HESAI

www.hesaitech.com
640-en-2002A1

Pandar64

64-Channel Mechanical LiDAR User Manual

HESAI Wechat

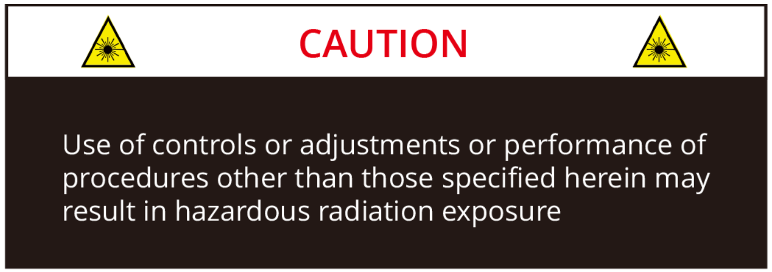
Contents

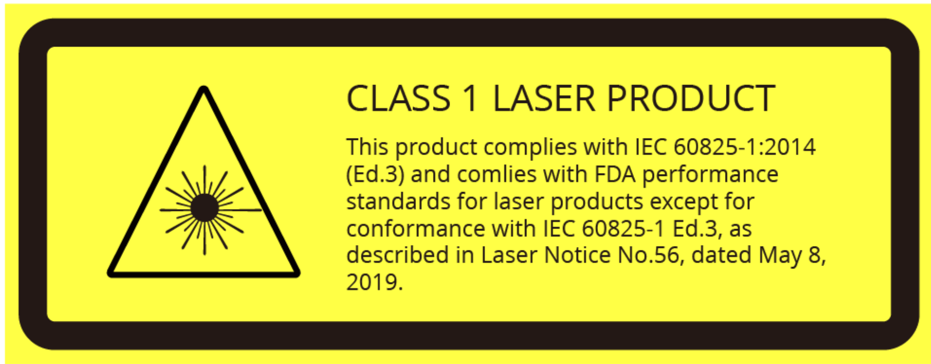
Safety Notice

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 Pandar64.

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.

$$d=\frac{1}{2}ct$$

d: Distance
c: Speed of light
t: Laser beam travel time

Figure 1.1 ToF Formula

1.2 LiDAR Structure

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

Figure 1.2 Partial Cross-Sectional Diagram

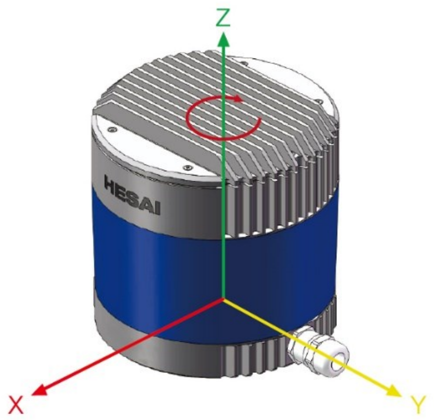


Figure 1.3 Coordinate System (Isometric View)

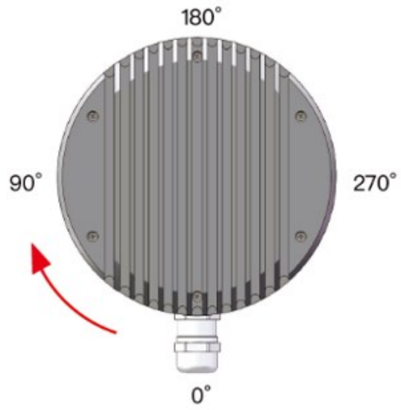


Figure 1.4 Rotation Direction (Top View)

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

Each laser channel has an intrinsic horizontal angle offset. When Channel 18 passes the zero degree position (y-axis) illustrated in Figure 1.4, the azimuth data in the corresponding UDP data block will be 0°.

1.3 Channel Distribution

The vertical resolution is

- 0.167° between Channel 6 and Channel 54
- 1° between Channel 5 and Channel 6, as well as between Channel 54 and Channel 62
- not evenly distributed in the remaining channels, as detailed in Appendix I

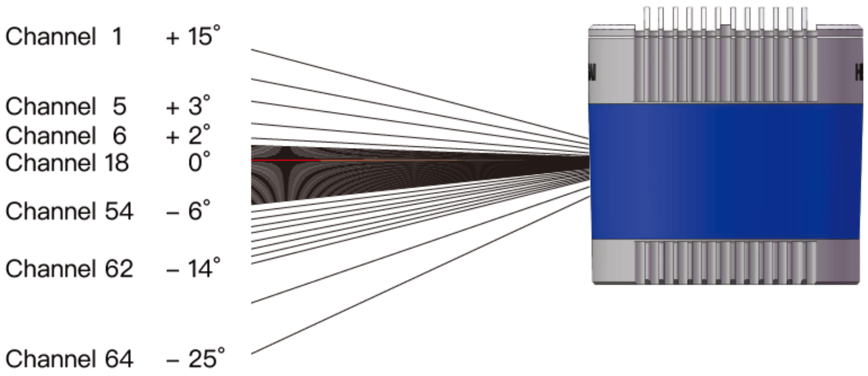


Figure 1.5 Channel Vertical Distribution

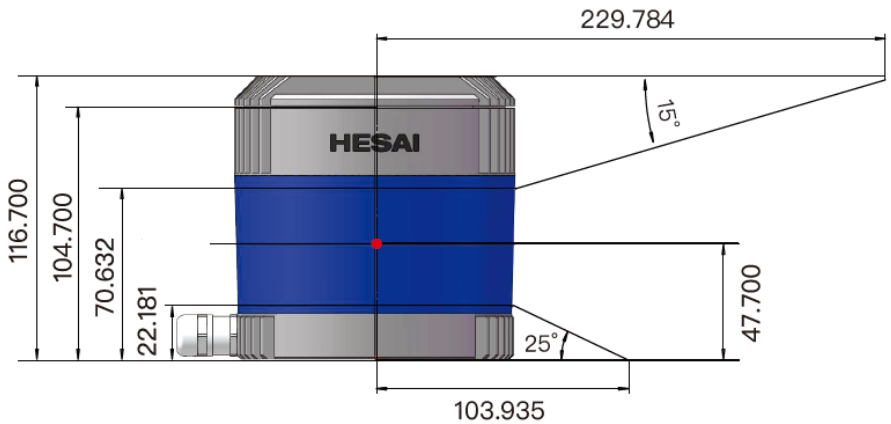


Figure 1.6 Laser Firing Position (Unit: mm)

Each channel has an intrinsic angle offset, both horizontally and vertically. The 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	64
Range	0.3 to 200 m (at 10% reflectivity)
Range Accuracy	±5 cm (0.3 to 1 m)
	±2 cm (1 to 200 m)
FOV (Horizontal)	360°
Resolution (Horizontal)	0.2° (10 Hz), 0.4° (20 Hz)
FOV (Vertical)	40° (-25° to +15°)
Resolution (Vertical)	0.167° (-6° to +2°);
	1° (+2° to +3°, -14° to -6°);
	2° (+3° to +5°);
	3° (+5° to +11°);
	4° (+11° to +15°);
	5° (-19° to -14°); 6° (-25° to -19°)
Frame Rate	10 Hz, 20 Hz
Returns	Single Return
	Dual Return (Strongest, Last)
CERTIFICATIONS	
	RoHS, REACH, WEEE
	CE, FCC, FDA, IC, EAC, KCC

MECHANICAL/ELECTRICAL/OPERATIONAL	
Wavelength	905 nm
Laser Class	Class 1 Eye Safe
Ingress Protection	IP6K7
Dimensions	Height: 116.7 mm
	Top/Bottom Diameter: 118.00 / 116.00 mm
Operating Voltage	DC 9 to 48 V
Power Consumption	22 W
Operating Temperature	-20°C to 65°C
Weight	1.52 kg
DATA I/O	
Data Transmission	UDP/IP Ethernet (100 Mbps)
Data Outputs	Distance, Azimuth Angle, Intensity
Data Points Generated	Single Return: 1,152,000 points/sec @10 Hz
	Dual Return: 2,304,000 points/sec @10 Hz
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

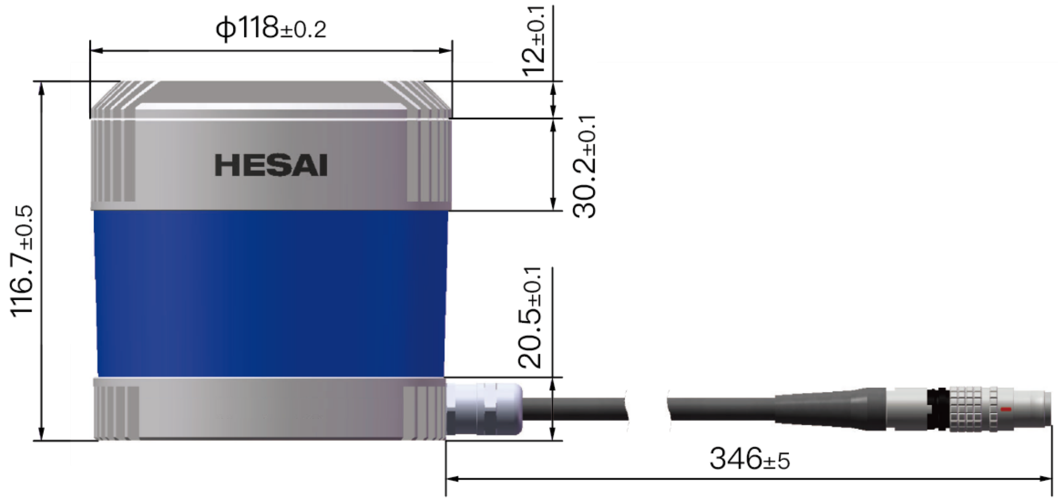


Figure 2.1 Front View (Unit: mm)

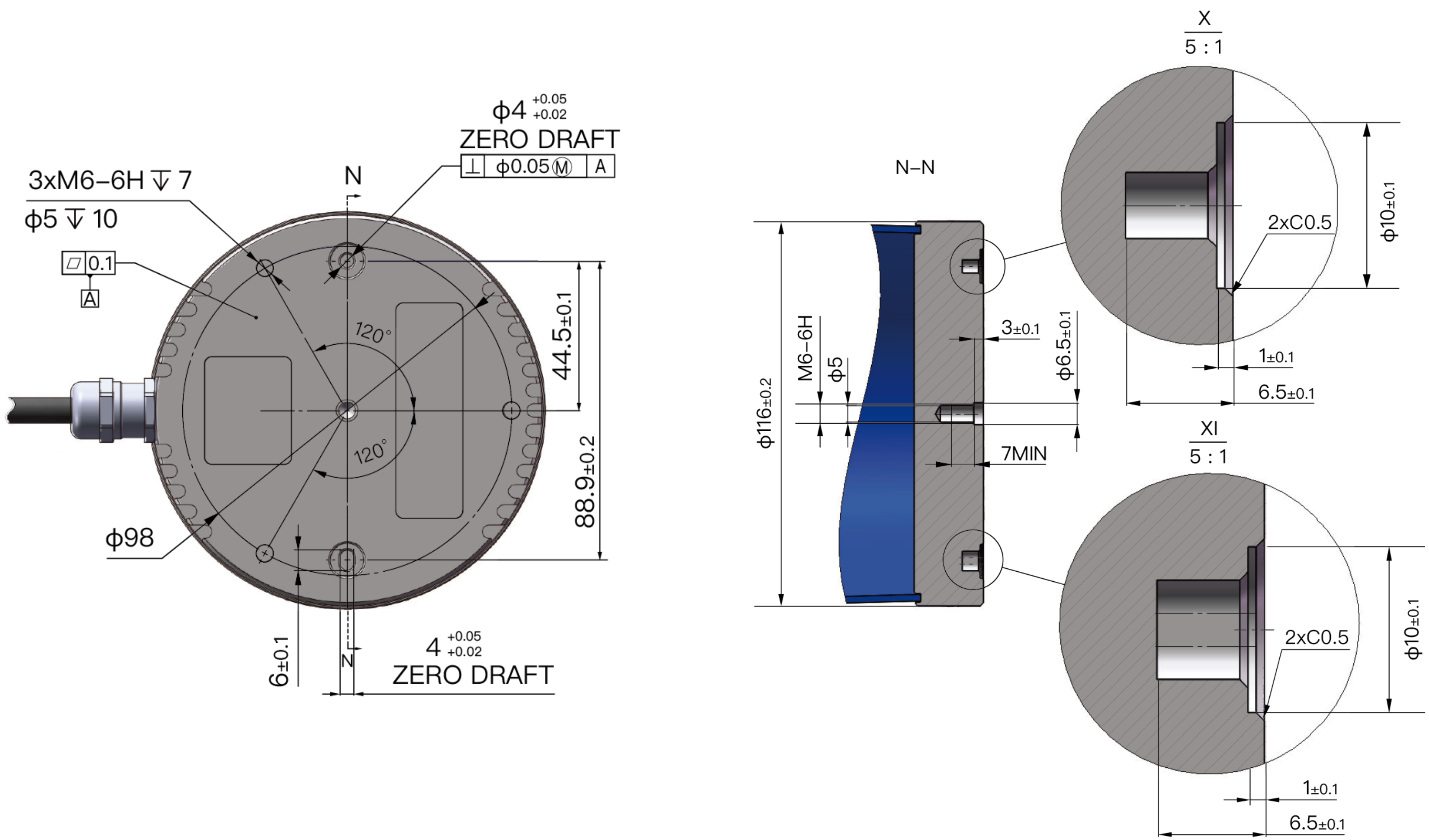


Figure 2.2 Bottom View (Unit: mm)

