HESAI

www.hesaitech.com
X01-en-2001A2

PandarXT

Medium-Range Mechanical LiDAR User Manual

HESAI Wechat

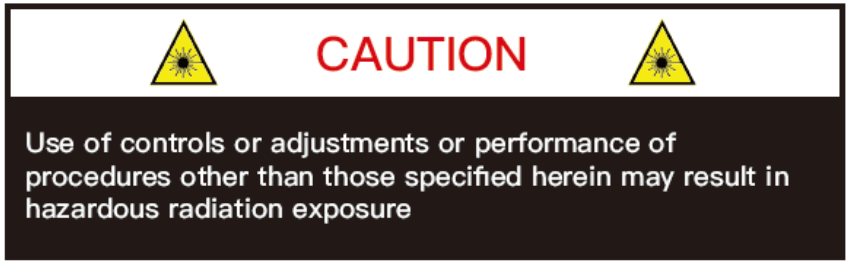
Contents

Safety Notice

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

■ Caution

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



■ Laser Safety Notice - Laser Class 1

This device satisfies the requirements of

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

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

■ Safety Precautions

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

Handling

This device contains metal, glass, plastic, as well as sensitive electronic components. Improper handling such as dropping, burning, piercing, and squeezing may cause damage to the device.
In case of dropping the device, STOP using the device immediately and contact Hesai technical support.

Enclosure

This device contains high-speed rotating parts. To avoid potential injuries, DO NOT operate the device if the enclosure is loose or damaged.
To ensure optimal performance, do not touch the device's enclosure with bare hands. If the enclosure is already stained, please refer to the Sensor Maintenance chapter in user manuals for the cleaning method.

Eye Safety

Although the device meets Class 1 eye safety standards, DO NOT look into the transmitting laser through a magnifying device (microscope, eye loupe, magnifying glass, etc.). For maximum self-protection, avoid looking directly at the device when it is in operation.

Repair

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

Power Supply

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

Prolonged Exposure to Hot Surface

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

Vibration

Strong vibration may cause damage to the device and should be avoided. If you need the mechanical vibration and shock limits of this product, please contact Hesai technical support.

Radio Frequency Interference

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

Medical Device Interference

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

Explosive Atmosphere and Other Air Conditions

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

Light Interference

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

1 Introduction

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

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

1.1 Operating Principle

Distance Measurement: Time of Flight (ToF)

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

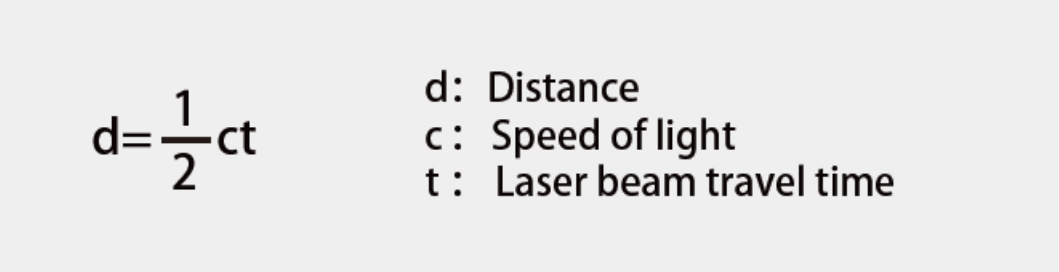


Figure 1.1 ToF Formula

1.2 LiDAR Structure

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

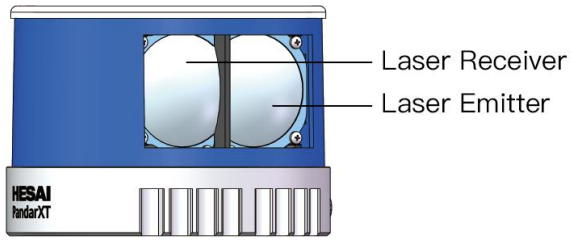


Figure 1.2 Partial Cross-Sectional Diagram

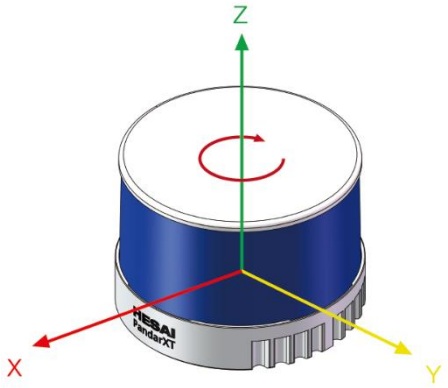


Figure 1.3 Coordinate System (Isometric View)

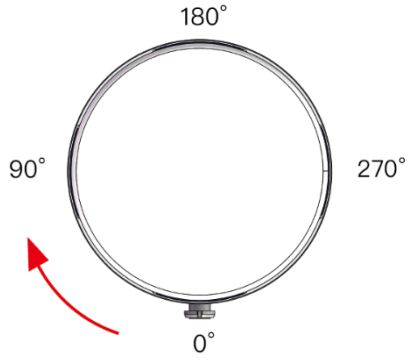


Figure 1.4 Rotation Direction (Top View)

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

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

1.3 Channel Distribution

The vertical resolution is 1° across the FOV, as shown in Figure 1.5.

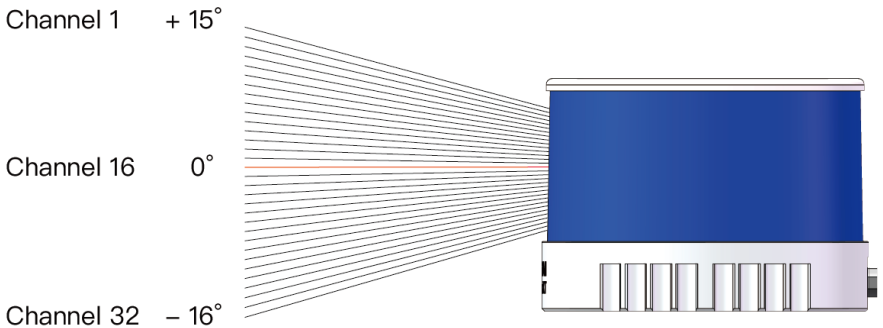


Figure 1.5 Channel Vertical Distribution

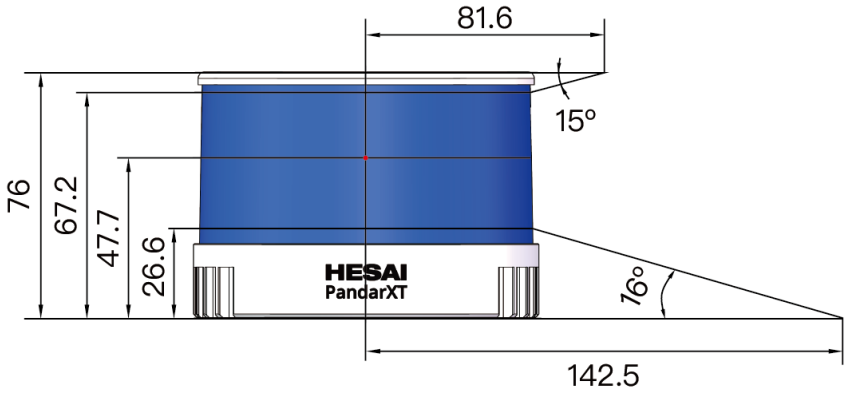


Figure 1.6 Laser Firing Position (Unit: mm)

Each channel has an intrinsic angle offset horizontally. The angle offsets are recorded in this LiDAR unit's calibration file.
Users can obtain the calibration file by sending the TCP command PTC_COMMAND_GET_LIDAR_CALIBRATION, as described in Hesai TCP API Protocol (Chapter 6).

1.4 Specifications

SENSOR	
Scanning Method	Mechanical Rotation
Channel	32
Range	0.3 to 80 m (at 10% reflectivity)
Range Accuracy	±5 cm (0.3 to 1 m)
	±2 cm (1 to 80 m)
FOV (Horizontal)	360°
Resolution (Horizontal)	0.09° (5 Hz)
	0.18° (10 Hz)
	0.36° (20 Hz)
FOV (Vertical)	31° (-16° to +15°)
Resolution (Vertical)	1°
Frame Rate	5 Hz, 10 Hz, 20 Hz
Returns	Single Return
	Dual Return (Strongest, Last)

CERTIFICATIONS	
	Class 1 Laser Product
	CE

MECHANICAL/ELECTRICAL/OPERATIONAL	
Wavelength	905 nm
Laser Class	Class 1 Eye Safe
Ingress Protection	IP67
Dimensions	Height: 76.0 mm
	Top/Bottom Diameter: 100.00 / 103.00 mm
Operating Voltage	DC 9 to 36 V
Power Consumption	10 W (typical)
Operating Temperature	-20°C to 65°C
Weight	0.8 kg

DATA I/O	
Data Transmission	UDP/IP Ethernet (100 Mbps)
Data Outputs	Distance, Azimuth Angle, Intensity
Data Points Generated	Single Return Mode: 640,000 points/sec
	Dual Return Mode: 1,280,000 points/sec
Clock Source	GPS / PTP
PTP Clock Accuracy	≤1 μs
PTP Clock Drift	≤1 μs/s

NOTE Specifications are subject to change without notice.

NOTE Range accuracy as the average range error across all channels may vary with range, temperature and target reflectivity.

2 Setup

2.1 Mechanical Installation

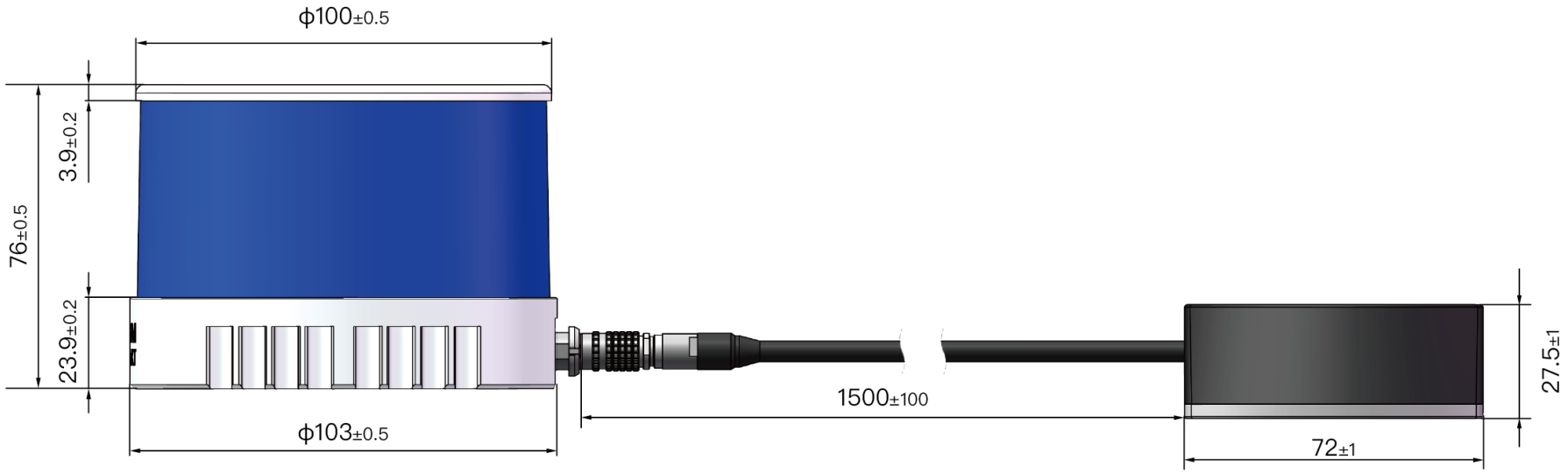


Figure 2.1 Front View (Unit: mm)

