



CX1S3 High Precision

User Manual

V1.0.1 2024.10



Safety Instruction

Before using the product, please read and follow the instructions of this manual carefully, and refer to relevant national and international safety regulations.

ΔAttention

Please do not disassemble or modify the lidar privately. If you need special instructions, please consult our technical support staff.

ΔLaser Safety Level

The laser safety of this product meets the following standards:

- IEC 60825-1:2014
 - 21 CFR 1040.10 and 1040.11 standards, except for the deviations (IEC 60825-1, third edition) stated in the Laser Notice No. 56 issued on May 8, 2019.
- Please do not look directly at the transmitting laser through magnifying devices (such as microscope, head-mounted magnifying glass, or other forms of magnifying glasses).

Eye Safety

The product design complies with Class 1 human eye safety standards. However, to maximize self-protection, please avoid looking directly at running products.



ΔSafety Warning

In any case, if the product is suspected to have malfunctioned or been damaged, please stop using it immediately to avoid injury or further product damage.

Housing

The product contains high-speed rotating parts, please do not operate unless the housing is fastened. Do not use a product with damaged housing in case of irreparable losses. To avoid product performance degradation, please do not touch the photomask with your hands.

Operation

This product is composed of metal and plastic, which contains precise circuit electronic components and optical devices. Improper operations such as high temperature, drop, puncture or squeeze may cause irreversible damage to the product.

Power Supply

Please use the connecting cable and matching connectors provided with the lidar to supply power. Using cables or adapters that are damaged or do not meet

the power supply requirements, or supply power in a humid environment may cause abnormal operation, fire, personal injury, product damage, or other property loss.

Light Interference

Some precise optical equipment may be interfered with by the laser emitted by this product, please pay attention when using it.

Vibration

Please avoid product damage caused by strong vibration. If the product's mechanical shock and vibration performance parameters are needed, please contact us for technical support.

Radio Frequency Interference

The design, manufacture and test of this product comply with relevant regulations on radiofrequency energy radiation, but the radiation from this product may still cause other electronic equipment to malfunction.

Deflagration and Other Air Conditions

Do not use the product in any area with potentially explosive air, such as areas where the air contains high concentrations of flammable chemicals, vapours or particles (like fine grains, dust or metal powder). Do not expose the product to the environment of high-concentration industrial chemicals, including near evaporating liquefied gas (like helium), so as not to impair or damage the product function.

Maintenance

Please do not disassemble the lidar without permission. Disassembly of the product may cause its waterproof performance to fail or personal injury.

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1. Product Profile

1.1. Overview

The CX1S3, a single-line hybrid solid-state LiDAR, is developed based on the CX126S3 hybrid solid-state LiDAR. With the advantages of high scanning speed, high resolution, and high reliability, the CX1S3 well meets the requirements of 2D modeling detection and obstacle avoidance in industrial scenarios, and provides accurate distance and reflectivity information with a range accuracy of ± 1.5 cm.

1.2. Mechanism

The CX1S3 hybrid solid-state lidar adopts the Time of Flight method. The lidar starts timing (t_1) when the laser pulses are sent out. And when the laser encounters the target object and the light returns to the sensor unit, the receiving end stops timing (t_2).

$$\text{Distance} = \text{Speed of Light} * (t_2 - t_1) / 2$$

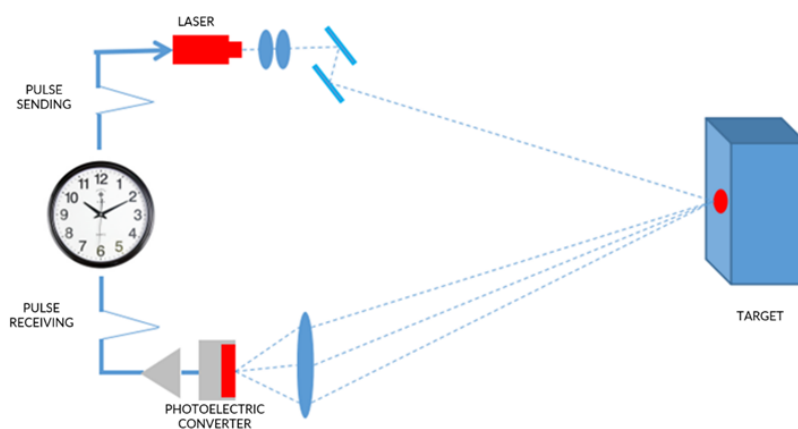


Figure 1.1 Mechanism of the CX1S3 Lidar

1.3. Specification

Table 1.1 Specifications of CX1S3-High Precision

Model	CX1S3G-R-2.0-50-A (high precision)
Detection Method	ToF
Wavelength	905 nm
Laser Class	Class 1 (eye-safe)
Channels	1
Detection Range	50 m (@10% reflectivity)

Range Accuracy	± 1.5 cm				
Data Point Generating Rate (Single Echo Mode)	60,000 pts/sec				
Horizontal FOV	120°				
Scanning Frequency (Hz)	30	60	90	120	150
Horizontal Angular Resolution	0.06°	0.12°	0.18°	0.24°	0.3°
Communication Interface	Industrial Fast Ethernet				
Time Source	GPS				
Operating Voltage	9 V ~32 VDC				
Operating Temperature	-40°C ~ +85°C				
Storage Temperature	-40°C ~ +105°C				
Shock Test	500 m/sec ² , lasting for 11 ms				
Vibration Test	5 Hz ~2000 Hz, 3G rms				
IP Grade	IP 6K9K				
Dimensions	110*100.4*45 mm				
Weight	<1 kg				

1.4. Dimensions

There are 4 mounting holes and 2 positioning holes at the bottom of CX1S3 lidar. Four M4*10 (hexagon socket head cap screws) mechanical screws with spring washers and flat washers are needed for locking and fixing the lidar. See the outline dimension drawing shown in Figure 1.2.

Mounting requirements: (1) Mounting screws: M4*10, hexagon socket head cap screws; (2) Screws: GB70; (3) Spring washers: GB93; (4) Flat washers: GB93.1; (5) Electric Torque Screwdriver: 5 NM.

