time reference, which eliminates time deviations due to clock drift.
In a system where multiple devices are working together, the timestamps of all devices are based on the same time base, which helps ensure data consistency and accuracy.

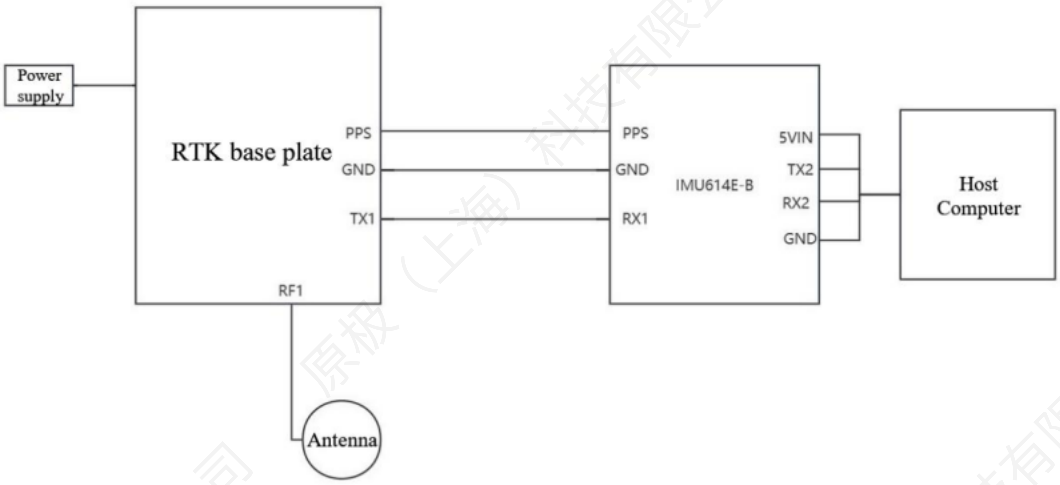
Currently, this module offers two kinds of time synchronization:

1. Access pps signaling + rmc messages,
2. Time synchronization on the host side via DRDY signal signals

8.1 Accessing pps signaling + rmc messages

8.1.1 Hardware Connection

(1) Connect the IMU with RTK base plate according to instructions



IMU614E-B connecting instructions

8.1.2 RTK Configuration Requirement

GPRMC 10HZ

Close the functions concerning inertial guidance assistance in RTK board and other statements.

PPS: once per second, triggered at the rising edge, with a pulse width of 5 milliseconds and is aligned to UTC (Coordinated Universal Time). The high voltage level must below 5v.

Please make sure the baud rate consistency between RTK serial and IMU.

Connect the RTK base plate with the main unit, then open the Serial Assistant, input commands accordingly:

CONFIG (view baud rate configuration)

config com1   115200 (Corresponding IMU baud rate)

saveconfig (Save the parameters)

8.1.3 Command Sequence for IMU Enable Time Synchronization Function

After IMU has connected to the main unit, please open the Serial Assistant, input commands accordingly:

AT+SETNO (Stop the data output, which makes it convenient for sending commands)

AT+SETIIC=0 (Activate time synchronization)

AT+SAVE (Save parameters)

AT+SETYES (Restore data output)

8.1.4 How to Confirm Whether Time Synchronization is Successful

Confirmation steps are as follows

Before the synchronization, it shows the count value of IMU itself with a unit of ms

After the synchronization the data will switch to the UTC converted truth value in ms, taking the truth value 43767630ms as an example,

Convert the given value (ms) to the value (s)

43,767,630ms= 43,767.63s

Convert the value (s) to the values with units of h, min, and s:

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

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

Then divide the number of seconds remaining by 60 (1min=60s) to get the number of minutes and the number of seconds remaining.

567s ÷ 60 = 9min...27s (rounding)

Results:

Combine the value of h, min, s and the initial fractional part of the above steps to form the final UTC time representation (hhmmss. sss).

The ultimate UTC time will be: 120927.63

2. According to different setting of IMU update rate, the time-stamp interval will change.

For example:

When the IMU update rate is 10HZ, the corresponding time-stamp interval will be 100ms;

