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402-en-1902A3

Pandar40P

40-Channel Mechanical LiDAR User Manual

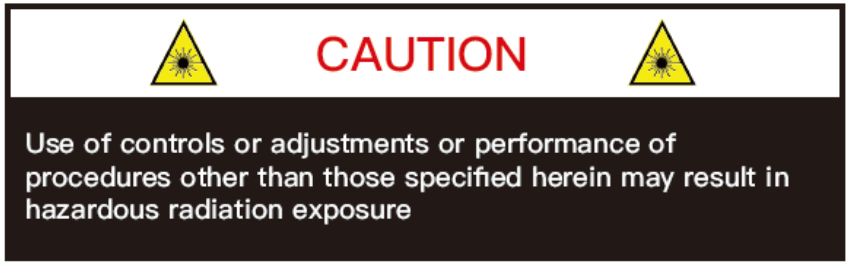
HESAI Wechat

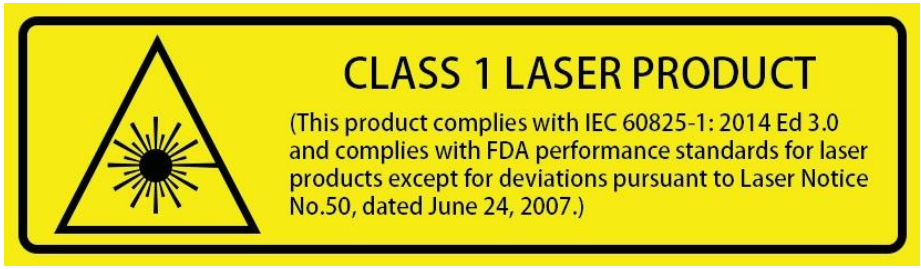
Safety Notice

PLEASE READ AND FOLLOW ALL INSTRUCTIONS CAREFULLY AND CONSULT ALL RELEVANT NATIONAL AND INTERNATIONAL SAFETY REGULATIONS FOR YOUR APPLICATION.

■ Caution

To avoid violating the warranty and to minimize the chances of getting electrically shocked, please do not disassemble the device. The device must not be tampered with and must not be changed in any way. There are no user-serviceable parts inside the device. For repairs and maintenance inquiries, please contact an authorized Hesai Technology service provider.





■ Laser Safety Notice – Laser Class 1

This device satisfies the requirements of

- IEC 60825-1:2014
- 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No.50, dated June 24, 2007

NEVER LOOK INTO THE TRANSMITTING LASER THROUGH A MAGNIFYING DEVICE (MICROSCOPE, EYE LOUPE, MAGNIFYING GLASS, ETC.)

■ Safety Precautions

In all circumstances, if you suspect that the device malfunctions or is damaged, stop using it immediately to avoid potential hazards and injuries. Contact an authorized Hesai Technology service provider for more information on device disposal.

Handling

This device contains metal, glass, plastic, as well as sensitive electronic components. Improper handling such as dropping, burning, piercing, and squeezing may cause damage to the device.

Enclosure

This device contains high-speed rotating parts. To avoid potential injuries, DO NOT operate the device if the enclosure is loose or damaged.

Repair

DO NOT open and repair the device without direct guidance from Hesai Technology. Disassembling the LiDAR may cause degraded performance, failure in water resistance, or potential injuries to the operator.

Power Supply

Use only the cables and power adapters provided by Hesai Technology. Only the power adapters that meet the device's power requirements and the applicable safety standards can be used. Using damaged cables/adapters or supplying power in a humid environment can result in fire, electric shock, personal injuries, product damage, or property loss.

Prolonged Exposure to Hot Surface

Prolonged exposure to the device's hot surface may cause discomfort or injury. If the device has been powered and operating for a long time, avoid skin contact with the device and its power adapter.

Vibration

Strong vibration may cause damage to the device and should be avoided. The device can withstand a sudden impact of 50 G for 11 milliseconds, or 3.21 Grms short-term vibration within 5 Hz to 2000 Hz for 4 hours.

Radio Frequency Interference

Please observe the signs and notices on the device that prohibit or restrict the use of electronic devices. Although the device is designed, tested, and manufactured to comply with the regulations on RF radiation, the radiation from the device may still influence other electronic devices.

Medical Device Interference

Some components in the device can emit electromagnetic fields, which may interfere with medical devices such as cochlear implants, heart pacemakers and defibrillators. Consult your physician and medical device manufacturers for specific information regarding your medical device and whether you need to keep a safe distance from the LiDAR. If you suspect that the LiDAR is interfering with your medical device, stop using the LiDAR immediately.

Explosive Atmosphere and Other Air Conditions

Do not use the device in any area where potentially explosive atmospheres are present, such as high concentrations of flammable chemicals, vapors or particulates (including particles, dust, and metal powder) in the air. Exposing the device to high concentrations of industrial chemicals, including liquefied gases that are easily vaporized (such as helium), can damage or weaken the device's function. Please observe all the signs and instructions on the device.

Light Interference

Some precision optical instruments may be interfered by the laser light emitted from the device.

Eye Safety

Although the device meets Class 1 eye safety standards, operators should still avoid looking directly at the LiDAR for maximum self-protection.

Contents

1 Introduction 1

1.1 Operating Principle 1
1.2 LiDAR Structure 2
1.3 Channel Distribution 3
1.4 Specifications 4

2 Setup 5

2.1 Mechanical Installation 5
2.2 Interfaces 8
2.3 Connection Box (Optional) 9
2.4 Get Ready to Use 12

3 Data Structure 13

3.1 Point Cloud Data Packet 14
3.2 GPS Data Packet 17

4 Web Control 23

4.1 Home 24
4.2 Settings 25
4.3 Azimuth FOV 28
4.4 Operation Statistics 31
4.5 Upgrade 32

5 PandarView 33

5.1 Installation 33
5.2 Use 34
5.3 Features 36

6 Communication Protocol 40

6.1 Packet Structure 40
6.2 Command Description 41

7 Sensor Maintenance 49

8 Troubleshooting 50

Appendix I Channel Distribution 52

Appendix II Absolute Time and Laser Firing Time 54

Appendix III PTP Protocol 57

Appendix IV Phoenix Contact 59

Appendix V Nonlinear Reflectivity Mapping 60

Appendix VI Certification Info 64

Appendix VII Support and Contact 65

1 Introduction

This manual describes the specifications, installation, and data output format of Pandar40P.

This manual is under constant revision. Please contact Hesai for the latest version.

1.1 Operating Principle

Distance Measurement: Time of Flight (ToF)

1) A laser diode emits a beam of ultrashort laser pulses onto the object.
2) Diffuse reflection of the laser occurs upon contact with the target object. The beams are detected by the optical sensor.
3) Distance to object can be accurately measured by calculating the time between emission and receipt by the sensor.

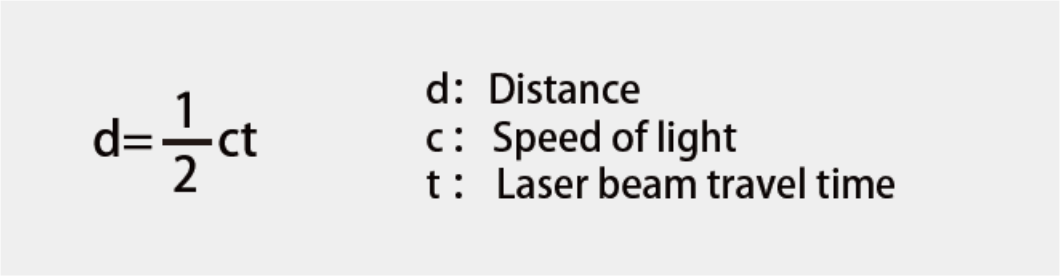


Figure 1.1 ToF Formula

1.2 LiDAR Structure

40 pairs of laser emitters and receivers are attached to a motor that rotates horizontally.

Figure 1.2 Partial Cross-Sectional Diagram

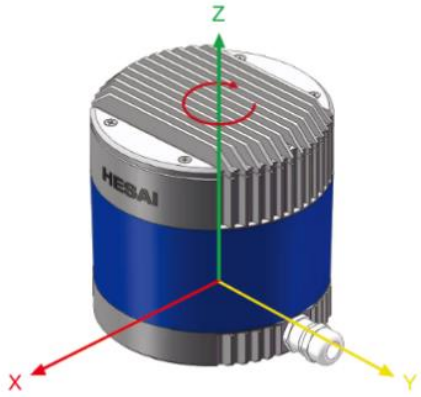


Figure 1.3 Coordinate System (Isometric View)

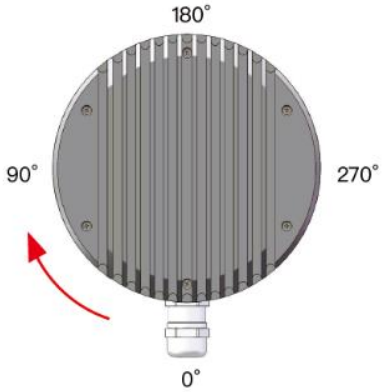


Figure 1.4 Rotation Direction (Top View)

The LiDAR's coordinate system is shown above. The Z-axis is the axis of rotation.
The origin is shown as a red dot in Figure 1.6 on the next page. After geometric transforms, all the measurements are relative to the origin.

Each laser channel has an intrinsic horizontal angle offset. When Channel 12 passes the zero degree position (y-axis) illustrated in Figure 1.4, the azimuth data in the corresponding UDP data block will be 0°.

1.3 Channel Distribution

The vertical resolution is

- 0.33° between Channel 6 and Channel 30
- 1° between Channel 5 and Channel 6, Channel 30 and Channel 38
- not evenly distributed in the remaining channels, as detailed in Appendix I

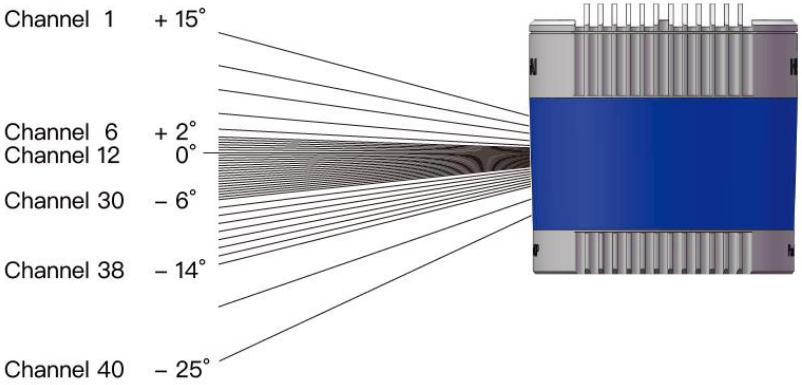


Figure 1.5 Channel Vertical Distribution

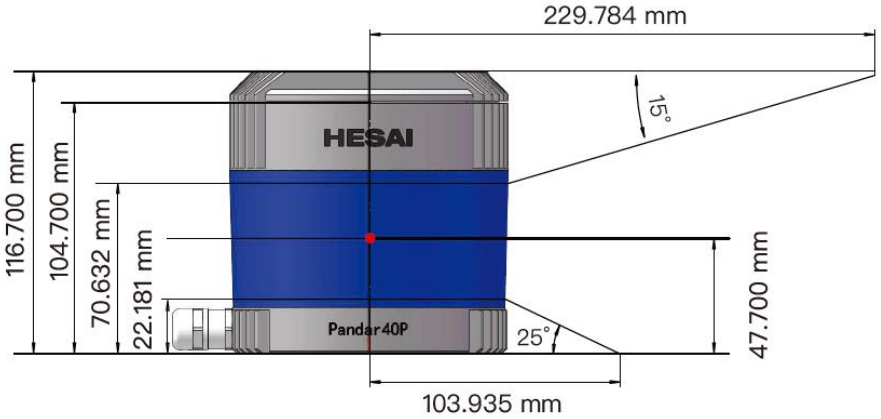


Figure 1.6 Laser Firing Position

1.4 Specifications

SENSOR	
Scanning Method	Mechanical Rotation
Channel	40
Range	0.3 to 200 m (at 10% reflectivity)
Range Accuracy	±5 cm (0.3 to 1 m) ±2 cm (1 to 200 m)
FOV (Horizontal)	360°
Resolution (Horizontal)	0.2° (10 Hz), 0.4° (20 Hz)
FOV (Vertical)	40° (-25° to +15°)
Resolution (Vertical)	0.33° (-6° to +2°); 1° (+2° to +3°, -14° to -6°); 2° (+3° to +5°); 3° (+5° to +11°); 4° (+11° to +15°); 5° (-19° to -14°); 6° (-25° to -19°)
Frame Rate	10 Hz, 20 Hz
Returns	Single and Dual Returns (Strongest, Last)

MECHANICAL/ELECTRICAL/OPERATIONAL	
Wavelength	905 nm
Laser Class	Class 1 Eye Safe
Ingress Protection	IP6K7
Dimensions	Height: 116.7 mm Top/Bottom Diameter: 116.00 / 115.00 mm
Operating Voltage	DC 9 to 48 V
Power Consumption	18 W
Operating Temperature	-20℃ to 65℃
Certifications	RoHS, REACH, WEEE CE, FCC, IC, EAC, KCC
Weight	1.52 kg

DATA I/O	
Data Transmission	UDP/IP Ethernet (100 Mbps)
Data Outputs	Distance, Azimuth Angle, Intensity
Data Points Generated	Single Return Mode: 720,000 points per second Dual Return Mode: 1,440,000 points per second
Clock Source	GPS / PTP
PTP Clock Accuracy	≤1 μs
PTP Clock Drift	≤1 μs/s

NOTE Specifications are subject to change without notice.
NOTE Range accuracy as the average range error across all channels may vary with range, temperature and target reflectivity.