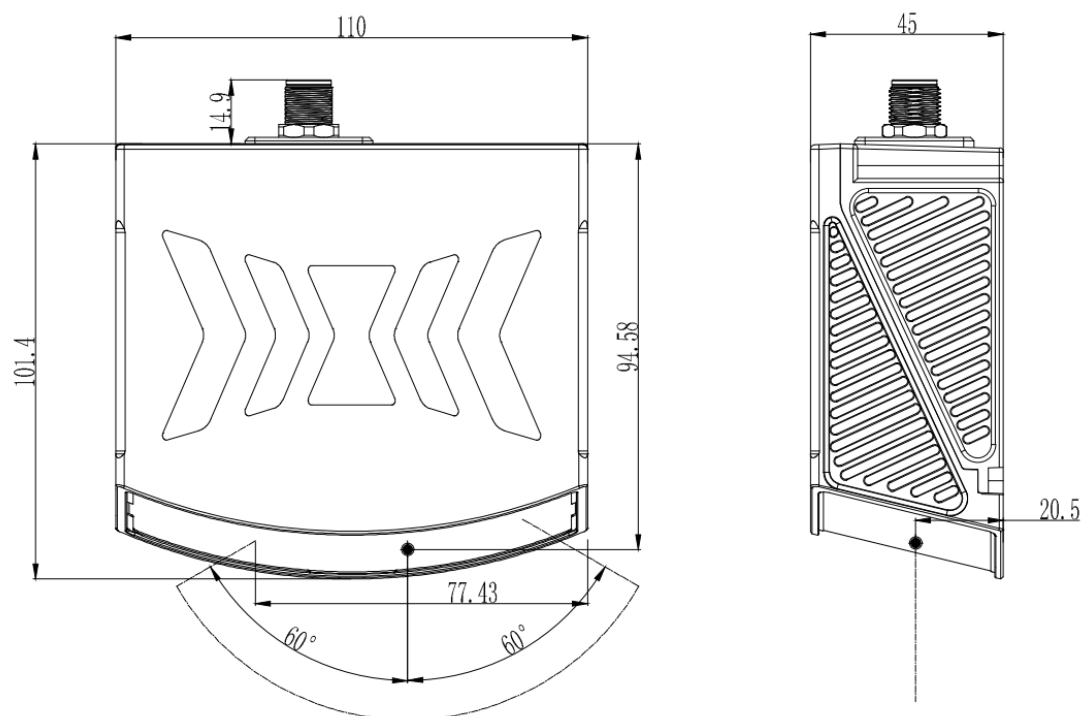


Figure 1.2 CX1S3 Lidar Dimension

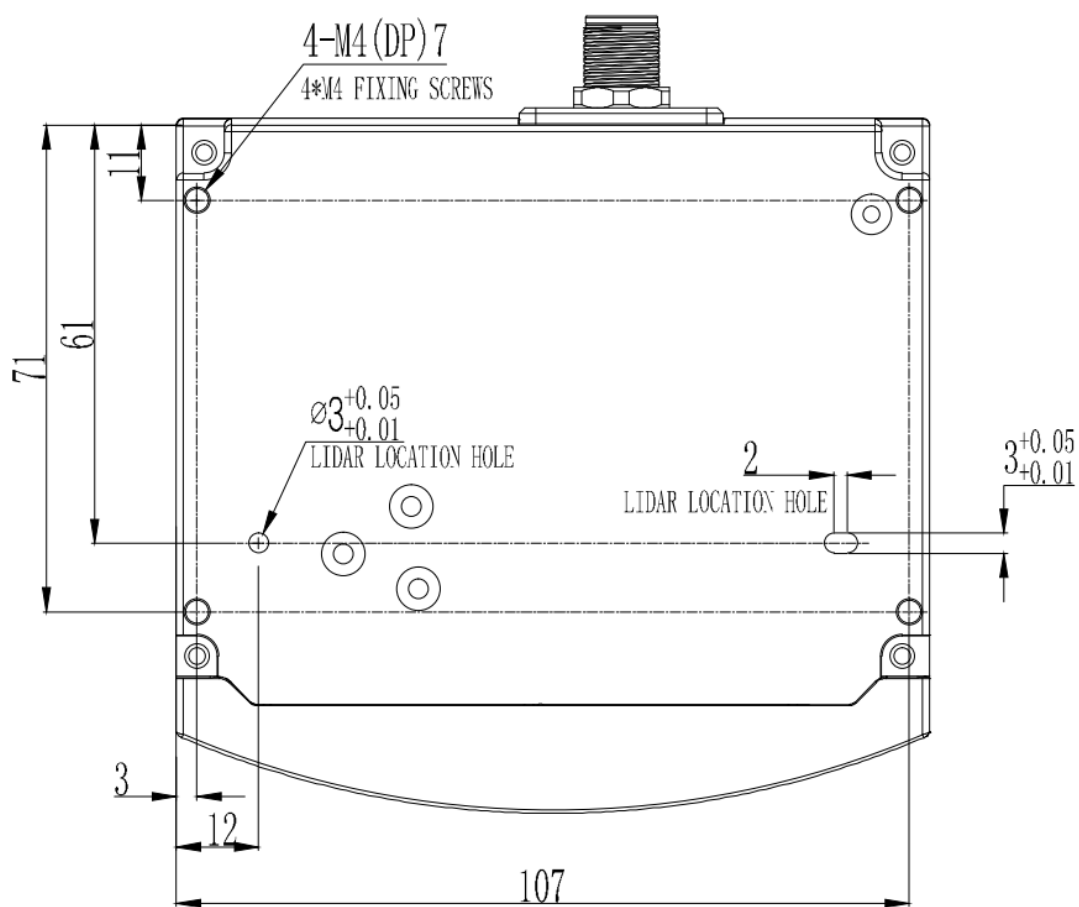


Figure 1.3 CX1S3 Mounting Dimensions

The CX1S3 lidar utilizes mirror rotation and special optical design to scan 120°

horizontally. Figure 1.4 shows the optical center position, which is also the coordinate origin of the point cloud display software on the host computer.

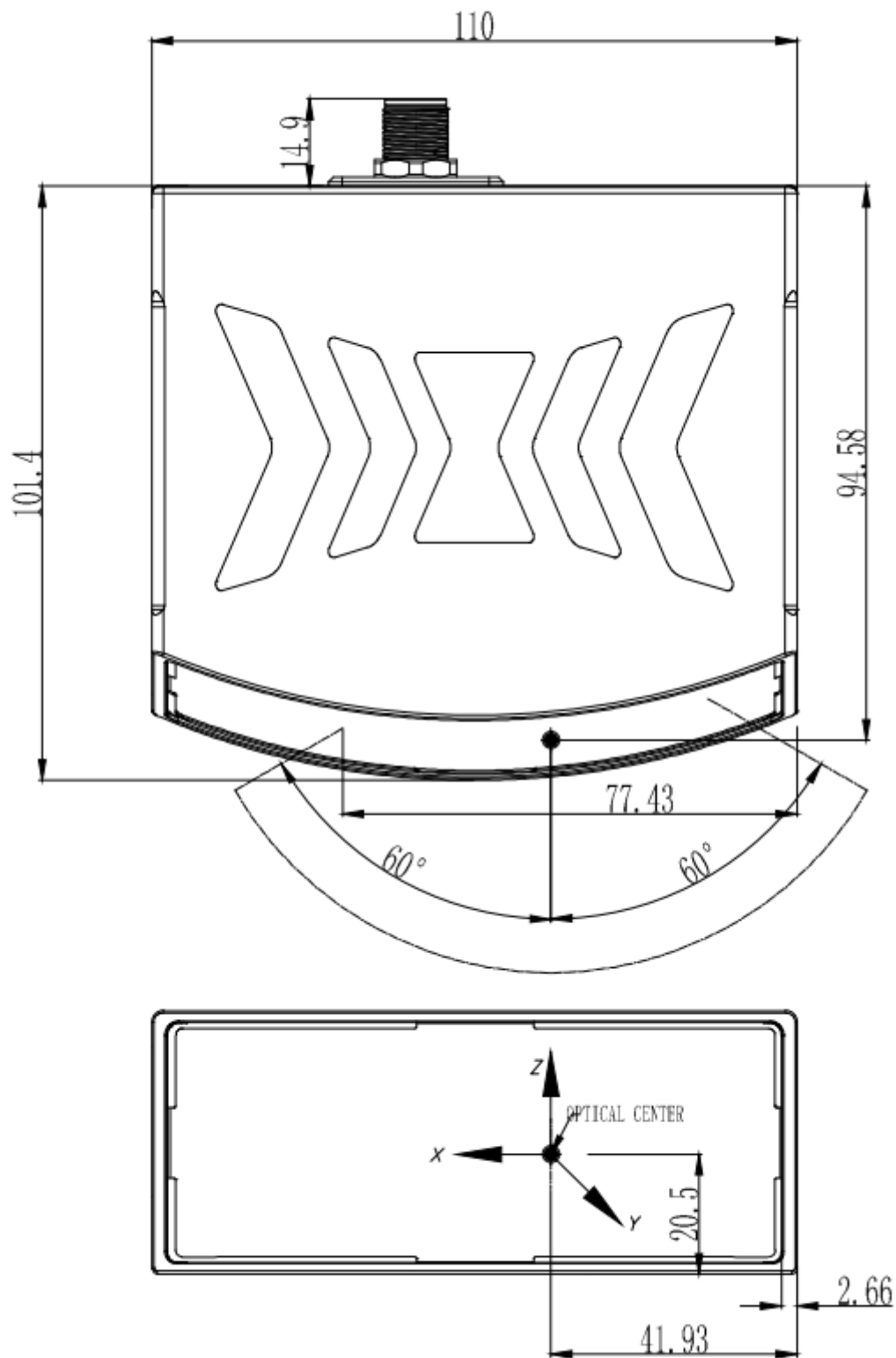


Figure 1.4 The Optical Center of the CX1S3

2. Electrical Interface

2.1. Power Supply

The power input range of the CX1S3 lidar is 9 V~32 VDC. If other DC power supply is adopted, the recommended output voltage of the power supply is 24 VDC. Please note that DC 9 V and 32 V are short-term power supply in extreme environment, which cannot be used as working voltage. When the voltage output fluctuates, the lidar may not be able to work normally.

The maximum output current should be ≥ 2 A (the lidar requires a large instantaneous current when starting, and a small starting current may cause its failure to start normally). The output ripple noise should be <120 mVp-p and output voltage accuracy $<5\%$.

The higher the power supply voltage and the stronger the discharge capacity, the more severe the impact on the lidar (such as powered by direct vehicle power supply without adapters and interface boxes). Therefore, it is necessary to use high-power TVS transient suppression diodes to protect the lidar to avoid damage.

The line length of the lidar power supply is 5~10 m, and the power supply voltage needs to be over 12 V but less than 32 V. If the line length is more than 10 m, then it is recommended to use a 220 V AC adapter nearby for power supply (DC long-distance power supply is not recommended).

2.2. Electrical Interface

There interface model of the CX1S3 lidar is SZCNT12-M12-Z08A118A, the definition of the interfaces is shown as below:

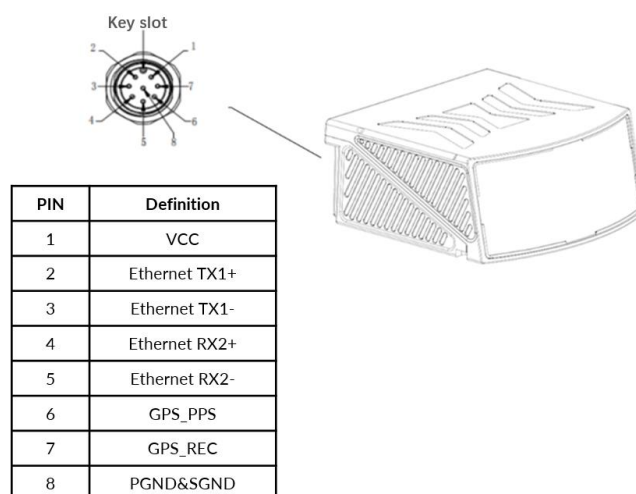


Figure 2.1 The Interface of CX1S3

Table 2.1 Pin Definition of the 8-Pin Male Connector

Pin	Definition	Level	Description
1	VIN	9~32 V	Power+
2	Eth_TX1+	-1~1 V	Ethernet data flow: lidar→external devices
3	Eth_TX1-	-1~1 V	Ethernet data flow: lidar→external devices
4	Eth_RX2+	-1~1 V	Ethernet data flow: external devices→lidar
5	Eth_RX2-	-1~1 V	Ethernet data flow: external devices→lidar
6	GPS_PPS	-13~13 V	GPS Sync Pulse/External Sync Pulse
7	GPS_Rec	-13~13 V	GPS latitude & longitude, hour/minute/second
8	GND	0 V	Power-&GPS signal ground

There are different methods available for you to choose to connect the lidar, see the details below.

