HESAI

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PandarQT

64-Channel Short-Range Mechanical LiDAR User Manual

HESAI Wechat

Contents

About This Manual

■ Using This Manual

- Make sure to read through this user manual before your first use and follow the instructions herein when you operate the product. Failure to comply with the instructions may result in product damage, property loss, personal injuries, and/or a breach of warranty.
- This user manual does not contain information on product certifications. Please check the certification marks on the product's bottom plate and read through the corresponding certification warnings.
- If you incorporate this LiDAR product into your product(s), you are required to provide this user manual (or the means to access this user manual) to the intended users of your product(s).

■ Access to This Manual

To obtain the latest version:

- Visit the Download page of Hesai's official website: https://www.hesaitech.com/en/download
- Or contact your sales representative at Hesai
- Or contact Hesai's technical support team: service@hesaitech.com

■ Technical Support

If your question is not addressed in this user manual, please contact us at:

service@hesaitech.com

www.hesaitech.com/zh/support

https://github.com/HesaiTechnology (Please leave your questions under the corresponding GitHub projects.)

■ Legends

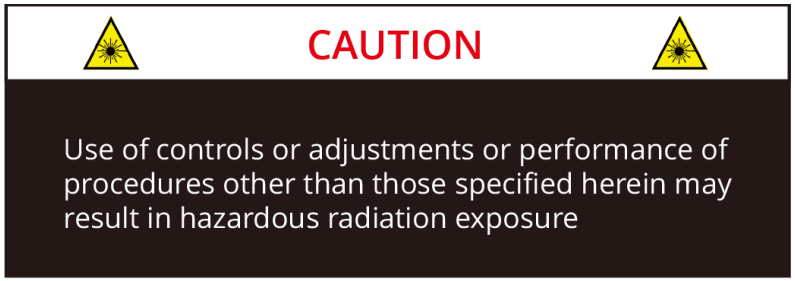
⚠ Warnings: instructions that must be followed to ensure safe and proper use of the product.

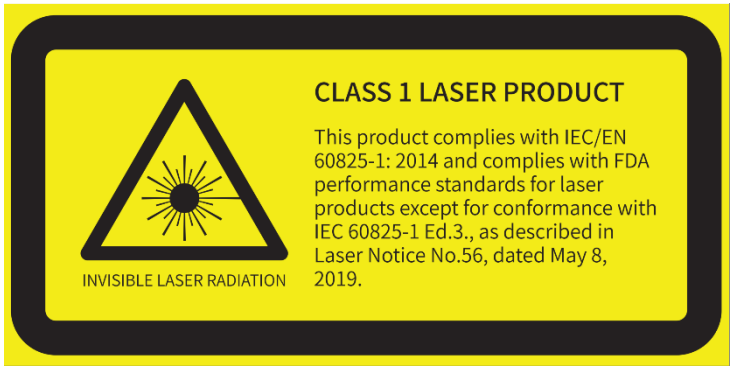
Notes: additional information that may be helpful.

Safety Notice

■ Special Warnings

Laser Safety





Hot Surface

During or after a period of operation, do NOT touch the product's enclosure with your skin.

Abnormalities

In any of the circumstances listed below, stop using the product immediately:

- You suspect that the product malfunctions or is damaged. For example, the product produces significant noise or is visibly vibrating.
- You or other people in the nearby environment feel discomfort.
- Any device or equipment in the nearby environment malfunctions.

Meanwhile, contact Hesai Technology or an authorized Hesai Technology service provider for more information on product disposal. Contact information can be found in the product's user manual (refer to the *About this Manual* section).

Prohibition of Disassembly

Unless expressly agreed to in writing by Hesai Technology, do NOT disassemble the product.

■ Operating Environment

Radio Frequency Interference

Before using the product, make sure to read all the signs and notices on the product enclosure (including the bottom plate). Although the product is designed, tested, and manufactured to comply with the regulations on RF radiation (such as FCC, CE-EMC, or KCC), the radiation from the product may still influence electronic devices.

Vibration

- If significant mechanical shocks and vibration may exist in the product's operating environment, please contact Hesai's technical support team to obtain the shock and vibration limits of this product model. Exposure to over-the-limit shocks or vibration may damage the product.
- Make sure to package the product in shock-proof materials to avoid damage during transport.

Explosive Atmosphere and Other Air Conditions

- Do NOT use the product 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.
- Do NOT expose the product to high concentrations of industrial chemicals, including liquefied gases that are easily vaporized (such as helium). Such exposure can damage or weaken the product's function.

Ingress Protection

Please check the product's user manual for its IP rating (refer to the *Specifications* section). Make sure to avoid any ingress beyond that rating.

Operating Temperature

Please check the product's user manual for its operating temperature (refer to the *Specifications* section). Make sure not to exceed the operating temperature range.

Recommended Storage Conditions

Store the product in a dry, well ventilated place. The recommended ambient temperature is 23±5°C, and the humidity between 30% and 70%.

Light Interference

Certain precision optical instruments may be interfered by the laser light emitted from the product. Please check all the instructions of these instruments and take preventive measures if necessary. For example, when the product is temporarily not used for measurement, the protective leather cover (supplied with the product) can be used to block laser light emission.

■ Personnel

Recommended Operator Qualifications

The product should be operated by professionals with engineering backgrounds or experience in operating optical, electrical, and mechanical instruments. Please follow the instructions in this manual when operating the product and contact Hesai technical support if needed.

Medical Device Interference

- Some components in the product can emit electromagnetic fields. If the product operators or other people in the nearby environment wear medical devices (such as cochlear implants, heart pacemakers, and defibrillators), make sure to consult the physicians and medical device manufacturers for medical advice, such as determining whether it is safe to work near the product.
- If you suspect that the product is interfering with your medical device, stop using the product immediately.

■ Installation and Operation

Power Supply

- You are recommended to use only the cables and power adapters provided by Hesai Technology.
- If you are to design, configure, or select the power supply system (including cables) for the product, make sure to comply with the electrical specifications in the product's user manual (refer to the *Specifications* section and the *Power Supply Requirements* section); for technical support, please contact Hesai Technology. Do NOT use off-spec or damaged cables or adapters.

Electrical Interface

- Before powering on the product, make sure the electrical interfaces are dry and clean. Do NOT power on the product in a humid environment.
- Please check the *Interfaces* section in the product's user manual and strictly follow the instructions on plugging/unplugging the connector. If abnormalities already exist (such as bent pins, broken cables, and loose screws), stop using the product and contact Hesai technical support.
- To prevent breakdown, turn off the power source before connection and disconnection.

Eye Safety

The product is a Class 1 laser product. It satisfies the requirements of:

- IEC 60825-1:2014.
- 21 CFR 1040.10 and 1040.11 except for deviations (IEC 60825-1 Ed.3) pursuant to Laser Notice No.56, dated May 8, 2019.

Please follow the standard laser safety guidelines accordingly.

For maximum self-protection, it is strongly warned NOT to look into the transmitting laser through a magnifying product (microscope, eye loupe, magnifying glass, etc.).

This product does not have a power switch. It starts operating once connected to power. During operation, the entire cover lens can be regarded as the product's laser emitting window; looking at the cover lens can be regarded as looking into transmitting laser.

Product Enclosure

- The product contains metal, glass, plastic, as well as sensitive electronic components. In case the product has been dropped and burnt, stop using it immediately and contact Hesai technical support.
- Do NOT squeeze or pierce the product. If the product enclosure is broken, stop using it immediately and contact Hesai technical support.
- The product contains high-speed rotating parts. To avoid potential injuries, do NOT operate the product if the enclosure is loose.
- Before operating the product, make sure it is properly and securely mounted. The mounting should prevent the product from leaving its mounting position in case of external forces (such as collisions, high winds, and stone impacts).
- If the product enclosure consists of fins or grooves, please wear gloves when handling the product. Applying too much pressure with your bare hands may cause cuts, bruises or other injuries.

Product Enclosure: Cover Lens

- To keep the product's cover lens from fingerprints and other stains, do NOT touch the cover lens with bare hands. If the cover lens is already stained, please refer to the cleaning method in the *Sensor Maintenance* section of the user manual.
- To prevent scratches, do NOT touch the product's cover lens with hard or sharp objects. If scratches already exist, stop using the product and contact Hesai technical support. Severe scratches may affect the quality of the product's point cloud data.

Hot Surface

During operation or a time period after operation, the product's enclosure can be hot.

- To prevent discomfort or even burns, do NOT touch the product's enclosure with your skin.
- To prevent fires, do NOT touch the product's enclosure with flammable materials.

Peripherals

The product may be used along with accessories and devices, such as suction cup mounts, extension cables, power supplies, network devices, GPS/PTP devices, and cleaning equipment. Please refer to all relevant specifications in the product's user manual, or contact Hesai technical support. Using off-spec or unsuitable devices may result in product damage or even personal injuries.

Firmware and Software Upgrading

Make sure to use only the upgrade files provided by Hesai Technology. Make sure to observe all the instructions provided for that upgrade file.

Custom Firmware and Software

- Before using a custom version of firmware and software, please thoroughly understand the differences in functions and performance between this custom version and the standard version.
- Make sure to strictly follow all the instructions and safety precautions provided for that custom version. If the product does not function as anticipated, stop using the product immediately and contact Hesai technical support.

Point Cloud Data Processing

The point cloud data processing features (provided on certain product models) are configurable and are intended only to assist users in extracting information from the point cloud data. Users are in full control whether to use any of these features. Moreover, users are responsible for analyzing the product's intended application scenarios and evaluating the risks of enabling one or more of these features in combination. The point cloud data processing features include but are not limited to: Noise Filtering, Interstitial Points Filtering, Retro Multi-Reflection Filtering, and Nonlinear Reflectivity Mapping.

■ Repair and Maintenance

For product repair or maintenance issues, please contact Hesai Technology or an authorized Hesai Technology service provider. Contact information can be found in the product's user manual (refer to the *About this Manual* section).

Repair

Unless expressly agreed to in writing by Hesai Technology, do NOT by yourself or entrust any third party to disassemble, repair, modify, or retrofit the product. Such a breach:

- can result in product damage (including but not limited to water resistance failure), property loss, and/or personal injuries;
- shall constitute a breach of warranty.

1 Introduction

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

1.1 Operating Principle

Distance Measurement: Time of Flight (ToF)

1) A laser diode emits a beam of ultrashort laser pulses onto the target object.
2) The laser pulses are reflected after hitting the target object. The returning beam is detected by an optical sensor.
3) Distance to the object can be accurately measured by calculating the time between laser emission and receipt.

$$d = \frac{ct}{2}$$

d: distance
c: speed of light
t: travel time of the laser beam

Figure 1.1 Distance Measurement Using Time of Flight

1.2 LiDAR Structure

Laser emitters and receivers are attached to a motor that rotates horizontally.

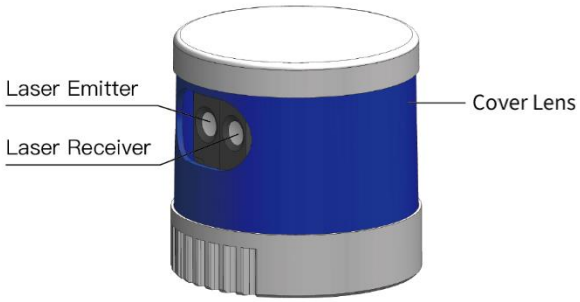


Figure 1.2 Partial Cross-Sectional Diagram

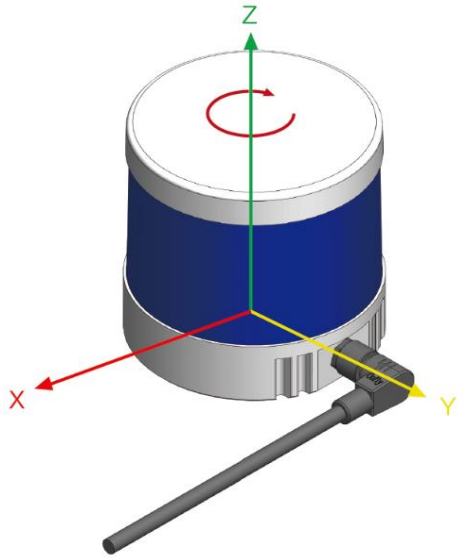


Figure 1.3 Coordinate System (Isometric View)

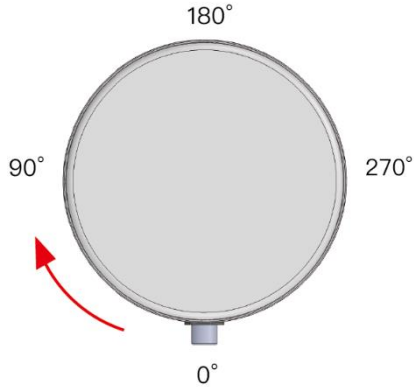


Figure 1.4 Default Rotation Direction (Top View)

The LiDAR's coordinate system is illustrated in Figure 1.3. Z-axis is the axis of rotation.
By default, the LiDAR rotates clockwise in the top view. To select counterclockwise rotation, see Section 4.2 (Web Control - Settings).

