CX128S2

User Manual

V1.0.5   2024.10

Leishen Intelligent System Co., Ltd.   **http://www.lslidar.com/**

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

CX128S2 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 CX128S2 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

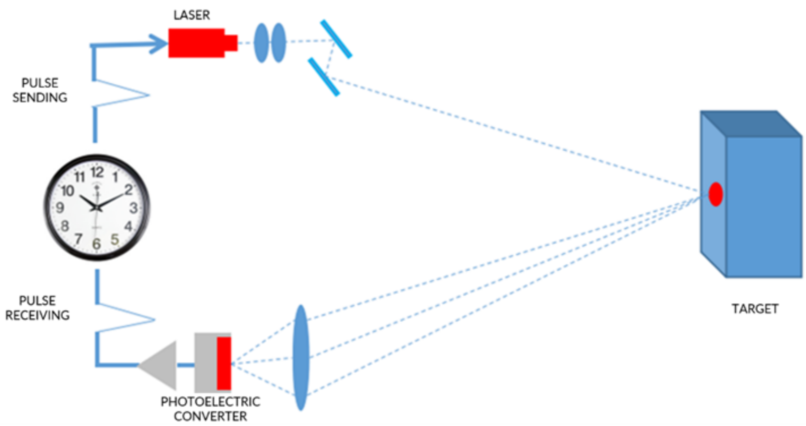

Figure 1.1 Mechanism of the CX128S2 Lidar

1.3 Specification

Table 1.1 Specifications of CX128S2

Model	CX128S2
Detection Method	ToF
Wavelength	905 nm
Laser Class	Class 1 (eye-safe)
Channels	128
Detection Range	200 m @10% reflectivity

Range Accuracy	±3 cm
Data Point Generated (Single Echo Mode)	1,530,000 pts/sec
Vertical FOV	25° (-12.5°~+12.5°)
Horizontal FOV	120°
Vertical Angular Resolution	0.125°@ROI, 0.25°@non-ROI
Horizontal Angular Resolution	5 Hz: 0.05°/ 10 Hz: 0.1°/20 Hz: 0.2°
Scanning Rate	5 Hz, 10 Hz, 20 Hz
Communication Interface	Automotive Ethernet 1000 Base-T1
Time Source	PPS; gPTP
Power Supply Voltage	9 V ~32 V DC
Power Consumption	15 W
Operating Temperature	-40℃ ~ +85℃
Storage Temperature	-40℃ ~ +105℃
Shock Test	500 m/sec², lasting for 11 ms
Vibration Test	5 Hz ~2000 Hz, 3G rms
IP Grade	IP 6K9K
Dimensions	139*112.78*47 mm
Weight	≤ 935 g

1.4 Dimensions

There are 4 mounting holes and 2 positioning holes at the bottom of CX128S2 lidar. Four M4*10 (hexagon socket head cap screws) mechanical screws with spring washers and flat washers are needed for locking and fixing the lidar. See the outline dimension drawing shown in Figure 1.2.