(1) Adapter Cable (Default)

In order to facilitate wiring, Leishen Intelligent provides an adapter cable. The cable and its wiring definition are as follows:

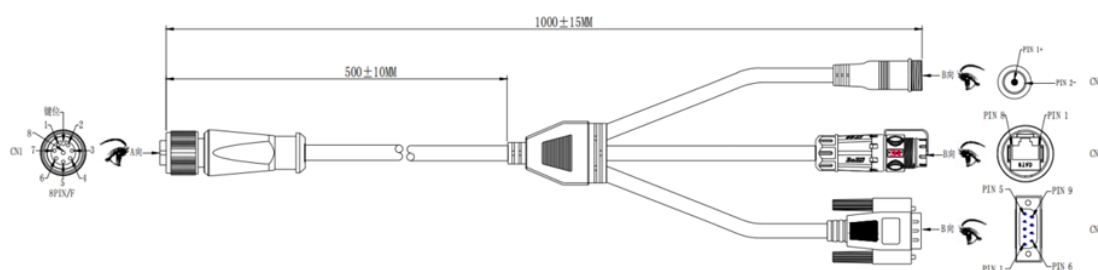


Figure 2.2 3-in-1 Power Supply and Ethernet cable

Table 2.2 Wiring Definition of the Adapter Cable

CN 1	Definition	Color	CN 2	Color	CN3	Color	CN4	Color	Description
1	VCC	Red	1	Red					Power+
2	Eth TX1+	Orange			1	Orange/White			Ethernet data flow: lidar→external devices
3	Eth TX1-	Light orange			2	Orange			Ethernet data flow: lidar→external devices

4	Eth RX2+	Light blue			3	Green/White			Ethernet data flow: external devices→lidar
5	Eth RX2-	Blue			6	Green			Ethernet data flow: external devices→lidar
6	GPS_PPS	Yellow					2	Yellow	GPS Sync Pulse/External Sync Pulse
7	GPS_Rtc	White					3	White	GPS latitude & longitude, hour/minute/second
8	GND	Black	2	Black			5	Black	Power-&GPS signal ground

Table 2.3 Interface Definition of the Adapter Cable

S/N	Connector	Note
CN 1	Lidar Connecting Port	Aviation terminal, model: L102-M12-T08A02M
CN 2	Power Port	Connect to external power supply, connector specification: DC 5.5*2.1 mm
CN 3	Standard Ethernet Port	Fast Ethernet, standard RJ45 connector with standard 1236 wiring scheme
CN 4	Timing Synchronization Port	DB-9 connector, REC baud rate: 9600 bps; the recommended PPS pulse width is to exceed 1 ms, period: 1s; PPS and REC signals are compatible with both TTL and RS232 levels

Note: Pin 2 of CN 2 and pin 5 of CN 4 connect to the same ground wire (unit: mm).

(2) Interface Box (Optional)

To facilitate the testing and connection of connectors, the CX1S3 lidar can also be equipped with an interface box (optional), which is not a necessary accessory for lidar operation. On the interface box, there is a Φ 5.5*2.1 mm DC socket, an indicator light, an RJ45 Ethernet port and a 6-pin GPS port, as shown in the figure below.

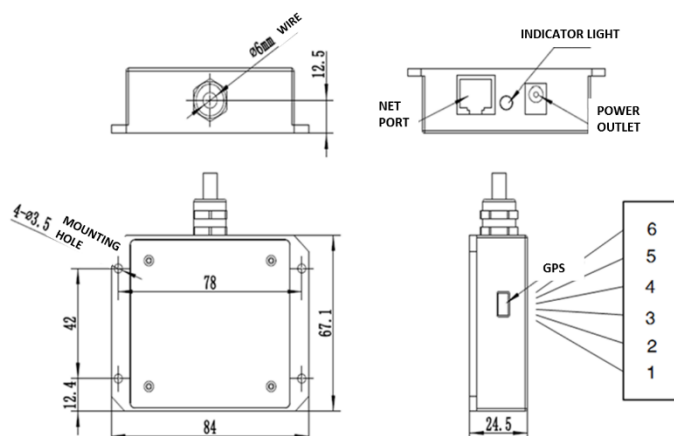


Figure 2.3 Interface Box

The GPS interface socket specification of the interface box is SM06B-SRSS-TB of JST, and the recommended plug interface for the external GPS module is SHR-06V-S-B of JST. The interface definitions are as follows:

Table 2.4 GPS Interface Definition

PIN	Function Definition	I/O	Requirement
1	PPS Sync Signal	I	TTL level ranges from 3.3 V to 12 V, its period is 1 second, and the recommended pulse width is over 1 ms
2	GPS Power Supply 5 V	O	No hot plug or unplug
3	GPS_GND	O	Good contact
4	GPS (latitude/longitude, hour/ minute/second)	I	REC baud rate is 9600 bps, compatible with TTL and RS232 levels
5	GPS_GND	O	Good contact
6	NC	-	-

3. Get Ready

3.1. Lidar Connection

To get ready for the lidar operation, please connect the lidar, host computer, and power supply. Also, please remove the protective film on the optical windows in case the detecting performance is influenced.

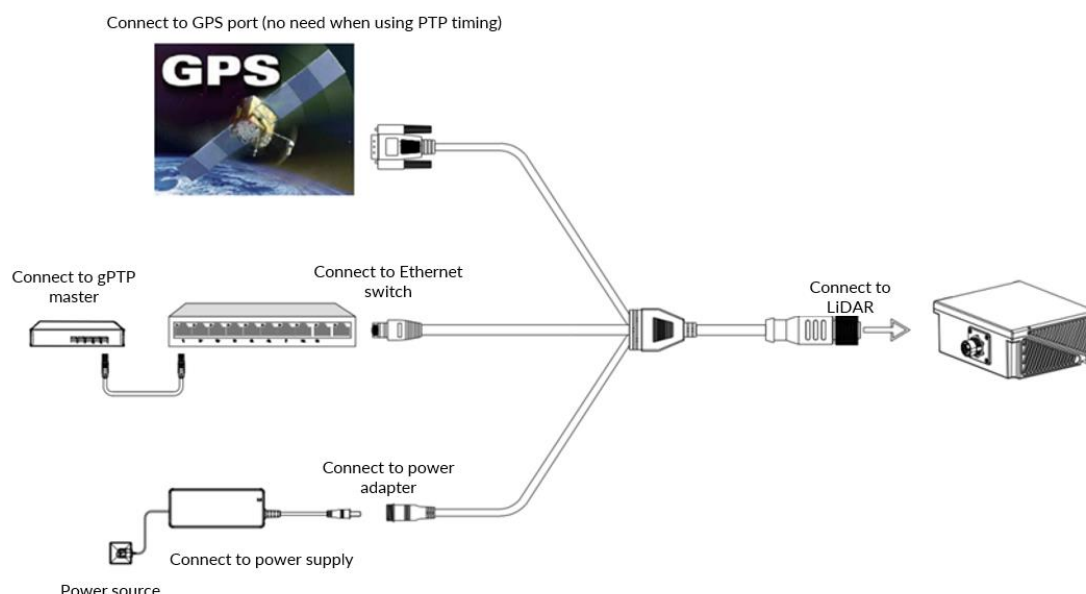


Figure 3.1 Connect the LiDAR and Other Devices

Note: Under any circumstances, it is forbidden to plug and unplug the aviation terminal with power on. When plugging and unplugging the GPS module from the GPS port of the interface box, or connecting or disconnecting the signal from the GPS pin of the cable, please make sure that the lidar is powered off.

The default IP address and port number of the lidar network are as follows:

Table 3.1 Default Lidar Network Configuration

	IP Address	UDP Device Package Port	UDP Data Package Port
Lidar	192.168.1.200	2368 (Fixed)	2369 (Fixed)
Computer	192.168.1.102	2369	2368

Note:

The lidar IP (local IP) and the computer IP (destination IP) cannot be set to the same, otherwise the lidar will not work normally.

In the multicast mode, no two destination ports should be set to the same port number.

The lidar IP range are **forbidden** to be set to

- 1) Class D IP address (multicast address: i.e. 224.0.0.0~ 239.255.255.255)
- 2) Class E IP address (reserved address: i.e. 240.0.0.0~ 255.255.255.254)
- 3) Broadcast address (i.e. 255.255.255.255 and x.x.x.255 for each network segment)
- 4) Special class IP address (0.x.xx and 127.xxx)

The lidar destination IP are **forbidden** to be set to

- 1) Class E IP address (i.e. 240.0.0.0 to 255.255.255.254)
- 2) Special class address (0.x.xx and 127.x.x.x)

When connecting to the lidar, if the computer IP and the lidar IP are in different network segments, you need to set the gateway; if they are in the same network segment, you only need to set different IPs, for example: 192.168.1.x, and the subnet mask is 255.255.255.0. If you need to find the Ethernet configuration information of the lidar, please connect the lidar to the computer and use “Wireshark” to capture the ARP packet of the device for analysis. For the feature identification of the ARP packet, see the figure below.

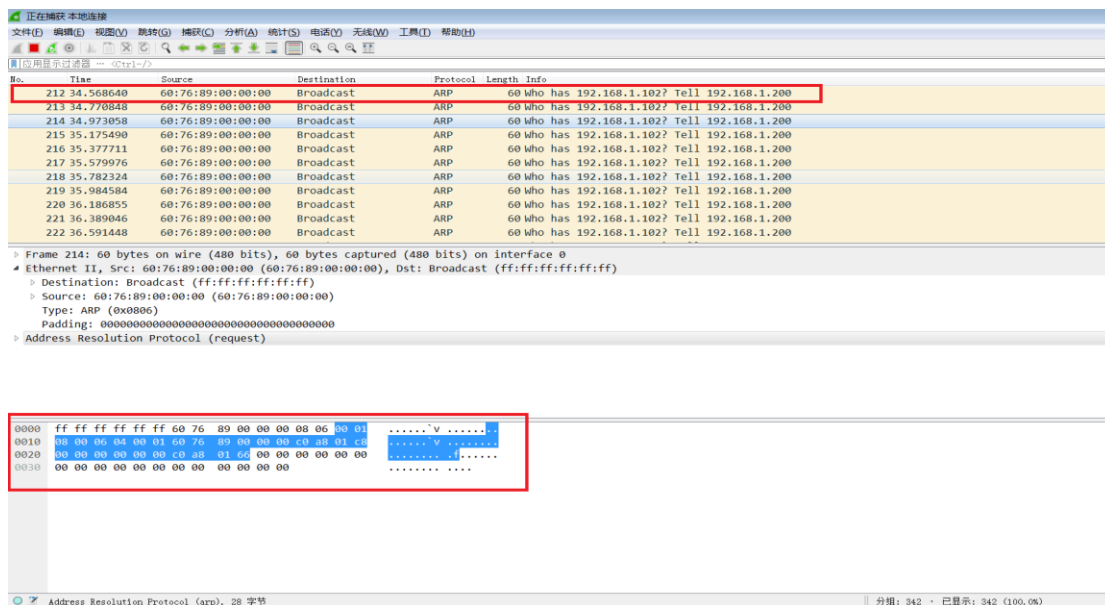



Figure 3.2 Wireshark captures APR packets

3.2. Operation Under Windows OS

Upper Computer Platform (Windows Client): a host computer software to view point cloud image under Windows operating system, which is also referred to as “point cloud display software”. Simple functions like parameter configuration, lidar test and fault detection can be realized through the software, too. For more information on how to use the software, please refer to the Upper Computer Platform Operation manual is included in the LiDAR service package or you can

click on the icon  in the upper right corner of the software to jump to the operation manual.