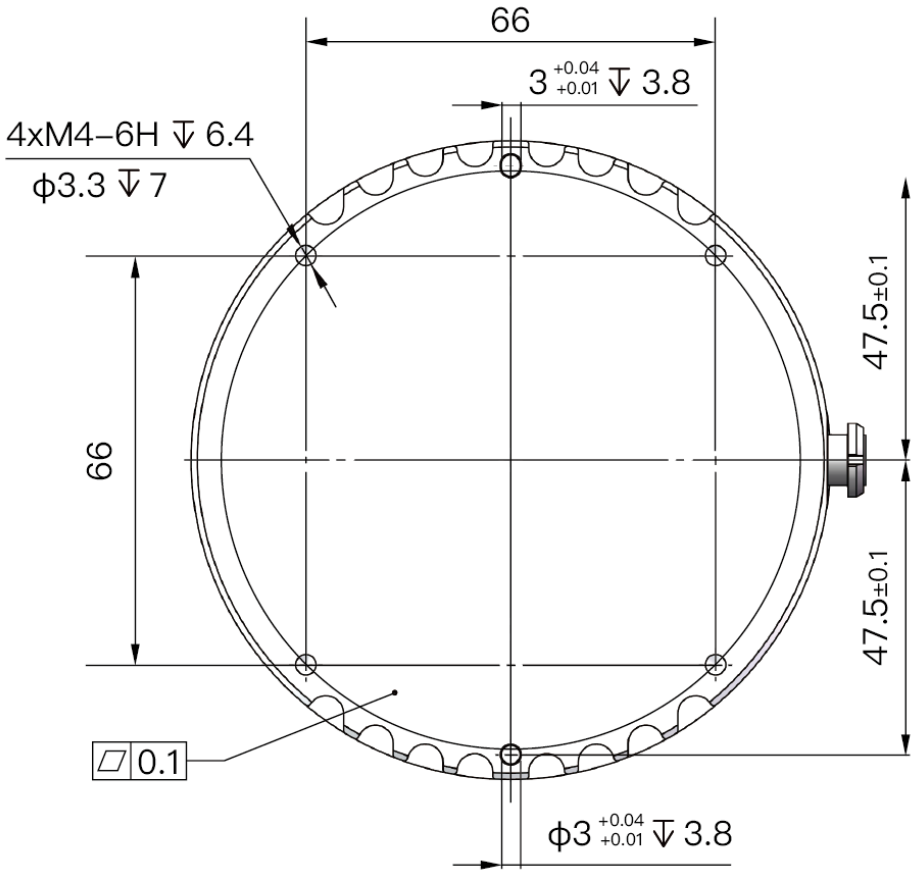


Figure 2.2 Bottom View (Unit: mm)

■ Recommended Installation

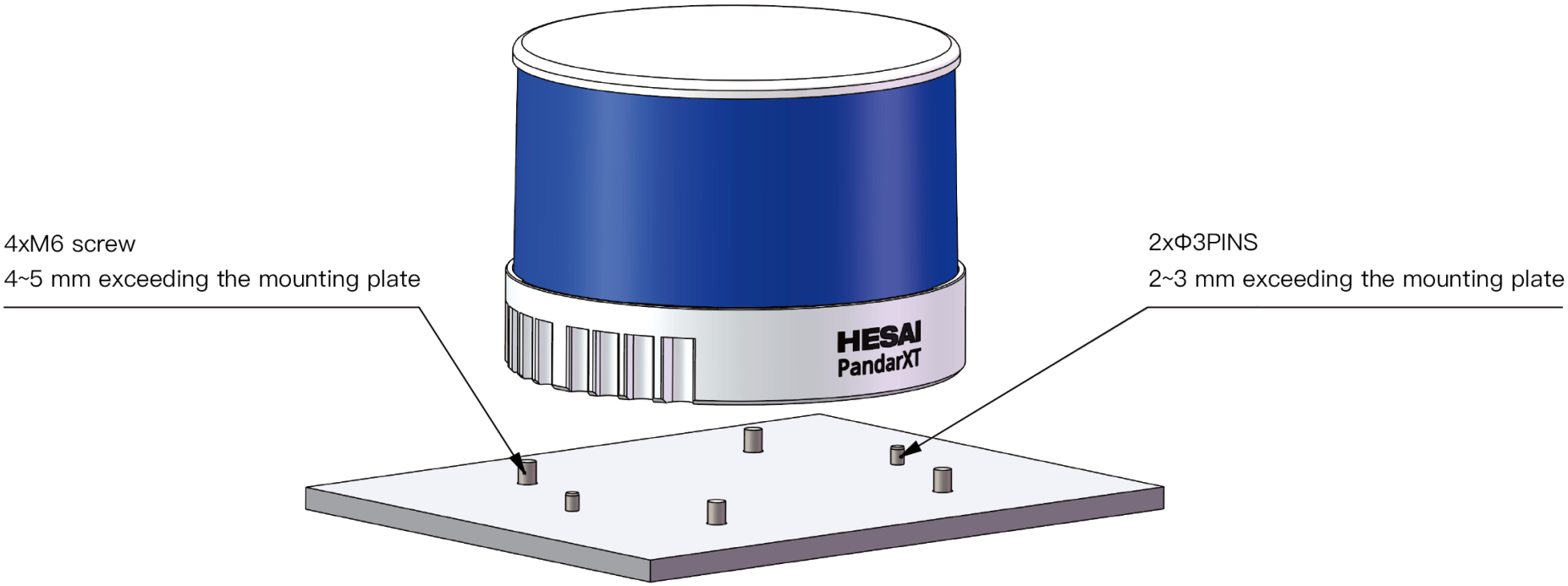


Figure 2.3 Quick Installation

2.2 Interfaces

Lemo part number: EEG.0T.309.CLN (socket, on the LiDAR)

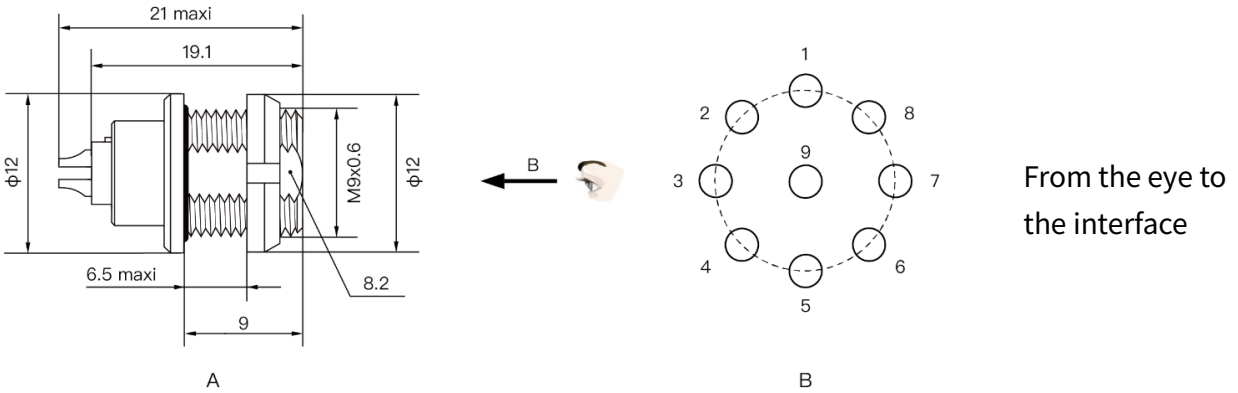


Figure 2.4 Lemo Connector (Socket)

Pin #	Function	Color	Voltage
1	GPS PPS	BLACK	TTL 3.3V/5V
2	GPS DATA	PURPLE	-13 V to +13 V
3	GND	BROWN	0 V
4	VIN	WHITE	12 V
5	Ethernet TX+	YELLOW	-1 V to 1 V

Pin #	Function	Color	Voltage
6	Ethernet TX-	GREEN	-1 V to 1 V
7	Ethernet RX+	PINK	-1 V to 1 V
8	Ethernet RX-	GRAY	-1 V to 1 V
9	-	-	-

NOTE For GPS PPS signal, the recommended pulse width is ⩾1 ms, and the cycle is 1 s (rising edge to rising edge)

NOTE Before connecting or disconnecting an external GPS signal (either using the cable's GPS wire or via the connection box's GPS port), make sure the LiDAR is powered off. If the LiDAR has to stay powered on, make sure to:

- ground yourself in advance
- avoid touching the GPS wire or GPS port with your bare hands

■ Connector Use

Connection	Disconnection
• Turn off the power source • Align the red dots on the connector shells • Push the plug straight into the socket	• Turn off the power source • Pull the release sleeve on the male connector to its outermost position and hold there • Pull the plug from the socket

NOTE

• DO NOT attempt to force open a connection by pulling on the cables or the shells, or by twisting the connectors in any way. Doing so can loosen the connectors' shells, or even damage the contacts.

• In case a connector's shell is accidentally pulled off, stop using the connector and contact Hesai technical support.

• DO NOT attempt to assemble the connector's shell and cable collet; DO NOT connect a connector without its shell. Doing so may damage the LiDAR's circuits.

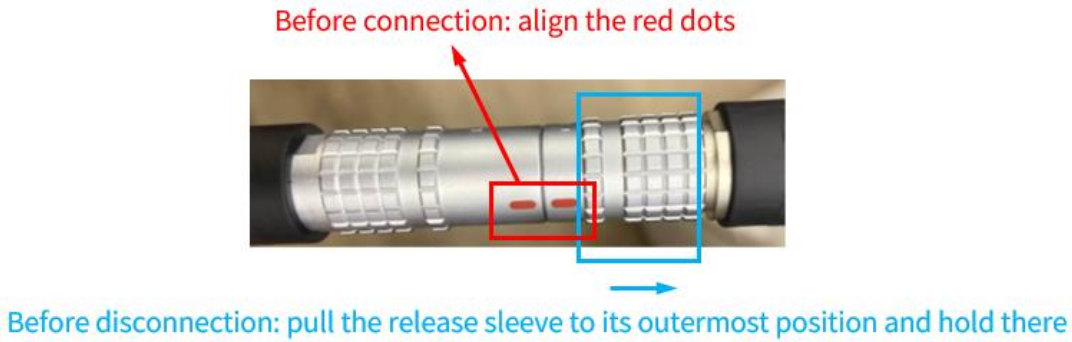


Figure 2.5 Lemo Connection/Disconnection

■ Cables

OD (outside diameter) = 7.50±0.30 mm

Minimum bend radius: 7.5 * OD

NOTE To avoid damaging the cable, do not bend the cable at the cable gland.

2.3 Connection Box (Optional)

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

The connection box comes equipped with a power port, a GPS port, and a standard Ethernet port.

Lemo part number: FGG.0T.309.CLAC50Z (plug, on the connection box)

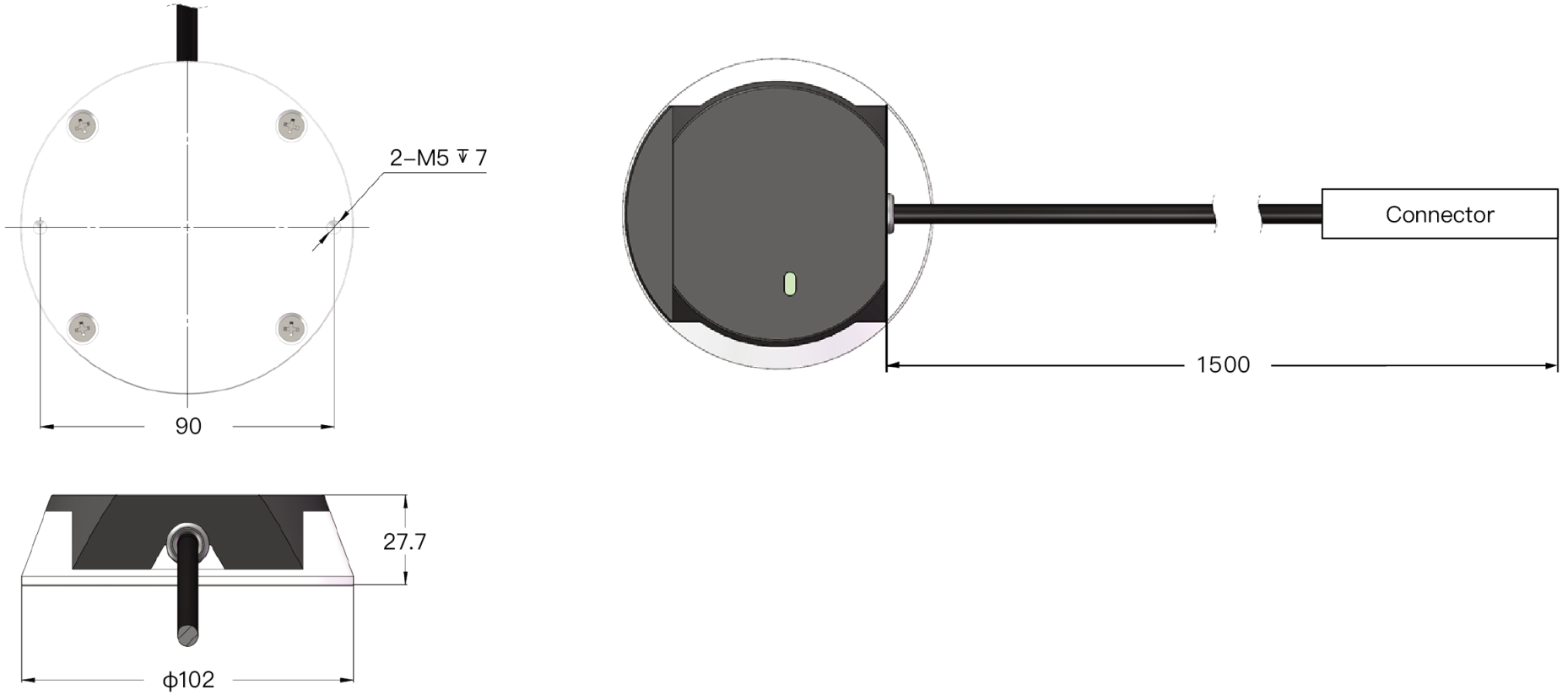


Figure 2.6 Connection Box (Unit: mm)

