



CH16X1

User Manual

V1.0.2 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

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).

Distance = Speed of Light * ($t_2 - t_1$) / 2

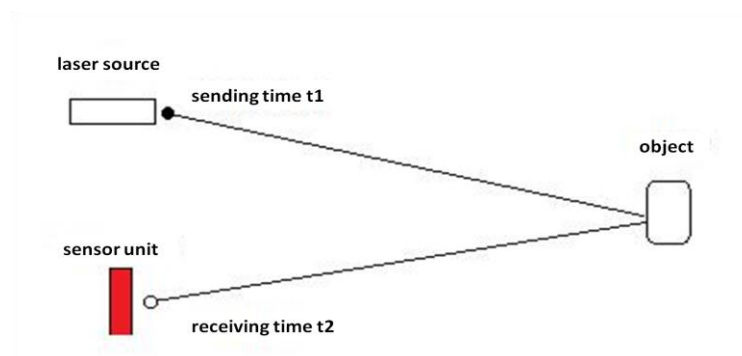


Figure 1.1 Mechanism of the CH16X1 Lidar

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°

Vertical Angular Resolution	0.25°
Horizontal Angular Resolution	5Hz: 0.06°; 10Hz: 0.12°; 20Hz: 0.24°
Scanning Rate	5 Hz, 10 Hz, 20 Hz
Communication Interface	Fast Industry Ethernet
Operating Voltage	9 V~36 VDC
Power Consumption	12 W
Operating Temperature	-40℃ ~ +85℃
Storage Temperature	-40℃ ~ +105℃
Shock Test	500 m/sec ² , lasting for 11 ms
Vibration Test	5 Hz~2000 Hz, 3G rms
IP Grade	IP6K9K
Dimensions	118*90*75 mm
Weight	1 kg

1.4 Dimensions

There are 4 mounting holes and 2 positioning holes at the bottom of CH16X1 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.

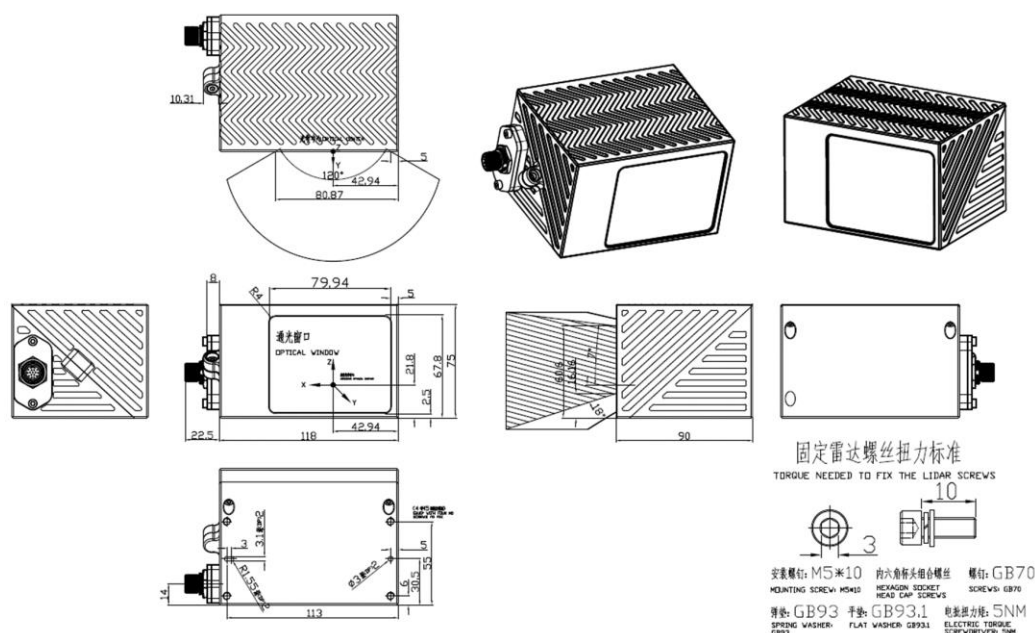


Figure 1.2 CH16X1 Lidar Dimension

The CH16X1 lidar utilizes mirror rotation and special optical design to scan 120° horizontally. Figure 1.3 shows the appearance of the CH16X1 lidar while Figure 1.4 shows the optical center position, which is also the coordinate origin of the point cloud display software.



