



CH128X1

User Manual

V1.0.6 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

CH128X1 is based on the major technological breakthrough made by Leishen Intelligent in the miniaturization technology of auto-grade high-wire-beam hybrid solid-state lidar. It well meets the requirements of long-range detection and perception performance in autonomous driving. With a compact size, which is suitable for embedding in the roof or front protection position, this product is more in line with the aesthetic needs of passenger vehicles' exterior design.

1.2 Mechanism

The CH128X1 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).

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

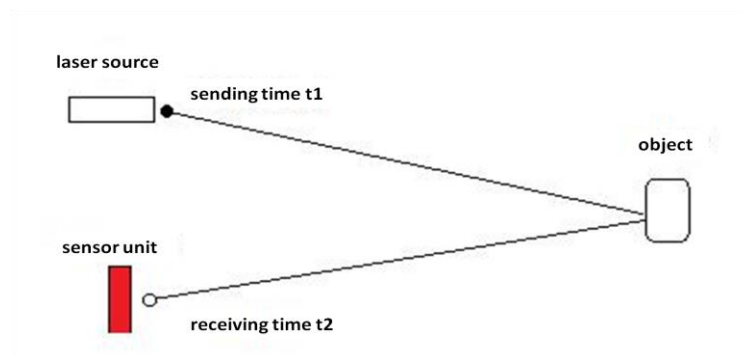


Figure 1.1 Mechanism of the CH128X1 Lidar

1.3 Specification

Table 1.1 Specifications of CH128X1

Model	CH128X1
Detection Method	TOF
Wavelength	905 nm
Laser Class	Class 1 (eye-safe)
Channels	128
Detection Range	200 m (160 m @10%)
Range Accuracy	±3 cm
Data Point Generated (Single Echo	760,000 pts/sec

Mode)	
Vertical FOV	25° (-18°~7°)
Horizontal FOV	120°
Vertical Angular Resolution	0.125°@ROI, 0.25°@non-ROI
Horizontal Angular Resolution	5 Hz: 0.1°; 10 Hz: 0.2°; 20 Hz: 0.4°
Scanning Rate	5 Hz, 10 Hz, 20 Hz
Communication Interface	Gigabit Industry Ethernet
Time Source	PPS; gPTP
Operating Voltage	9 V~36 VDC
Operating Temperature	-40℃ ~ +85℃
Storage Temperature	-40℃ ~ +105℃
Power Consumption	15W
Shock Test	500 m/sec ² , lasting for 11 ms
Vibration Test	5 Hz~2000 Hz, 3G rms
IP Grade	IP6K9K
Functional Safety Level	ISO26262 (ASIL B)
Dimensions	118*90*75 mm
Weight	1 kg

1.4 Dimensions

There are 4 mounting holes and 2 positioning holes at the bottom of CH128X1 lidar. Four M5*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: M5*10, hexagon socket head cap screws; (2) Screws: GB70; (3) Spring washers: GB93; (4) Flat washers: GB93.1; (5) Electric Torque Screwdriver: 5NM.