2.3.1 Connection Box Interfaces

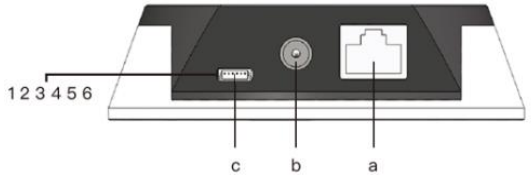


Figure 2.7 Connection Box (Front)

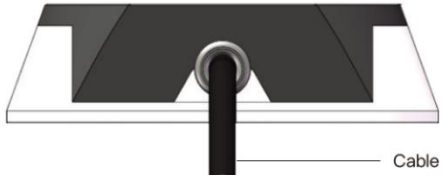


Figure 2.8 Connection Box (Back)

Port #	Port Name	Description
a	Standard Ethernet Port	RJ45, 100 Mbps Ethernet
b	Power Port	Connects to a DC power adapter External power supply: 9 V to 36 V, at least 30 W Port size: Φ6.3 mm (external), Φ2 mm (internal)
c	GPS Port	Connector type: JST SM06B-SRSS-TB Recommended connector for the external GPS module: JST SHR-06V-S-B Voltage standard: RS232 Baud rate: 9600 bps

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

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

2.3.2 Connection

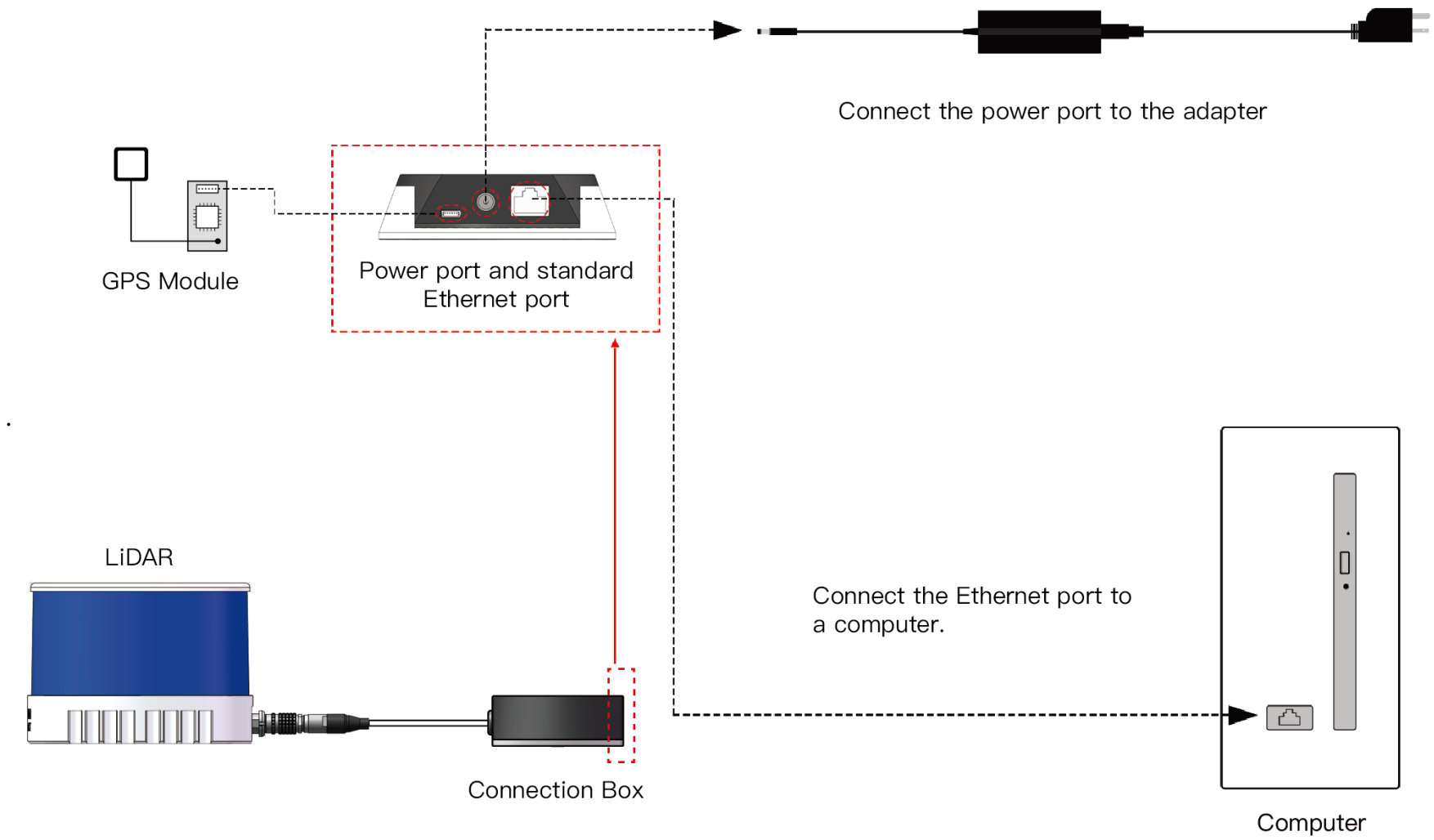


Figure 2.9 Connection Box - Connection

NOTE Refer to Appendix III when PTP protocol is used.

2.4 Get Ready to Use

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

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

For Ubuntu:	For Windows:
Use the 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" interface, 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 Chapter 5 (PandarView)

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

The SDKs (Software Development Kits) are published on Hesai's official GitHub page. Please find the download links at:
www.hesaitech.com/en/download (Product Documentation → select product model)

3 Data Structure

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

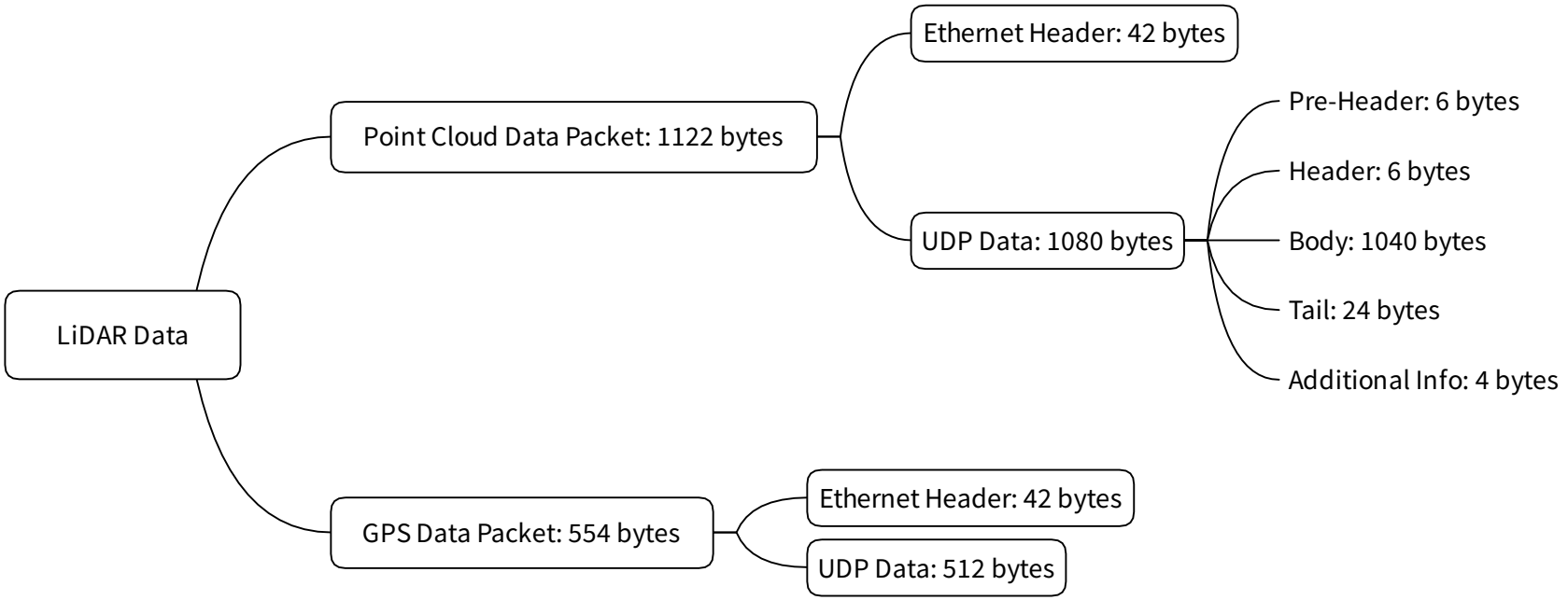


Figure 3.1 Data Structure with UDP Sequence OFF

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 0xFF FF FF FF (broadcast).