2 Setup

2.1 Mechanical Installation

Figure 2.1 Isometric View

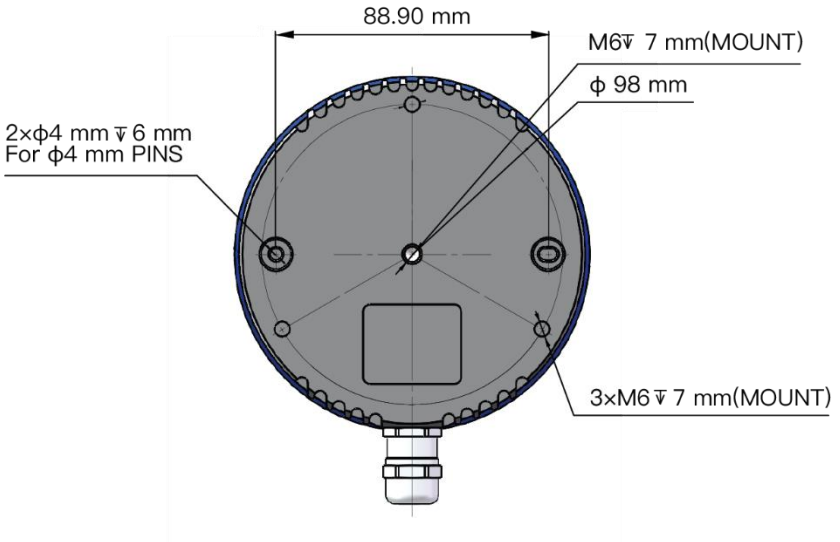


Figure 2.2 Bottom View

■ Quick Installation

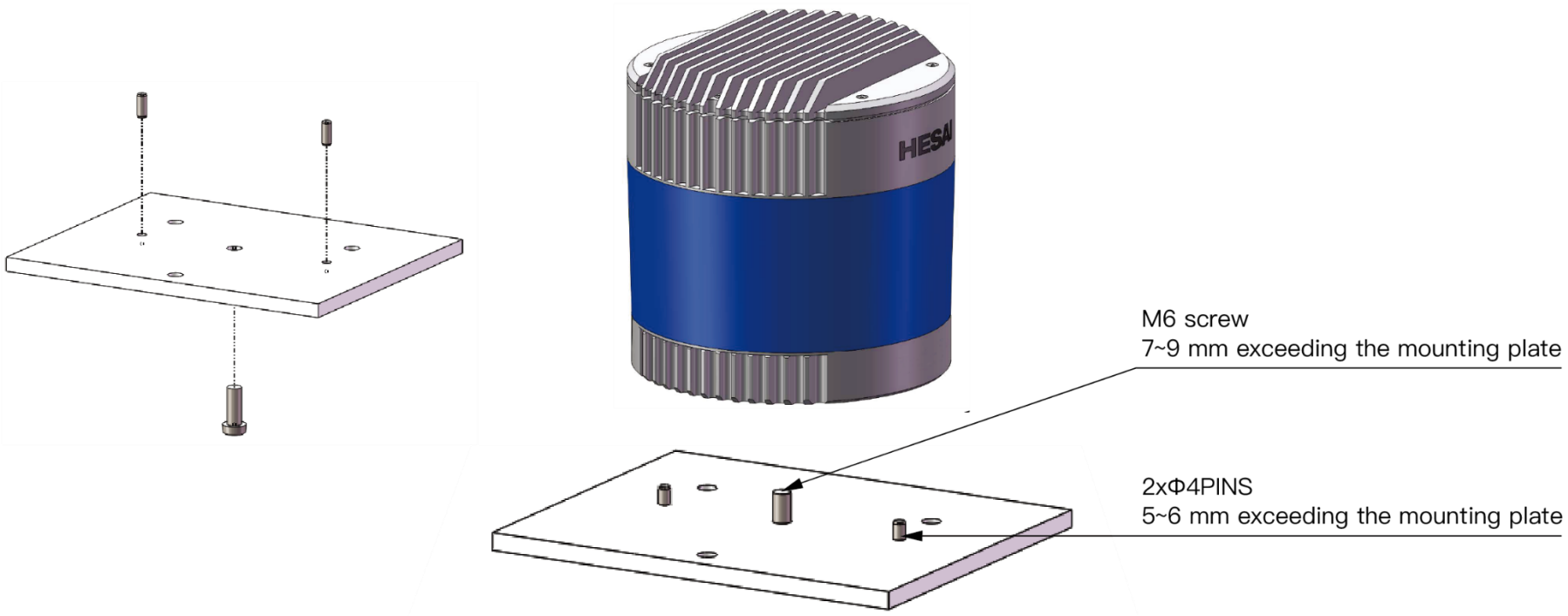


Figure 2.3 Diagram of Quick Installation

■ Stable Installation

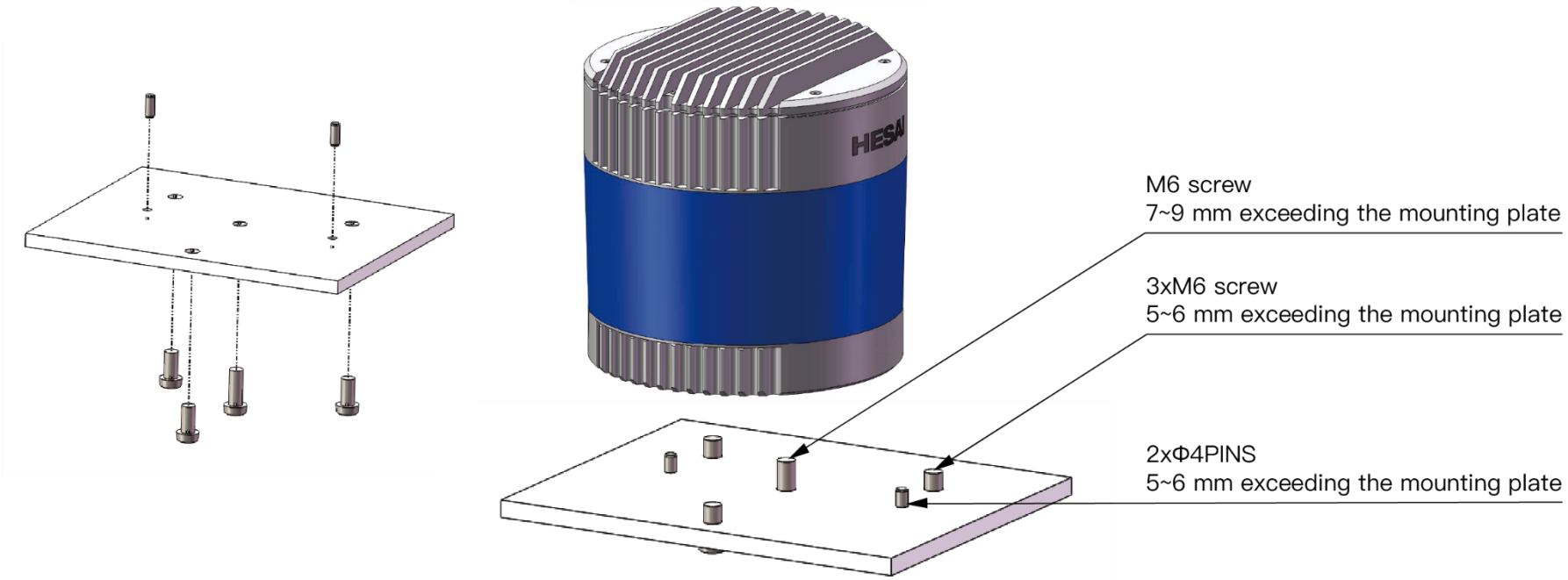


Figure 2.4 Diagram of Stable Installation

2.2 Interfaces

Lemo Contact is the default communication connector. (Another option is the Phoenix Contact, detailed in Appendix IV.)
Lemo part number: FGG.2T.316.CLAC75Z (male, on the LiDAR)

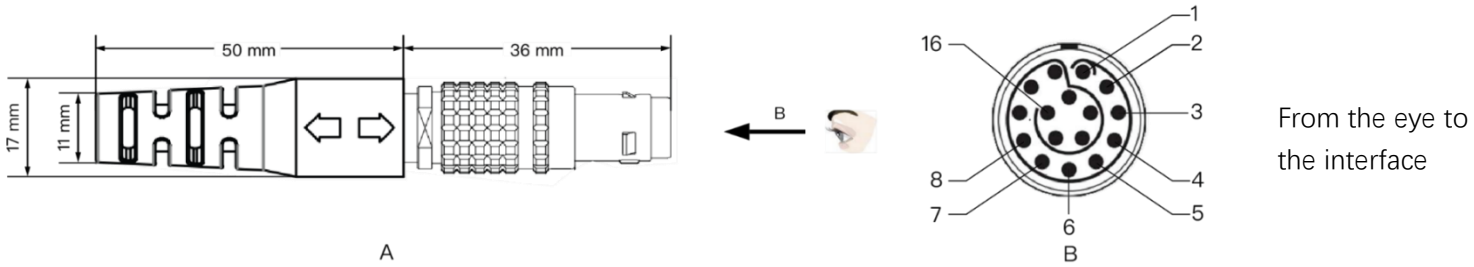


Figure 2.5 Lemo Connector (Male)

Table 2.1 Pin Description of Lemo Connector

Pin #	Function	Color	Voltage
1 ~ 4	-	-	-
5	Ethernet RX-	BLUE	-1 V to 1 V
6	Ethernet RX+	BLUE/WHITE	-1 V to 1 V
7	Ethernet TX-	ORANGE	-1 V to 1 V
8	Ethernet TX+	ORANGE/WHITE	-1 V to 1 V
9	GPS Serial Data	WHITE	-13 V to +13 V
10	GPS PPS	YELLOW	TTL level 3.3 V/5 V Pulse width: 1 ms or longer is recommended Cycle: 1 s (from rising edge to rising edge)
11	P12V	RED	12 V
12	P12V	GRAY	12 V
13	Ground (Return)	BLACK	0
14	Ground (Return)	GRAY/WHITE	0
15	-	PURPLE	-
16	-	PURPLE/WHITE	-

The cable length from the LiDAR exit to the tip of the connector is 0.3 m.

2.3 Connection Box (Optional)

Users may connect the LiDAR directly or using the connection box.
The connection box comes equipped with a power port, a GPS port, and a standard Ethernet port.
The cable length between the connector and the connection box is 1.7 m by default.
Lemo part number: PHG.2T.316.CLLC75Z (female, on the connection box)

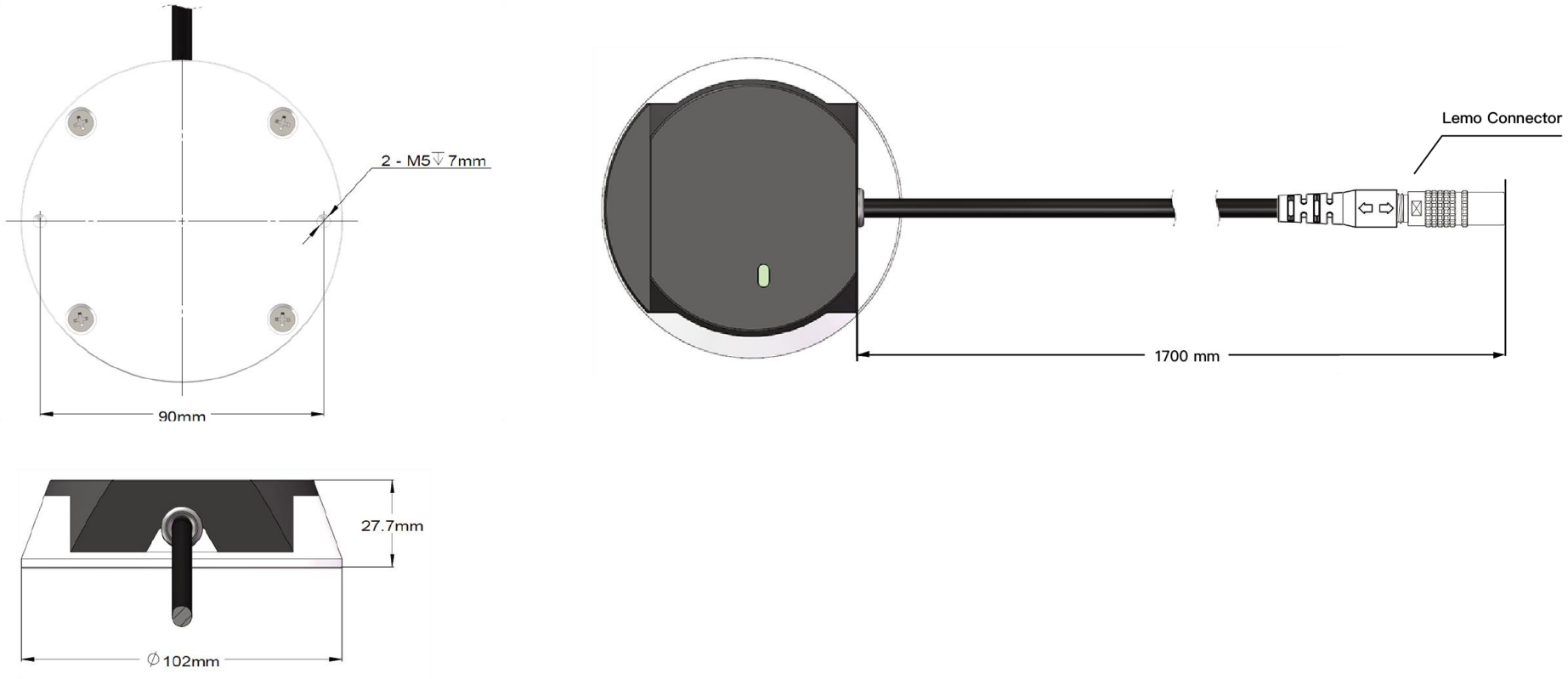


Figure 2.6 Connection Box

2.3.1 Connection Box Interfaces

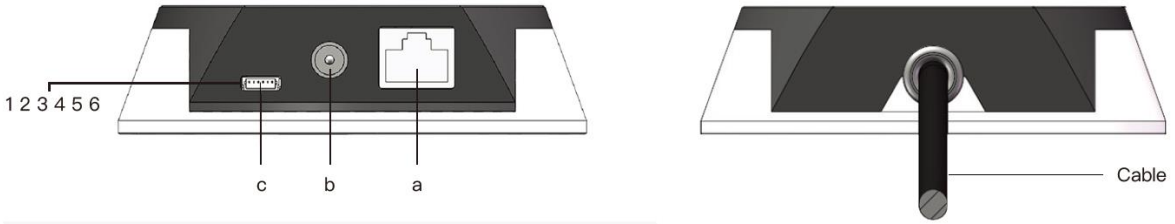


Figure 2.7 Connection Box

Table 2.2 Connection Box Interfaces

Port #	Port Name	Description
a	Standard Ethernet Port	RJ45, 100 Mbps Ethernet
b	Power Port	Use DC-005 DC power adapter Input voltage ranges from 9 V to 48 V. Power consumption is 18 W
c	GPS Port	Connector type: JST SM06B-SRSS-TB Recommended connector for the external GPS module: JST SHR-06V-S-B Voltage standard: RS232 Baud rate: 9600 bps

The GPS port pin numbers are 1 to 6 from left to right, defined as follows:

Table 2.3 GPS Pin Description

Pin #	Direction	Pin Description	Requirements
1	Input	PPS (pulse-per-second) signal for synchronization	TTL level 3.3 V/5 V Pulse width: 1 ms or longer is recommended Cycle: 1 s (from rising edge to rising edge)
2	Output	Power for the external GPS module	5 V
3	Output	Ground for the external GPS module	-
4	Input	Receiving serial data from the external GPS module	RS232 level
5	Output	Ground for the external GPS module	-
6	Output	Transmitting serial data to the external GPS module	RS232 level

2.3.2 Connection

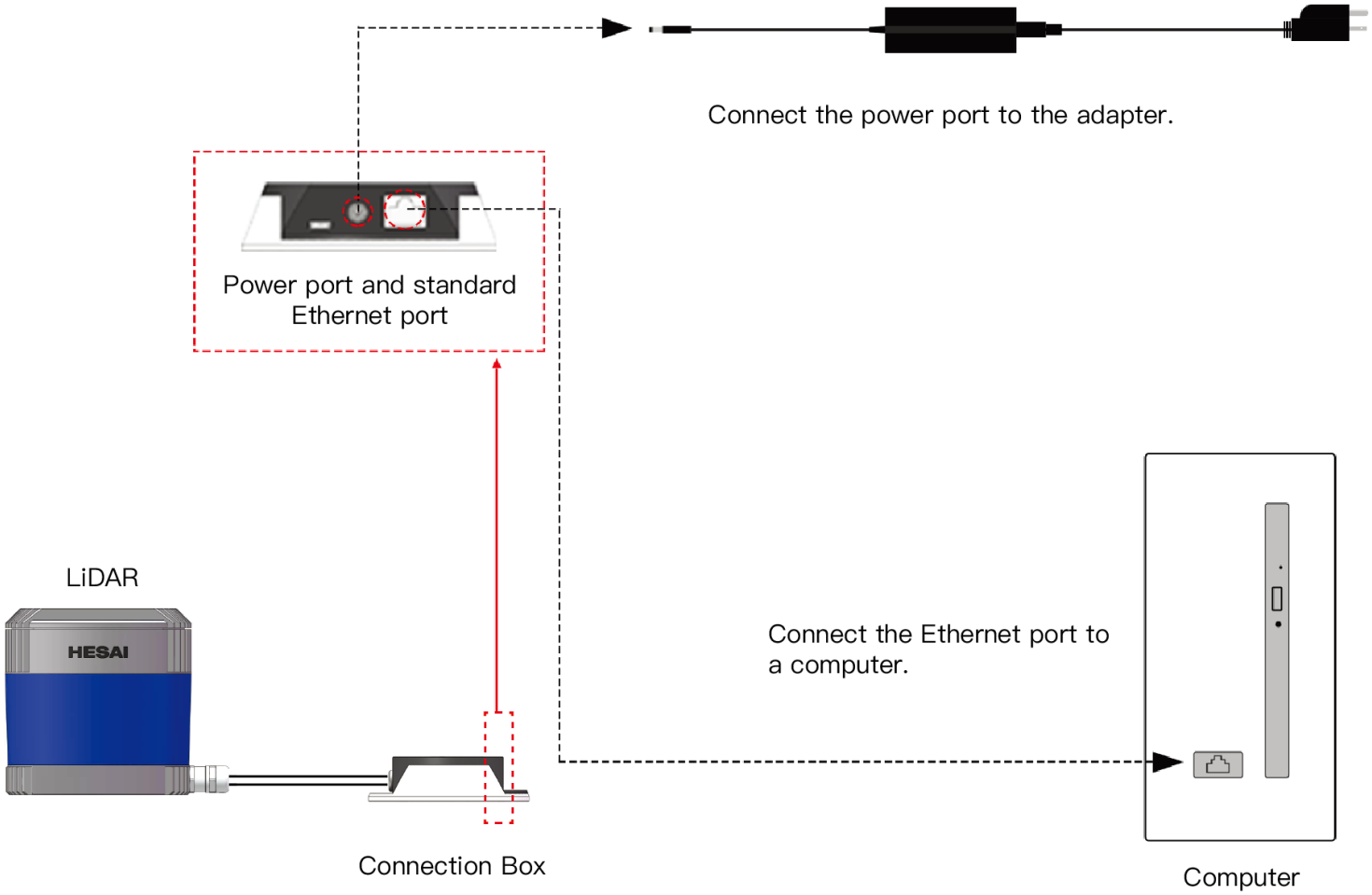


Figure 2.8 LiDAR Connection When Using the Connecting Box

NOTE Refer to Appendix III when PTP protocol is used.