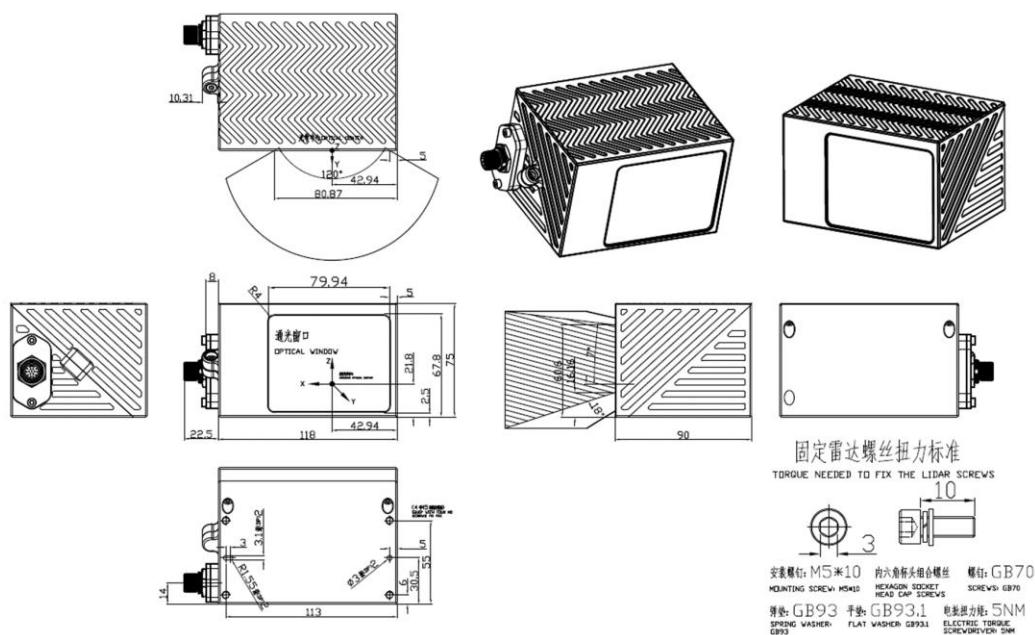


Figure 1.2 CH128X1 Lidar Dimensions

The CH128X1 lidar utilizes mirror rotation and special optical design to scan 120° horizontally, with a dense light distribution of 128 lines. Figure 1.3 shows the appearance of the CH128X1 lidar while Figure 1.4 shows the optical center position, which is also the coordinate origin of the host computer display software.



Figure 1.3 External View of CH128X1

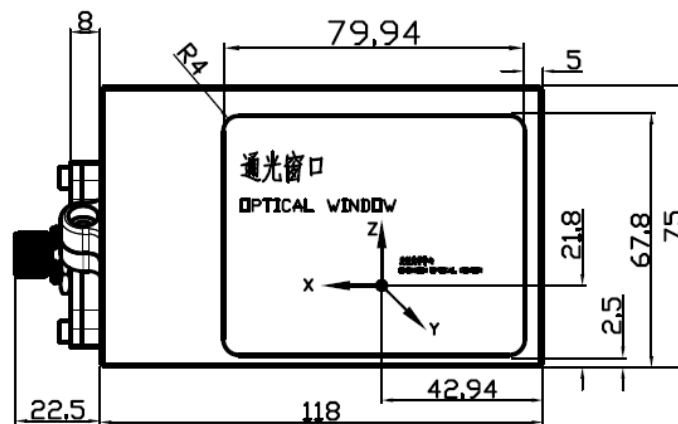


Figure 1.4 The Optical Center of the Lidar

2. Electrical Interface

2.1 Power Supply

The power input range of the CH128X1 lidar is 9V~36VDC. If other DC power supply is adopted, the recommended output voltage of the power supply is 12VDC, 19VDC or 24VDC. Please note that DC 9V and 36V 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 $\geq 2A$ (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 $<5\%$. It is recommended to use 12V/3A or 24V/2A power adapter.

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 19V. If the line length is more than 10 m, then it is recommended to use a 220VAC adapter nearby for power supply (DC long-distance power supply is not recommended).

2.2 Electrical Interface

The cable from the side of the CH128X1 lidar base is a 17-pin industry ethernet cable.

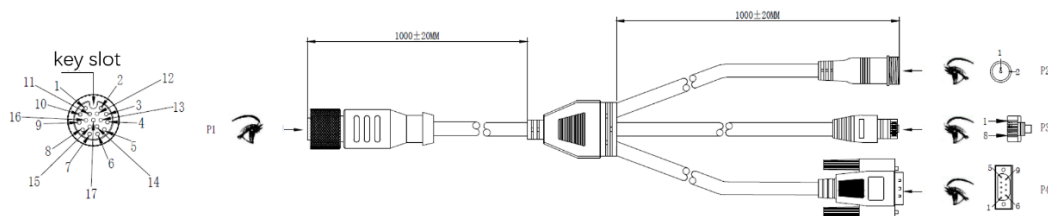


Figure 2.1 The 17-PIN Industry Ethernet Cable

The wiring definition of the 17-pin industry ethernet cable is presenting in the tables below:

Table 2.1 Wiring Definition of the 17-pin Industry Ethernet Cable

P1	Color	Type	Definition	RJ45/Network Port (P3)	DB/GPS Port (P4)	DC Port (P2)
2	Orange/White	Twisted-Pair	TX_D1+ Ethernet TX+	1	/	
3	Orange		TX_D1- Ethernet TX-	2		
7	Green/White	Twisted-Pair	RX_D2+ Ethernet RX+	3		
6	Green		RX_D2- Ethernet RX-	6		
4	Blue	Twisted-Pair	TX_D3+ Ethernet TX+	4		
5	Blue/White		TX_D3- Ethernet TX-	5		
8	Brown/White	Twisted-Pair	RX_D4+ Ethernet RX+	7		
9	Brown		RX_D4- Ethernet RX-	8		
1	Blue	Single Wire	GPS_GND		5	
10	Yellow	Single Wire	GPS_PPS GPS sync pulse per second		2	
11	White	Single Wire	GPS_GPRMC GPS longitude, latitude, hour minute and second		3	
12	Red	Single Wire	VCC Power+			1
13	Red	Single Wire				
14	Red	Single Wire				
15	Black	Single Wire	GND Power-			2
16	Black	Single Wire				
17	Black	Single Wire				
Shell	Shield	Braided	Shell	Shell	Shell	/

3. Get Ready

3.1 Lidar Connection

To get ready for the lidar operation, please connect the lidar, host computer, GPS module and power supply as shown in Figure 3.1.



Figure 3.1 Connecting the Lidar

3.2 Software Preparation

The lidar can be operated under both Windows operating system and Linux operating system. Software needed is as follows:

Wireshark: to capture the ARP (Address Resolution Protocol) packets.

Note: Wireshark is a third-party software that you need to download by yourself. Leishen Intelligent bears no responsibility to any copyright and commercial disputes caused by the use of this software.

To view the point cloud data generated by the lidar, you can either use the **Upper Computer Platform** (Windows Client) or the **ROS Driver Program**.

Upper Computer Platform: a host computer software to view point cloud image under Windows operating system, which is also referred to as “point cloud display software”.

- Software Acquisition

This Upper Computer Platform has been pre-stored in the Service Pack provided along with the lidar. It can also be obtained from the sales or technical

support personnel.

- 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 also included in the Upper Computer Platform installation files package.

ROS Driver Program (optional): to view the point cloud data under Linux operating system. This program has been included in the customer service package which can be obtained from the sales or technical support personnel.

4. Usage Guide

This part states operation instructions of the Upper Computer Platform and ROS drive presented by the Leishen Intelligent System Co., Ltd.

4.1 Operation Under Windows OS

4.1.1 Lidar Configuration

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

Table 4.1 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 xx.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.