Point Cloud Ethernet Header: 42 bytes		
Field	Bytes	Description
Ethernet II MAC	12 bytes	Destination: broadcast (0xFF: 0xFF: 0xFF: 0xFF: 0xFF: 0xFF) Source: (xx:xx:xx:xx:xx:xx)
Ethernet Data Packet Type	2 bytes	0x08, 0x00
Internet Protocol	20 bytes	Shown in Figure 3.2
UDP Port Number	4 bytes	UDP source port (0x2710, representing 10000) Destination port (0x0940, representing 2368)
UDP Length	2 bytes	0x0440, representing 1088 bytes (8 bytes more than the size of the Point Cloud UDP Data, shown in Figure 3.1)
UDP Checksum	2 bytes	-

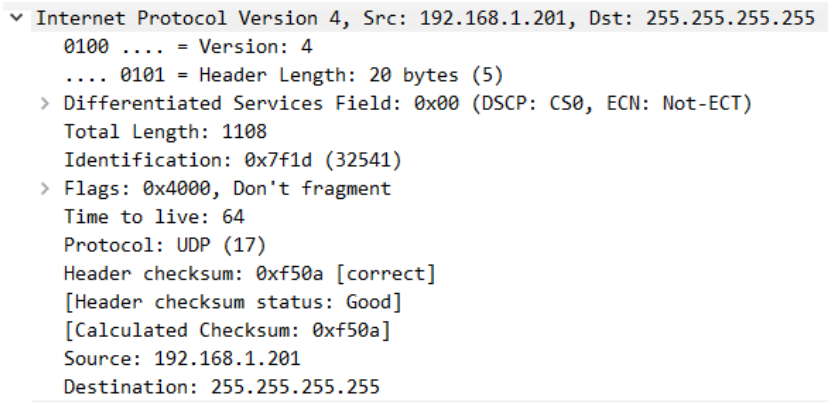


Figure 3.2 Point Cloud Ethernet Header - Internet Protocol

3.1.2 UDP Data

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

■ **Pre-Header**

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 0x06 for the PandarXT series
Protocol Version Minor	1	For each product model, to indicate the current protocol version Currently 0x01 for the PandarXT series
Reserved	2	-

■ Header

Header: 6 bytes		
Field	Bytes	Description
Laser Num	1	0x20 (32 channels)
Block Num	1	0x08 (8 blocks per packet)
Echo Count	1	The first block in this data packet 0x00 - Single Return 0x01 - Last Return in Dual Return mode 0x02 - Strongest Return in Dual Return mode
Dis Unit	1	0x04 (4 mm)
Echo Num	1	Number of returns (i.e. echoes) 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 0 - UDP sequence OFF 1 - UDP sequence ON **NOTE** Always 0x01 for the PandarXT series

■ Body

Body: 1040 bytes (8 blocks)				
Block 1	**Block 2**	**Block 3**	**...**	**Block 8**
Azimuth 1	Azimuth 2	Azimuth 3	...	Azimuth 8
Channel 1	Channel 1	Channel 1	...	Channel 1
Channel 2	Channel 2	Channel 2	...	Channel 2
...	...	...	...	...
Channel 32	Channel 32	Channel 32	...	Channel 32

Under the Dual Return mode, the ranging data from each firing is stored in two adjacent blocks:

- The odd number block is the last return, and the even number block is the strongest return
- If the last and strongest returns coincide, the second strongest return will be placed in the even number block
- The Azimuth changes every two blocks

Block size = Size of Azimuth + 32 * Size of Channel X = 130 bytes

Each Block in the Body: 130 bytes			
Field	Bytes	Description	
Azimuth	2	Current reference angle of the rotor Azimuth[15:0]: lower byte Azimuth_L[7:0], upper byte Azimuth_H[15:8]. Azimuth Angle = [Azimuth_H, Azimuth_L] / 100° = Azimuth / 100°	
Channel X	4	2-byte Distance	Distance[15:0]: lower byte Distance_L[7:0], upper byte Distance_H[15:8] Distance Value = [Distance_H, Distance_L] * 4 mm = Distance * 4 Maximum Distance Value = (2 ^ 16 - 1) * 4 mm = 262.14 m
		1-byte Reflectivity	Reflectivity, in percentage (0 to 255%)
		Reserved	-

■ Tail

Tail: 24 bytes		
Field	Bytes	Description
Reserved	9	-
High Temperature Shutdown Flag	1	0x01 for high temperature; 0x00 for normal operation ・ When high temperature is detected, the shutdown flag will be set to 0x01, and the system will shut down after 60 s. The flag remains 0x01 during the 60 s and the shutdown period ・ When the system is no longer in high temperature status, the shutdown flag will be reset to 0x00 and the system will automatically return to normal operation
Return Mode	1	0x37 for Strongest Return mode, 0x38 for Last Return mode, and 0x39 for Dual Return mode
Motor Speed	2	speed_2_bytes [15:0] = speed (RPM)
Date & Time	6	Year (current year minus 1900), month, date, hour, minute, second Binary, 1 byte each
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)
Factory Information	1	0x42

■ Additional Info

Additional Info: 4 bytes		
Field	Bytes	Description
UDP Sequence	4	Sequence number of this UDP packet 1 to 0xFF FF FF FF in little endian format

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 PandarXT's Channel 5 in Block 2 as an example:

1) Vertical angle of Channel 5 is 11°, according to Appendix I (Channel Distribution)

NOTE The accurate vertical angle is recorded in this LiDAR's unit's calibration file
Users can obtain the calibration file by sending the TCP command PTC_COMMAND_GET_LIDAR_CALIBRATION, as described in Hesai TCP API Protocol (see Chapter 6)

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

- Current reference angle of the rotor: Azimuth field of Block 2
- Horizontal angle offset: 0° for Channel 5, according to Appendix I (Channel Distribution)
- Firing time offset = Laser Firing Time 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

NOTE The accurate horizontal angle is recorded in this LiDAR's unit's calibration file

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

■ **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 a frame**

3.2 GPS Data Packet

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

Before NMEA messages are available from the external GPS module

Each rising edge of the LiDAR's internal 1 Hz signal triggers a GPS Data Packet.
The time and date in the GPS Data Packets are unreal, starting from 00 01 01 00 00 00 (year, month, day, hour, minute, second) and increasing with the internal 1 Hz signal.

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

The internal 1 Hz signal will be locked to the PPS. Each rising edge still triggers a GPS Data Packet.
Meanwhile, the LiDAR will extract the actual date and time from NMEA messages ($GPRMC or $GPGGA), and stamp them into both Point Cloud Data Packets and GPS Data Packets.

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

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

When GPS signal is lost

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

3.2.1 Ethernet Header

The source IP is 192.168.1.201 by default. The destination IP address is 255.255.255.255 and in broadcast form.

GPS 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, represents 10000) Destination port (0x277E, represents 10110)
UDP Length	2	0x208, representing 520 bytes (8 bytes more than the size of the GPS UDP Data, shown in Figure 3.1)
UDP Checksum	2	-

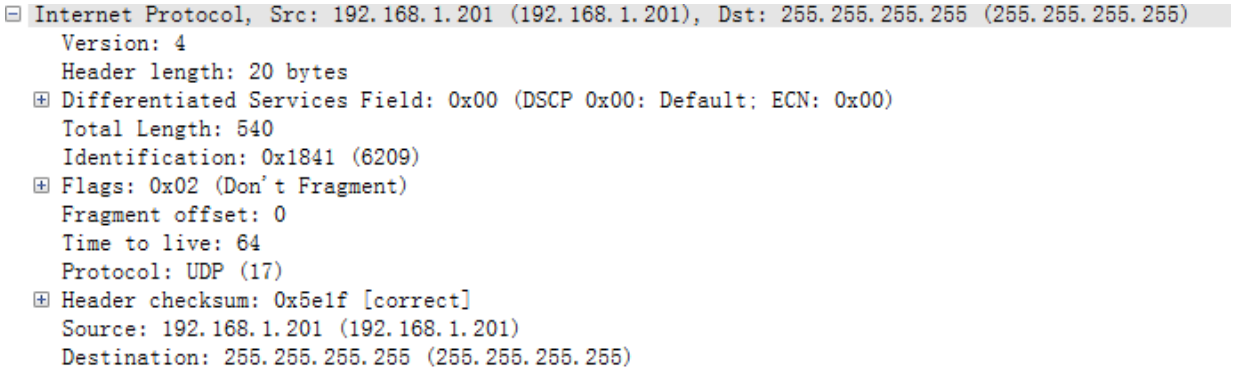


Figure 3.3 GPS Ethernet Header - Internet Protocol

3.2.2 UDP Data

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

■ GPRMC Data Format

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

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

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

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

For example, the following two formats are both acceptable:

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

■ GPGGA Data Format

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

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

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

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

For example, the following two formats are both acceptable:

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

3.2.3 GPS Data Analysis

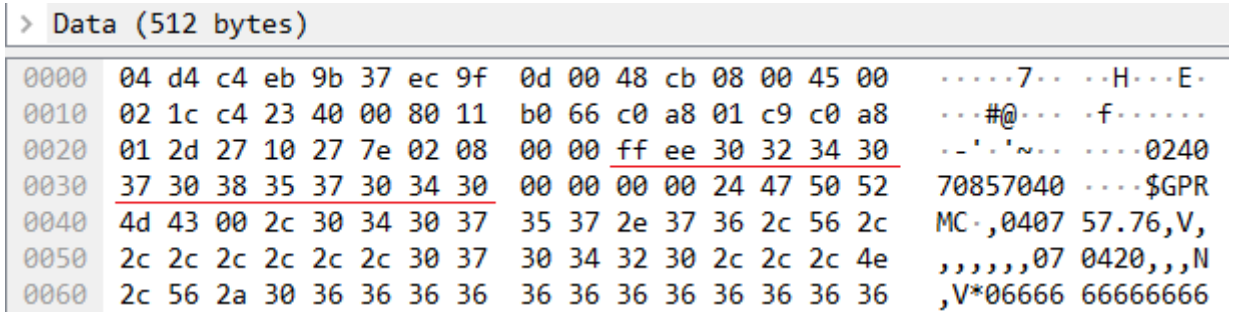


Figure 3.4 GPS Data Packet - UDP Data (Example)

Date

Field	Data (ASCII Code)	Characters	Meaning
Year	0x30 0x32	'0', '2'	20
Month	0x34 0x30	'4', '0'	04
Day	0x37 0x30	'7', '0'	07

Time

Field	Data (ASCII Code)	Characters	Meaning
Second	0x38 0x35	'8', '5'	58
Minute	0x37 0x30	'7', '0'	07
Hour	0x34 0x30	'4', '0'	04

µs Time

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

Reset to 0 at the rising edge of each PPS signal

4 Web Control

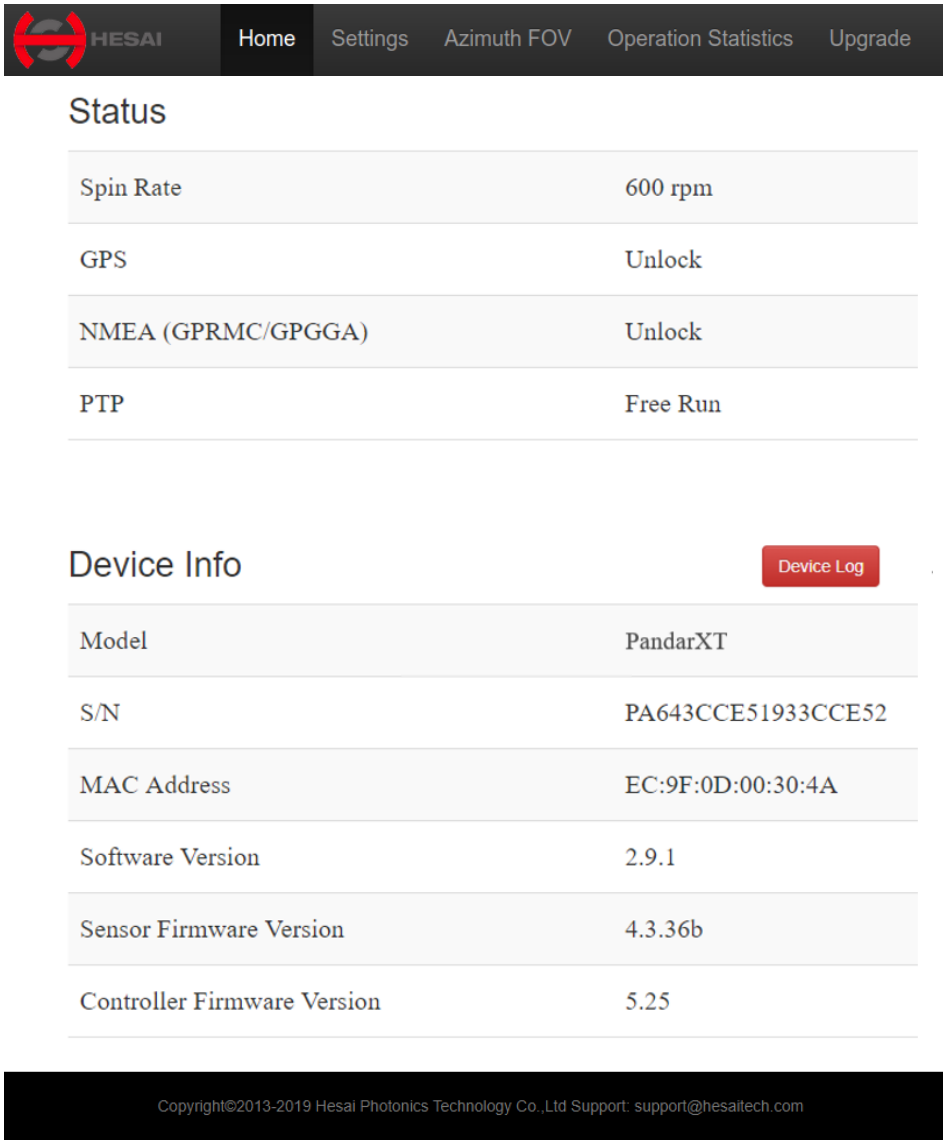
Web control is used for setting parameters, checking device info, and upgrading.

