HESAI

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Pandar128

128-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 Pandar128.

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

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

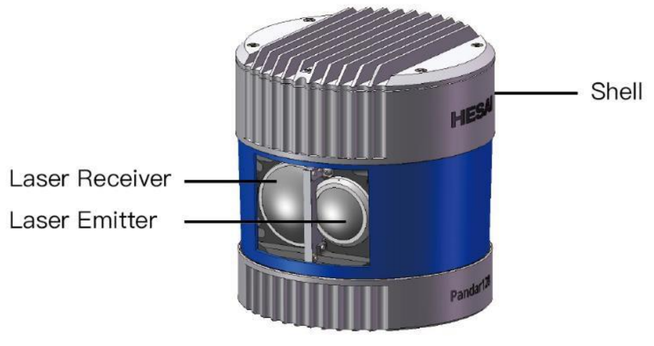


Figure 1.2 Partial Cross-Sectional Diagram

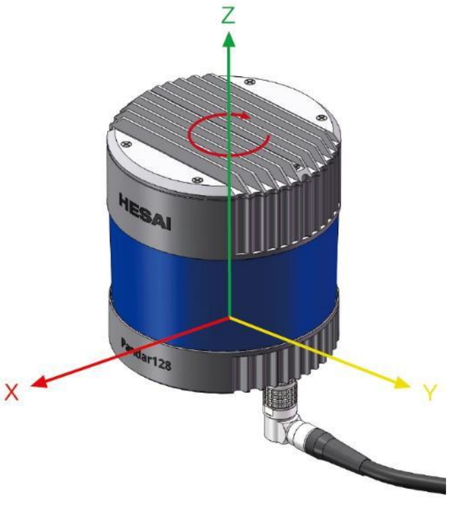


Figure 1.3 Coordinate System (Isometric View)

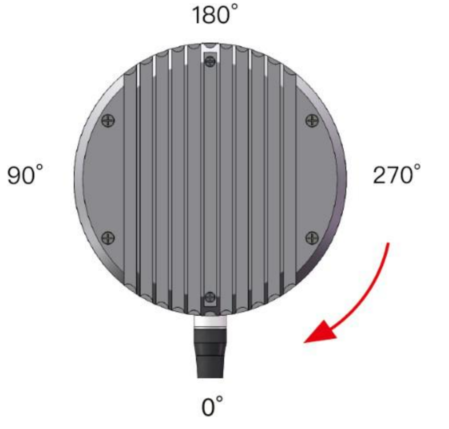


Figure 1.4 Rotation Direction (Top View)

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 42 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

- 0.125° from Channel 26 to Channel 90
- 0.5° from Channel 2 to Channel 26, as well as from Channel 90 to Channel 127
- 1° between Channel 1 and Channel 2, as well as between Channel 127 and Channel 128
- detailed in Appendix I

