PandarQT

64-Channel Short-Range Mechanical LiDAR User Manual

HESAI Wechat

Contents

About This Manual

Please 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.

■ Access to This Manual

To obtain the latest version:
- Visit the Download page of Hesai's official website: https://www.hesaitech.com/downloads/
- 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
https://www.hesaitech.com/technical-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.
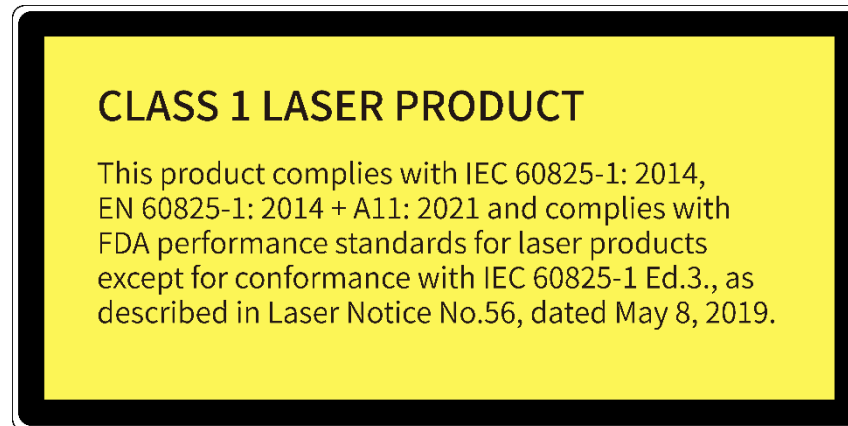
☼ Notes: additional information that may be helpful.

Safety Notice

- Please make sure to read through this safety notice and follow all the instructions and warnings. Failure to comply with the instructions and
- warnings may result in product damage, property loss, and/or personal injuries.
- Please check the certification information on the product's nameplate and read through the corresponding certification warnings. If specific users require not to present certification information on the nameplate, please follow the agreed-to arrangements.
- 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).
- This lidar product is intended as a component of an end product. It is the responsibility of the end-product supplier to assess the risk of use in accordance with applicable standards, and inform the intended user of safety-related information.
- Should there be other agreements with specific users, the other agreements shall apply.
- Before using a product, please confirm with Hesai the development maturity of the product in a timely manner. For products still in development, Hesai makes no warranty of non-infringement nor assumes any responsibility for quality assurance.

■ **Special Warnings**

Laser Safety

CLASS 1 LASER PRODUCT

This product complies with IEC 60825-1: 2014,
EN 60825-1: 2014 + A11: 2021 and complies with
FDA performance standards for laser products
except for conformance with IEC 60825-1 Ed.3., as
described in Laser Notice No.56, dated May 8, 2019.

Hot Surface

Hot parts!
Burned fingers when handling the parts.
Wait one-half hour after switching off before handling parts.

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.

Prohibition of Disassembly

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

■ Operating Environment

Radio Frequency Interference

- Please check the certification information on the product's nameplate and read through the corresponding certification warnings. If specific users require not to present certification information on the nameplate, please follow the agreed-to arrangements.
- 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.

Chemical Environment

Do NOT expose the product to corrosive or strong polar chemical environments (such as liquids or gases), including but not limited to strong acids, strong bases, esters, and ethers. This is to avoid damage to the product (including but not limited to water resistance failure).

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, certain product models are equipped with protective covers, which can be used to block laser light emission when the product is temporarily not used for measurement.

■ **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/EN 60825-1:2014
- EN 60825-1:2014+A11:2021
- 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.

CAUTION: use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

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 / optical window can be regarded as the product's laser emitting window; looking at the cover lens / optical window 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.
- Certain product models contain 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 / optical window

- Do NOT apply protective film, wax or any other substance on the cover lens / optical window.
- To keep the product's cover lens / optical window from fingerprints and other stains, do NOT touch the cover lens / optical window with bare hands. If the cover lens / optical window 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 / optical window 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.
- Before installing any exterior part, please ensure that each exterior part and its movable area do not overlap the detection blind zone of lidar product. For questions on determining the detection blind zone, contact Hesai technical support.

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.

Certain product models support active heating of the cover lens / optical window to reduce the impact of ice and frost. Users can turn off this function.

- While active heating is ON, please avoid direct skin contact with the cover lens / optical window.
- For the location of the cover lens, please refer to the Introduction section in the product's user manual.

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 in 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

Certain product models support one or more point cloud data processing features, include but are not limited to: Noise Filtering, Interstitial Points Filtering, Retro Multi-Reflection Filtering, and Non-Linear Reflectivity Mapping.

These features are configurable and are intended only to assist the user in extracting information from the point cloud data. Users are in full control of whether to use any of these features. Moreover, users are responsible for analyzing the product's intended application scenarios and evaluating the risk of enabling one or more of these features in combination.

The supported features for this product model can be found on web control.

■ Repair and Maintenance

For product repair or maintenance issues, please contact Hesai Technology or an authorized Hesai Technology service provider.

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.
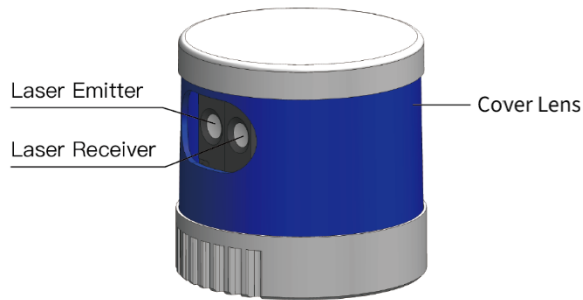
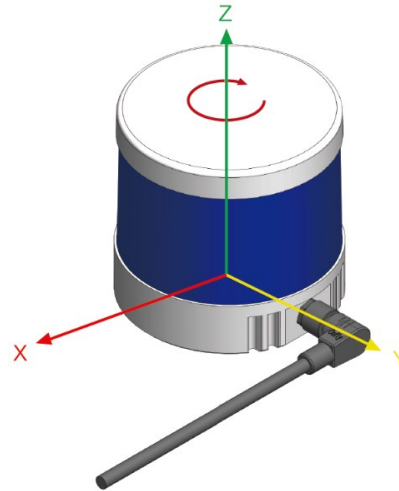

Figure 1.2 Partial Cross-Sectional Diagram

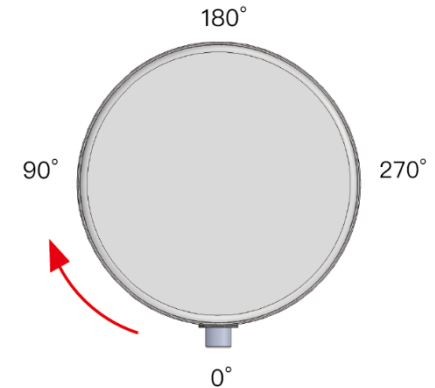Figure 1.3 Coordinate System (Isometric View)

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.

Lidar azimuthal position is defined in Figure 1.4. Y-axis corresponds to 0°.

Each laser channel has an intrinsic azimuth offset. The horizontal center of the emitter-receiver array defines the lidar's azimuthal position.

For example, when the horizontal center passes the 90° position:

- the lidar is at the 90° position;
- the Azimuth field in the corresponding data block in the Point Cloud Data Packet will be 90°.

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).