2.4 Get Ready to Use

The LiDAR does not have a power switch. It starts operating once connected to power and the Ethernet.

- To receive data on your PC, set the PC's IP address to 192.168.1.100 and subnet mask to 255.255.255.0

For Ubuntu-16.04:	For Windows:
Use the ifconfig command in the terminal: ~$ sudo ifconfig enp0s20f0u2 192.168.1.100 (replace enp0s20f0u2 with the local network port name)	1) Open the Network Sharing Center, click on "Ethernet" 2) In the "Ethernet Status" interface, click on "Properties" 3) Double-click on "Internet Protocol Version 4 (TCP/IPv4)" 4) Configure the IP address to 192.168.1.100 and subnet mask to 255.255.255.0

- To record and display point cloud data, see Chapter 5 PandarView
- To set parameters, check device info, or upgrade firmware, see Chapter 4 Web Control
- The SDK (Software Development Kits) download links can be found at www.hesaitech.com/en/download

3 Data Structure

100 Mbps Ethernet UDP/IP is used for data output. The output data includes Point Cloud Data Packets and GPS Data Packets. Each data packet consists of an Ethernet header and UDP data.

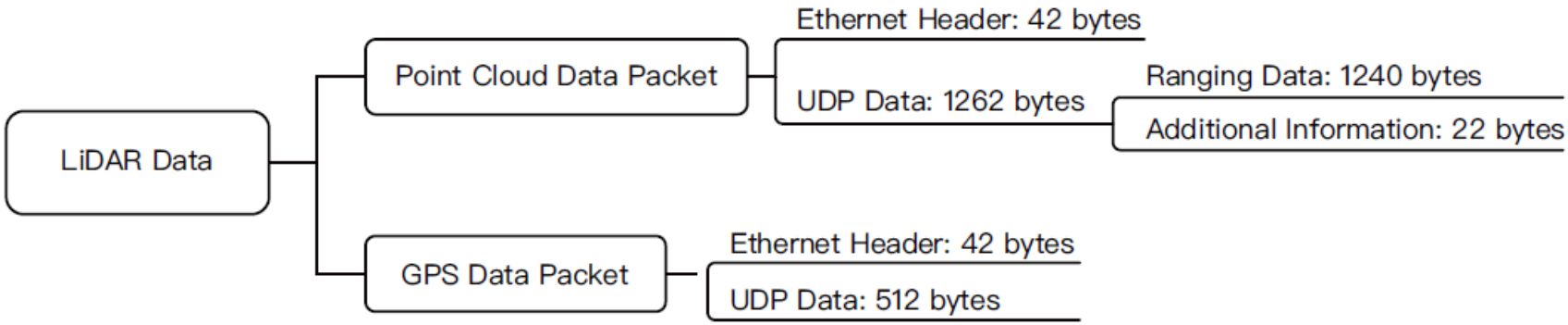


Figure 3.1 Data Structure with UDP Sequence OFF

The UDP sequence feature is OFF by default. When UDP sequence is ON, the Additional Information in the UDP data changes from 22 bytes to 26 bytes.

3.1 Point Cloud Data Packet

3.1.1 Ethernet Header

Each LiDAR has a unique MAC address.
The source IP is 192.168.1.201 by default. The destination IP address is 0xFF FF FF FF and in broadcast form.

Table 3.1 Point Cloud Data Packet – Ethernet Header

Ethernet Header: 42 bytes		
Ethernet II MAC	12 bytes	Destination: broadcast (0xFF: 0xFF: 0xFF: 0xFF: 0xFF: 0xFF) Source: (xx:xx:xx:xx:xx:xx)
Ethernet Data Packet Type	2 bytes	0x08, 0x00
Internet Protocol	20 bytes	Shown in the figure below
UDP Port Number	4 bytes	UDP source port (0x2710, representing 10000) Destination port (0x0940, representing 2368)
UDP Length	2 bytes	0x04F6 when UDP sequence is OFF, representing 1270 bytes (8 bytes more than the size of the Point Cloud UDP Data, shown in Figure 3.1) 0x04FA when UDP sequence is ON, representing 1274 bytes
UDP Checksum	2 bytes	-

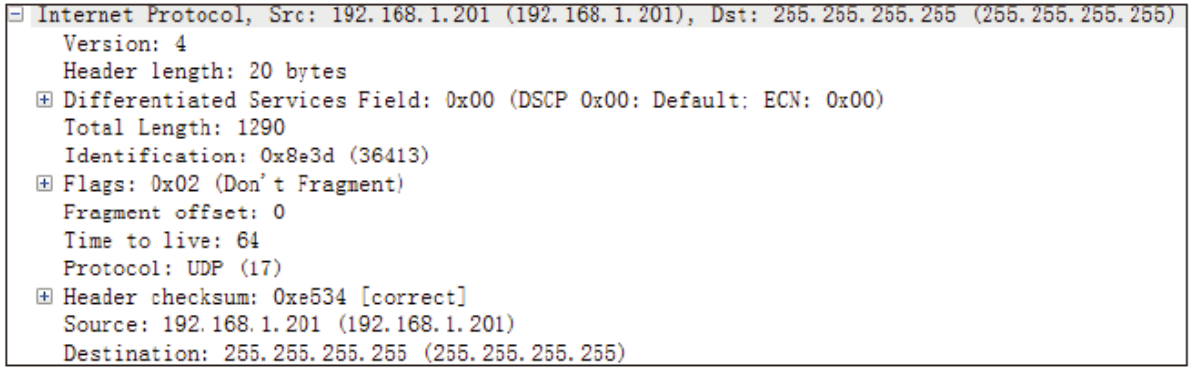


Figure 3.2 Point Cloud Ethernet Header – Internet Protocol

3.1.2 UDP Data

All the multi-byte values are unsigned and in little endian format.

Ranging Data

Table 3.2 Point Could UDP Data – Ranging Data

Ranging Data: 1240 bytes (10 blocks)				
Block 1	**Block 2**	**Block 3**	**…**	**Block 10**
0xFFEE	0xFFEE	0xFFEE	…	0xFFEE
Azimuth 1	Azimuth 2	Azimuth 3	…	Azimuth 10
Channel 1	Channel 1	Channel 1	…	Channel 1
Channel 2	Channel 2	Channel 2	…	Channel 2
…	…	…	…	…
Channel 40	Channel 40	Channel 40	…	Channel 40

Table 3.3 Point Cloud UDP Data - Block Definition

Each block in the Ranging Data: 124 bytes			
0xFFEE	2 bytes	Header, meaningless, 0xFF first	
Azimuth	2 bytes	Current reference angle of the rotor Azimuth[15:0]: lower byte Azimuth_L[7:0], upper byte Azimuth_H[15:8] Azimuth Angle = [Azimuth_H, Azimuth_L] / 100° = Azimuth / 100°	
Channel XX	3 bytes	2-byte distance data	Distance[15:0]: lower byte Distance_L[7:0], upper byte Distance_H[15:8] Distance Value = [Distance_H, Distance_L] * 4 mm = Distance * 4 Maximum Distance Value = (2 ^ 16 – 1) * 4 mm = 262.14 m
		1-byte reflectivity data	Reflectivity, in percentage (0 to 255%)

NOTE Under the Dual Return mode, the ranging data from each firing is stored in two adjacent blocks: the odd number block is the last return, and the even number block is the strongest return. If the last and strongest returns coincide, the second strongest return will be placed in the even number block. The azimuth changes every two blocks.

Additional Information

Table 3.4 Point Cloud UDP Data – Additional Information

Additional Information: 22/26 bytes when UDP sequence is OFF/ON		
Reserved	5 bytes	-
High Temperature Shutdown Flag	1 byte	0x01 for high temperature; 0x00 for normal operation • When high temperature is detected, the shutdown flag will be set to 0x01, and the system will shut down after 60 s. The flag remains 0x01 during the 60 s and the shutdown period • When the system is no longer in high temperature status, the shutdown flag will be reset to 0x00 and the system will automatically return to normal operation
Reserved	2 bytes	-
Motor Speed	2 bytes	speed_2_bytes[15:0] = speed (RPM)
GPS Timestamp	4 bytes	Packing time of this data packet, in units of 1 μs Range: 0 to 1000000 μs (1 s)
Return Mode Information	1 byte	0x37 for Strongest Return mode, 0x38 for Last Return mode, and 0x39 for Dual Return mode
Factory Information	1 byte	0x42 (or 0x43)
UTC	6 bytes	UTC time in decimal: year, month, date, hour, minute, second
UDP Sequence	4 bytes	Added only when UDP sequence is ON Label the sequence number of Point Cloud UDP packets, 1 to 0xFF FF FF FF in little endian format

Example of UDP Data Analysis in Point Cloud Data Packets

Take Pandar40P's Channel 5 in Block 3 of the UDP Data as an example:

1) Vertical angle of Channel 5 is 3.00°, according to Appendix I Channel Distribution
2) Horizontal angle is the current reference angle of the rotor (Azimuth of Block 3) plus the horizontal angle offset (-1.042°, according to Appendix I). Define clockwise in the top view as the horizontal angles' positive direction
3) The 2-byte distance data in the UDP Data Packet, multiplied by 4 mm, is the actual distance in real world millimeters

After determining the horizontal angle, vertical angle, and distance of a data point, this point can be drawn in a polar or rectangular coordinate system. The real-time point cloud data is drawn by analyzing every point in the UDP data.

3.2 GPS Data Packet

GPS Data Packets are triggered every second. All the multi-byte values are unsigned and in little endian format.

Before NMEA messages are available from the external GPS module

Each rising edge of the LiDAR's internal 1 Hz signal triggers a GPS Data Packet.

The time and date in the GPS Data Packets are unreal, starting from 00 01 01 00 00 00 (year, month, day, hour, minute, second) and increasing with the internal 1 Hz signal.

Once the LiDAR receives the PPS (pulse-per-second) signal and NMEA messages

The internal 1 Hz signal will be locked to the PPS. Each rising edge still triggers a GPS Data Packet.

Meanwhile, the LiDAR will extract the actual UTC time and date from NMEA messages ($GPRMC or $GPGGA), and stamp them into both Point Cloud Data Packets and GPS Data Packets.

- Point Cloud Data Packets: 6-byte UTC Time (year, month, day, hour, minute, second) in decimal
- GPS Data Packets: 6-byte Date (year, month, day) and 6-byte Time (second, minute, hour) in ASCII

The GPS module sends first the PPS signal and then the NMEA message. At the rising edge of the PPS pulse, the corresponding NMEA message is not yet available. Therefore, the LiDAR extracts UTC information from the previous NMEA message and automatically adds 1 full second.

When GPS signal is lost

The LiDAR will still trigger GPS Data Packets by the rising edge of the internal 1 Hz signal. However, the GPS time in the packets will be counted by the internal 1 Hz signal and will drift from the actual GPS time.

3.2.1 Ethernet Header

The source IP is 192.168.1.201 by default. The destination IP address is 0xFF FF FF FF and in broadcast form.

Table 3.5 GPS Data Packet – Ethernet Header

Ethernet Header: 42 bytes		
Ethernet II MAC	12 bytes	Destination: broadcast (0xFF: 0xFF: 0xFF: 0xFF: 0xFF: 0xFF) Source: (xx:xx:xx:xx:xx:xx)
Ethernet Data Packet Type	2 bytes	0x08, 0x00
Internet Protocol	20 bytes	Shown in the figure below
UDP Port Number	4 bytes	UDP source port (0x2710, represents 10000) Destination port (0x277E, represents 10110)
UDP Length	2 bytes	0x208, representing 520 bytes (8 bytes more than the size of the GPS UDP Data, shown in Figure 3.1)
UDP Checksum	2 bytes	-

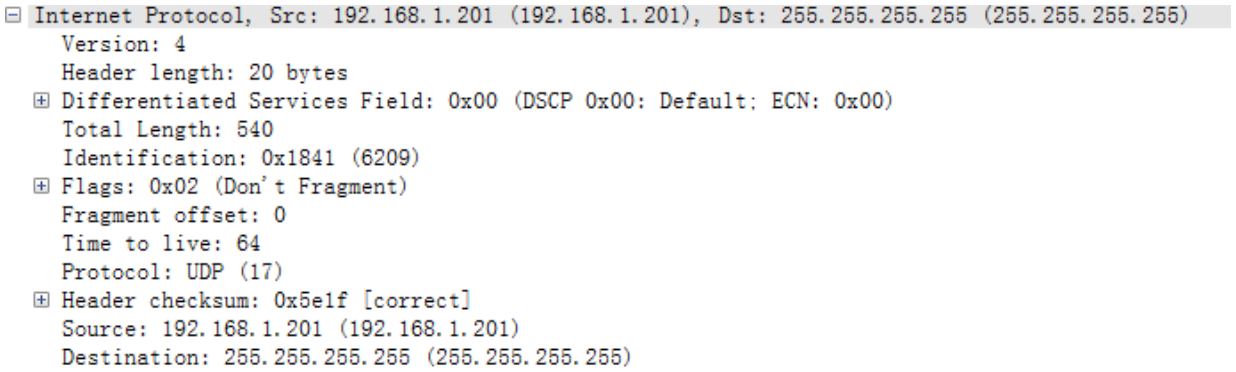


Figure 3.3 GPS Ethernet Header – Internet Protocol

3.2.2 UDP Data

Table 3.6 GPS Data Packet – UDP Data

GPS UDP data: 512 bytes				
GPS time data	18 bytes	Header	2 bytes	0xFFEE, 0xFF first
		Date	6 bytes	Year, month, and day (2 bytes each, lower byte first) in ASCII
		Time	6 bytes	Second, minute, and hour (2 bytes each, lower byte first) in ASCII
		µs Time	4 bytes	In units of µs (lower byte first)
GPRMC/GPGGA data	84 bytes	ASCII code, valid till 2 bytes after '*' NMEA sentence that contains the UTC time information Users can select either GPRMC or GPGGA in the Settings page of web control, as shown in Section 4.2		
reserved	404 bytes	404 bytes of 0xDF		
GPS positioning status	1 byte	ASCII code, obtained from $GPRMC or $GPGGA When $GPRMC is selected: A (hex = 41) for Valid Position V (hex = 56) for Invalid Position NUL (hex = 0) for GPS being unlocked When $GPGGA is selected: 0 = invalid 1 = GPS fix (SPS) 2 = DGPS fix 3 = PPS fix 6 = estimated (dead reckoning)		
flag of PPS lock	1 byte	1 – locked 0 – unlocked		
reserved	4 bytes	-		

GPRMC Data Format

$GPRMC, <01>, <02>, <03>, <04>, <05>, <06>, <07>, <08>, <09>, <10>, <11>, <12>*hh

Field #	Field	Description
<01>	UTC Time	Hour, minute, and second Can be in hhmmss (hour, minute, second) format
<02>	Location Status	A (hex = 41) for Valid Position V (hex = 56) for Invalid Position NUL (hex = 0) for GPS being unlocked
…		
<09>	UTC Date	Date information Can be in ddmmyy (day, month, year) format
…		

The LiDAR's GPS data interface is compatible with a variety of GPRMC formats, as long as:

<01> is the hour, minute, and second information
<09> is the date information.