Figure 1.3 External View of CH16X1

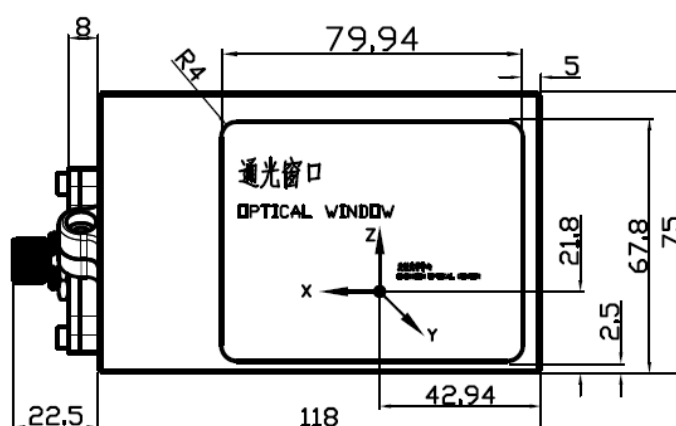


Figure 1.4 The Optical Center of the Lidar

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 $<120\text{ mVp-p}$ 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

An 8-pin male connector is on the side of the CH16X1 lidar base. See the figure below.

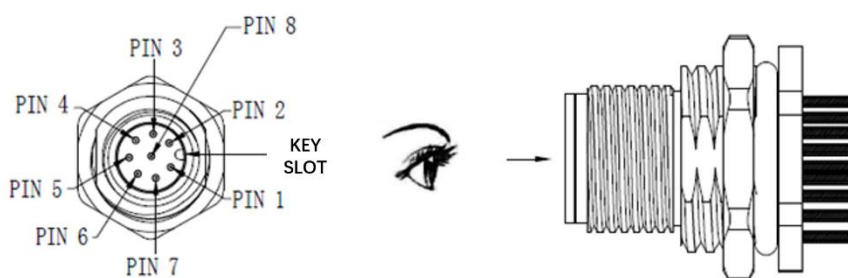


Figure 2.1 The 8-Pin Male Connector

Table 2.1 Wiring Definition of the 8-Pin Male Connector

PIN	Definition	Description
1	VCC	Power+
2	TD_P	Ethernet TX+: lidar - external device
3	TD_N	Ethernet TX-: lidar - external device
4	RD_P	Ethernet RX+: external device - lidar
5	RD_N	Ethernet RX-: external device - lidar
6	GPS_PPS	GPS sync pulse/external sync pulse
7	GPS_REC	GPS longitude, latitude, hour minute and second
8	GND	Power-
PE	PE	GND

The cable connecting to the 8-pin male connector is an 8-pin cable, see the figure below.

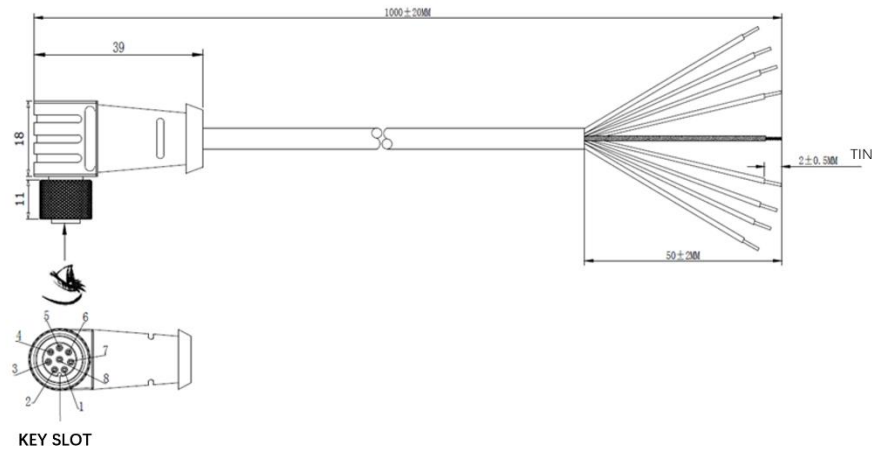


Figure 2.2 The 8-Pin Cable

Table 2.2 Wiring Definition of the 8-Pin Cable

PIN	Color	Definition	Description
1	Red	VCC	Power+
2	Light blue	TD_P	Ethernet TX+
3	Blue	TD_N	Ethernet TX-
4	Light orange	RD_P	Ethernet RX+
5	Orange	RD_N	Ethernet RX-
6	Yellow	GPS_PPS	GPS sync pulse/external sync pulse
7	White	GPS_REC	GPS longitude, latitude, hour minute and second
8	Black	GND	Power-
PE	SHELD	PE	GND

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.

