



# CH16X1

## User Manual

V1.0.2 2022.11



## **Safety Instruction**

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

### **⚠Attention**

Please do not disassemble or modify the Lidar privately. If you need special instructions, please consult the technical support staff of LeiShen Intelligent for warranty and maintenance matters.

### **⚠Laser Safety Level**

The laser safety level 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 a magnifying device (such as a microscope, a head-mounted magnifying glass, or other forms of magnifying glass).

### **Eye Safety**

The product design complies with Class 1 human eye safety standards. However, it is prohibited to look directly at the transmitting laser through magnifying equipment (such as a microscope, head-mounted magnifier or other forms of magnifying glass). In order to maximize self-protection, users should still avoid looking directly at the running product.



### **⚠Safety 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 damage to the product.

### **Operation**

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

### **Power Supply**

Use the connecting cable and matching connectors provided by LeiShen Intelligent to supply

power. Using cables or adapters that do not meet the power supply requirements or are damaged, 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 by the laser emitted by this product, please pay attention when using it.

### **Housing**

The product contains high-speed rotating parts, please do not operate when the housing is unfastened. Do not use a product with a damaged housing, so as to avoid irreparable losses. In order to avoid product performance degradation, please do not touch the photomask with your hands.

### **Vibration**

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

### **Radio Frequency Interference**

Before use, please read the certification and safety information on the nameplate of the product base. Although the design, testing and manufacturing of the product are in compliance with the relevant regulations on radio frequency energy radiation, the radiation from the 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, vapors 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 (such as helium), so as not to damage or impair the function of the product. Please follow all signs and instructions.

### **Maintenance**

Do not disassemble the Lidar without authorization. Disassembling the product may cause the waterproof performance to fail or personal injury.

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# 1. Product Profile

## 1.1 Overview

CH16X1 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 CH16X1 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 ( $t_2$ ).

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

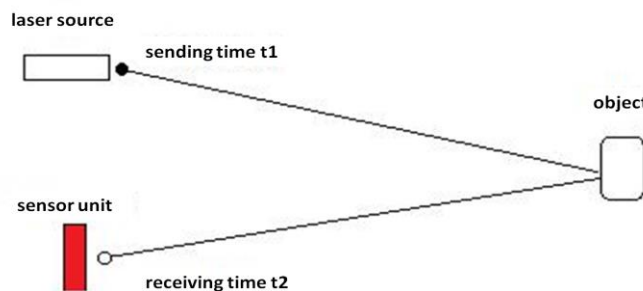


Figure 1.1 Mechanism of the CH16X1 Lidar

## 1.3 Specification

Table 1.1 Specifications of CH16X1

Model	CH16X1
Detection Method	ToF
Wavelength	905 nm
Laser Class	Class 1 (eye-safe)
Channels	16
Detection Range	200 m (160 m @10%)
Range Accuracy	±3 cm
Data Point Generated (Single Echo Mode)	95,000 pts/sec
Vertical FOV	-2°~2°
Horizontal FOV	120°





Figure 1.3 External View of CH16X1

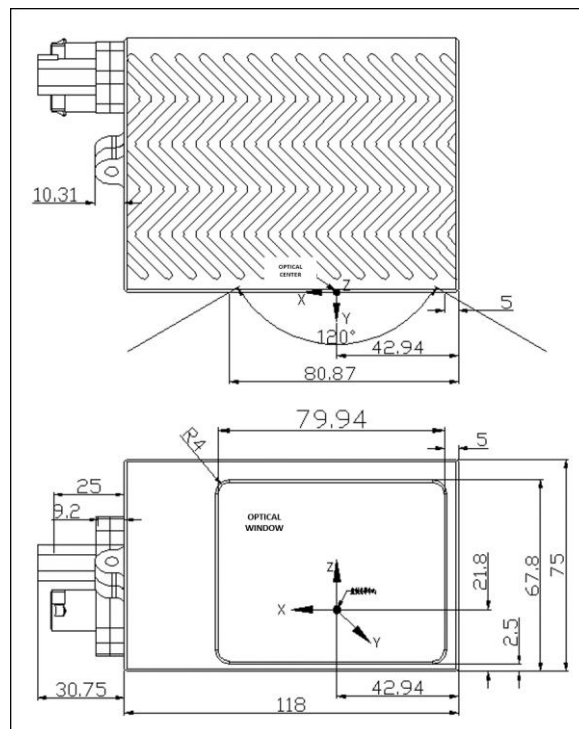


Figure 1.4 The Optical Center of the Lidar

## 2. Electrical Interface

### 2.1 Power Supply

The power input range of the CH16X1 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 cables from the side of the CH16X1 Lidar base are a 6-pin power cord and a 2-pin automotive Ethernet cable. The cables are as shown in the figures below.