Quick Installation

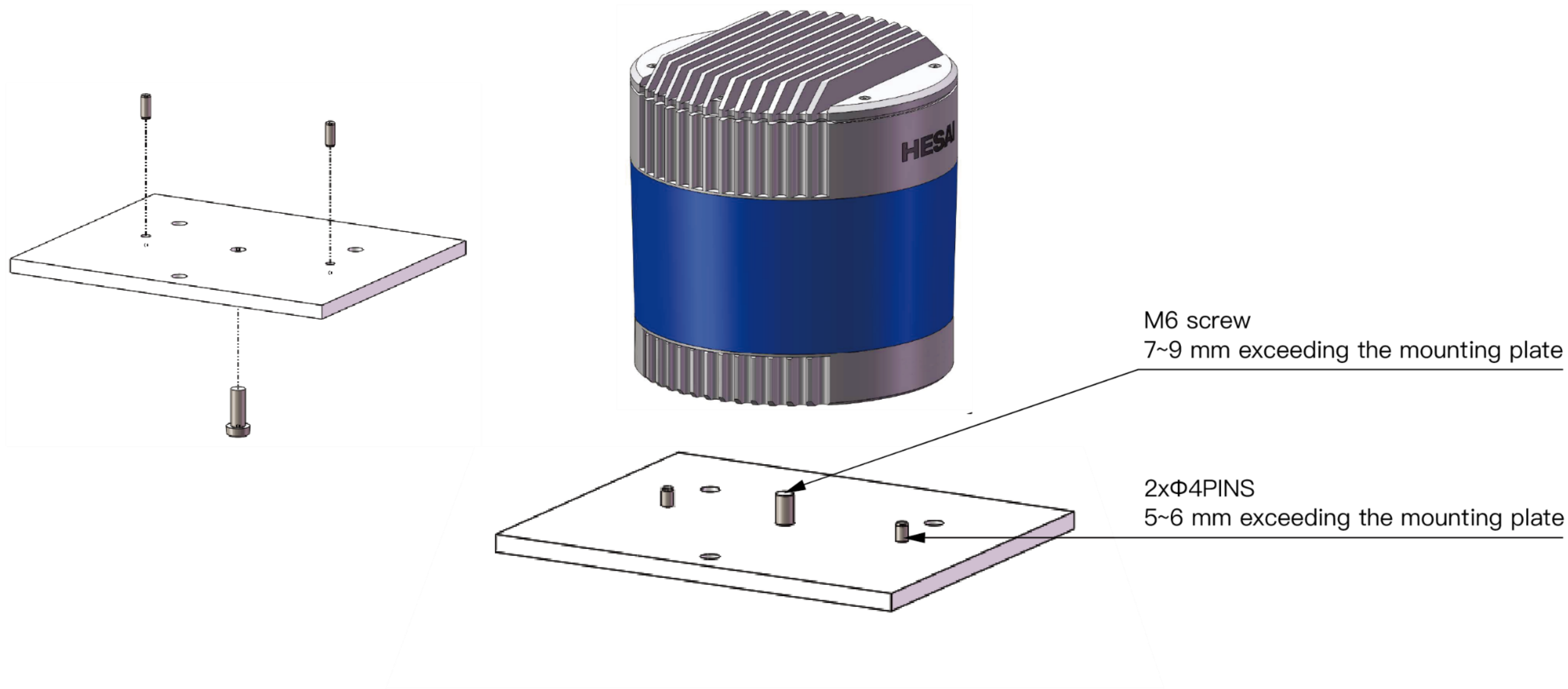


Figure 2.3 Quick Installation

■ Stable Installation

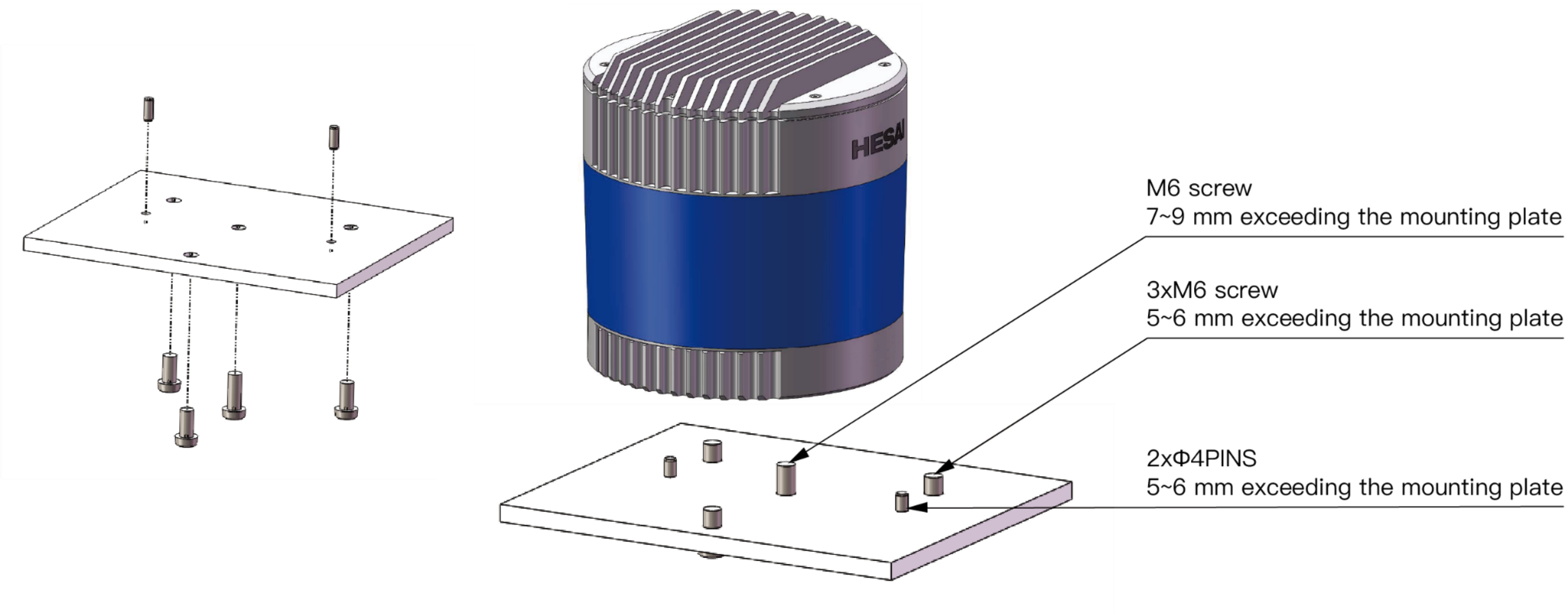
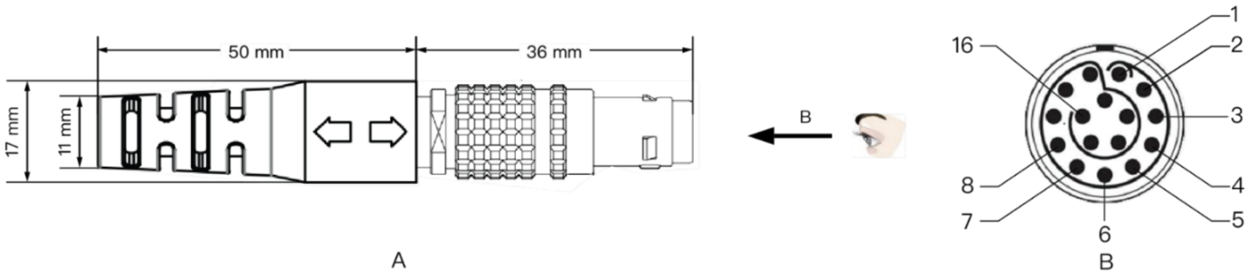


Figure 2.4 Stable Installation

2.2 Interfaces

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



From the eye to the interface

Figure 2.5 Lemo Connector (Male Plug)

Pin #	Function	Color	Voltage
1 ~ 4	-	-	-
5	Ethernet RX-	BLUE	-1 V to 1 V
6	Ethernet RX+	BLUE/WHITE	-1 V to 1 V
7	Ethernet TX-	ORANGE	-1 V to 1 V
8	Ethernet TX+	ORANGE/WHITE	-1 V to 1 V
9	GPS Serial Data	WHITE	-13 V to +13 V
10	GPS PPS	YELLOW	TTL level 3.3 V/5 V

Pin #	Function	Color	Voltage
11	P12V	RED	12 V
12	P12V	GRAY	12 V
13	Ground (Return)	BLACK	0
14	Ground (Return)	GRAY/WHITE	0
15	Index	PURPLE	0 V to 3.3 V
16	Encoder	PURPLE/WHITE	0 V to 3.3 V

NOTE For the GPS PPS signal, pulse width is recommended to be over 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

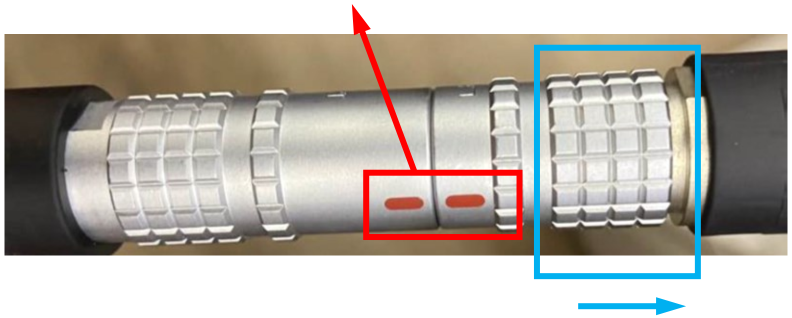
NOTE

• 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.

Before connection: align the red dots



Before disconnection: pull the release sleeve to its outermost position and hold there

Figure 2.6 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.
The cable length between the connector and the connection box is 1.7 m by default.
Lemo part number: PHG.2T.316.CLLC75Z (female socket, on the connection box)

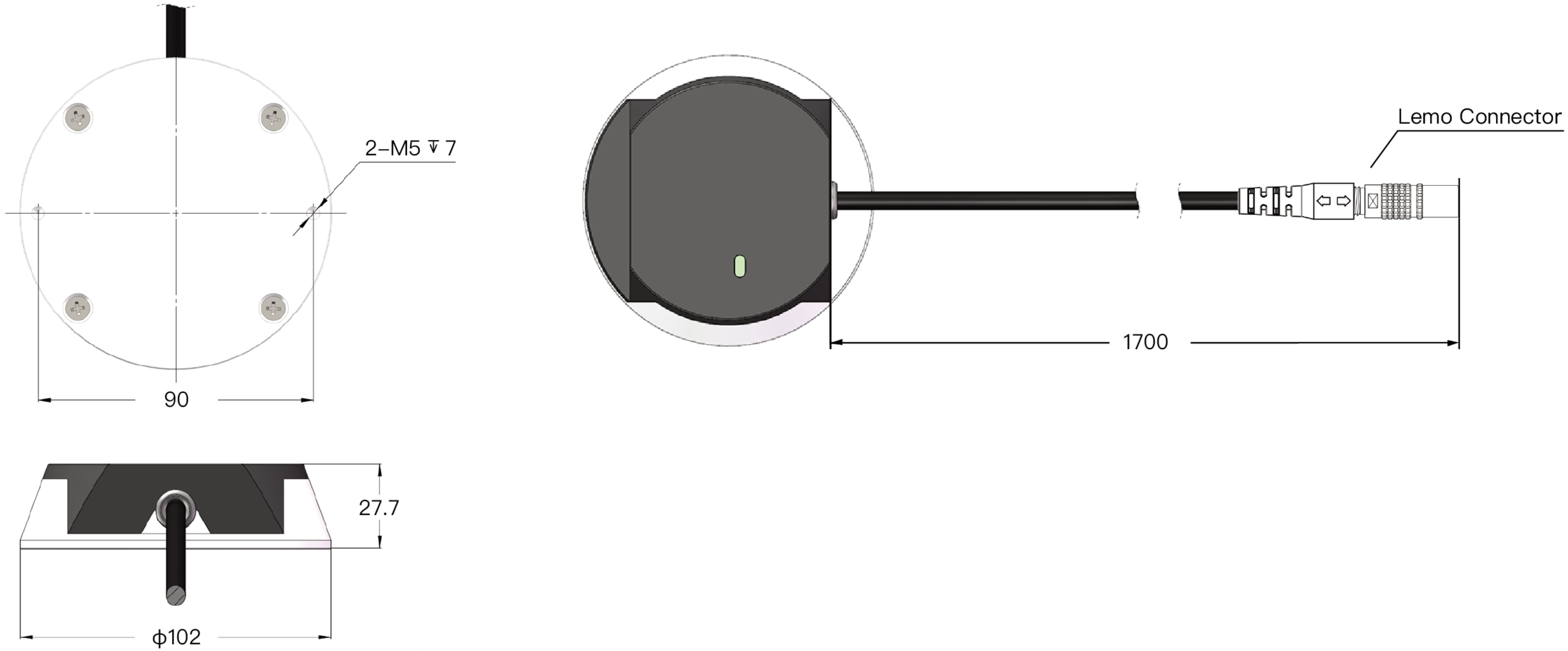


Figure 2.7 Connection Box (Unit: mm)

2.3.1 Connection Box Interfaces

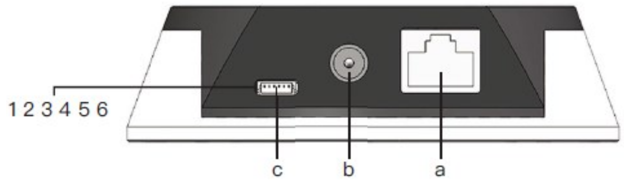


Figure 2.8 Connection Box (Front)

Port #	Port Name	Description
a	Standard Ethernet Port	RJ45, 100 Mbps Ethernet
b	Power Port	Use DC-005 DC power adapter External power supply: 9 V to 48 V, at least 22 W
c	GPS Port	Connector type: JST, SM06B-SRSS-TB Recommended connector for the external GPS module: JST, SHR-06V-S-B Voltage standard: RS232 Baud rate: 9600 bps

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

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

For Pandar64 LiDARs with Lemo connectors, a trigger port is added to output external trigger signals.