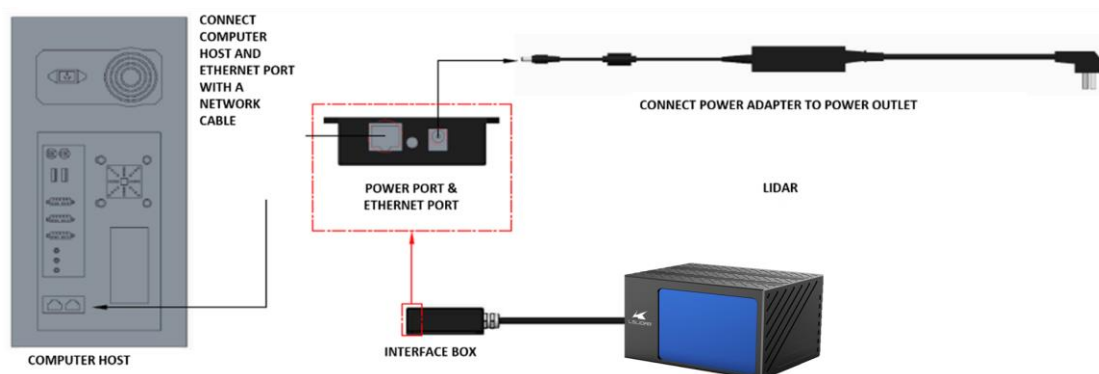


Figure 3.1 Connecting the Lidar

3.2 Software Preparation

The 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 driver.

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.

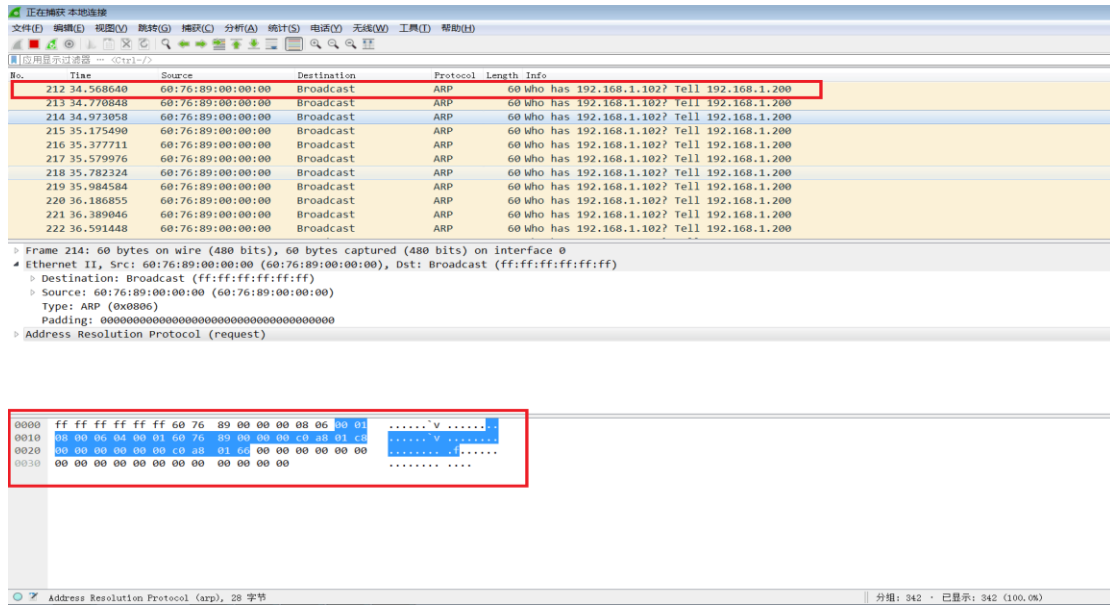


Figure 4.1 Wireshark captures APR packets

4.1.2 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 software, 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.