**Note:** There are two types of power supply cables (only differ in wire colors) for random shipments.

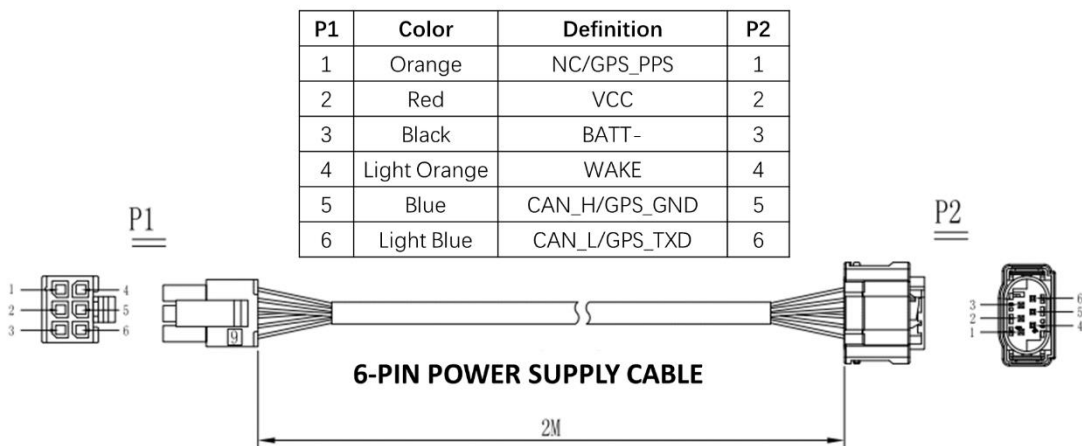


Figure 2.1 The 6-PIN Power Supply Cable ①

Table 2.1 Wiring Definition of the 6-PIN Power Supply Cable ①

S/N	Color	Definition (for lidar with CAN protocol)	Description	Definition (for lidar with GPS time service)	Description
1	Orange	NC	-	GPS_PPS	GPS Inputting PPS Signal

2	Red	VCC	Power+	VCC	Power+
3	Black	BATT-	Power-	BATT-	Power-
4	Light Orange	Wake	Wake-up Input Signal	Wake	Wake-up Input Signal
5	Blue	CAN_H	CAN_H	GPS_GND	GPS_GND
6	Light Blue	CAN_L	CAN_L	GPS_TXD	GPS_TXD

P1	Color	Definition	P2
1	White	NC/GPS_PPS (22AWG)	1
2	Red	VCC (18AWG)	2
3	Black	GND (18AWG)	3
4	Yellow	WAKE (22AWG)	4
5	Green	CAN_H/GPS_GND (22AWG)	5
6	Blue	CAN_L/GPS_TXD (22AWG)	6

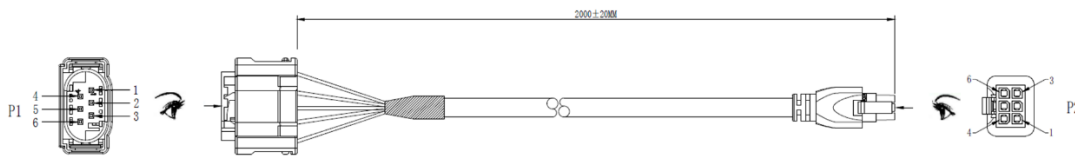


Figure 2.2 The 6-PIN Power Supply Cable ②

Table 2.2 Wiring Definition of the 6-PIN Power Supply Cable ②

S/N	Color	Definition (for lidar with CAN protocol)	Description	Definition (for lidar with GPS time service)	Description
1	White	NC	-	GPS_PPS	GPS Inputting PPS Signal
2	Red	VCC	Power+	VCC	Power+
3	Black	GND	Power-	GND	Power-
4	Yellow	Wake	Wake-up Input Signal	Wake	Wake-up Input Signal
5	Green	CAN_H	CAN_H	GPS_GND	GPS_GND
6	Blue	CAN_L	CAN_L	GPS_TXD	GPS_TXD

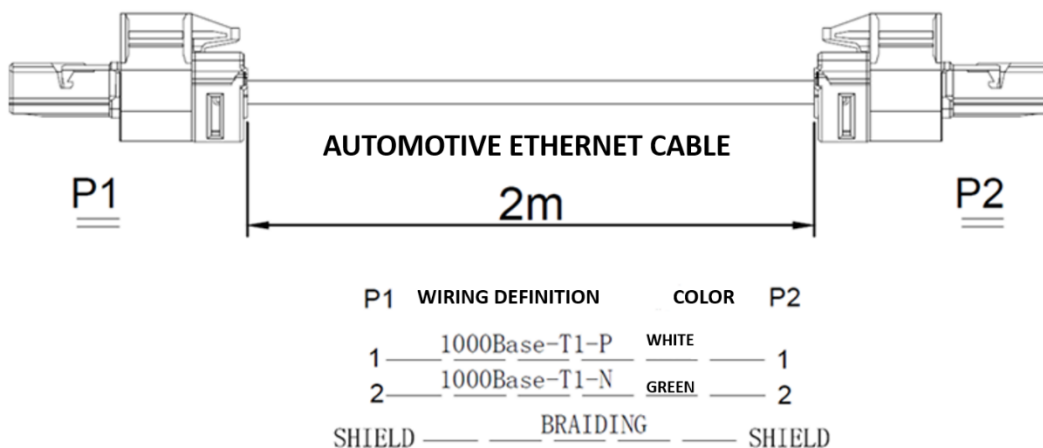


Figure 2.3 The 2-PIN Automotive Ethernet Cable

Table 2.3 The 2-PIN Automotive Ethernet Cable Wiring Definition

S/N	Color	Definition	Description
1	White	1000Base-T1_P	Ethernet TX+
2	Green	1000Base-T1_N	Ethernet TX-

An interface box is sent to you with the Lidar, whose function is to facilitate the testing and connection of the Lidar. Please note that the interface box is not a necessary accessory for Lidar operation.

The interface box of the CH16X1 Lidar includes: an automotive ethernet port, an automotive power port, a  $\Phi 2.1$  mm DC socket, an indicator light, a RJ45 network port and a 6-PIN GPS port, as shown in Figure 2.4.