For example, the following two formats are both acceptable:

$GPRMC,072242,A,3027.3680,N,11423.6975,E,000.0,316.7,160617,004.1,W*67
$GPRMC,065829.00,A,3121.86377,N,12114.68322,E,0.027,,160617,,,A*74

GPGGA Data Format

$GPGGA, <01>, <02>, <03>, <04>, <05>, <06>, <07>, <08>, <09>, <10>, <11>, <12>*hh

Field #	Field	Description
<01>	UTC Time	Hour, minute, and second Can be in hhmmss (hour, minute, second) format
…		
<06>	GPS Fix Quality	0 = invalid 1 = GPS fix (SPS) 2 = DGPS fix 3 = PPS fix 6 = estimated (dead reckoning)
…		

The LiDAR's GPS data interface is compatible with a variety of GPGGA formats, as long as:

<01> is the hour, minute, and second information

For example, the following two formats are both acceptable:

$GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,46.9,M,,*47
$GPGGA,134658.00,5106.9792,N,11402.3003,W,2,09,1.0,1048.47,M,-6.27,M,08,AAAA*60

Example of UDP Data Analysis in GPS Data Packets

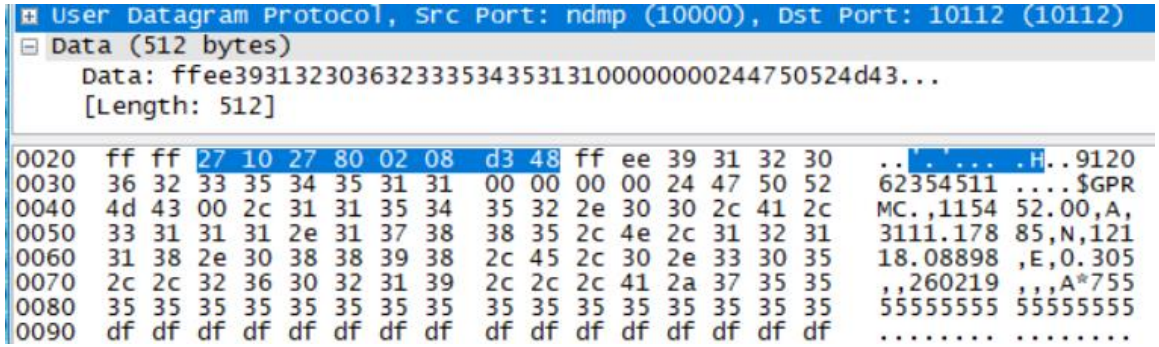


Figure 3.4 GPS Data Packet – UDP Data (Example)

Date

Field	Data (ASCII Code)	Characters	Meaning
Year	0x39 0x31	'9', '1'	19
Month	0x32 0x30	'2', '0'	02
Day	0x36 0x32	'6', '2'	26

(UTC) Time

Field	Data (ASCII Code)	Characters	Meaning
Second	0x33 0x35	'3', '5'	53
Minute	0x34 0x35	'4', '5'	54
Hour	0x31 0x31	'1', '1'	11

μs Time

4 bytes, in units of μs, using the same clock source as the GPS Timestamp in Point Cloud Data Packets

Reset to 0 at the rising edge of each PPS signal

4 Web Control

Web control is used for setting parameters, checking device info, and upgrading.

To access web control

1) Connect the LiDAR to your PC using an Ethernet cable
2) Set the IP address according to Section 2.4 Get Ready to Use
3) Enter this URL into your web browser: 192.168.1.201/index.html

NOTE Use Google Chrome or Firefox instead of IE. Turn off VPN.

4.1 Home

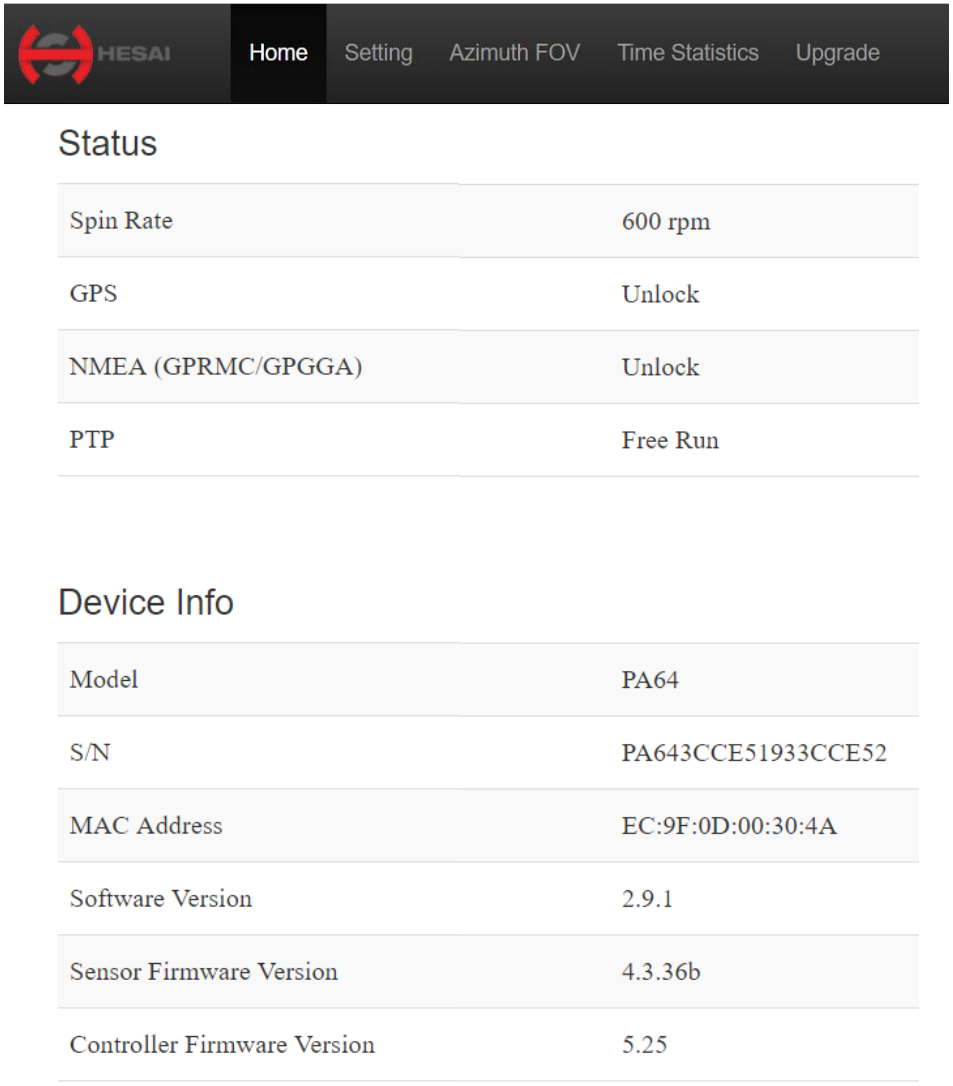


Figure 4.1 Home Page of Web Control

Spin Rate of the motor (revs per minute) = frame rate (Hz) * 60

GPS (PPS) Status

Lock	LiDAR's internal clock is in sync with the GPS
Unlock	Not in sync

NMEA (GPRMC/GPGGA) Status

Lock	After receiving a valid NMEA message
Unlock	Not receiving a valid NMEA message

PTP Status

Free Run	No PTP master is selected; only the LiDAR's clock is used
Tracking	Slave is trying to sync with the selected PTP Master, but the offset is more than 1 μs
Locked	Offset between the Slave and the Master is below 1 μs
Frozen (Holdover)	LiDAR has lost connection to the PTP master and is attempting to recover it. Meanwhile, LiDAR starts drifting from the previous clock; when drifting out of specifications, it goes back to the Free Run mode.

4.2 Settings

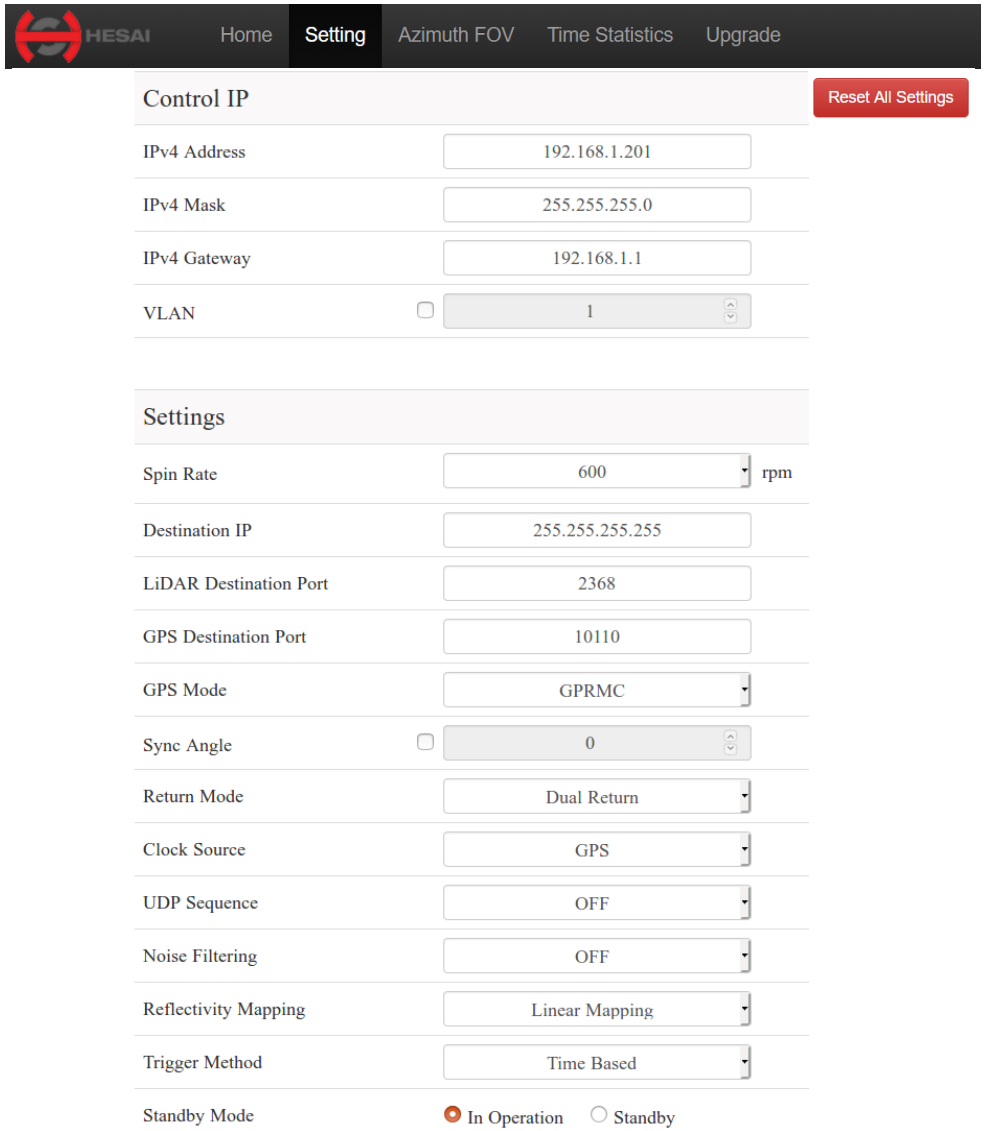


Figure 4.2 Settings Page of Web Control

1. Control IP

VLAN Tagging can be used when the receiving host also supports VLAN function.

- Check the VLAN checkbox and input a VLAN ID (range: 1~4094) for the LiDAR unit.
- Set the VLAN ID of the receiving host to be the same.

2. Destination IP

Mode	Destination IP
Broadcast (default)	255.255.255.255
Multicast	239.0.0.0~239.255.255.255
Unicast	Same as the PC's IP address

3. LiDAR Functions

Spin Rate	600 rpm / 1200 rpm
Return Mode	Last / Strongest / Dual Return
UDP Sequence	OFF / ON #1 / ON #2
	OFF by default. When UDP Sequence is ON, UDP packets are labeled with a sequence number. See Section 3.1 for changes in data structure. **ON #1**: UDP sequence increments even though no UDP packet is generated outside the FOV specified in Section 4.3. **ON #2**: UDP sequence increments only when UDP packets are generated.

(continued on the next page)

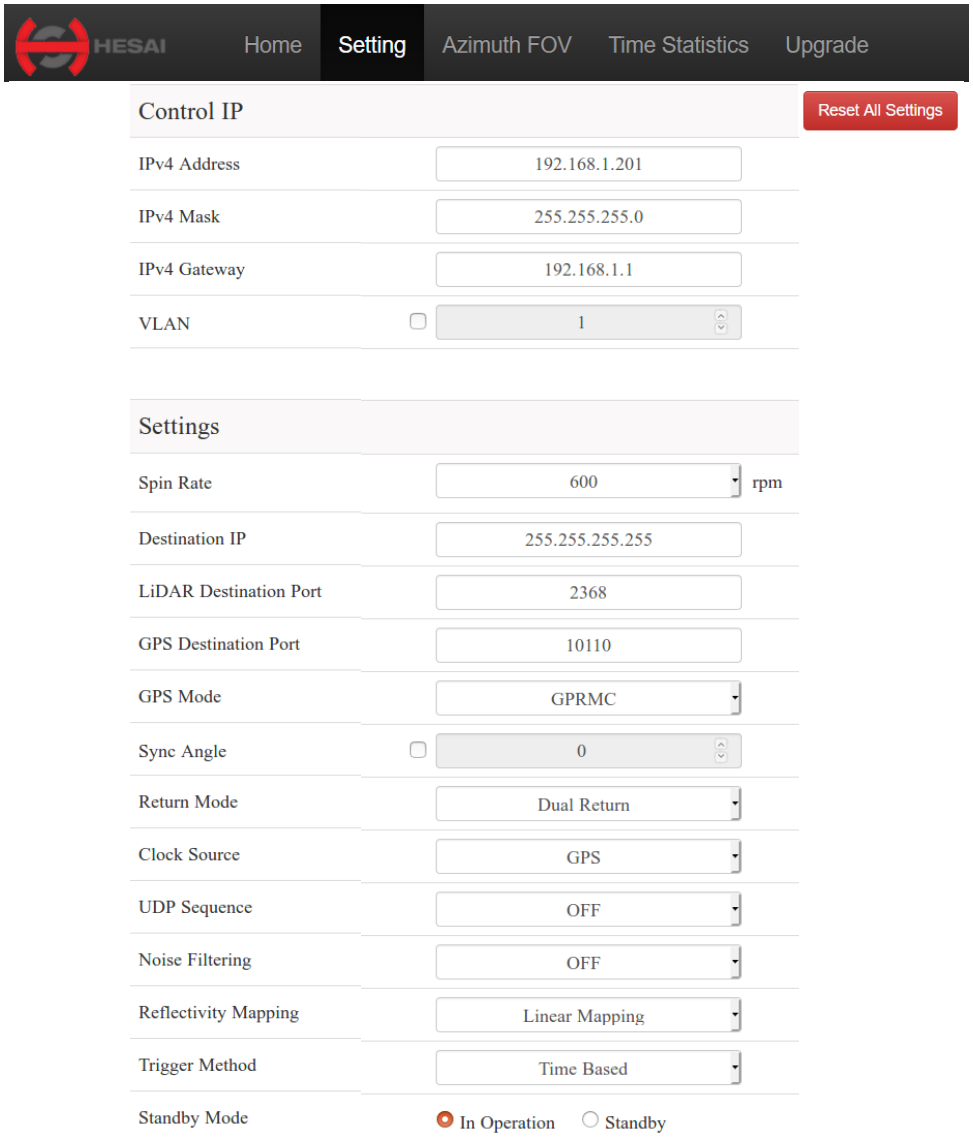


Figure 4.2 Settings Page of Web Control

(continued)

Sync Angle	0~360 degrees
	By default, the LiDAR's zero-degree position (defined in Section 1.2) is not in sync with PPS. If syncing is needed, check the check box and input a sync angle.
Noise Filtering	Noise points mitigation in rain and fog
Reflectivity Mapping	Linear / Nonlinear Mapping
	By default, the 1-byte reflectivity data in the Point Cloud Data Packet linearly represents target reflectivity from 0 to 255%. Users can alternatively choose Nonlinear Mapping to increase the contrast in the low-reflectivity region. See Appendix V Nonlinear Reflectivity Mapping.
Trigger Method	Angle-Based / Time-Based
	In the angle-based trigger mode, lasers fire every 0.2 deg at 10 Hz or 0.4 deg at 20 Hz. In the time-based mode, lasers fire every 55.56 us.
Standby Mode	Whether to stop the motor from running and lasers from firing

4. Reset All Settings

By clicking the **Reset All Settings** button on the top-right corner, all configurable parameters in the Settings page and the Azimuth FOV page will be reset to their default values.

The default values are shown on Figure 4.2 and Figure 4.5.