Channel 64   +52.1º

Channel 58   +40.0º

Channel 46   +20.0º

Channel 33   +0.7º

Channel 19   −20.0º

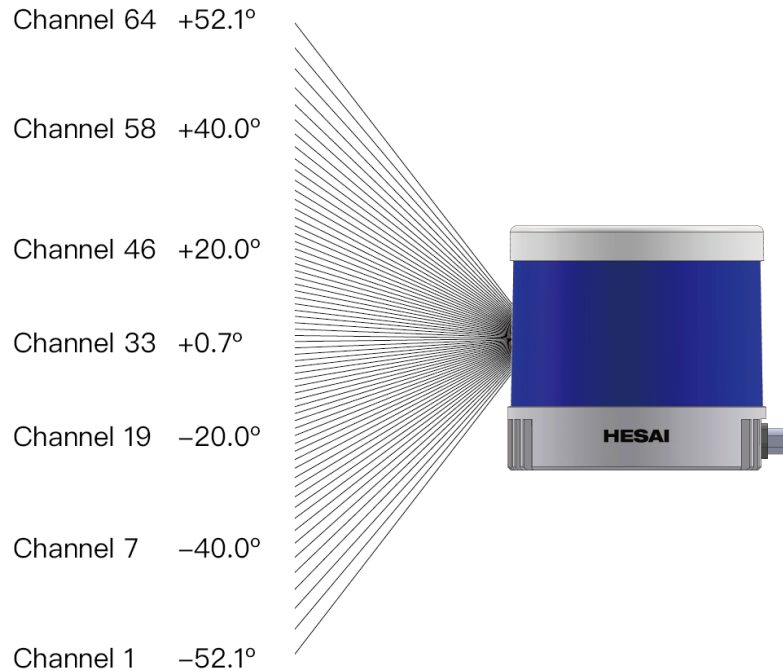Channel 7   −40.0º

Channel 1   −52.1º
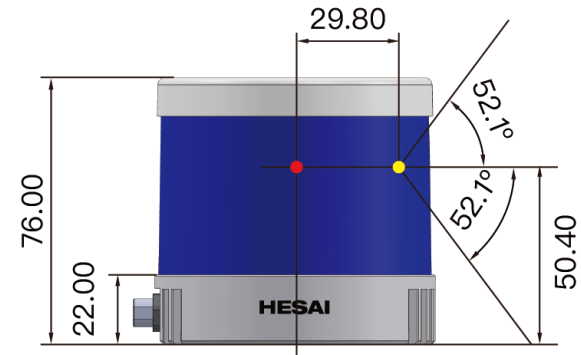
Figure 1.5 Channel Vertical Distribution

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 PTC command 0x05, as described in Hesai TCP API Protocol (Section 5);
- or export the file using PandarView 2 (see the PandarView 2 user manual).

1.4   Specifications

SENSOR	
Scanning Method	Mechanical Rotation
Channel	64
Instrument Range	0.1 to 60 m
Range Capability ①	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
Return Modes	Single Return (First, Last)
	Dual Return (Last & First)

MECHANICAL/ELECTRICAL/OPERATIONAL		
Wavelength	885 nm	
Laser Class	Class 1 Eye Safe	
Ingress Protection	IP6K7 & IP6K9K	
Dimensions	Height:	76.0 mm
	Top/Bottom:	Φ76.3/80.2 mm
Rated Voltage Range	DC 12 to 48 V	
Power Consumption ③	8 W	
Operating Temperature	-20℃ to 65℃	
Storage Temperature	-40℃ to 85℃	
Weight	0.47 kg	

DATA I/O		
Data Transmission	Ethernet (100BASE-T1)	
	Slave Mode by default	
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)

① Range capability
・ Test conditions: middle 48 channels (Channels 9~56) 100 klux ambient illuminance, 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.
・ The external power supply should be able to provide at least 24 W.
・ Rated input voltage: 12 to 48 V
・ Allowable input voltage: 9 to 55 V

④ PTP Clock Drift
・ Defined as the drift at a constant temperature after the lidar (slave clock) loses connection to the PTP master.
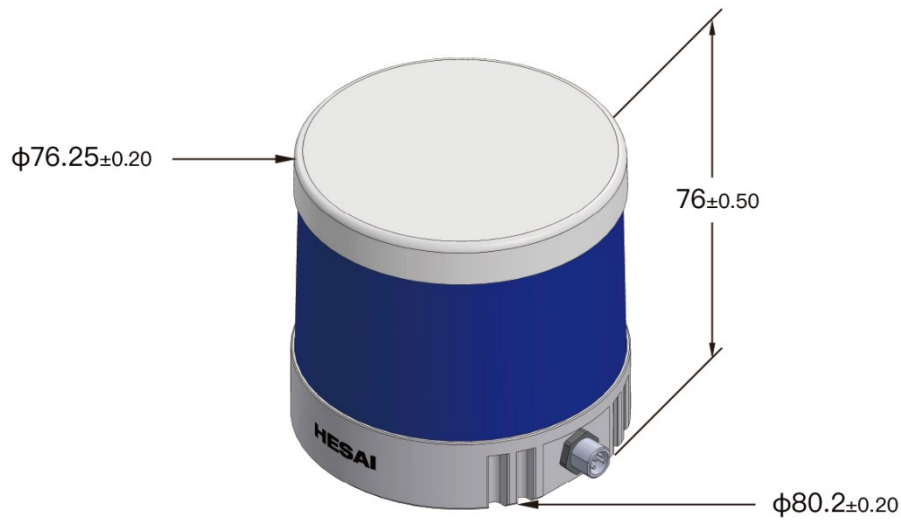
2 Setup

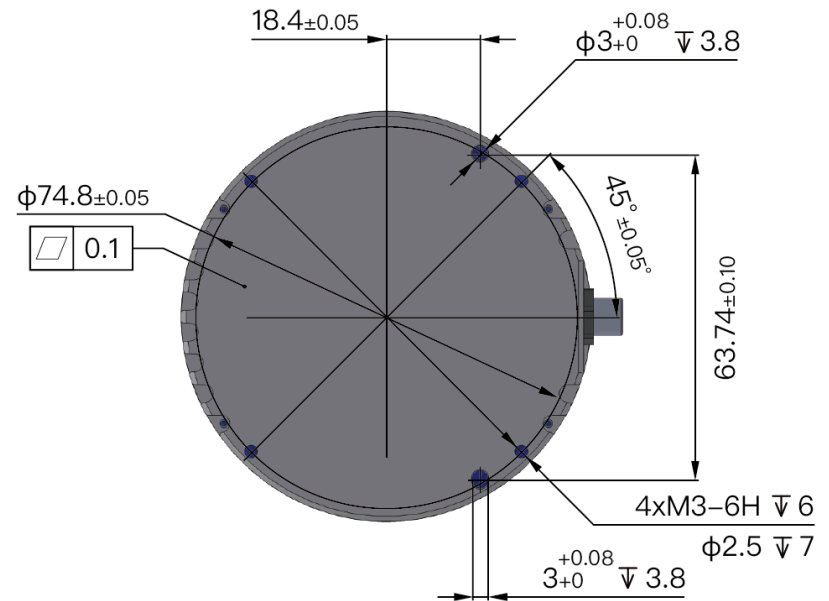## 2.1 Mechanical Installation

Figure 2.1 Isometric View (Unit: mm)

Figure 2.2 Mounting Base (Unit: mm)