Under this circumstances, the time-stamp will send in a cycle of one frame per 10ms to ensure synchronization with the IMU data. Under is the example.

```
%time_us,accx,accy,accz,gyrox,gyroy,gyroz,temperature,roll,pitch,yaw,mx,my,mz
43767630,0.000911493,-0.00593111,-0.999837,-0.112592,0.0775201,-0.239427,37.375,0.37371,0.0374005,359.763
43767640,0.00104886,-0.00639931,-1.00023,-0.11155,0.0945329,-0.198418,37.375,0.372709,0.0378392,359.763
43767650,0.0010143,-0.00654209,-1.00144,-0.143203,0.0859424,-0.187509,37.375,0.372681,0.038661,359.763
43767660,0.000973708,-0.00638983,-1.00176,-0.166009,0.092228,-0.200648,37.375,0.372481,0.0390947,359.763
43767670,0.00147395,-0.00683136,-1.001,-0.192246,-0.00178328,-0.157266,37.375,0.372781,0.0399402,359.763
43767680,0.00223095,-0.00695176,-1.00109,-0.0757273,-0.000226222,-0.138093,37.375,0.372781,0.0399402,359.763
43767690,0.00127585,-0.00571409,-1.00053,-0.173622,0.0492768,-0.163678,37.375,0.373524,0.0425388,359.763
43767700,0.00074174,-0.00655202,-1.00021,-0.115697,0.000131873,-0.160155,37.375,0.372256,0.0430011,359.763
43767710,0.00167231,-0.00625615,-1.00077,-0.196135,-0.000426489,-0.177769,37.375,0.372131,0.0433163,359.763
43767720,0.00185977,-0.0061884,-1.00042,-0.224989,-0.0107625,-0.0937578,37.375,0.371704,0.0457214,359.763
43767730,0.00024303,-0.00667565,-1.00119,-0.252968,0.0338021,-0.143835,37.375,0.371704,0.0457214,359.763
43767740,0.000261399,-0.00675453,-1.00142,-0.221033,0.0709242,-0.198763,37.375,0.37201,0.0447791,359.763
43767750,0.000898074,-0.00627877,-1.00137,-0.146918,0.0208479,-0.177816,37.375,0.372149,0.0439286,359.763
43767760,0.00114561,-0.00632768,-1.00142,-0.116412,0.0106449,-0.195621,37.375,0.371879,0.0448294,359.763
43767770,0.00031602,-0.0065025,-1.00118,-0.151384,0.107034,-0.151737,37.375,0.371925,0.0443909,359.763
43767780,0.000111739,-0.00596614,-1.00127,-0.191872,0.0392804,-0.190575,37.375,0.371925,0.0443909,359.763
43767790,-0.000446753,-0.00575444,-1.00054,-0.144282,0.0438216,-0.206097,37.375,0.371021,0.0432654,359.763
43767800,0.000744278,-0.00620892,-1.00097,-0.0806283,0.0402478,-0.2018,37.375,0.370079,0.0418417,359.763
43767810,0.000249961,-0.00627208,-1.00092,-0.205578,0.0244218,-0.173429,37.375,0.369413,0.0418069,359.763
43767820,3.2315e-05,-0.00632706,-1.00116,-0.190721,0.0747152,-0.227714,37.375,0.3691,0.0408873,359.763
43767830,-0.00024524,-0.00670832,-1.00086,-0.117692,0.111822,-0.193005,37.375,0.3691,0.0408873,359.763
43767840,0.000537576,-0.00604259,-1.00108,-0.146042,0.043116,-0.178889,37.375,0.369541,0.0392609,359.763
43767850,0.00102963,-0.00625389,-1.00084,-0.165271,0.000858686,-0.146898,37.375,0.369012,0.0390227,359.763
43767860,0.00121603,-0.0058367,-1.00105,-0.207972,0.0699086,-0.172457,37.375,0.368091,0.0399286,359.763
43767870,0.00114882,-0.00628435,-1.00111,-0.192793,0.0395967,-0.177017,37.375,0.36763,0.0405705,359.763
```

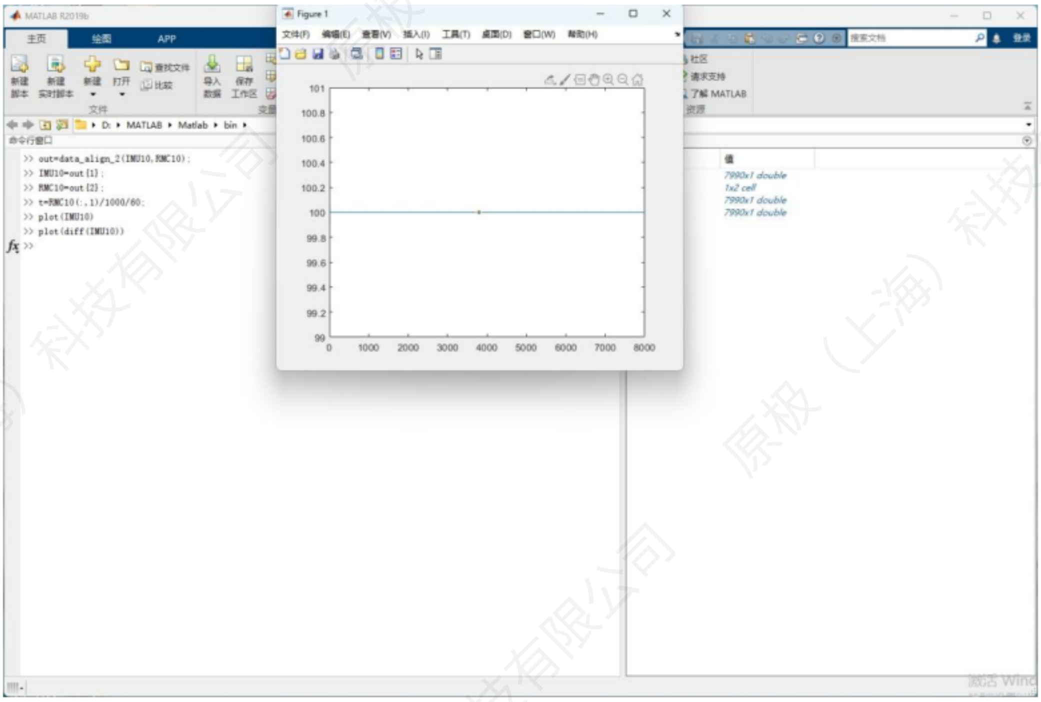
8.1.5 How to Verify that the Time-stamp is Correct after a Successful Time Synchronization

1. RMC data and time-synchronized AHRS data are simultaneously captured and decoded.
2. Convert the two time-stamps to the same format, using matlab and other tools to count the following two groups of corresponding time-stamp data in the following indicators

(1). Whether the time-stamp intervals are stable and whether there are packet losses.