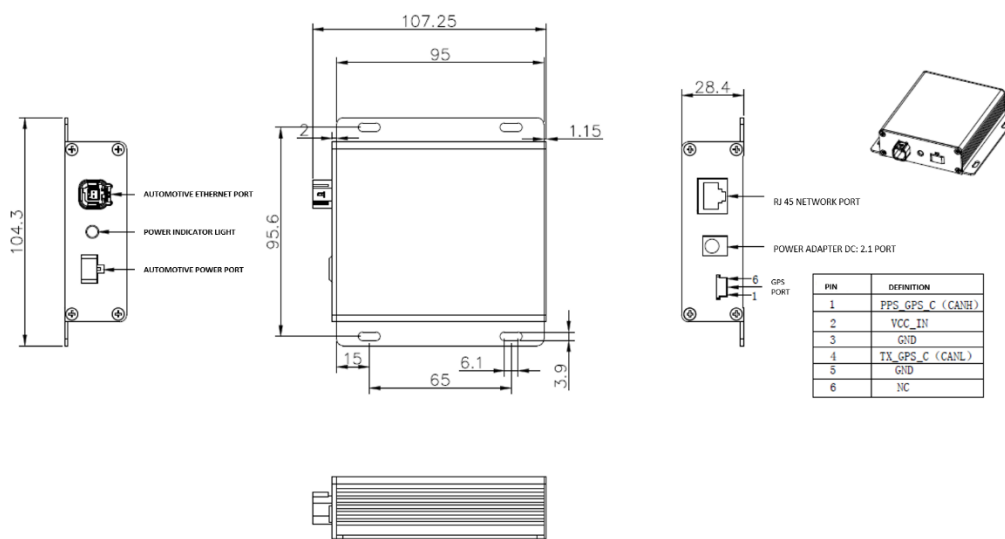


Figure 2.4 Interface Box of CH16X1

The GPS socket of the Interface Box is the SM06B-SRSS-TB presented by the JST Company, and the recommended plug interface for the external GPS module is JST's SHR-06V-S-B. The interface definition of the GPS is here below:

Table 2.4 The Interface Definition of the GPS

PIN	Function Definition	I/O	Requirements
1	PPS Sync Signal	I	TTL level range from 3.3 V to 12 V; its cycle is 1 second, and the recommended pulse width is more than 5 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	RS232 level, baud rate 9600 bps
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, GPS module and power supply through the interface box as shown in Figure 3.1.

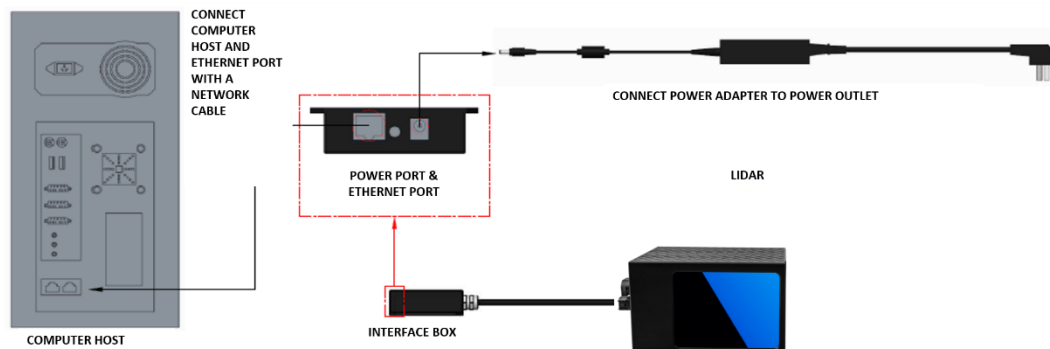


Figure 3.1 Connecting the Lidar

### 3.2 Software Preparation

The CH16X1 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 **Windows Client** or the **ROS Drive Program**.

**Windows Client (optional):** 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 Windows Client has been pre-stored in the USB flash drive provided along with the Lidar. It can also be obtained from the sales or technical support personnel. No installation is required to the client.

- 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 Windows Client, the installation of the **WinPcap** third-party library is necessary. This software has also been pre-stored in the USB flash drive provided with the Lidar.

To install the WinPcap software, please follow the following steps:

**Step 1.** Insert the USB driver into computer port and open it.

**Step 2.** Find the WinPcap installation file and double-click it to initiate the installation.

**Step 3.** Click “next” to enter the installation path selection interface.

**Step 4.** Click “next” to enter the installation interface.

**Step 5.** Click the “install” button, and wait for the installation to be completed.

**ROS Drive Program (optional):** to view the point cloud data under Linux operating system. This program has been pre-stored in the USB flash drive provided with the Lidar. It can also be obtained from the sales or technical support personnel. No installation is required.

## 4. Usage Guide

This part states operation instructions of the Windows Client 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.

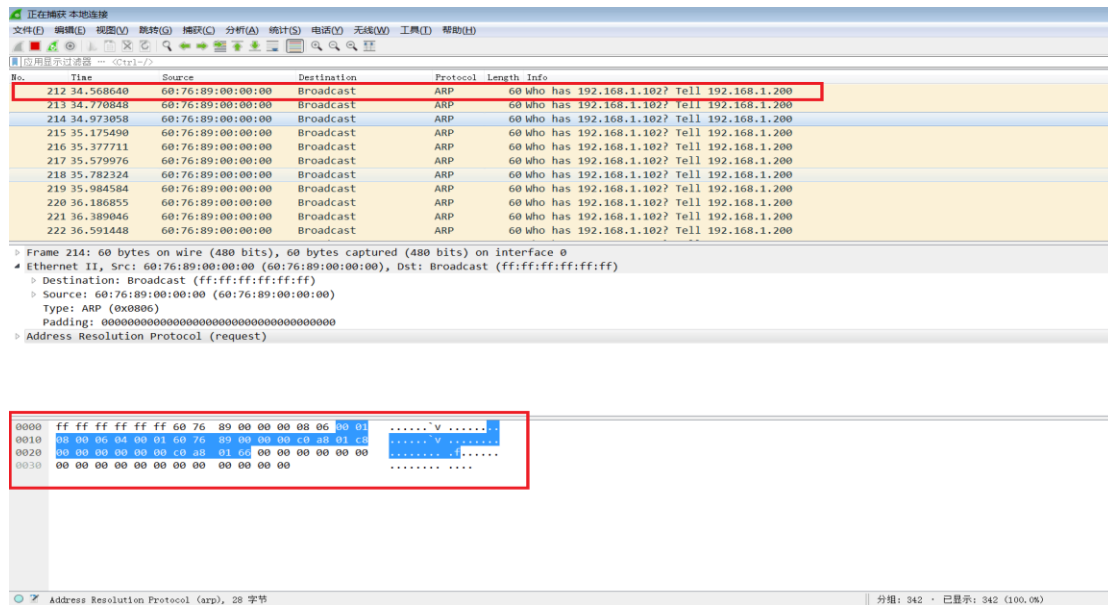


Figure 4.1 Wireshark captures APR packets

### 4.1.2 Windows Client Interface

The software interface includes menu area, tool bar area, 3D window area, data

table area, etc.