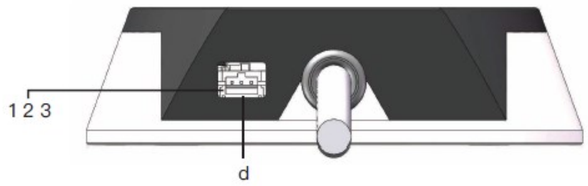


Figure 2.9 Connecting Box (Back)

Port #	Port Name	Description
d	Trigger Port	Connector (socket): Molex, LLC 5023520300 Recommended wire connector (plug): Molex, LLC 5023510300 Voltage: 0 V to 3.3 V Signal type: pulse Max. current output level: 12 mA

Pin Description for the trigger port:

Pin #	Direction	Pin Description
1	Input	GND, to ground the external trigger signal
2	Output-Encoder	Trigger signal output: outputs one pulse when the LiDAR rotates 0.05 degrees 7 µs@600RPM, 3.5 µs@1200RPM
3	Output-Index	Trigger signal output: outputs one pulse when the LiDAR rotates one revolution 4 µs@600RPM, 2 µs@1200RPM

2.3.2 Connection

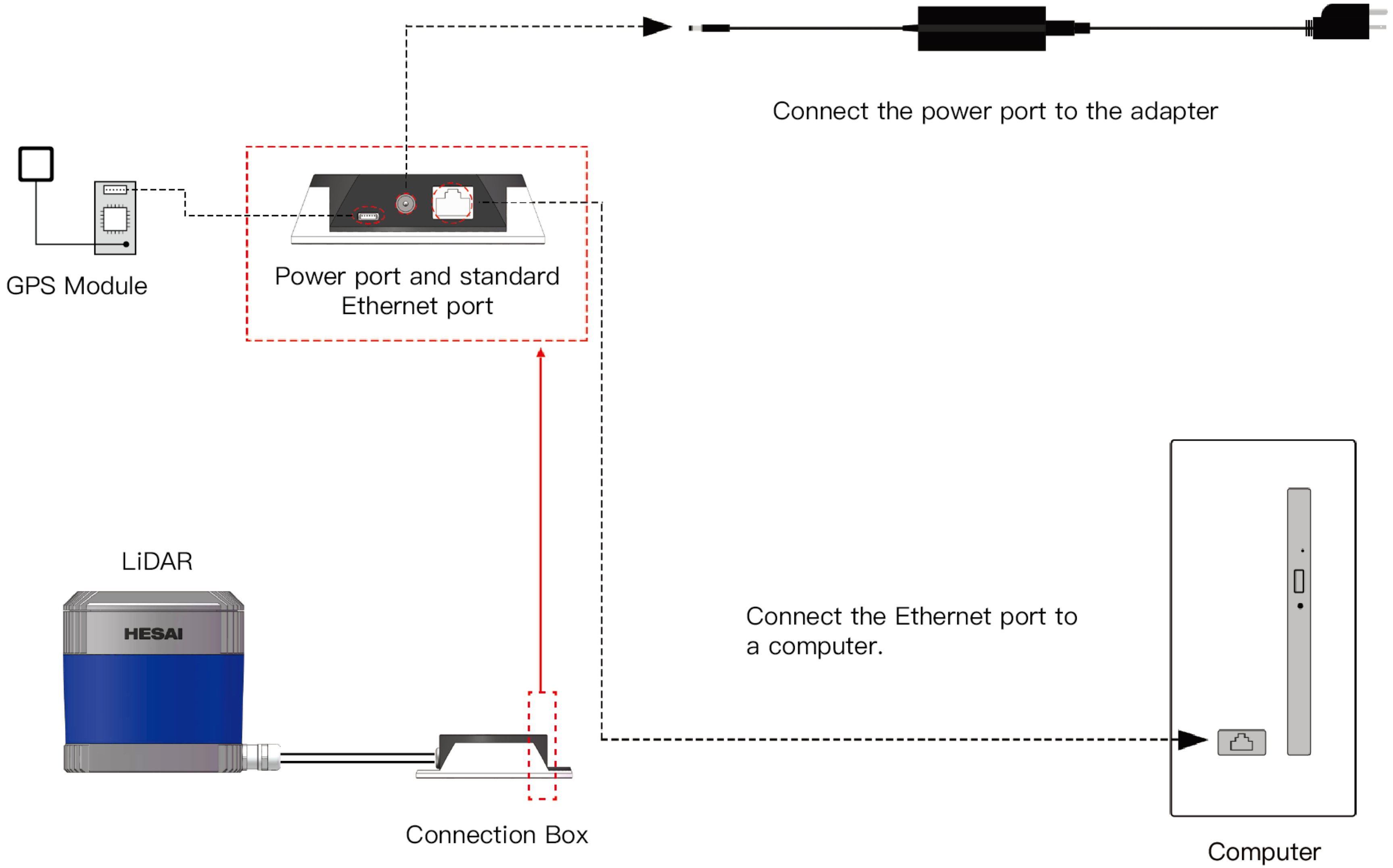


Figure 2.10 Connection Box - Connection

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.

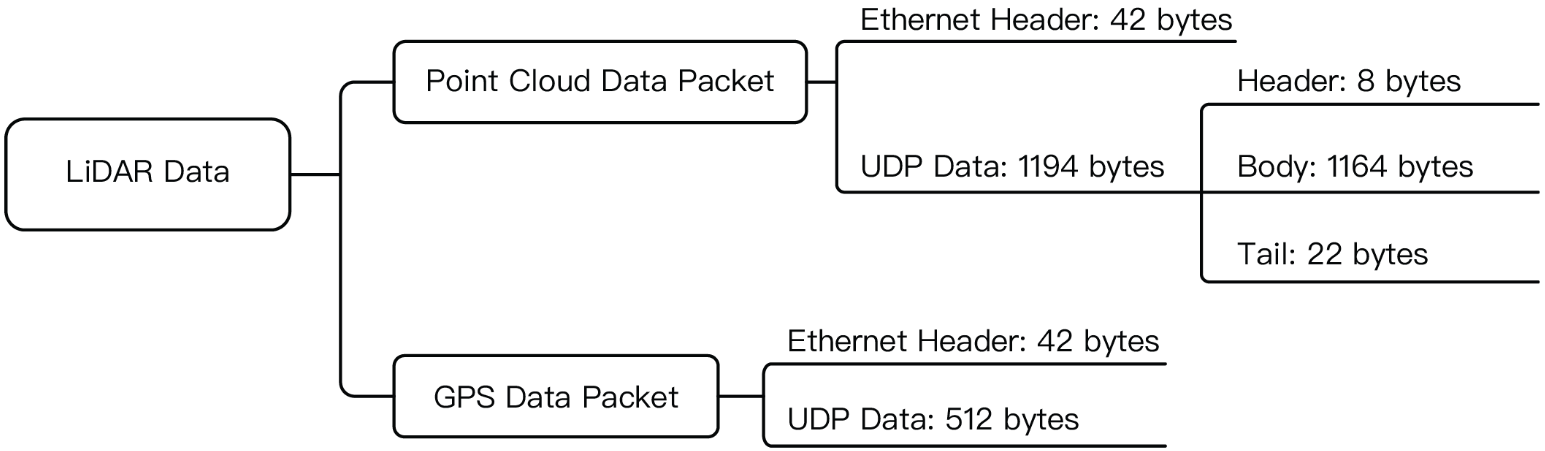


Figure 3.1 Data Structure with UDP Sequence OFF

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

3.1 Point Cloud Data Packet

3.1.1 Ethernet Header

Each LiDAR has a unique MAC address. The source IP is 192.168.1.201 by default, 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	0x04B2 when UDP sequence is OFF, representing 1202 bytes (8 bytes more than the size of the Point Cloud UDP Data, shown in Figure 3.1) 0x04B6 when UDP sequence is ON, representing 1206 bytes
UDP Checksum	2 bytes	-

```
⊟ Internet Protocol, Src: 192.168.1.201 (192.168.1.201), Dst: 255.255.255.255 (255.255.255.255)
    Version: 4
    Header length: 20 bytes
  ⊞ Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00)
    Total Length: 1222
    Identification: 0xe960 (59744)
  ⊞ Flags: 0x02 (Don't Fragment)
    Fragment offset: 0
    Time to live: 64
    Protocol: UDP (17)
  ⊞ Header checksum: 0x8a55 [correct]
    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

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

■ **Header**

Header: 8 bytes		
Field	Bytes	Description
0xEEFF	2 bytes	SOP (start of packet), 0xEE first
Laser N	1 byte	0x40 (64 channels)
Block N	1 byte	0x6 (6 blocks per packet)
Reserved	1 byte	-
Dis Unit	1 byte	4 mm
Reserved	1 byte	-
Reserved	1 byte	-

■ **Body**

Body: 1164 bytes (6 blocks)				
Block 1	**Block 2**	**Block 3**	**...**	**Block 6**
Azimuth 1	Azimuth 2	Azimuth 3	...	Azimuth 6
Channel 1	Channel 1	Channel 1	...	Channel 1
Channel 2	Channel 2	Channel 2	...	Channel 1
...	...	...	...	...
Channel 64	Channel 64	Channel 64	...	Channel 64

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

Block size = 64 * Size of Channel XX + Size of Azimuth

<table>
<tr><th colspan="4">Each Block in the Body: 194 bytes</th></tr>
<tr><th>Field</th><th>Bytes</th><th colspan="2">Description</th></tr>
<tr><td>Azimuth</td><td>2 bytes</td><td colspan="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°</td></tr>
<tr><td rowspan="2">Channel XX</td><td rowspan="2">3 bytes</td><td>2-byte distance data</td><td>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</td></tr>
<tr><td>1-byte reflectivity data</td><td>Reflectivity, in percentage (0 to 255%)</td></tr>
</table>

■ Tail

Tail: 22/26 bytes when UDP sequence is OFF/ON		
Field	Bytes	Description
Reserved	5 bytes	-
High Temperature Shutdown Flag	1 byte	0x01 for high temperature; 0x00 for normal operation ・ When high temperature is detected, the shutdown flag will be set to 0x01, and the system will shut down after 60 s. The flag remains 0x01 during the 60 s and the shutdown period ・ When the system is no longer in high temperature status, the shutdown flag will be reset to 0x00 and the system will automatically return to normal operation
Reserved	2 bytes	-
Motor Speed	2 bytes	speed_2_bytes [15:0] = speed (RPM)
GPS Timestamp	4 bytes	Packing time of this data packet, in units of 1 μs Range: 0 to 1000000 μs (1 s)
Return Mode Information	1 byte	0x37 for Strongest Return mode, 0x38 for Last Return mode, and 0x39 for Dual Return mode
Factory Information	1 byte	0x42 (or 0x43)
Date & Time	6 bytes	Year (current year minus 2000), month, date, hour, minute, second Binary, 1 byte each
UDP Sequence	4 bytes	Added only when UDP sequence is ON Label the sequence number of Point Cloud UDP packets, 1 to 0xFF FF FF FF in little endian format

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 Pandar64's Channel 5 in Block 3 as an example:

1) Vertical angle of Channel 5 is 3.04°, 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 (Chapter 6).

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

- Define clockwise in the top view as the horizontal angles' positive direction
- Current reference angle of the rotor is the Azimuth field of Block 2
- Horizontal angle offset of Channel 5 is -1.042°, according to Appendix I Channel Distribution

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 3

■ **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	-

```
⊟ Internet Protocol, Src: 192.168.1.201 (192.168.1.201), Dst: 255.255.255.255 (255.255.255.255)
    Version: 4
    Header length: 20 bytes
  ⊞ Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00)
    Total Length: 540
    Identification: 0x1841 (6209)
  ⊞ Flags: 0x02 (Don't Fragment)
    Fragment offset: 0
    Time to live: 64
    Protocol: UDP (17)
  ⊞ Header checksum: 0x5e1f [correct]
    Source: 192.168.1.201 (192.168.1.201)
    Destination: 255.255.255.255 (255.255.255.255)
```

Figure 3.3 GPS Ethernet Header - Internet Protocol

3.2.2 UDP Data

<table>
<tr><th colspan="5">GPS UDP data: 512 bytes</th></tr>
<tr><th>Field</th><th>Bytes</th><th colspan="3">Description</th></tr>
<tr><td rowspan="4">GPS time data</td><td rowspan="4">18</td><td>Header</td><td>2 bytes</td><td>0xFFEE, 0xFF first</td></tr>
<tr><td>Date</td><td>6 bytes</td><td>Year, month, and day (2 bytes each, lower byte first) in ASCII</td></tr>
<tr><td>Time</td><td>6 bytes</td><td>Second, minute, and hour (2 bytes each, lower byte first) in ASCII</td></tr>
<tr><td>µs Time</td><td>4 bytes</td><td>In units of µs (lower byte first)</td></tr>
<tr><td>GPRMC/GPGGA data</td><td>84</td><td colspan="3">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</td></tr>
<tr><td>Reserved</td><td>404</td><td colspan="3">404 bytes of 0xDF</td></tr>
<tr><td>GPS positioning status</td><td>1</td><td colspan="3">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)</td></tr>
<tr><td>Flag of PPS lock</td><td>1</td><td colspan="3">1 - locked 0 - unlocked</td></tr>
<tr><td>Reserved</td><td>4</td><td colspan="3">-</td></tr>
</table>

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 Typically 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 Typically 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