Determining factors:
10HZ output: interval stabling at 100ms

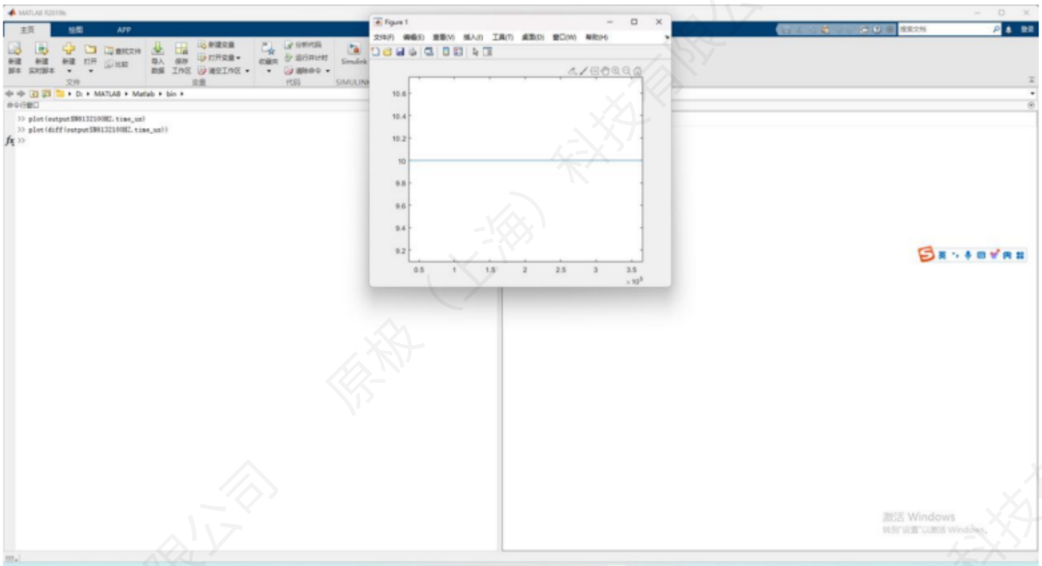
```
%time_us,accx,accy,accz,gyrox,gyroy,gyroz,temperature,roll,pitch,yaw,mx,my,mz
10138100,-0.00785668,0.000511979,-1.00068,0.00577856,0.0224228,-0.170839,43.6992,-0.185733,-0.373024,2.66486
10138200,-0.00548826,-8.32841e-06,-1.00069,0.120156,-0.0394001,0.0182559,43.6992,-0.177175,-0.373694,2.66124
10138300,-0.0177959,-0.0481571,-1.00444,-0.452245,-0.0625247,-6.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



IMU10HZ

100HZ output: interval stabling at 10ms

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



IMU100HZ

(2). Collect statistics on whether the time difference between two sets of corresponding timestamped data with the same output frequency and the same starting point is 0. (This must be under a good satellite condition)

Under are examples for statistics:

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

IMU10HZ

12174500	12174500	0
12174600	12174600	0
12174700	12174700	0
12174800	12174800	0
12174900	12174900	0
12175000	12175000	0
12175100	12175100	0
12175200	12175200	0
12175300	12175300	0
12175400	12175400	0
12175500	12175500	0
12175600	12175600	0
12175700	12175700	0
12175800	12175800	0
12175900	12175900	0
12176000	12176000	0
12176100	12176100	0
12176200	12176200	0
12176300	12176300	0
12176400	12176400	0
12176500	12176500	0
12176600	12176600	0
12176700	12176700	0

IMU100HZ

8.2 Time Synchronization through DRDY in the main unit

8.2.1 Functions of DRDY