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

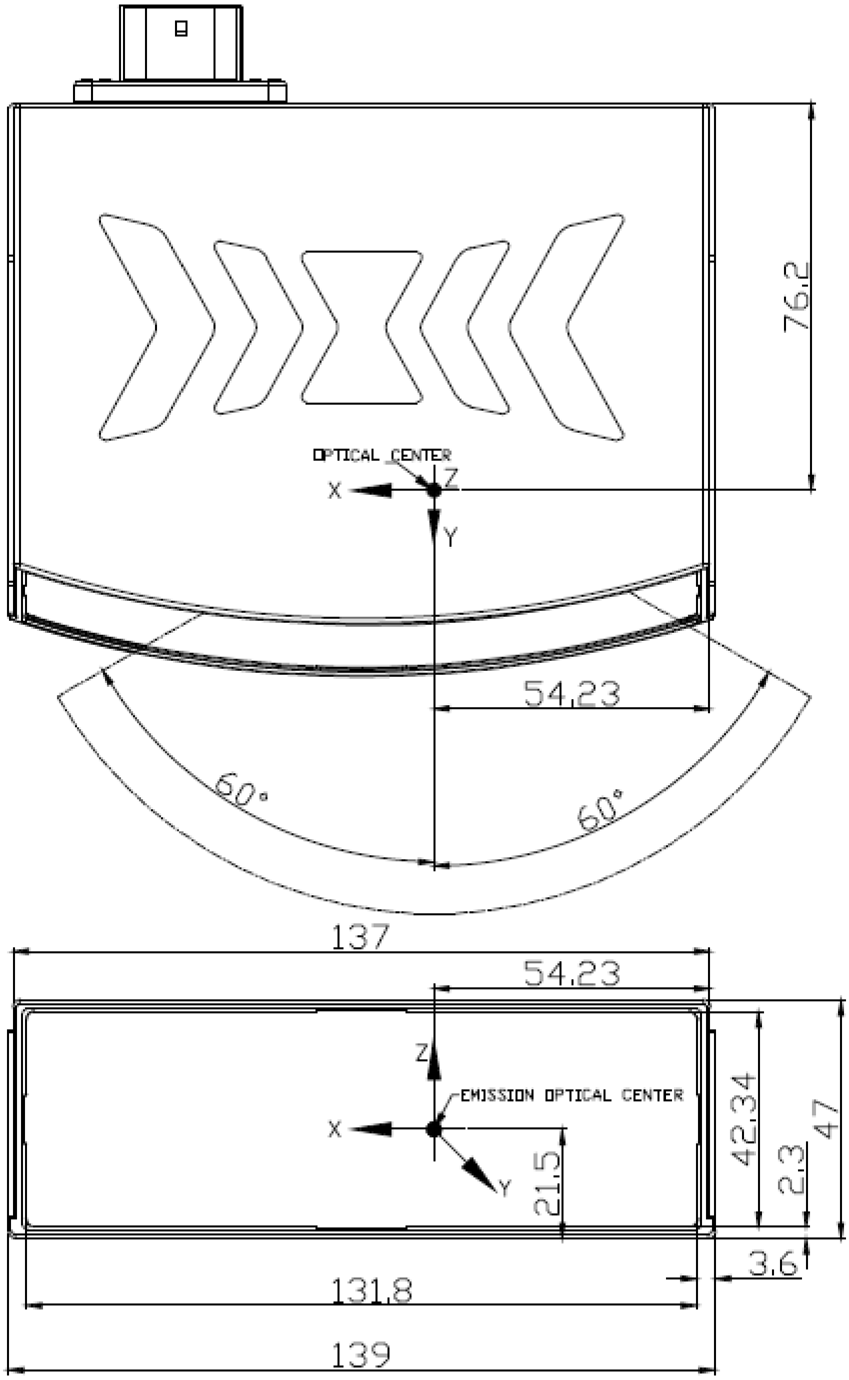

Figure 1.2 CX128S2 Lidar Dimension (unit: mm)

The CX128S2 lidar utilizes mirror rotation and special optical design to scan 120° horizontally, with a dense light distribution of 128 lines. Figure 1.3 shows the optical center position, which is also the coordinate origin of the host computer display software.

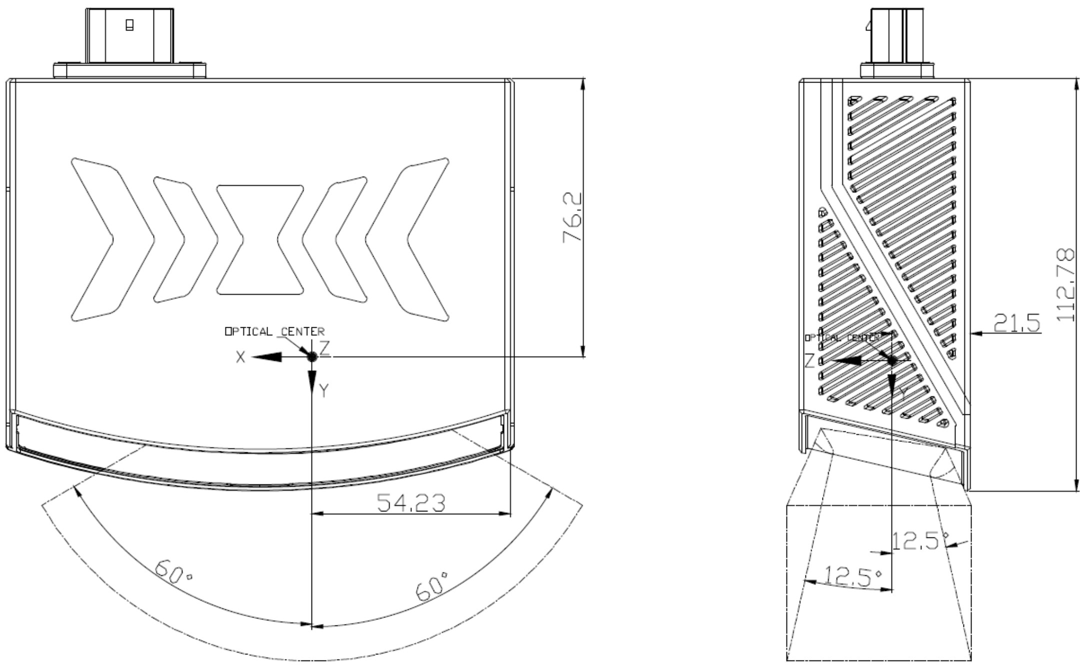

Figure 1.3 The Optical Center of the Lidar (left: FLAT; right: ARC)

2. Electrical Interface

2.1 Power Supply

The power input range of the CX128S2 lidar is 9 V～32 V DC. If other DC power supply is adopted, the recommended output voltage of the power supply is 24 V DC. Please note that DC 9 V and 32 V are short-term power supply in extreme environment, which cannot be used as working voltage. When the voltage output fluctuates, the lidar may not be able to work normally.