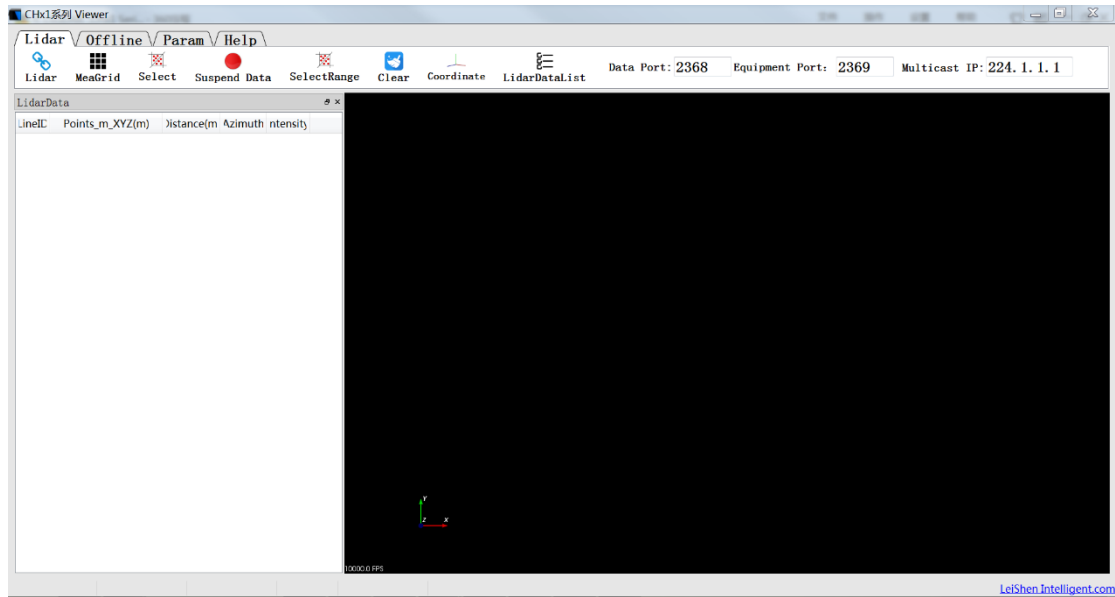


Figure 4.2 Initial Interface

**Note:** In the point cloud display area (right side), with 20 circles and 40\*40 grids, the radius of each two adjacent circles differs by 10 m. The difference between each two grids (horizontal or longitudinal) is 10 m. And the radius of the outermost circle is 200 m.

The grids and circles make it easy to view the position of the point cloud. The direction of the coordinate axis in the 3D display interface is consistent with the direction of the X-Y axis in the point cloud reference system.



**Note:** To view the software version, click “Help->About” in the tool bar.









#### Point cloud display interface supports the following operations:

- 1) Zoom in/out the display interface with the mouse wheel; hold the right mouse button and drag it up/down to zoom in/out.
- 2) Hold the left mouse button and drag it to adjust the angle of view;
- 3) Hold the mouse wheel and drag it to pan the display interface; or hold the shift key on the keyboard and the left mouse button to pan the interface.











#### Menu button function introduction

- Lidar Menu


Button	Description
 Lidar	Click to start receiving display data
	Show/hide measurement grid

 <b>Select</b>	Mark the selected points in the point cloud image	
 <b>Pause</b>	Pause point cloud image and data generating	
 <b>SelectRange</b>	Select point clouds from different angles	
	Clear screen	
	Show/hide coordinate	
	Show/hide the column on the left	
	Three-view option: set the observation angle from top, front, and left.	





● Offline Menu

Button	Description	
 <b>Open</b>	Open offline data	
 <b>Record</b>	Record and save data, valid only when Lidar receives data in real time	
	Skip to the beginning	
	When paused, view the previous frame; When playing, rewind (click multiple times to select 2x, 3x, 1/2x, 1/4x and 1x speed)	
	Click to start playing after the point cloud file is loaded When playing, click to pause	
	When paused, view the next frame; When playing, fast forward (click multiple times to select 2x, 3x, 1/2x, 1/4x and 1x speed)	
	Skip to the end	
	Drag the progress bar or enter the frame number to skip to the specified position	

● Parameter Menu

Button	Description	
 <b>Parameter</b>	Open Lidar parameter form	<p>The upper part of the form shows the Lidar configuration. The parameters include local IP, destination IP, subnet mask, gateway, data port, device port, and motor speed setting (5Hz/10Hz/20Hz can be selected under combobox), whether to obtain the local time, Mac address information, and device packet sending interval.</p> <p>The lower part shows the real-time status information. According to the DIFOP status packet sent out regularly by the Lidar, the current status information is displayed, including GPS position</p>



		information, satellite time information, motor speed, current Lidar IP, and current Lidar port number.
 <b>Channel</b>	Select laser channel	Vertical Angle column represents the vertical angle of the corresponding channel data; Channel column represents the data sequence number corresponding to the channel; Laser ID represents the channel number of the Lidar.
 <b>SaveData</b>	Save the data in .csv format	The data includes Points_X, Points_Y, Points_Z, Laser_id, Azimuth, Distance, Intensity.
 <b>DualEcho</b>	Set the mode of echo	Dual echo, strongest echo, second echo
 <b>Intensity</b>	Set the display mode of the point cloud	Intensity, laser ID, azimuth angle, etc.
Horizontal Angle range: <input type="text" value="0.00"/> ~ <input type="text" value="180.00"/>	Set the horizontal angle	Set the horizontal angle display range

**Note:** The computer graphics card must support OpenGL 2 or higher graphics acceleration to display the point cloud normally.