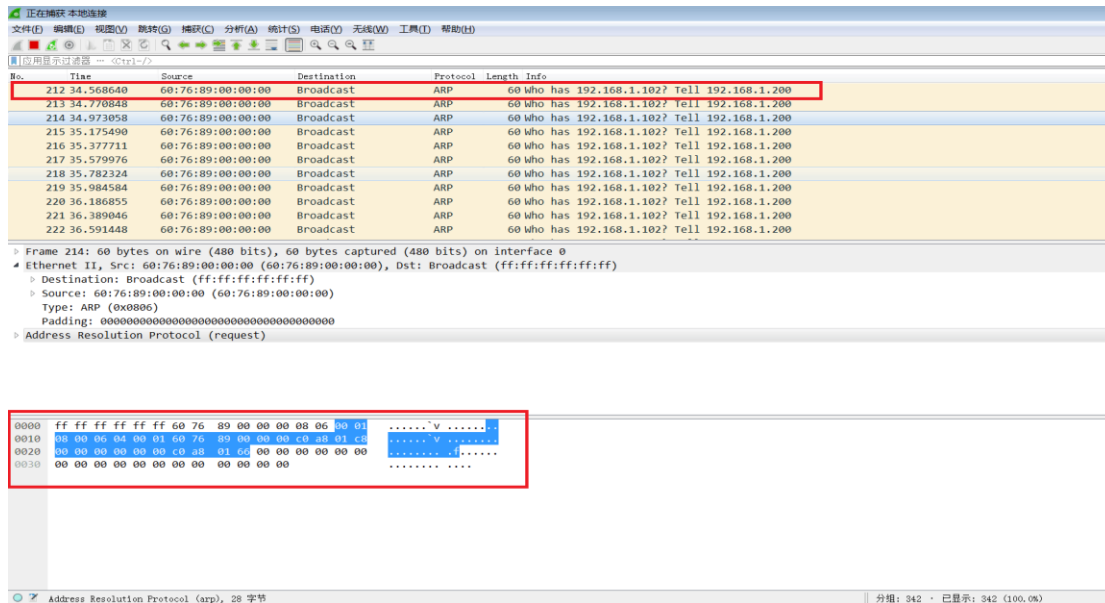


Figure 4.1 Wireshark Captures APR Packets

- 1) Wireshark is a third-party software, and you may need to download it by yourself. Leishen Intelligent bears no responsibility for any copyright and commercial disputes caused by users' use of the software.
- 2) Please disable all virtual NICs when using the SDK to prevent interference with data reception.
- 3) When developing with Visual Studio, please use the "release mode" in priority to reduce issues caused by data blocking, read and write delays.

4.1.2 Upper Computer Platform

Upper Computer Platform (windows client), 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 client, too.

For more information on how to use the software, please refer to the software operation manual included in the LiDAR service package or click on the icon



in the upper right corner of the software to jump to the software operation manual after you installed it.

4.1.3 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 microsecond timestamp information of each laser;

Step 2. Read the device package to obtain information such as the UTC time (GPS, NTP or PTP time service) 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 UTC time, 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.

4.2 ROS Driver Operation Under Linux OS

4.2.1 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@ls-Inspiron-15-3511:~$ ifconfig
enxf8e43b292f8c: 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::898a:1bfd:a729:2f4e prefixlen 64 scopeid 0x20<link>
    ether f8:e4:3b:29:2f:8c txqueuelen 1000 (以太网)
    RX packets 254127 bytes 313581906 (313.5 MB)
    RX errors 254118 dropped 3 overruns 0 frame 254118
    TX packets 76 bytes 9406 (9.4 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

Figure 4.3 ifconfig Command Feedback

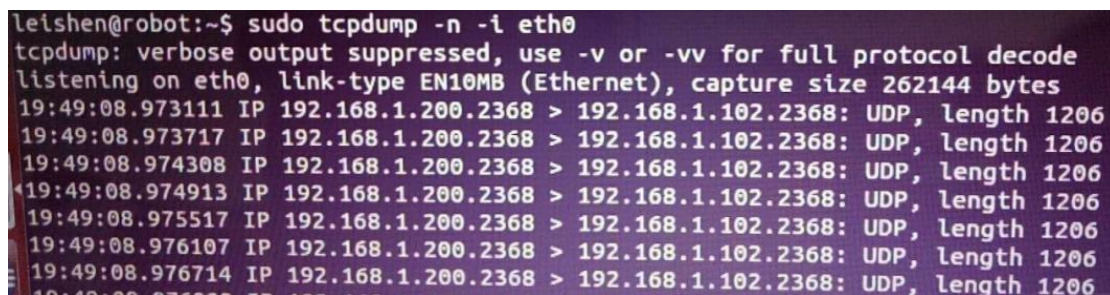
Note: The default destination IP of the lidar is 192.168.1.102, and the computer must be configured according to the actual lidar destination IP. After setting the IP for the first time, please restart the lidar.

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 1206-byte data packets sent by the lidar to the destination, which means that the lidar data is sent normally).



```
leishen@robot:~$ sudo tcpdump -n -i eth0
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on eth0, link-type EN10MB (Ethernet), capture size 262144 bytes
19:49:08.973111 IP 192.168.1.200.2368 > 192.168.1.102.2368: UDP, length 1206
19:49:08.973717 IP 192.168.1.200.2368 > 192.168.1.102.2368: UDP, length 1206
19:49:08.974308 IP 192.168.1.200.2368 > 192.168.1.102.2368: UDP, length 1206
19:49:08.974913 IP 192.168.1.200.2368 > 192.168.1.102.2368: UDP, length 1206
19:49:08.975517 IP 192.168.1.200.2368 > 192.168.1.102.2368: UDP, length 1206
19:49:08.976107 IP 192.168.1.200.2368 > 192.168.1.102.2368: UDP, length 1206
19:49:08.976714 IP 192.168.1.200.2368 > 192.168.1.102.2368: UDP, length 1206
19:49:08.976888 IP 192.168.1.200.2368 > 192.168.1.102.2368: UDP, length 1206
```

Figure 4.4 sudo tcpdump -n -i eth0 Command Feedback

4.2.2 Software Operation Example

Note: all the commands in the examples below are for reference only. For the details, please refer to the README file included in the customer service package which you can contact the sales person or technical support to acquire.