5. Clock Source and PTP Parameters

Clock Source	GPS / PTP	In the PTP mode, LiDARs do not output GPS Data Packets, as detailed in Appendix III PTP Protocol.

When GPS is selected as the clock source:

GPS Mode	GPRMC / GPGGA	Format of the data received from the external GPS module. Both the NMEA sentence and the GPS positioning status are put into the GPS Data Packet. See Section 3.2.2 for details.

When PTP is selected as the clock source:

PTP Domain Number	Integer from 0 to 127	Domain attribute of the local clock
PTP Network Transport	UDP/IP (default) or L2	UDP/IP follows the PTPv2 standard defined in IEEE 1588-2008
PTP logAnnounceInterval	-2 to 3 log seconds	Time interval between Announce messages (default: 1)
PTP logSyncInterval	-7 to 3 log seconds	Time interval between Sync messages (default: 1)
PTP logMinDelayReqInterval	-7 to 3 log seconds	Minimum permitted mean time between Delay_Req messages (default: 0)

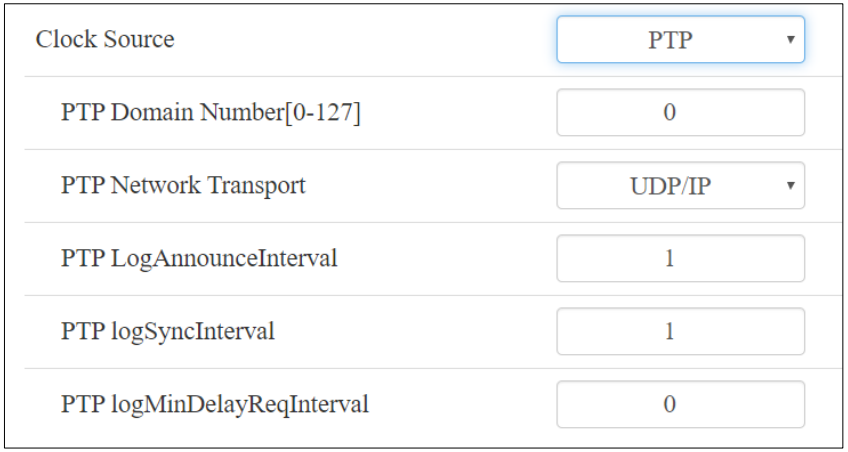


Figure 4.3 Settings Page of Web Control – PTP Parameters

4.3 Azimuth FOV

For Azimuth FOV Setting, users can select one of the three modes.

Figure 4.4 Azimuth FOV Page of Web Control

4.3.1 For all channels

A continuous angle range, specified by a start angle and an end angle, will be applied to all the channels.
Outside the specified angle range, there will be no laser firing or data generated.

NOTE Click "Save" to apply your settings.

Figure 4.5 Azimuth FOV for All Channels

4.3.2 For each channel

Users can configure one continuous angle range for each channel.
Outside the specified range for each channel, there will be no laser firing or data generated in that channel.

By default, the status button for each channel is green, indicating that angle range configuration is active.

To deactivate the angle range configuration for one channel, click the corresponding button to make it gray. Thus the angle range for this channel becomes [0°, 360°].

Click the "Enable/Disable All" button to activate/deactivate the angle range configuration for all channels.

NOTE Click "Save" to apply your settings.

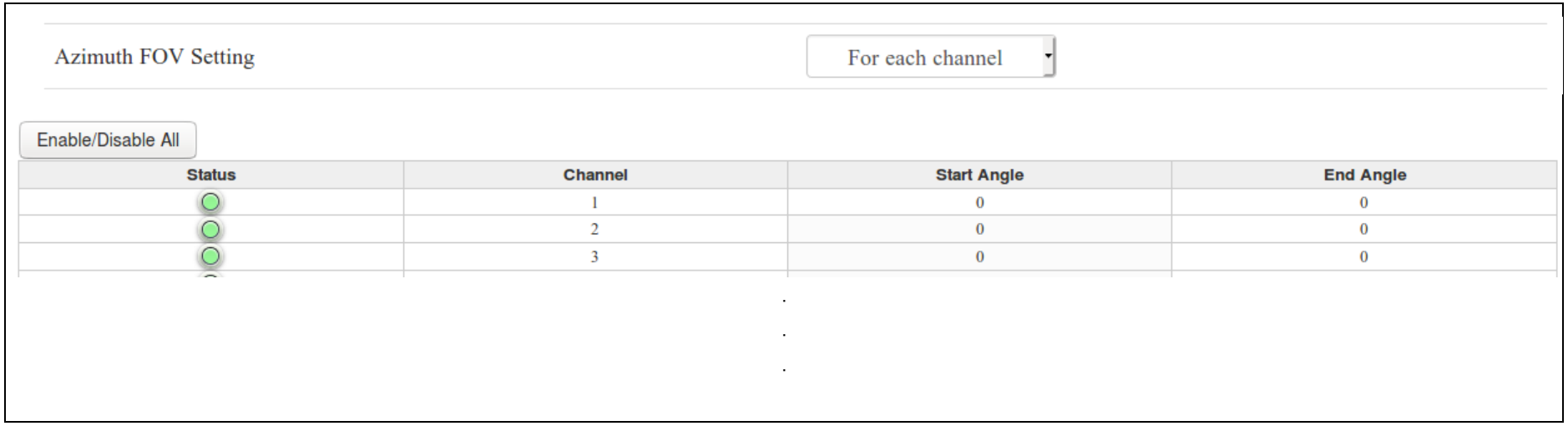


Figure 4.6 Azimuth FOV for Each Channel

4.3.3 Multi-section FOV

Users can configure up to ten continuous angle ranges (i.e. sections) for each channel.

By default, the status button for each channel is green, indicating that multi-section configuration is active.

To deactivate the multi-section configuration for one channel, click the corresponding button to make it gray. Thus the angle range for this channel becomes [0°, 360°].

Click the "Enable/Disable All" button to activate/deactivate the angle range configuration for all channels.

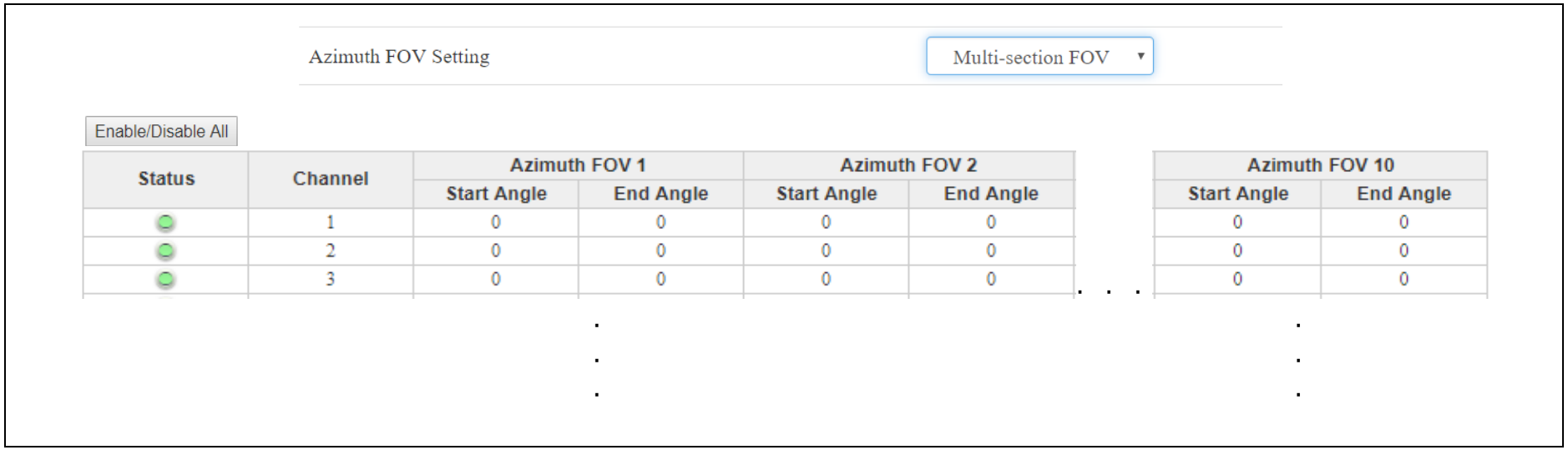
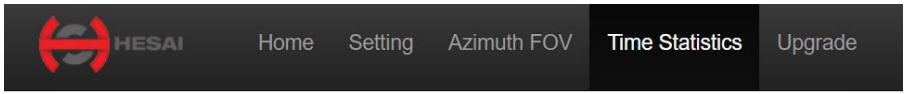


Figure 4.7 Multi-Section Azimuth FOV

4.4 Operation Statistics

The LiDAR's operation time in aggregate and in different temperature ranges are listed.



Start-up Counts	40
Internal Temperature	27.71°C
Total Operation Time	54 h 49 min

Internal Temperature	Operation Time
< -40 °C	0 h 0 min
-40 ~ -20 °C	0 h 0 min
-20 ~ 0 °C	0 h 0 min
0 ~ 20 °C	0 h 0 min
20 ~ 40 °C	5 h 12 min
40 ~ 60 °C	49 h 37 min
60 ~ 80 °C	0 h 0 min
80 ~ 100 °C	0 h 0 min
100 ~ 120 °C	0 h 0 min
>120 °C	0 h 0 min

Figure 4.8 Operation Statistics Page of Web Control

4.5 Upgrade

Click the **Upload** button and select an upgrade file (provided by Hesai). Reboot the LiDAR when the upgrade is complete.

Below shows the software and firmware versions described in this manual.

NOTE A software reboot is triggered by clicking the **Restart** button on the top right corner. Afterwards, the start-up counts in the Operation Statistics page increments by 1.

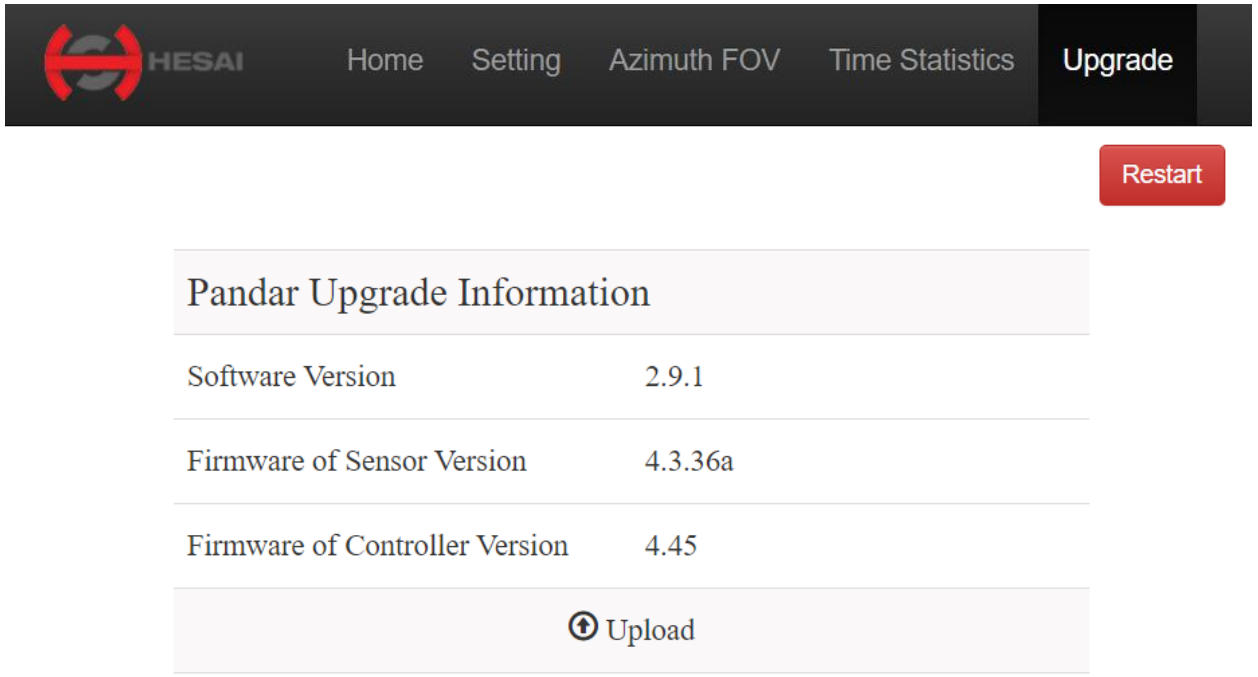


Figure 4.9 Firmware Upgrade Page of Web Control

5 PandarView

PandarView is a software that records and displays the point cloud data from Hesai LiDARs, available in **64-bit Windows 7/8/10** and **Ubuntu-16.04**.

5.1 Installation

Copy the installation files from the USB disk included in the LiDAR's protective case, or download these files from Hesai's official website: www.hesaitech.com/en/download

NOTE Separate Python installation is required only for older PandarView versions.

System	Installation Files	Installation Steps
Windows	PandarView_Windows_V1.6.9.msi python-2.7.13.msi	When upgrading PandarView to a newer version, please uninstall the current version
		Double click and install python Use the default settings in the setup wizard, including "install for all users"
		Double click and install PandarView_Windows using the default settings
Ubuntu-16.04	PandarView_Installer_V1.6.9.tar.gz	Enter the following command in the terminal: sudo apt-get install qt4-default libboost-all-dev
		Unzip PandarView_Installer.tar.gz and run PandarView_Installer.bin

This manual describes PandarView 1.6.9. Users can check the software version from "About" in the menu bar.

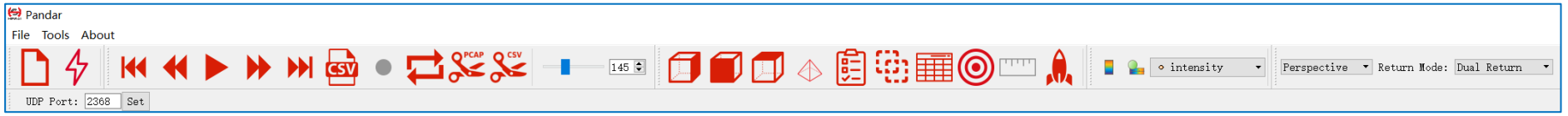


Figure 5.1 Menu and Buttons (PandarView 1.6.9)

5.2 Use

Set the PC's IP address according to Section 2.4 Use.

■ Check Live Data

Click on and select your LiDAR model to begin receiving data over Ethernet.

■ Record a PCAP File

Click on to pop up the "Choose Output File" window.
Click on "Save" to begin recording a PCAP file.
Click on again to stop recording.

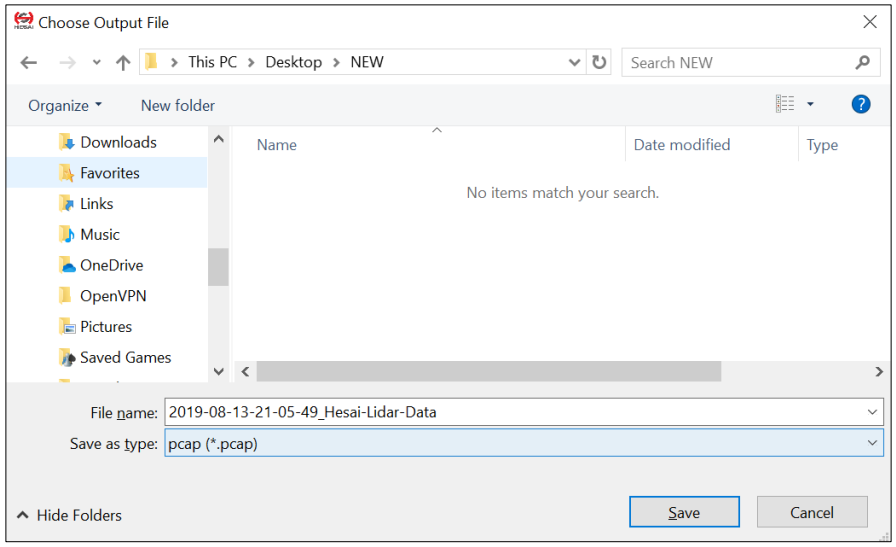


Figure 5.2 Choose Output File

■ Open a PCAP File

Click on to pop up the "Choose Open File" window. Select a PCAP file to open.

■ Import a Correction File

Each LiDAR comes with a correction file (.CSV) in the provided USB disk.

When a PCAP file is open, click on "File" in the menu bar and "Import Correction File".