```
> Data (512 bytes)
0000  04 d4 c4 eb 9b 37 ec 9f  0d 00 48 cb 08 00 45 00   ·····7·· ··H···E·
0010  02 1c c4 23 40 00 80 11  b0 66 c0 a8 01 c9 c0 a8   ···#@··· ·f······
0020  01 2d 27 10 27 7e 02 08  00 00 ff ee 30 32 34 30   ·-'·'~·· ····0240
0030  37 30 38 35 37 30 34 30  00 00 00 00 24 47 50 52   70857040 ····$GPR
0040  4d 43 00 2c 30 34 30 37  35 37 2e 37 36 2c 56 2c   MC·,0407 57.76,V,
0050  2c 2c 2c 2c 2c 2c 30 37  30 34 32 30 2c 2c 2c 4e   ,,,,,,07 0420,,,N
0060  2c 56 2a 30 36 36 36 36  36 36 36 36 36 36 36 36   ,V*06666 66666666
```

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

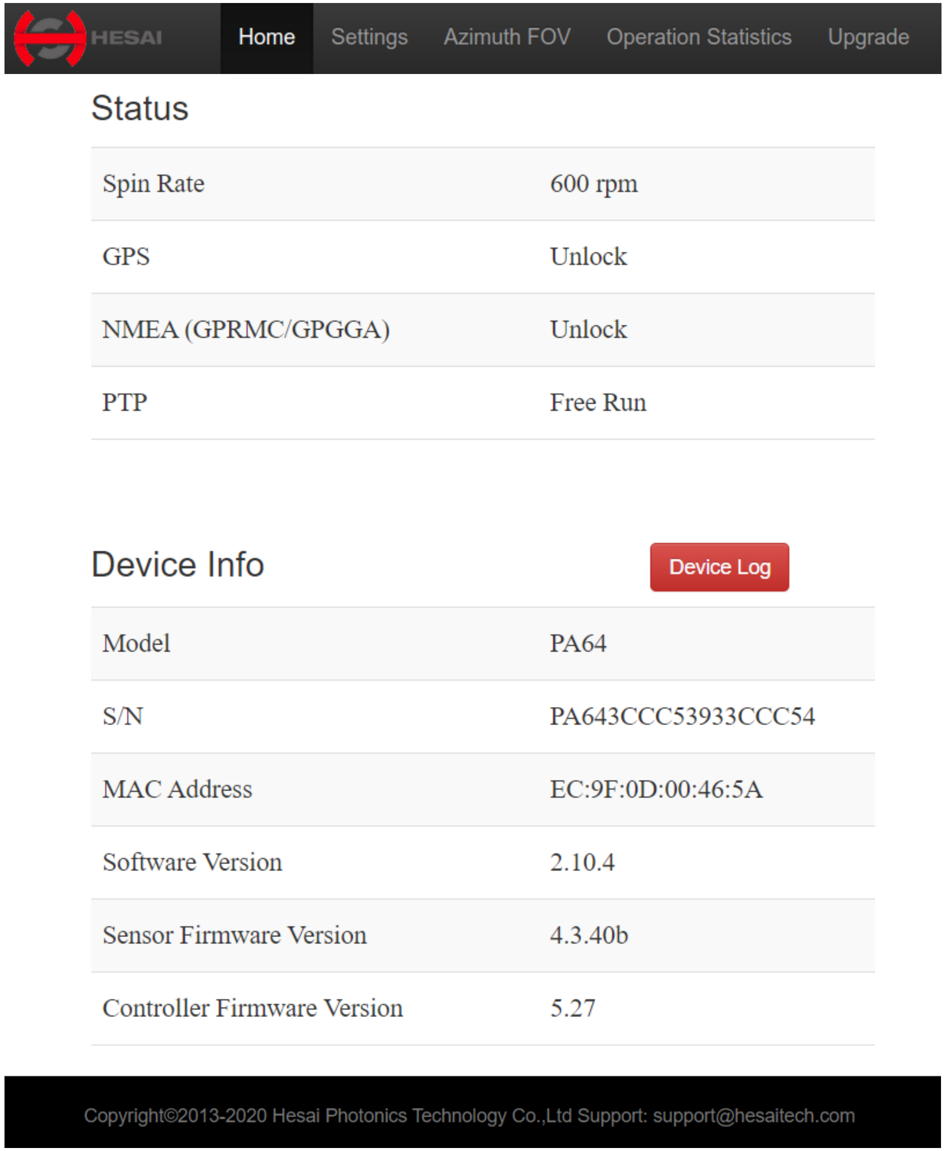
Web control is used for setting parameters, checking device info, and upgrading.

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 in 2 seconds

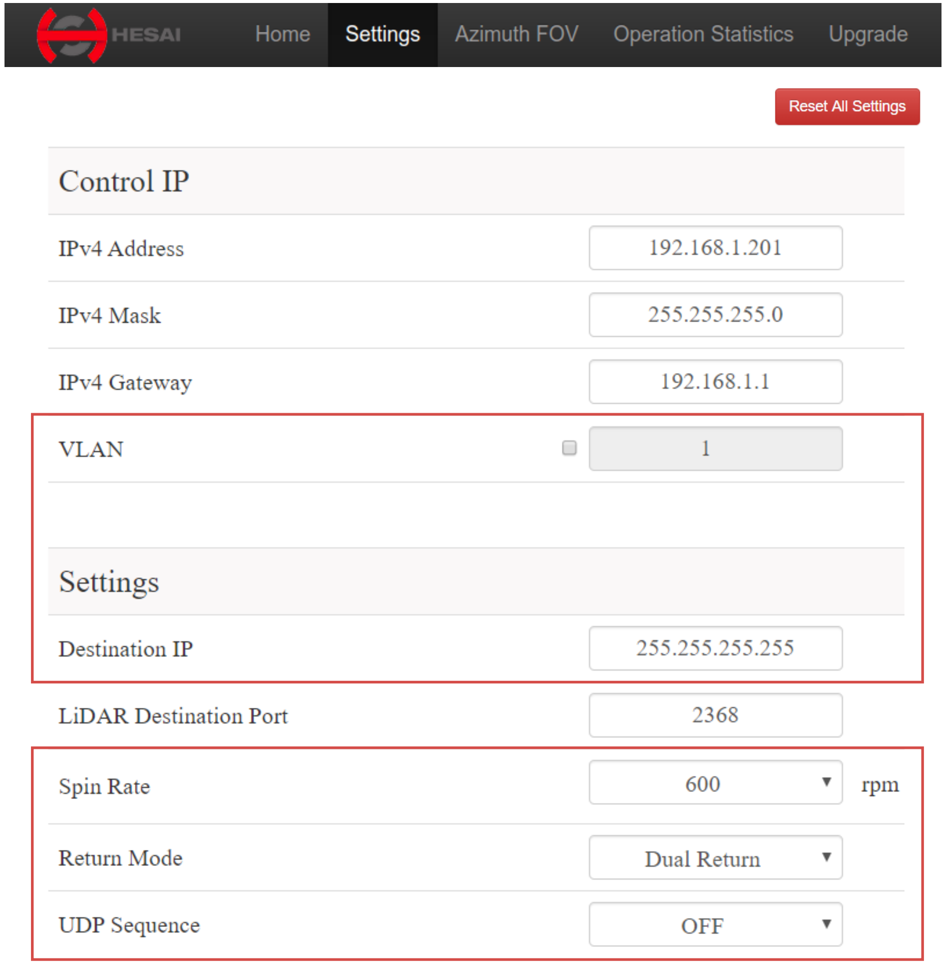
PTP Status

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



（接下页）

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

Range: except for 0.0.0.0, 127.0.0.1, and the LiDAR's IP

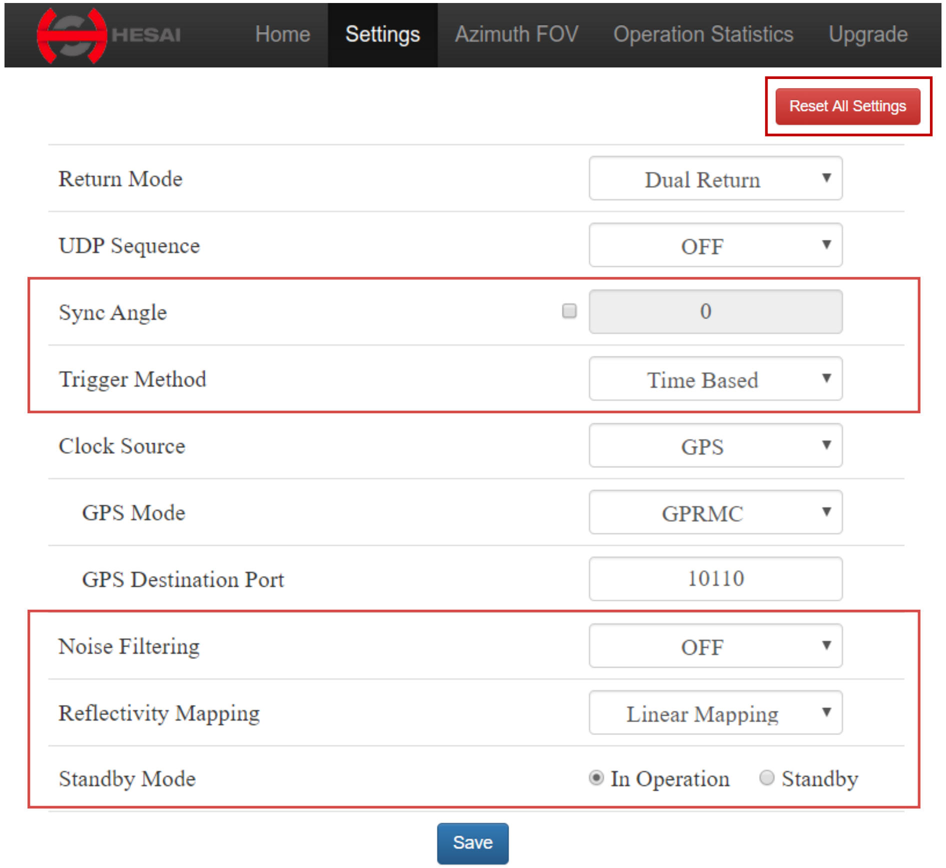
Mode	Destination IP
Broadcast (default)	255.255.255.255
Multicast	239.0.0.0~239.255.255.255
Unicast	Same as the PC's IP address

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 within the user-specified azimuth FOV. **ON #2:** Increments at all times.

(continued on the next page)

(接上页)



(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.
Noise Filtering	Noise points mitigation in rain and fog
Reflectivity Mapping	Linear / Nonlinear Mapping
	Linear: the 1-byte reflectivity in Point Cloud Data Packets linearly represents target reflectivity (0 to 255%). **Nonlinear**: increases the contrast in low-reflectivity region, see Appendix V.
Standby Mode	Whether to stop the motor from running and lasers from firing

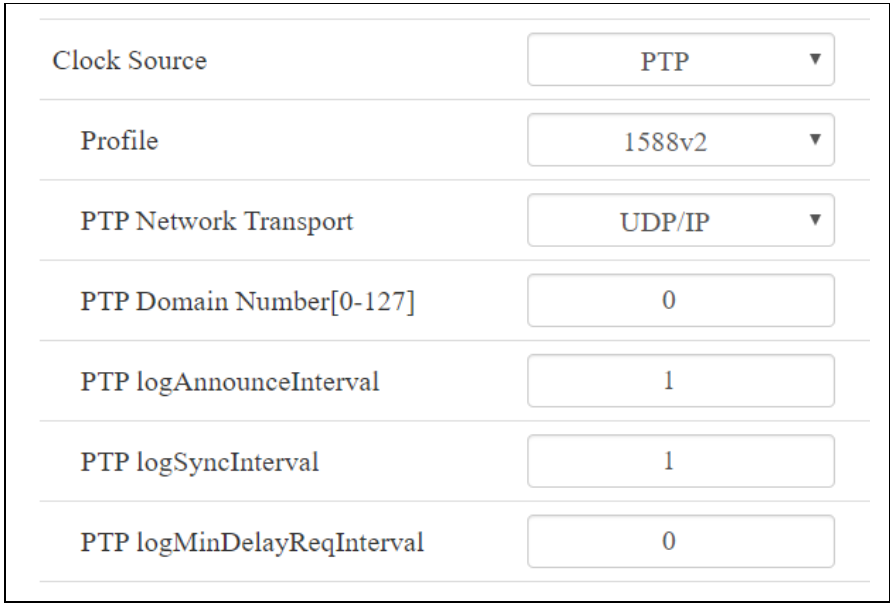
4. Reset All Settings

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

The default values are shown in the screenshots in Section 4.2 and 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
GPS Destination Port	10110 (default)
	Port used for sending GPS Data packets

• When PTP is selected as the clock source:

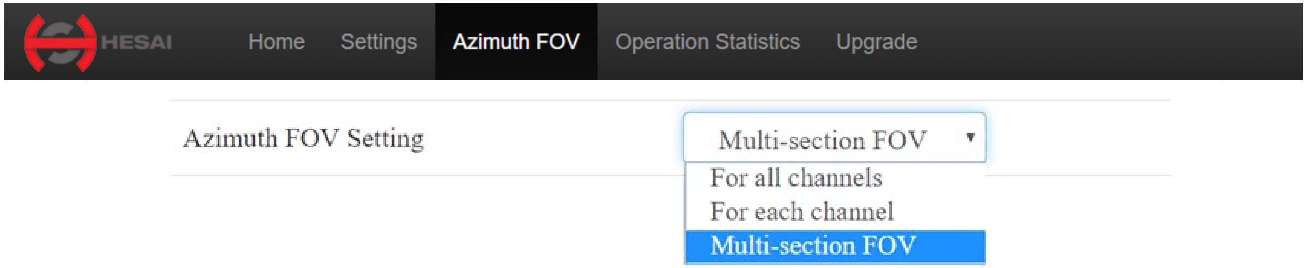
Profile	1588v2 (default) / 802.1AS
	IEEE timing and synchronization standard
PTP Network Transport	UDP/IP (default) or L2
	1588v2: users can select UDP/IP or L2 **802.1AS**: only supports L2 network
PTP Domain Number	Integer from 0 to 127
	Domain attribute of the local clock

• When using the 1588v2 profile:

PTP logAnnounceInterval	-2 to 3 log seconds
	Time interval between Announce messages (default: 1)
PTP logSyncInterval	-7 to 3 log seconds
	Time interval between Sync messages (default: 1)
PTP logMinDelayReq-Interval	-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

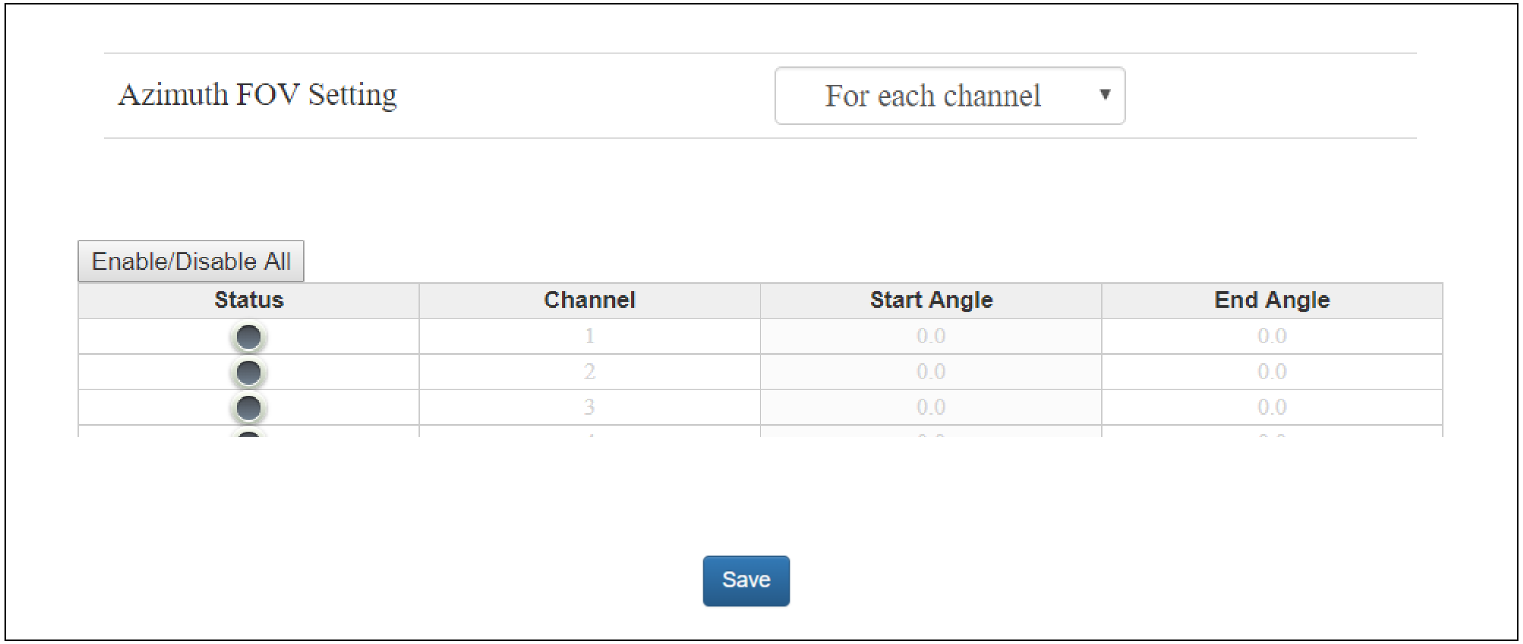
A continuous angle range, specified by a Start Angle and an End Angle, will be applied to all the channels. Outside the specified angle range, there will be no laser firing or data generated.

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.

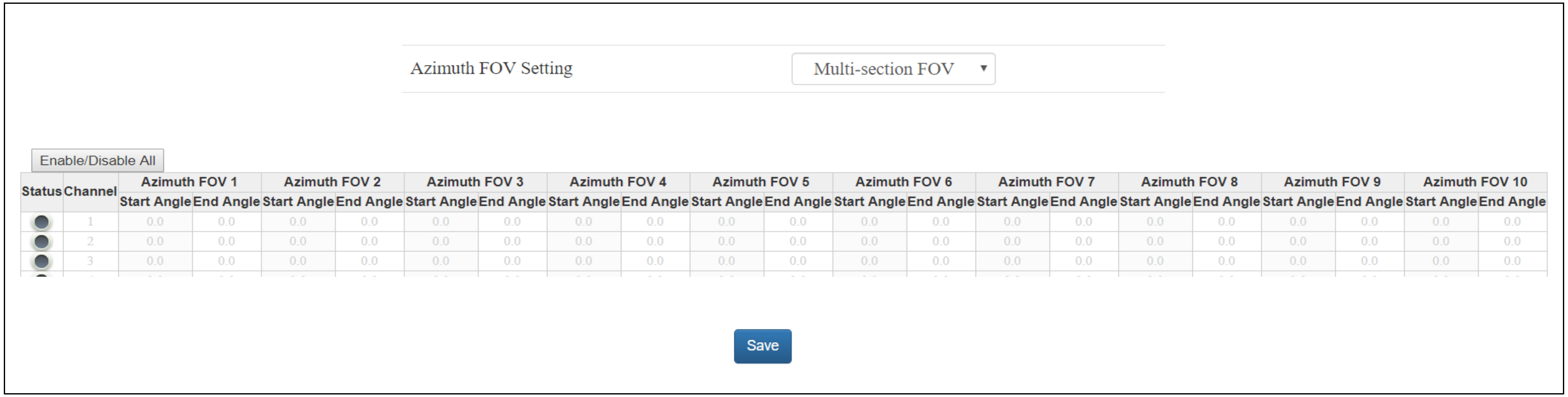


4.3.3 Multi-section FOV

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



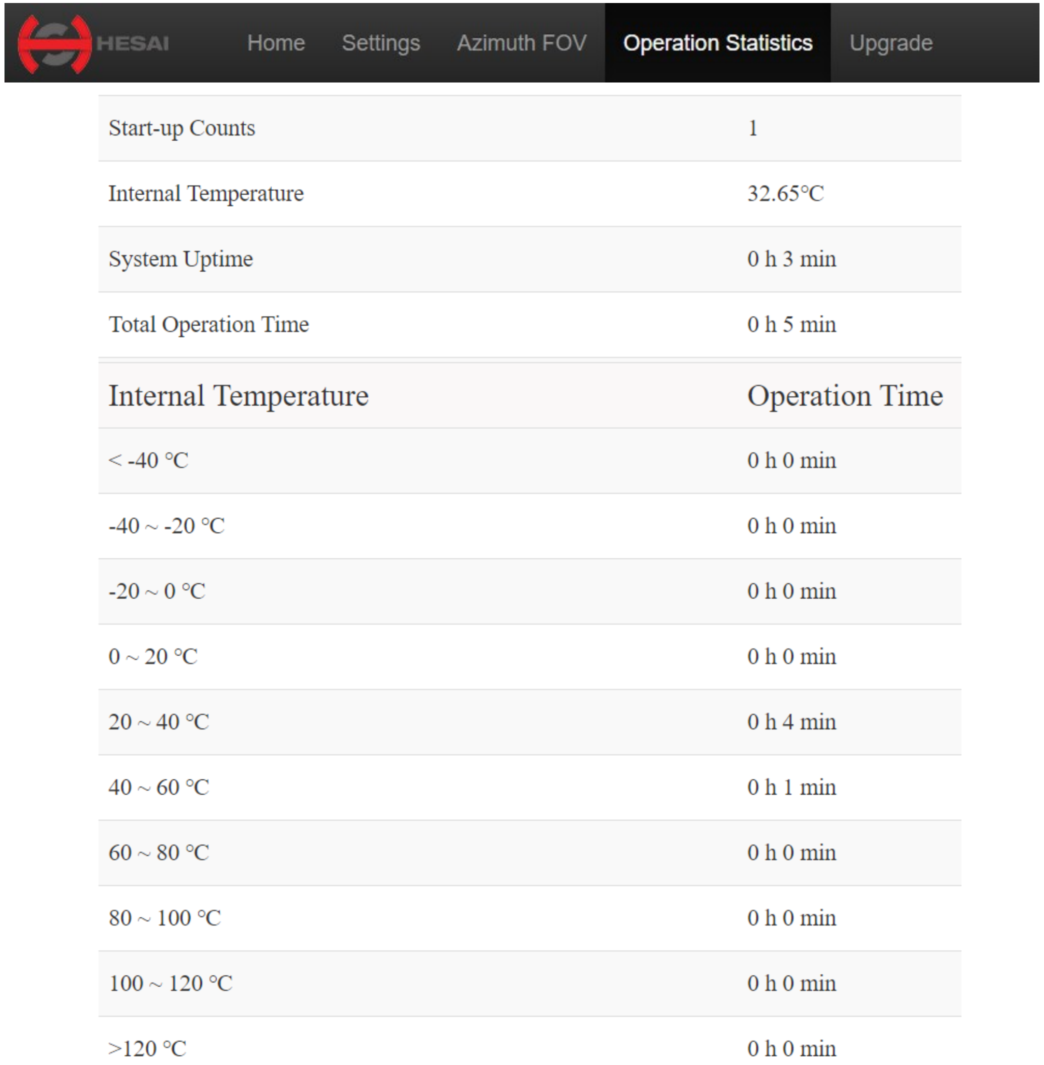
4.3.4 Note

- 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.

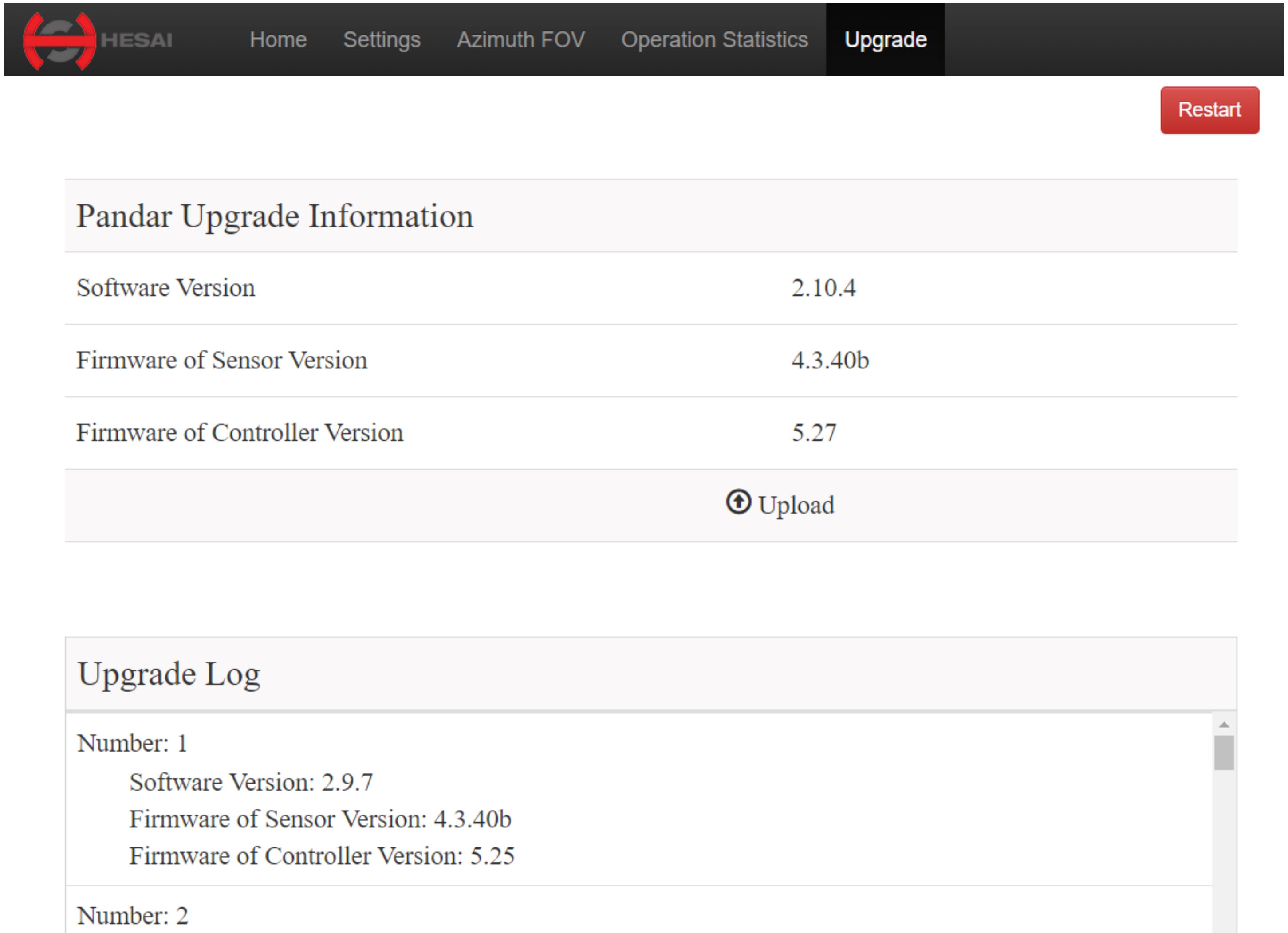


Start-up Counts	1
Internal Temperature	32.65°C
System Uptime	0 h 3 min
Total Operation Time	0 h 5 min

Internal Temperature	Operation Time
< -40 °C	0 h 0 min
-40 ~ -20 °C	0 h 0 min
-20 ~ 0 °C	0 h 0 min
0 ~ 20 °C	0 h 0 min
20 ~ 40 °C	0 h 4 min
40 ~ 60 °C	0 h 1 min
60 ~ 80 °C	0 h 0 min
80 ~ 100 °C	0 h 0 min
100 ~ 120 °C	0 h 0 min
>120 °C	0 h 0 min

4.5 Upgrade

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



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.

To upgrade the software and firmware

- Contact Hesai technical support to obtain the upgrade file
- Click the "Upload" button, select the 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.

NOTE

- Software and Controller Firmware: when upgrading, power supply must remain on.
- Sensor Firmware: when upgrading, an interruption in the power supply can result in upgrade failure - the Sensor Firmware Version on the Upgrade page will be "XXXXX" after reboot. In that case, upgrade Sensor Firmware again, until the Upgrade page displays the correct version number after reboot.
- Software upgrade: if the current version is earlier than 2.9.1, please first upgrade to 2.9.1, and then upgrade to higher versions.