The maximum output current should be ≥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%.

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 interface specification of the CX128S2 lidar is: ECT PNA: 818018316. The standard cable connecting to the CX128S2 lidar interface is a 2-in-1 cable: consisting of one 6-pin power supply and signal cable and one 2-pin automotive ethernet cable. As shown below.

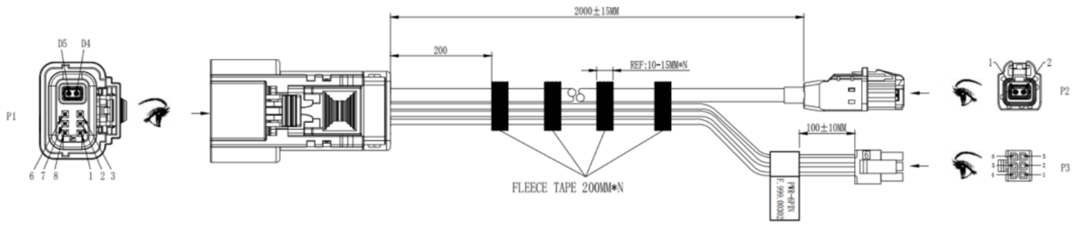

Figure 2.1 The Standard Cable of CX128S2

Table 2.1 Wiring Definition of the Standard Cable of CX128S2

S/N	Color	Definition	Description

D4	White	Ethernet D+	1000 Base-T1; Ethernet TX+
D5	Green	Ethernet D-	1000 Base-T1; Ethernet TX-
1	White	GPS-PPS/spare	GPS PPS, External Sync PPS / NC when using CAN
2	Red	VCC/20AWG	Power+
3	Black	GND/20AWG	Power-
6	Yellow	WAKE/20AWG	Wake-up Input Signal
7	Green	GPS-GND/CAN_H	GPS Ground / CAN High Level
8	Blue	GPS-TXD/CAN_L	GPS (latitude/longitude, hour/minute/second)/ CAN Low Level

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 CX128S2 lidar includes: an automotive ethernet port, an automotive power port, a Φ2.1 mm DC socket, an indicator light, a RJ45 network port and a 6-PIN GPS port, as shown in Figure 2.4.

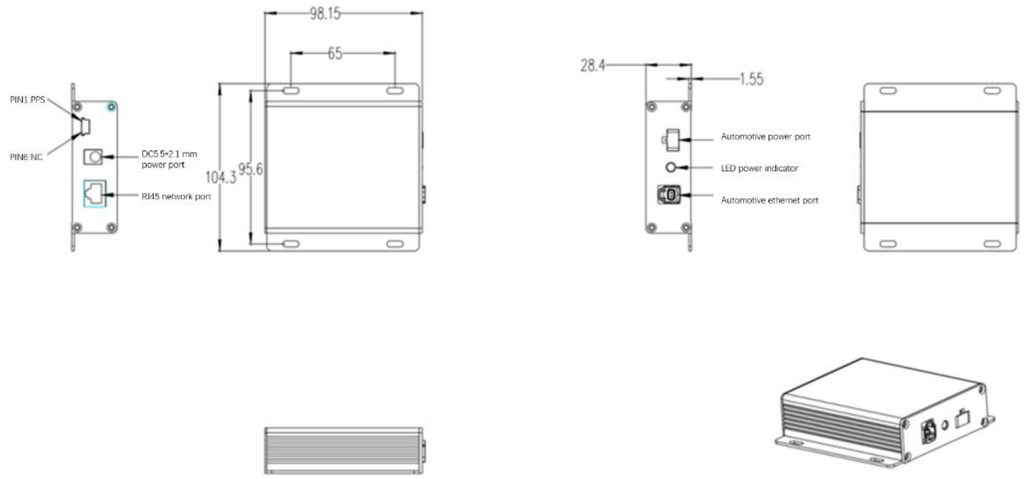

Figure 2.2 Interface Box of CX128S2

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 3.3V to 12V; its cycle is 1 second, and the recommended pulse width is more than 5 ms
2	GPS Power Supply 5V	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 and power supply using the interface cable. And please remove the protective film on the optical window to avoid affecting the detection effect.