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 ls_lidar_ch_decoder ls_lidar_ch.launch
```

Reopen a terminal again and execute the following command:

```
roslaunch rviz
```

Note 1): If the lidar destination port and motor speed are modified, please open "ls_lidar_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.

5. Communication Protocol

Lidar data output and configuration use Gigabit Ethernet UDP/IP communication protocol. There are 3 UDP packet protocols, and the packet length is 1248 bytes (42 bytes Ethernet header and 1206 bytes payload).

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	1248 bytes	about 0.148 ms
Device Information Output Protocol	DIFOP	Outputting parameter configuration and status information		1s (for 1 packet)
User Configuration Write Protocol	UCWP	Inputting user configured device parameters		Not Fixed

5.1 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 1206-byte payload, with a total length of 1248 bytes.

Single echo mode: The payload consists of 1197 bytes of point cloud data and 9 bytes of additional information (including 3 bytes of UTC time of hour, minute and second, 4 bytes of Timestamp and 2 bytes of Factory).

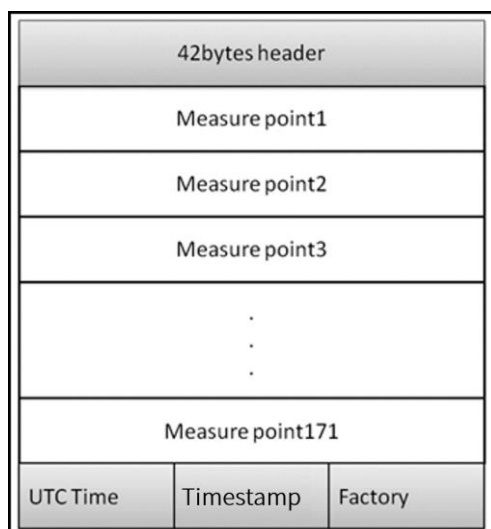
Dual echo mode: The payload consists of 1199 bytes of point cloud data and 7 bytes of additional information (including 1 bytes of UTC time of second, 4 bytes of Timestamp and 2 bytes of Factory).

5.1.1 Format

The CH128X1 lidar supports single echo mode which measures the most recent

echo value.

Each MSOP data packet contains 1206 bytes of data. Each packet of data contains 171 points, that is, $171 \times 7 = 1197$ bytes, and the frame tail is 9 bytes (including 3 bytes of UTC Time of hour, minute and second, 4 bytes of Timestamp and 2 bytes of Factory). See the figure below:



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 EE11, 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.

5.1.2 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

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, whose value range from 0 to 127, a total of 128 lines. The 128 lines respectively corresponds to the lowermost ray to the uppermost ray in the entire vertical field of view. For example, line No. 0 represents a vertical angle of -18° , line No. 1 represents a vertical angle of -17.75° , and the angle difference between adjacent lines is 0.25° or 0.125° .

Byte 2 and **Byte 3** represent the horizontal angle, whose data are stored in Big-Endian mode. The unit is 0.01° . 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.)

Azimuth

The resolution of the horizontal angle value (0.1° , 0.2° , 0.4°) is determined according to the motor speed (5Hz, 10Hz, 20Hz). 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.

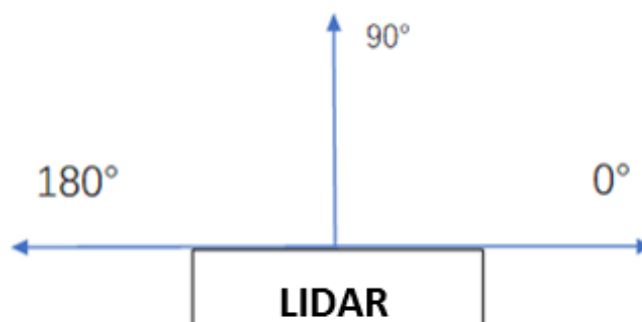


Figure 5.1 The Azimuth of the Lidar

Additional Information

The additional information is 9 bytes in length, including 3 bytes UTC time of hour, minute and second, 4 bytes of microsecond Timestamp and 2 bytes of Factory.

Additional Information: 9 bytes			
Name		Length (byte)	Function
UTC time		3	Hour, minute and second of the UTC time
Timestamp		4	Timestamp (μs)
Factory	Vendor Information	1	0x80 represents the CH128X1 lidar
	Echo Information	1	0x1 represents single echo lidar 0x2 represents dual echo lidar