DRDY (Data Ready) is an important status or interrupt signals in IMU, it indicates that the IMU data is ready to be read. When IMU has completed a round of data collecting and processing, DRDY will turn to active (normally it is in low voltage), which means new data such as acceleration and angular velocity are ready to be processed.

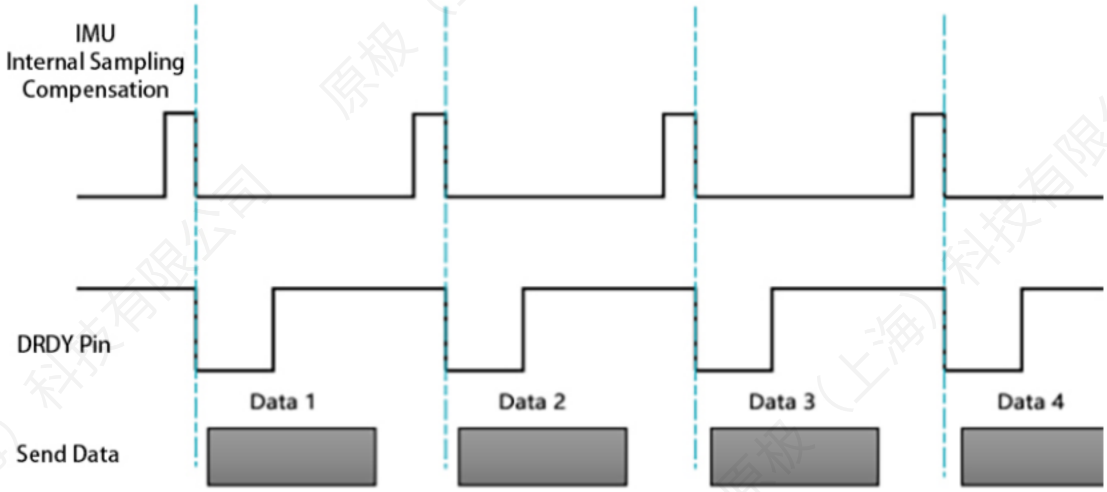
Once the main unit is connected to the IMU, it can determine the exact moment when the data is ready by detecting the clock synchronization signal provided by the DRDY from within the IMU, adding a time-stamp and analysing the data at that moment. This means that whenever the DRDY changes, the main unit knows that the data is ready and can record the time at that point as a time-stamp for that data.

8.2.2 DRDY

The DRDY pin output serves two purposes:

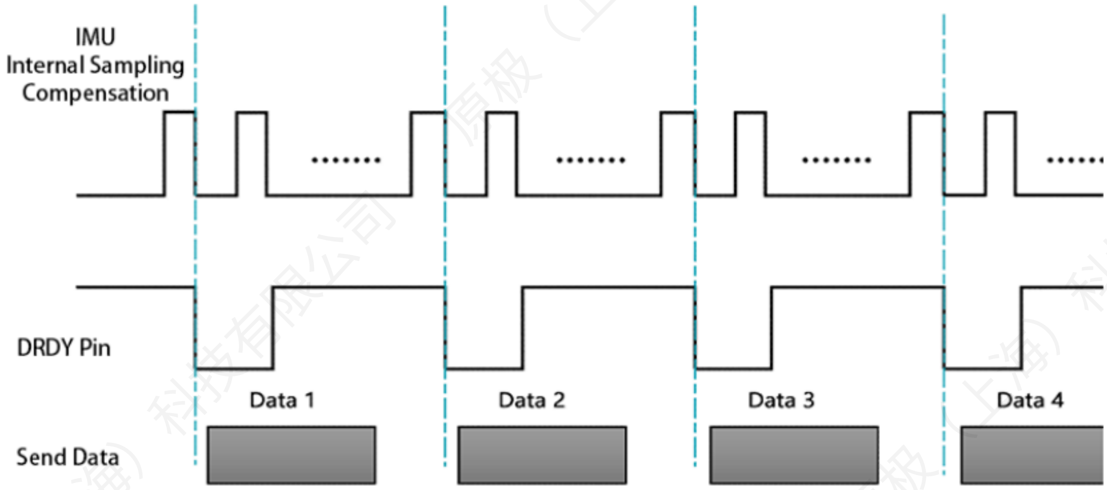
1. to provide a clock synchronization signal from within the IMU;
2. to provide a signal to indicate the start of data frame transmission.

Fig. 21 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.

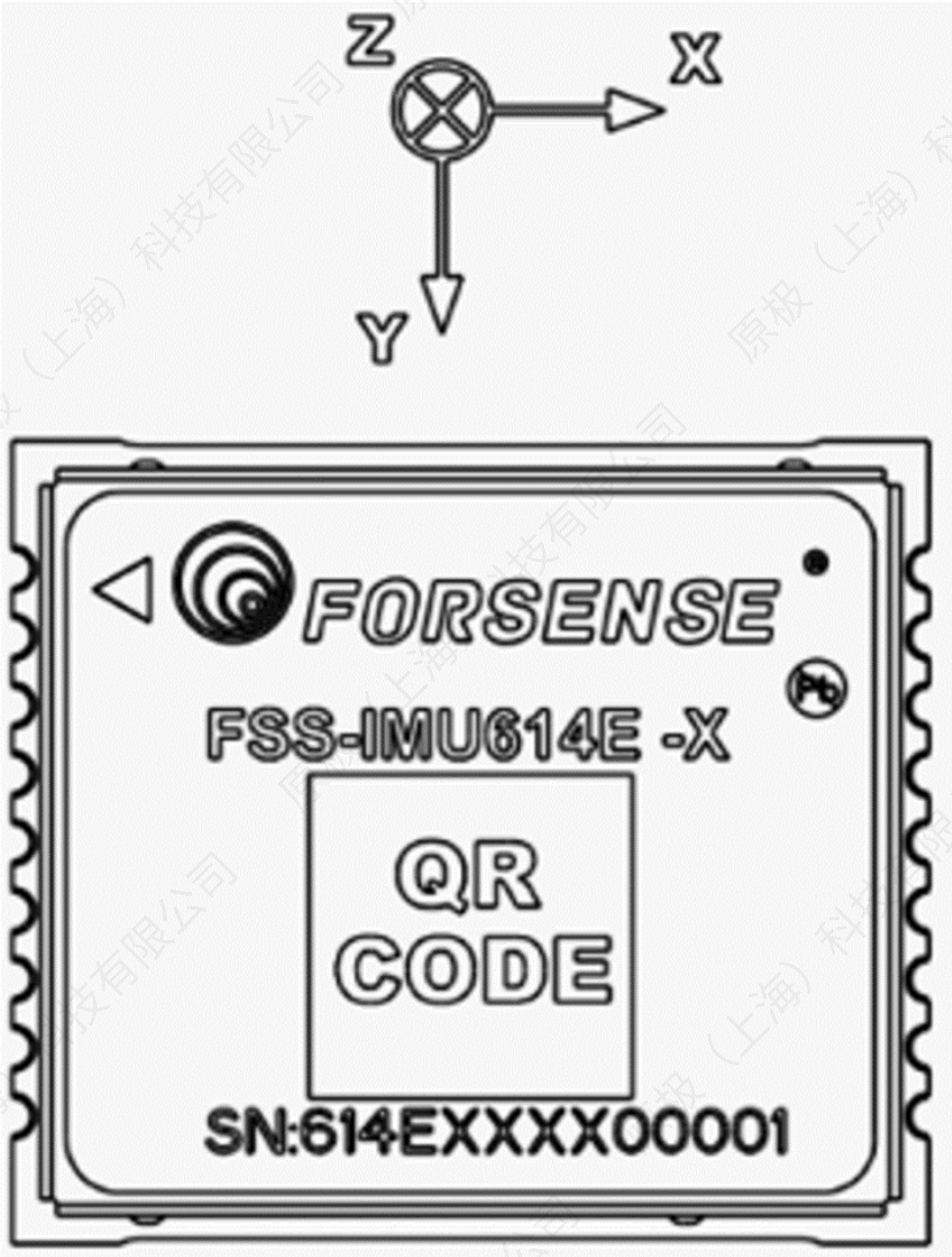
Fig. 22 Serial Output Frequency Less Than IMU Internal Sampling Frequency



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.

9. Definition of Coordinate System

Fig. 23 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:

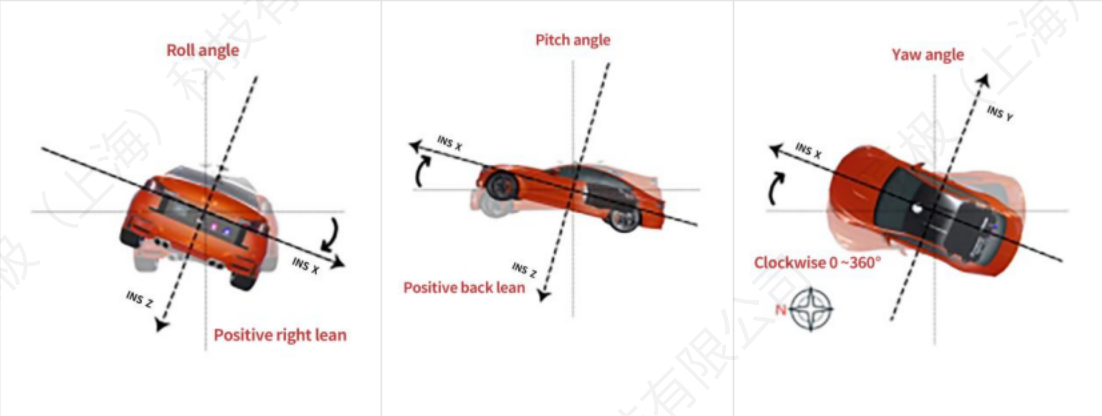
Rotate around Z-axis: Yaw angle range: 0° ~360°;

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

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

The diagram of roll, pitch, and yaw Angles are as follows:

Fig. 24 Diagram of Roll, Pitch, and Yaw Angles

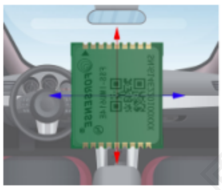
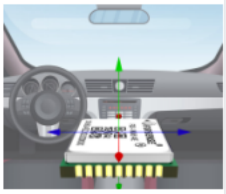