### 4.1.3 Operation Procedure

**Step 1.** Set the data port number (default 2368), device port (or telemetry port in the picture below) number (default 2369).

Data Port: 
Telemetry Port:

**Step 2.** When the power supply of the Lidar is connected to the network cable,

click  Lidar to receive the Lidar data in real time.

**Step 3.** The data table contains PointID, Points\_m\_XYZ, Azimuth, Distance, Intensity, Laser\_id, timestamp, in which PointID is the point number; Points\_m\_XYZ are the coordinates; Azimuth is the azimuth angle; Distance is the distance value; Intensity is the reflection intensity; Laser\_id is the Lidar channel number and timestamp is the timestamp value.

### 4.1.4 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 microsecond timestamp information of each laser;

**Step 2.** Read the device package to obtain information such as the horizontal correction angle value, 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.

### 4.1.5 Note

#### Notice about the Lidar setting and usage:

- 1) It is not possible to use Windows Client to receive data in two processes (open twice at the same time) in the same computer. The port occupancy of the PC is generally exclusive, so the other software that uses the same process or the same port number cannot work normally after a process is bound to a specified port number. When Windows Client detects that the port is occupied, it will prompt that the communication network port configuration has failed, and automatically close the software. You need to close the software process that occupied the port, and reopen the Windows Client to use it normally.
- 2) At the same time, since Qt is adopted in the low-level software development, please create English paths when naming files and path folders.
- 3) Since the port number of the CH16X1 Lidar can be modified through user configuration, and the Lidar sends data to the host computer through the preset destination IP and port. Therefore, when the local laptop or desktop computer and other devices are receiving data, their IP address should be the same as the destination IP, and the port bound to the local host computer program needs to be the same as the destination port number, as shown in the figure below (these are the data packet parameters captured and analyzed by Wireshark software). The data in the red boxes indicate the destination IP and port number of the Lidar.

Time	Source	Destination	Protocol	Length	Info
1 0.000000	192.168.3.208	192.168.3.144	UDP	1248	2368 → 2368 Len=1206
2 0.000704	192.168.3.208	192.168.3.144	UDP	1248	2368 → 2368 Len=1206
3 0.001318	192.168.3.208	192.168.3.144	UDP	1248	2368 → 2368 Len=1206

Figure 4.3 Data Packet Parameters Captured by Wireshark Software

Please set the host computer IP according to the following steps:

**Step 1.** In the Control Panel -> Network and Internet -> Network Sharing Center, click the “local connection” button.

**Step 2.** Click “Properties” in the pop-up status box, and click “TCP/IPv4 protocol” in the pop-up properties box, as shown in the figure below.

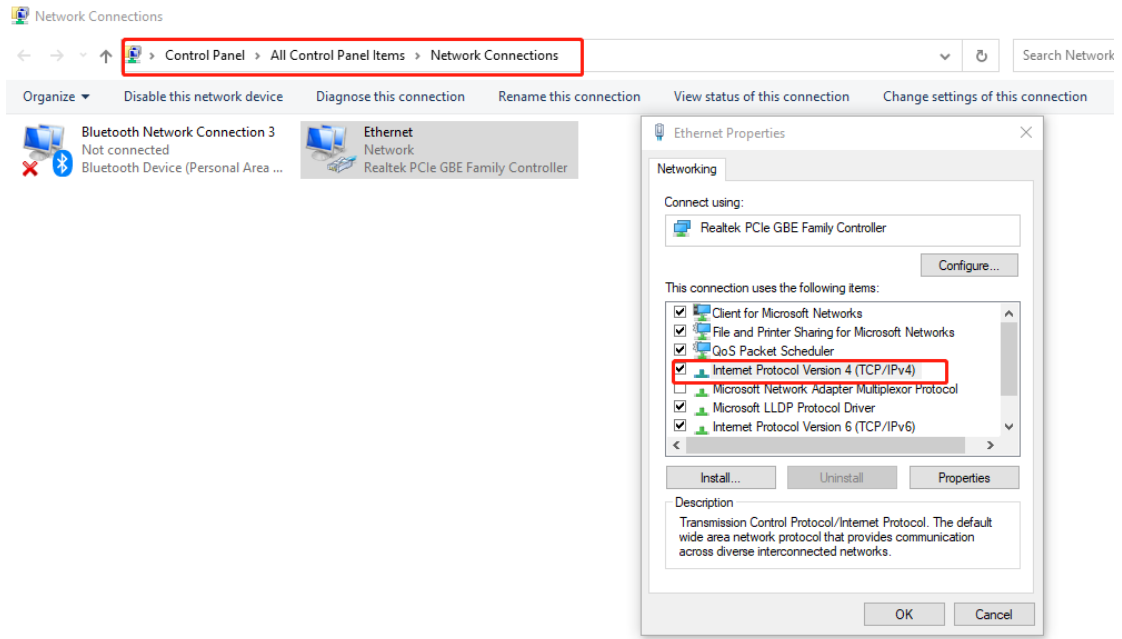


Figure 4.4 Network Connections

**Step 3.** In the TCP/IPv4 property settings, set the IP address to the Lidar's destination IP (The default destination IP of the Lidar is 192.168.1.102), and the subnet mask is set to 255.255.255.0.