- Software downgrade: if the current version is between 2.9.6 and 2.10.4, and the system needs to downgrade to a version earlier than 2.7.x, please reset all settings (click the "Reset All Settings" button on the top-right corner of the Settings page) before performing the downgrade.

5 PandarView

PandarView is a software that records and displays point cloud data from Hesai LiDARs, available in 64-bit Windows 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_V1.7.22.msi	Before upgrading PandarView to a newer version, please uninstall the current version
		Double click and install PandarView_Windows using the default settings
Ubuntu-16.04	PandarViewX64_Release_V1.7.22.tar.gz	Unzip the file and run PandarView_Installer.bin
Ubuntu-18.04	PandarViewX64_18.04_Release_V1.7.22.tar.gz	

This manual describes PandarView 1.7.22. The menu bar and buttons are shown below.

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

5.2 Use

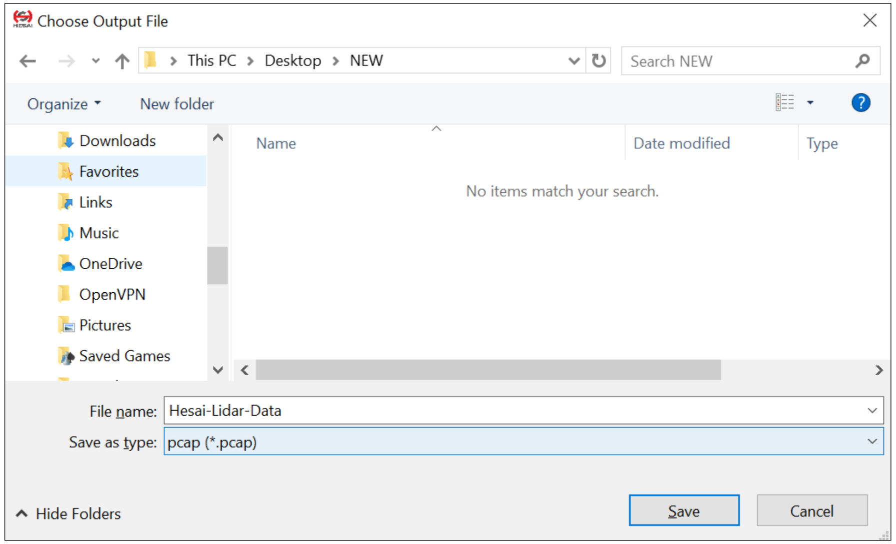
Set the PC's IP address according to Section 2.4 (Get Ready to Use)

■ Check Live Data

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

■ Record Point Cloud Data

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



Play Point Cloud Data

1) Open a .PCAP File

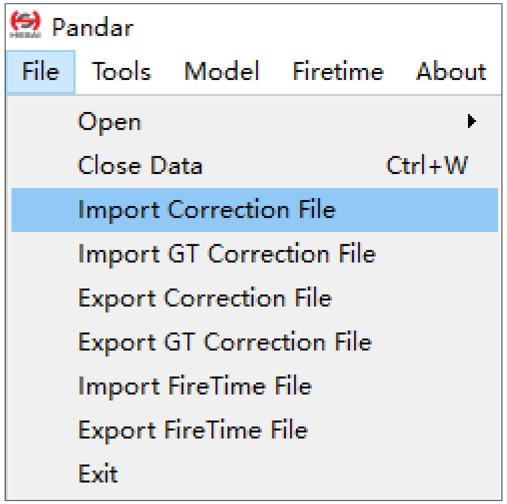
Click on to pop up the "Choose Open File" window. Select a .PCAP file to open.

2) Import a Correction File

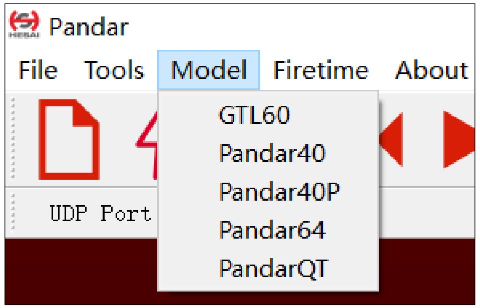
Each LiDAR unit has a corresponding calibration file (.CSV) in the provided USB disk.

In case the file is lost, contact a sales representative or technical support engineer from Hesai to receive the file.

We recommend importing the calibration file of this LiDAR unit into PandarView (File -- Import Correction File), in order to display the point cloud most accurately.



If the calibration file of this LiDAR unit is temporarily not at hand, select the LiDAR model in the "Model" menu, so that a general calibration file for this model will be loaded to improve point cloud display.



3) Play the .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)	2X 3X 1/2X 1/4X
/	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)	2X 3X 1/2X 1/4X
	Jump to the end of the file	
CSV	Save a single frame to .CSV	
	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	
PCAP	Save multiple frames to .PCAP	Start Frame: 0 End Frame: 408 Specify the start and end frames
CSV	Save multiple frames to .CSV	
20	Drag this progress bar or enter a frame number to jump to a specific frame	

5.3 Features

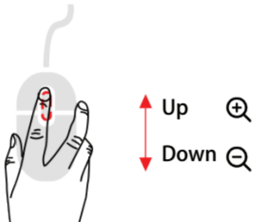
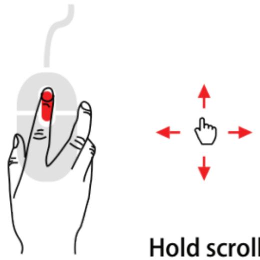
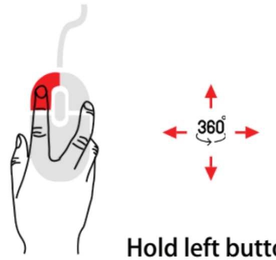
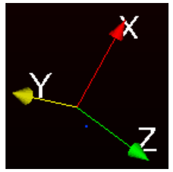
■ Standard Viewpoints


Right

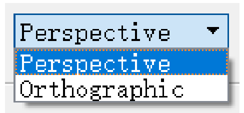

Front


Top

■ Mouse Shortcuts

 Scroll	 Hold scroll	 Hold left button	
Scroll the mouse wheel up/down to zoom in/out	Press the mouse wheel and drag to pan the view	Hold the left button and drag to adjust the point of view	The bottom-left coordinate axes show the current point of view

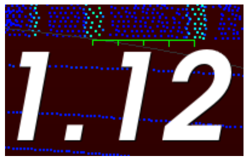
■ 3D Projection and Distance Measurement



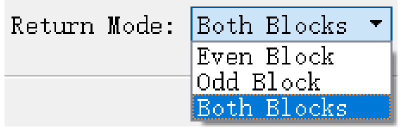
PandarView supports perspective projection (default) and orthographic projection.

The distance ruler is available only under orthographic projection:

- Click on  to enter measurement mode. Hold the Ctrl key and drag the mouse to make a measurement in units of meters
- Click on  again to quit



Return Mode



- Both blocks (default): to show the point cloud data from all blocks
- Even/Odd Block: to show the point cloud data from even/odd-numbered blocks

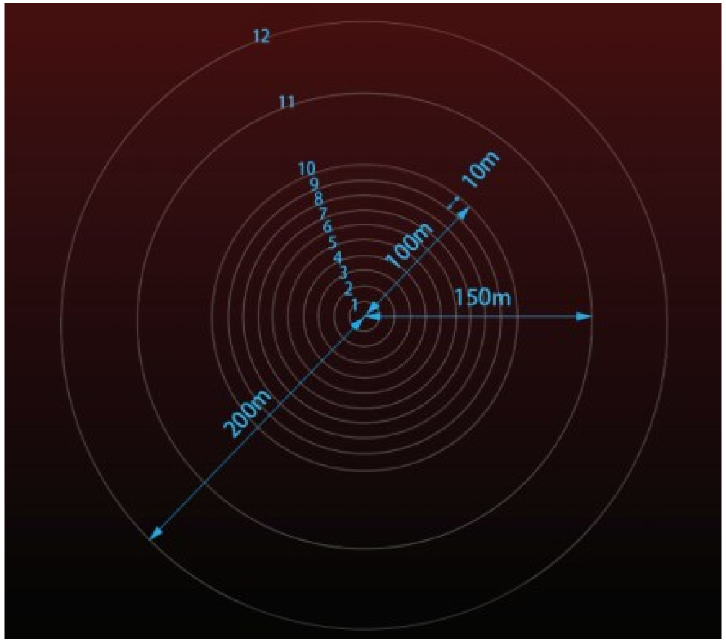
NOTE See the definition of blocks in Section 3.1.2 (Point Cloud UDP Data)

UDP Port

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

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".



Fire Time Correction

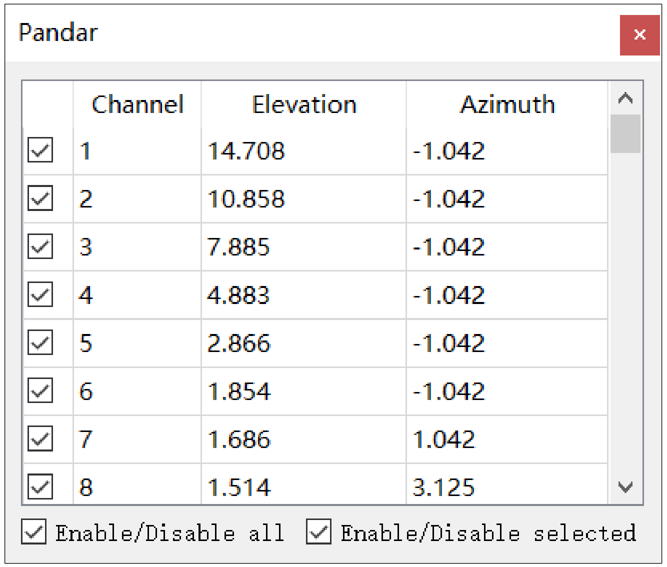
After opening a .PCAP file and selecting the LiDAR model in the "Model" menu, the fire time correction file (.CSV) for this model will be loaded.
Click on to finetune point cloud display using the fire time correction file.
Click on again to cancel the finetuning effects.

Channel Selection

Click on to open the Channel Selection box

- Check/Uncheck the boxes on the left to show/hide each channel. By default, the point cloud data from all channels are shown.
- Check/Uncheck the "Enable/Disable all" option at the bottom of the table to show/hide all channels
- When multiple channels are selected by holding the Shift or Ctrl key, check/uncheck the "Enable/Disable selected" option to show/hide multiple channels

Click on again to close the Channel Selection box.

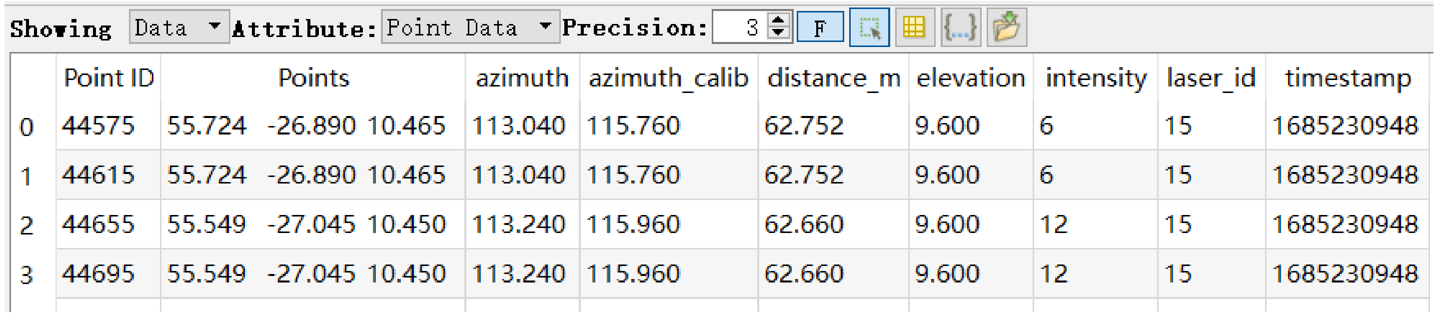

Pandar

	Channel	Elevation	Azimuth