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;

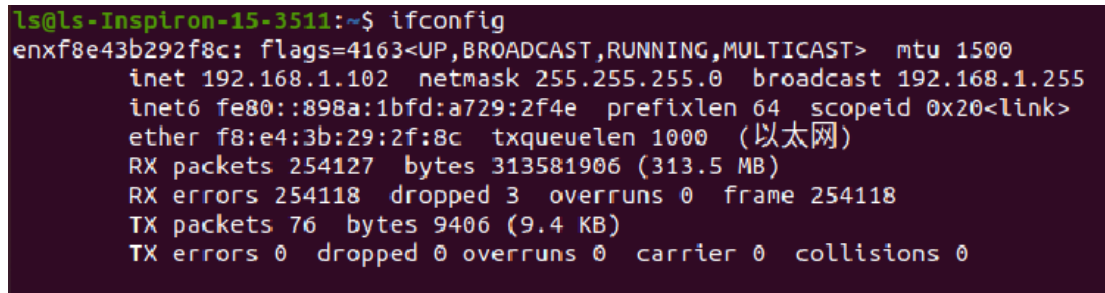
Step 6. Reconfigure information such as Ethernet, PPS synchronization horizontal angle, motor speed and other information as needed, and pack the configuration package protocol.

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 4.7 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
19:49:08.976988 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 lsidar_ch_decoder lsidar_ch.launch
```

Reopen a terminal again and execute the following command:

```
roslaunch rviz rviz
```

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

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

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

Step 5. Display the data detected by the lidar

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

5. Communication Protocol

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

The communication protocols of the lidar are:

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

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

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

Table 5.1 UDP Packet Protocol

Protocol Name	Abbr.	Function	Length	Transmission Interval
Main data Stream Output Protocol	MSOP	Outputting measured data and timestamp	1212	About 0.148 ms
Device Information Output Protocol	DIFOP	Outputting parameter configuration and status information	1206	1s (for 1 packet)
User Configuration Write Protocol	UCWP	Inputting user configured device parameters	1206	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.

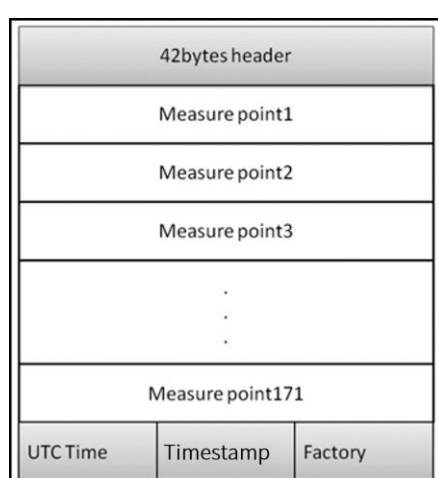
The data package includes a 42-byte Ethernet header and a 1212-byte payload, with a total length of 1254 bytes. The payload consists of 1197 bytes of point cloud data and 15 bytes of additional information (including 3 bytes reserved, 6

bytes of UTC, 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.

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 15 bytes (including 3 bytes reserved, 6 bytes of UTC, 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 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° , line No. 1 represents a vertical angle of -1.75° , and the angle difference between adjacent lines is 0.25° .

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

Byte 4, **Byte 5**, and **Byte 6** represent the distance value. Their data are stored in Big-Endian mode. The two high bytes are the integer part, whose unit is "cm"; and the last byte is the decimal part, whose unit is $1/256$ cm. To analyze the distance value, for example: the distance value in the obtained data packet is represented by the hexadecimal number 0x02, 0x18, 0x32, and the first two bytes are composed of 16-bit unsigned data, that is: 0x0218, which is converted to decimal distance value: 536 cm. The last byte is the decimal part, 0x32 equals 50 in decimal, that is, $50 \times 1/256 \text{ cm} = 0.1953125 \text{ cm}$. Then the two parts add up to 536. 1953125 cm.

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

Azimuth

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

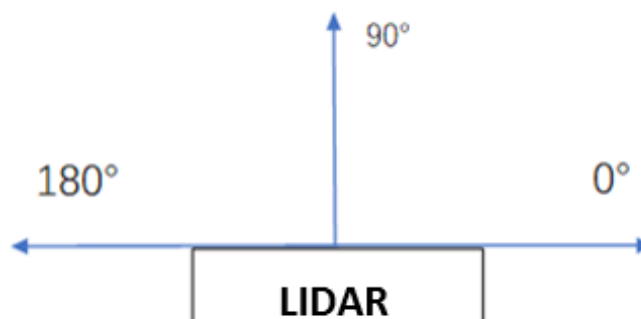


Figure 5.1 The Azimuth of the Lidar

Additional Information

The additional information of the single echo mode is 15 bytes in length, including 3 bytes reserved, 6 bytes of UTC, 4 bytes of microsecond Timestamp and 2 bytes of Factory.

Additional Information: 15 bytes			
Name		Length (byte)	Function
Reserved		3	Reserved
UTC		6	Year, month, day, hour, minute and second of the UTC
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 (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 0-3,599,999,999 (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	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 (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 6-byte year, month, day, hour, minute, second information and the 4-byte timestamp (accurate to microseconds) of the data 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.

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 ($3,600 \times 10^6 \mu s$) 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° , line No. 1 represents a vertical angle of -1.75° , and the angle difference between adjacent lines is 0.25° . See the figure below:

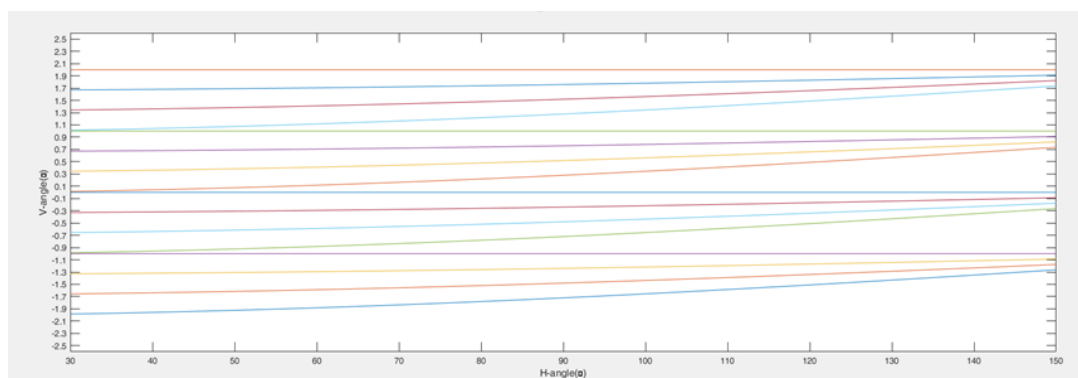


Figure 7.1 Angle Between Light and Lidar's Horizontal Direction

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

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.

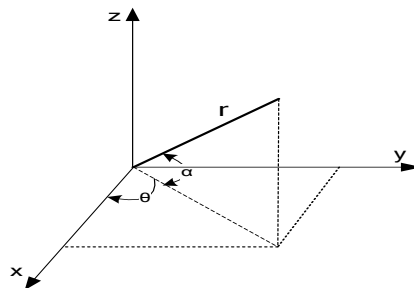


Figure 7.2 Coordinate Mapping

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 CH16X1 lidar is about 2.64 μ s, and the measurement interval of adjacent points is 2.64 μ s.

A data packet has a total of 171 measurement data. The packaging time of the data packet is about $2.64 \mu\text{s} \times 171 \approx 452 \mu\text{s}$, and the data rate is about $1\text{s}/452 \mu\text{s} \approx 2,212$ data packets/second.

8.1 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 6-byte year, month, day, hour, minute and second information and the 4-byte microsecond timestamp from the data packet.

8.2 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 $452 \mu\text{s}$. 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:

$$T_{\text{Block_end}}(N) = (T_{\text{Packet_end}} - 2.64 \mu\text{s} \times (171 - N)). (N = 1, 2, \dots, 171).$$

Revision History

Rev.	Release Date	Revised Content	Issued/Revised By
V1.0.0	2022-09-26	Initial Version	LS1286
V1.0.1	2023-02-14	Mechanical drawing modified	LS1286
V1.0.2	2024-10-18	Operation under Windows OS updated	LS1499



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