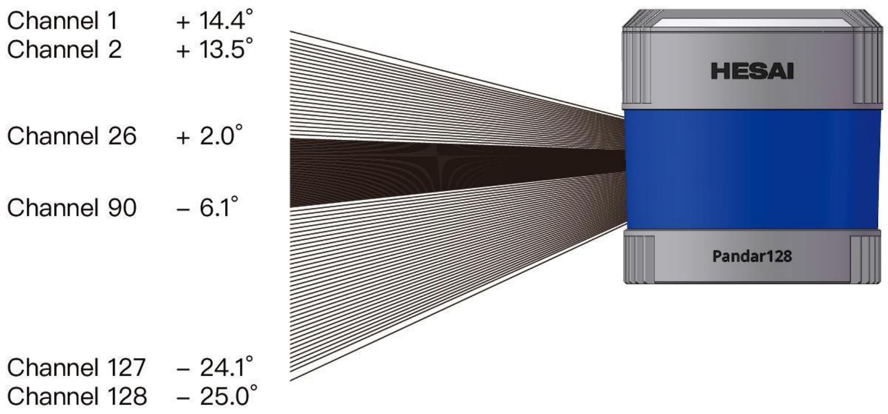


Figure 1.5 Channel Vertical Distribution

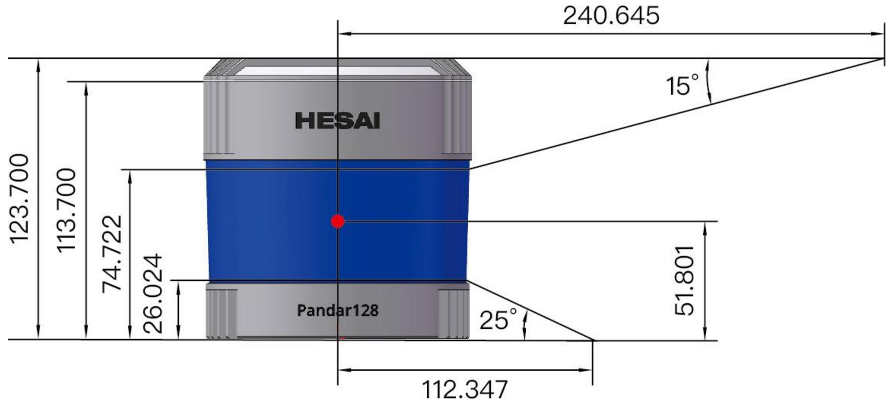


Figure 1.6 Laser Firing Position

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 Section 6.2.

1.4 Specifications

SENSOR	
Scanning Method	Mechanical Rotation
Channel	128
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)	Configurable on-the-fly
	0.1°/0.2° (10 Hz)
	0.2°/0.4° (20 Hz)
FOV (Vertical)	40° (−25° to +15°)
Resolution (Vertical)	0.125° (−6° to +2°)
	0.5° (+2° to +14°, −6° to −24°)
	1° (+14° to +15°, −24° to −25°)
Frame Rate	10 Hz, 20 Hz
Returns	Single Return
	Dual Return (Strongest, Last)
CERTIFICATIONS	
	FDA

MECHANICAL/ELECTRICAL/OPERATIONAL	
Wavelength	905 nm
Laser Class	Class 1 Eye Safe
Ingress Protection	IP6K9K
Dimensions	Height: 122.7 mm
	Top/Bottom Diameter: 118.00 / 116.00 mm
Operating Voltage	DC 9 to 48 V
Power Consumption	25 W (at 0.1° horizonal resolution)
	20 W (at 0.2° horizonal resolution)
Operating Temperature	−40℃ to 85℃
Weight	1.63 kg
DATA I/O	
Data Transmission	UDP/IP Ethernet (1000 Mbps)
Data Outputs	Distance, Azimuth Angle, Intensity
Data Points Generated	Single Return: 4,608,000 points/sec (max)
	Dual Return Mode: 9,216,000 points/sec (max)
Clock Source	GPS / PTP
PTP Clock Accuracy	≤1 μs
PTP Clock Drift	≤1 μs/s

NOTE Specifications are subject to change without notice.

NOTE The range and horizontal resolution of each channel is shown in Appendix I (Channel Distribution).

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

2.
Set up

Please find operational manual

3. Data Structure

1000 Mbps Ethernet UDP/IP is used for data output. The output data includes Point Cloud Data Packets and GPS Data Packets.