1) When there is a GPS device inputting PPS signal to the lidar, the timestamp is generated according to the PPS time as the cycle time, and the range of the timestamp is 0-999,999 (μs);

2) 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 (μs);

3) When there is no synchronization device inputting PPS signal, the lidar generates timestamp with a period of 1 hour. The range of the timestamp is 0-999,999 (μs).

5.2 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

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 (0x0940, represents 2368)	34	2
	5	Computer Port (0x0941, represents 2369)	36	2
UDP Length & Sum Check	6	Length (0x04BE, represents 1214 bytes)	38	2
	7	Sum Check	40	2
Payload: 1206 bytes				
Name	S/N	Information	Offset	Length (byte)
Header	0	Device Package Identification Header	0	8
Data	1	Motor Speed	8	2
	2	Ethernet Configuration	10	22
	3	Reserved	32	8
	4	Lidar Rotation / Stationary	40	2
	5	Device Flow Packet Interval	42	2
	6	Clock Source Selection	44	1
	7	Standby Mode	45	1
	8	Phase Lock Enable	46	1
	9	Phase Lock Angle Setting	47	2
	10	Reserved	49	3
	11	GPS Time	52	6
	12	Latitude and Longitude	58	22
	13	Reserved	80	1124
Tail	14	Frame Tail	1204	2

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.

5.3 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

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
Payload: 1206 bytes-				
Name	S/N	Information	Offset	Length (byte)
Header	0	Configuration Package Identification Header	0	8
Data	1	Motor Speed	8	2
	2	Ethernet Configuration	10	22
	3	Reserved	32	8
	4	Lidar Rotation / Stationary	40	2
	5	Configuration Flow Packet Interval	42	2
	6	Clock Source Selection	44	1
	7	Standby Mode	45	1
	8	Phase Lock Enable	46	1
	9	Phase Lock Angle Setting	47	2
	10	Reserved	49	3
	11	GPS Time	52	6
	12	Latitude and Longitude	58	22
	13	Reserved	80	1124
Tail	14	Frame Tail	1204	2

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.

5.3.1 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	Byte1	Byte2
Function	Speed: 5 Hz/10 Hz/20 Hz	

The motor rotates clockwise. Three speeds can be set: when it is set to 0x04B0, the speed is 1200rpm; when it is set to 0x0258, the speed is 600rpm; when it is set to 0x012C, the speed is 300rpm. 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. Port1 is the UDP data port number and port2 is the UDP device port number.

Ethernet Configuration (22 bytes)								
S/N	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
Function	IP_SRC				IP_DEST			
S/N	Byte9	Byte10	Byte11	Byte12	Byte13	Byte14	Byte15	Byte16
Function	MAC_ADDR (Read Only)						Data Port: Port1	
S/N	Byte17	Byte18	Byte19	Byte20	Byte21	Byte22		
Function	Device Port: Port2		Reserved					

Lidar Rotation & Stationary

Lidar Rotation & Stationary (2 bytes)		
S/N	Byte1	Byte2
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

Device Flow Packet Interval (2 bytes)		
S/N	Byte0	Byte1
Function	0: send 1 device packet every time 4 data packets are sent; other values: 1 packet per second;	

The configuration 0x0000 means to send 1 device packet every time 4 packets

are sent, and other values mean 1 packet per second. The default value is 1.

Clock Source Selection

Clock Source Selection (2 bytes)	
S/N	Byte0
Function	0: GPS; 1: PTP the unit of GPS timestamp is μ s; the unit of PTP timestamp is ns

0x00 indicates that the timing mode of the clock source is GPS timing, external GPS device is connected; 0x01 indicates that the timing mode of the clock source is PTP timing, external PTP timing source is connected.