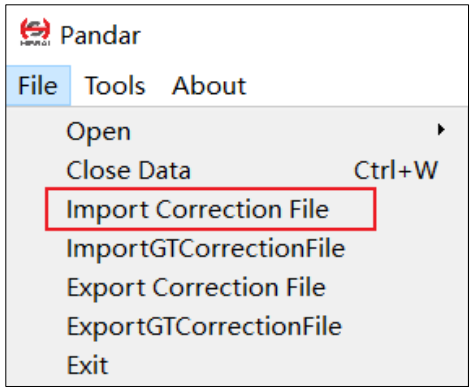
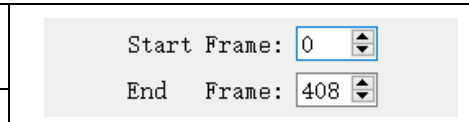


Figure 5.3 File Menu

■ Play a PCAP File

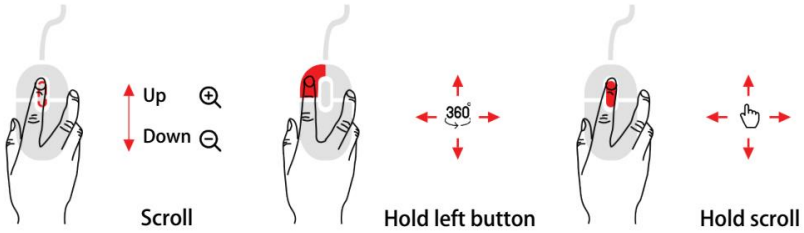
Button	Description
	Jump to the beginning of the file
	While paused, jump to the previous frame While playing, rewind. May click again to adjust the rewind speed (2x, 3x, 1/2x, 1/4x, and 1x) 
	After loading a point cloud file, click to play the file While playing, click to pause
	While paused, jump to the next frame. While playing, forward. May click again to adjust the forward speed (2x, 3x, 1/2x, 1/4x, and 1x) 
	Jump to the end of the file
	Save a single frame to .CSV (the XYZ coordinates as the first three columns)
	While playing, this Record button will be gray and unclickable
	While playing, click to loop playback. Otherwise the player will stop at the end of the file
	Save multiple frames to .PCAP
	Save multiple frames to .CSV (the XYZ coordinates as the last three columns)
 Specify the start and end frames	
	Drag this progress bar or enter a frame number to jump to a specific frame

5.3 Features

■ Viewpoint Selection

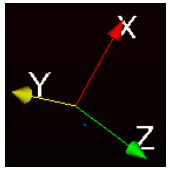
Users can select from the right view, front view, and top view.

■ Mouse Shortcuts



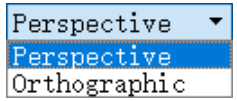
- Slide the scroll wheel up/down to magnify/minimize
- Drag while holding the left button to adjust the point of view
- Drag while holding the scroll wheel to pan

NOTE The bottom-left coordinate axes show the current point of view



■ 3D Projection and Distance Measurement

Both perspective projection (default) and orthographic projection are supported.

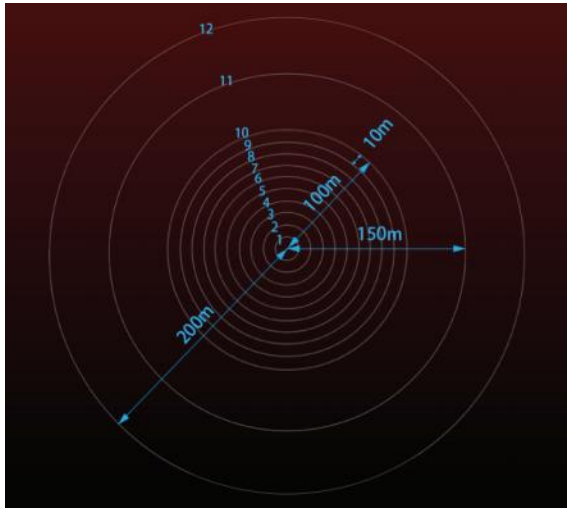


The distance measurement ruler is available only under orthographic projection. After clicking on , drag your mouse while holding the Ctrl key to make a measurement in units of meters. Click on again to quit.

■ Distance Reference Circles

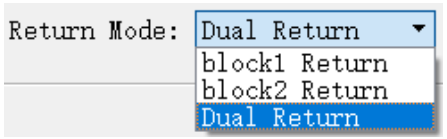
Click on to show/hide the 12 distance reference circles in gray. The actual distances are marked below.

To change the color and line width of these circles, click on “Tools” in the menu bar and open “Grid Properties”.



■ Return Mode

Users can select from Block 1 Return (i.e. Last Return), Block 2 Return (i.e. Strongest Return), and Dual Return.



■ UDP Port

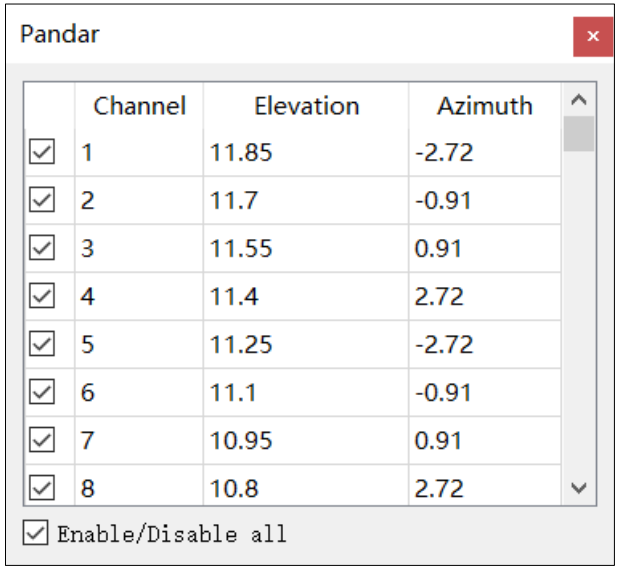
Enter the UDP port number, and click “Set” to apply it.

■ Channel Selection

Click on  to show/hide point cloud data from the selected laser channels.

Check/Uncheck the boxes on the left to show/hide each channel.

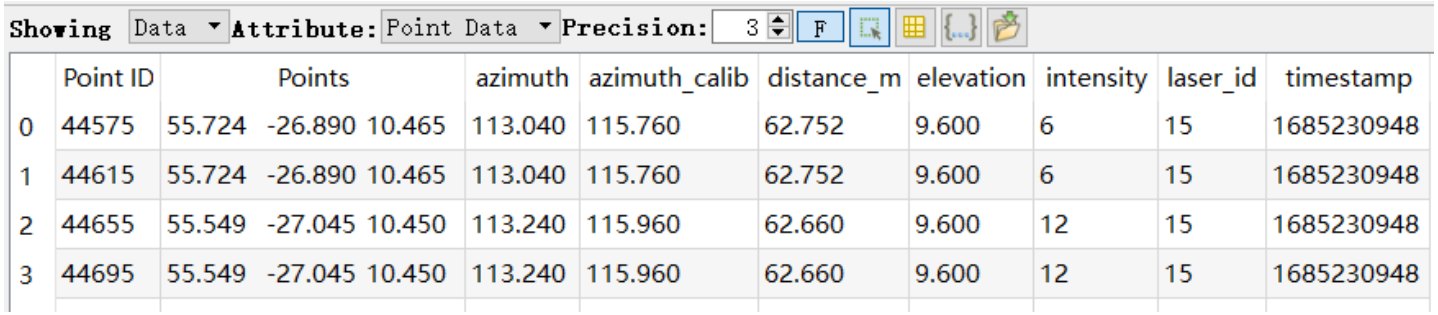
Check the “Enable/Disable all” option at the bottom of the table to show/hide all channels.



■ Point Selection and Data Table

Click on  and drag the mouse over the point cloud to highlight an area of points.

Click on  to view the data of the highlighted points, as shown below.



Showing Data Attribute: Point Data Precision: 3 F

	Point ID	Points	azimuth	azimuth_calib	distance_m	elevation	intensity	laser_id	timestamp
0	44575	55.724 -26.890 10.465	113.040	115.760	62.752	9.600	6	15	1685230948
1	44615	55.724 -26.890 10.465	113.040	115.760	62.752	9.600	6	15	1685230948
2	44655	55.549 -27.045 10.450	113.240	115.960	62.660	9.600	12	15	1685230948
3	44695	55.549 -27.045 10.450	113.240	115.960	62.660	9.600	12	15	1685230948

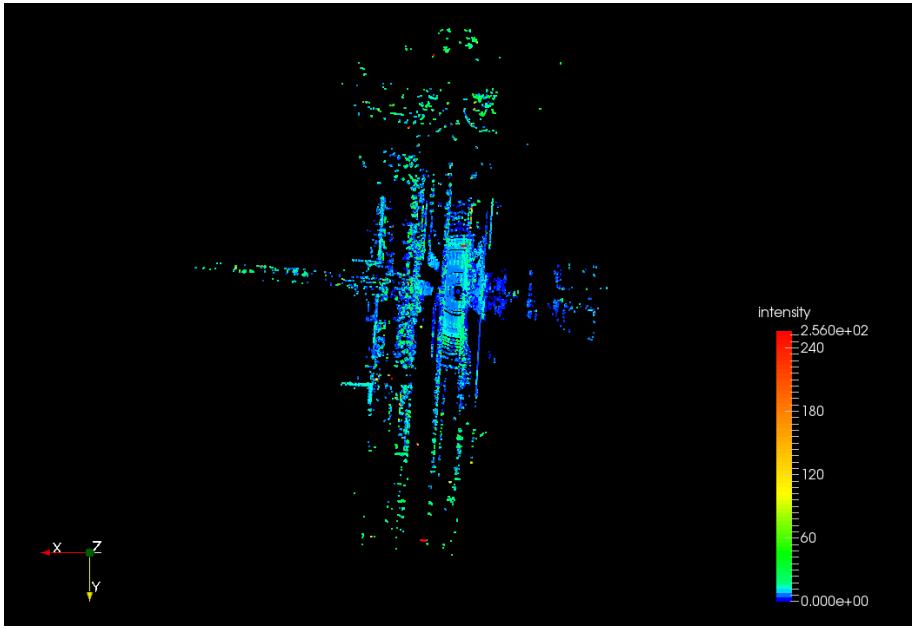
Some of the data fields are defined below:

Field	Description
points	The XYZ coordinates of each point
azimuth	Rotor's current reference angle
azimuth_calib	Azimuth + horizontal angle offset

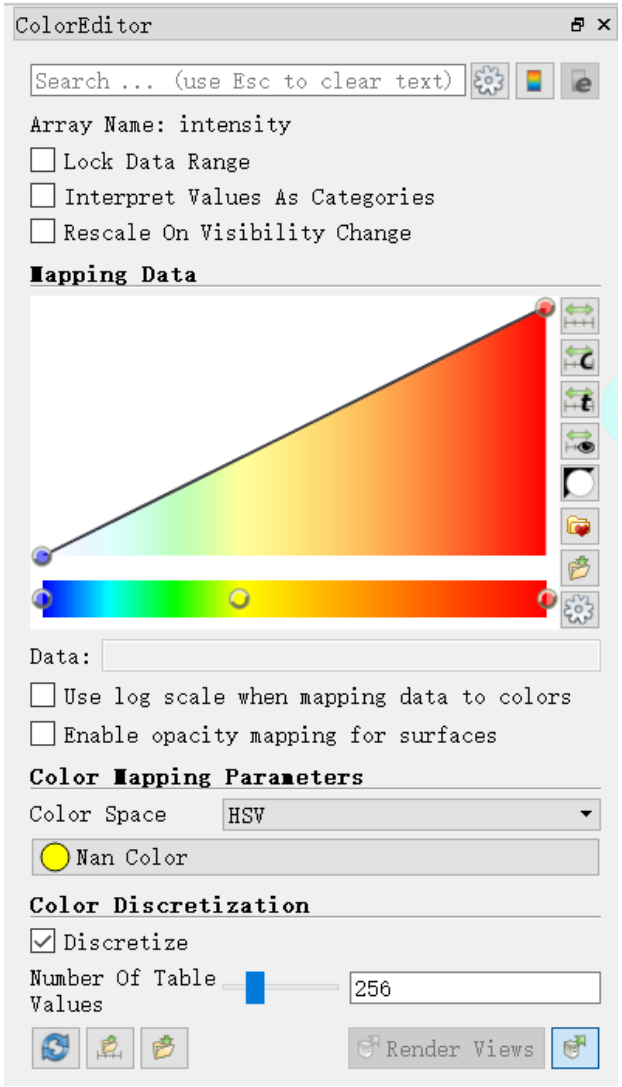
To cancel the selection, click on  again and click on any place outside the selected area.

■ Color Schemes.

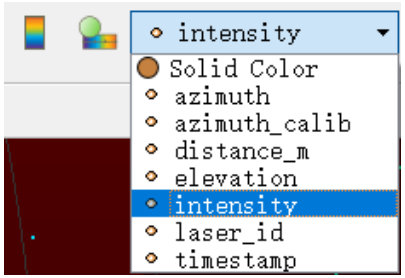
Click on  to show the color legend at the lower right corner.



Click on  to open or close the Color Editor.



The default color scheme is intensity based. Users can choose from other colors schemes based on azimuth, azimuth_calib, distance, elevation, laser_id, or timestamp.



6 Communication Protocol

To ensure real-time communication, Hesai's TCP protocol uses binary format and has disabled Nagle's algorithm.

6.1 Packet Structure

A client can send command messages to the server (LiDAR). Each command message includes a fixed 8-byte header and a variable command-specific payload. The header describes the command type and payload length.

Table 6.1 Command Message Sent from Client to LiDAR

Type	Length	Field Description
0x47	1 byte	Fixed content
0x74	1 byte	Fixed content
Cmd	1 byte	Command code. See Section 6.2 Command Description
Return Code	1 byte	Useless
Payload Length	4 bytes	Data length for the command 0x00 – no payload
Payload	Indicated in Payload Length	Additional data for the command

The server (LiDAR) outputs a feedback message for every command it receives.