The origin is shown as a red dot in Figure 1.6 on the next page. All measurements are relative to the origin.

When the horizontal center of the emitter-receiver array passes the zero-degree position in Figure 1.4, the azimuth data in the corresponding UDP data block will be 0°.

1.3 Channel Distribution

The vertical resolution is unevenly distributed across all channels, as illustrated in Figure 1.5 and detailed in Appendix I (Channel Distribution).

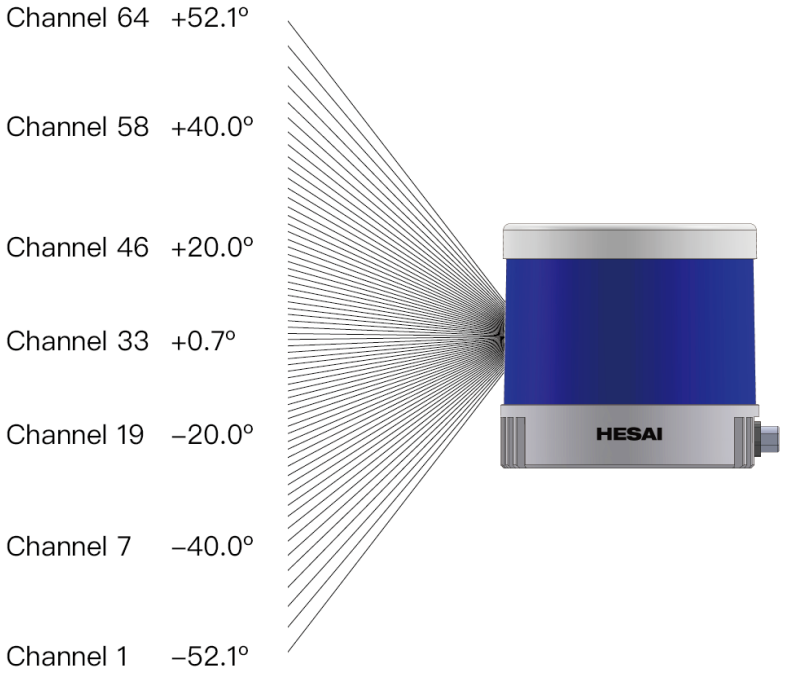


Figure 1.5 Channel Vertical Distribution

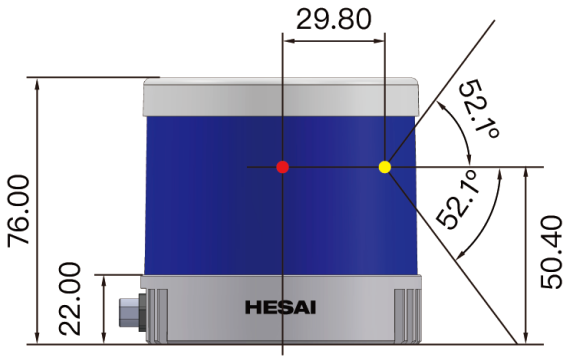


Figure 1.6 Laser Firing Position (Unit: mm)

Each channel has an intrinsic angle offset, both horizontally and vertically. The offsetted angles are recorded in this LiDAR unit's angle correction file. The calibration file provides the elevation and azimuth of each channel's incident beam, relative to the center of the entrance pupil (shown as a yellow dot in Figure 1.6).

In case you need to obtain the file again:

- Send this PTC command *PTC_COMMAND_GET_LIDAR_CALIBRATION*, as described in Hesai TCP API Protocol (Chapter 5).
- Or export the file using PandarView, see the PandarView user manual.
- Or contact a sales representative or technical support engineer from Hesai.

1.4 Specifications

SENSOR	
Scanning Method	Mechanical Rotation
Channel	64
Instrument Range	0.1 to 60 m
Range Capability ①	0.1 to 20 m (at 10% reflectivity)
Range Accuracy ②	±3 cm (typical)
Range Precision ②	2 cm (typical)
FOV (Horizontal)	360°
Resolution (Horizontal)	0.6°
FOV (Vertical)	104.2° (-52.1° to +52.1°)
Resolution (Vertical)	Finest at 1.45°
Frame Rate	10 Hz
Returns	Single Return (First, Last)
	Dual Return (First & Last)

MECHANICAL/ELECTRICAL/OPERATIONAL		
Wavelength	885 nm	
Laser Class	Class 1 Eye Safe	
Ingress Protection	IP67 & IP69K	
Dimensions	Height:	76.0 mm
	Top/Bottom:	Φ80.2 mm
Rated Voltage Range	DC 12 to 48 V	
Power Consumption ③	8 W	
Operating Temperature	-20°C to 65°C	
Storage Temperature	-40°C to 85°C	
Weight	0.47 kg	

DATA I/O		
Data Transmission	UDP/IP Ethernet (Automotive 100BASE-T1)	
	Slave Mode	
Measurements	Distance, Azimuth Angle	
Data Points Generated	Single Return:	384,000 points/sec
	Dual Return:	768,000 points/sec
Point Cloud Data Rate	Single Return:	13.37 Mbps
	Dual Return:	26.74 Mbps
Clock Source	PTP	
PTP Clock Accuracy	≤1 μs (typical)	
PTP Clock Drift ④	≤1 μs/s	

Specifications are subject to change. Please refer to the latest version. (Continued on the next page)

(Continued)

① Range capability

- Test conditions: middle 48 channels (Channels 9~56) 100 klux ambient intensity, PoD > 90%.

② Range Accuracy and Range Precision

- May vary with range, temperature, and target reflectivity.
- Range accuracy: difference between the average of multiple measurements and the true value, measured under the same conditions.
- Range precision: standard deviation of multiple measurements, measured under the same conditions.

③ Power Consumption

- Not including accessories such as the connection box.

④ PTP Clock Drift

- Defined as the drift at a constant temperature after the LiDAR (slave clock) loses connection to the PTP master.

2 Setup

2.1 Mechanical Installation

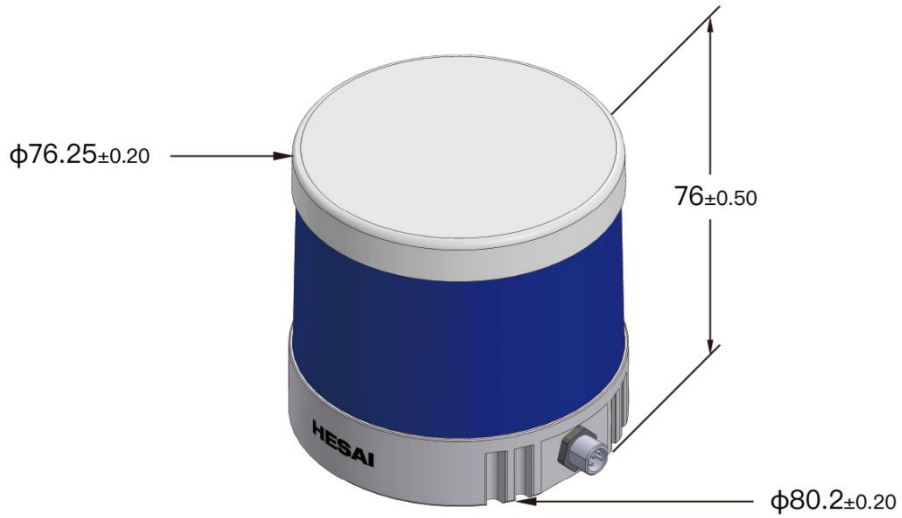


Figure 2.1 Isometric View (Unit: mm)

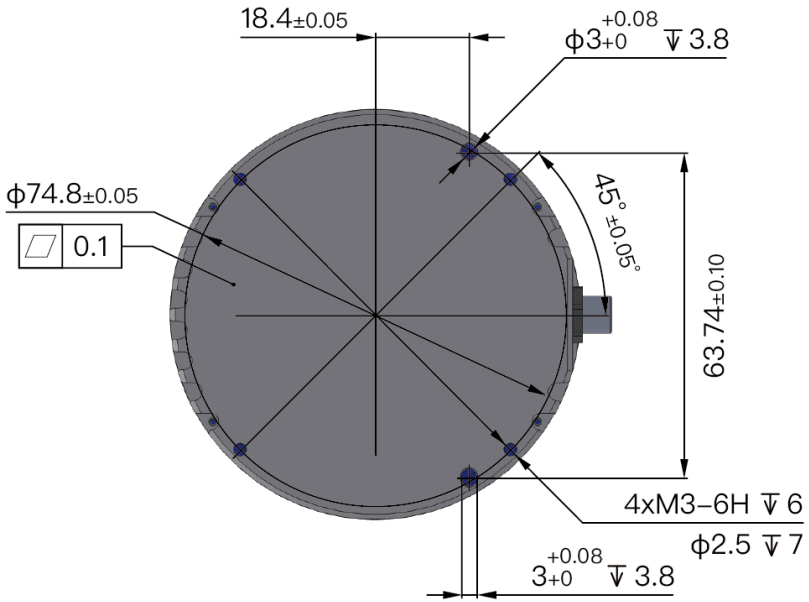


Figure 2.2 Mounting Base (Unit: mm)

■ Recommended Installation

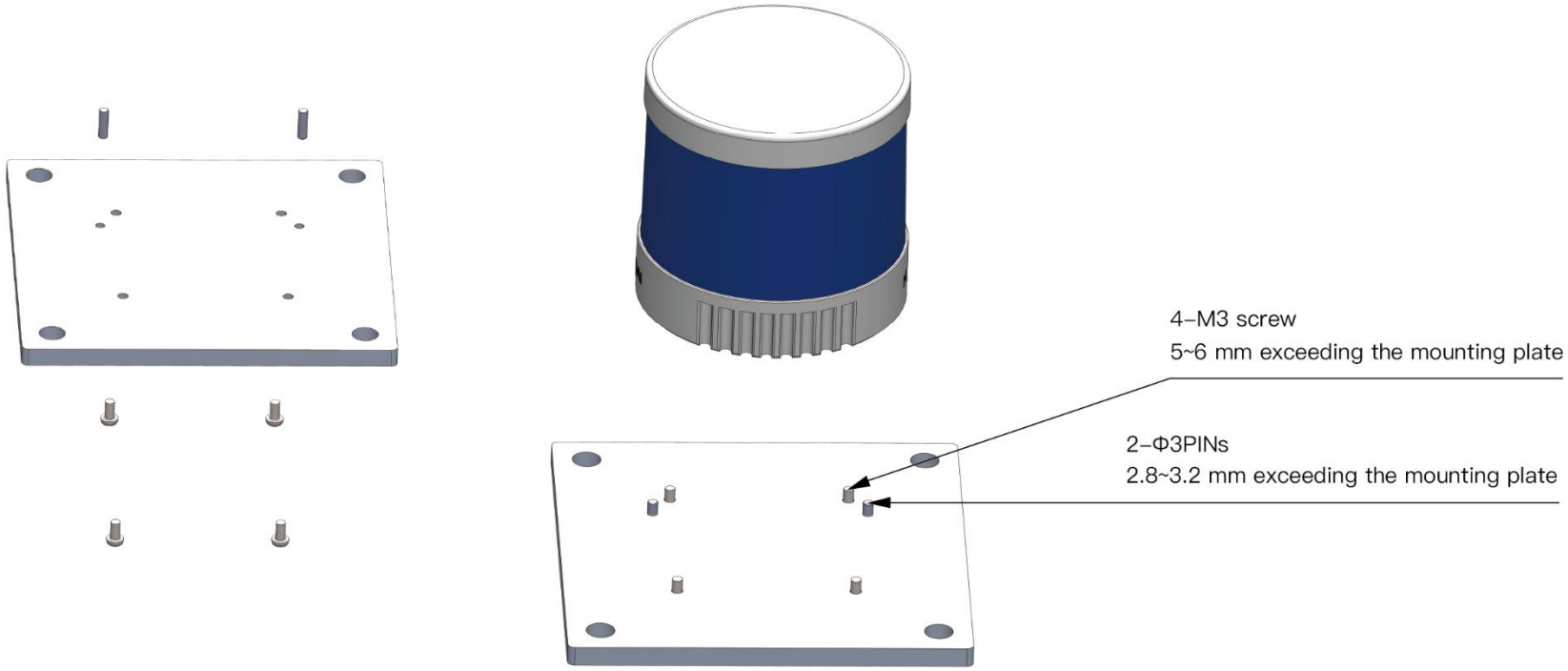


Figure 2.3 Recommended Installation

■ Side Installation

Figure 2.4 Side Installation

2.2 Interfaces

PandarQT uses a 4-pin M8 male socket (with pins inside), which includes power wires and a 100BASE-T1 twisted-pair.