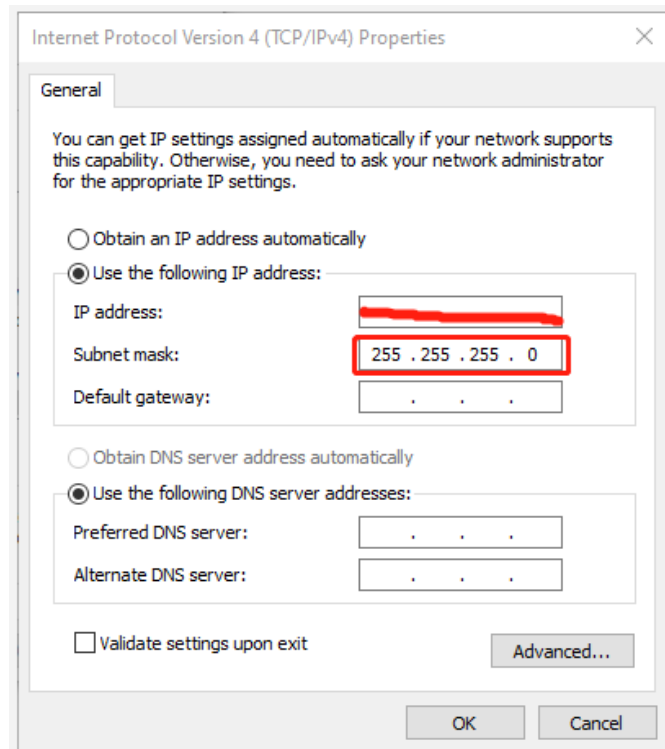


Figure 4.5 IP Address and Subnet Mask Setting

4) Since the Lidar display software needs to obtain a large number of data packets through the network in a short time, it may be considered as a malicious program by the network firewall and be prohibited. Therefore, there may be situations in which the data packet has been sent to the computer by the Wireshark software, but the point cloud display software cannot display it.

To address this problem, in Control Panel -> System and Security -> Windows Firewall Settings, click to allow this program to pass through Windows Firewall, setting steps are as shown in the figures below:

**Step 1.** In Control Panel -> System and Security -> Windows Defender Firewall, click "Allow an app or feature through the Windows Defender Firewall".

**Step 2.** Browse to find the software installation path, select it and click OK.

**Step 3.** Tick the part marked in the red box according to the nature of your network, and click OK to see the data.

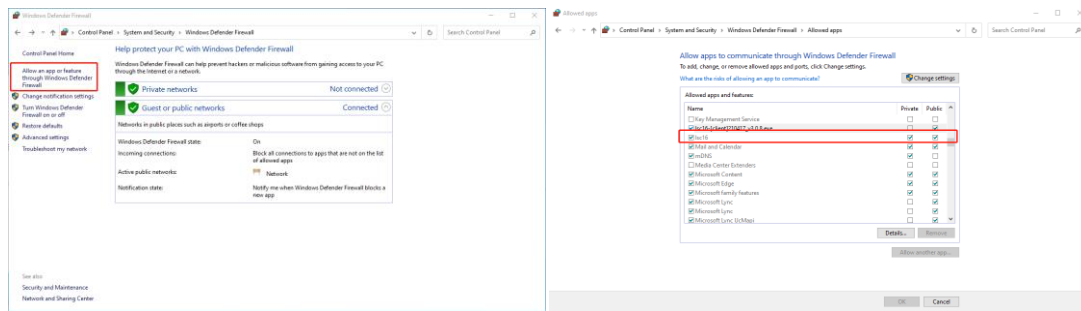


Figure 4.6 Windows Defender Firewall Setting

## Computer graphics settings

When installing the Lidar display software on a desktop or laptop with dual graphics cards, the default global settings of the computer operating system is to use the global settings (automatic selection: integrated graphics), which affects the display efficiency of the software. In order to ensure the use and display efficiency of the software, you need to manually set the computer graphics.

The condition of dual graphics cards can be checked in the computer configuration, and the condition of the display adapter can be seen in My Computer->Properties->Device Manager.

Take a laptop with Intel(R)HD Graphics 530 integrated graphics and NVIDIA GeForce GTX 960 discrete graphics as an example. The setting steps to manually switch the applicable graphics card of the software to high-performance discrete graphics card are as follows:

**Step 1.** Right-click on a blank space on the desktop to pop up a right-click menu and select “NVIDIA Control Panel”.

**Step 2.** Select the “Manage 3D Settings” in the NVIDIA Control Panel interface.

**Step 3.** Click the “Program Settings” button in the Manage 3D Settings interface.

**Step 4.** Click the “Add” button on the Manage 3D Settings interface.

**Step 5.** Click the “Browse” button in the pop-up interface.

**Step 6.** Find the application file (.exe file) of the software according to its installation path in the pop-up browsing interface.

**Step 7.** Click “OK” to automatically return to the NVIDIA control panel, select the high-performance NVIDIA processor in the combo box of the preferred graphics processor for this program in Option -2., and click “Apply” in the lower right corner.

After the computer application is set, close the NVIDIA Control Panel to complete the setting.