- Operating Environment

This software can only run under the Windows x64 operating system at present. The computer configuration requirements for installing the software are: CPU: Intel(R) Core (TM) i5 or higher; Graphics Card: NVIDIA GeForce GTX750 or higher achieves the best effect, otherwise the display of the point cloud may be affected. And the computer graphics card must support OpenGL 2 or higher graphics acceleration to display the point cloud normally.

- Supplemental Software

To use the Upper Computer Platform, it is necessary to install the **Npcap** third-party library which is included in the Upper Computer Platform installation files package.

3.3. ROS Driver Operation Under Linux OS

3.3.1. Hardware Connection and Test

Step 1. Connect the lidar to the internet and power supply

Step 2. Set the computer wired IP according to the destination IP of the lidar, (whether the computer wired IP is set successfully can be checked by the ifconfig command, as shown in the figure, the destination IP is 192.168.1.102)

```
ls@lidar:~$ ifconfig
enp3s0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.1.102 netmask 255.255.255.0 broadcast 192.168.1.255
    inet6 fe80::8f7d:d4f9:2c6a:850d prefixlen 64 scopeid 0x20<link>
    ether f0:2f:74:a1:99:53 txqueuelen 1000 (以太网)
    RX packets 377598 bytes 78074323 (78.0 MB)
    RX errors 0 dropped 1272 overruns 0 frame 0
    TX packets 958224 bytes 1418001117 (1.4 GB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

Figure 3.3 ifconfig Command Feedback

Note: The default destination IP of the lidar is 192.168.1.102, and the computer must be configured according to the actual lidar destination IP. After setting the IP for the first time, please restart the lidar.

Step 3. After the lidar is powered on and restarted, check the wired connection icon of the computer to see whether it is connected properly.

Step 4. Open the terminal: ping the lidar IP, and test whether the hardware is connected normally. If the ping is successful, then the data is received,

otherwise check the hardware connection.

Step 5. Use “sudo tcpdump -n -i eth0” (here eth0 is the name of the wired network device, see the device name of ifconfig wired connection display for details) to view the data packets sent by the lidar (as shown in the figure, there are 1212-byte data packets sent by the lidar to the destination, which means that the lidar data is sent normally).

```
ls@lidar:~$ sudo tcpdump -ni enp3s0
[sudo] ls 的密码:
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on enp3s0, link-type EN10MB (Ethernet), capture size 262144 bytes
10:41:44.738778 IP 192.168.1.201.2369 > 192.168.1.102.2370: UDP, length 1212
10:41:44.739965 IP 192.168.1.201.2369 > 192.168.1.102.2370: UDP, length 1212
10:41:44.741178 IP 192.168.1.201.2369 > 192.168.1.102.2370: UDP, length 1212
10:41:44.742370 IP 192.168.1.201.2369 > 192.168.1.102.2370: UDP, length 1212
10:41:44.743707 IP 192.168.1.201.2369 > 192.168.1.102.2370: UDP, length 1212
10:41:44.744850 IP 192.168.1.201.2369 > 192.168.1.102.2370: UDP, length 1212
10:41:44.746045 IP 192.168.1.201.2369 > 192.168.1.102.2370: UDP, length 1212
10:41:44.747198 IP 192.168.1.201.2369 > 192.168.1.102.2370: UDP, length 1212
10:41:44.748452 IP 192.168.1.201.2369 > 192.168.1.102.2370: UDP, length 1212
10:41:44.749645 IP 192.168.1.201.2369 > 192.168.1.102.2370: UDP, length 1212
10:41:44.750761 IP 192.168.1.201.2369 > 192.168.1.102.2370: UDP, length 1212
```

Figure 3.4 sudo tcpdump -n -i eth0 Command Feedback

3.3.2. Software Operation Example

Note: The following instructions are for reference only. Please refer to the README file of the ROS drive bag in the customer service pack for details.

Step 1. Establish a workspace and build a compilation environment

```
mkdir -p ~/leishen_ws/src
```

```
cd ~/leishen_ws
```

Note: The workspace can be named arbitrarily. For example, “leishen_ws” can be changed to any name.

Step 2. Download the lidar driver and dependency package

The driver and dependency package can also be obtained directly from our website or customer service. Copy the obtained driver file to the newly created workspace “leishen_ws/src”, and use the “tar -xvf” command to decompress it.

Step 3. Compile and package

```
cd ~/leishen_ws
```

```
catkin_make
```

Step 4. Run the program

```
source ~/leishen_ws /devel/setup.bash
```

```
roslaunch lsidar_ch_decoder lsidar_ch.launch
```

Reopen a terminal again and execute the following command:

```
roslaunch rviz rviz
```

Note 1): If the lidar destination port and motor speed are modified, please open “lsidar_ch.launch” to modify the configuration accordingly. The default data packet port is 2368, device packet port is 2369, IP address is 192.168.1.200.

Note 2): If timeout appears, it means that the driver has no data reception. Please check the hardware connection.

Note 3): If steps 1, 2, and 3 have been completed, next time after the “Displays Window” is reopened, start directly from step 4.

Step 5. Display the data detected by the lidar

In the “Displays Window” that pops up, modify the value of “Fixed Frame” to “laser_link”. Click the “Add” button at the same time, and click “PointCloud2” under “By topic” to add a multi-line point cloud node.

3.4. Point Cloud Data Parsing

If you need to parse lidar data, please follow the steps below:

Step 1. Parse the data package to obtain the relative horizontal angle, ranging information, intensity data and time information of each laser;

Step 2. Read the device package to obtain information such as the time information (GPS or PTP/gPTP time synchronization) and the current configuration of the device;

Step 3. Obtain the vertical angle of each line according to the laser beam distribution;

Step 4. According to the distance measurement value, vertical angle and the calculated horizontal angle of the point cloud data, the XYZ coordinate values are obtained;

Step 5. If necessary, calculate the precise time of the point cloud data through time information, microsecond timestamp, light-emitting time of each laser, as well as single and dual echo modes;

Step 6. Reconfigure information such as Ethernet, PPS synchronization horizontal angle, motor speed and other information as needed, and pack the configuration package protocol.

4. Communication Protocol

Lidar data output and configuration use Fast Ethernet UDP/IP communication protocol. There are 3 UDP packet protocols, among which MSOP packet length is 1254 bytes (42 bytes Ethernet header and 1212 bytes payload). DIFOP and UCWP are 1248 bytes (42 bytes Ethernet header and 1206 bytes payload) Lidar supports unicast, broadcast and multicast communication.

The communication protocols of the lidar are:

Main data Stream Output Protocol (MSOP): outputting the distance, angle, intensity and other information measured by the lidar;

Device Information Output Protocol (DIFOP): outputting the current status of lidar and accessory equipment and various configuration information;

User Configuration Write Protocol (UCWP): setting the configuration parameters of the lidar.

Table 5.1 UDP Packet Protocol

Protocol Name	Abbr.	Function	Length	Transmission Interval
Main data Stream Output Protocol	MSOP	Outputting measured data and timestamp	1254 bytes	About 1.425 ms (single echo); About 0.908 ms (dual echo)
Device Information Output Protocol	DIFOP	Outputting parameter configuration and status information	1248 bytes	1s (for 1 packet)
User Configuration Write Protocol	UCWP	Inputting user configured device parameters	1248 bytes	Not Fixed

4.1. MSOP Protocol

The data package outputs measured data such as the angle value, distance value, intensity value, and timestamp of the point cloud. The data of the package adopts Big-Endian mode.

The data package includes a 42-byte Ethernet header and a 1212-byte payload, with a total length of 1254 bytes.

Single echo mode: The payload consists of 1197 bytes of point cloud data and 15 bytes of additional information (including 3 bytes reserved, 6 bytes of UTC time of year, month, day, hour, minute and second, 4 bytes of Timestamp and 2 bytes of Factory).

Dual echo mode: The payload consists of 1199 bytes of point cloud data and 13

bytes of additional information (including 1 byte reserved, 6 bytes of UTC time of year, month, day, hour, minute and second, 4 bytes of Timestamp and 2 bytes of Factory).

4.1.1. Format

The CX1S3 lidar supports single echo mode which measures the most recent echo value and dual echo mode which measures the most recent and second recent echo values.

Single Echo Mode

Each MSOP data packet contains 1212 bytes of data. Each packet of data contains 171 points, that is, $171 \times 7 = 1197$ bytes, and the frame tail is 15 bytes (including 3 bytes reserved, 6 bytes of UTC time of year, month, day, hour, minute and second, 4 bytes of Timestamp and 2 bytes of Factory). See the table below:

Header (42 bytes)		
Measure point 1		
Measure point 2		
Measure point 3		
.....		
Measure point 171		
Reserved (3 bytes)		
UTC Time (6 bytes)	Timestamp (4 bytes)	Factory (2 bytes)

Note: The lidar displays the point cloud image by frame. In the MSOP data package, if the data of the first point is FF AA BB CC DD EE 11, then it is the start mark of the point cloud frame (the lidar scans to the far right at this time). The start mark can be anywhere in a packet of data, not necessarily the packet header. This point is not displayed as point cloud data, but is only a judgment mark for the beginning of an image frame.

Dual Echo Mode

Each MSOP data packet contains 1212 bytes of data. Each packet of data contains 109 points, that is, $109 \times 11 = 1199$ bytes, and the frame tail is 13 bytes (including 1 byte reserved, 6 bytes of UTC time of year, month, day, hour, minute and second, 4 bytes of Timestamp and 2 bytes of Factory). See the table below:

Header (42 bytes)		
Measure point 1		

Measure point 2		
Measure point 3		
.....		
Measure point 109		
Reserved (1 byte)		
UTC Time (6 bytes)	Timestamp (4 bytes)	Factory (2 bytes)

Note: The lidar displays the point cloud image by frame. In the MSOP data package, if the data of the first point is FF AA BB CC DD EE 11 22 33 44 55, then it is the start mark of the point cloud frame (the lidar scans to the far right at this time). The start mark can be anywhere in a packet of data, not necessarily the packet header. This point is not displayed as point cloud data, but is only a judgment mark for the beginning of an image frame.

4.1.2. Data Package Parameter Description

Ethernet Header

The Ethernet header has a total of 42 bytes, as shown in the table below.

Ethernet Header: 42 Bytes				
Name	S/N	Information	Offset	Length (byte)
Ethernet II MAC	0	Destination	0	6
	1	Source	6	6
Ethernet Packet Type	2	Type	12	2
Internet Protocol	3	Version, Header Length, Differentiated Services, Field, Total Length, Identification, Flags, Fragment Offset, Time to Live, Protocol, Header, Checksum, Source IP Address, Destination IP Address	14	20
UDP Port Number	4	Lidar Port (0x0941, represent 2369)	34	2
	5	Computer Port (0x0940, represent 2368)	36	2
UDP Length & Sum Check	6	Length (0x04BE, represent 1214 bytes)	38	2
	7	Sum Check	40	2

Subframe (Single Echo Mode)

The subframe is the effective data area of the data packet, which contains a total of 1197 bytes, including 171 points, that is, $171 \times 7 = 1197$ bytes. Take the first measure point as an example:

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Line_num	Horizontal angle[15:8]	Horizontal angle[7:0]	Distance[23:16]	Distance[15:8]	Distance[7:0]	strength

Byte 1 represents the line number, which is 0x00 by default.

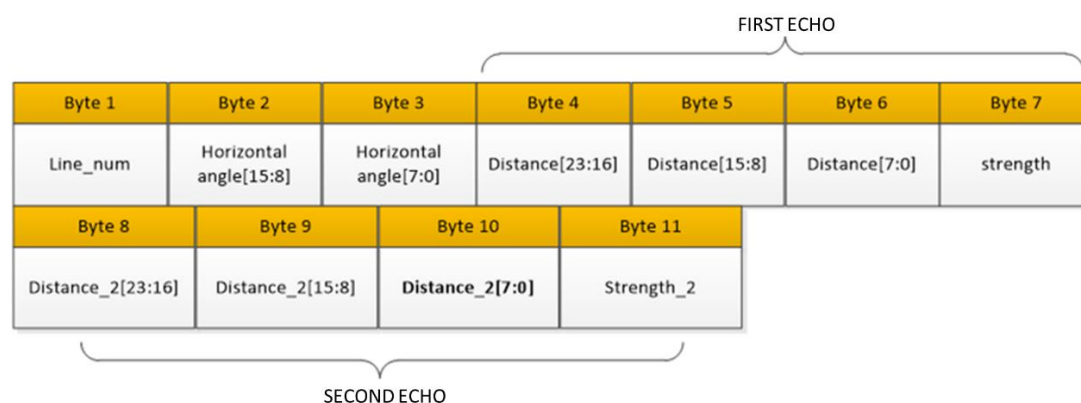
Byte 2 and **Byte 3** represent the horizontal angle, whose data are stored in Big-Endian mode. The unit is 0.01 degrees. For example, 0x11AD=4525, that is 45.25°.

Byte 4, **Byte 5**, and **Byte 6** represent the distance value. Their data are stored in Big-Endian mode. The two high bytes are the integer part, whose unit is “cm”; and the last byte is the decimal part, whose unit is 1/256 cm. To analyze the distance value, for example: the distance value in the obtained data packet is represented by the hexadecimal number 0x02,0x18,0x32, and the first two bytes are composed of 16-bit unsigned data, that is: 0x0218, which is converted to decimal distance value: 536 cm. The last byte is the decimal part, 0x32 equals 50 in decimal, that is, $50 \times 1/256 \text{ cm} = 0.1953125 \text{ cm}$. Then the two parts add up to 536.1953125 cm.

Byte 7 represents echo strength, and the value range is 0~255. (Echo strength can reflect the energy reflection characteristics of the measured object in the actual measurement environment. Therefore, the echo strength can be used to distinguish objects with different reflection characteristics.)

Subframe (Dual Echo Mode)

The subframe is the effective data area of the data packet, which contains a total of 1199 bytes, including 109 points, that is, $109 \times 11 = 1199$ bytes. Take the first measure point as an example:



Byte 1 represents the line number, which is 0x00 by default.

Byte 2 and **Byte 3** represent the horizontal angle, whose data are stored in Big-Endian mode. The unit is 0.01 degrees. For example, 0x11AD=4525, that is 45.25°.

Byte 4, **Byte 5**, and **Byte 6** represent the first echo distance value. Their data are stored in Big-Endian mode. The two high bytes are the integer part, whose unit is “cm”; and the last byte is the decimal part, whose unit is 1/256 cm. To

analyze the distance value, for example: the distance value in the obtained data packet is represented by the hexadecimal number 0x02,0x18,0x32, and the first two bytes are composed of 16-bit unsigned data, that is: 0x0218, which is converted to decimal distance value: 536 cm. The last byte is the decimal part, 0x32 equals 50 in decimal, that is, $50 \times 1/256 \text{ cm} = 0.1953125 \text{ cm}$. Then the two parts add up to 536.1953125 cm.

Byte 7 represents the first echo strength, and the value range is 0-255. (Echo strength can reflect the energy reflection characteristics of the measured object in the actual measurement environment. Therefore, the echo strength can be used to distinguish objects with different reflection characteristics.)