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 Windows Client 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.

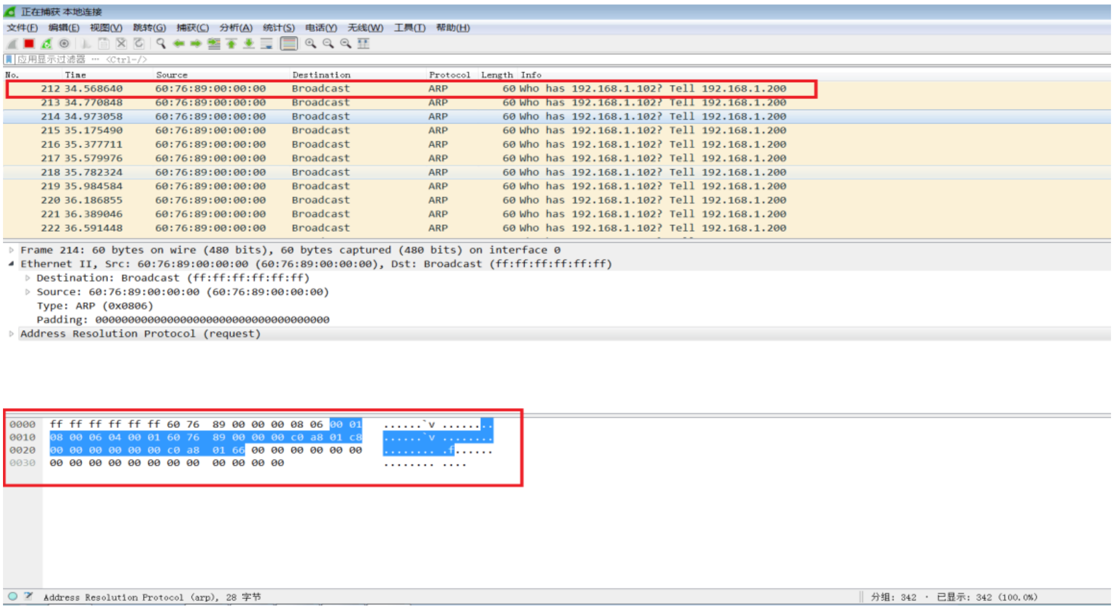

Figure 4.1 Wireshark captures APR packets

1) Wireshark is a third-party software, and you may need to download it by yourself. Leishen Intelligent bears no responsibility for any copyright and commercial disputes caused by users' use of the software.

2) Please disable all virtual NICs when using the SDK to prevent interference with data reception.

3) When developing with Visual Studio, please use the "release mode" in priority to reduce issues caused by data blocking, read and write delays.

4.1.2 Upper Computer Platform

Upper Computer Platform (windows client), which is also referred to as "point cloud display software". Simple functions like parameter configuration, lidar test and fault detection can be realized through the client, too.

For more information on how to use the software, please refer to the software operation manual included in the LiDAR service package or click on the icon  in the upper right corner of the software to jump to the software operation manual after you installed it.

4.1.3 Point Cloud Data Parsing

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

Step 1. Parse the data package to obtain the relative horizontal angle, ranging information, intensity data and nanosecond 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, nanosecond 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 4.2 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).

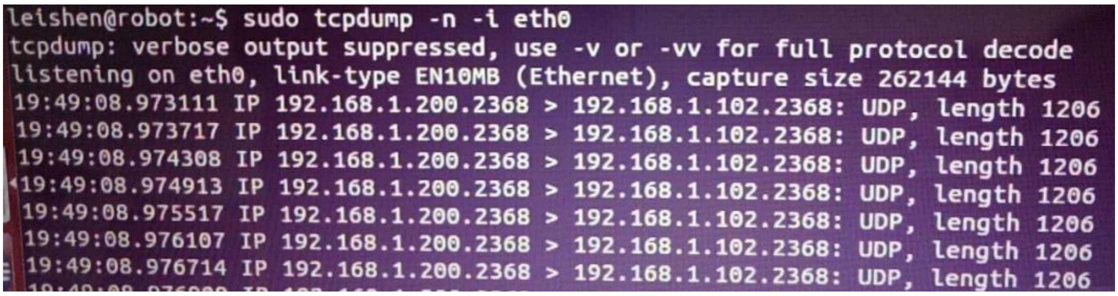

Figure 4.3 sudo tcpdump -n -i eth0 Command Feedback

4.2.2 Software Operation Example

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

Step 1. Establish a workspace and build a compilation environment

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

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

Step 2. Download the lidar driver and dependency package

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

Step 3. Compile and package

```
cd ~/leishen_ws
catkin_make
```

Step 4. Run the program

source ~/leishen_ws /devel/setup.bash

roslaunch lslidar_ch_decoder lslidar_ch.launch

Reopen a terminal again and execute the following command:

rosrun rviz rviz

Note 1): If the lidar destination port and motor speed are modified, please open “lslidar_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, among which MSOP packet length is 1254 bytes (42 bytes Ethernet header and 1212 bytes payload). DIFOP and UCWP are 1248 bytes (42 bytes Ethernet header and 1206 bytes payload) Lidar supports unicast, broadcast and multicast communication.