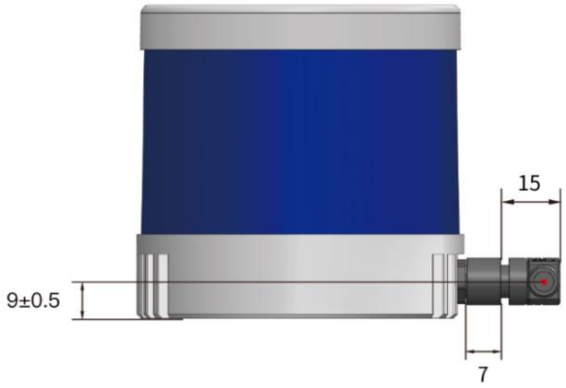


Figure 2.5 Connector Dimensions (Unit: mm)

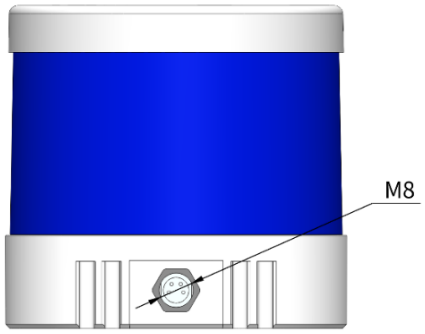


Figure 2.6 Connector

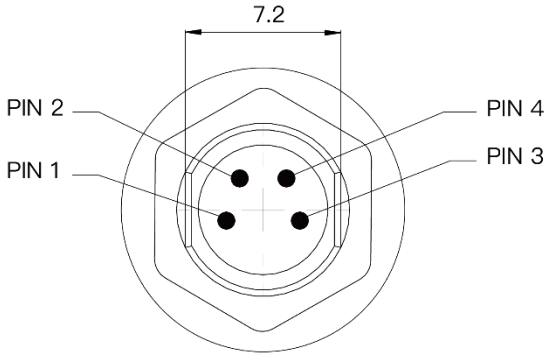


Figure 2.7 Connector Pinout (4-pin)

Pin definition is listed below:

Pin #	Signal	Voltage
1	VIN	12 to 48 V
2	GND	0 V
3	Ethernet_TRX+	-1 to 1 V
4	Ethernet_TRX-	-1 to 1 V

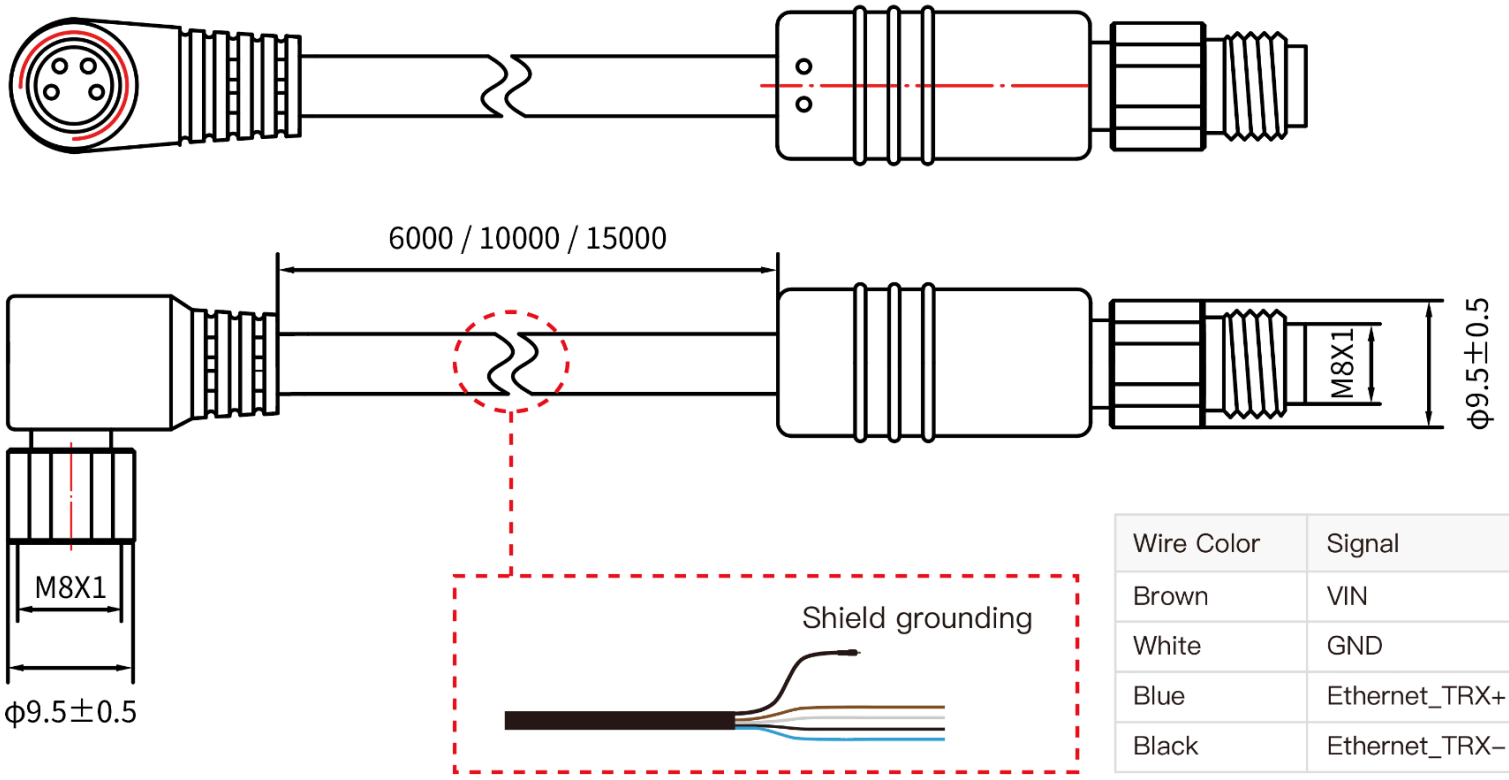
⚠ Please plug and unplug the connector with care. Do not pull, twist, or squeeze it with excessive force.

■ Extension Cable (Optional)

The default length is 6, 10, or 15 m.

Contact Hesai if you need customized cables for connecting the LiDARs to your control units directly.

Refer to Appendix IV (Power Supply Requirements) for wire gauge and cable length selection.



Wire Color	Signal
Brown	VIN
White	GND
Blue	Ethernet_TRX+
Black	Ethernet_TRX–

Figure 2.8 Extension Cable and Connector Size

2.3 Connection Box (Optional)

Users may connect the LiDAR directly or using the connection box.

The connection box converts automotive 100BASE-T1 to 100BASE-TX typical Ethernet, as well as providing a power port.

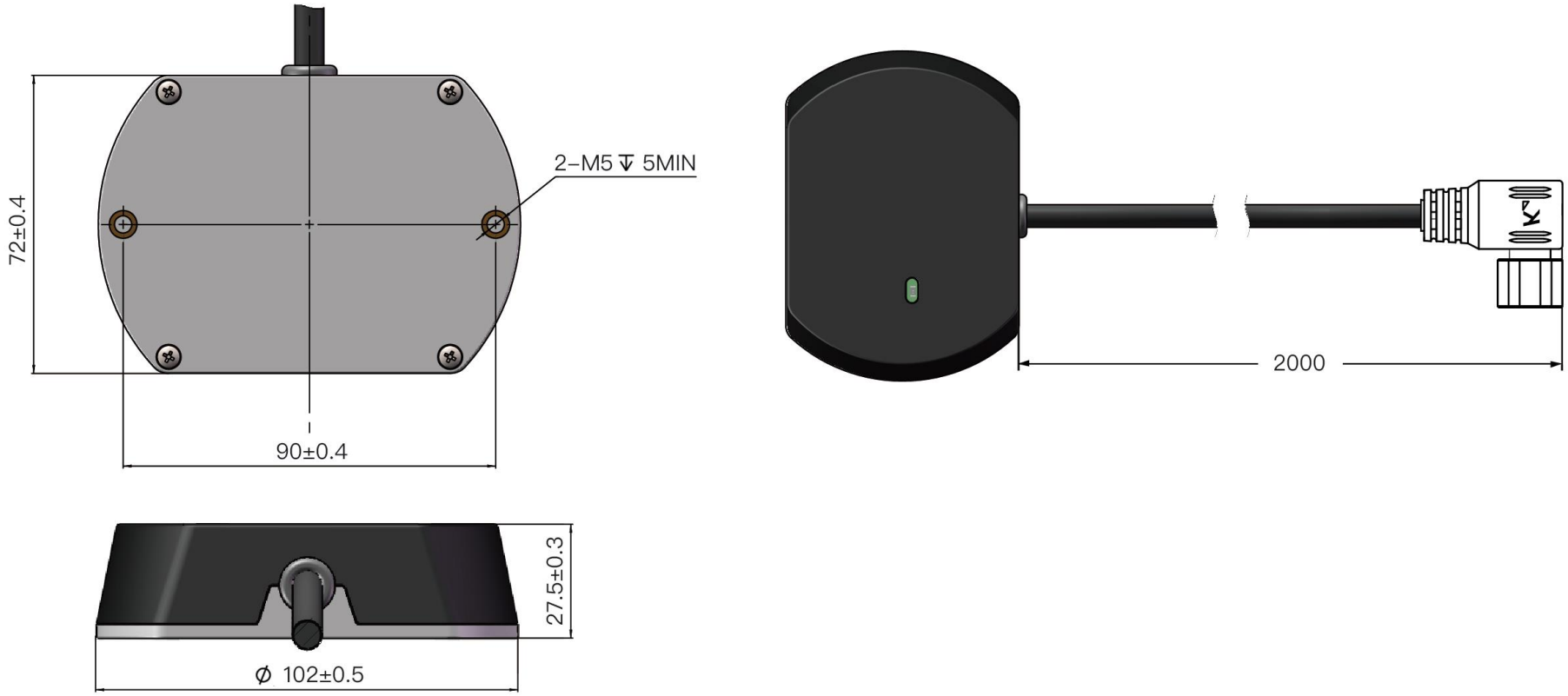


Figure 2.9 Connection Box - Connection (Unit: mm)

2.3.1 Connection Box Interfaces

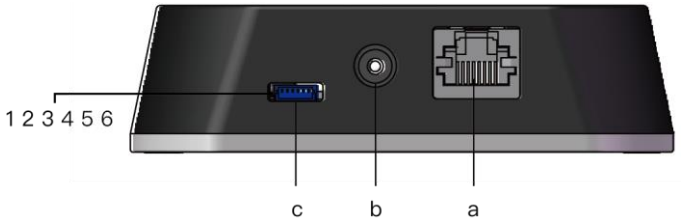


Figure 2.10 Connection Box (Front)

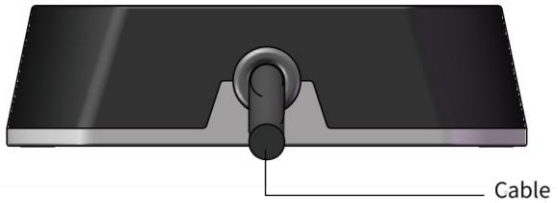


Figure 2.11 Connection Box (Back)

Port #	Port Name	Description
a	Standard Ethernet Port	RJ45, 100BASE-TX Ethernet
b	Power Port	Connects to a DC power adapter Connector part number: PJ-057AH External power supply: • 24 W at least • Rated input voltage: 12 to 48 V • Allowable input voltage: 9 to 55 V
c	Reserved	-