2.1.1　Recommended Installation

4−M3 screw
5~6 mm exceeding the mounting plate

2−Φ3PINs
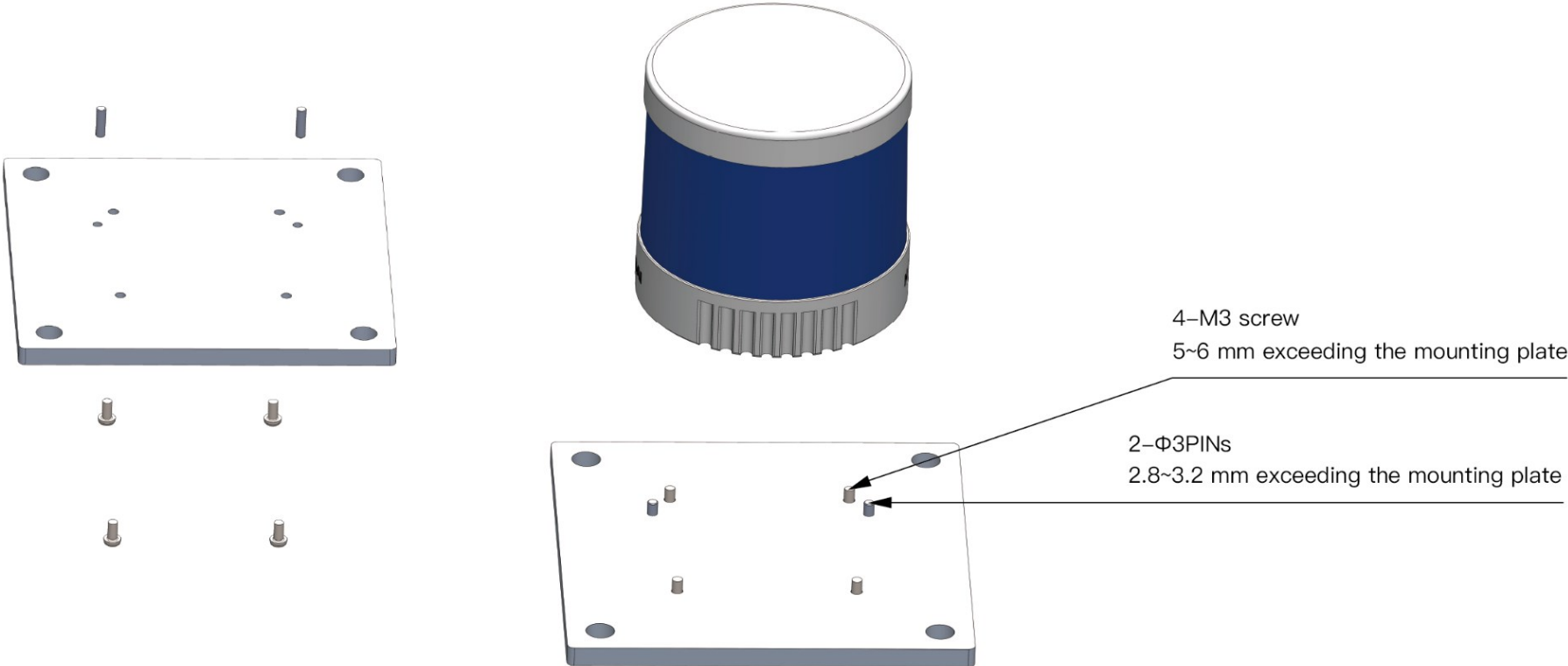2.8~3.2 mm exceeding the mounting plate

Figure 2.3 Recommended Installation
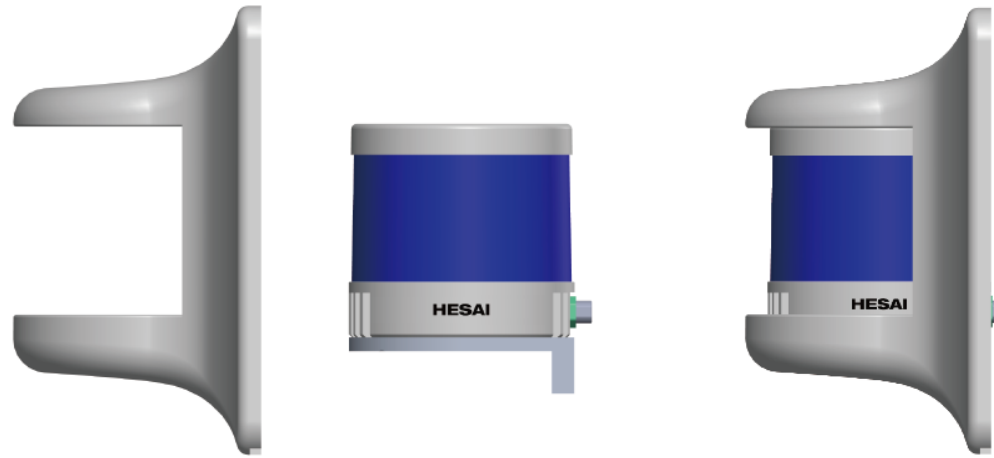
2.1.2　Side Installation

Figure 2.4 Side Installation

2.1.3　Notes on Screw Installation

■　Screw Type

SEMS screws (with pre-attached flat washers and lock washers) are recommended. Property class should be at least 4.8.

■　Threadlocker

Before fastening a screw, apply 1 or 2 dots of threadlocker in the thread fit area. LOCTITE® 263 Threadlocker is recommended.
To ensure curing in place, wait for at least 12 hours before operating the lidar.

■　Screw Torque

The base material of the threaded holes is aluminum alloy instead of steel. Refer to the following table for the appropriate screw torque.

Thread Size	Recommended Screw Torque
M3	0.5 to 0.6 Nm
M4	1 to 1.5 Nm
M5	2 to 2.5 Nm
M6	3.5 to 4 Nm

■　Thread service life

25 times.
Each screwing counts as one time, so as each unscrewing.

2.2   Interfaces

PandarQT uses a 4-pin M8 male socket (with pins inside), which includes power wires and a 100BASE-T1 twisted-pair.
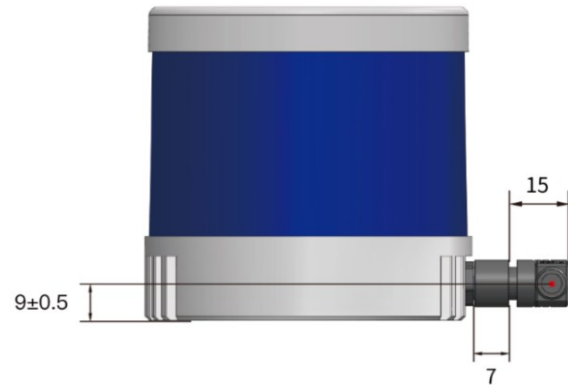
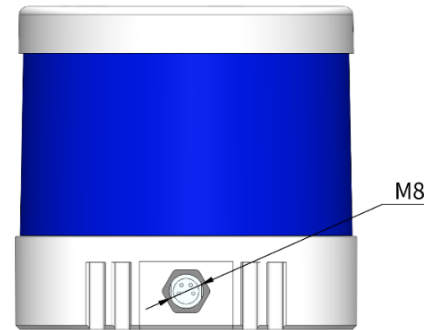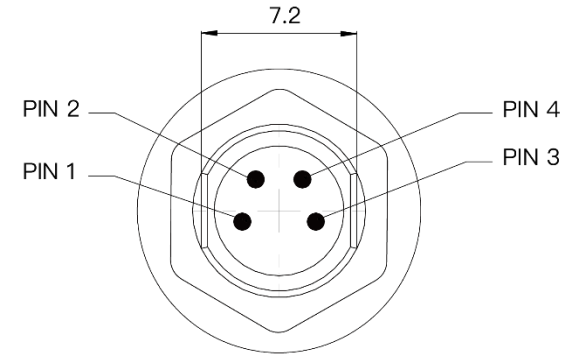| Figure 2.5 Connector Dimensions (Unit: mm)	Figure 2.6 Connector	Figure 2.7 Connector Pinout (4-pin)

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.