The communication protocols of the lidar are:

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

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

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

Table 5.1 UDP Packet Protocol

Protocol Name	Abbr.	Function	Length	Transmission Interval
Main data Stream Output Protocol	MSOP	Outputting measured data and timestamp	1254 bytes	about 74 μs;
Device Information Output Protocol	DIFOP	Outputting parameter configuration and status information	1248 bytes	1s (for 1 packet)
User Configuration Write Protocol	UCWP	Inputting user configured device parameters	1248 bytes	Not Fixed

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.

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

Dual echo mode: The payload consists of 1199 bytes of point cloud data and 13 bytes of additional information (including 1 byte reserved, 6 bytes of UTC time of year, month, day, hour, minute and second, 4 bytes of Timestamp and 2 bytes of Factory).

5.1.1 Format

The CX128S2 lidar supports single echo mode which measures the most recent echo value and dual echo mode which measures the most recent and second recent echo values.

Single Echo Mode

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

<table>
<tr><td colspan="3">42 bytes header</td></tr>
<tr><td colspan="3">Measure point 1</td></tr>
<tr><td colspan="3">Measure point 2</td></tr>
<tr><td colspan="3">Measure point 3</td></tr>
<tr><td colspan="3">.
.
.</td></tr>
<tr><td colspan="3">Measure point 171</td></tr>
<tr><td colspan="3">Reserved 3 bytes</td></tr>
<tr><td>UTC 6 bytes</td><td>Timestamp 4 bytes</td><td>Factory 2 bytes</td></tr>
</table>

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

42 bytes header		
Measure point 1		
Measure point 2		
Measure point 3		
. . .		
Measure point 109		
Reserved 1 byte		
UTC 6 bytes	Timestamp 4 bytes	Factory 2 bytes

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

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*7=1197 bytes. Take the first measure point as an example:

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

Byte 1 represents the line number, whose value range from 0 to 127, a total of 128 lines. The 128 lines respectively corresponds to the lowermost ray to the uppermost ray in the entire vertical field of view. For example, line No. 0 represents a vertical angle of -12.5°, line No. 1 represents a vertical angle of -12.25°, and the angle difference between adjacent lines is 0.25° or 0.125°.

Byte 2 and **Byte 3** represent the horizontal angle, whose data are stored in Big-Endian mode. The unit is 0.01 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*1/256 cm=0.1953125 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*11=1199 bytes. Take the first measure point as an example:

FIRST ECHO (Byte 4 – Byte 7)

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 8	Byte 9	Byte 10	Byte 11
Distance_2[23:16]	Distance_2[15:8]	**Distance_2[7:0]**	Strength_2

SECOND ECHO (Byte 8 – Byte 11)

Byte 1 represents the line number, whose value range from 0 to 127, a total of 128 lines. The 128 lines respectively corresponds to the lowermost ray to the uppermost ray in the entire vertical field of view. For example, line No. 0 represents a vertical angle of -12.5°, line No. 1 represents a vertical angle of -12.25°, and the angle difference between adjacent lines is 0.25° or 0.125°.

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

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.

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 (0.05°, 0.1°, 0.2°) 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.

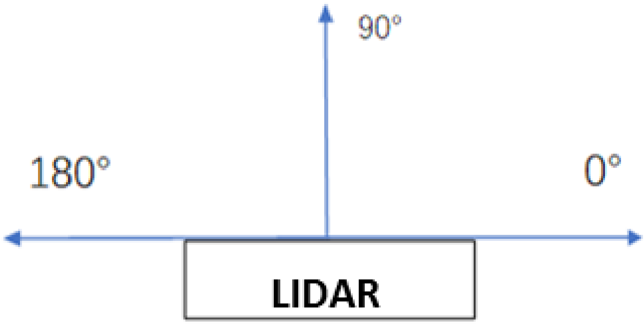

Figure 5.1 The Azimuth of the Lidar

Additional Information

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

Additional Information (single echo mode): 15 bytes			
Name		**Length (byte)**	**Function**
Reserved		3	Reserved
UTC time		6	Year, month, day, hour, minute and second of the UTC time
Timestamp		4	Timestamp (ns)
Factory	Vendor Information	1	0x80 represents the CX128S2 lidar
	Echo Information	1	0x1 represents single echo lidar 0x2 represents dual echo lidar