2.3.2 Connection

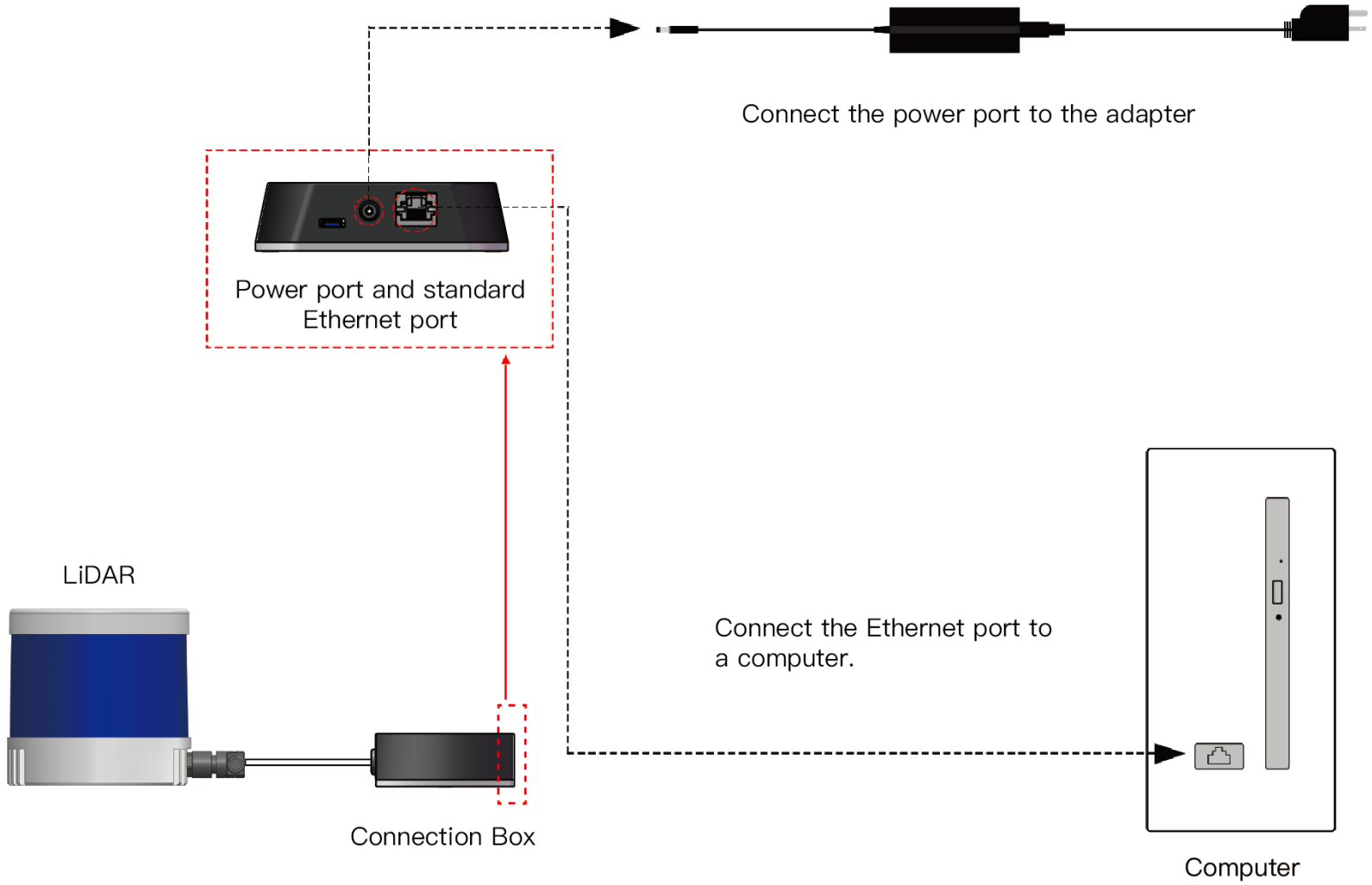


Figure 2.12 Connection Box – Connection

Refer to Appendix III when PTP protocol is used.

2.4 Get Ready to Use

Before operating the LiDAR, strip away the protective cover outside the cover lens.

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:	For Windows:
Input this ifconfig command in the terminal: ~$ sudo ifconfig enp0s20f0u2 192.168.1.100 (replace enp0s20f0u2 with the local Ethernet port name)	Open the Network Sharing Center, click on "Ethernet" In the "Ethernet Status" box, click on "Properties" Double-click on "Internet Protocol Version 4 (TCP/IPv4)" 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 PandarView User Manual.

To set parameters, check device info, or upgrade firmware/software, see Chapter 4 (Web Control)

To obtain the SDKs (Software Development Kits) for your product model,

- please find the download link at: www.hesaitech.com/en/download (Product Documentation → select product model)
- or visit Hesai's official GitHub page: https://github.com/HesaiTechnology

3 Data Structure

The LiDAR outputs Point Cloud Data Packets using 100BASE-T1 Automotive Ethernet UDP/IP.
Unless otherwise specified, all the multi-byte fields are unsigned values in little endian format.

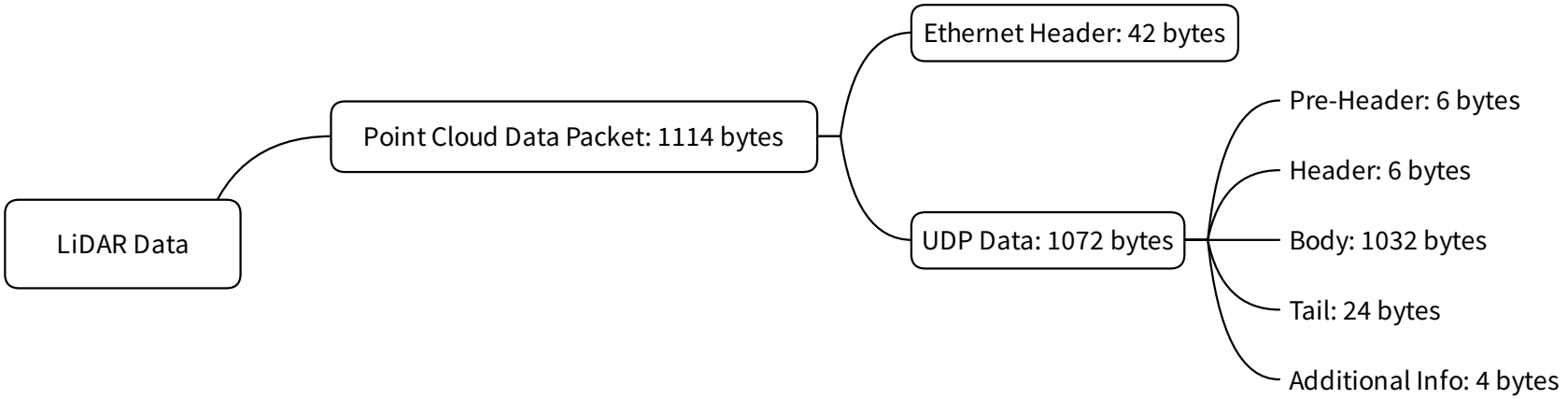


Figure 3.1 Data Structure

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, and the destination IP is 255.255.255.255 (broadcast).

Point Cloud Ethernet Header: 42 bytes		
Field	Bytes	Description
Ethernet II MAC	12	Destination: broadcast (0xFF: 0xFF: 0xFF: 0xFF: 0xFF: 0xFF) Source: (xx:xx:xx:xx:xx:xx)
Ethernet Data Packet Type	2	0x08, 0x00
Internet Protocol	20	Shown in the figure below
UDP Port Number	4	UDP source port (0x2710, representing 10000) Destination port (0x0940, representing 2368)
UDP Length	2	0x0438, representing 1080 bytes (8 bytes more than the size of the Point Cloud UDP Data, shown in Figure 3.1)
UDP Checksum	2	-

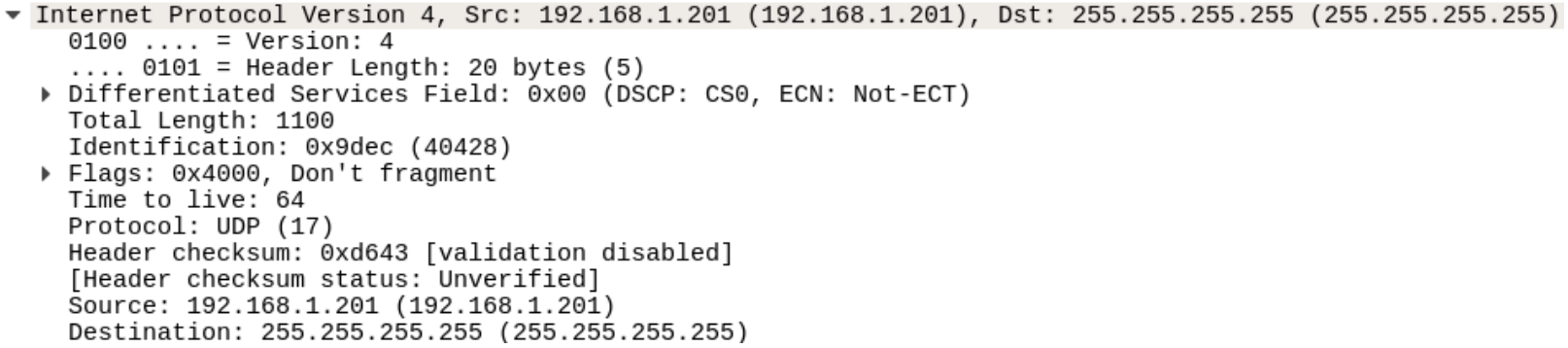


Figure 3.2 Point Cloud Ethernet Header - Internet Protocol

3.1.2 UDP Data

■ **Pre-Header: 6 bytes**

Field	Bytes	Description
0xEE	1	SOP (start of packet)
0xFF	1	SOP (start of packet)
Protocol Version Major	1	To distinguish between product models Currently 0x03
Protocol Version Minor	1	For each product model, to indicate the current protocol version Currently 0x01
Reserved	2	-

■ **Header: 6 bytes**

Field	Bytes	Description
Laser Num	1	0x40 (64 channels)
Block Num	1	0x04 (4 blocks per packet)
First Block Return	1	Reserved
Dis Unit	1	0x04 (4 mm)
Return Number	1	Number of returns that each channel generates 0x01 - one return 0x02 - two returns
UDP Seq	1	[7:1] is reserved Least significant bit [0] shows whether this packet includes a UDP sequence number field 1 - UDP sequence ON

■ **Body: 1032 byte**

Field	Bytes	Description
Azimuth 1	2	For Block 1: current reference angle of the rotor azimuth angle in degrees = Azimuth / 100
Block 1	256	For Block 1: measurements made by Channels 1 to 64, see table below
Azimuth 2	2	For Block 2
Block 2	256	For Block 2
Azimuth 3	2	For Block 3
Block 3	256	For Block 3
Azimuth 4	2	For Block 4
Block 4	256	For Block 4

Under the Dual Return mode, the measurements from each round of firing are stored in two adjacent blocks.

- The odd number block is the first return, and the even number block is the last return.
- The azimuth changes every two blocks.

Each Block in the Body: 4 * 64 = 256 bytes			
Field	Bytes	Description	
Channel X	4	2-byte Distance	Distance Value = Distance * Dis Unit (See "Header" in this section)
		1-byte Reflectivity	Reflectivity Value = Reflectivity * 1% Range: 0 to 255 This field is not yet supported.
		1-byte Reserved	-

■ **Tail: 24 bytes**

<table>
<tr><th>Field</th><th>Bytes</th><th>Description</th></tr>
<tr><td>Reserved</td><td>10</td><td>-</td></tr>
<tr><td>Motor Speed</td><td>2</td><td>Unit: RPM</td></tr>
<tr><td>Timestamp</td><td>4</td><td>The "µs time" part of the absolute time of this data packet (defined in Appendix II)
Unit: µs
Range: 0 to 1000000 µs (1 s)</td></tr>
<tr><td>Return Mode</td><td>1</td><td>0x33 for the First Return mode
0x38 for the Last Return mode
0x3B for the Dual Return mode (first & last)</td></tr>
<tr><td>Factory Information</td><td>1</td><td>0x42</td></tr>
<tr><td>Date & Time</td><td>6</td><td>The absolute UTC time of this data packet, accurate to the second.

<table><tr><th>Each Byte</th><th>Range</th></tr><tr><td>Year (current year minus 1900)</td><td>Positive integers</td></tr><tr><td>Month</td><td>1 to 12</td></tr><tr><td>Day</td><td>1 to 31</td></tr><tr><td>Hour</td><td>0 to 23</td></tr><tr><td>Minute</td><td>0 to 59</td></tr><tr><td>Second</td><td>0 to 59</td></tr></table></td></tr>
</table>

■ **Additional Info: 4 bytes**

Field	Bytes	Description
UDP Sequence	4	Sequence number of this UDP packet 0 to 0xFF FF FF FF

3.1.3 Point Cloud Data Analysis

The analysis of point cloud UDP data consists of three steps.

■ **Analyze the vertical angle, horizontal angle, and distance of a data point**

Take Channel 5 in Block 2 as an example:

1) Vertical angle of Channel 5 is -43.848°, according to Appendix I (Channel Distribution)

The accurate vertical angle is recorded in this LiDAR's unit's angle correction file, see Section 1.3 (Channel Distribution).

- 0° represents the horizontal direction
- Define upward as positive
- The Channel # from the bottommost starts from 1

2) Horizontal angle = current reference angle of the rotor + horizontal angle offset + firing time angular offset

- Current reference angle of the rotor: Azimuth field of Block 2
- Horizontal angle offset: 7.388° for Channel 5, according to Appendix I (Channel Distribution)

The accurate horizontal angle offset is recorded in this LiDAR's unit's angle correction file, see Section 1.3 (Channel Distribution).