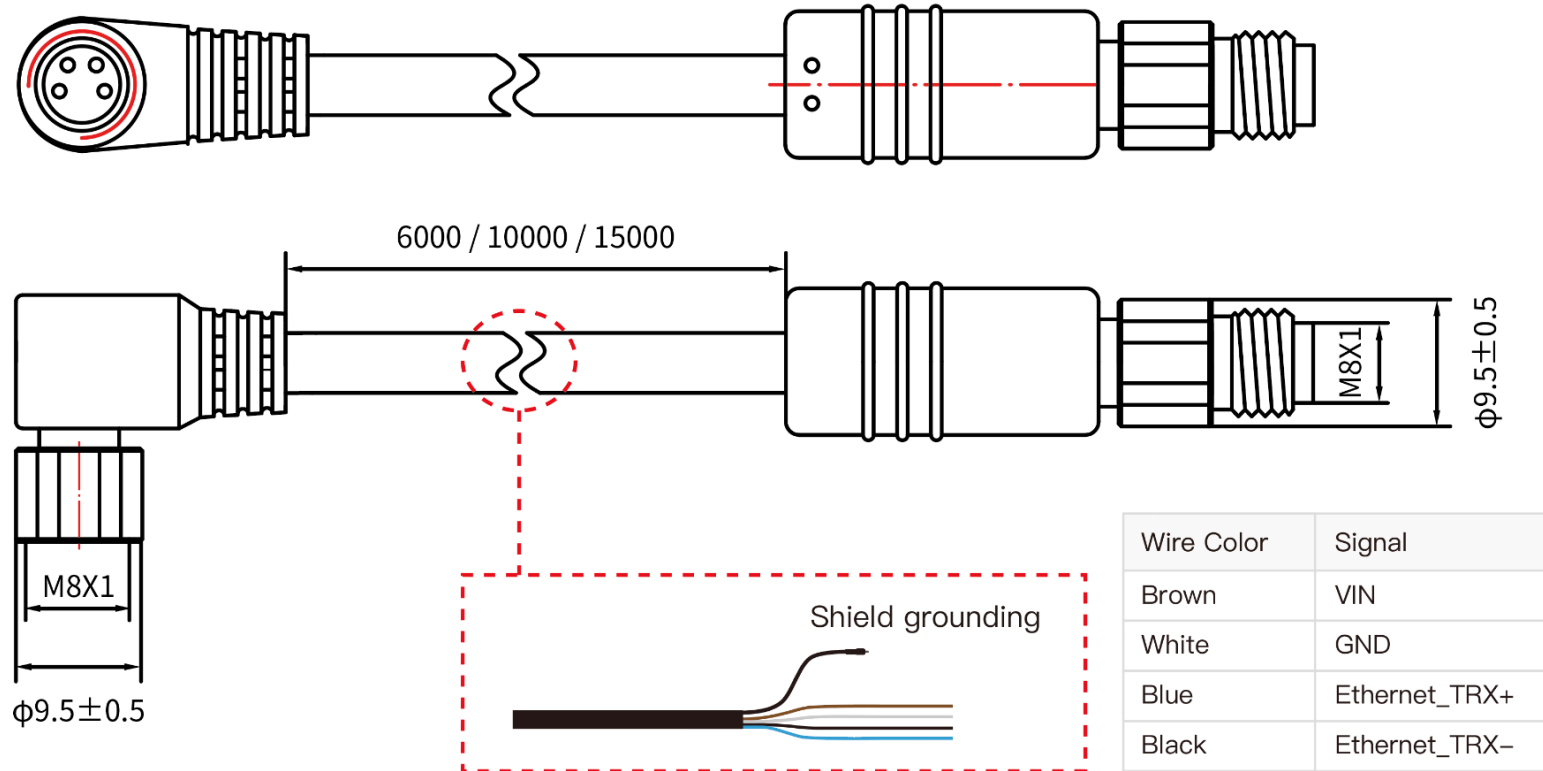Refer to Appendix IV (Power Supply Requirements) for wire gauge and cable length selection.

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.
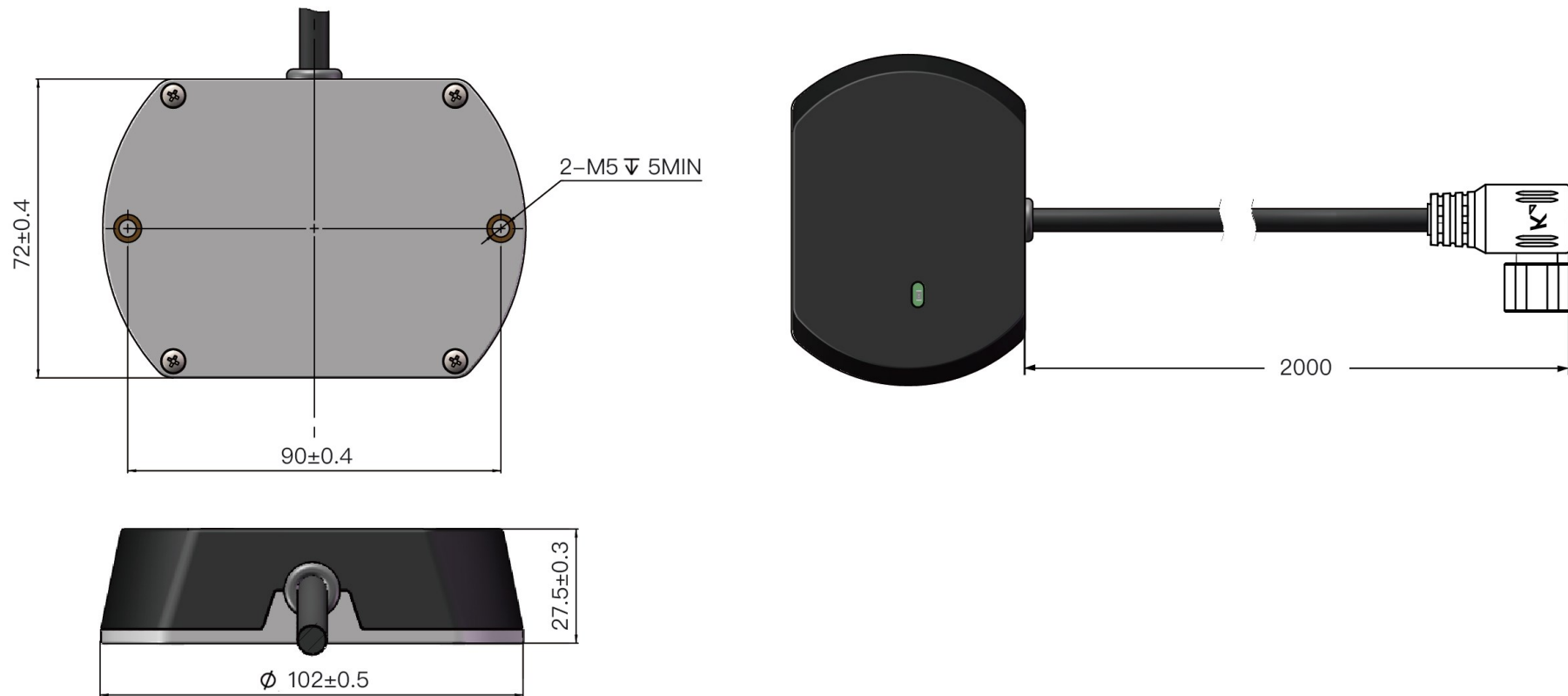
Figure 2.9 Connection Box - Connection (Unit: mm)

2.3.1   Connection Box Interfaces
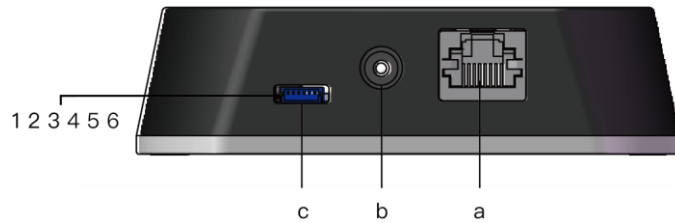
Figure 2.10 Connection Box (Front)
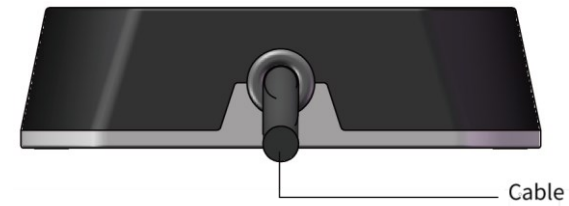
Figure 2.11 Connection Box (Back)

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
c	Reserved	-

2.3.2   Connection

Connect the power port to the adapter

Power port and standard
Ethernet port

LiDAR

Connect the Ethernet port to
a computer.