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

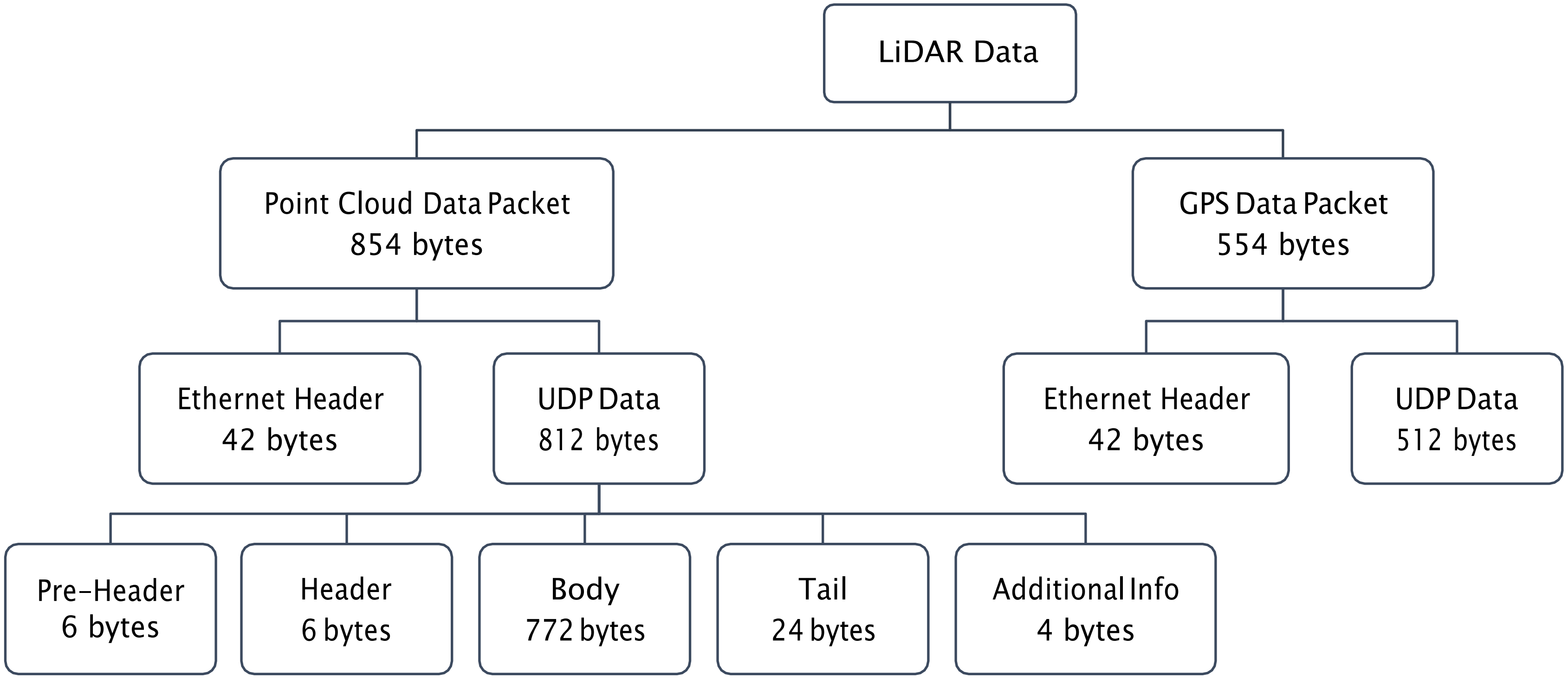


Figure 3.1 Data Structure

2.1 Point Cloud Data Packet

2.1.1 Ethernet Header

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

Point Cloud Ethernet Header: 42 bytes		
Field	Bytes	Description
Ethernet II MAC	12	Destination: broadcast (0xFF: 0xFF: 0xFF: 0xFF: 0xFF: 0xFF) Source: (xx:xx:xx:xx:xx:xx)
Ethernet Data Packet Type	2	0x08, 0x00
Internet Protocol	20	Shown in the figure below
UDP Port Number	4	UDP source port (0x2710, representing 10000) Destination port (0x0940, representing 2368)
UDP Length	2	0x0334, representing 820 bytes (8 bytes more than the size of the Point Cloud UDP Data)
UDP Checksum	2	–