Byte 8, Byte 9 and Byte 10 represent the second echo distance value. Their data are stored in Big-Endian mode. The two high bytes are the integer part, whose unit is “cm”; and the last byte is the decimal part, whose unit is 1/256 cm. The distance value analysis method is the same as the first echo.

Byte 11 represents the second echo strength, and the value range is 0-255. (Echo strength can reflect the energy reflection characteristics of the measured object in the actual measurement environment. Therefore, the echo strength can be used to distinguish objects with different reflection characteristics) .

Azimuth

The resolution of the horizontal angle value is determined according to the motor speed. The horizontal angle defines the right side of the lidar as 0°, the left side as 180°, and the vertical direction as 90°. The range of the lidar’s horizontal direction is 30° to 150°, as shown in the figure below.

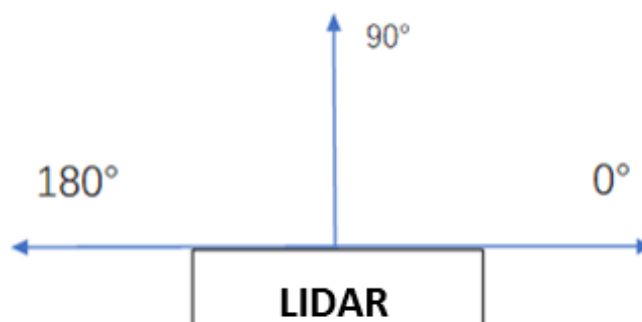


Figure 5.1 The Azimuth of the Lidar

Additional Information

The additional information of the single echo mode is 15 bytes in length, including 3 bytes reserved, 6 bytes of UTC time of year, month, day, hour, minute and second, 4 bytes of Timestamp and 2 bytes of Factory.

Additional Information (single echo mode): 15 bytes			
Name		Length (byte)	Function
Reserved		3	Reserved
UTC time		6	Year, month, day, hour, minute and second of the UTC time
Timestamp		4	Timestamp (ns)
Factory	Vendor Information	1	0x7D represents the CX1S3 lidar
	Echo Information	1	0x1 represents single echo lidar 0x2 represents dual echo lidar

The additional information of the dual echo mode is 13 bytes in length, including 1 byte reserved, 6 bytes of UTC time of year, month, day, hour, minute and second, 4 bytes of Timestamp and 2 bytes of Factory.

Additional Information (dual echo mode): 13 bytes			
Name		Length (byte)	Function
Reserved		1	Reserved
UTC time		6	Year, month, day, hour, minute and second of the UTC time
Timestamp		4	Timestamp (ns)
Factory	Vendor Information	1	0x7D represents the CX1S3 lidar
	Echo Information	1	0x1 represents single echo lidar 0x2 represents dual echo lidar

- 1) When there is an external synchronization device inputting PPS signal, the timestamp is generated according to the external synchronization PPS time as the cycle time, and the range of the timestamp is 0-999,999,999 (ns);
- 2) When there is no synchronization device inputting PPS signal, the lidar generates timestamp with a period of 1 second. The range of the timestamp is 0-999,999,999 (ns).

4.2. DIFOP Protocol

The device package outputs read-only parameters and status information such as version number, Ethernet configuration, motor speed and operating status, and fault diagnosis. The data of the device package adopts Big-Endian mode.

The device package includes a 42-byte Ethernet header and a 1206-byte payload, with a length of 1248 bytes. The payload is composed of an 8-byte frame header, 1196-byte data and a 2-byte frame tail.

Figure 5.2 Data Format of the Device Package

No.	Information	Offset	Length (Byte)	Note
0	DIFOP Identification Header	0	8	a5 ff 00 5a 11 11 55 55
1	Motor Speed	8	2	0x00: rotating; 0x01: stopped

2	Ethernet Configuration (IP, MAC, port, NTP)	10	22	
3	Ethernet Configuration (gateway, subnet mask)	32	8	
4	Lidar Rotation/ Stationary	40	2	
5	Device Flow Packet Interval	42	2	
6	Clock Source Selection	44	1	0: gps; 1: ptp (p2p+I2); 2: reserved; 3: ptp (p2p+udp4); 4: ptp (e2e+I2); 5: ptp (e2e+udp4). GPS timestamp unit: μ s; ptp timestamp unit: ns.
7	Standby Mode	45	1	0: normal operation; 1: standby mode
8	Phase Lock Enable	46	1	0: disabled; 1: enable
9	Phase Lock Angle Setting	47	2	The value is multiplied by 100 to write into the lidar; divide the value by 100 to read back
10	Reserved	49	2	
11	Reserved	51	1	
12	UTC Time	52	6	
13	Latitude and Longitude	58	22	
14	Left APD Board Temperature	80	2	$\text{temp} = (\text{data}/4096) * 2.5 * 100 - 50$
15	Left LD Board Temperature	82	2	$\text{temp} = (\text{data}/4096) * 2.5 * 100 - 50$
16	Left APD High Voltage	84	2	$\text{HV} = 281 - 0.0692142 * \text{data}$
17	Right APD Board Temperature	86	2	$\text{temp} = (\text{data}/4096) * 2.5 * 100 - 50$
18	Right LD Board Temperature	88	2	$\text{temp} = (\text{data}/4096) * 2.5 * 100 - 50$
19	Right APD High Voltage	90	2	$\text{HV} = 281 - 0.0692142 * \text{data}$
20	GPS Status	92	1	0: connected; 1: disconnected
21	PPS Status	93	1	0: connected; 1: disconnected
22	High Temperature Pause	94	2	
23	Cover Dirty Count	96	1	
24	Cover Dirty Alarm Message	97	1	
25	Cover Dirty Energy Value	98	2	
26	Left Threshold Adjustment Value	100	1	
27	Right Threshold	101	1	

	Adjustment Value			
28	Power Board Temperature	102	2	$\text{temp} = (\text{data} / 4096) * 2.5 * 100 - 50$
29	Main Control Board FPGA Temperature	104	2	$\text{temp} = (\text{data} * 503.975) / 4096 - 273.15$
30	Input Voltage	106	2	$\text{data} / 100.0$
31	12 V Voltage	108	2	$\text{data} / 100.0$
32	2.5 V Voltage	110	2	$\text{data} / 100.0$
33	1.8 V Voltage	112	2	$\text{data} / 100.0$
34	1.2 V Voltage	114	2	$\text{data} / 100.0$
35	Left Emitting Voltage	116	2	$\text{data} / 100.0$
36	Right Emitting Voltage	118	2	$\text{data} / 100.0$
37	Phase Lock Angle Offset	120	2	
38	Reserved	122	1	
39	Reserved	123	1081	
40	Tail	1204	2	Of, f0

Header is the device packet identification header, which is fixed as 0xA5,0xFF, 0x00,0x5A,0x11,0x11,0x55,0x55, and the first 4 bytes can be used as the packet inspection sequence. The tail is fixed as 0x0F, 0xF0.

4.3. UCWP Protocol

The UCWP configures the lidar's Ethernet, motor speed and other parameters, and the data of the configuration package adopts the Big-Endian mode.

The configuration packet includes a 42-byte Ethernet header and a 1206-byte payload, with a length of 1248 bytes. The payload is composed of an 8-byte Header, 1196-byte Data, and a 2-byte Tail.

Note: It is recommended that you configure the lidar through the Windows point cloud display software. Please do not pack and configure the lidar parameters by yourself.

Figure 5.3 Data Format of the Configuration Package

No	Information	Offset	Length (Byte)	Note
0	UCWP Identification Header	0	8	aa 00 ff 11 22 22 aa aa
1	Motor Speed	8	2	300, 600, 1200
2	Ethernet Configuration (IP, MAC, port, NTP)	10	22	
3	Ethernet Configuration (gateway, subnet mask)	32	8	
4	Lidar Rotation/ Stationary	40	2	0x00: rotating; 0x01: stopped (when rotating, the motor speed

				should be set)
5	Device Flow Packet Interval	42	2	
6	Clock Source Selection	44	1	0: gps; 1: ptp (p2p+l2); 2: reserved; 3: ptp (p2p+udp4); 4: ptp (e2e+l2); 5: ptp (e2e+udp4). GPS timestamp unit: μ s; ptp timestamp unit: ns.
7	Standby Mode	45	1	0: normal; 1: standby mode
8	Phase Lock Enable	46	1	0: disabled; 1: enable
9	Phase Lock Angle Settings	47	2	The value is multiplied by 100 to write into the lidar; divide the value by 100 to read back
10	Reserved	49	1155	
11	Tail	1204	2	Of, f0

Header is the configuration packet identification header, which is fixed as 0xAA,0x00,0xFF,0x11,0x22,0x22,0xAA,0xAA, and the first 4 bytes are used as the packet inspection sequence. The Tail of the frame is fixed as 0x0F,0xF0.

4.3.1. Configuration Parameters and Status Description

Here below are the configuration parameters and status description of specific lidar information.

Motor Speed

Motor Speed (2 bytes)		
S/N	Byte 1	Byte 2
Function	Speed: 30 Hz/60 Hz/90 Hz/120 Hz/150 Hz	

The motor rotates clockwise. Five speeds can be set: when it is set to 0x0BB8, the speed is 3000 RPM; when it is set to 0x0960, the speed is 2400 RPM; when it is set to 0x0708, the speed is 1800 RPM; when it is set to 0x04B0, the speed is 1200 RPM; when it is set to 0x0258, the speed is 600 RPM. Other setting data is not supported.

Ethernet Configuration

The length of the source IP address "IP_SRC" is 4 bytes and the length of the destination IP address "IP_DEST" is also 4 bytes. Each lidar has a fixed MAC address "MAC_ADDR" (6 bytes in length), which cannot be configured. Port 1 is the UDP data port number and port 2 is the UDP device port number.

Ethernet Configuration (22 bytes)								
S/N	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Function	IP_SRC				IP_DEST			
S/N	Byte 9	Byte 10	Byte	Byte	Byte	Byte	Byte	Byte

			11	12	13	14	15	16
Function	MAC_ADDR (Read Only)						Data Port: Port 1	
S/N	Byte 17	Byte 18	Byte 19	Byte 20	Byte 21	Byte 22		
Function	Device Port: Port 2		Reserved					

Lidar Rotation & Stationary

Lidar Rotation & Stationary (2 bytes)		
S/N	Byte 1	Byte 2
Function	0: Rotation; 1: Stationary	

0x0000 indicates that the lidar is rotating, and 0x0001 indicates that the lidar is stationary, and the default value of the lidar is rotating scan.

Device Flow Packet Interval

The interval is 1s (for 1 packet).

Clock Source Selection

Clock Source Selection (2 bytes)	
S/N	Byte 0
Function	0:gps; 1: ptp (p2p+l2); 2: reserved; 3: ptp (p2p+udpv4); 4: ptp (e2e+l2); 5: ptp (e2e+udpv4). GPS timestamp unit:μs; ptp timestamp unit: ns.

Configure 0x00 to indicate GPS timing, for which the lidar should be connected to a GPS clock source. Configure 0x03, 0x04, 0x05 to indicate gPTP timing, for which the lidar should be connected to a gPTP clock source.

Standby Mode

Standby Mode (2 Bytes)	
S/N	Byte 0
Function	0 means normal mode; 1 means standby mode

Configure 0x00 to indicate normal mode; configure 0x01 to indicate standby mode, where the laser does not emit light.

Phase Lock Enable

Phase Lock Enable (2 Bytes)	
S/N	Byte 0
Function	0: not enabled; 1: enabled

Configure 0x00 to indicate that phase lock is not enabled; configure 0x01 to indicate that phase lock is enabled and the phase lock function is activated.

Phase Lock Angle Setting

Phase Lock Angle Setting (2 Bytes)		
S/N	Byte 0	Byte 1
Function	Set phase lock angle	

Multiply the angular accuracy of 0.01° by 100 and then write it to the lidar. If the phase lock is at 100, then configure 10000, i.e. 0x2710 in hex. The lidar locks the motor around 100° when the phase lock is enabled.

UTC Time