Connection Box

Computer
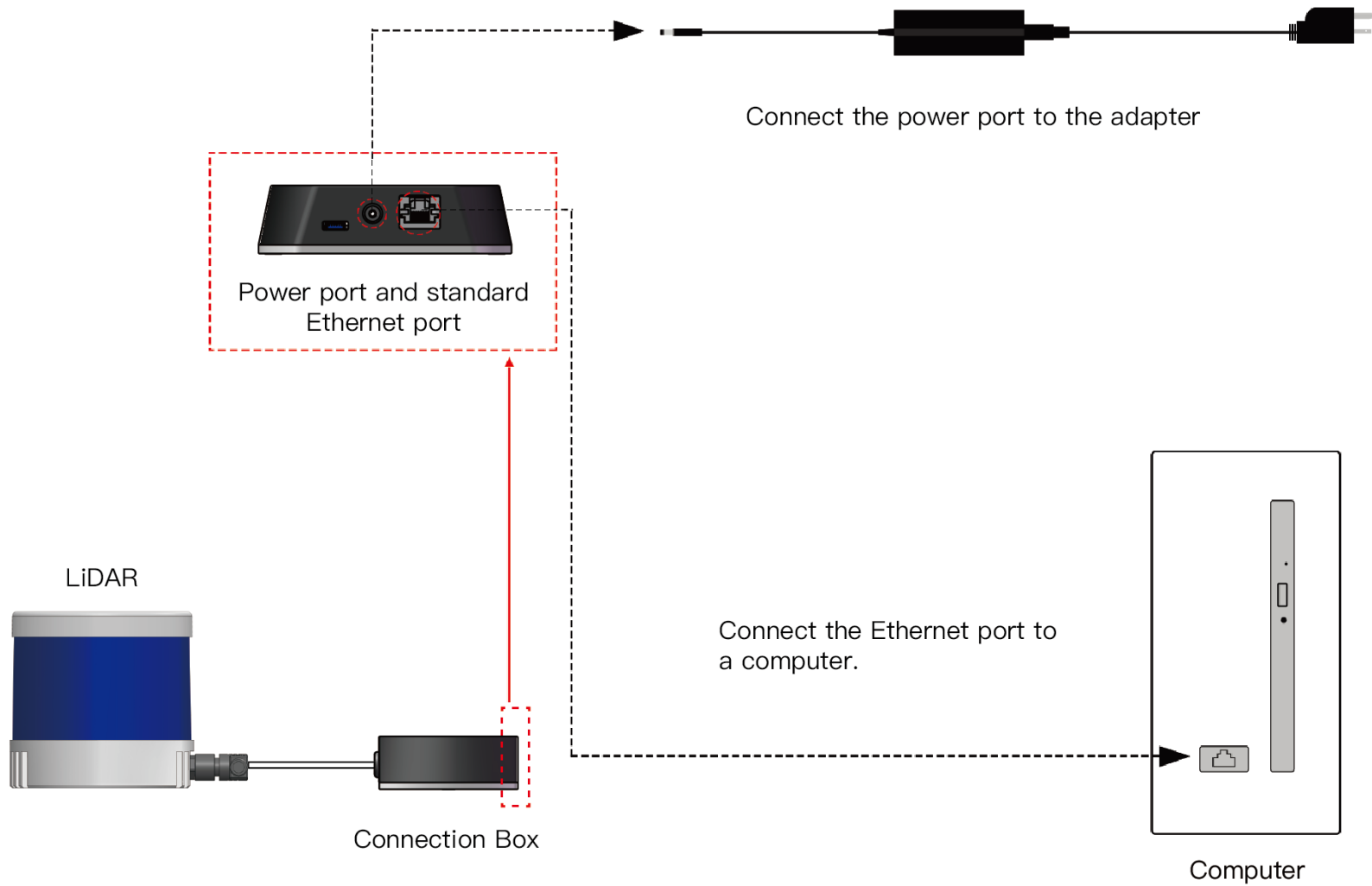
Figure 2.12 Connection with PTP (Software Device)

Connect the power port to the adapter.

Power port and
standard Ethernet
port

PTP Master (third party)

LiDAR

Ethernet Switch
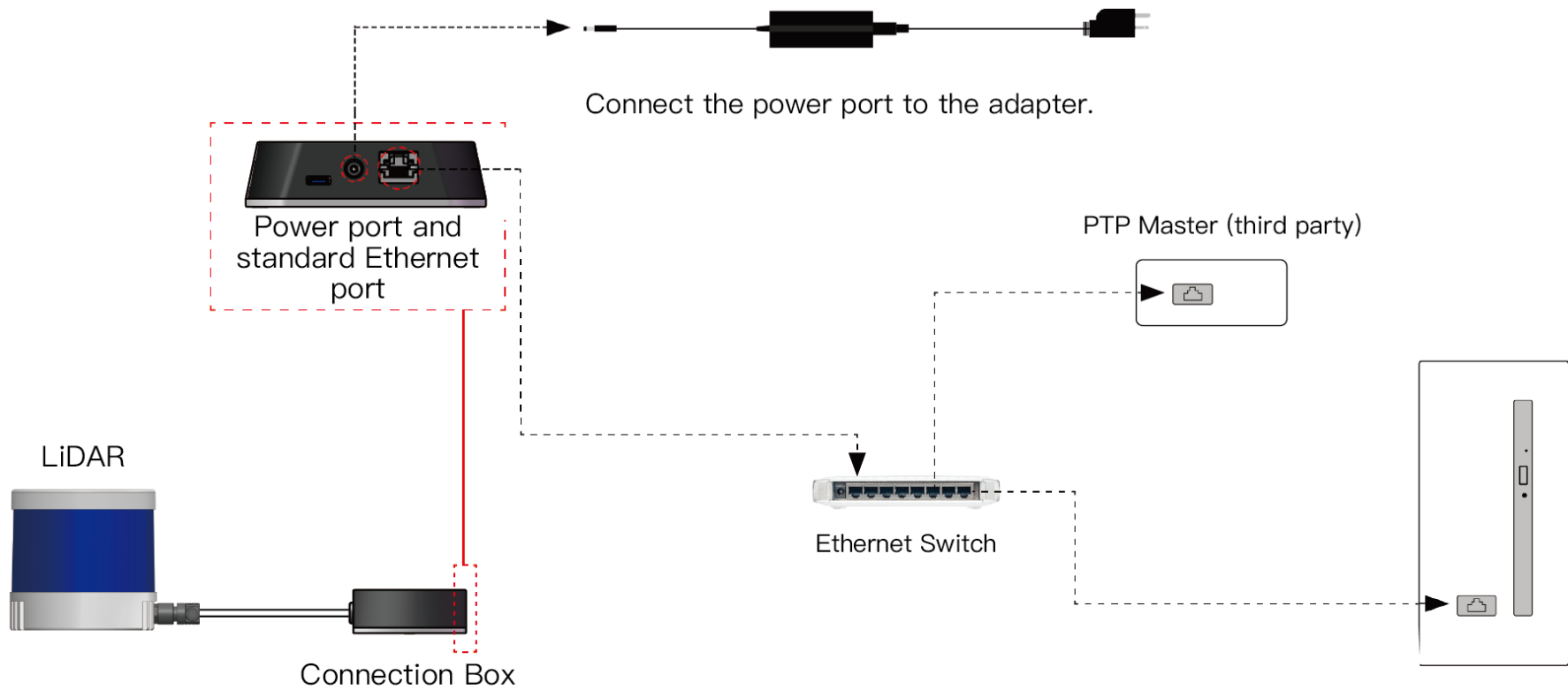
Connection Box

Figure 2.13 Connection with PTP (Hardware Device)

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 2 User Manual).