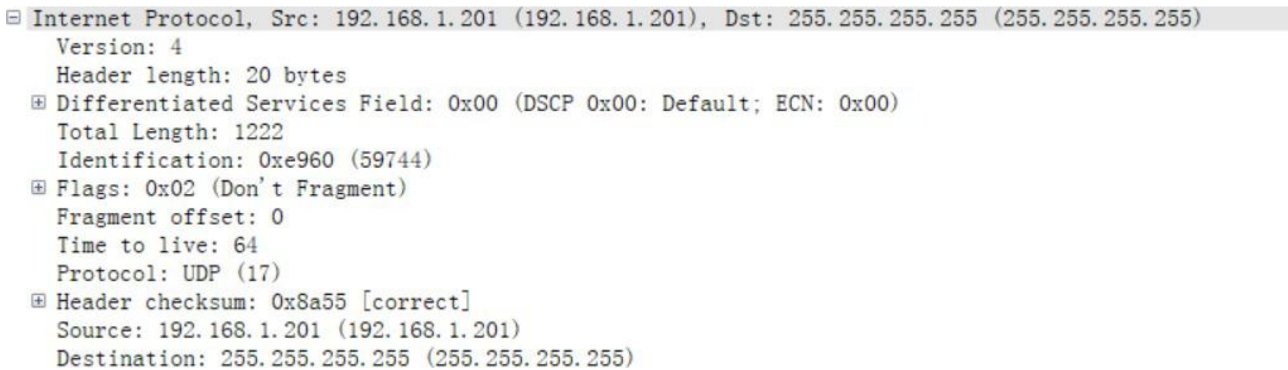

```
⊟ Internet Protocol, Src: 192.168.1.201 (192.168.1.201), Dst: 255.255.255.255 (255.255.255.255)
    Version: 4
    Header length: 20 bytes
  ⊞ Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00)
    Total Length: 1222
    Identification: 0xe960 (59744)
  ⊞ Flags: 0x02 (Don't Fragment)
    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

3.2.2 UDP Data

■ **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	Major version number of the protocol: to distinguish between product models 0x01 for Pandar128
Protocol Version Minor	1	Minor version number of the protocol: for each product model, to indicate the current protocol version Currently 0x03 for Pandar128
Reserved	2	-

■ **Header**

Header: 6 bytes		
Field	Bytes	Description
Laser Num	1	0x80 (128 channels)
Block Num	1	0x02 (2 blocks per packet)
Echo Count	1	The type of return of the first block in this data packet 0x00 - in the Single Return mode 0x01 - last return in the Dual Return mode 0x02 - strongest return in the Dual Return mode