Table 6.2 Feedback Message from LiDAR to Client

Type	Length	Field Description
0x47	1 byte	Fixed content
0x74	1 byte	Fixed content
Cmd	1 byte	Command code
Return Code	1 byte	Return code from server
Data Length	4 bytes	Data length for the command 0x00 – no payload
Payload	Indicated in Payload Length	Additional data for the command

6.2 Command Description

Table 6.3 List of Commands

Command	Command Code	Payload Length	Function
PTC_COMMAND_GET_LIDAR_CALIBRATION	0x5	0	To retrieve the LiDAR's calibration file
PTC_COMMAND_PTP_DIAGNOSTICS	0x6	1 byte	To retrieve PTP diagnostics for a specified PTP Query Type
PTC_COMMAND_GET_INVENTORY_INFO	0x7	0	To retrieve inventory info
PTC_COMMAND_GET_CONFIG_INFO	0x8	0	To retrieve configuration parameters
PTC_COMMAND_GET_LIDAR_STATUS	0x9	0	To retrieve status info such as temperature and system uptime

■ PTC_COMMAND_GET_LIDAR_CALIBRATION

Command message payload

None

Feedback message payload

LiDAR's calibration file in CSV Format (ASCII)

Including 3 fields: LaserID, Elevation, and Azimuth Offset

■ PTC_COMMAND_PTP_DIAGNOSTICS

Command message payload

1-byte PTP Query Type

Table 6.4 PTP Query Type

PTP Query Type	Value
PTP STATUS	0x1
PTP TLV PORT_DATA_SET	0x2
PTP TLV TIME_STATUS_NP	0x3
PTP TLV GRANDMASTER_SETTINGS_NP	0x4

Feedback message payload

a. PTP STATUS

Table 6.5 PTP STATUS

Field	Length	Description
master_offset	8 bytes	Offset between master and slave, in units of ns
ptp_state	4 bytes	"NONE", /*0*/ "INITIALIZING", /*1*/ "FAULTY", /*2*/ "DISABLED", /*3*/ "LISTENING", /*4*/ "PRE_MASTER"/*5*/ "MASTER", /*6*/ "PASSIVE", /*7*/ "UNCALIBRATED", /*8*/ "SLAVE", /*9*/ "GRAND_MASTER", /*10*/ 参加 PTP 标准
elapsed_millisec	4 bytes	Time elapsed since the last handshake between master/slave, in milliseconds

b. PTP TLV PORT_DATA_SET

Per IEEE-1588 standard management TLV PORT_DATA_SET

Table 6.6 PTP TLV PORT_DATA_SET

Field	Length	Description
portIdentity	10 bytes	Port identity Including 8-bytes clock identity and 2-byte port number
portState	1 byte	Same as ptp_state in the PTP STATUS message
logMinDelayReqInterval	1 byte	Minimum permitted mean time interval between Delay_Req messages Specified as a power of two in seconds Default: 0 (representing 1 second).
peerMeanPathDelay	8 bytes	Peer mean path delay value, in units of ns
logAnnounceInterval	1 byte	Mean time interval between Announce messages of the portDS set Specified as a power of two in seconds
announceReceiptTimeout	1 byte	Number of missed Announce messages before the last Announce messages of the portDS set expires
logSyncInterval	1 byte	Mean time interval between Sync messages Specified as a power of two in seconds
delayMechanism	1 byte	Delay mechanism Possible values: E2E, P2P, and Auto
logMinPdelayReqInterval	1 byte	Minimum permitted mean time interval between Pdelay_Req messages Specified as a power of two in seconds
versionNumber	1 byte	PTP version number 2 as v2

c. LinuxPTP TLV TIME_STATUS_NP (0xc000)

LinuxPTP specific TLV

Table 6.7 LinuxPTP TLV TIME_STATUS_NP

Field	Length	Description
master_offset	8 bytes	Time difference between master and slave at the last handshake, in units of ns
ingress_time	8 bytes	Hardware ingress time stamp of the last sync message received by the slave
cumulativeScaledRateOffset	4 bytes	Relative information in the last received follow_up message
scaledLastGmPhaseChange	4 bytes	Relative information in the last received follow_up message
gmTimeBaseIndicator	2 bytes	Relative information in the last received follow_up message
lastGmPhaseChange	10 bytes	Relative information in the last received follow_up message
gmPresent	4 bytes	Whether grandmaster is present
gmIdentity	8 bytes	Grandmaster identity when gmPresent is 1

d. LinuxPTP TLV GRANDMASTER_SETTINGS_NP (0xc001)

Table 6.8 LinuxPTP TLV GRANDMASTER_SETTINGS_NP

Field	Length	Description
clockQuality	4 bytes	Clock quality of the current grandmaster clock selected by the slave
utc_offset	2 bytes	UTC_Offset value set by the grandmaster clock
time_flags	1 byte	Time flag of the grandmaster
time_source	1 byte	Time source of the grandmaster

■ PTC_COMMAND_GET_INVENTORY_INFO

Command message payload

None

Feedback message payload

Table 6.9 PTC_COMMAND_GET_INVENTORY_INFO

Field	Length	Description
sn	18 bytes	Serial number of the device
date_of_manufacture	16 bytes	Date of manufacture in ASCII (yyyy-mm-dd)
mac	6 bytes	MAC address of the device
sw_ver	16 bytes	Software version in ASCII (xx.xx.xx)
hw_ver	16 bytes	Hardware version in ASCII
control_fw_ver	16 bytes	Controller firmware version in ASCII
sensor_fw_ver	16 bytes	Sensor firmware version in ASCII
angle_offset	2 bytes	Zero-angle offset, as an unsigned short value in network byte order (big endian)
model	1 byte	0 – Pandar40P 2 – Pandar64 5 - Pandar40
motor_type	1 byte	0 - single direction 1 - dual direction **NOTE** Not supported on Pandar40
num_of_lines	1 byte	Number of channels
reserved	11 bytes	-

■ PTC_COMMAND_GET_CONFIG_INFO

Command message payload

None

Feedback message payload

Table 6.10 PTC_COMMAND_GET_CONFIG_INFO (continued on the next page)

Field	Length	Description
ipaddr	4 bytes	IP address of the device Default 192.168.1.201
mask	4 bytes	Subnet mask of the device Default 255.255.255.0
gateway	4 bytes	Gateway of the device Default 192.168.1.1
dest_ipaddr	4 bytes	Destination IP address of Point Cloud Data Packets Default 255.255.255.255
dest_lidar_udp_port	2 bytes	Destination UDP port of Point Could Data Packets Default 2368
dest_gps_udp_port	2 bytes	Destination UDP port of GPS Data Packets, valid only when the 'clock_source' is 'GPS' Default 10110
spin_rate	2 bytes	Rotation speed of the motor, in units of rpm Default 600
sync	1 byte	Whether to synchronize the given angle (sync_angle) with GPS PPS 0 – Disable (default) 1 – Enable
sync_angle	2 bytes	Default 0
start_angle	2 bytes	Default 0 Device will output point cloud data in the angle ranges between 'start_angle' and 'stop_angle'
stop_angle	2 bytes	Default 36000, in units of 0.01 degrees
clock_source	1 byte	To configure clock source 0 – GPS (default) 1 – PTP
udp_seq	1 byte	Whether the point cloud data will include a UDP sequence number field 0 – UDP sequence OFF (default) 1 – UDP sequence ON
trigger_method	1 byte	0 - angle based 1 - time based (default)

Table 6.10 PTC_COMMAND_GET_CONFIG_INFO (continued)

return_mode	1 byte	0 - last return 1 - strongest return 2 - dual return
standby_mode	1 byte	0 - in operation 1 - standby
motor_status	1 byte	0x0* - cannot reverse the rotation direction 0x1* - supports reversing the rotation direction 0x*0 - currently rotating clockwise 0x*1 - currently rotating counterclockwise
vlan_flag	1 byte	0 - VLAN not in use 1 - VLAN in use
vlan_id	2 bytes	VLAN ID
reserved	9 bytes	-

■ PTC_COMMAND_GET_LIDAR_STATUS

Command message payload

None

Feedback message payload

Table 6.11 PTC_COMMAND_GET_LIDAR_STATUS

Field	Length	Description
system_uptime	4 bytes	System uptime in seconds
motor_speed	2 bytes	Real-time motor speed, in units of rpm
temperature	4 * 8 bytes	Real-time temperature array (unit: 0.01°C) 0 – bottom circuit board T1 1 – bottom circuit board T2 2 – laser emitting board RT_L 3 – receiving board RT_R 4 – receiving board RT2 5 – top circuit RT3 6 – top circuit RT4 7 – top circuit RT5
gps_pps_lock	1 byte	1 - Lock 0 - Unlock
gps_gprmc_status	1 byte	1 - Lock 0 – Unlock **NOTE** Not supported on Pandar40
startup_times	4 bytes	System start-up times
total_operation_time	4 bytes	Total time in operation
ptp_clock_status	1 byte	0 - free run 1 – tracking 2 – locked 3 – frozen **NOTE** Not supported on Pandar40
reserved	5 bytes	-

7 Sensor Maintenance

Storage

Store the device in a dry, well ventilated environment. The ambient temperature should be between -40°C and +85°C, and the humidity below 85%. Please check the specifications page in this user manual for product IP rating, and avoid any ingress beyond that rating.

Transport

Package the device in shock-proof materials to avoid damage during transport.

Cleaning

If the device's enclosure is stained with dirt, fingerprints, or oil, perform the follow cleaning steps.

1) Spray the LiDAR enclosure with warm, neutral solvent using a spray bottle

Solvent type	99% isopropyl alcohol (IPA) or 99% ethanol (absolute alcohol)
Solvent temperature	40 to 60 ℃

2) After the stains on the LiDAR enclosure loosen, gently wipe the enclosure along its curved surface with a piece of soft microfiber cloth

3) Should another cleaning agent be applied to remove certain stains, repeat Step 1 afterwards

4) Spray the enclosure with clean water, and gently wipe off the remaining liquid with another piece of soft microfiber cloth

8 Troubleshooting

Table 8.1 Troubleshooting (To Be Continued)

Symptoms	Points to Check
Indicator light is off on the connection box	1) Make sure the power adapter is properly connected and in good condition 2) Make sure the connection box is intact
Motor is not running	Same as above
Motor is running but no output data received, neither on Wireshark nor PandarView	1) Make sure the Ethernet cable is properly connected 2) Check the IP configuration: use Wireshark to get the LiDAR's IP and make sure it's in the same subnet with the PC's 3) Check the angle range of laser firing and data generation on the Azimuth FOV page of web control 4) Check the firmware version of the sensor on the Upgrade page of web control. If the version is not shown properly but as "xxxx", contact Hesai for further diagnostics
Can receive data on Wireshark but not on PandarView	1) Make sure the Destination IP and the Destination LiDAR Port are set correctly on the Settings page of web control 2) Make sure the PC's firewall is disabled
Cannot open web control	1) Make sure the Ethernet cable is properly connected. 2) Make sure the LiDAR's and the PC's IP addresses are correct, possibly using Wireshark 3) Restart the PC, or connect the LiDAR to another PC
Abnormal packet size (missing packets)	1) Check if the FOV (field of view) has been changed on the Azimuth FOV page of web control 2) Check if the Ethernet is overloaded 3) Check if a switch is connected into the network. The data transmitted from other devices may cause network congestion and packet loss 4) Connect the PC only to the LiDAR and check for packet loss

Table 8.1 Troubleshooting (Continued)

Symptoms	Points to Check
Abnormal point cloud (misaligned points, flashing points, or incomplete FOV)	1) Make sure the LiDAR's enclosure is clean. If not, refer to Chapter 7 Sensor Maintenance for the cleaning method 2) Make sure the LiDAR's calibration file is imported. (Pandar40P automatically imports the calibration file, while Pandar40 requires manual importing) 3) Check for packet loss. If no packet is missing while the point cloud flashes, please update PandarView to the latest version and restart the PC. If problem persists, try connecting the LiDAR to another PC
GPS cannot be locked	1) Make sure the GPS receiver is properly connected 2) Make sure the PPS signal is connected to the LiDAR 3) Make sure the Destination GPS Port is correct on the Settings page of web control 4) Make sure the input GPS signals satisfy the electrical requirements in Section 2.2 Interface and Section 2.3.1 Connection Box Interfaces in the user manual

Appendix I Channel Distribution

Each channel's horizontal angle = rotor's current reference angle + horizontal angle offset
Define clockwise in the top view as positive.

Each channel's vertical angle is a constant. 0° represents the horizontal direction. Define upward as positive.

Table 1.1 Pandar40P Channel Distribution (To Be Continued)

Channel # in UDP Data	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range (in meters) with Reflectivity
01 (Top Beam)	-1.042	15.00	130	200@20%
02	-1.042	11.00	130	200@20%
03	-1.042	8.00	130	200@20%
04	-1.042	5.00	130	200@20%
05	-1.042	3.00	230	200@20%
06	-1.042	2.00	230	200@20%
07	3.125	1.67	230	200@20%
08	-5.208	1.33	230	200@20%
09	-1.042	1.00	230	200@10%
10	3.125	0.67	230	200@10%
11	-5.208	0.33	230	200@10%
12 (Horizontal Beam)	-1.042	0.00	230	200@10%
13	3.125	-0.33	230	200@10%
14	-5.208	-0.67	230	200@10%
15	-1.042	-1.00	230	200@10%
16	3.125	-1.33	230	200@10%
17	-5.208	-1.67	230	200@10%
18	-1.042	-2.00	230	200@10%
19	3.125	-2.33	230	200@20%

Table 1.1 Pandar40P Channel Distribution (Continued)

Channel # in UDP Data	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range (in meters) with Reflectivity
20	-5.208	-2.67	230	200@20%
21	-1.042	-3.00	230	200@20%
22	3.125	-3.33	230	200@20%
23	-5.208	-3.67	230	200@20%
24	-1.042	-4.00	230	200@20%
25	3.125	-4.33	230	200@20%
26	-5.208	-4.67	230	200@20%
27	-1.042	-5.00	130	200@20%
28	3.125	-5.33	130	200@20%
29	-5.208	-5.67	130	200@20%
30	-1.042	-6.00	130	200@20%
31	-1.042	-7.00	130	200@20%
32	-1.042	-8.00	130	200@20%
33	-1.042	-9.00	130	200@20%
34	-1.042	-10.00	130	200@20%
35	-1.042	-11.00	130	200@20%
36	-1.042	-12.00	130	200@20%
37	-1.042	-13.00	130	200@20%
38	-1.042	-14.00	130	200@20%
39	-1.042	-19.00	130	200@20%
40 (Bottom Beam)	-1.042	-25.00	130	200@20%

Appendix II Absolute Time and Laser Firing Time

■ Absolute Time of Point Cloud Data Packets

The absolute packing time of a Point Cloud Data Packet is the sum of UTC time and μs time.

- UTC time can be retrieved either from the current Point Cloud Data Packet (6 bytes, year, month, date, hour, minute, second), or from the previous GPS Data Packet (6 bytes of Date and 6 bytes of time).
- μs time can be retrieved from this Point Cloud Data Packet (4 bytes)

NOTE The calculation of absolute time is different when PTP protocol is used. See Appendix III PTP Protocol.

■ Laser Firing Time

Assuming that the absolute packing time of a Point Cloud Data Packet is t0, the **end time of each block** (the time when all the lasers finish firing) can be calculated.

For Pandar40P, there are 10 blocks of ranging data in each Point Cloud Data Packet, as shown below. Each block contains the ranging data from 40 channels, one return per channel.

Table II.1 Point Could UDP Data – Ranging Data

Ranging Data: 1240 bytes (10 blocks)				
Block1	**Block2**	**Block3**	**…**	**Block10**
0xFFEE	0xFFEE	0xFFEE	…	0xFFEE
Azimuth 1	Azimuth 2	Azimuth 3	…	Azimuth 10
Channel 1	Channel 1	Channel 1	…	Channel 1
Channel 2	Channel 2	Channel 2	…	Channel 2
…	…	…	…	…
Channel 40	Channel 40	Channel 40	…	Channel 40

Single Return Mode

The ranging data generated by one round of firing is stored in one block.

The calculation of each Block's end time is as follows:

Table II.2 End Time of Each Block – Single Return

Block	End Time (μs)
Block 10	t0 - 28.58
Block N	t0 - 28.58 - 55.56 * (10 - N)
Block 3	t0 - 28.58 - 55.56 * 7
Block 2	t0 - 28.58 - 55.56 * 8
Block 1	t0 - 28.58 - 55.56 * 9

Dual Return Mode

The ranging data generated by one round of firing is stored in two adjacent blocks: the odd number block is the last return, and the even number block is the strongest return. If the last and strongest returns coincide, the second strongest return will be placed in the even number block.

Therefore, Block 1 & Block 2 have the same firing time, Block 3 & Block 4 the same firing time, and so on.

Table II.3 End Time of Each Block – Dual Return

Block	End Time (μs)
Block 10 & Block 9	t0 - 28.58
Block 8 & Block 7	t0 - 28.58 - 55.56 * 1
Block 6 & Block 5	t0 - 28.58 - 55.56 * 2
Block 4 & Block 3	t0 - 28.58 - 55.56 * 3
Block 2 & Block 1	t0 - 28.58 - 55.56 * 4

Having acquired the end time of each block, the **laser firing time of each channel** can be calculated as follows.
For example, assume that the end time of Block 6 is t6, then:

Table II.4 Laser Firing Time of Each Channel

Firing Sequence	Laser ID	Firing Time (μs)
1	4	t6 - 3.62
2	40	t6 - 3.62 (same as above)
3	36	t6 - 4.92
4	28	t6 - 6.23
5	12	t6 - 8.19
6	16	t6 - 8.19 (same as above)
7	32	t6 - 9.5
8	24	t6 - 11.47
9	29	t6 - 12.77
10	17	t6 - 14.74

Firing Sequence	Laser ID	Firing Time (μs)
11	3	t6 - 16.04
12	39	t6 - 16.04 (same as above)
13	35	t6 - 17.35
14	25	t6 - 18.65
15	9	t6 - 20.62
16	13	t6 - 20.62 (same as above)
17	31	t6 - 21.92
18	21	t6 - 23.89
19	26	t6 - 25.19
20	14	t6 - 27.16

Firing Sequence	Laser ID	Firing Time (μs)
21	2	t6 - 28.47
22	38	t6 - 28.47 (same as above)
23	34	t6 - 29.77
24	6	t6 - 31.74
25	22	t6 - 31.74 (same as above)
26	10	t6 - 33.71
27	30	t6 - 35.01
28	18	t6 - 36.98
29	23	t6 - 38.95
30	11	t6 - 40.91

Firing Sequence	Laser ID	Firing Time (μs)
31	1	t6 - 42.22
32	37	t6 - 42.22 (same as above)
33	33	t6 - 43.52
34	5	t6 - 45.49
35	19	t6 - 45.49 (same as above)
36	7	t6 - 47.46
37	27	t6 - 48.76
38	15	t6 - 50.73
39	20	t6 - 52.7
40	8	t6 - 54.67

Appendix III PTP Protocol

The Precision Time Protocol (PTP), also known as the IEEE 1588 standard, is used to synchronize clocks across a computer network. It can achieve sub-microsecond clock accuracy and is suitable for measurement and control systems.