- Firing time angular offset = Firing Time Offset of Channel 5 (see Appendix II) * Spin Rate of the Motor (see Section 4.1 Web Control - Home)
- Define clockwise in the top view as the horizontal angles' positive direction

3) Actual distance in real world millimeters = distance measurement * Distance Unit (4 mm)

Distance measurement is the Distance field of Channel 5 in Block 2

(Continued on the next page)

(Continued)

- **Draw the data point in a spherical or rectangular coordinate system**
- **Obtain the real-time point cloud data by analyzing and drawing every data point in each frame**

4 Web Control

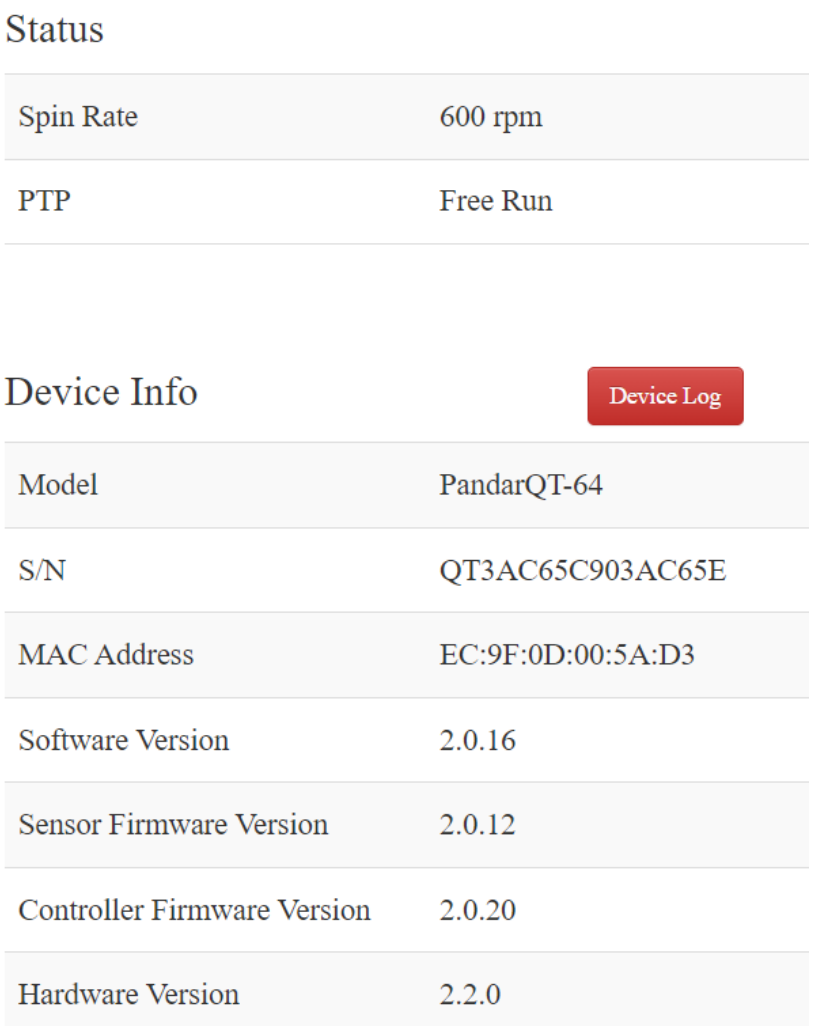
Web control is used for setting parameters, checking device info, and upgrading.

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

Google Chrome and Mozilla Firefox are recommended.

4.1 Home



This screenshot may not display the most current version numbers. See Section 4.5 (Upgrade).

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

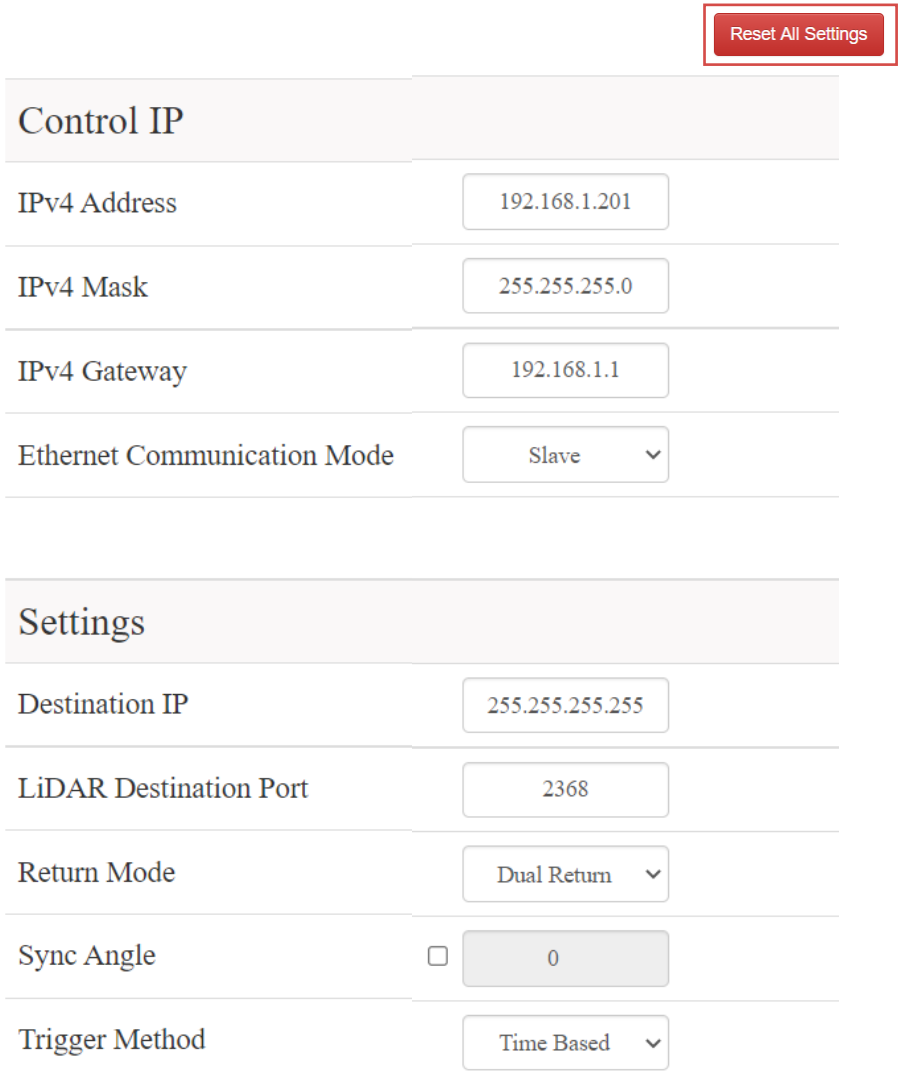
PTP Status

Free Run	No PTP master is selected
Tracking	Slave is trying to sync with the selected PTP Master, but the absolute offset exceeds the user-specified limit in Section 4.2 (Settings)
Locked	Absolute offset between Slave and Master is within the user-specified limit
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.

Device Log

Click to download a .JSON file containing the LiDAR's status, device info, all configurable parameters, and upgrade log.

4.2 Settings



In the Settings page

- Standby Mode: effective immediately
- All other settings: effective after clicking the "Save" button at the bottom

1. Reset All Settings

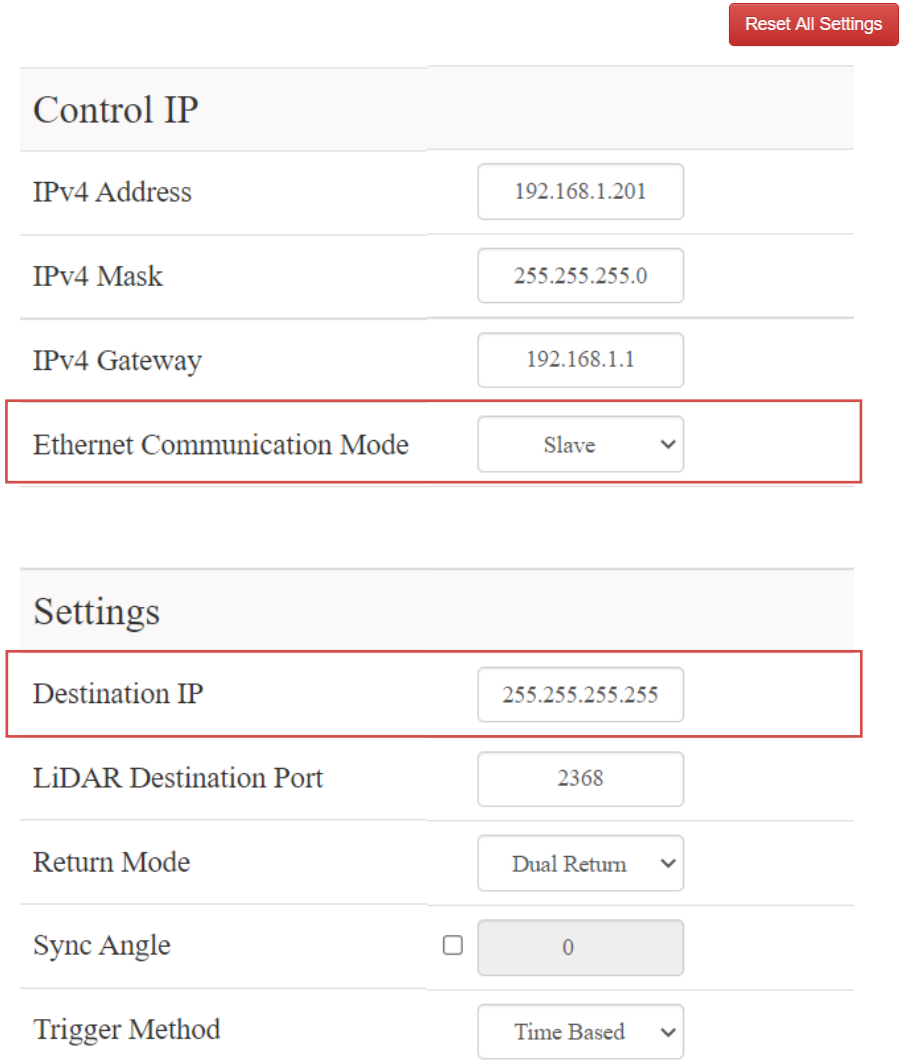
By clicking the "Reset All Settings" button on the top-right corner, all configurable parameters on web control will be reset to factory defaults.

The default values are shown in the screenshots in

- Section 4.2 (Settings)
- Section 4.3.1 (Azimuth FOV - for All Channels)

(continued on the next page)

(continued)



(continued on the next page)

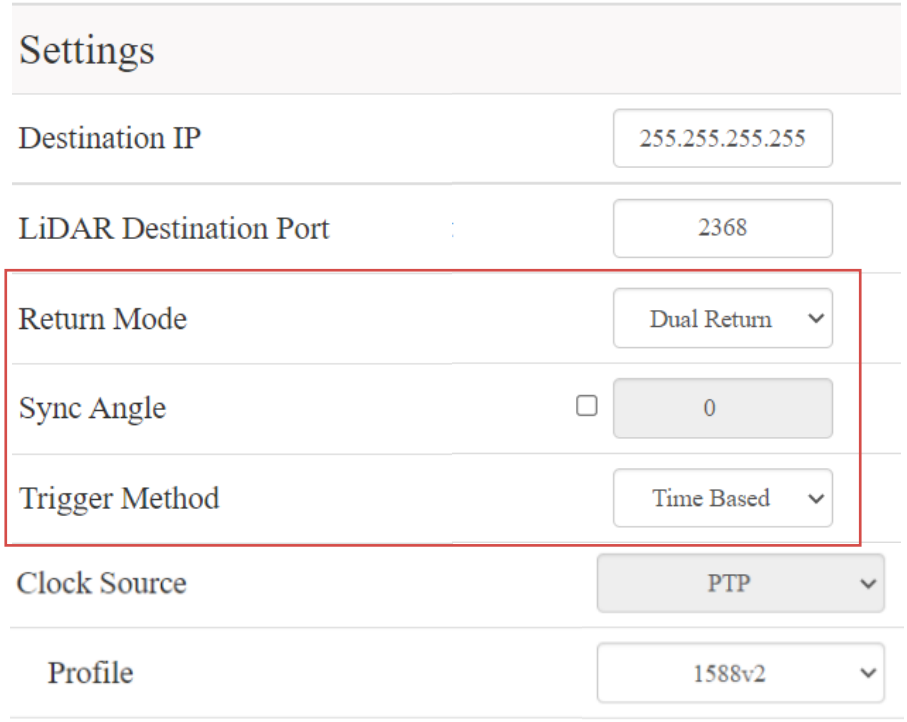
2. Control IP

Ethernet Comm. Mode	Slave / Master **Slave mode (default)**: • The receiving host should be in Master mode. • Connect the LiDAR directly or use a connection box. **Master mode**: • Connect the LiDAR to a Master host, select "Master" and click "Save" at the page bottom. • Connection to web control will be lost. Then connect the LiDAR directly to a Slave host. • Connection box is not supported.