## 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-Inspron-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 4.7 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
19:49:08.977308 IP 192.168.1.200.2368 > 192.168.1.102.2368: UDP, length 1206
```

Figure 4.8 sudo tcpdump -n -i eth0 Command Feedback

## 4.2.2 Software Operation Example

**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 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	(Single Echo) about 148.428 $\mu$ s; (Dual Echo) about 94.612 $\mu$ s
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).

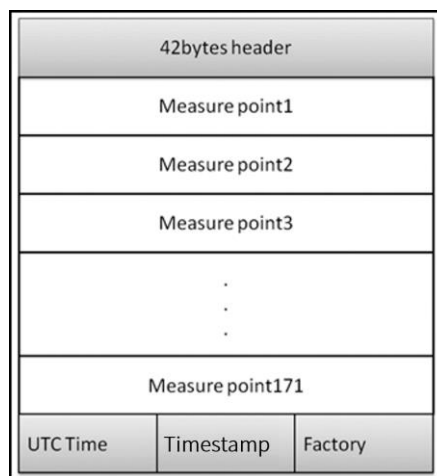


### 5.1.1 Format

The CH16X1 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

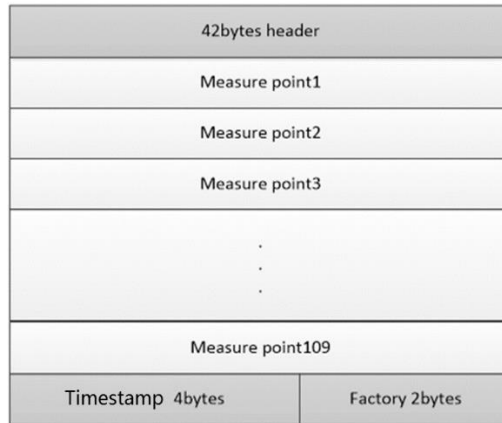
Each MSOP data packet contains 1206 bytes of data. Each packet of data contains 171 points, that is,  $171 \times 7 = 1197$  bytes, and the frame tail is 9 bytes (including 3 bytes of UTC Time of hour, minute and second, 4 bytes of Timestamp and 2 bytes of Factory). See the figure below:



**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.

#### Dual Echo Mode

Each MSOP data packet contains 1206 bytes of data. Each packet of data contains 109 points, that is,  $109 \times 11 = 1199$  bytes, and the frame tail is 7 bytes (including 1 byte of UTC 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 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.

## 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 (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, whose value range from 0 to 15, a total of 16 lines. The 16 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  $-2^\circ$ , line No. 1 represents a vertical angle of  $-1.75^\circ$ , and the angle difference between adjacent lines is  $0.25^\circ$ .

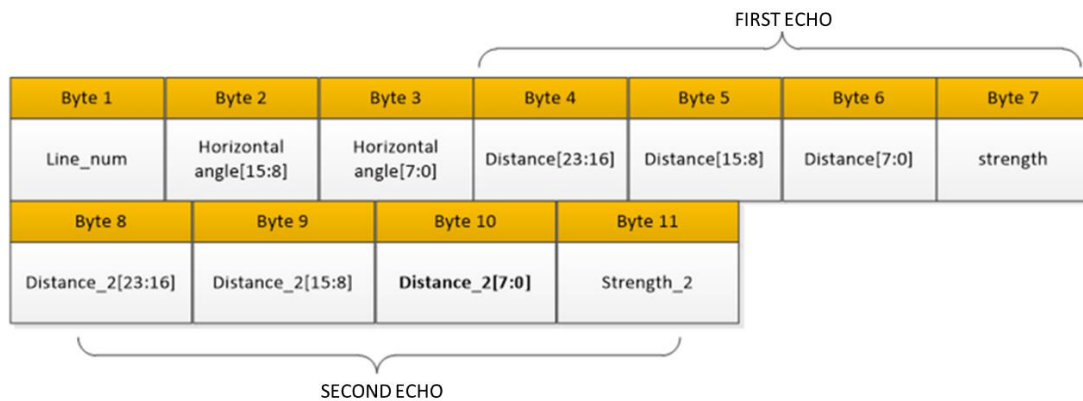
**Byte 2** and **Byte 3** represent the horizontal angle, whose data are stored in Big-Endian mode. The unit is 0.01 degrees. For example,  $0x11AD = 4525$ , that is  $45.25^\circ$ .

**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, whose value range from 0 to 15, a total of 16 lines. The 16 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  $-2^\circ$ , line No. 1 represents a vertical angle of  $-1.75^\circ$ , and the angle difference between adjacent lines is  $0.25^\circ$ .

**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  $45.25^\circ$ .

**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,  $50 \cdot 1/256 \text{ cm} = 0.1953125 \text{ cm}$ . 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 (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.

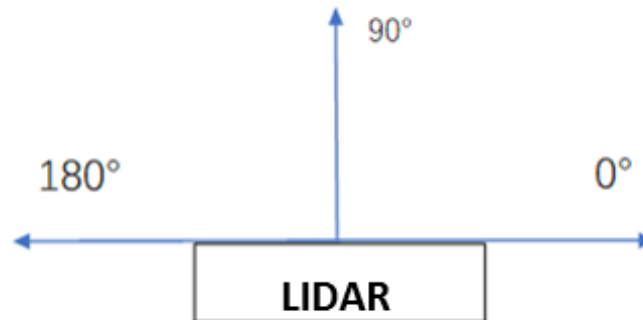


Figure 5.1 The Azimuth of the Lidar

## Additional Information

The additional information of the single echo mode 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.

The additional information of the dual echo mode is 7 bytes in length, including 1-byte UTC time of second, 4 bytes of microsecond Timestamp and 2 bytes of Factory.

Additional Information (single echo mode): 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 CH16X1 Lidar
	Echo Information	1	0x1 represents single echo Lidar 0x2 represents dual echo Lidar

Additional Information (dual echo mode): 7 bytes			
Name		Length (byte)	Function
UTC time		1	Second of the UTC time
Timestamp		4	Timestamp (μs)
Factory	Vendor Information	1	0x80 represents the CH16X1 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 ( $\mu\text{s}$ );

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 ( $\mu\text{s}$ );

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 0-3,599,999,999 ( $\mu\text{s}$ ).

## 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	Lidar Rotation / Stationary	40	2
	4	Device Flow Packet Interval	42	2
	5	GPS Time	52	6
	6	Latitude and Longitude	58	22
Tail	7	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	Lidar Rotation / Stationary	40	2
	4	Configuration Flow Packet Interval	42	2
Tail	7	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 1200 rpm; when it is set to 0x0258, the speed is 600 rpm; when it is set to 0x012C, the speed is 300 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. 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.

## UTC

The Lidar receives GPS signals and parses the \$GPRMC information. The UTC time synchronizes with GPS. If there is no GPS timing, UTC 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 (6 bytes Read Only)						
S/N	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