To access web control

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

NOTE Google Chrome or Firefox is recommended.

4.1 Home



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

GPS (PPS) Status

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

NMEA (GPRMC/GPGGA) Status

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

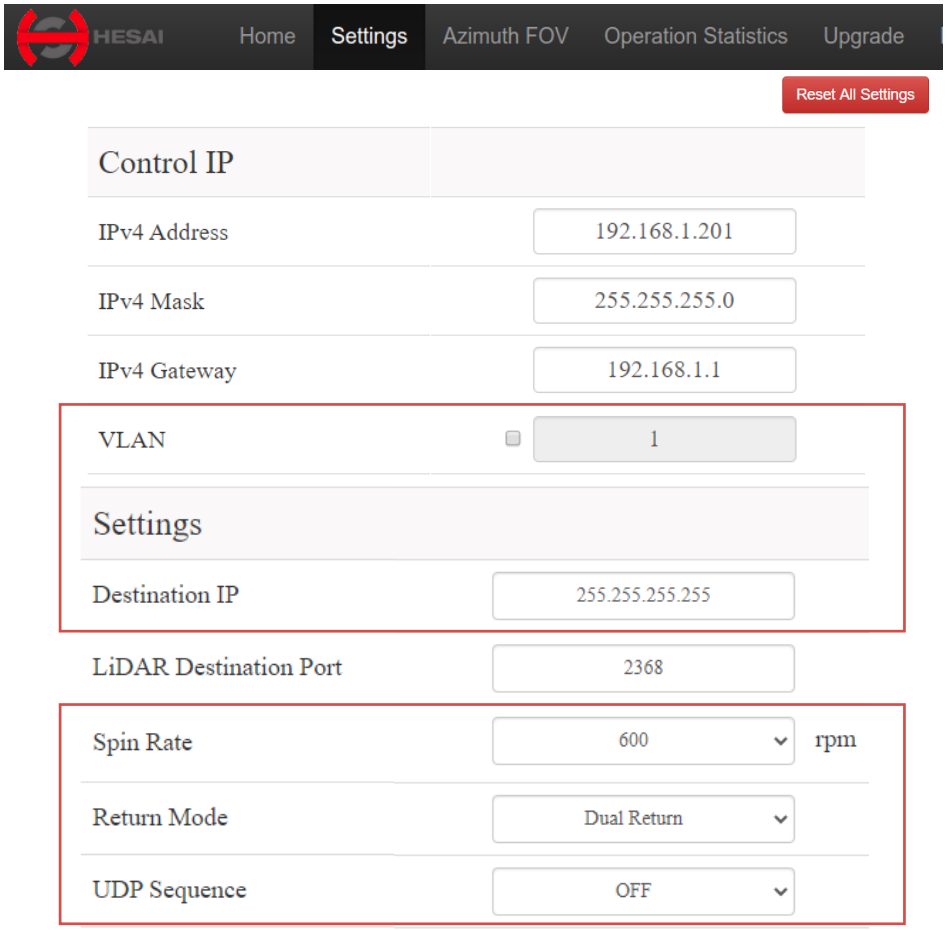
PTP Status

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

Device Log

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

4.2 Settings



(Continued on the next page)

1. Control IP

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

- Check the VLAN checkbox and input a VLAN ID (1~4094)
- Set the VLAN ID of the receiving host to be the same

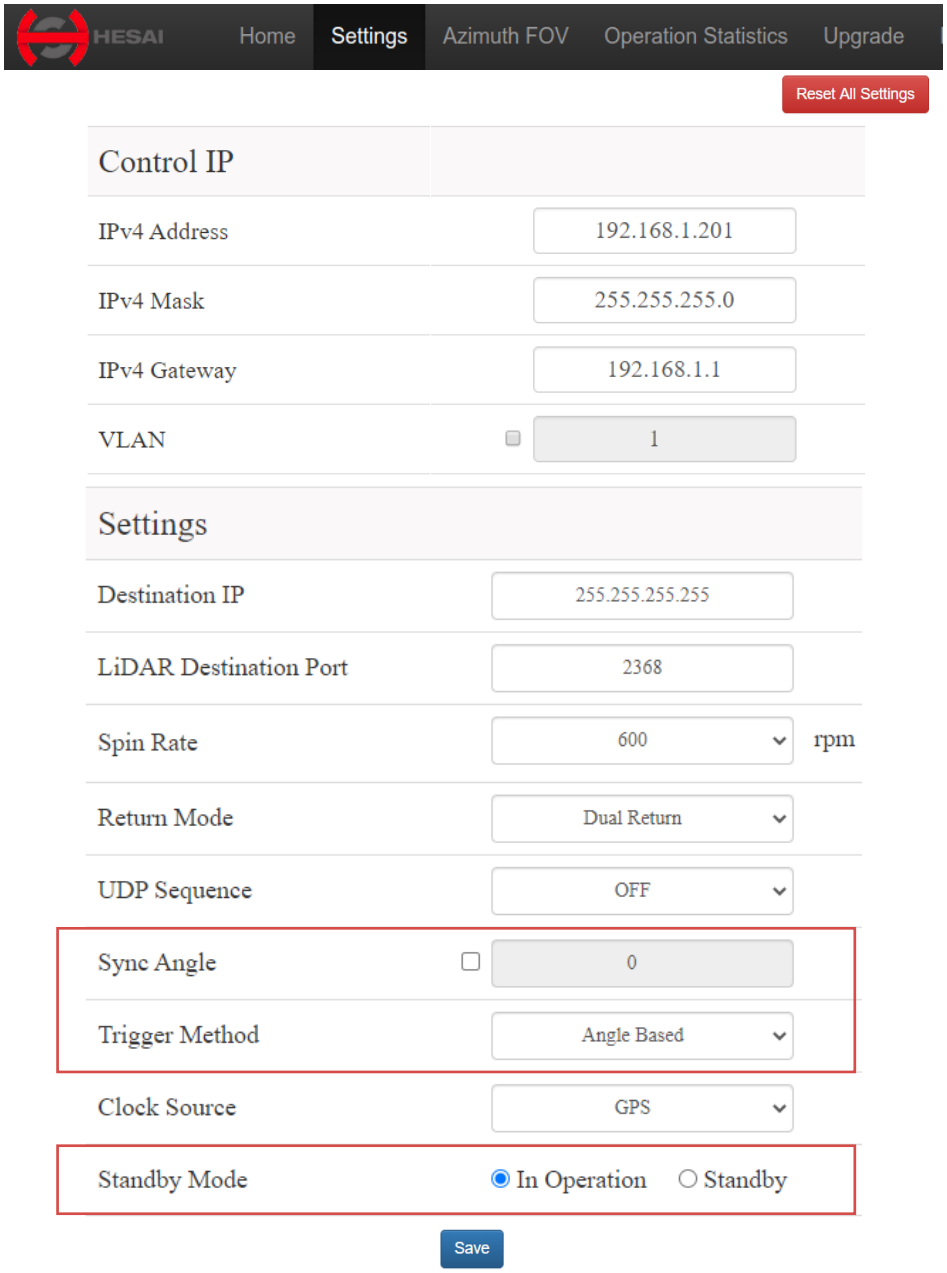
2. Destination IP

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

3. LiDAR Functions

Spin Rate	600 rpm / 1200 rpm
Return Mode	Last / Strongest / Dual Return
UDP Sequence	OFF / ON #1 / ON #2
	Point Cloud UDP packets can be labeled with a sequence number, see Section 3.1. **ON #1**: UDP sequence increments only when UDP packets are generated. **ON #2**: UDP sequence increments even though no UDP packet is generated outside the user-specified azimuth FOV.

(continued on the next page)



(continued)

Sync Angle	0~360 degrees By default, the LiDAR's 0° position (see Section 1.2) is not in sync with PPS. If syncing is needed, check the check box and input a sync angle.
Trigger Method	Angle-Based / Time-Based **Angle-based**: lasers fire every 0.2° at 10 Hz or 0.4° at 20 Hz. **Time-based**: lasers fire every 55.56 us.
Standby Mode	Whether to stop the motor from running and lasers from firing

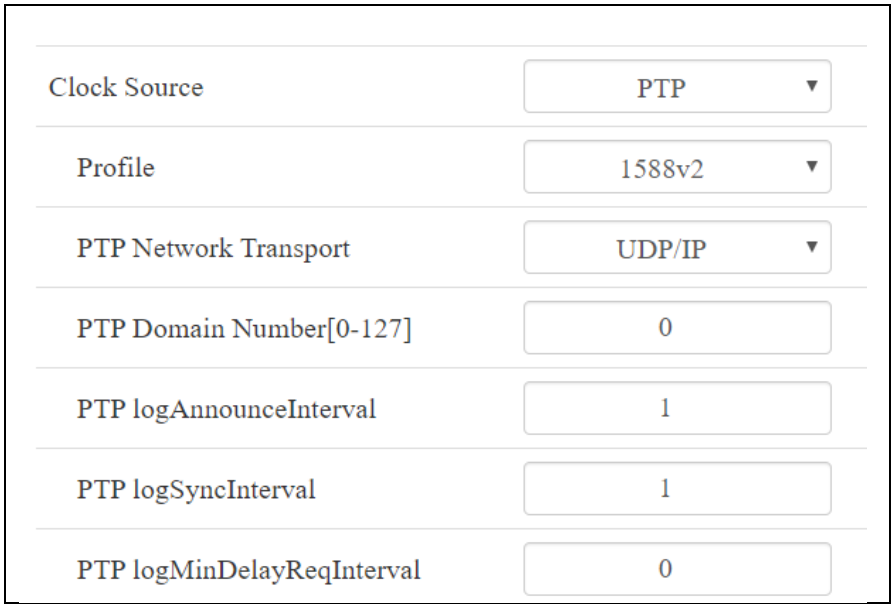
4. Reset All Settings

By clicking the "Reset All Settings" button on the top-right corner, all configurable parameters in the Settings page and the Azimuth FOV page will be reset to factory defaults.

The default values are shown in the left-hand screenshot and in Section 4.3.1.