The lidar receives GPS signals and parses the \$GPRMC information. The UTC time synchronizes with GPS. If there is no GPS timing, UTC time is all 0s. The GPS baud rate supported by the lidar is 9600. There are 8 data bits, 1 stop bit and no parity bit.

UTC Time (6 bytes Read Only)						
S/N	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6
Function	Year	Month	Day	Hour	Minute	Second
	0~255 corresponding to the year 2000~2255	1~12 month	1~31 day	0~23 hour	0~59 min	0~59 sec

Latitude and Longitude

Latitude and Longitude (22 bytes Read Only)								
S/N	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Function	Reserved	Latitude						
S/N	Byte 9	Byte 10	Byte 11	Byte 12	Byte 13	Byte 14	Byte 15	Byte 16
Function			Longitude					
S/N	Byte 17	Byte 18	Byte 19	Byte 20	Byte 21	Byte 22		
Function					N/S	W/E		

The latitude and longitude are output in the form of ASCII code.

4.3.2. Configuration Package Example

If you want to reset the lidar IP as 192.168.1.105, computer IP as 192.168.1.225, data port number as 6688, device port number as 8899, motor speed as 1200 RPM, according to the definition of the UCWP Packet and each register, it can be reconfigured as follows:

Table 5.4 Configuration Package Example

Info	Content	Config	Length (byte)
Header		0xAA, 0x00, 0xFF, 0x11, 0x22, 0x22, 0xAA, 0xAA	8
Motor Speed	1200 rpm	0x04, 0xB0	2
Lidar IP (IP_SRC)	192.168.1.105	0xC0, 0xA8, 0x01, 0x69	4
Computer IP (IP_DEST)	192.168.1.225	0xC0, 0xA8, 0x01, 0xE1	4
Data Port (port 1)	6688	0x1A20	2
Device Port (port 2)	8899	0x22C3	2
Lidar Rotation / Stationary	Rotation	0x0000	2
Reserved	Reserved	0x00	1180
Tail	Fixed value	0x0F, 0xF0	2

When using this protocol to configure the device, byte-level or section-level addressing and writing are not allowed, and the entire list must be written completely. After the list is written, the corresponding function will be updated and take effect immediately.

5. Time Synchronization

The way to synchronize the lidar and external equipment is gPTP time synchronization and gPTP time synchronization. If there is no external synchronization input, the lidar internally generates timing information.

Single echo mode: The absolute accurate time of the point cloud data is obtained by adding the 6-byte year, month, day, hour, minute, second information and the 4-byte timestamp (accurate to nanoseconds) of the data packet.

Dual echo mode: The absolute accurate time of the point cloud data is obtained by adding the 6-byte year, month, day, hour, minute, second information and the 4-byte timestamp (accurate to nanoseconds) of the data packet.

5.1. GPS Time Synchronization

When GPS synchronization is employed, the lidar will start timing in nanoseconds after receiving the PPS second pulse, and the time value will be output as the timestamp of the data packet. The lidar extracts UTC information from the \$GPRMC of the GPS as the UTC time output.

There are two types of CX1S3 lidar GPS_REC interface level protocols, namely TTL level standard and RS232 level standard. The two protocols differ in two aspects, respectively:

TTL level pin definition:

Pin GPS_RX receives the standard serial port data of the TTL level output from GPS module;

Pin GPS_PPS receives the positive TTL synchronous pulse signal output by the GPS module;

RS232 pin definition:

Pin GPS_RX receives the standard serial data of the R232 level output from the GPS module;

Pin GPS_PPS receives the positive synchronization pulse signal output by the GPS module, and the level is required to be 3.0 V ~15.0 V.

If the GPS used outputs according to the RS232 serial port protocol, and the lidar receives data according to the TTL protocol, then a RS232 to TTL conversion module is needed.

The GPS equipment is time-synchronized to mark and calculate the precise

emission and data measurement time of each laser. The precise time of the lidar point cloud can be matched with the pitch, roll, yaw, latitude, longitude and height of the GPS/inertial measurement system.

The default serial configuration baud rate of the GPS data output received by the lidar is 9600, 8N1. The PPS high pulse width is required to be more than 1 ms.

The standard format of GPRMC information is as follows:

\$GPRMC, <1>, <2>, <3>, <4>, <5>, <6>, <7>, <8>, <9>, <10>, <11>, <12> *hh


Table 6.1 The Standard Format of GPRMC Information

S/N	Name	Description/Format
1	UTC Time	hhmmss (hour/minute/second)
2	Positioning State	A=Effective Positioning, V=Invalid Positioning
3	Latitude	ddmm.mmmm (degree/minute)
4	Latitude Hemisphere	N (Northern Hemisphere) or S (Southern Hemisphere)
5	Longitude	dddmm.mmmm (degree/minute)
6	Longitude Hemisphere	E (East Longitude) or W (West Longitude)
7	Ground Speed	000.0~999.9 knot
8	Ground Direction	000.0~359.9 degree, take true north as the reference datum
9	UTC Date	ddmmyy (day/month/year)
10	Magnetic Declination	000.0~180.0 degree
11	Direction of Magnetic Declination	E (East) or W (West)
12	Mode Indication	Only NMEA0183 version 3.00 outputs, A= autonomic positioning, D= difference, E=estimation, N=invalid data

5.2. gPTP Synchronization

Generalized Precise Time Protocol (gPTP) is derived from Precise Time Protocol (PTP) and is used to synchronize the time of individual devices within a local area network with high precision.

This Lidar supports gPTP timing synchronization. Before synchronizing the lidar via gPTP, the time source needs to be set to “PTP” in the lidar's point cloud display software. And the lidar should be connected to a gPTP master as shown in below.

The settings steps on the point cloud display software are as follows: run the software, click on “” to bring up the parameter modification window, change “Source Selection” to “PTP” as shown in the figure below.

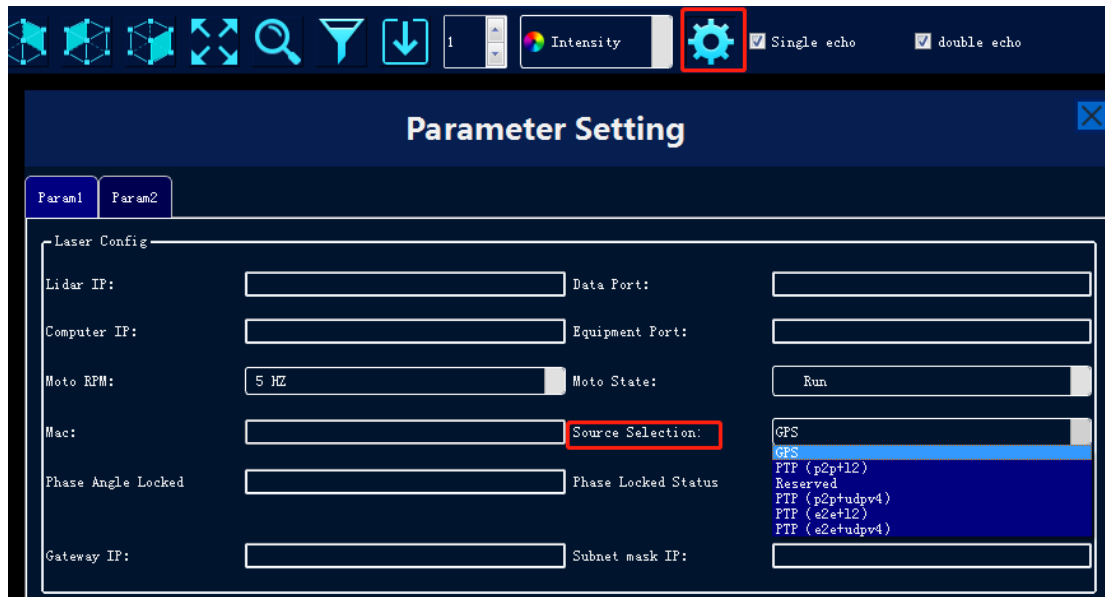


Figure 6.1 Clock Source Selection

Note:

The Timestamp and Date & Time in the point cloud packets will be synchronized strictly according to the time signal provided by the gPTP master clock. The time output from some master clocks may have a fixed offset from the Lidar's Date & Time, make sure the master clock is set up correctly and calibrated.

If "PTP" has been selected as the time source and no gPTP master clock is currently available, the lidar will start timing from the internal default start time (00:00:00 on 1 January, 2000); if a gPTP time source is provided and then interrupted, the lidar will continue timing from the time of the interruption.

5.3. Lidar Internal Timing

When there is no other equipment to synchronize, the lidar uses 1 second (1×10^9 ns) as the cycle. With the nanosecond as the timing unit, the timing value is output as the time stamp of the data packet. At this time, there is no UTC time reference.

When the lidar disconnected from the external clock source after time synchronization, then the lidar will continue timing from the time of the interruption.

When there is no other external clock source after-power on, the lidar will start internal timing. At this time, there would be 2 different cases in terms of time display on the point cloud display software: when the clock source is set to "GPS", the time will be counted from January 1, 2000, 00:00:00; when the time source is set to "PTP", the time will be counted from January 1, 1970, 00:00:00.

6. Angle and Coordinate Calculation

6.1. Vertical Angle

Take **single echo mode** as an example: The vertical angle is obtained from the data packet, whose effective data area contains a total of 1197 bytes, including 171 points, that is, $171 \times 7 = 1197$ bytes. Take the first measure point as an example:

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Line_num	Horizontal angle[15:8]	Horizontal angle[7:0]	Distance[23:16]	Distance[15:8]	Distance[7:0]	strength

Byte 1 represents the line number, it is 0x00 by default and the corresponding vertical angle is 0°.

6.2. Horizontal Angle

Byte 2 and **Byte 3** represent the horizontal angle, whose data are stored in Big-Endian mode. The unit is 0.01 degrees. For example, 0x11AD=4525, that is 45.25°.

6.3. Distance Value and Intensity

Byte 4, **Byte 5**, and **Byte 6** represent the first echo distance value. Their data are stored in Big-Endian mode. The two high bytes are the integer part, whose unit is “cm”; and the last byte is the decimal part, whose unit is 1/256 cm. To analyze the distance value, for example: the distance value in the obtained data packet is represented by the hexadecimal number 0x02,0x18,0x32, and the first two bytes are composed of 16-bit unsigned data, that is: 0x0218, which is converted to decimal distance value: 536 cm. The last byte is the decimal part, 0x32 equals 50 in decimal, that is, $50 \times 1/256 \text{ cm} = 0.1953125 \text{ cm}$. Then the two parts add up to 536.1953125 cm.

Byte 7 represents the first echo strength, and the value range is 0-255. (Echo strength can reflect the energy reflection characteristics of the measured object in the actual measurement environment. Therefore, the echo strength can be used to distinguish objects with different reflection characteristics.)

Note: There are 4 more bytes of distance value and intensity information in dual echo mode than in single echo mode. (for more information, see 5.1.2 subframe)

Byte 8, Byte 9 and Byte 10 represent the secondary echo distance value. Their data are stored in Big-Endian mode. The two high bytes are the integer part, whose unit is “cm”; and the last byte is the decimal part, whose unit is 1/256 cm. The distance value analysis method is the same as the first echo.

Byte 11 represents the second echo strength, and the value range is 0-255. (Echo strength can reflect the energy reflection characteristics of the measured object in the actual measurement environment. Therefore, the echo strength can be used to distinguish objects with different reflection characteristics.)

6.4. Cartesian Coordinate Representation