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	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	6688	0x1A20	2

(port1)			
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.

**Single echo mode:** 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.

**Dual echo mode:** The absolute accurate time of the point cloud data is obtained by adding the 1-byte second information and the 4-byte timestamp (accurate to microseconds) of the data packet and the 5-byte UTC time (year, month, day, hour and minute) 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.

**Single echo mode:** In the UTC output, the year, month and day information is in the device packet and the hour, minute and second information is in the data packet.

**Dual echo mode:** In the UTC output, the year, month, day, hour and minute information is in the device packet and the second information is in the data packet.

There are two types of CH16X1 Lidar GPS\_REC interface level protocols, namely TTL level standard and RS232 level standard; the GPS\_REC interface

specification on the power box is SH1.0-4P female socket. The two protocols differ in two aspects, respectively:

**TTL level pin definition:**

Pin GPS\_TX 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\_TX 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

## 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 3.3~5 V, 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 there is no GPS and other equipment to synchronize, the Lidar uses 1 hour ( $360 \times 10^6 \mu\text{s}$ ) as the cycle. With the microsecond 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. 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.

## 7. Angle and Coordinate Calculation

### 7.1 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, whose value range from 0 to 15, a total of 16 lines. The 16 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  $-2^\circ$ , line No. 1 represents a vertical angle of  $-1.75^\circ$ , and the angle difference between adjacent lines is  $0.25^\circ$ . See the figure below:

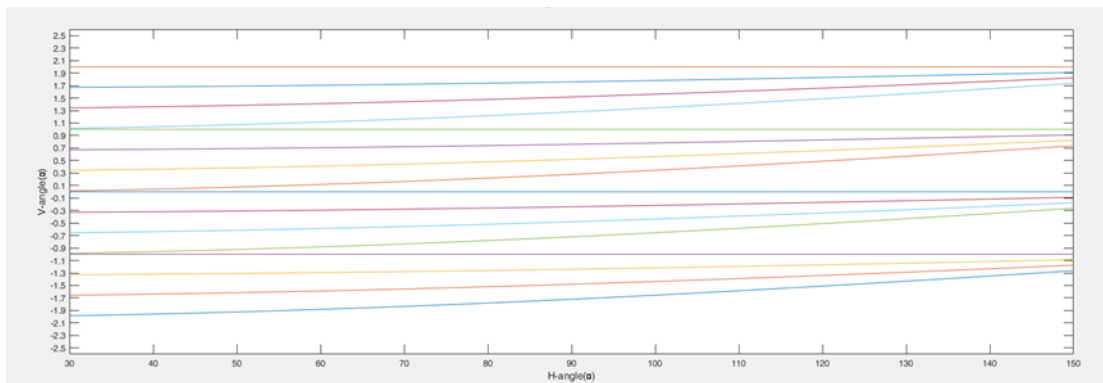


Figure 7.1 Angle Between Light and Lidar's Horizontal Direction

## 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  $45.25^\circ$ .

## 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,  $50 \cdot 1/256$  cm =  $0.1953125$  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.)

## 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,  $\alpha$  is the vertical angle,  $\theta$  is the horizontal rotation angle (the horizontal correction angle needs to be considered when calculating). And x, y, and z are the coordinates of the polar coordinates projected onto the x, y, and z axes.

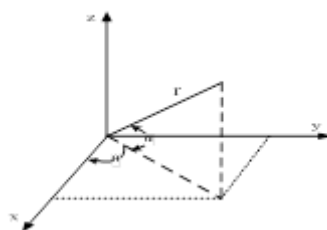


Figure 7.2 Coordinate Mapping

## 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 CH16X1 Lidar is about 0.868  $\mu\text{s}$ , and the measurement interval of adjacent points is 0.868  $\mu\text{s}$ .

## 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  $0.868 \mu\text{s} * 171 \approx 148.428 \mu\text{s}$ , and the data rate is about  $1\text{s} / 148.428 \mu\text{s} \approx 6,737$  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 CH16X1 Lidar contains 171 measurement data. Therefore, the end time interval of each data packet (single echo mode) is 148.428  $\mu\text{s}$ . Assuming that the absolute time of the data packet end is  $T_{\text{Packet\_end}}$ , the steps for calculating the end time of the data block  $T_{\text{Block\_end}}(N)$  are as follows:

$$T_{\text{Block\_end}}(N) = (T_{\text{Packet\_end}} - 0.868 \mu\text{s} * (171 - N)). \quad (N = 1, 2, \dots, 171).$$

## 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  $1\text{s} / 94.612 \mu\text{s} \approx 10,569$  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 CH16X1 Lidar contains 109 measurement data. Therefore, the end time interval of each data packet (dual echo mode) is 94.612  $\mu\text{s}$ . Assuming that the absolute time of the data packet end is  $T_{\text{Packet\_end}}$ , the steps for calculating the end time of the data block  $T_{\text{Block\_end}}(N)$  are as follows:

$$T_{\text{Block\_end}}(N) = (T_{\text{Packet\_end}} - 0.868 \mu\text{s} * (109 - N)). \quad (N = 1, 2, \dots, 109).$$



## Revision History

Rev.	Release Date	Revised Content	Issued/Revised By
V1.0.0	2022-09-23	Initial Version	LS1286
V1.0.1	2022-09-26	Windows Client Interface modification	LS1286
V1.0.2	2022-11-10	New power cable and wire definition added; note of lidar IP setting added	LS1286



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