5. Clock Source and PTP Parameters

Clock Source	GPS / PTP
	In PTP mode, LiDARs do not output GPS Data Packets (see Appendix III)



- When GPS is selected as the clock source:

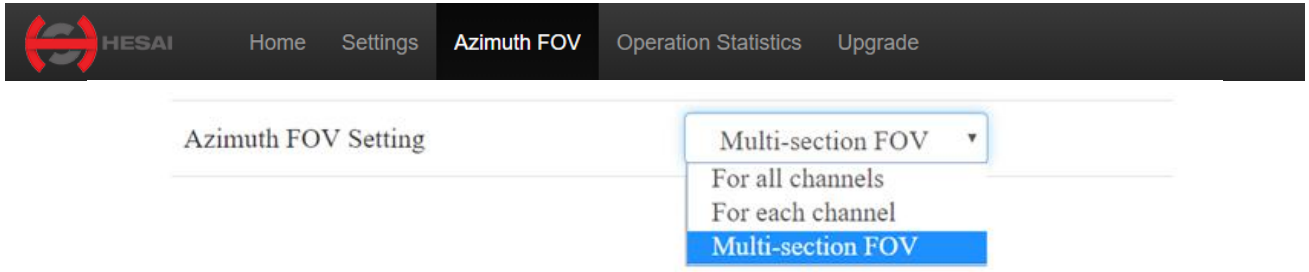
GPS Mode	GPRMC / GPGGA
	Format of NMEA data received from the external GPS module, see Section 3.2.2
Destination Port	10110 (default)
	Port used for sending GPS Data packets

- When PTP is selected as the clock source:

Profile	1588v2 (default) or 802.1AS
	IEEE timing and synchronization standard
PTP Network Transport	UDP/IP (default) or L2
	UDP/IP: using PTPv2 (IEEE 1588-2008) L2: using gPTP (IEEE 802.1 AS)
PTP Domain Number	Integer from 0 to 127
	Domain attribute of the local clock
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

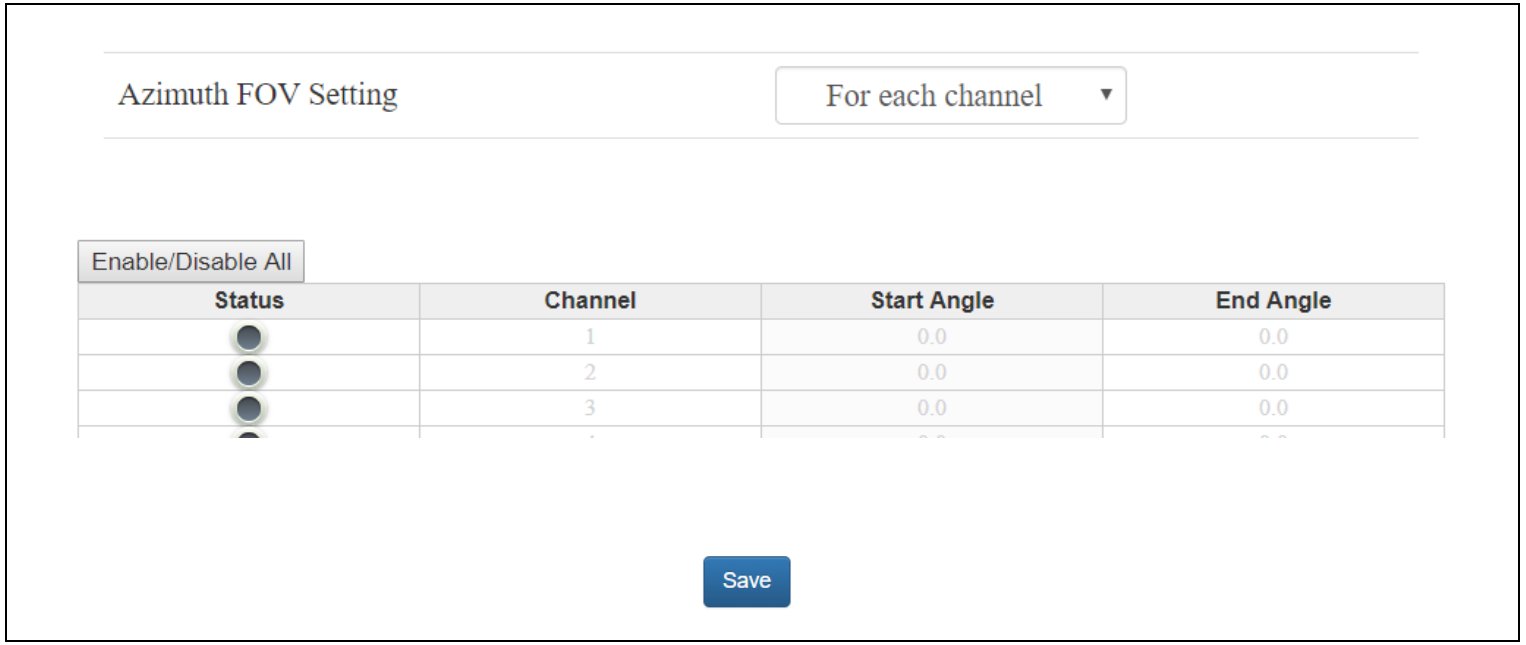
A continuous angle range, specified by a Start Angle and an End Angle, will be applied to all the channels.
Outside the specified angle range, there will be no laser firing or data generated.

4.3.2 For each channel

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

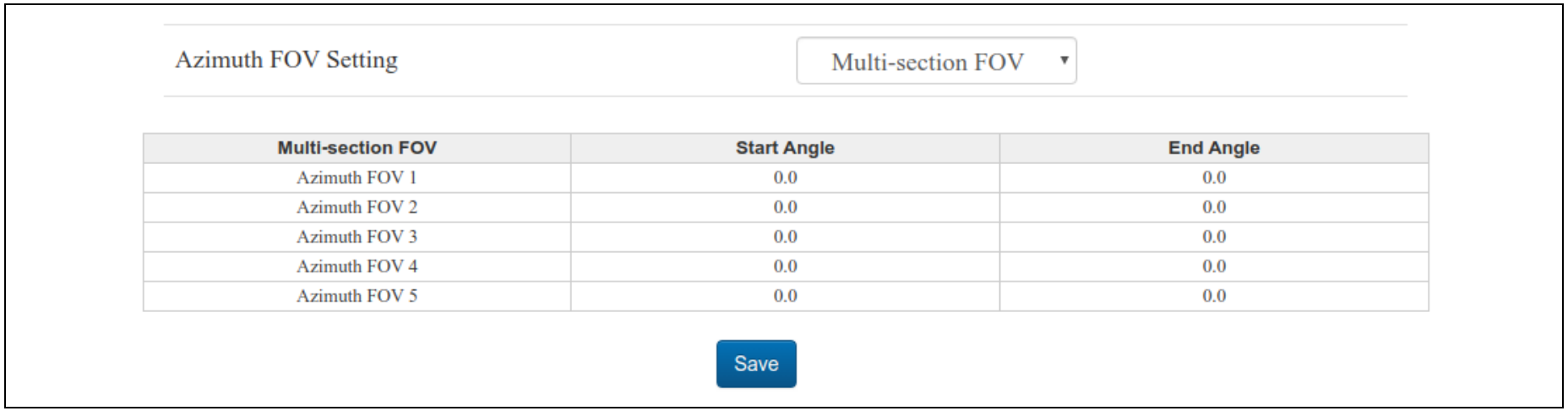
The "Status" button for each channel is gray by default, indicating that the angle range is [0°, 360°].
To activate the angle range configuration for each channel, click the corresponding button to make it green.

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 for all channels.
Outside the specified ranges, there will be no laser firing or data generated.



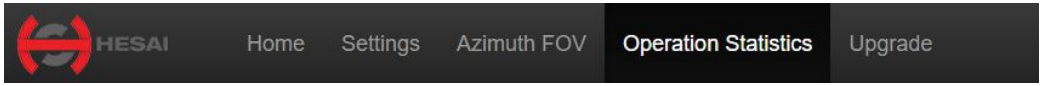
4.3.4 Note

- 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.

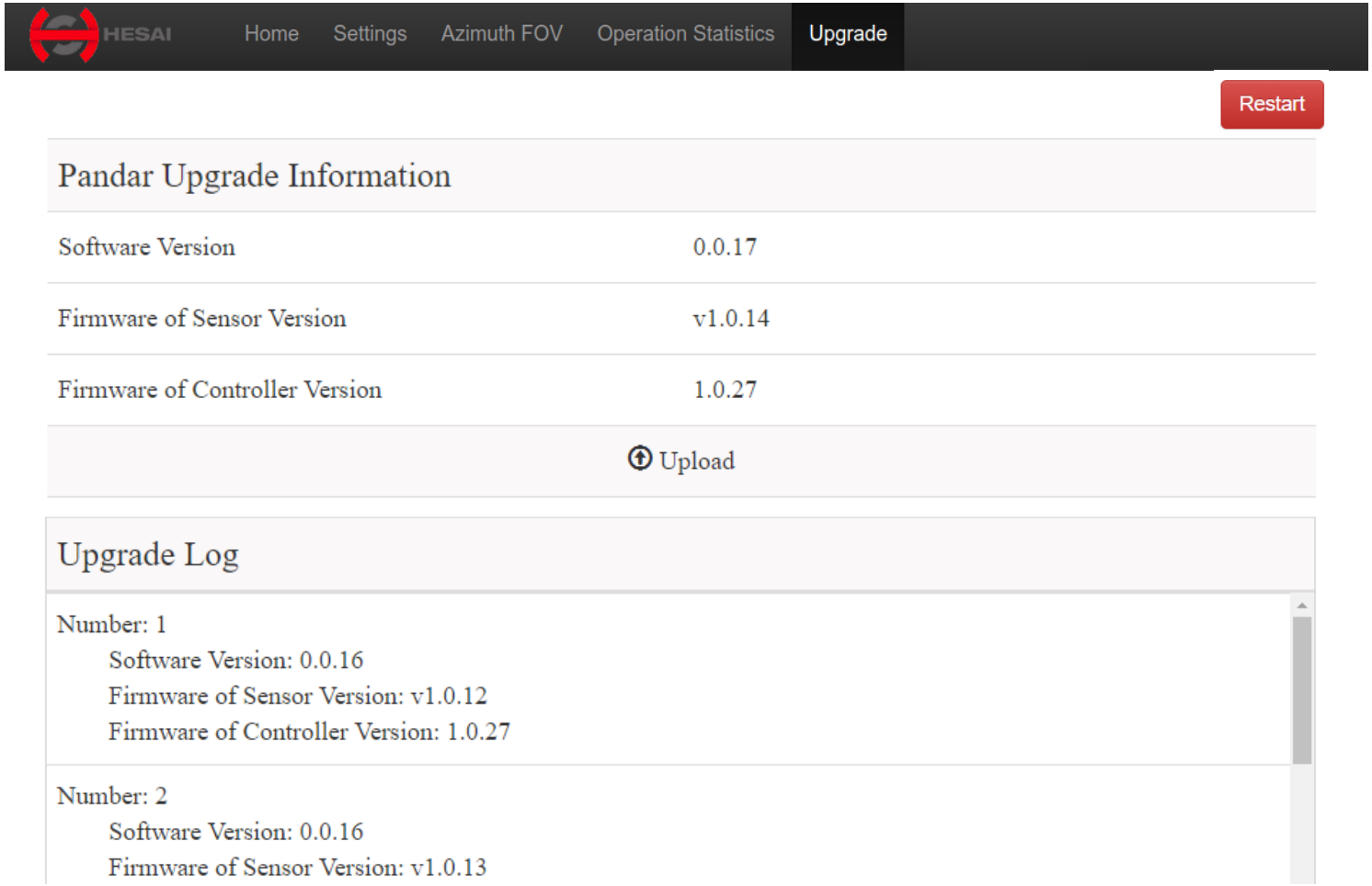


Start-up Counts	462
Internal Temperature	46.72℃
System Uptime	0 h 14 min
Total Operation Time	40 h 17 min

Internal Temperature	Operation Time
< -40 ℃	0 h 0 min
-40 ~ -20 ℃	0 h 0 min
-20 ~ 0 ℃	0 h 0 min
0 ~ 20 ℃	0 h 1 min
20 ~ 40 ℃	0 h 43 min
40 ~ 60 ℃	34 h 33 min
60 ~ 80 ℃	0 h 24 min

4.5 Upgrade

The screenshot below shows the software and firmware versions described in this manual. 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.

5 PandarView

PandarView is a software that records and displays point cloud data from Hesai LiDARs, available in 64-bit Windows 7/8/10 and Ubuntu-16.04/18.04

5.1 Installation

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

System	Installation Files	Installation Steps
Windows	PandarViewX64_Release_V1.7.6.msi python-2.7.13.msi **NOTE** Separate Python installation is required only for PandarView versions earlier than v1.6.9.	When upgrading PandarView to a newer version, please uninstall the current version
		Double click and install python Use default settings in the setup wizard, including "install for all users"
		Double click and install PandarView_Windows using the default settings
Ubuntu-16.04	PandarViewX64_Release_V1.7.6.tar.gz	Unzip the file and run PandarView_Installer.bin
Ubuntu-18.04	PandarViewX64_18.04_Release_V1.7.6.tar.gz	

This manual describes PandarView 1.7.6. The menu bar and buttons are shown below.

NOTE Users can check the software version from "About" in the menu bar.