☑	1	14.708	-1.042
☑	2	10.858	-1.042
☑	3	7.885	-1.042
☑	4	4.883	-1.042
☑	5	2.866	-1.042
☑	6	1.854	-1.042
☑	7	1.686	1.042
☑	8	1.514	3.125

☑ Enable/Disable all ☑ Enable/Disable selected

■ 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.



	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

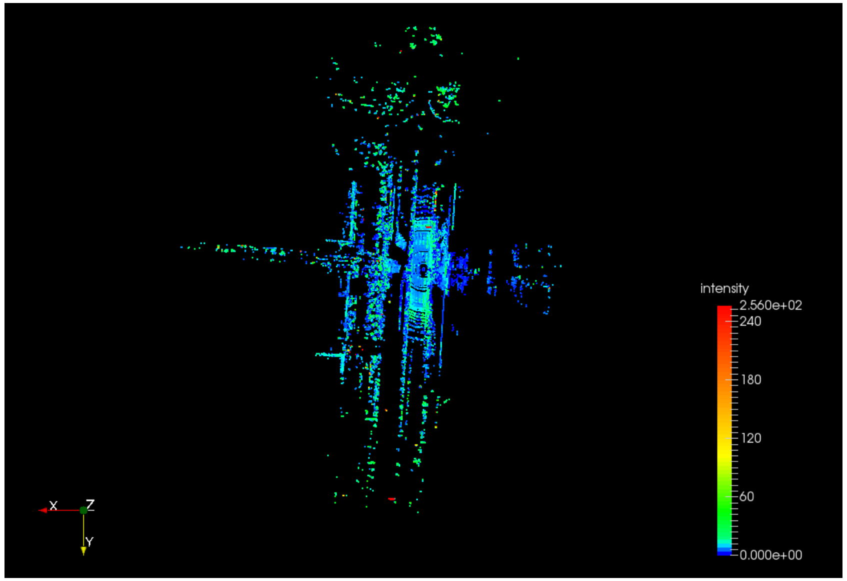
Some of the data fields are defined below:

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

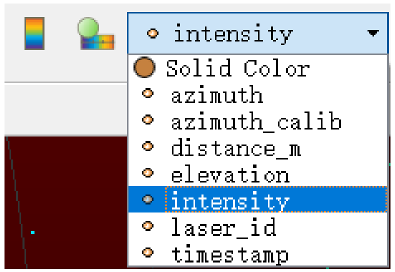
To cancel the selection, click on again and click on any place outside the selected area.

Color Schemes

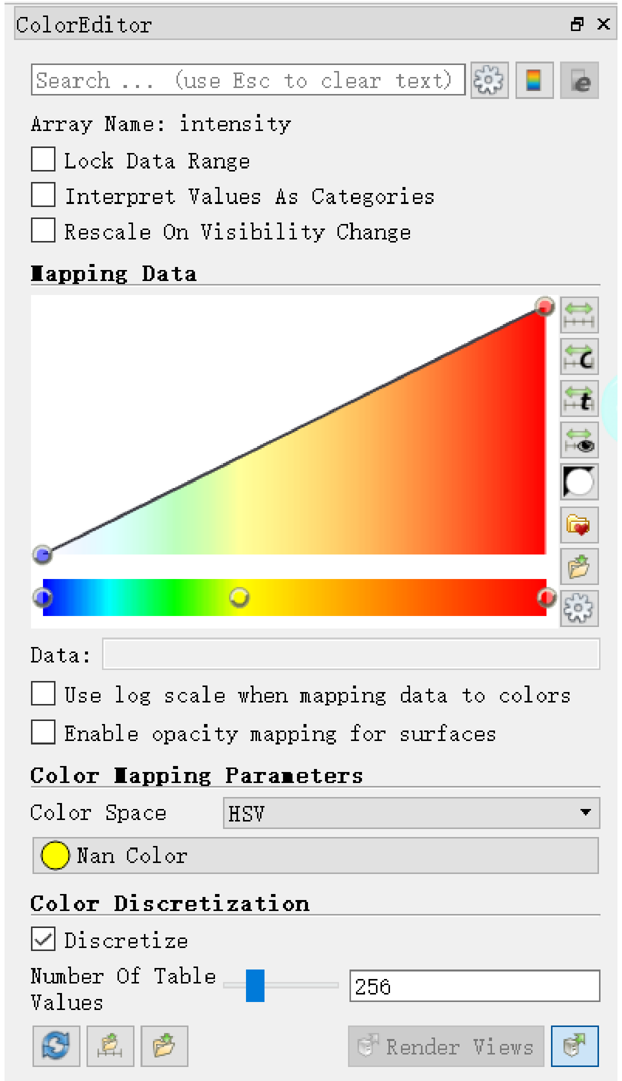
Click on to show the color legend at the lower right corner.



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

To receive Hesai LiDAR's TCP and HTTP API Protocols, please contact Hesai technical support.

7 Sensor Maintenance

■ **Storage**

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

■ **Transport**

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

■ **Cleaning**

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 • the latest PandarView version is installed on the PC
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 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 next page
- Define clockwise in the top view as positive

■ Vertical Angle

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

- 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).

Pandar64 Channel Distribution (To Be Continued)

Channel # in UDP Data	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range (in meters) with Reflectivity
01 (Top Beam)	-1.042	14.882	130	200@20%
02	-1.042	11.032	130	200@20%
03	-1.042	8.059	130	200@20%
04	-1.042	5.057	130	200@20%
05	-1.042	3.04	130	200@20%
06	-1.042	2.028	130	200@20%
07	1.042	1.86	130	200@20%
08	3.125	1.688	230	200@20%
09	5.208	1.522	130	200@20%
10	-5.208	1.351	230	200@20%
11	-3.125	1.184	230	200@20%
12	-1.042	1.013	230	200@10%
13	1.042	0.846	230	200@10%
14	3.125	0.675	230	200@10%
15	5.208	0.508	230	200@10%
16	-5.208	0.337	230	200@10%
17	-3.125	0.169	230	200@10%
18 (Horizontal Beam)	-1.042	0	230	200@10%
19	1.042	-0.169	230	200@10%
20	3.125	-0.337	230	200@10%

Pandar64 Channel Distribution (To Be Continued)

Channel # in UDP Data	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range (in meters) with Reflectivity
21	5.208	-0.508	230	200@10%
22	-5.208	-0.675	230	200@10%
23	-3.125	-0.845	230	200@10%
24	-1.042	-1.013	230	200@10%
25	1.042	-1.184	230	200@10%
26	3.125	-1.351	230	200@10%
27	5.208	-1.522	230	200@10%
28	-5.208	-1.688	230	200@10%
29	-3.125	-1.86	230	200@10%
30	-1.042	-2.028	230	200@10%
31	1.042	-2.198	230	200@20%
32	3.125	-2.365	230	200@20%
33	5.208	-2.536	230	200@20%
34	-5.208	-2.7	230	200@20%
35	-3.125	-2.873	230	200@20%
36	-1.042	-3.04	230	200@20%
37	1.042	-3.21	230	200@20%
38	3.125	-3.375	230	200@20%
39	5.208	-3.548	130	200@20%
40	-5.208	-3.712	230	200@20%

Pandar64 Channel Distribution (To Be Continued)

Channel # in UDP Data	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range (in meters) with Reflectivity
41	-3.125	-3.884	130	200@20%
42	-1.042	-4.05	230	200@20%
43	1.042	-4.221	130	200@20%
44	3.125	-4.385	130	200@20%
45	5.208	-4.558	130	200@20%
46	-5.208	-4.72	130	200@20%
47	-3.125	-4.892	130	200@20%
48	-1.042	-5.057	130	200@20%
49	1.042	-5.229	130	200@20%
50	3.125	-5.391	130	200@20%
51	5.208	-5.565	130	200@20%
52	-5.208	-5.726	130	200@20%
53	-3.125	-5.898	130	200@20%
54	-1.042	-6.061	130	200@20%
55	-1.042	-7.063	130	200@20%
56	-1.042	-8.059	130	200@20%
57	-1.042	-9.06	130	200@20%
58	-1.042	-9.885	130	200@20%
59	-1.042	-11.032	130	200@20%
60	-1.042	-12.006	130	200@20%

Pandar64 Channel Distribution (Continued)

Channel # in UDP Data	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range (in meters) with Reflectivity
61	-1.042	-12.974	130	200@20%
62	-1.042	-13.93	130	200@20%
63	-1.042	-18.889	130	200@20%
64 (Bottom Beam)	-1.042	-24.897	130	200@20%

Appendix II Absolute Time and Laser Firing Time

■ Absolute Time of Point Cloud Data Packets

The absolute packing time of a Point Cloud Data Packet is the sum of 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)

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

■ End Time of Each Block

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

For Pandar64, there are 6 blocks of ranging data in each Point Cloud Data Packet, as shown below. Each block contains the ranging data from 64 channels, one return per channel.

Body: 1164 bytes (6 blocks)				
Block 1	**Block 2**	**Block 3**	**...**	**Block 6**
Azimuth 1	Azimuth 2	Azimuth 3	...	Azimuth 6
Channel 1	Channel 1	Channel 1	...	Channel 1
Channel 2	Channel 2	Channel 2	...	Channel 1
...	...	...	...	...