Standby Mode

Standby Mode (2 Bytes)	
S/N	Byte0
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	Byte0
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	Byte0	Byte1
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	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
Function	Year	Month	Day	Hour	Minute	Second
	0~255	1~12	1~31	0~23	0~59	0~59

	corresponding to the year 2000~2255	month	day	hour	min	sec
--	---	-------	-----	------	-----	-----

Latitude and Longitude

Latitude and Longitude (22 bytes Read Only)								
S/N	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
Function	Reserved	Latitude						
S/N	Byte9	Byte10	Byte11	Byte12	Byte13	Byte14	Byte15	Byte16
Function	Longitude							
S/N	Byte17	Byte18	Byte19	Byte20	Byte21	Byte22		
Function					N/S	W/E		

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

5.3.2 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 (port1)	6688	0x1A20	2
Device Port (port2)	8899	0x22C3	2
Lidar Rotation / Stationary	Rotation	0x0000	2
Reserved	Reserved	0x00	1180
Tail		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.

6. Time Synchronization

There are three ways to synchronize the lidar and external equipment: GPS synchronization and external PPS synchronization. If there is no external synchronization input, the lidar internally generates timing information.

The absolute accurate time of the point cloud data is obtained by adding the 3-byte hour, minute, second information and the 4-byte timestamp (accurate to microseconds) of the data packet and the 3-byte UTC time (year, month and day) of the device packet.

6.1 GPS Synchronization

When GPS synchronization is employed, the lidar will start timing in microseconds 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. In the UTC time output, the year, month and day information is in the device packet and the hour, minute and second information is in the data packet.

There are two types of CH128X1 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 3.0V~15.0V.

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

6.2 External Synchronization

In external synchronization, the lidar receives the PPS signal input by other external devices and times it in microseconds, and the timing value is output as the time stamp of the data packet. At this time, there is no UTC time reference. If UTC time is required, it must be written in the configuration package, otherwise the UTC time output information of the device package is invalid.

The PPS level of the external synchronization signal is 3.3~5V, and the lidar receives the rising edge trigger, and the PPS high pulse width is required to be more than 1 ms.

6.3 Lidar Internal Timing

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 and the timing value will be output as a timestamp of the data packet without UTC time reference. 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.

7. Angle and Coordinate Calculation

7.1 Vertical Angle

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, whose value range from 0 to 127, a total of 128 lines. The 128 lines respectively corresponds to the lowermost ray to the uppermost ray in the entire vertical field of view. For example, line No. 0 represents a vertical angle of -18° , line No. 1 represents a vertical angle of -17.75° , and the angle difference between adjacent lines is 0.25° or 0.125° . See the figure below:

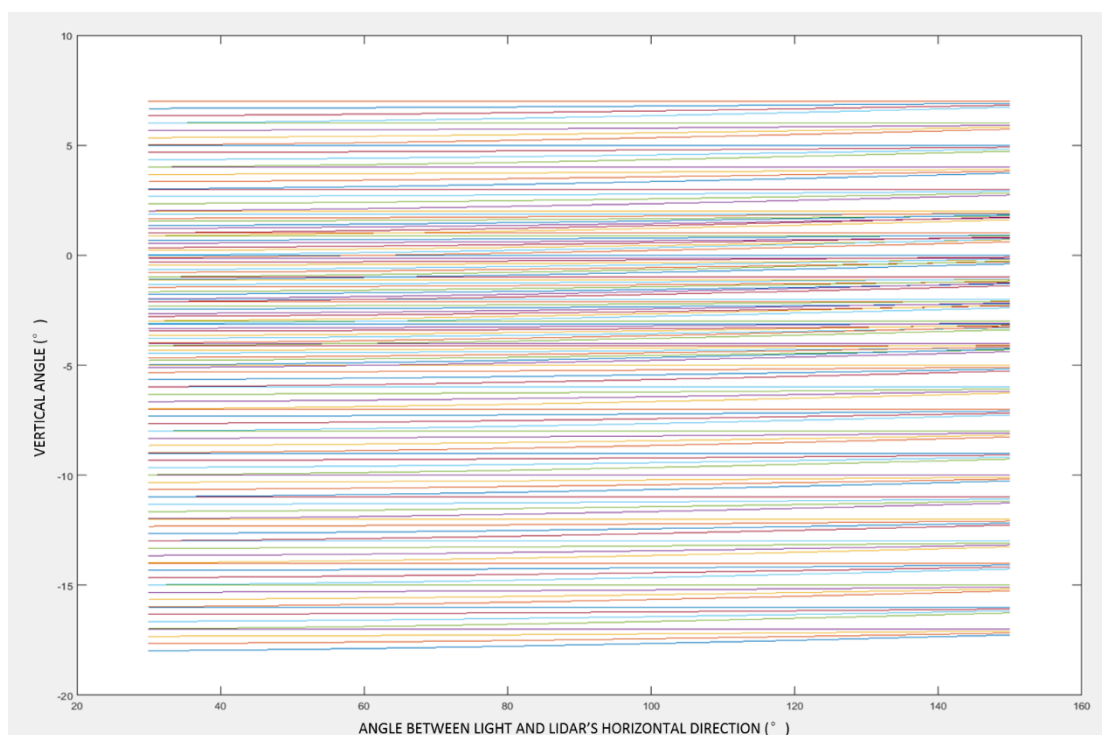


Figure 7.1 Angle Between Light and Lidar's Horizontal Direction

7.2 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°.

7.3 Distance Value and Intensity

Byte 4, Byte 5, and Byte 6 represent the 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*1/256 cm=0.1953125 cm. Then the two parts add up to 536.1953125 cm.

7.4 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.

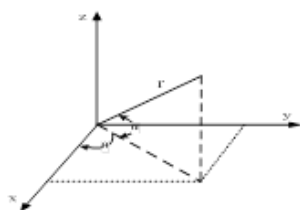


Figure 7.2 Coordinate Mapping

8. 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 synchronization source, such as a GPS.

The laser emission interval of the CH128X1 lidar is about 0.868 μ s, and the measurement interval of adjacent points is 0.868 μ s.

In the single echo mode, a data packet has a total of 171 measurement data. The packaging time of the data packet is about $0.868 \mu\text{s} \times 171 \approx 148.428 \mu\text{s}$, and the data rate is about $1\text{s} / 148.428 \mu\text{s} \approx 6737$ data packets/second.

8.1 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 $0.868 \mu\text{s} \times 171 \approx 148.428 \mu\text{s}$, and the data rate is about $1\text{s} / 148.428 \mu\text{s} \approx 6737$ data packets/second.

8.1.1 Calculation of Data Packet End Time

The timestamp in the data packet is a relative time in microseconds, 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 3-byte hour, minute and second information and the 4-byte microsecond timestamp from the data packet first, and then obtain the year, month and day information of the UTC time from the device package. The combination of the three will be the exact time when the data packet ends.

8.1.2 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 CH128X1 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:

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

8.2 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 $0.868 \mu\text{s} * 109 \approx 94.612 \mu\text{s}$, and the data rate is about $1\text{s} / 94.612 \mu\text{s} \approx 10569$ data packets/second.

8.2.1 Calculation of Data Packet End Time

The timestamp in the data packet is a relative time in microseconds, 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 1-byte second information and the 4-byte microsecond timestamp from the data packet first, and then obtain the year, month, day, hour and minute information of the UTC time from the device package. The combination of the three will be the exact time when the data packet ends.

8.2.2 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 CH128X1 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:

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

Appendix A. Maintenance

Shipping Requirements

LS series lidars use 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 $23\pm5^{\circ}\text{C}$, 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	2022-07-20	Initial Version	LS1286
V1.0.1	2022-11-10	Note of lidar IP setting added	LS1286
V1.0.2	2023-02-14	Mechanical drawing modified	LS1286
V1.0.3	2023-02-27	Communication protocol and accurate time calculation modified	LS1286
V1.0.4	2023-03-10	Mechanical drawing of the 17-pin industry ethernet cable modified; Appendix A&B added	LS1286
V1.0.5	2024-03-20	Wiring definition modified	LS1499
V1.0.6	2024-10-17	Operation under Windows OS updated; time synchronization updated	LS1499

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