To set parameters, check device info, or upgrade firmware/software (see Section 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.

Unless otherwise specified, all the multi-byte fields are unsigned values in little endian format.
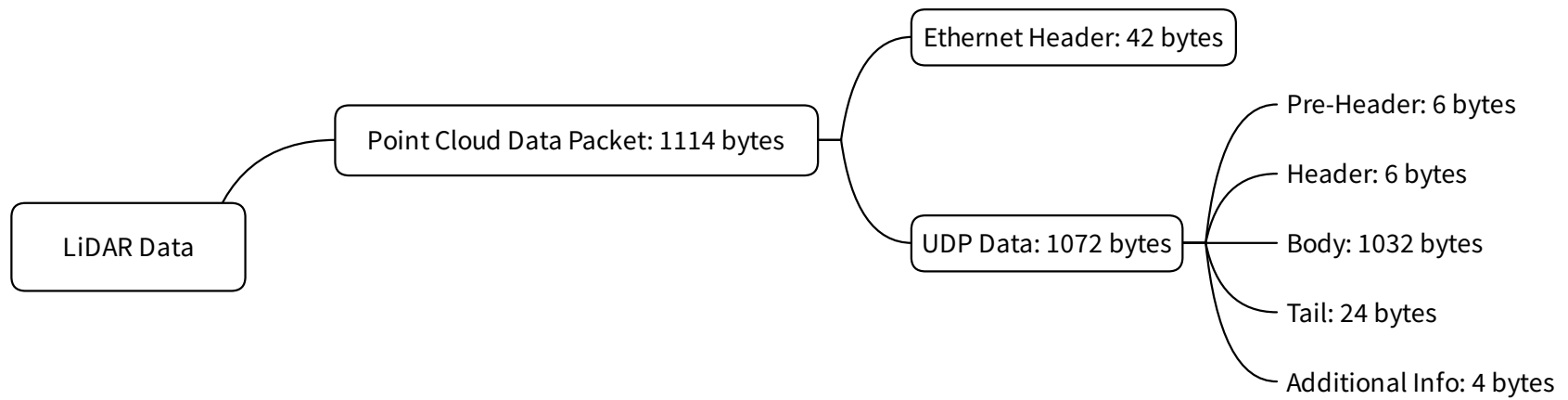
Figure 3.1 Data Structure

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	-

```
▼ Internet Protocol Version 4, Src: 192.168.1.201 (192.168.1.201), Dst: 255.255.255.255 (255.255.255.255)
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
  ▸ Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
    Total Length: 1100
    Identification: 0x9dec (40428)
  ▸ Flags: 0x4000, Don't fragment
    Time to live: 64
    Protocol: UDP (17)
    Header checksum: 0xd643 [validation disabled]
    [Header checksum status: Unverified]
    Source: 192.168.1.201 (192.168.1.201)
    Destination: 255.255.255.255 (255.255.255.255)
```

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	Main class of the point cloud UDP packet structure Currently 0x03
Protocol Version Minor	1	Subclass of the point cloud UDP packet structure 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 each channel, starting form Channel 1 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

Field	Bytes	Description
Reserved	10	-
Motor Speed	2	Unit: RPM
Timestamp	4	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)
Return Mode	1	0x33 for the First Return mode 0x38 for the Last Return mode 0x3B for the Dual Return mode (last & first)
Factory Information	1	0x42
Date & Time	6	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>

■ 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

Take Channel 5 in Block 2 as an example:

■ **Analyze the vertical angle of a data point**

The designed vertical angle of Channel 5 is -43.848°, according to Appendix I (Channel Distribution)

🔆 Notes
- The accurate vertical angle is recorded in this LiDAR's unit's angle correction file, see Section 1.3 (Channel Distribution).
- 0° is the horizontal direction; define upward as positive (see Figure 1.5).
- Channel # counts from 1, top to bottom.

■ **Analyze the horizontal angle of a data point**

🔆 Y-axis is the 0° position; define clockwise in the top view as positive (see Figure 1.4).

Horizontal angle = ① + ②
① Angular position of current block (see Appendix II for definition)
② Firing time angular offset of the current firing channel

① = ③ + ④

③ Rotor reference angle during the current round of firing

In the Azimuth field of Block 2.

④ Horizontal angle offset of the current firing channel

The designed offset for Channel 5 is 7.388°, according to Appendix I (Channel Distribution Table).

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

② = ⑤ * ⑥

⑤ Firing time offset of the current firing channel

Look up the table in Appendix II (Absolute Time of Point Cloud Data).

⑥ Spin rate of the motor

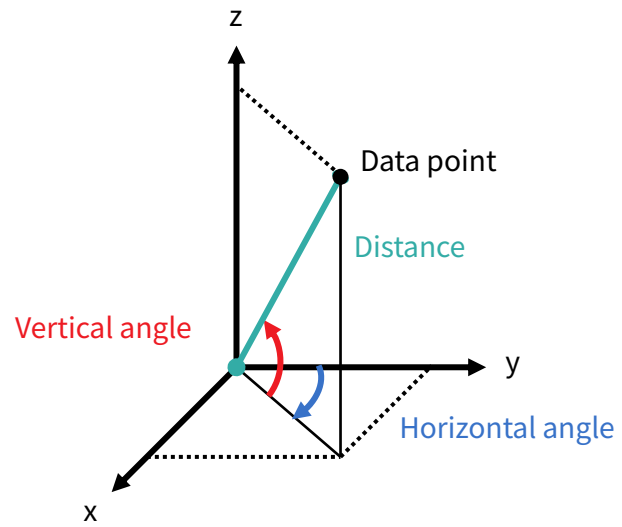See Section 4.1 (Web Control – Home).

■ **Analyze the distance of a data point**

Actual distance in real world millimeters = distance measurement * Distance Unit
- Distance measurement: Distance field of Channel 5 in Block 2
- Distance Unit: 4 mm

■ Draw the data point in a polar 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

Status
Spin Rate	600 rpm
PTP	Free Run

Device Info   **Device Log**

Model	PandarQT
S/N	QTXXXXXXXXXXXXXX
MAC Address	XX:XX:XX:XX:XX:XX
Hardware Version	2.2.0
Software Version	2.0.18
Sensor Firmware Version	2.0.13
Controller Firmware Version	2.0.20

Button	Description
Device Log	Click to download a .JSON file that contains the lidar status, device info, all configurable parameters, and the upgrade log.

Parameter	Description		
Spin Rate	Spin Rate of the motor (rpm) = frame rate (Hz) * 60		
PTP	PTP status		
	Free Run	No PTP master is selected.	
	Tracking	Attempting to sync with the selected PTP Master, but the absolute offset exceeds the user-specified limit in Section 4.2 (Settings).	
	Locked	Absolute offset is within the user-specified limit.	
	Frozen (Holdover)	Attempting to recover the connection to the PTP master.	