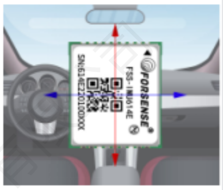


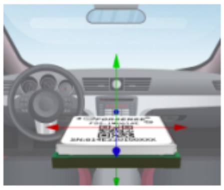
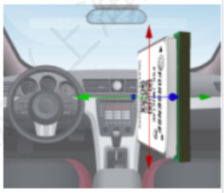
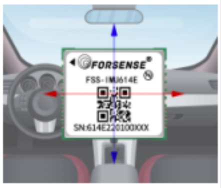
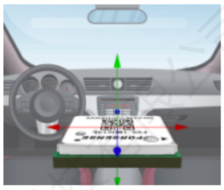
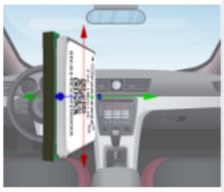
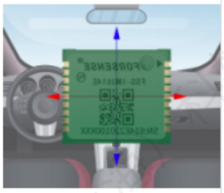
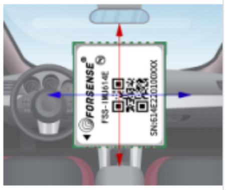
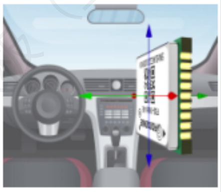
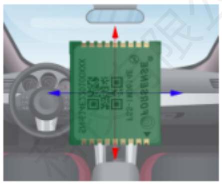
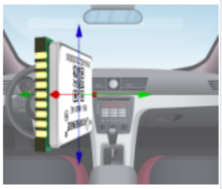
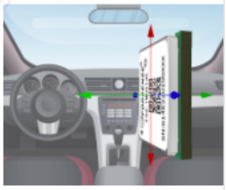
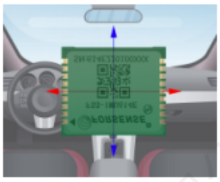
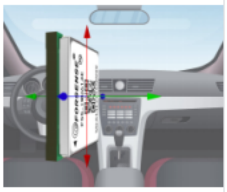
Instructions for the Coordinate System

In order to better understand the coordinate system, we take the relative position of an IMU unit inside a car as an example to illustate.

The picture is demonstrated the head as the front, while the lens positioned as the back, and we can detemine the relative position through the arrow on the module label.

Adjust the coordinate system means adjust the defination of he three axis, making sure the three axis maintain complaince with the requirement(X-axis faces front, Y-axis faces left and Z-axis faces down).

Coordiate System	Diagram	Coordiate System	Diagram	Coordiate System	Diagram
101		109		117	
102		110		118	

103		111		119	
104		112		120	
105		113		121	
106		114		122	
107		115		123	
108		116		124	

10. CRC Look-up Table Calculations

It is recommended to refer directly to the sample code.

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

Note 2: The initial value of crc32 is 1 and the CRC calculation does not include all the data of the frame itself.

C++