3. Settings：Destination IP

Mode	Destination IP
Broadcast	255.255.255.255
Subnet broadcast	x.x.x.255 (reaching x.x.x.1 to x.x.x.254)
Multicast	User-defined
Unicast	Same as the PC's IP address

(continued)



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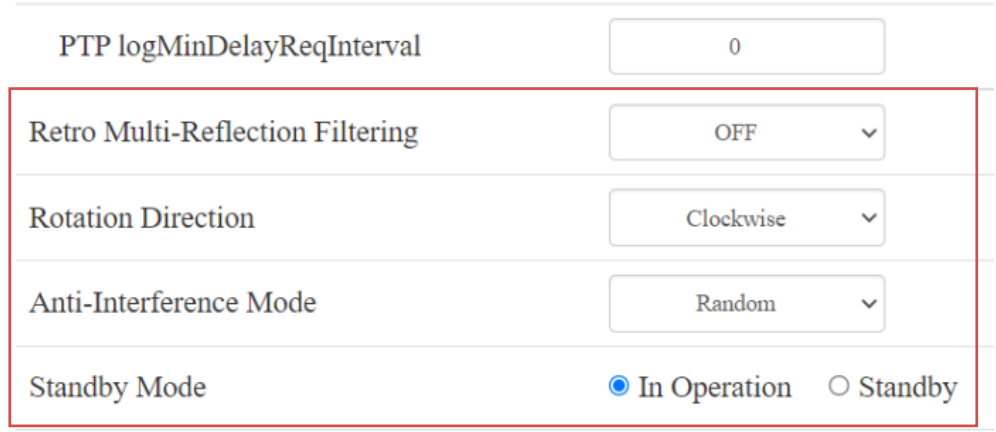
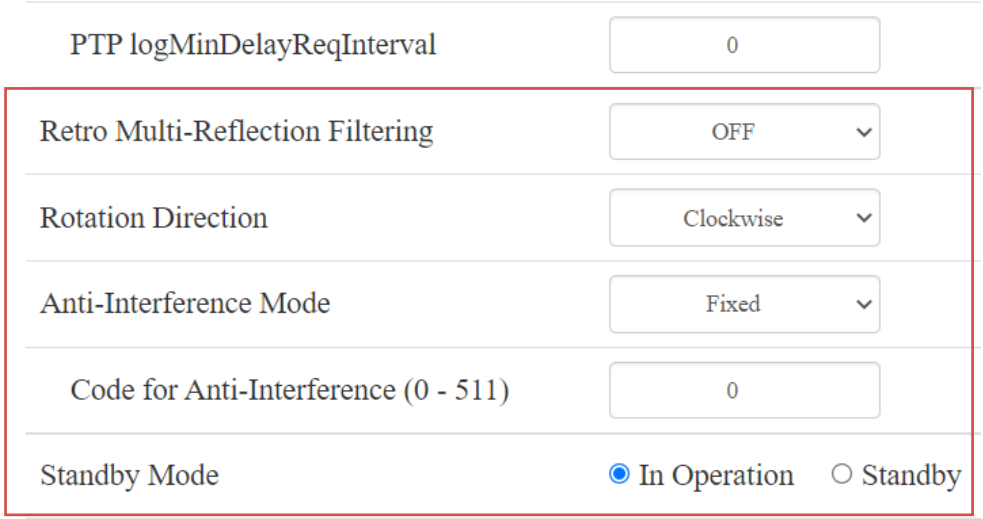
4. LiDAR Functions

Return Mode	Dual (default) / First / Last Return
Sync Angle	0~360 degrees
	By default, the LiDAR's 0° position (see Section 1.2) is not in sync with the whole second of the PTP clock. If syncing is needed, check the check box and input a sync angle.
Trigger Method	Angle-Based / Time-Based
	Angle-based: lasers fire every 0.6° at 10 Hz Time-based: lasers fire every 166.66 us

(continued)

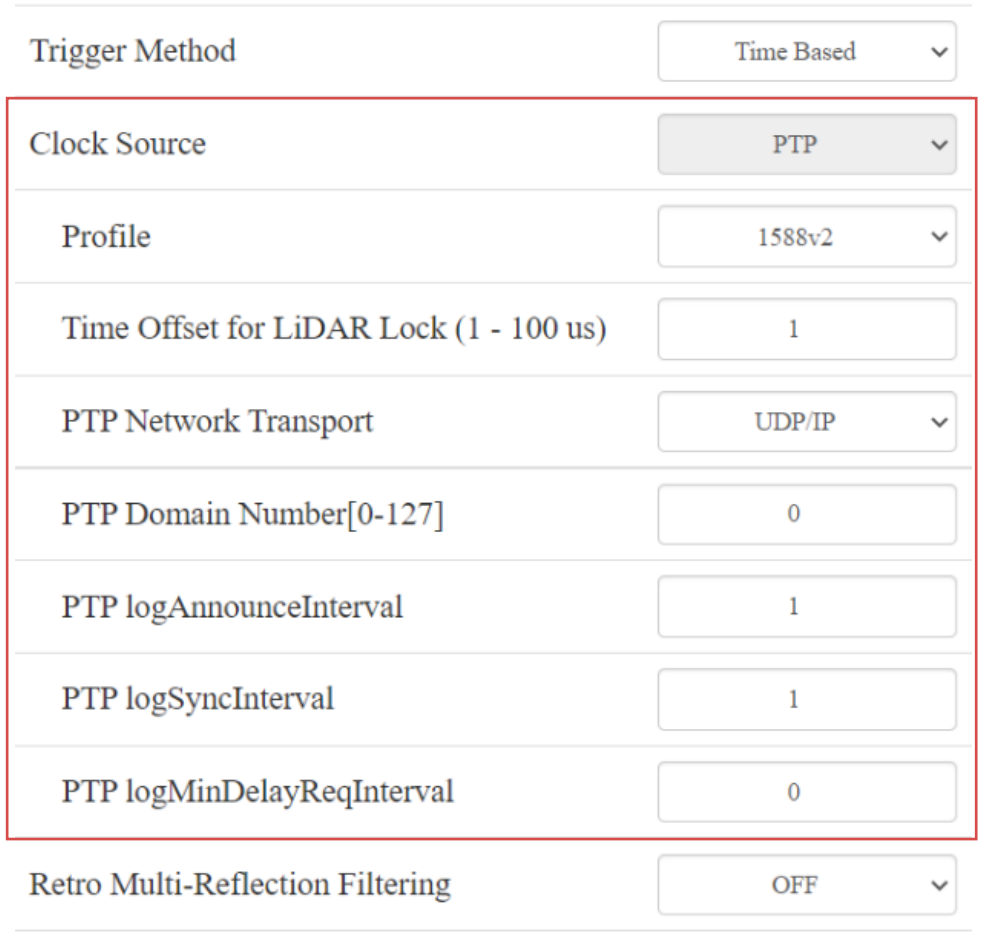




Retro Multi-Reflection Filtering	To mitigate the false positive points at twice the distance of a retroflector.
Rotation Direction	Clockwise / Counterclockwise
	After selecting Counterclockwise, refresh the webpage to check that the settings have taken effect. If the page after refreshing still shows Clockwise, refresh the page again and check.
Anti-Interference Mode	Random / Fixed
	To minimize the interference between LiDARs. **Random Mode**: For each firing, an anti-interference code is randomly assigned. **Fixed Mode**: Users specify an anti-interference code for this LiDAR unit. Make sure to use different codes for nearby LiDARs.
Standby Mode	In Operation / Standby
	In Standby mode, the motor stops running and lasers stop firing.

5. Clock Source and PTP Parameters

Clock Source	PTP
	Detailed in Appendix III (PTP Protocol)



- When PTP is selected as the clock source:

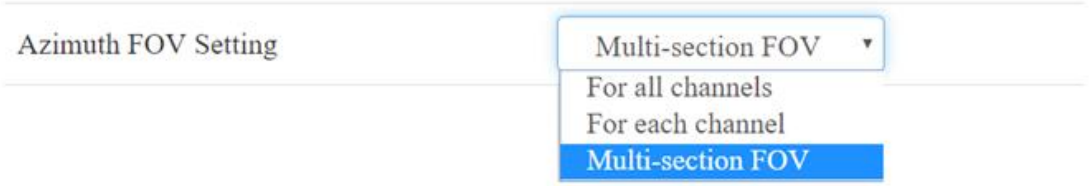
Profile	1588v2 (default) / 802.1AS
	IEEE timing and synchronization standard
Time Offset for LiDAR Lock	1 to 100 μs (integer)
	Specify the upper limit of the absolute offset between Slave and Master when the LiDAR is in PTP Locked status. See Section 4.1 (Home)
PTP Network Transport	UDP/IP (default) or L2
	1588v2: users can select UDP/IP or L2 **802.1AS and 802.1AS Automotive**: only supports L2 network
PTP Domain Number	Integer from 0 to 127
	Domain attribute of the local clock

- When using the 1588v2 profile:

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)

4.3 Azimuth FOV

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



4.3.1 For all channels

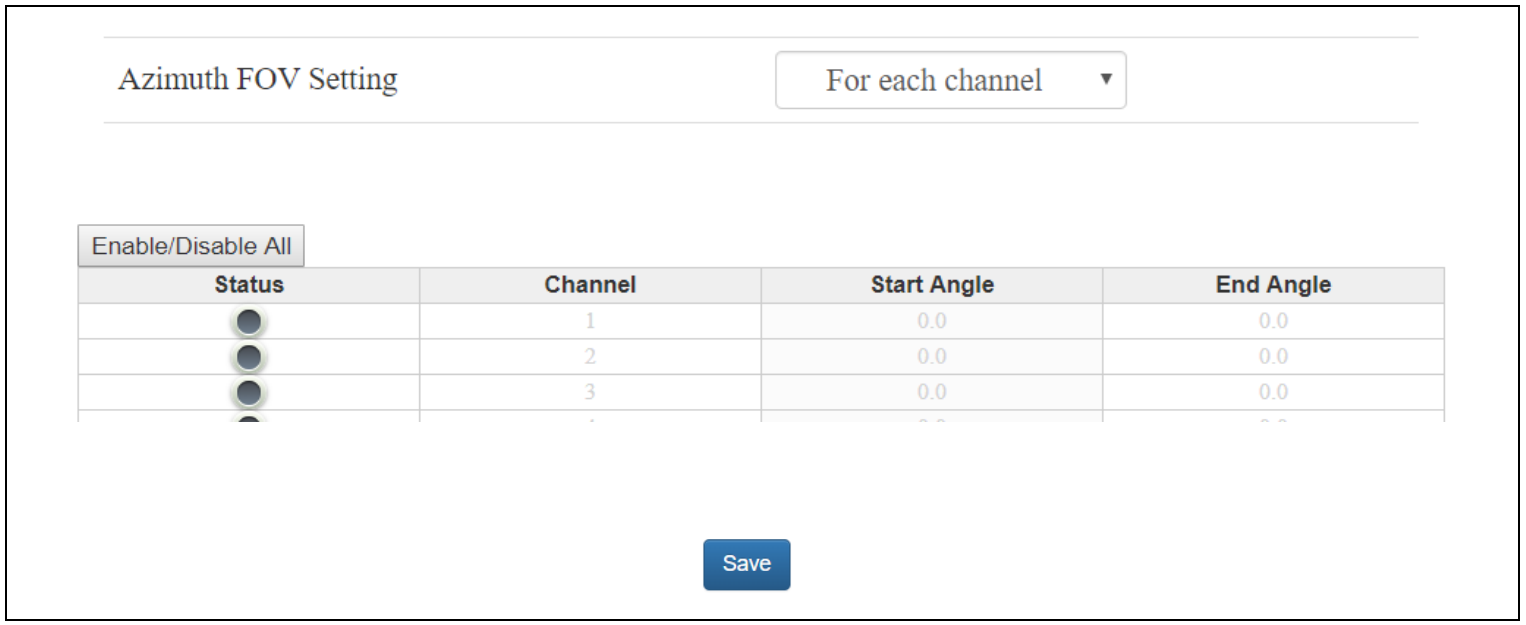
A continuous angle range, specified by a Start Angle and an End Angle, will be applied to all channels.
The LiDAR outputs valid data only within the specified range.

4.3.2 For each channel

Users can configure one continuous angle range for each channel.
Each channel outputs valid data only within its specified range.

The "Status" button for each channel is gray by default, indicating that the channel does not output valid data.
To activate the angle range configuration for each channel, click the corresponding button to make it green.