5.2 Use

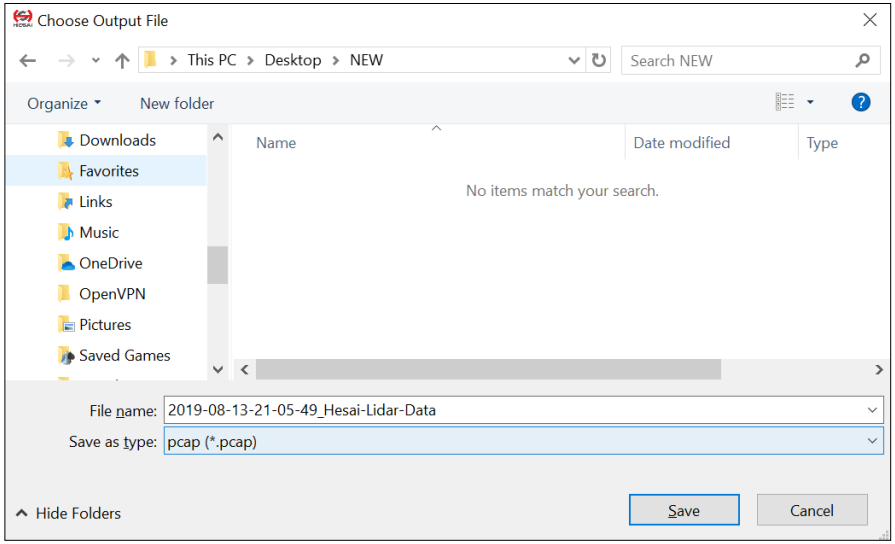
Set the PC's IP address according to Section 2.4 (Get Ready to Use)

■ Check Live Data

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

■ Record a PCAP File

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



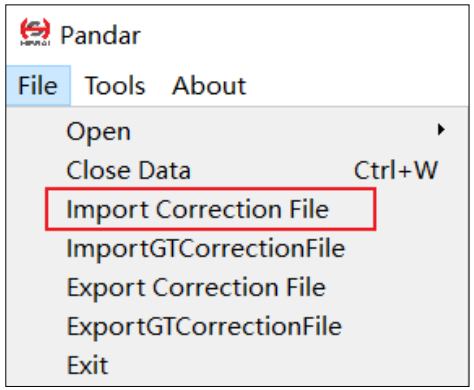
■ Open a PCAP File

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

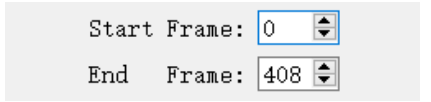
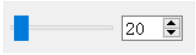
■ Import a Correction File

Each LiDAR contains a correction file in .CSV format. When opening a PCAP file in PandarView, the correction file is automatically uploaded.

In case the correction file is lost, click on "File" in the menu bar and "Import Correction File".



■ Play a PCAP File

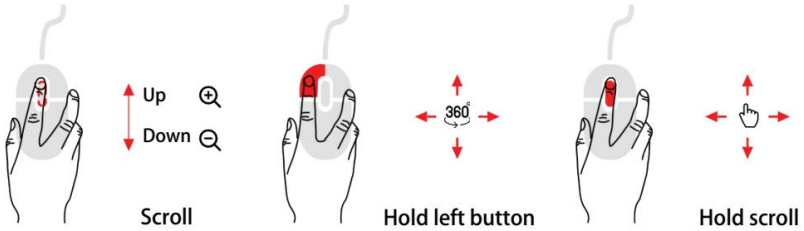
Button	Description
	Jump to the beginning of the file
	While paused, jump to the previous frame While playing, rewind. May click again to adjust the rewind speed (2x, 3x, 1/2x, 1/4x, and 1x) 
	After loading a point cloud file, click to play the file While playing, click to pause
	While paused, jump to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

5.3 Features

■ Viewpoint Selection

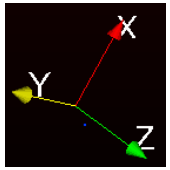
Users can select from the right view, front view, and top view.

■ Mouse Shortcuts



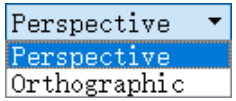
- Slide the scroll wheel up/down to magnify/minimize
- Drag while holding the left button to adjust the point of view
- Drag while holding the scroll wheel to pan

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



■ 3D Projection and Distance Measurement

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

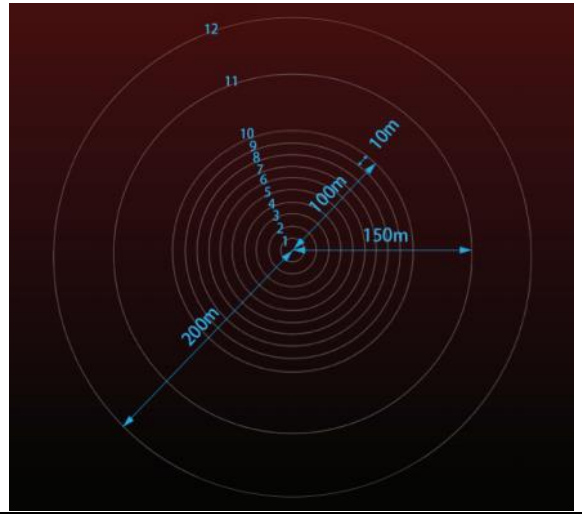


The distance ruler is available only under orthographic projection. After clicking on , drag your mouse while holding the Ctrl key to make a measurement in units of meters. Click on again to quit.

■ Distance Reference Circles

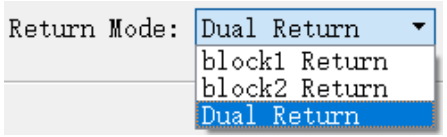
Click on to show/hide the 12 distance reference circles in gray. The actual distances are marked below.

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



■ Return Mode

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



■ UDP Port

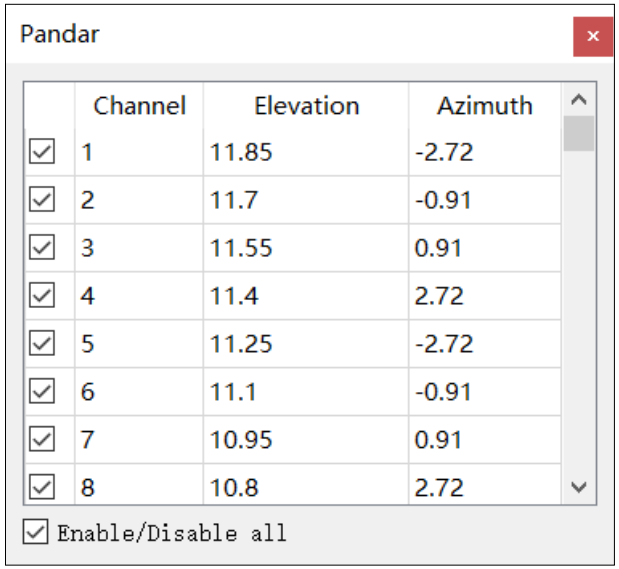
Enter the UDP port number, and click "Set" to apply it.

■ Channel Selection

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

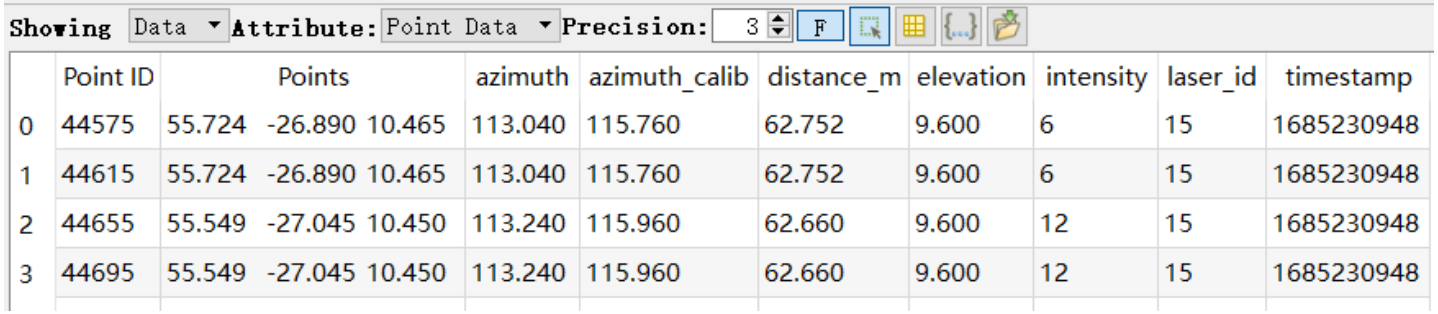
Check/Uncheck the boxes on the left to show/hide each channel.

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



■ Point Selection and Data Table

Click on  and drag the mouse over the point cloud to highlight an area of points.
Click on  to view the data of the highlighted points, as shown below.



Showing Data Attribute: Point Data Precision: 3 F

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

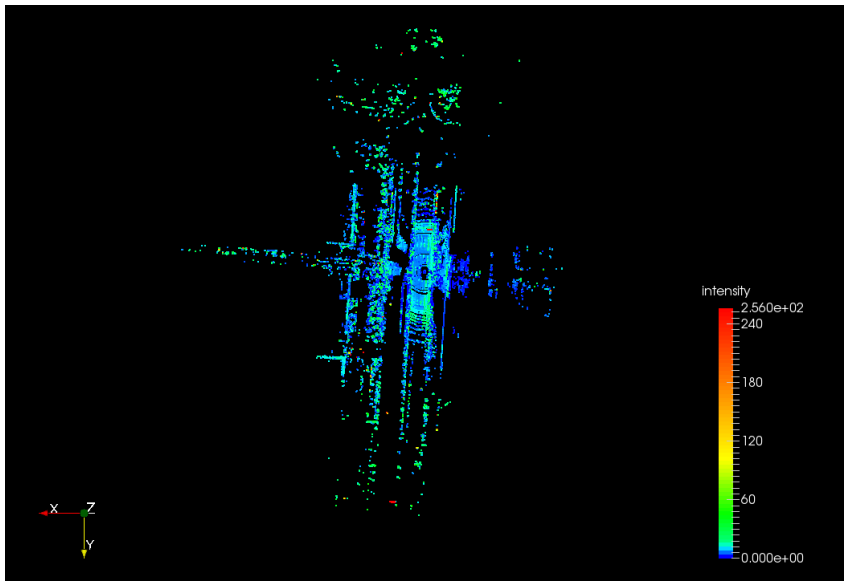
Some of the data fields are defined below:

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

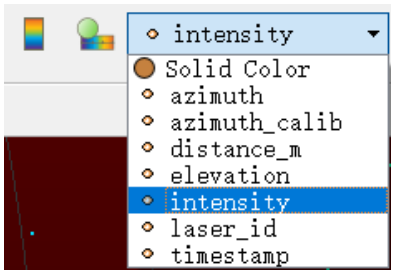
To cancel the selection, click on  again and click on any place outside the selected area.

■ Color Schemes

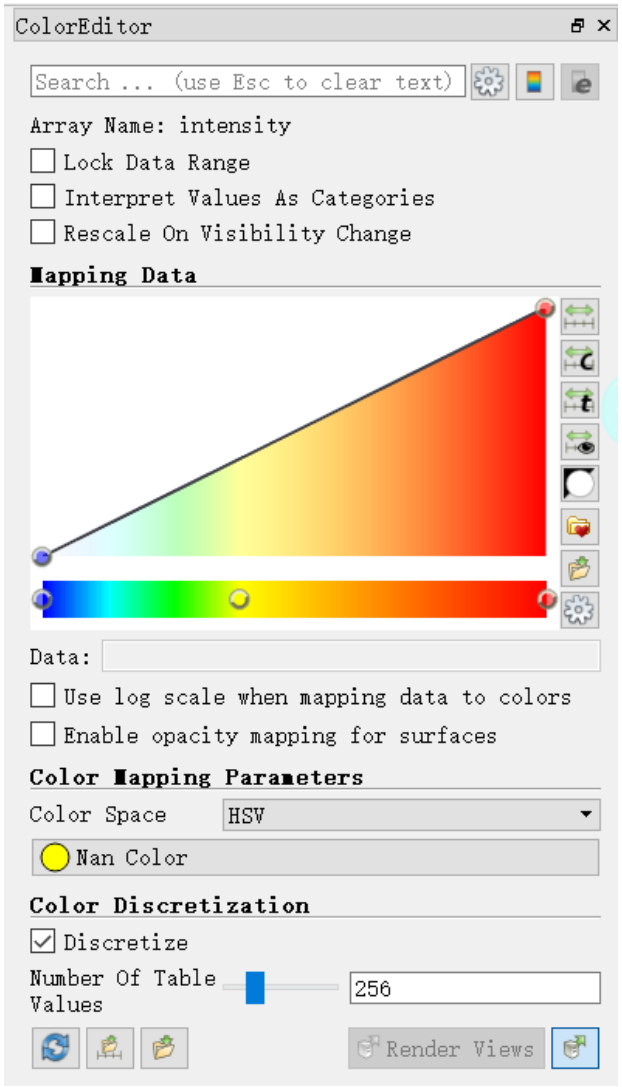
Click on to show the color legend at the lower right corner.