```cpp
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,
```

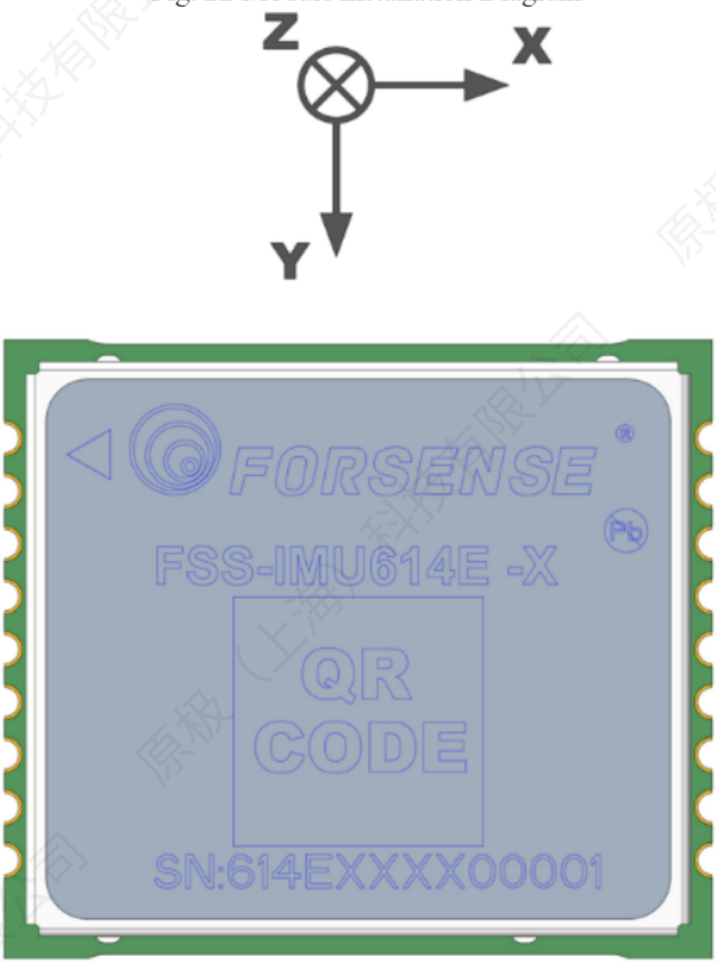
```
0xd80d2bda,  0xaf0a1b4c,  0x36034af6,  0x41047a60,  0xdf60efc3,  0xa867df55,
0x316e8eef,  0x4669be79,  0xcb61b38c,  0xbc66831a,  0x256fd2a0,  0x5268e236,
0xcc0c7795,  0xbb0b4703,  0x220216b9,  0x5505262f,  0xc5ba3bbe,  0xb2bd0b28,
0x2bb45a92,  0x5cb36a04,  0xc2d7ffa7,  0xb5d0cf31,  0x2cd99e8b,  0x5bdeae1d,
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;
}
```

11. Usage Examples

11.1 Device Installation

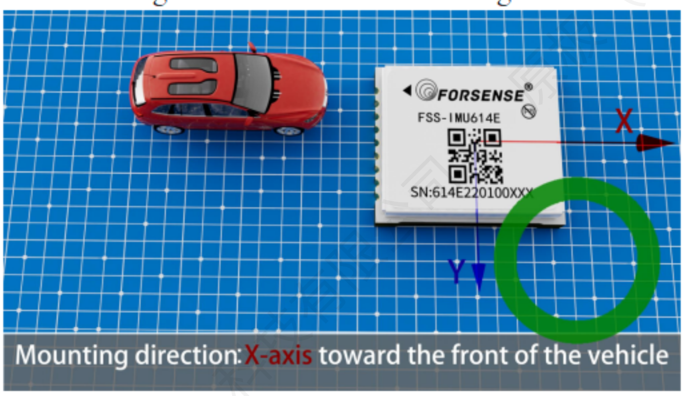
1. The module should be firmly fixed on a rigid plane rather than in a position of high vibration;
2. The module should be installed toward the front of the vehicle.

Fig. 22 Module Installation Diagram

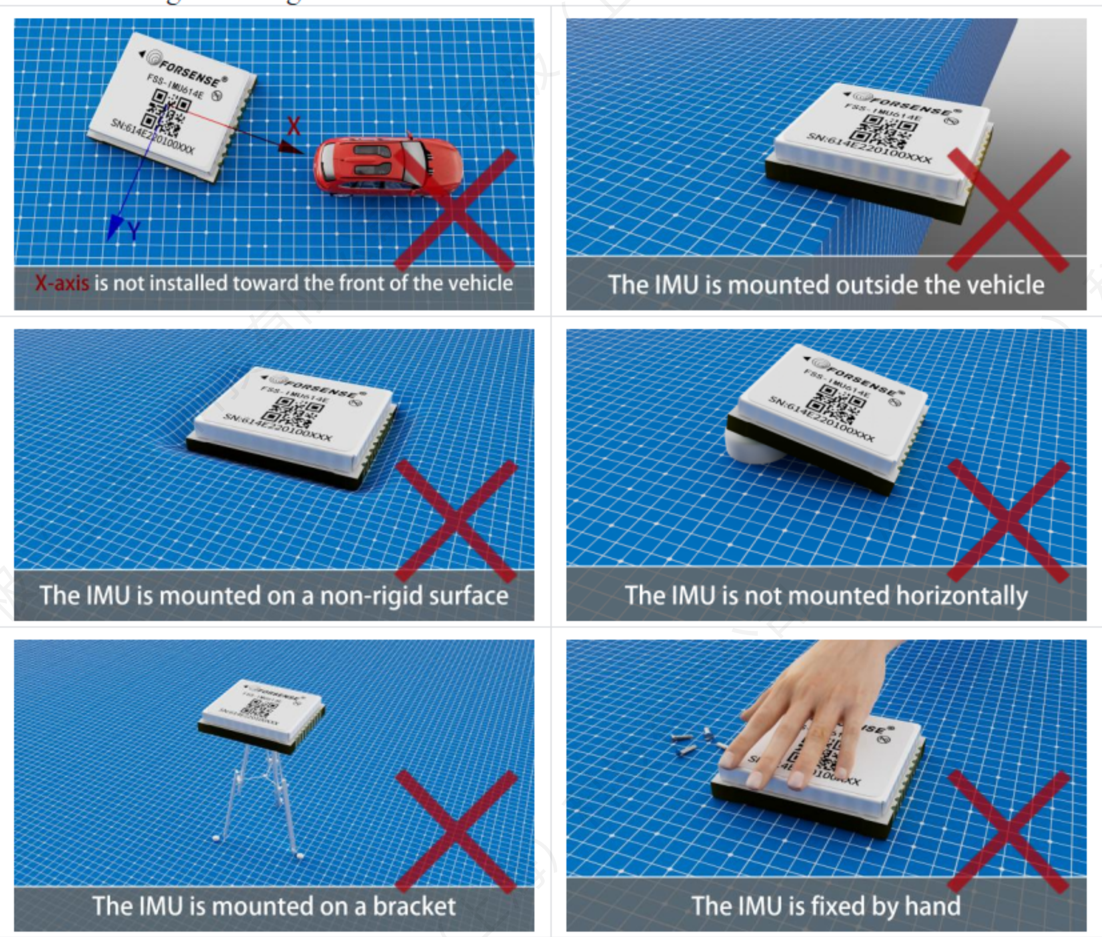


The correct installation diagram is as follows
X-axis toward the front of the vehicle

Fig. 23 Correct Installation Diagram



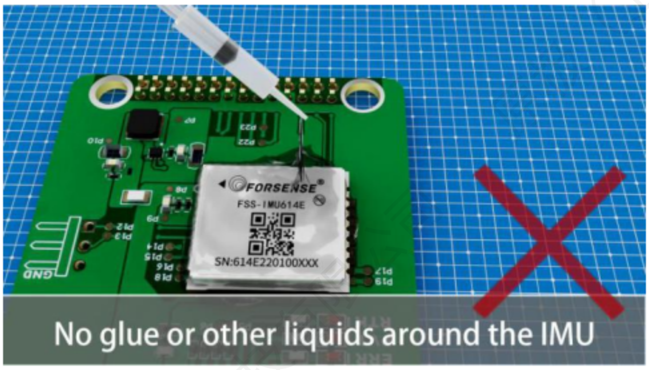
The following mounting methods are incorrect:



3. IMU Installation Precautions

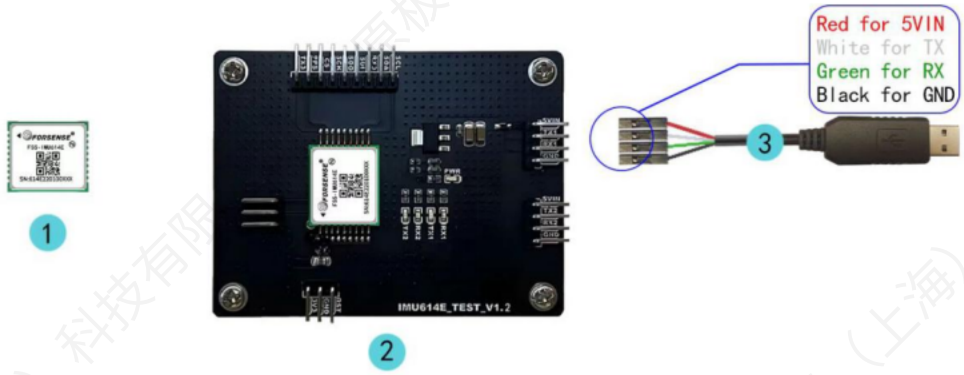