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

Additional Information (dual echo mode): 13 bytes			
Name		**Length (byte)**	**Function**
Reserved		1	Reserved
UTC time		6	Year, month, day, hour, minute and second of the UTC time
Timestamp		4	Timestamp (ns)
Factory	Vendor Information	1	0x80 represents the CX128S2 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 0-999,999,999 (ns);

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 0-999,999,999 (ns);

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

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

No.	Information	Offset	Length (Byte)	Note
0	DIFOP Identification Header	0	8	a5 ff 00 5a 11 11 55 55
1	Motor Speed	8	2	
2	Ethernet Configuration (IP, MAC, port, NTP)	10	22	
3	Ethernet Configuration (gateway, subnet mask)	32	8	
4	Lidar Rotation/ Stationary	40	2	
5	Device Flow Packet Interval	42	2	
6	Clock Source Selection	44	1	
7	Standby Mode	45	1	0: normal; 1: standby mode
8	Phase Lock Enable	46	1	0: disabled; 1: enable
9	Phase Lock Angle Setting	47	2	The value is multiplied by 100 to write into the lidar; divide the value by 100 to read back
10	Error Code	49	2	
11	Reserved	51	1	
12	UTC Time (GPS time)	52	6	
13	Latitude and Longitude	58	22	
14	Left APD Board Temperature	80	2	temp=(data/4096)*2.5*100-50
15	Left LD Board Temperature	82	2	temp=(data/4096)*2.5*100-50
16	Left APD High Voltage	84	2	HV=281-0.0692142*data
17	Right APD Board Temperature	86	2	temp=(data/4096)*2.5*100-50

18	Right LD Board Temperature	88	2	temp=(data/4096) *2.5*100-50
19	Right APD High Voltage	90	2	HV=281-0.0692142*data
20	GPS Status	92	1	
21	PPS Status	93	1	
22	High Temperature Pause	94	2	
23	Cover Dirty Count	96	1	
24	Cover Dirty Alarm Message	97	1	
25	Cover Dirty Energy Value	98	2	
26	Left Threshold Adjustment Value	100	1	
27	Right Threshold Adjustment Value	101	1	
28	Power Board Temperature	102	2	temp=(data/4096) *2.5*100-50
29	Main Control Board FPGA Temperature	104	2	temp= (data* 503.975)/4096-273.15
30	Input Voltage	106	2	data / 100.0
31	12 V Voltage	108	2	data / 100.0
32	2.5 V Voltage	110	2	data / 100.0
33	1.8 V Voltage	112	2	data / 100.0
34	1.2 V Voltage	114	2	data / 100.0
35	Left Emitting Voltage	116	2	data / 100.0
36	Right Emitting Voltage	118	2	data / 100.0
37	Phase Lock Angle Offset	120	2	
38	Cover Dirty Count Initial Value	122	1	
39	Reserved	123	1081	
40	Tail	1204	2	0f, f0

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

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

No.	Information	Offset	Length (Byte)	Note
0	UCWP Identification Header	0	8	aa 00 ff 11 22 22 aa aa
1	Motor Speed	8	2	300, 600, 1200
2	Ethernet Configuration (IP, MAC, port, NTP)	10	22	
3	Ethernet Configuration (gateway, subnet mask)	32	8	
4	Lidar Rotation/ Stationary	40	2	0x00: rotating; 0x01: stopped (when rotating, the motor speed should be set)
5	Device Flow Packet Interval	42	2	
6	Clock Source Selection	44	1	
7	Standby Mode	45	1	0: normal; 1: standby mode
8	Phase Lock Enable	46	1	0: disabled; 1: enable
9	Phase Lock Angle Settings	47	2	The value is multiplied by 100 to write into the lidar; divide the value by 100 to read back
10	Reserved	49	1155	
11	Tail	1204	2	0f, f0

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

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.

Clock Source Selection

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

Standby Mode

Standby Mode (2 Bytes)	
S/N	Byte0
Function	0 means normal mode; 1 means standby mode

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

Phase Lock Enable

Phase Lock Enable (2 Bytes)	
S/N	Byte0
Function	0: not enabled; 1: enabled

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

Phase Lock Angle Setting

Phase Lock Angle Setting (2 Bytes)		
S/N	Byte0	Byte1
Function	Set phase lock angle	

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

UTC Time

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

UTC Time (6 bytes Read Only)						
S/N	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
Function	Year	Month	Day	Hour	Minute	Second
	0~255 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.