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



Click on  to open or close the Color Editor.



6 Communication Protocol

Please find Hesai LiDAR's TCP and HTTP API Protocols:

- in the USB disk (provided for certain product models), or
- at https://www.hesaitech.com/en/download

7 Sensor Maintenance

■ Storage

Store the device in a dry, well ventilated place. The ambient temperature shall be between -40°C and +105°C, and the humidity below 85%.
Please check the specifications page in this user manual for product IP rating, and avoid any ingress beyond that rating.

■ Transport

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

■ Cleaning

Stains on the device's enclosure, such as dirt, fingerprints, and oil, can negatively affect the point cloud data quality.
Please perform the follow steps to remove the stains.

NOTE

- To avoid damaging the optical coating, DO NOT apply pressure when wiping the enclosure
- Only clean the stained area of the enclosure
- 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 enclosure, 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

(Continued on the next page)

(Continued)

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

Solvent type	99% isopropyl alcohol (IPA) or 99% ethanol (absolute alcohol) or distilled water
Solvent temperature	40 to 60 °C

4) When the stains have loosened, dip a piece of lint-free wipe into the solvent made in Step 3, and gently wipe the enclosure 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 enclosure with clean water, and gently wipe off the remaining liquid with another piece of lint-free wipe

8 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 ・ the power adapter is properly connected and in good condition ・ the connection box is intact
Motor is not running	Same as above
Motor is running but no output data received, neither on Wireshark nor PandarView	Verify that ・ the Ethernet cable is properly connected ・ the LiDAR's IP is in the same subnet with the PC's ・ the horizontal FOV is properly set on the Azimuth FOV page of web control ・ the firmware version of the sensor is shown on the Upgrade page of web control. If the version is shown as "xxxx", contact Hesai for further diagnostics
Can receive data on Wireshark but not on PandarView	Verify that ・ the Destination IP and the Destination LiDAR Port are correctly set on the Settings page of web control ・ the PC's firewall is disabled, or that PandarView is added to the firewall exceptions
Cannot open web control	Verify that ・ the Ethernet cable is properly connected ・ the 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 the PC, or connect the LiDAR to another PC

(Continued on the next page)

(Continued)

Symptoms	Points to Check
Abnormal packet size (missing packets)	Check whether ・ the horizontal FOV has been changed on the Azimuth FOV page of web control ・ the Ethernet is overloaded ・ a 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
Abnormal point cloud (misaligned points, flashing points, or incomplete FOV)	Verify that ・ the LiDAR's enclosure is clean. If not, refer to Chapter 7 (Sensor Maintenance) for the cleaning method ・ the LiDAR's calibration file is imported Afterwards, check for packet loss ・ If no packet is missing while the point cloud flashes, please update PandarView to the latest version and restart the PC ・ If problem persists, try connecting the LiDAR to another PC
GPS cannot be locked	Verify that ・ the GPS receiver is properly connected ・ the PPS signal is connected to the LiDAR ・ the Destination GPS Port is correct on the Settings page of web control ・ the input GPS signals satisfy the electrical requirements in Section 2.2 (Interface) and Section 2.3.1 (Connection Box) in this user manual

Appendix I Channel Distribution

■ Horizontal Angle

Each channel's horizontal angle = current reference angle of the rotor + horizontal angle offset

- The current reference angle of the rotor is the Azimuth field in the Body of Point Cloud UDP Data
- Horizontal angle offset: listed in the table below
- Define clockwise in the top view as positive

■ Vertical Angle

Each channel's vertical angle is a constant, listed in the table below

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

NOTE

The Horizontal Angle (Azimuth) Offset and Vertical Angle (Elevation) in the table next page are design values.

The accurate values are recorded in this LiDAR's unit's calibration file. Users can obtain the calibration file by sending the TCP command PTC_COMMAND_GET_LIDAR_CALIBRATION, as described in Hesai TCP API Protocol (see Chapter 6)

PandarXT Channel Distribution (To Be Continued)

Channel # in UDP Data	Horizontal Angle (Azimuth) Offset	Vertical Angle (Elevation)	Instrument Range (in meters)	Range (in meters) with Reflectivity
01 (Top Beam)	0	15	120	50@10%
02	0	14	120	50@10%
03	0	13	120	50@10%
04	0	12	120	50@10%
05	0	11	120	50@10%
06	0	10	120	50@10%
07	0	9	120	50@10%
08	0	8	120	50@10%
09	0	7	120	80@10%
10	0	6	120	80@10%
11	0	5	120	80@10%
12	0	4	120	80@10%
13	0	3	120	80@10%
14	0	2	120	80@10%
15	0	1	120	80@10%
16 (Horizontal Beam)	0	0	120	80@10%
17	0	-1	120	80@10%
18	0	-2	120	80@10%
19	0	-3	120	80@10%
20	0	-4	120	80@10%

PandarXT Channel Distribution (Continued)

Channel # in UDP Data	Horizontal Angle (Azimuth) Offset	Vertical Angle (Elevation)	Instrument Range (in meters)	Range (in meters) with Reflectivity
21	0	-5	120	80@10%
22	0	-6	120	80@10%
23	0	-7	120	80@10%
24	0	-8	120	80@10%
25	0	-9	120	50@10%
26	0	-10	120	50@10%
27	0	-11	120	50@10%
28	0	-12	120	50@10%
29	0	-13	120	50@10%
30	0	-14	120	50@10%
31	0	-15	120	50@10%
32 (Bottom Beam)	0	-16	120	50@10%

Appendix II Absolute Time and Laser Firing Time

■ Absolute Time of Point Cloud Data Packets

For PandarXT, there are 8 blocks of ranging data in the Body of each Point Cloud Data Packet, as shown below.

Body: 1040 bytes (8 blocks)				
Block 1	**Block 2**	**Block 3**	**...**	**Block 8**
Azimuth 1	Azimuth 2	Azimuth 3	...	Azimuth 8
Channel 1	Channel 1	Channel 1	...	Channel 1
Channel 2	Channel 2	Channel 2	...	Channel 2
...	...	...	...	...
Channel 32	Channel 32	Channel 32	...	Channel 32

Single Return Mode

The ranging data generated by one round of firing is 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 8.

Dual Return Mode

The ranging data generated by one round of firing is stored in two adjacent blocks

- The odd number block is the last return, and the even number block is the strongest return
- If the last and strongest returns coincide, the second strongest return will be placed in the even number block
- The start time is the same for these two blocks

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 7 & 8.

Calculation

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

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

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

■ 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 8	t0 + 3.28
Block N	t0 + 3.28 - 50 * (8 - N)
Block 3	t0 + 3.28 - 50 * 5
Block 2	t0 + 3.28 - 50 * 6
Block 1	t0 + 3.28 - 50 * 7

Dual Return Mode

Block	Start Time (μs)
Block 8 & Block 7	t0 + 3.28
Block 6 & Block 5	t0 + 3.28 - 50 * 1
Block 4 & Block 3	t0 + 3.28 - 50 * 2
Block 2 & Block 1	t0 + 3.28 - 50 * 3

■ Laser Firing Time of Each Channel

In each round of firing, the firing sequence is from Channel 1 to Channel 32.

Assuming that the start time of Block 6 is t6, the laser firing time of **Channel i** is

$$t6 + (1.512 * i + 0.28),\ i \in \{1, 2, ..., 32\}.$$

Appendix III PTP Protocol

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

■ **LiDAR Connection When Using PTP**

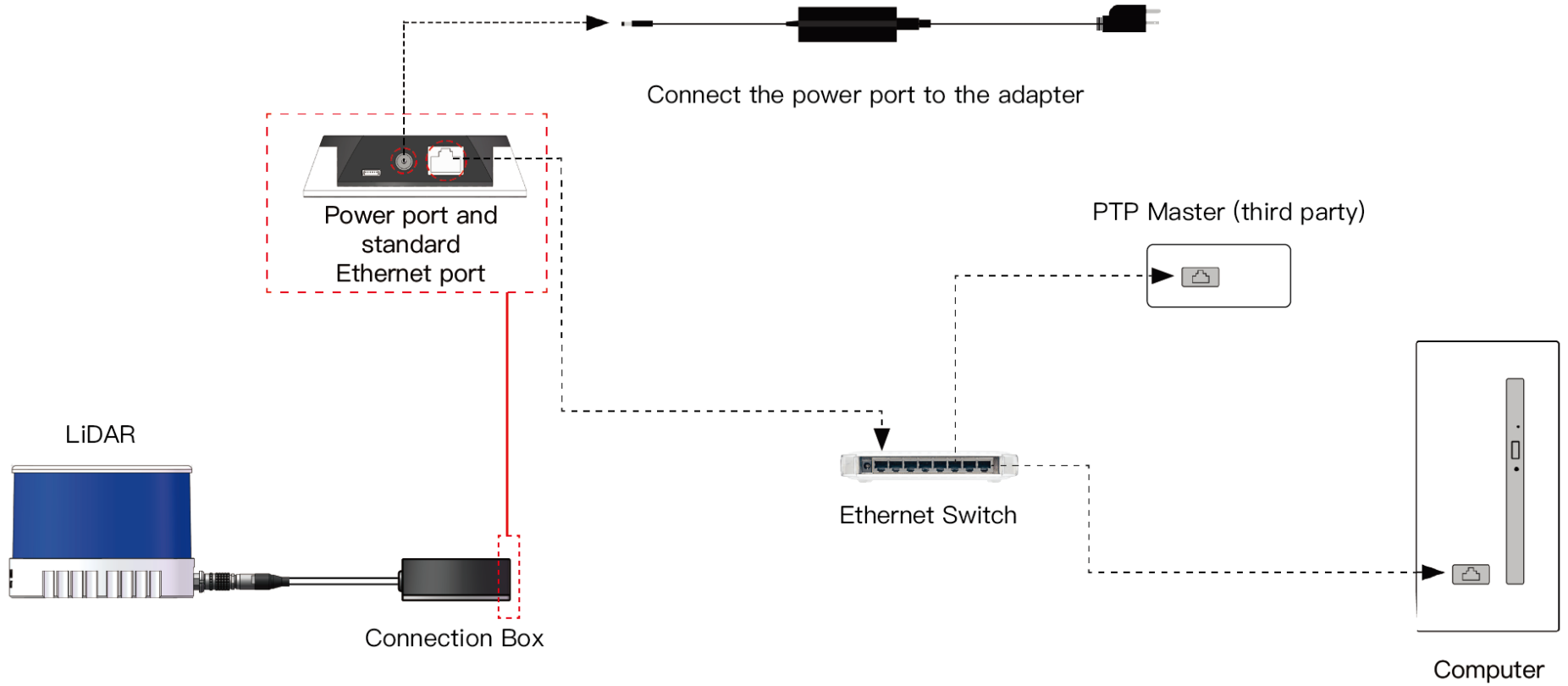


Figure III.1 Connection When Using PTP

■ Absolute Packing Time When Using PTP

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

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

NOTE

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

Appendix IV Certification Info

■ FCC Declaration

FCC ID: 2ASO2PANDARXT

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

Caution

The user is cautioned that changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Note

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
—Reorient or relocate the receiving antenna.
—Increase the separation between the equipment and receiver.
—Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
—Consult the dealer or an experienced radio/TV technician for help.

Appendix V Support and Contact

■ Technical Support

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

service@hesaitech.com
www.hesaitech.com
https://github.com/HesaiTechnology

NOTE Please leave your questions under the corresponding GitHub projects.

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