Dis Unit	1	0x04 (4 mm)
Echo Num	1	The number of returns (i.e. echoes) that each channel generates 0x01 - Single Return 0x02 - Dual Return
UDP Seq	1	Whether the packet includes a UDP sequence number field 0x00 - UDP sequence OFF (default) 0x01 - UDP sequence ON

■ Body

Body: 772 bytes (2 blocks)	
Block 1	**Block 2**
Azimuth 1	Azimuth 2
Channel 1	Channel 1
Channel 2	Channel 2
…	…
Channel 128	Channel 128

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

- Block 1 is the last return, and Block 2 is the strongest return
- If the last and strongest returns coincide, the second strongest return will be placed in Block 2
- The Azimuth of Block1 and Block 2 is the same

Block size = Size of Azimuth + 128 * Size of Channel XX = 386 bytes

<table>
<tr><th colspan="4">Each Block in the Body: 386 bytes</th></tr>
<tr><td>Field</td><td>Bytes</td><td colspan="2">Description</td></tr>
<tr><td>Azimuth</td><td>2</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 (in degrees) = [Azimuth_H, Azimuth_L] / 100 = Azimuth / 100</td></tr>
<tr><td rowspan="2">Channel XX</td><td rowspan="2">3</td><td>2-byte Distance</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 mm
Maximum Distance Value = (2 ^ 16 – 1) * 4 mm = 262.14 m</td></tr>
<tr><td>1-byte Reflectivity</td><td>Reflectivity, in percentage (0 to 255%)</td></tr>
</table>

■ Tail

Tail: 24 bytes		
Field	Bytes	Description
Reserved	6	-
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
Reserved	3	-
Motor Speed	2	speed_2_bytes [15:0] = speed (RPM)
Timestamp	4	The “μs time” part of the absolute time of this data packet (defined in Appendix II.1) Unit: μs Range: 0 to 1000000 μs (1 s)
Return Mode	1	0x37 for Strongest Return mode, 0x38 for Last Return mode, and 0x39 for Dual Return mode
Factory Information	1	0x42 (or 0x43)
Date & Time	6	Date and time in decimal: year, month, date, hour, minute, second

■ 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 Pandar128's Channel 5 in Block 2 as an example:

1) Vertical angle of Channel 5 is 12.165°, 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 Section 6.2