No glue or other liquids around the IMU to prevent them from flowing into the interior of the IMU through gaps, thus impairing performance of the IMU.

Fig. 24 Wrong Installation Diagram



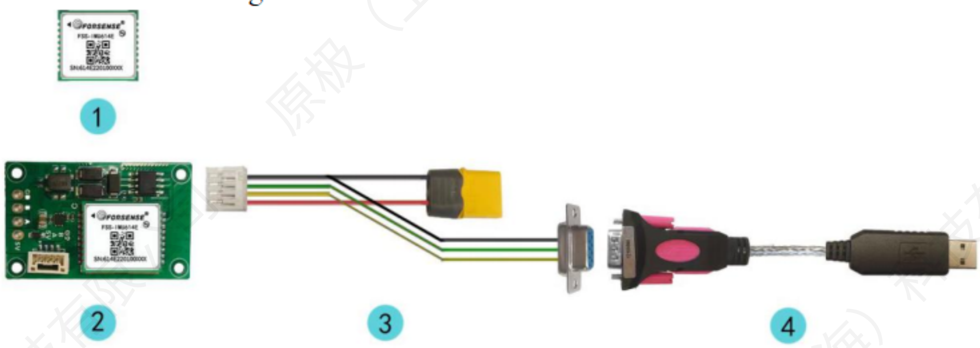
11.2 Example of Test Substrates Connection

Fig. 25 Instructions of Test Substrates Connection of 614E Module



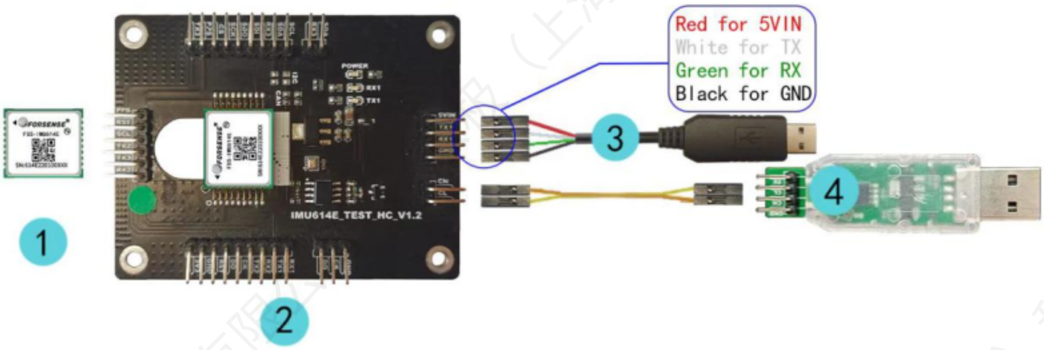
	Name	Quantity
1	IMU 614E Series Module	1
	Accessories Name	Quantity
2	IMU614E Test Substrates	1
3	TTL Serial Cable	1

Fig. 26 614E RS485 ver. SMD Test Substrates



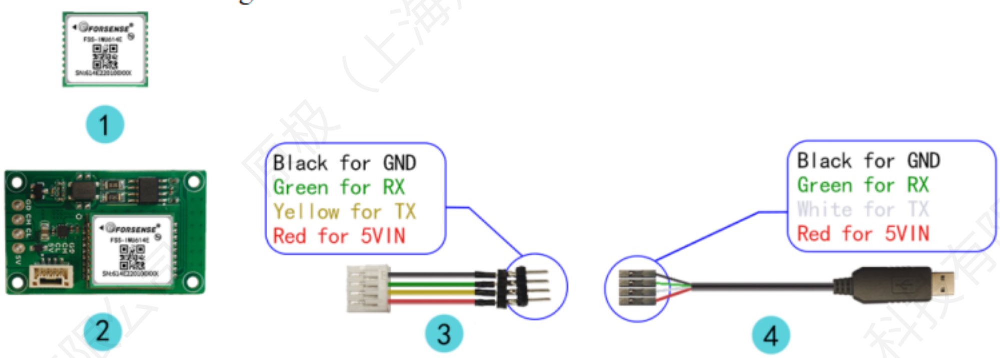
	Name	Quantity
1	IMU 614E Series Module	1
	Accessories Name	Quantity
2	RS485 Test Substrates	1
3	RS485 Test Substrates and Wire	1
4	RS485-USB Adapter	1

Fig. 27 614E CAN ver. SMD Test Substrates



	Name	Quantity
1	IMU 614E Series Module	1
	Accessories Name	Quantity
2	CAN Test Substrates	1
3	4-PIN Connector	1
4	USB to CAN Module	1

Fig. 28 614E TTL ver. SMD Test Substrates



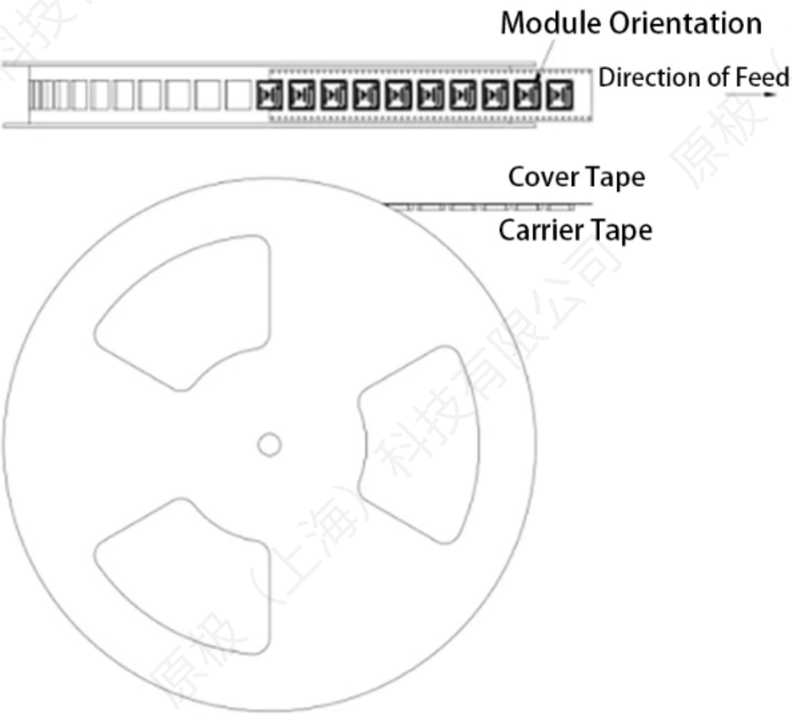
	Name	Quantity
1	IMU 614E Series Module	1
	Accessories Name	Quantity
2	TTL Test Substrates	1
3	4-PIN Connector	1
4	TTL Serial Cable	1

12. Packaging

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

12.1 Tape and Reel Packaging