Channel 64	Channel 64	Channel 64	...	Channel 64

Single Return Mode

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

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

Block	End Time (μs)
Block 6	t0 - 42.58
Block N	t0 - 42.58 - 55.56 * (6 - N)
Block 3	t0 - 42.58 - 55.56 * 3
Block 2	t0 - 42.58 - 55.56 * 4
Block 1	t0 - 42.58 - 55.56 * 5

Dual Return Mode

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

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

Block	End Time (μs)
Block 6 & Block 5	t0 - 42.58
Block 4 & Block 3	t0 - 42.58 - 55.56 * 1
Block 2 & Block 1	t0 - 42.58 - 55.56 * 2

■ Laser Firing Time of Each Channel

Assuming that the end time of Block 6 is t6, the laser firing time can be calculated as follows.

Laser Firing Time of Each Channel (To Be Continued)

Firing Sequence	Channel #	Firing Time (μs)
1	12	t6 - (1.304 * 15 + 1.968 * 16 + 3.62)
1	40	t6 - (1.304 * 15 + 1.968 * 16 + 3.62)
2	18	t6 - (1.304 * 15 + 1.968 * 15 + 3.62)
2	38	t6 - (1.304 * 15 + 1.968 * 15 + 3.62)
3	11	t6 - (1.304 * 15 + 1.968 * 14 + 3.62)
3	26	t6 - (1.304 * 15 + 1.968 * 14 + 3.62)
4	17	t6 - (1.304 * 15 + 1.968 * 13 + 3.62)
4	32	t6 - (1.304 * 15 + 1.968 * 13 + 3.62)
5	8	t6 - (1.304 * 15 + 1.968 * 12 + 3.62)
5	23	t6 - (1.304 * 15 + 1.968 * 12 + 3.62)
6	14	t6 - (1.304 * 15 + 1.968 * 11 + 3.62)
6	29	t6 - (1.304 * 15 + 1.968 * 11 + 3.62)
7	20	t6 - (1.304 * 15 + 1.968 * 10 + 3.62)
7	35	t6 - (1.304 * 15 + 1.968 * 10 + 3.62)
8	13	t6 - (1.304 * 15 + 1.968 * 09 + 3.62)
8	28	t6 - (1.304 * 15 + 1.968 * 09 + 3.62)
9	19	t6 - (1.304 * 15 + 1.968 * 08 + 3.62)
9	34	t6 - (1.304 * 15 + 1.968 * 08 + 3.62)
10	10	t6 - (1.304 * 15 + 1.968 * 07 + 3.62)
10	25	t6 - (1.304 * 15 + 1.968 * 07 + 3.62)

Firing Sequence	Channel #	Firing Time (μs)
11	16	t6 - (1.304 * 15 + 1.968 * 06 + 3.62)
11	31	t6 - (1.304 * 15 + 1.968 * 06 + 3.62)
12	22	t6 - (1.304 * 15 + 1.968 * 05 + 3.62)
12	37	t6 - (1.304 * 15 + 1.968 * 05 + 3.62)
13	15	t6 - (1.304 * 15 + 1.968 * 04 + 3.62)
13	30	t6 - (1.304 * 15 + 1.968 * 04 + 3.62)
14	21	t6 - (1.304 * 15 + 1.968 * 03 + 3.62)
14	36	t6 - (1.304 * 15 + 1.968 * 03 + 3.62)
15	27	t6 - (1.304 * 15 + 1.968 * 02 + 3.62)
15	42	t6 - (1.304 * 15 + 1.968 * 02 + 3.62)
16	24	t6 - (1.304 * 15 + 1.968 * 01 + 3.62)
16	33	t6 - (1.304 * 15 + 1.968 * 01 + 3.62)
17	1	t6 - (1.304 * 15 + 1.968 * 00 + 3.62)
17	44	t6 - (1.304 * 15 + 1.968 * 00 + 3.62)
18	2	t6 - (1.304 * 14 + 1.968 * 00 + 3.62)
18	46	t6 - (1.304 * 14 + 1.968 * 00 + 3.62)
19	3	t6 - (1.304 * 13 + 1.968 * 00 + 3.62)
19	52	t6 - (1.304 * 13 + 1.968 * 00 + 3.62)
20	4	t6 - (1.304 * 12 + 1.968 * 00 + 3.62)
20	50	t6 - (1.304 * 12 + 1.968 * 00 + 3.62)

Laser Firing Time of Each Channel (Continued)

Firing Sequence	Channel #	Firing Time (μs)
21	5	t6 - (1.304 * 11 + 1.968 * 00 + 3.62)
21	48	t6 - (1.304 * 11 + 1.968 * 00 + 3.62)
22	6	t6 - (1.304 * 10 + 1.968 * 00 + 3.62)
22	54	t6 - (1.304 * 10 + 1.968 * 00 + 3.62)
23	41	t6 - (1.304 * 09 + 1.968 * 00 + 3.62)
23	58	t6 - (1.304 * 09 + 1.968 * 00 + 3.62)
24	47	t6 - (1.304 * 08 + 1.968 * 00 + 3.62)
24	62	t6 - (1.304 * 08 + 1.968 * 00 + 3.62)
25	53	t6 - (1.304 * 07 + 1.968 * 00 + 3.62)
25	64	t6 - (1.304 * 07 + 1.968 * 00 + 3.62)
26	7	t6 - (1.304 * 06 + 1.968 * 00 + 3.62)
26	56	t6 - (1.304 * 06 + 1.968 * 00 + 3.62)
27	43	t6 - (1.304 * 05 + 1.968 * 00 + 3.62)
27	59	t6 - (1.304 * 05 + 1.968 * 00 + 3.62)
28	49	t6 - (1.304 * 04 + 1.968 * 00 + 3.62)
28	63	t6 - (1.304 * 04 + 1.968 * 00 + 3.62)
29	9	t6 - (1.304 * 03 + 1.968 * 00 + 3.62)
29	55	t6 - (1.304 * 03 + 1.968 * 00 + 3.62)
30	39	t6 - (1.304 * 02 + 1.968 * 00 + 3.62)
30	57	t6 - (1.304 * 02 + 1.968 * 00 + 3.62)

Firing Sequence	Channel #	Firing Time (μs)
31	45	t6 - (1.304 * 01 + 1.968 * 00 + 3.62)
31	60	t6 - (1.304 * 01 + 1.968 * 00 + 3.62)
32	51	t6 - (1.304 * 00 + 1.968 * 00 + 3.62)
32	61	t6 - (1.304 * 00 + 1.968 * 00 + 3.62)

Appendix III PTP Protocol

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

■ **LiDAR Connection When Using PTP**

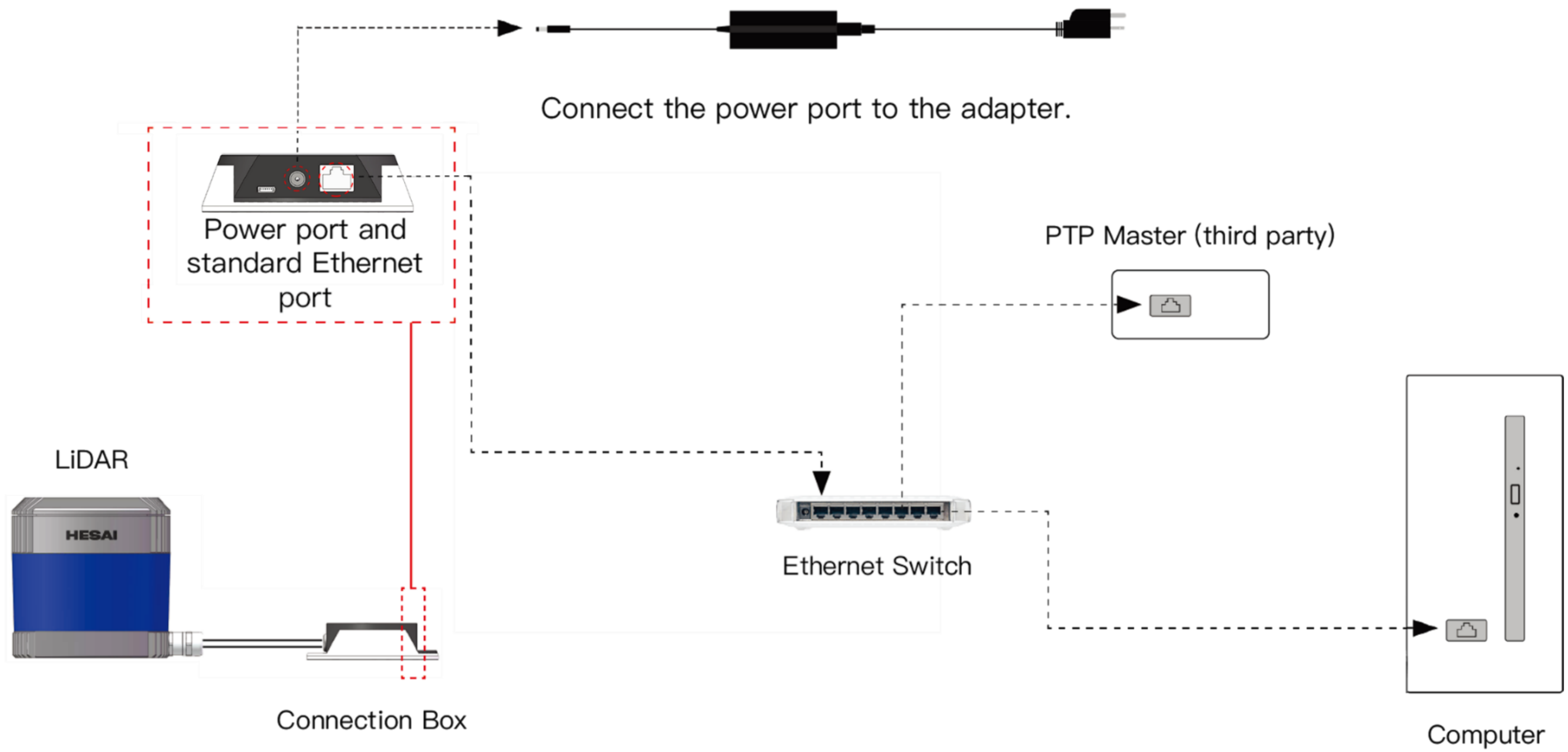


Figure III.1 Connection When Using PTP

■ 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 Phoenix Contact

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

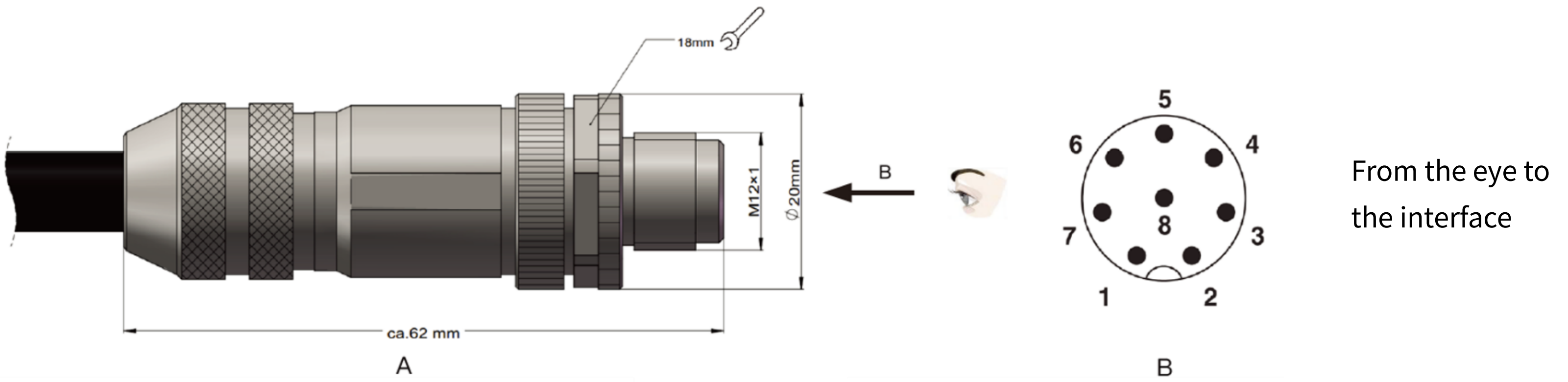


Figure IV.1 Phoenix Connector (Male)

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

Appendix V Nonlinear Reflectivity Mapping

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

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

The nonlinear relationship is detailed below.

Figure V.1 Nonlinear Reflectivity Mapping

Nonlinear Reflectivity Mapping (Continued on the Next Page)

Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)
0	0	20	0.67	40	2.69	60	5.9