In order to obtain the vertical angle, horizontal angle and distance parameters of the lidar, the angle and distance information in polar coordinates can be converted to the x, y, z coordinates in the right-hand Cartesian coordinate system. The conversion relationship is shown in the following formula:

$$\begin{cases} x = r \cos \alpha \cos \theta; \\ y = r \cos \alpha \sin \theta; \\ z = r \sin \alpha \end{cases}$$

In the above formula, r is the distance, α is the vertical angle, θ is the horizontal rotation angle. And x , y , and z are the coordinates of the polar coordinates projected onto the x , y , and z axes.

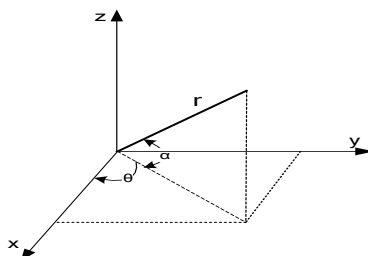


Figure 7.1 Coordinate Mapping

7. Accurate Time Calculation

To accurately calculate the time of the point cloud data, it is necessary to obtain the timestamp of the data packet and the UTC time of the device package output by the lidar. The timestamp and UTC time come from the same time synchronization source.

The laser emission interval of the CX1S3 lidar is about 0.434 μ s (TBD), and the measurement interval of adjacent points is 0.434 μ s (TBD).

7.1. Single Echo Mode

In the single echo mode, a data packet has a total of 171 measurement data. The packaging time of the data packet is about $0.434 \mu\text{s} \times 171 \approx 74.214 \mu\text{s}$, and the data rate is about $1\text{s} / 74.214 \mu\text{s} \approx 13474$ data packets/second.

7.1.1. Calculation of Data Packet End Time

The timestamp in the data packet is a relative time in nanoseconds, which is defined as the packing time of the laser measurement data of the last channel in the data packet (packet end time), and its duration is less than 1 second. Therefore, to calculate the absolute end time of the data packet, it is necessary to obtain the 6-byte year, month, day, hour, minute and second information and the 4-byte nanosecond timestamp from the data packet first, and then combine the two to get the exact time when the data packet ends.

7.1.2. Accurate Time Calculation of Channel Data

The precise measurement time of each data can be calculated with the exact time of the end of the data packet and the light-emitting time interval of the 171 data.

Each data packet block of the CX1S3 lidar contains 171 measurement data. Therefore, the end time interval of each data packet is the time of the last point. Assuming that the absolute time of the data packet end is $T_{\text{Packet_end}}$, and the end time of the previous packet is $T_{\text{Packet_end_last}}$, then the end time interval of each data packet— $T_{\text{Interval}} = (T_{\text{Packet_end}} - T_{\text{Packet_end_last}}) / 171$;

The steps for calculating the end time of each data block $T_{\text{Point_end}(N)}$ are as follows:

$T_{\text{Point_end}(N)} = (T_{\text{Packet_end}} - T_{\text{Interval}} \times (171 - N))$. ($N = 1, 2, \dots, 171$), where $T_{\text{Point_end}(N)}$ indicates the end time of the N^{th} data point.

7.2. Dual Echo Mode

In the dual echo mode, a data packet has a total of 109 measurement data. The packaging time of the data packet is about $0.434 \mu\text{s} \times 109 \approx 47.306 \mu\text{s}$, and the data rate is about $1\text{s} / 47.306 \mu\text{s} \approx 21138$ data packets/second.

7.2.1. Calculation of Data Packet End Time

The timestamp in the data packet is a relative time in nanoseconds, which is defined as the packing time of the laser measurement data of the last channel in the data packet (packet end time), and its duration is less than 1 second. Therefore, to calculate the absolute end time of the data packet, it is necessary to obtain the 6-byte year, month, day, hour, minute and second information and the 4-byte nanosecond timestamp from the data packet first, and then combine the two to get the exact time when the data packet ends.

7.2.2. Accurate Time Calculation of Channel Data

The precise measurement time of each data can be calculated with the exact time of the end of the data packet and the light-emitting time interval of the 109 data.

Each data packet block of the CX1S3 lidar contains 109 measurement data. Therefore, the end time interval of each data packet is the time of the last point. Assuming that the absolute time of the data packet end is $T_{\text{Packet_end}}$, and the end time of the previous packet is $T_{\text{Packet_end_last}}$, then the end time interval of each data packet— $T_{\text{Interval}} = (T_{\text{Packet_end}} - T_{\text{Packet_end_last}}) / 109$;

The steps for calculating the end time of each data block $T_{\text{Point_end}(N)}$ are as follows:

$T_{\text{Point_end}(N)} = (T_{\text{Packet_end}} - T_{\text{Interval}} \times (109 - N))$. ($N = 1, 2, \dots, 109$), where $T_{\text{Point_end}(N)}$ indicates the end time of the N^{th} data point.

Appendix A. Maintenance

Shipping Requirements

This series of lidars are packed with the packaging materials specially customized by our company, which can resist certain vibrations and impacts. For long-distance transportation, special packaging materials must be used to avoid irreversible damage during transportation.

Installation

Use screws that meet the specifications to fix the lidar base, and make sure the base has good heat dissipation. Wear powder-free clean gloves during installation to avoid optical cover contamination and mechanical damage.

Storage Conditions

It is recommended to store the products in a ventilated and dry place where the temperature is 23 ± 5 °C, and the relative humidity is 30% ~ 70%. Do not store in environments where humidity, pH, etc. exceed the protection level.

Dirt Treatment

If the mask is dirty during use, such as with fingerprints, muddy water, dry leaves or insect corpses, etc., the lidar's ranging effect will be directly affected. Please clean it according to the following steps:

Tools: PVC gloves, clean cloth, absolute ethanol (99%)

Environment: ventilated and dry, away from fire

- (1) Put on PVC gloves and fix the lidar base with your fingers; if it is not stubborn stains, use a dust-free cloth or dry air to gently remove the stains;
- (2) For stubborn stains, evenly spray the ethanol in the spray bottle on the location to be cleaned and wait for the stain to be dissolved. Then use a dustless cloth dipped in ethanol solvent, and gently wipe the mask. If the cloth is contaminated, please replace it in time. After cleaning the stain, use a new dustless cloth to remove any remaining liquid.

Appendix B. Troubleshooting

For any of the following problems during the use of the lidar, please refer to the corresponding solutions for troubleshooting. If you are unable to implement the following steps, or if you are still unable to solve the problem after implementing the steps, please contact our technical support.

Problem	Solution
The indicator light on the interface box is not working	Confirm: <ul style="list-style-type: none"> power supply meets electrical requirements interface box is in good condition with no damage power cord contact is good and undamaged; power adapter is working properly re-power the lidar to see if the fault disappears
Motor is not running	Confirm: <ul style="list-style-type: none"> power supply meets electrical requirements good contact between interface box and the lidar re-power the lidar to see if the fault disappears
Motor running but no data output on the host PC or Wireshark	Confirm: <ul style="list-style-type: none"> power supply meets electrical requirements the network cable is well connected the IP address of the computer matches the destination IP address of the lidar your computer's firewall and other security software that may affect Ethernet broadcasts is turned off if the lidar emits laser beam with an IR camera or IR card re-power the lidar to see if the fault disappears
Wireshark has data but the host PC has no data	Confirm: <ul style="list-style-type: none"> your computer's firewall is turned off the IP address of the computer matches the destination IP address of the lidar data port and device port in the host computer are set correctly lidar port is not occupied by another process Npcap plugin is installed re-power the lidar to see if the fault disappears
Point cloud missing	Confirm: <ul style="list-style-type: none"> lidar housing is clean and free of stains horizontal FOV setting in the host computer the number of packets received by the lidar is normal whether the lidar emits laser beams, this can be checked with an IR camera or an IR card whether there are network conflicts whether there is a network blockage caused by other devices transmitting large amounts of data connect the PC to the lidar only and observe if the point cloud is missing re-power the lidar to see if the fault disappears
Abnormal point cloud image on the host PC (flickering point cloud;	Confirm: <ul style="list-style-type: none"> the lidar housing is clean and free of stains lidar surroundings are not complex

irregular point cloud alignment)	<ul style="list-style-type: none"> ● horizontal FOV setting in the host computer ● whether the network is blocked by other devices transmitting data
Error occurs when running the Windows Client, no interface display	<p>Confirm:</p> <ul style="list-style-type: none"> ● the graphics card is used correctly, discrete graphics card is recommended ● the graphics card meets the minimum configuration requirements ● the driver for the graphics card is correctly installed
Crash or no response of the Windows Client when modifying lidar parameters	<p>Confirm:</p> <ul style="list-style-type: none"> ● Npcap plugin is installed ● the device package port number is correctly filled in ● the computer memory is not full

Revision History

Rev.	Release Date	Revised Content	Issued/Revised By
V1.0.0	2024-09-06	Initial Version	Leishen
V1.0.1	2024-10-11	Mechanical drawings updated; operation under Windows OS updated	Leishen

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