4.2   Settings

Reset All Settings

Control IP

IPv4 Address	192.168.1.201
IPv4 Mask	255.255.255.0
IPv4 Gateway	192.168.1.1

Settings

Destination IP		255.255.255.255
Lidar Destination Port		2368
Return Mode		Dual Return
Sync Angle	☐	0
Trigger Method		Time Based

Clock Source	PTP
Profile	1588v2
PTP Network Transport	UDP / IP
PTP Domain Number [0-127]	0
PTP logAnnounceInterval	1
PTP logSyncInterval	1
PTP logMinDelayReqInterval	0
Time Offset for Lidar Lock（1-100 μs）	1
Rotation Direction	Clockwise
Standby Mode	In Operation / Standby

Save

Button	Description
Reset All Settings	Reset all the configurable parameters to factory defaults, including: ・ Section 4.2 (Settings) ・ Section 4.3 (Azimuth FOV)
Save	Save and execute all the settings on this page. ・ Exception: Standby Mode takes effect immediately without having to click "Save".

4.2.1   Network Settings

Parameter	Options	Description
Ethernet Comm. Mode	Slave (default) Master	Only for automotive Ethernet (1000Base-T1). **Slave mode (default):** ・ The receiving host shall 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 bottom of the Settings page. ・ Connection to web control will be lost. Then connect the lidar directly to a Slave host. ・ Connection box is not supported. ⚠ If the lidar's Ethernet communication mode is the same as the receiving host's, users will lose access to web control. To minimize such risks, please take special care when changing the default settings.
Destination IP	Any address except for 0.0.0.0, 127.0.0.1, and the lidar's IP. Default: 255.255.255.255	<table><tr><td>Mode</td><td>Destination IP</td></tr><tr><td>Broadcast (default)</td><td>255.255.255.255</td></tr><tr><td>Multicast</td><td>User-defined</td></tr><tr><td>Unicast</td><td>Same as the PC's IP address</td></tr></table>

4.2.2　Function Settings

Parameter	Options	Description
Return Mode	First Last Last and First (default)	Also shown in Point Cloud Data Packets (see the Return Mode field in Section 3.1.2 Point Cloud UDP Data).
Sync Angle	0° to 360°	Phase lock angle ・ To activate this function, check the checkbox and input an azimuth. ・ At every full second, the lidar will rotate to that azimuthal position (see Section 1.2 Lidar Structure). Definition of full second ・ When GPS is locked: the rising edge of the GPS PPS signal ・ When PTP is tracking or locked: retrieved from the PTP master clock ・ When neither GPS nor PTP is locked: the rising edge of the lidar's internal 1 Hz signal ・ Detailed in Appendix II (Absolute Time of Point Cloud Data) To phase-lock multiple lidars: Connect the lidars to the same clock source and set the same sync angle, and these lidars will rotate to that same azimuthal position at every full second.
Trigger Method	Angle-Based (default) Time-Based	The way laser firings are triggered. | Angle-based	Lasers fire every 0.6° at 10 Hz.
Time-based	Lasers fire every 166.66 µs.	
Retro Multi-Reflection Filtering	OFF (default) ON	To mitigate the false positives at twice the distance of a retroflector.

Parameter	Options	Description
Rotation Direction	Clockwise (default) Counterclockwise	Direction of motor rotation
Anti-Interference Mode	Random (default) 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 (default) Standby	In Standby mode, the motor stops running and lasers stop firing.

4.2.3 Time Settings

```
Clock Source                          PTP
    Profile                           1588v2
    Time Offset for Lidar Lock        1
    PTP Network Transport             UDP/IP
    PTP Domain Number                 0
    PTP logAnnounceInterval           1
    PTP logSyncInterval               1
    PTP logMinDelayReqInterval        0
```

Parameter	Options	Description
Clock Source	PTP	Detailed in Appendix III (PTP Protocol)
Profile	1588v2 (default) 802.1AS	IEEE timing and synchronization standard
Time Offset for Lidar Lock	1 to 100 µs (integer) Default: 1	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) L2	Network transport protocol <table><tr><td>UDP/IP</td><td>Available only for 1588v2 profile</td></tr><tr><td>L2</td><td>Available for all profiles</td></tr></table>

Parameter	Options	Description
Domain Number	0 to 127 (integer) Default: 0	Domain attribute of the local clock

When using the 1588v2 profile:

Parameter	Options	Description
PTP logAnnounceInterval	-2 to 3 Default: 1	Time interval between Announce messages Default: 1 log second (2 seconds)
PTP logSyncInterval	-7 to 3 Default: 1	Time interval between Sync messages Default: 1 log second (2 seconds)
PTP logMinDelayReqInterval	-7 to 3 Default: 0	Minimum permitted mean time between Delay_Req messages Default: 0 log second (1 second)

4.3　Azimuth FOV

Button	Description
Save	Save and execute all the settings on this page.

Parameter	Options	Description
Azimuth FOV Setting	For all channels (default) For each channel Multi-section FOV	Configuration mode of the azimuth FOV. The lidar outputs valid data only within the specified azimuth FOV ranges.

💡 **Note**

· The angles in degrees are accurate to the first decimal place.

· If the Start Angle is larger than the End Angle, then the actual range 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°).

4.3.1 For all channels

Input a Start Angle and an End Angle to form a continuous angle range.
This range applies to all channels.

Azimuth FOV Setting	For all channels ▾
Azimuth FOV for All Channels	Start: 0.0
	End: 360.0

Save

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.

Azimuth FOV Setting			For each channel ▼

Enable/Disable All

Status	Channel	Start Angle	End Angle
●	1	0.0	0.0
●	2	0.0	0.0
●	3	0.0	0.0

Save

4.3.3 Multi-section FOV

For each channel, input multiple (≤5) sets of Start Angles and End Angles to form multiple continuous angle ranges.

The "Status" button for each channel
- Gray by default, indicating that the angle range is [0°, 360°].
- To activate the angle range in the table, click the corresponding button to make it green.

The "Enable/Disable All" button
- For all channels, activate/deactivate the angle ranges in the table.

| Azimuth FOV Setting | Multi-section FOV ∨ |

Enable/Disable All

Status	Channel	Azimuth FOV 1		Azimuth FOV 2		Azimuth FOV 3		Azimuth FOV 4		Azimuth FOV 5	
		Start Angle	End Angle	Start Angle	End Angle	Start Angle	End Angle	Start Angle	End Angle	Start Angle	End Angle
●	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
●	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
●	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Save

4.4   Operation Statistics

These operating parameters are shown in real time:

Start-Up Counts	510
Internal Temperature	32.10℃
System Uptime	0 h 5 min
Total Operation Time	559 h 43 min

Internal Temperature	Operation Time
< -40 ℃	0 h 1 min
-40 to -20 ℃	0 h 46 min
...	...
100 to 120 ℃	1 h 44 min
>120 ℃	0 h 0 min

4.5   Upgrade

Preparation

- Please contact Hesai technical support to receive encrypted and signed upgrade files.
- During the upgrade, it is recommended to place a protective cover (supplied with the lidar) or other opaque material over the lidar's cover lens.

Upgrade

- Click the "Upload" button, select an upgrade file, 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.

Button	Description
Restart	Software reboot Afterwards, the Start-Up Counts in the Operation Statistics page increments by 1.

Parameter	Current Value
Software Version	2.0.18
Firmware of Sensor Version	2.0.13
Firmware of Controller Version	2.0.20
Upgrade Log	-

💡 **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 acquire Hesai lidar's PTC (Pandar TCP Commands) and HTTP API Reference Manual, please contact Hesai technical support.