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

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

6.1 GPS Synchronization

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

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

Dual echo mode: In the UTC time 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 CX128S2 lidar GPS_REC interface level protocols, namely TTL level standard and RS232 level standard. The two protocols differ in two aspects, respectively:

TTL level pin definition:

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

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

RS232 pin definition:

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

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

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

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

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

The standard format of GPRMC information is as follows:

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

Table 6.1 The Standard Format of GPRMC Information

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

6.2 External Synchronization

In external synchronization, the lidar receives the PPS signal input by other external devices and times it in nanoseconds, 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 gPTP Synchronization

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

This series of lidar supports gPTP timing synchronization. Before synchronizing the lidar via gPTP, the time source needs to be set to “PTP” in the lidar's point cloud display software.

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

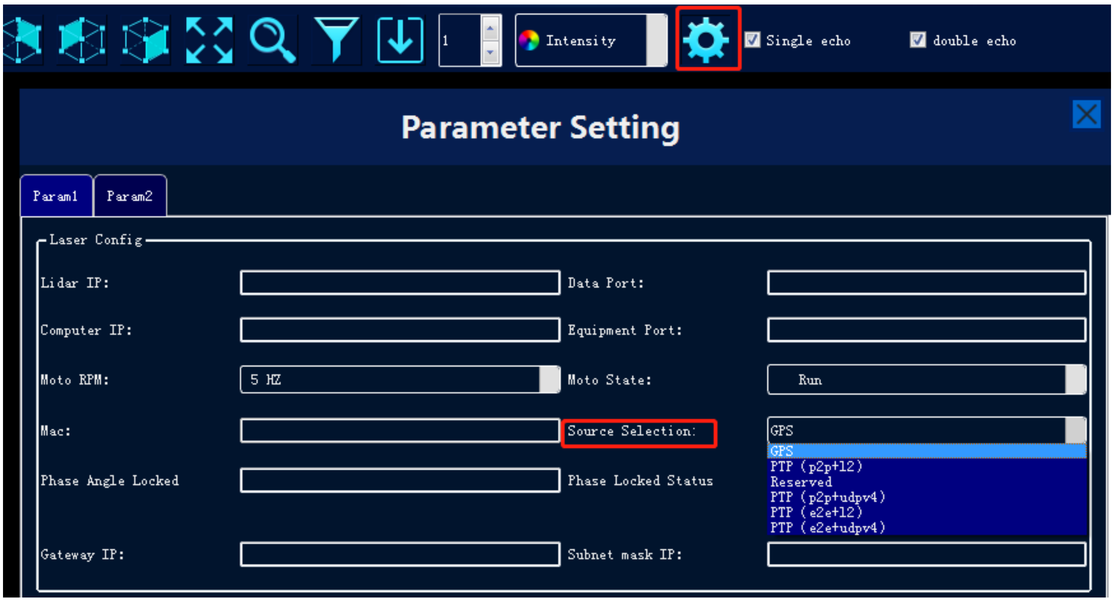

Figure 6.1 Choose Lidar Clock Source

Note:

When PTP is selected as the clock source, the lidar no longer outputs GPS packets and the time unit changes to nanoseconds (ns). The Timestamp and Date & Time in the point cloud packets will be synchronized strictly according to the time signal provided by the PTP master clock.

If PTP has been selected as the time source and no PTP master clock is currently available, the lidar will start timing from the internal default start time (00:00:00

on 1 January 2000); if a PTP time source is provided and then interrupted, the lidar will continue timing from the time of the interruption.

6.4 Lidar Internal Timing

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

When there is no other external clock source after-power on, the lidar will start internal timing and the timing value will be output as a timestamp of the data packet without UTC time reference. At this time, there would be 2 different cases in terms of time display on the point cloud display software: when the clock source is set to "GPS", the time will be counted from January 1, 2000, 00:00:00; when the time source is set to "PTP", the time will be counted from January 1, 1970, 00:00:00.

7. Angle and Coordinate Calculation

7.1 Vertical Angle

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*7=1197 bytes. Take the first measure point as an example:

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

Byte 1 represents the line number, whose value range from 0 to 127, a total of 128 lines. The 128 lines respectively corresponds to the lowermost ray to the uppermost ray in the entire vertical field of view. For example, line No. 0 represents a vertical angle of -12.5°, line No. 1 represents a vertical angle of -12.25°, and the angle difference between adjacent lines is 0.25° or 0.125°. See the figure below:

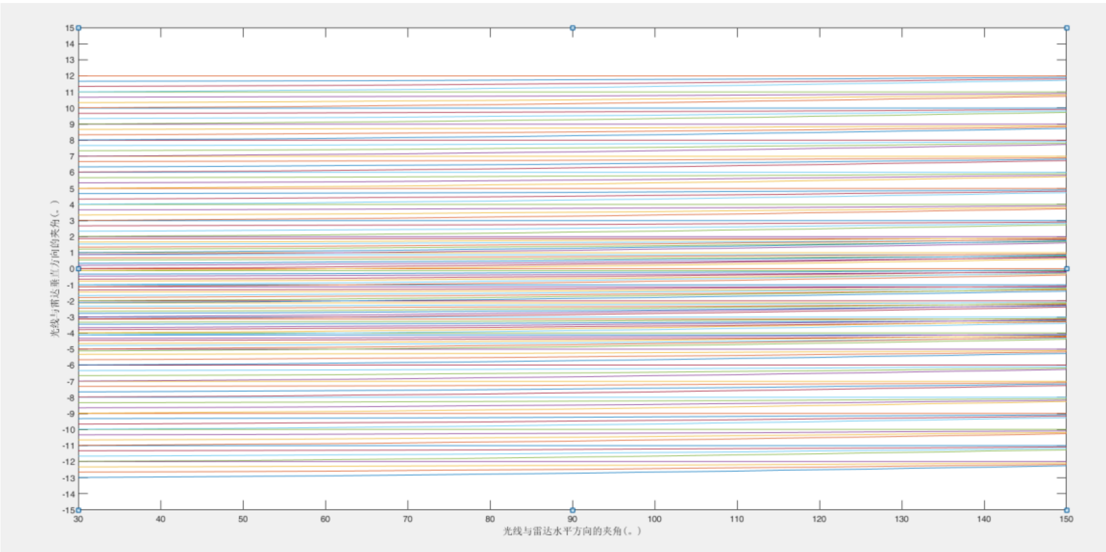

Figure 7.1 Angle Between Light and Lidar's Horizontal Direction

7.2 Horizontal Angle

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

7.3 Distance Value and Intensity

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

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, 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.

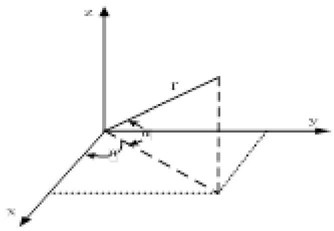

Figure 7.2 Coordinate Mapping

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 CX128S2 lidar is about 0.434 μs, and the measurement interval of adjacent points is 0.434 μs.

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 0.434 μs*171~=74 .214 μs, and the data rate is about 1s/74 .214 μs ~=13474 data packets/second.

8.1.1 Calculation of Data Packet End Time

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

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 CX128S2 lidar contains 171 measurement data. Therefore, the end time interval of each data packet is the time of the last point. Assuming that the absolute time of the data packet end is T_{Packet_end}, and the end time of the previous packet is $T_{Packet\_end\_last}$, then the end time interval of each data packet—$T_{Interval} = (T_{Packet\_end} - T_{Packet\_end\_last}) / 171$;

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

$T_{Point\_end(N)} = (T_{Packet\_end} - T_{Interval}*(171-N))$. (N = 1, 2, ..., 171), where $T_{Point\_end(N)}$ indicates the end time of the N^{th} data point.

8.2 Dual Echo Mode

In the dual echo mode, a data packet has a total of 109 measurement data. The packaging time of the data packet is about 0.434 μs*109~=47.306 μs, and the data rate is about 1s/47.306 μs ~=21138 data packets/second.

8.2.1 Calculation of Data Packet End Time

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

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 CX128S2 lidar contains 109 measurement data. Therefore, the end time interval of each data packet is the time of the last point. Assuming that the absolute time of the data packet end is T_{Packet_end}, and the end time of the previous packet is $T_{Packet\_end\_last}$, then the end time interval of each data packet—$T_{Interval} = (T_{Packet\_end} - T_{Packet\_end\_last}) / 109$;

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

$T_{Point\_end(N)} = (T_{Packet\_end} - T_{Interval}*(109-N))$, (N = 1, 2, ..., 109), where $T_{Point\_end(N)}$ indicates the end time of the N^{th} data point.

Revision History

Rev.	Release Date	Revised Content	Issued/Revised By
V1.0.0	2023-02-24	Initial Version	LS1286
V1.0.1	2023-05-11	Mechanical drawing updated (arc version added)	LS1286
V1.0.2	2024-03-22	Specification table updated; mechanical drawing updated (flat version deleted)	LS1499
V1.0.3	2024-04-23	Communication protocol updated	LS1499
V1.0.4	2024-07-12	Specifications table updated; Power supply voltage updated	LS1499
V1.0.5	2024-10-17	Operation under Windows OS updated; time synchronization updated	LS1499

*This product information is subject to change without notice.

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