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

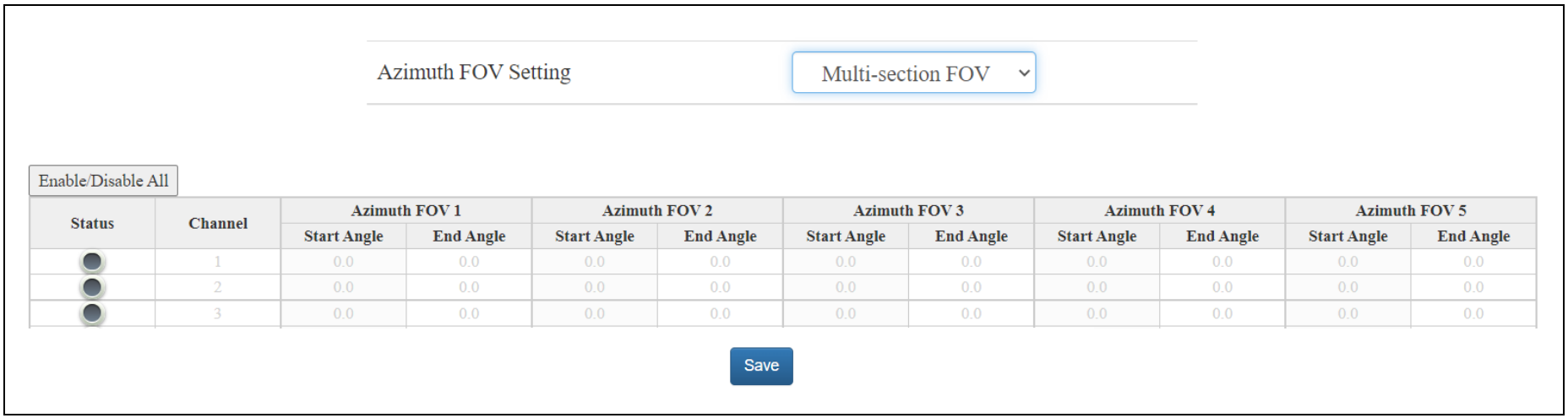


4.3.3 Multi-section FOV

Users can configure up to five continuous angle ranges (i.e. sections) for each channel.
Each channel outputs valid data only within its specified ranges.

The "Status" button for each channel is gray by default, indicating that the channel does not output valid data.
To activate the angle range configuration for each channel, click the corresponding button to make it green.

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



4.3.4 Note

- Click "Save" to apply your settings.
- The angles in degrees are accurate to the first decimal place.
- If the Start Angle is larger than the End Angle, then the actual azimuth FOV is the union of [Start Angle, 360°] and [0°, End Angle].

For instance, when the angle range is set to be [270°, 90°], the actual azimuth FOV is [270°, 360°]∪[0°, 90°].

4.4 Operation Statistics

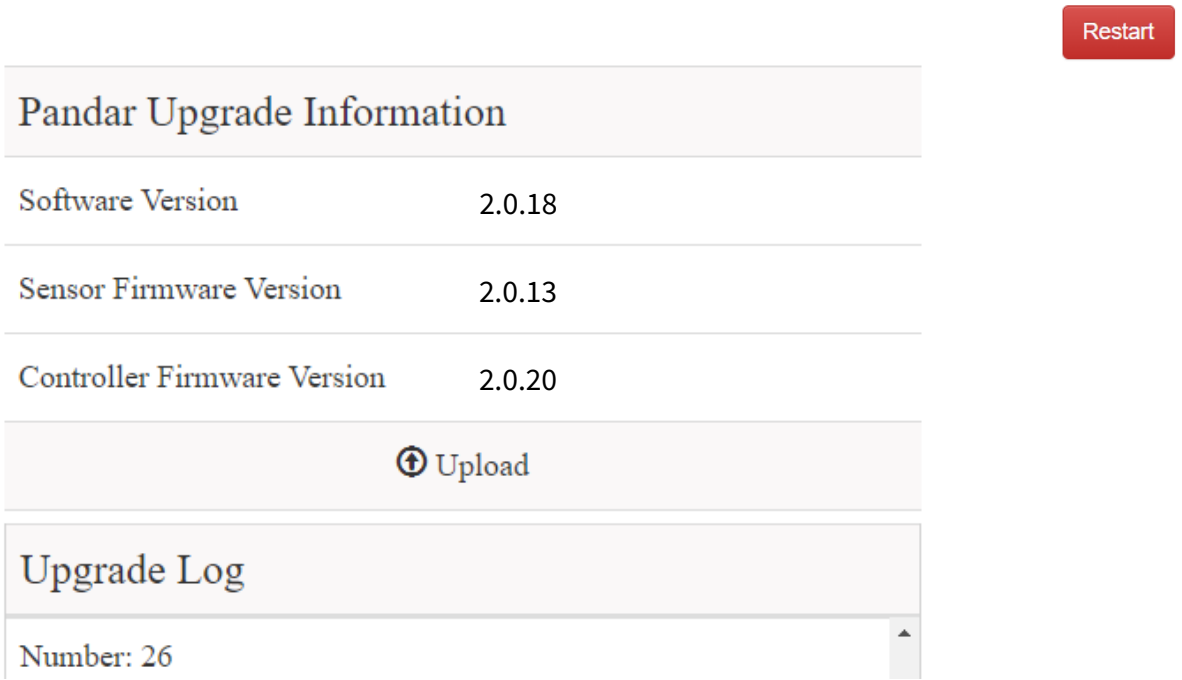
The LiDAR's operation time in aggregate and in different temperature ranges are listed, as well as the internal temperature.

Start-Up Counts	663
Internal Temperature	55.02°C
System Uptime	0 h 2 min
Total Operation Time	78 h 7 min

Internal Temperature	Operation Time
< -40 °C	0 h 0 min
-40 to -20 °C	0 h 0 min
-20 to 0 °C	0 h 44 min
0 to 20 °C	3 h 17 min
20 to 40 °C	10 h 18 min
40 to 60 °C	58 h 27 min
60 to 80 °C	4 h 29 min
80 to 100 °C	0 h 52 min
100 to 120 °C	0 h 0 min
>120 °C	0 h 0 min

4.5 Upgrade

The software and firmware versions described in this manual are shown in the picture below.
During the upgrade, it is recommended to place a protective leather cover (supplied with the LiDAR) or other opaque material over the LiDAR's cover lens.
Click the "Upload" button, select an upgrade file (provided by Hesai), and confirm your choice in the pop-up window.
When the upgrade is complete, the LiDAR will automatically reboot, and the past versions will be logged in the Upgrade Log.



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.

Notes

- Only support three-in-one upgrade files that contain:
  - Software
  - Controller Firmware
  - Sensor Firmware
- When upgrading, power supply must remain on.

5 Communication Protocol

To receive Hesai LiDAR's PTC (Pandar TCP Commands) and HTTP API Protocols, please contact Hesai technical support.

6 Sensor Maintenance

■ Cleaning

Stains on the product's cover lens, such as dirt, fingerprints, and oil, can negatively affect point cloud data quality.
Please perform the following steps to remove the stains.

⚠ Warnings

- Turn OFF the power source before cleaning.
- To avoid damaging the optical coating, do NOT apply pressure when wiping the cover lens.

Notes

- Only clean the stained area of the cover lens.
- Check before using a lint-free wipe. If the wipe is stained, use another.

1) Thoroughly wash your hands or wear a pair of powder-free PVC gloves.
2) To remove dust, blow dry air onto the cover lens, or use a piece of lint-free wipe to lightly brush across the dusty area.

To remove persistent stains, move on to the next step.

3) Spray the cover lens with warm, neutral solvent using a spray bottle.

Solvent type	99% isopropyl alcohol (IPA) or 99% ethanol (absolute alcohol) or distilled water ⚠ When using IPA or alcohol, please ensure adequate ventilation and keep away from fire.
Solvent temperature	20 to 25°C

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4) When the stains have loosened, dip a piece of lint-free wipe into the solvent made in Step 3, and gently wipe the cover lens back and forth along its curved surface.

5) Should another cleaning agent be applied to remove certain stains, repeat Steps 3 and 4.

6) Spray the cover lens with clean water, and gently wipe off the remaining liquid with another piece of lint-free wipe.

7 Troubleshooting

In case the following procedures cannot solve the problem, please contact Hesai technical support.

Symptoms	Points to Check
Indicator light is off on the connection box	Verify that ・ power adapter is properly connected and in good condition ・ connection box is intact ・ input voltage and current satisfy the requirements in Section 2.3 (Connection Box) Power on again to check if the symptom persists.
Motor is not running	Verify that ・ power adapter is properly connected and in good condition ・ if a connection box is used, the connection box is intact ・ input voltage and current satisfy the requirements in Section 1.4 (Specifications) and 2.3 (Connection Box) ・ web control can be accessed (see "cannot open web control" on the next page) Power on again to check if the symptom persists.
Motor is running but no output data is received, neither on Wireshark nor on PandarView	Verify that ・ Ethernet cable is properly connected (by unplugging and plugging again) ・ LiDAR's Destination IP is correctly set on the Settings page of web control ・ horizontal FOV is properly set on the Azimuth FOV page of web control ・ firmware version of the sensor is correctly shown on the Upgrade page of web control ・ LiDAR is emitting laser light. This can be checked by using an infrared camera, an infrared sensor card, or a phone camera without infrared filter Power on again to check if the symptom persists.

(Continued on the next page)

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Symptoms	Points to Check
Can receive data on Wireshark but not on PandarView	Verify that ・ LiDAR Destination Port is correctly set on the Settings page of web control ・ PC's firewall is disabled, or that PandarView is added to the firewall exceptions ・ the latest PandarView version (see the Download page of Hesai's official website) is installed on the PC Power on again to check if the symptom persists.
Cannot open web control	Verify that ・ Ethernet cable is properly connected (by unplugging and plugging again) ・ LiDAR's IP is in the same subnet with the PC's. Users may use WireShark to check the LiDAR's IP that broadcasts data packets Afterwards, ・ restart PC, or connect the LiDAR to another PC ・ power on again to check if the symptom persists
Abnormal packet size (missing packets)	Verify that ・ horizontal FOV is properly set on the Azimuth FOV page of web control ・ motor's spin rate is steady on the Home page of web control ・ LiDAR's internal temperature is between -20°C and 95°C on the Operation Statistics page of web control ・ Ethernet is not overloaded ・ no switch is connected into the network. The data transmitted from other devices may cause network congestion and packet loss Afterwards, ・ connect the PC only to the LiDAR and check for packet loss ・ power on again to check if the symptom persists

(Continued on the next page)

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Symptoms	Points to Check
Abnormal point cloud (obviously misaligned points, flashing points, or incomplete FOV)	Verify that ・ LiDAR's cover lens is clean. If not, refer to Chapter 6 (Sensor Maintenance) for the cleaning method ・ LiDAR's calibration file is imported, see *PandarView User Manual* (Use) ・ horizontal FOV is properly set on the Azimuth FOV page of web control ・ motor's spin rate is steady on the Home page of web control ・ LiDAR's internal temperature is between -20°C and 95°C on the Operation Statistics page of web control Afterwards, check for packet loss ・ If no packet is missing while the point cloud flashes, please update PandarView to the latest version (see the Download page of Hesai's official website) and restart the PC If the point cloud is still abnormal ・ Try connecting the LiDAR to another PC ・ Power on again to check if the symptom persists
GPS cannot be locked	Verify that ・ GPS receiver is properly connected ・ PPS signal is connected to the LiDAR ・ Destination GPS Port is correct on the Settings page of web control ・ input GPS signals satisfy the electrical requirements in Section 2.2 (Interface) and Section 2.3.1 (Connection Box) Power on again to check if the symptom persists

Appendix I　Channel Distribution

The Horizontal Angle (Azimuth) Offsets and Vertical Angles (Elevation) in the table next page are design values.
The accurate values are in this LiDAR's unit's angle correction file, see Section 1.3 (Channel Distribution) and Section 3.1.3 (Point Cloud Data Analysis).

Channel Distribution (To Be Continued)

Channel # in UDP Data	Horizontal Angle (Azimuth) Offset	Vertical Angle (Elevation)
01 (Bottom)	8.736°	-52.121°
02	8.314°	-49.785°
03	7.964°	-47.577°
04	7.669°	-45.477°
05	7.417°	-43.465°
06	7.198°	-41.528°
07	7.007°	-39.653°
08	6.838°	-37.831°
09	6.688°	-36.055°
10	6.554°	-34.32°
11	6.434°	-32.619°
12	6.326°	-30.95°
13	6.228°	-29.308°
14	6.14°	-27.69°
15	6.059°	-26.094°
16	5.987°	-24.517°
17	-5.27°	-22.964°
18	-5.216°	-21.42°
19	-5.167°	-19.889°
20	-5.123°	-18.372°

Channel # in UDP Data	Horizontal Angle (Azimuth) Offset	Vertical Angle (Elevation)
21	-5.083°	-16.865°
22	-5.047°	-15.368°
23	-5.016°	-13.88°
24	-4.988°	-12.399°
25	-4.963°	-10.925°
26	-4.942°	-9.457°
27	-4.924°	-7.994°
28	-4.91°	-6.535°
29	-4.898°	-5.079°
30	-4.889°	-3.626°
31	-4.884°	-2.175°
32	-4.881°	-0.725°
33	5.493°	0.725°
34	5.496°	2.175°
35	5.502°	3.626°
36	5.512°	5.079°
37	5.525°	6.534°
38	5.541°	7.993°
39	5.561°	9.456°
40	5.584°	10.923°

Channel Distribution (Continued)

Channel # in UDP Data	Horizontal Angle (Azimuth) Offset	Vertical Angle (Elevation)
41	5.611°	12.397°
42	5.642°	13.877°
43	5.676°	15.365°
44	5.716°	16.861°
45	5.759°	18.368°
46	5.808°	19.885°
47	5.862°	21.415°
48	5.921°	22.959°
49	-5.33°	24.524°
50	-5.396°	26.101°
51	-5.469°	27.697°
52	-5.55°	29.315°
53	-5.64°	30.957°
54	-5.74°	32.627°
55	-5.85°	34.328°
56	-5.974°	36.064°
57	-6.113°	37.84°
58	-6.269°	39.662°
59	-6.447°	41.537°
60	-6.651°	43.475°

Channel # in UDP Data	Horizontal Angle (Azimuth) Offset	Vertical Angle (Elevation)
61	-6.887°	45.487°
62	-7.163°	47.587°
63	-7.493°	49.795°
64 (Top)	-7.892°	52.133°

Appendix II Absolute Time and Laser Firing Time

■ Absolute Time of Point Cloud Data Packets

The Body of each Point Cloud Data Packet contains 4 data blocks, detailed in Section 3.1.2 (Point Cloud UDP Data).