6 Sensor Maintenance

⚠️ **Warnings**

- The lidar's cover lens is made of plastic (polycarbonate, PC), similar to the material used for car lamps.
- Do NOT wipe the cover lens when it is dry, nor use abrasive cleaners. Doing so can damage the optical coating.
- Do NOT use organic cleaners, which can damage the cover lens and even cause cracking.
  - Organic cleaners include, but are not limited to: tar cleaners, self-cleaning agents, adhesive removers, coating removers, foam cleaners, paint mist removers, glass cleaners, thinning agents, de-icers, paint surface treatment agents, alcohol, and vinegar.
  - Do NOT use automatic car wash equipment to clean the lidar. Before washing the car or performing related operations, protect the cover lens to prevent any contact with organic cleaners.
- Do NOT apply excessive force to the lidar, as this can damage the cover lens.
- If a pressure washer is used to clean the cover lens, make sure the distance between the nozzle and the cover lens remains at least 60 cm.
- After prolonged exposure to strong sunlight and high temperatures, the cover lens should NOT be cleaned immediately.
- If snow or ice accumulates on the cover lens, do NOT use a pressure washer or ice scraper.
  - A small broom is recommended to remove snow.
  - A solvent-free (i.e., free of organic solvents) ice removal spray is recommended to remove ice; alternatively, wait for the ice to melt by itself.
- Do NOT wax the cover lens.

💡 **Notes**

- Please regularly check the cover lens, considering your car use frequency, parking environment, and climate conditions.
- If foreign objects (such as dust, fingerprints, or oil stains) are found on the cover lens, make sure to clean it.

If corrosive foreign objects (such as insect remains, bird droppings, tree resin, road dust, industrial dust, asphalt, soot particles, and road salt) are found on the cover lens, make sure to clean it immediately.

Cleaning procedure

1. Make sure the lidar is powered OFF.
2. Choose a cleaning agent:
- For light stains, use room temperature water.
- For heavier stains, use a mild soap solution (no more than two tablespoons of soap per quart or liter of water).
- For stubborn stains, use a solvent-free (i.e., free of organic solvents), neutral detergent at room temperature, such as car shampoo.
3. Take a clean soft sponge or anti-static microfiber cloth, dampen it with the chosen cleaning agent, and gently wipe the dirty area on the cover lens back and forth.
4. For stubborn stains, cover the dirty area with the dampened sponge or cloth to soften the stains before wiping.
5. Immediately after removing the stains, rinse the cover lens with clean water. Then use a clean soft sponge or microfiber cloth to gently wipe away any remaining liquid (which may contain residual cleaning agent or contaminants).

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); • the lidar is not in standby mode (see Section 4.2 Web Control – Settings). Power on again to check if the symptom persists.

Symptoms	Points to Check
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.
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 2 is added to the firewall exceptions; ・ PC's VLAN ID is the same as the lidar's; (**NOTE** This requirement applies only when the product model supports VLAN and that VLAN tagging is enabled.) ・ the latest version of PandarView 2 is installed on the PC. Power on again to check if the symptom persists.

Symptoms	Points to Check
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; • PC's VLAN ID is the same as the lidar's. (**NOTE** This requirement applies only when the product model supports VLAN and that VLAN tagging is enabled.) 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.

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 Section 6 (Sensor Maintenance) for the cleaning method; • Lidar's calibration file is imported; see *PandarView 2 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℃ and 95℃ on the Operation Statistics page of web control. Afterwards, check for packet loss: • If no packet is missing and yet the point cloud flashes, please update PandarView 2 to the latest version (see the Download page of Hesai's official website or contact Hesai technical support) 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.

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)	Channel # in UDP Data	Horizontal Angle (Azimuth) Offset	Vertical Angle (Elevation)
01 (Bottom)	8.736°	-52.121°	21	-5.083°	-16.865°
02	8.314°	-49.785°	22	-5.047°	-15.368°
03	7.964°	-47.577°	23	-5.016°	-13.88°
04	7.669°	-45.477°	24	-4.988°	-12.399°
05	7.417°	-43.465°	25	-4.963°	-10.925°
06	7.198°	-41.528°	26	-4.942°	-9.457°
07	7.007°	-39.653°	27	-4.924°	-7.994°
08	6.838°	-37.831°	28	-4.91°	-6.535°
09	6.688°	-36.055°	29	-4.898°	-5.079°
10	6.554°	-34.32°	30	-4.889°	-3.626°
11	6.434°	-32.619°	31	-4.884°	-2.175°
12	6.326°	-30.95°	32	-4.881°	-0.725°
13	6.228°	-29.308°	33	5.493°	0.725°
14	6.14°	-27.69°	34	5.496°	2.175°
15	6.059°	-26.094°	35	5.502°	3.626°
16	5.987°	-24.517°	36	5.512°	5.079°
17	-5.27°	-22.964°	37	5.525°	6.534°
18	-5.216°	-21.42°	38	5.541°	7.993°
19	-5.167°	-19.889°	39	5.561°	9.456°
20	-5.123°	-18.372°	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 of Point Cloud Data

■ Source of Absolute Time

The lidar retrieves the current absolute time by connecting to an external clock source (PTP).

- The lidar connects to a third-party PTP master to obtain the absolute time.
- Users may configure the PTP settings (see Section 4.2 Web Control – Settings).
- Users may check the PTP signal status (see Section 4.1 Web Control - Home).
- The lidar does not output GPS Data Packets.

The absolute time is updated as follows.

PTP Status	Date & Time (accurate to μs)	Description
Free Run	Virtual	Starts counting from a virtual UTC time (such as 2000-01-01 00:00:00), using the lidar's internal 1 Hz signal.
Tracking or Locked	Synchronized	Extract the actual date and time from the PTP Master's messages.
Frozen	Drifting	Starts counting from the last synchronized time, using the lidar's internal 1 Hz signal. Will gradually drift from the actual PTP time.

🔅 Notes
- PTP is a Plug & Play protocol; the lidar works as a PTP slave device and requires no additional setup.
- 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 lidar's time output. Please verify the configuration and calibration of your PTP master device.

■ **Absolute Time of Point Cloud Data Packets**

The absolute time of a Point Cloud Data Packet (denoted as t0) is calculated as follows:

$$t0 = t\_s + t\_ms$$

where

- t_s is the whole second part (see the Date & Time field).
- t_ms is the microsecond part (see the Timestamp field).
- For definition of the above fields (see Section 3.1.2 Point Cloud UDP Data – Tail).

■ **Start Time of Each Block**

Given the absolute time of a Point Cloud Data Packet (t0), the start time of each block (i.e., 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 Power Supply Requirements

To ensure the input voltage at the lidar's connector is within 12 to 48 V DC, please check the specifications of the power supply and cables.

■ **Power Supply**

Should be able to provide at least 4 A, 24 W.

■ **Cable Wire Gauge**

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

■ **Minimum Source Voltage**

Calculations can be made as follows:
- Cable length from the power source to the lidar connector is defined as L (unit: m).
- When using 22 AWG (52.94 Ω/km) cables, cable resistance is estimated as $R_1 = 0.106\,L$ (unit: Ω).
- Resistance of the lidar connector described in Section 2.2 (Interfaces) is defined as R_2 , excluding jumper cable assembly. $R_2 \leq 20$ mΩ.
- In all operating conditions, the lidar's peak power consumption $P_{\text{peak}} \leq 24$ W.
- A conservative estimate of the minimum source voltage is

$$U_{\text{source,min}} = 9 + \frac{P_{\text{peak,max}}}{9} * \left(R_1 + R_{2,\text{max}}\right) \approx (9.05 + 0.28L) \text{ (unit: V).}$$

(Continued)

Users may also estimate the minimum source voltage using the following lookup table.

Cable Total Length L	Minimum Source Voltage U
2 m	9.61 V
6 m	10.73 V
10 m	11.85 V
15 m	13.25 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.

Appendix IV Legal Notice