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 1.093°, 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 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**

2.2 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.

2.2.1 Ethernet Header

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

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

2.2.2 UDP Data

<table>
<tr><th colspan="5">GPS UDP data: 512 bytes</th></tr>
<tr><td>Field</td><td>Bytes</td><td colspan="3">Description</td></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 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

2.2.3 GPS Data Analysis

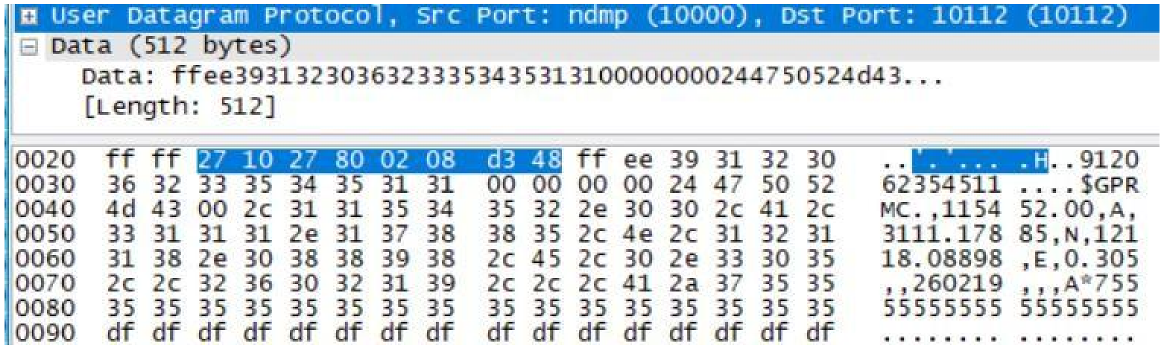


Figure 3.4 GPS Data Packet – UDP Data (Example)

Date

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

Time

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

μs Time

3 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

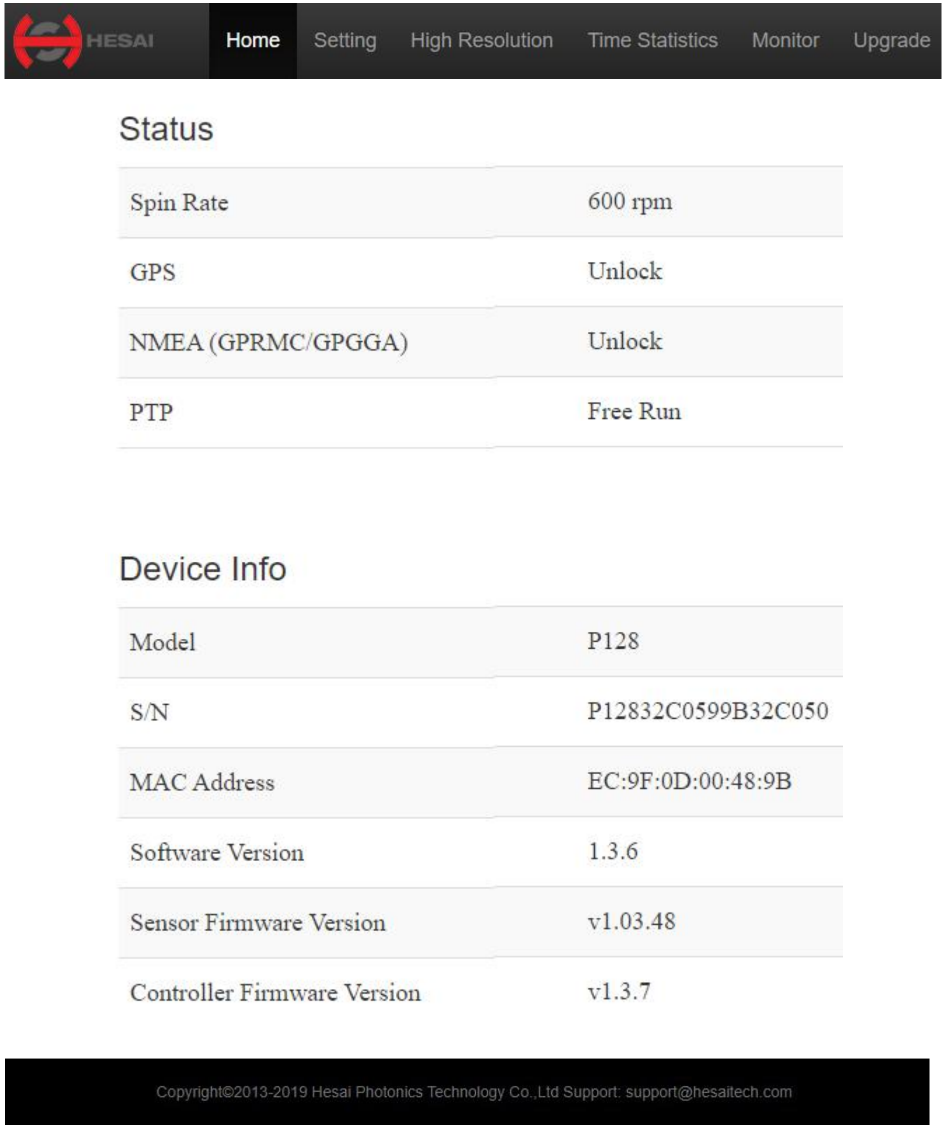
Web control is used for setting parameters, checking device info, and upgrading.

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