Single Return Mode

The measurements from one round of firing are stored in one block.

The absolute time of a Point Cloud Data Packet is the time when the LiDAR sends a command to trigger a round of firing that will be stored in Block 1.

Dual Return Mode

The measurements from one round of firing are stored in two adjacent blocks (Blocks 1 and 2, or Blocks 3 and 4).

The absolute time of a Point Cloud Data Packet is the time when the LiDAR sends a command to trigger a round of firing that will be stored in Blocks 1 and 2.

Calculation

The absolute time of a Point Cloud Data Packet is the sum of date, time (accurate to the second) and μs time.

- Date and Time can be retrieved from the current Point Cloud Data Packet (6 bytes of Date & Time)
- μs time can be retrieved from the current Point Cloud Data Packet (4 bytes of Timestamp)

■ Start Time of Each Block

Assuming that the absolute time of a Point Cloud Data Packet is t0, the start time of each block (the time when the first firing starts) can be calculated.

Single Return Mode

Block	Start Time (μs)
Block 1	t0 + 25.71
Block 2	t0 + 25.71 + 166.67
Block 3	t0 + 25.71 + 333.33
Block 4	t0 + 25.71 + 500.00

Dual Return Mode

Block	Start Time (μs)
Block 1 & Block 2	t0 + 25.71
Block 3 & Block 4	t0 + 25.71 + 166.67

■ Firing Time Offset of Each Channel

Assume that the start time of Block m is T(m), $m \in \{1, 2, 3, 4\}$, then the laser firing time of Channel n in Block m is

$$t(m, n) = T(m) + \Delta t + \Delta t(n), n \in \{1, 2, \cdots, 64\}.$$

The timing uncertainty $\Delta t \leqslant 10$ μs.

The lookup table of the firing time offsets $\Delta t(n)$ is on the next page.

Δt(n)—Firing Time Offset of Each Channel (Unit: μs)

(Continued on the Next Page)

Firing Sequence	Channel #	Δt(n)
1	1	2.31
2	2	4.37
3	3	6.43
4	4	8.49
5	5	10.54
6	6	12.60
7	7	14.66
8	8	16.71
9	9	19.16
10	10	21.22
11	11	23.28
12	12	25.34
13	13	27.39
14	14	29.45
15	15	31.50
16	16	33.56
17	17	36.61
18	18	38.67
19	19	40.73
20	20	42.78

Firing Sequence	Channel #	Δt(n)
21	21	44.84
22	22	46.90
23	23	48.95
24	24	51.01
25	25	53.45
26	26	55.52
27	27	57.58
28	28	59.63
29	29	61.69
30	30	63.74
31	31	65.80
32	32	67.86
33	33	70.90
34	34	72.97
35	35	75.02
36	36	77.08
37	37	79.14
38	38	81.19
39	39	83.25
40	40	85.30

Δt(n)—Firing Time Offset of Each Channel (Unit: μs)
(Continued)

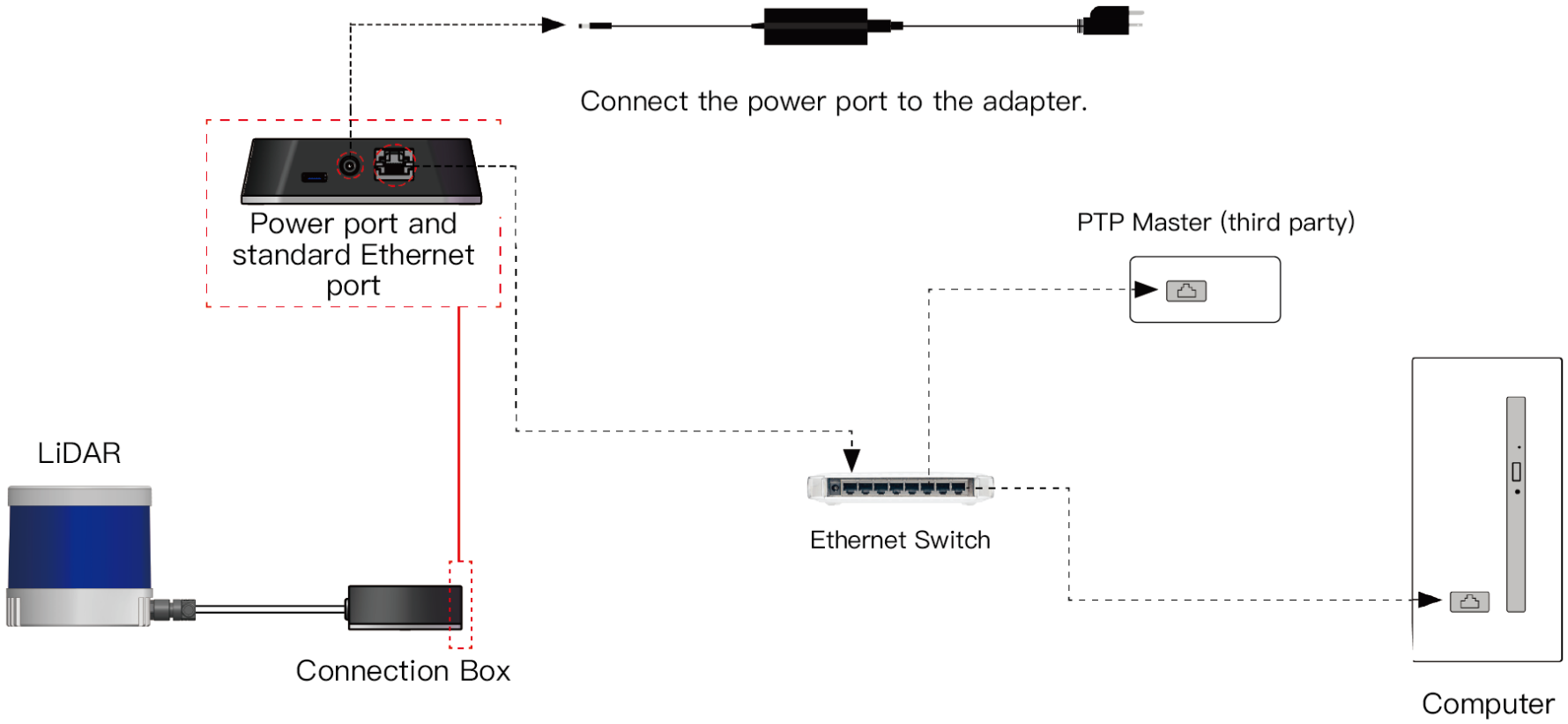
Firing Sequence	Channel #	Δt(n)
41	41	87.75
42	42	89.82
43	43	91.87
44	44	93.93
45	45	95.98
46	46	98.04
47	47	100.10
48	48	102.15
49	49	105.20
50	50	107.26
51	51	109.32
52	52	111.38
53	53	113.43
54	54	115.49
55	55	117.54
56	56	119.60
57	57	122.05
58	58	124.11
59	59	126.17
60	60	128.22

Firing Sequence	Channel #	Δt(n)
61	61	130.28
62	62	132.34
63	63	134.39
64	64	136.45

Appendix III PTP Protocol

The Precision Time Protocol (PTP) is used to synchronize clocks across a computer network. It can achieve sub-microsecond clock accuracy.

■ **LiDAR Connection When Using PTP**



■ Absolute Packing Time When Using PTP

To use PTP as the clock source, connect a third-party PTP master device to get the absolute time.

Notes

- PTP master is a third-party device and is not included with the LiDAR.
- The LiDAR works as a PTP slave device and the PTP protocol is Plug&Play.
- The timestamps and Date & Time fields in Point Cloud Data Packets strictly follow the PTP master device. Certain PTP master devices may have a specified offset from the Date & Time output by the LiDAR. Please verify the configuration and calibration of your PTP master device.
- 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.

Appendix IV Power Supply Requirements

To ensure that the input voltage at the LiDAR's connector is within 12 to 48 V DC, please check the specifications of the power source and the voltage drop over cables.

The LiDAR uses 22 AWG power cables. We recommend using 22 AWG cables or cables of thicker wire gauges.

- Define the cable length from the power source to the LiDAR's connector as L (unit: m)
- When using 22 AWG (59.4 Ω/km) cables, the estimated cable resistance is r = 0.12L (unit: Ω)
- The LiDAR's peak power consumption is below 24 W in all operating conditions
- Define the source voltage as $U_{in}(V)$, and the cable voltage drop during peak power consumption can be calculated as:

$$U_{drop}(V) = \frac{U_{in} - \sqrt{U_{in}^2 - 96r}}{2}$$

Users may also estimate the cable voltage drop using the following lookup table.
When cable length exceeds 10 m, source voltage should be at least 24 V.

Estimation of Cable Voltage Drop

Cable Total Length L	Source Voltage $U_{in} = 12$ V	Source Voltage $U_{in} = 24$ V	Source Voltage $U_{in} = 36$ V
2 m	0.50 V	0.24 V	0.12 V
6 m	1.67 V	0.74 V	0.36 V
10 m	3.30 V (LiDAR's input voltage < 9 V)	1.30 V	0.61 V
15 m	(LiDAR's input voltage < 9 V)	2.00 V	0.92 V

When the LiDAR's input voltage approaches 55 V, make sure there is no additional overshoot in the external power system. Even a short period of overvoltage can cause irreversible damage to the LiDAR.

■ Power Consumption

The LiDAR's peak power consumption is below 12 W in all operating conditions.
Yet after a power-on in an ambient temperature of 0°C or below, power consumption typically remains around 36 W for a period of time.

■ Power Up/Down

During a power-up, the voltage requirements are charted in Figure IV.1

- The LiDAR's input voltage should remain under 1 V for more than 200 ms before ramping up
- During the ramp-up, the input voltage should monotonically increase to 9 V of its designed value in less than 500 ms

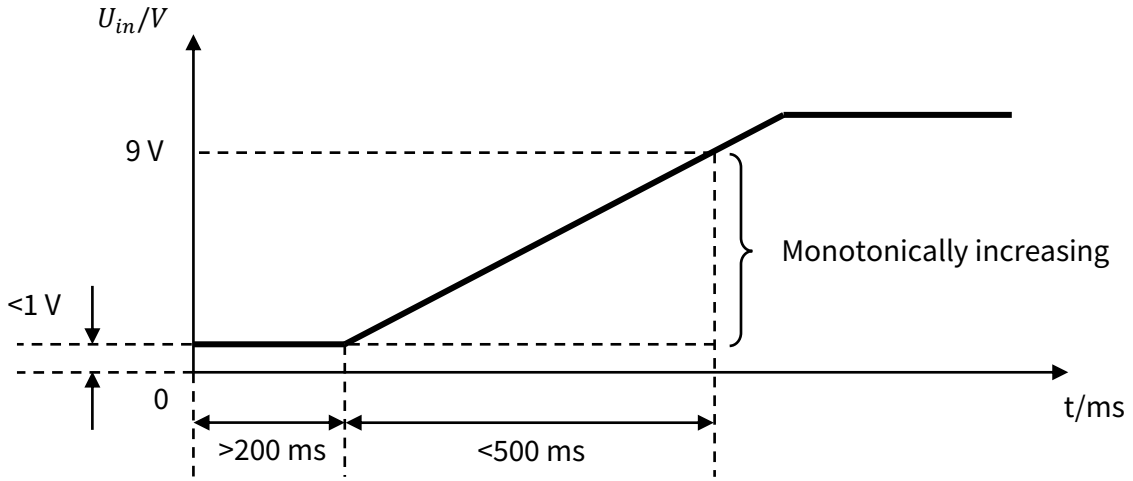


Figure IV.1 Voltage Requirements during a Power-Up

During a power-down, the LiDAR's input voltage, after dropping below 1 V, should remain for more than 200 ms before the next power-up.

Appendix V　Legal Notice

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