Fig. 29 Tape and Reel Packaging Diagram



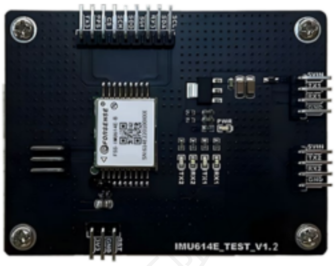
Reel Size: 13inch (OD 330 x ID 100 x Thickness 37mm)

12.2 Carrier Tape

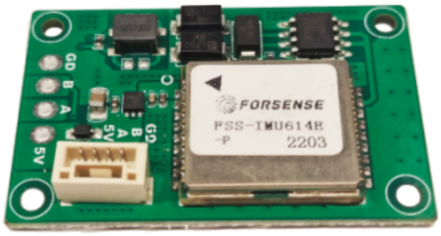
The IMU614E-B module is placed on the carrier tape in the position and orientation shown below before leaving the factory:

Fig. 30 Module Position and Orientation on Carrier Tape

13. Accessories



IMU614E-X Test Base Plate



SMD 485 IMU614E Test Base Plate

SMD CAN IMU614E Test Base Plate

SMD TTL IMU614E Test Base Plate

USB to CAN Module

TTL Serial Cable

14. Revision History

Version	Date	Status/Notes
Version 1.0	9/15/2023	First release
Version 1.1	10/7/2023	Updated the definition of coordinate system
Version 1.2	11/21/2023	Updated measurement ranges
Version 1.3	12/14/2023	Added accessories
Version 1.4	4/2/2024	Updated electrical characteristics
Version 1.5	2/26/2024	Updated reflow welding curves and ESD protection issues
Version 1.6	3/26/2024	Updated pin definitions
Version 1.7	5/10/2024	Updated the instrctions for upper computer connection
Version 1.8	6/7/2024	Updated I²C attitude output
Version 1.9	9/18/2024	Updated the steps for time-synchronization