■ LiDAR Connection When Using PTP

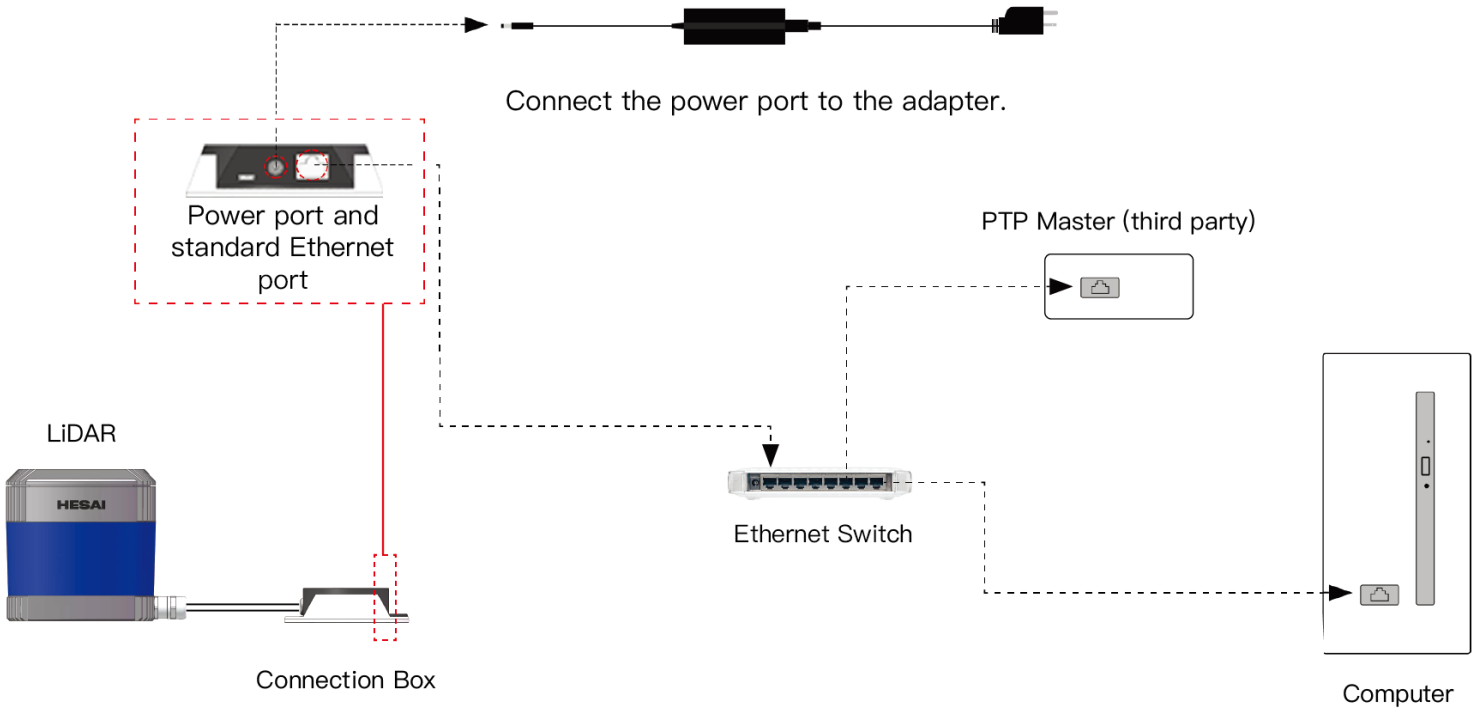


Figure III.1 LiDAR Connection When Using PTP

■ Absolute Packing Time When Using PTP

To use PTP as the clock source, users need to connect a PTP master device to get the absolute time.

If a PTP clock source is selected, the LiDAR will not transmit GPS Data Packets, but only Point Cloud Data Packets with 4-byte μs timestamps and 6-byte UTC time. The sum of the μs timestamp and the UTC time is the absolute packing time of this data packet.

NOTE

- The PTP master device is a third-party product and is not included with the LiDAR.
- The LiDAR's clock follows the PTP master device according to the PTP protocol.
- The timestamps and UTC time in Point Cloud Data Packets strictly follow the PTP time from the PTP master device. There may be offset with UTC time for certain PTP master devices. Please verify the configuration and calibration of your PTP master device in order to get precise time information.
- The LiDAR works as a PTP slave device and the PTP protocol is Plug&Play. No additional setup is required.
- If a PTP clock source is selected but no PTP master device is available, the LiDAR will count the time from an invalid past time. If a PTP clock source is supplied and later stopped, the LiDAR will continue to count the time with an internal clock.

NOTE The calculation of laser firing time remains the same whether PTP is used or not, as detailed in Appendix II.

Appendix IV Phoenix Contact

Phoenix Contact can be used as the LiDAR's communication connector, in place of the default Lemo Contact in Section 2.2 Interfaces.
Phoenix part number: SACC-M12MS-8CON-PG 9-SH - 1511857 (male, on the LiDAR), SACC-M12FS-8CON-PG 9-SH – 1511860 (female, on the connecting box)

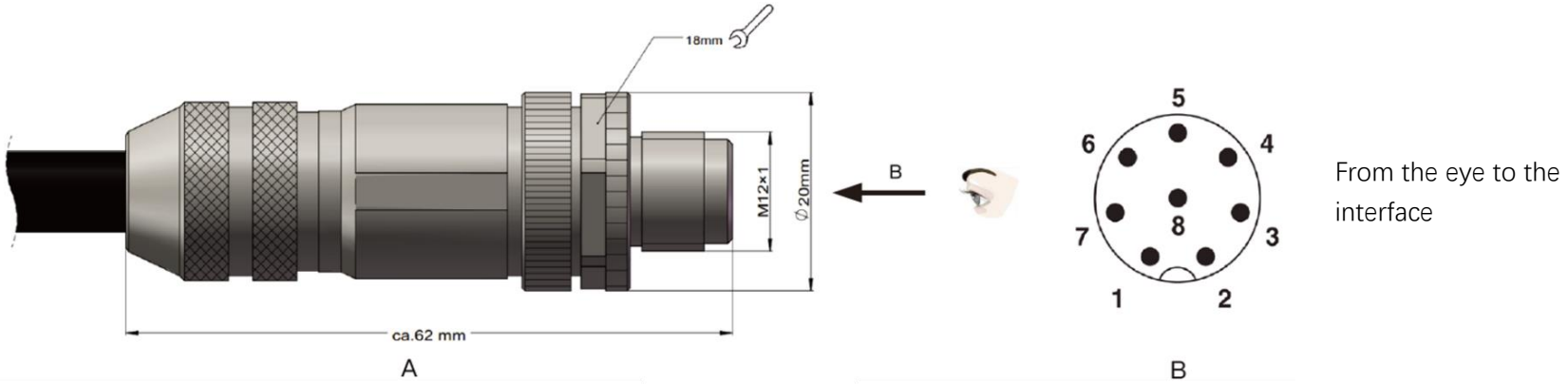


Figure IV.1 Phoenix Connector (Male)

Table IV.1 Pin Description of Phoenix Connector

Pin #	Function	Color	Voltage
1	Ethernet RX-	Blue	-1 V to 1 V
2	Ethernet RX+	Light Blue (Blue/White)	-1 V to 1 V
3	Ethernet TX-	Orange	-1 V to 1 V
4	Ethernet TX+	Light Orange (Orange/White)	-1 V to 1 V
5	GPS Serial Data	White	-13 V to +13 V
6	GPS PPS	Yellow	3.3 V/5 V
7	+12 V	Red	12 V
8	Ground (Return)	Black	-

Appendix V　Nonlinear Reflectivity Mapping

By default, the 1-byte reflectivity data in the Point Cloud Data Packet linearly represents target reflectivity from 0 to 255%.

Alternatively, users can choose the Nonlinear Mapping mode on the Settings page of web control (see Section 4.2 Settings).

The nonlinear relationship is detailed below.

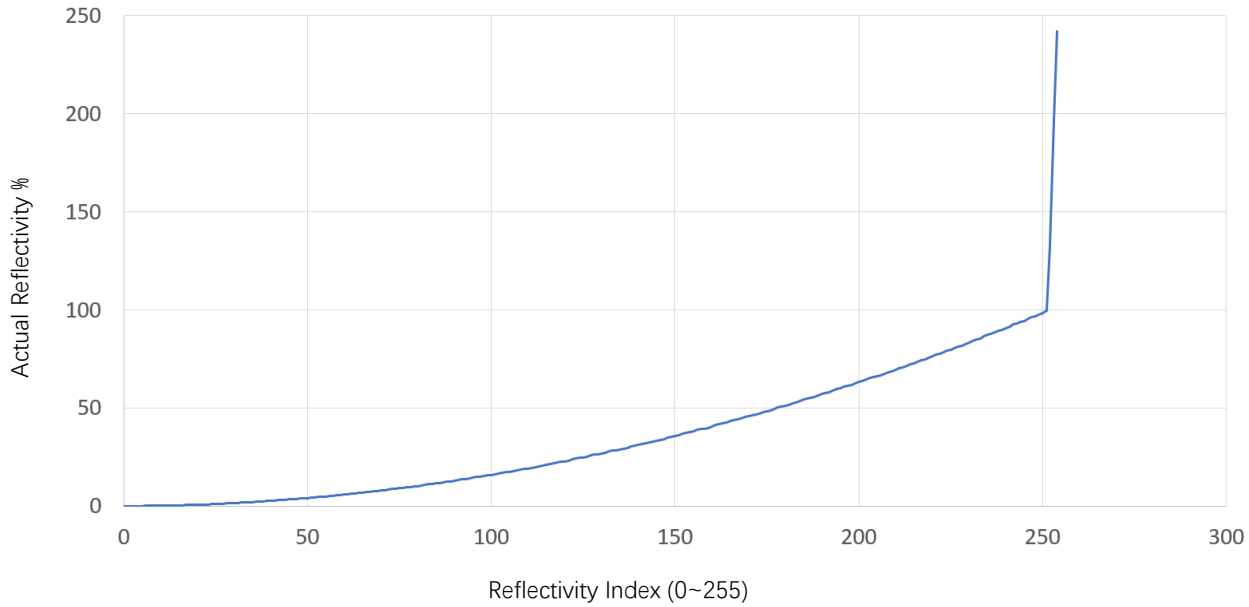


Figure V.1 Nonlinear Reflectivity Mapping

Table V.1 Nonlinear Reflectivity Mapping (To Be Continued)

Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)
0	0	65	6.9	130	26.83	195	60.25
1	0.01	66	7.1	131	27.25	196	60.75
2	0.02	67	7.3	132	27.75	197	61.25
3	0.03	68	7.5	133	28.17	198	61.75
4	0.04	69	7.7	134	28.5	199	62.5
5	0.05	70	7.9	135	28.83	200	63.25
6	0.08	71	8.12	136	29.25	201	63.75
7	0.11	72	8.37	137	29.75	202	64.5
8	0.13	73	8.62	138	30.25	203	65.25
9	0.15	74	8.87	139	30.75	204	65.75
10	0.19	75	9.1	140	31.17	205	66.25
11	0.23	76	9.3	141	31.5	206	66.75
12	0.26	77	9.5	142	31.83	207	67.5
13	0.29	78	9.7	143	32.25	208	68.25
14	0.34	79	9.9	144	32.75	209	68.75
15	0.39	80	10.17	145	33.25	210	69.5
16	0.44	81	10.5	146	33.75	211	70.25
17	0.5	82	10.83	147	34.25	212	70.75
18	0.56	83	11.12	148	34.75	213	71.5
19	0.61	84	11.37	149	35.25	214	72.25
20	0.67	85	11.62	150	35.75	215	72.75
21	0.75	86	11.87	151	36.25	216	73.5
22	0.81	87	12.12	152	36.75	217	74.25
23	0.87	88	12.37	153	37.25	218	74.75
24	0.95	89	12.62	154	37.75	219	75.5

Table V.1 Nonlinear Reflectivity Mapping (To Be Continued)

Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)
25	1.05	90	12.87	155	38.25	220	76.5
26	1.15	91	13.17	156	38.75	221	77.25
27	1.25	92	13.5	157	39.17	222	77.75
28	1.35	93	13.83	158	39.5	223	78.5
29	1.45	94	14.17	159	39.83	224	79.25
30	1.55	95	14.5	160	40.5	225	79.75
31	1.65	96	14.83	161	41.25	226	80.5
32	1.75	97	15.12	162	41.75	227	81.25
33	1.85	98	15.37	163	42.25	228	81.75
34	1.95	99	15.62	164	42.75	229	82.5
35	2.06	100	15.87	165	43.25	230	83.5
36	2.19	101	16.17	166	43.75	231	84.25
37	2.31	102	16.5	167	44.25	232	84.75
38	2.44	103	16.83	168	44.75	233	85.5
39	2.56	104	17.17	169	45.25	234	86.5
40	2.69	105	17.5	170	45.75	235	87.25
41	2.81	106	17.83	171	46.25	236	87.75
42	2.94	107	18.17	172	46.75	237	88.5
43	3.07	108	18.5	173	47.25	238	89.25
44	3.21	109	18.83	174	47.75	239	89.75
45	3.36	110	19.17	175	48.25	240	90.5
46	3.5	111	19.5	176	48.75	241	91.5
47	3.64	112	19.83	177	49.5	242	92.5
48	3.79	113	20.25	178	50.25	243	93.25
49	3.93	114	20.75	179	50.75	244	93.75

Table V.1 Nonlinear Reflectivity Mapping (Continued)

Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)
50	4.08	115	21.17	180	51.25	245	94.5
51	4.25	116	21.5	181	51.75	246	95.5
52	4.42	117	21.83	182	52.25	247	96.25
53	4.58	118	22.17	183	52.75	248	96.75
54	4.75	119	22.5	184	53.5	249	97.5
55	4.92	120	22.83	185	54.25	250	98.5
56	5.1	121	23.25	186	54.75	251	99.5
57	5.3	122	23.75	187	55.25	252	132
58	5.5	123	24.17	188	55.75	253	196
59	5.7	124	24.5	189	56.5	254	242
60	5.9	125	24.83	190	57.25		
61	6.1	126	25.25	191	57.75		
62	6.3	127	25.75	192	58.25		
63	6.5	128	26.17	193	58.75		
64	6.7	129	26.5	194	59.5		

Appendix VI Certification Info

■ FCC Declaration

HESAI

DECLARATION OF CONFORMITY

Manufacturer or Importer Name: Mantou Business and Technology Services
Manufacturer or Importer Address: 37 Winding Ridge, Oakland,New Jersey,07436

Rangefinder

Product Name: **40-Rangefinder**
Model No.: Pandar40P
Trade Name: HESAI

We, *the US Local Responsible Party*, declare under our sole responsibility that the above referenced product has been tested on samples according to FCC requirements, for which TUV SUD issued Test Report No.:7088818119401-00 and found compliant with the following standards: **FCC Part 15 Subpart B**.

Please be advised,

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:
(1) This device may not cause harmful interference
And (2) this device must accept any interference received, including interference that may cause undesirable operation

Signature: Charles Shen

Signed for and on behalf of:

Name: Charles Shen

Tel: 608-217-9358

Email: cyshen@aol.com

Position: Director
12/28/2018

Hesai Photonics Technology Co., Ltd
Building L2, Hongqiao World Centre, Shanghai
021-31588240

■ IC Statement

This device complies with Industry Canada licence-exempt RSS standard(s).

Operation is subject to the following two conditions:
(1) this device may not cause interference, and
(2) this device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence.

L'exploitation est autorisée aux deux conditions suivantes:
(1) l'appareil ne doit pas produire de brouillage, et
(2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Appendix VII Support and Contact

■ Technical Support

For any question not addressed in this manual, please contact us at:

service@hesaitech.com
www.hesaitech.com
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NOTE Please leave your questions under the corresponding GitHub projects.

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