1	0.01	21	0.75	41	2.81	61	6.1
2	0.02	22	0.81	42	2.94	62	6.3
3	0.03	23	0.87	43	3.07	63	6.5
4	0.04	24	0.95	44	3.21	64	6.7
5	0.05	25	1.05	45	3.36	65	6.9
6	0.08	26	1.15	46	3.5	66	7.1
7	0.11	27	1.25	47	3.64	67	7.3
8	0.13	28	1.35	48	3.79	68	7.5
9	0.15	29	1.45	49	3.93	69	7.7
10	0.19	30	1.55	50	4.08	70	7.9
11	0.23	31	1.65	51	4.25	71	8.12
12	0.26	32	1.75	52	4.42	72	8.37
13	0.29	33	1.85	53	4.58	73	8.62
14	0.34	34	1.95	54	4.75	74	8.87
15	0.39	35	2.06	55	4.92	75	9.1
16	0.44	36	2.19	56	5.1	76	9.3
17	0.5	37	2.31	57	5.3	77	9.5
18	0.56	38	2.44	58	5.5	78	9.7
19	0.61	39	2.56	59	5.7	79	9.9

Nonlinear Reflectivity Mapping (Continued on the Next Page)

Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)
80	10.17	100	15.87	120	22.83	140	31.17
81	10.5	101	16.17	121	23.25	141	31.5
82	10.83	102	16.5	122	23.75	142	31.83
83	11.12	103	16.83	123	24.17	143	32.25
84	11.37	104	17.17	124	24.5	144	32.75
85	11.62	105	17.5	125	24.83	145	33.25
86	11.87	106	17.83	126	25.25	146	33.75
87	12.12	107	18.17	127	25.75	147	34.25
88	12.37	108	18.5	128	26.17	148	34.75
89	12.62	109	18.83	129	26.5	149	35.25
90	12.87	110	19.17	130	26.83	150	35.75
91	13.17	111	19.5	131	27.25	151	36.25
92	13.5	112	19.83	132	27.75	152	36.75
93	13.83	113	20.25	133	28.17	153	37.25
94	14.17	114	20.75	134	28.5	154	37.75
95	14.5	115	21.17	135	28.83	155	38.25
96	14.83	116	21.5	136	29.25	156	38.75
97	15.12	117	21.83	137	29.75	157	39.17
98	15.37	118	22.17	138	30.25	158	39.5
99	15.62	119	22.5	139	30.75	159	39.83

Nonlinear Reflectivity Mapping (Continued on the Next Page)

Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)
160	40.5	180	51.25	200	63.25	220	76.5
161	41.25	181	51.75	201	63.75	221	77.25
162	41.75	182	52.25	202	64.5	222	77.75
163	42.25	183	52.75	203	65.25	223	78.5
164	42.75	184	53.5	204	65.75	224	79.25
165	43.25	185	54.25	205	66.25	225	79.75
166	43.75	186	54.75	206	66.75	226	80.5
167	44.25	187	55.25	207	67.5	227	81.25
168	44.75	188	55.75	208	68.25	228	81.75
169	45.25	189	56.5	209	68.75	229	82.5
170	45.75	190	57.25	210	69.5	230	83.5
171	46.25	191	57.75	211	70.25	231	84.25
172	46.75	192	58.25	212	70.75	232	84.75
173	47.25	193	58.75	213	71.5	233	85.5
174	47.75	194	59.5	214	72.25	234	86.5
175	48.25	195	60.25	215	72.75	235	87.25
176	48.75	196	60.75	216	73.5	236	87.75
177	49.5	197	61.25	217	74.25	237	88.5
178	50.25	198	61.75	218	74.75	238	89.25
179	50.75	199	62.5	219	75.5	239	89.75

Nonlinear Reflectivity Mapping (Continued)

Reflectivity Index (0~255)	Reflectivity (%)
240	90.5
241	91.5
242	92.5
243	93.25
244	93.75
245	94.5
246	95.5
247	96.25
248	96.75
249	97.5
250	98.5
251	99.5
252	132
253	196
254	242

Appendix VI Certification Info

■ FCC Declaration

FCC ID: 2ASO2PANDAR

FCC Warning

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.

FCC Statement

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

NOTE Any changes or modifications not expressly approved by the grantee of this device could void the user's authority to operate the equipment.

■ IC Statement

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

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

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

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

Appendix VII Support and Contact

■ Technical Support

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

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

NOTE Please leave your questions under the corresponding GitHub projects.

■ Legal Notice

Hesai Technology makes no representations or warranties, either expressed or implied, with respect to the contents hereof and specifically disclaims any warranties, merchantability or fitness for any particular purpose. Further, Hesai Technology reserves the right to revise this publication and to make changes from time to time in the contents hereof without obligation to notify any person of such revision or changes.

HESAI and HESAI logo are registered trademarks of Hesai Technology. All other trademarks, service marks, and company names in this manual or on Hesai's official website are properties of their respective owners.

The software included in this product contains copyright that is registered under Hesai Technology. Any third party is not permitted, except as expressly permitted by licensor or expressly required by applicable law, to decompile, reverse engineer, disassemble, modify, rent, lease, loan, distribute, sublicense, create derivative works based on the whole or any part of the software.

Hesai Photonics Technology Co., Ltd.

Phone: +86 400 805 1233
Website: www.hesaitech.com
Address: Building L2, Hongqiao World Centre, Shanghai, China

Business Email: info@hesaitech.com
Service Email: service@hesaitech.com

HESAI Wechat