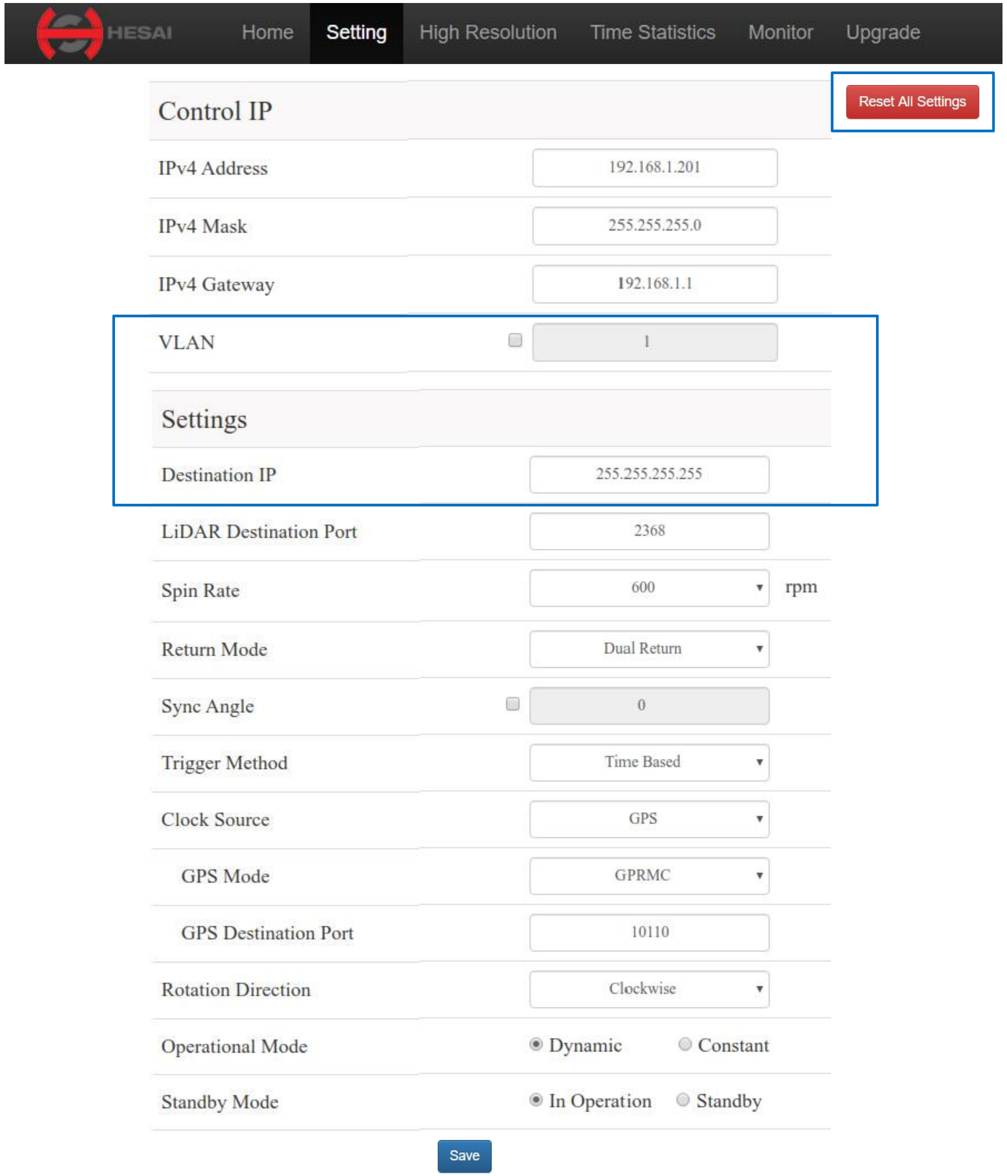
NMEA (GPRMC/GPGGA) Status

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

PTP Status

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

4.2 Settings



1. Reset All Settings

By clicking the "Reset All Settings" button on the top-right corner, all configurable parameters in the Settings page and the Azimuth FOV page will be reset to their default values.
The default values are shown in the left-hand screenshot and in Section 4.3.1.

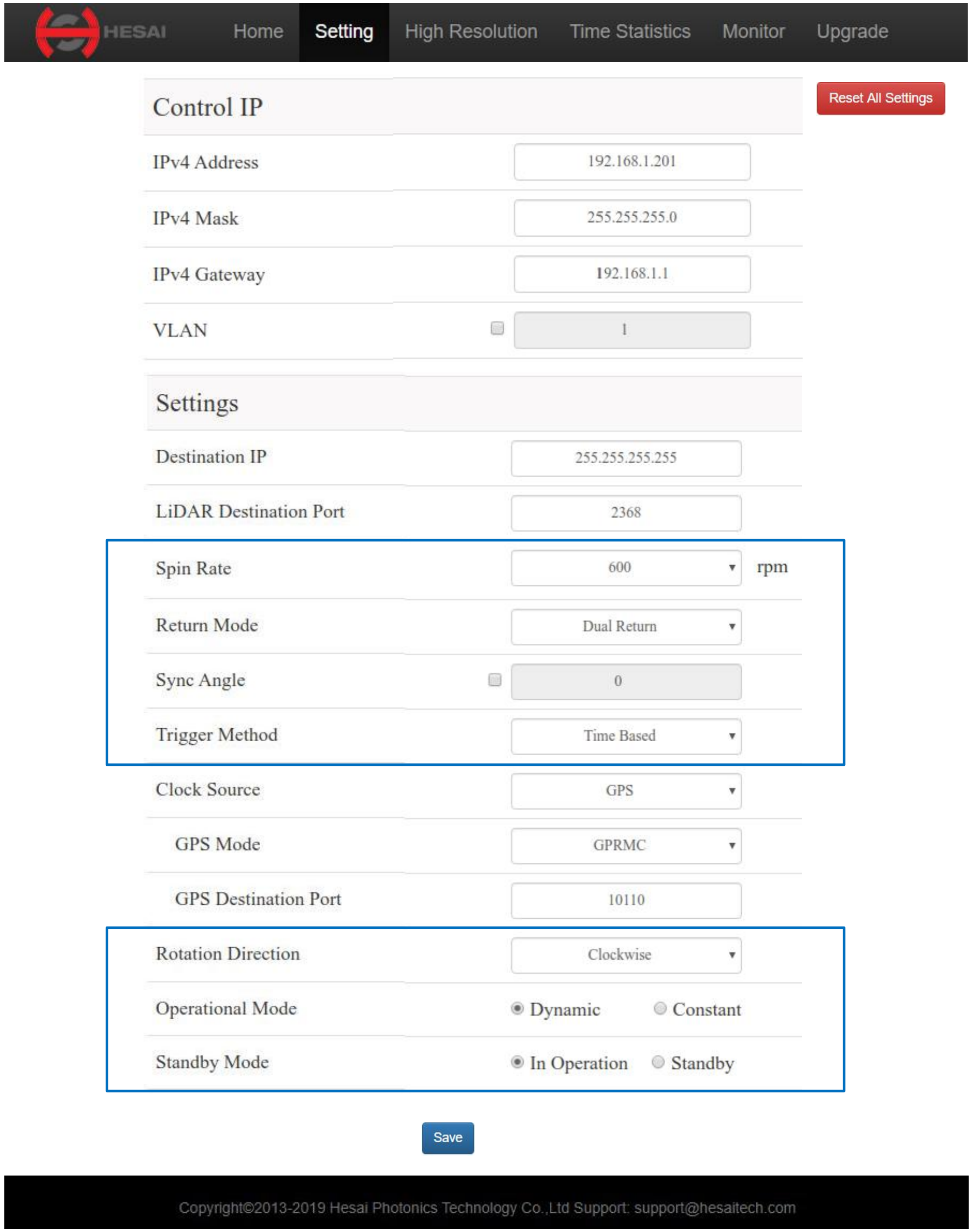
2. Control IP – VLAN

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

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

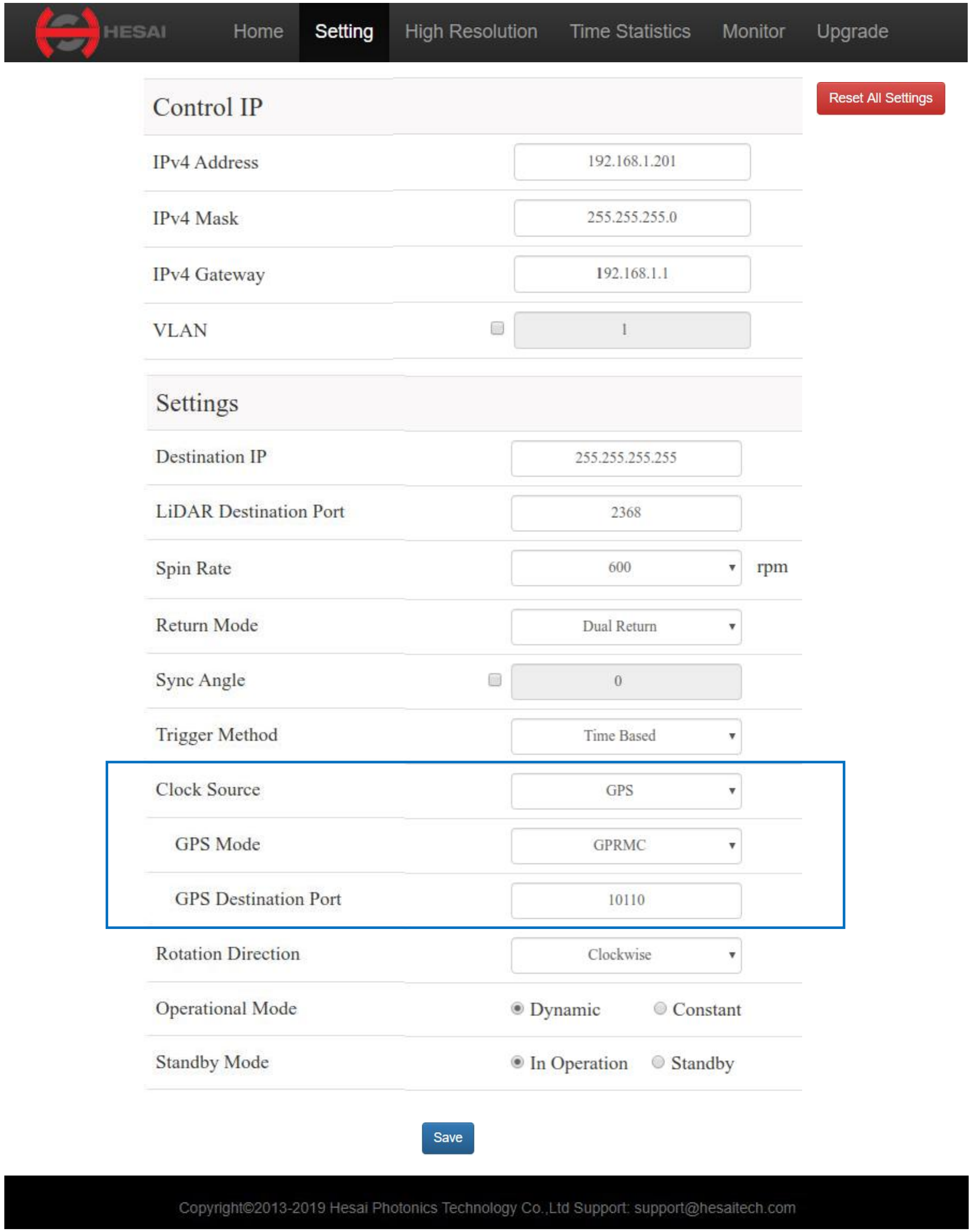
3. Settings – Destination IP

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



4. Settings – Others

Spin Rate	600 rpm / 1200 rpm
Return Mode	Last / Strongest / Dual Return
Sync Angle	0~360 degrees
	By default, the LiDAR's zero-degree position (defined in Section 1.2) is not in sync with PPS. If syncing is needed, check the check box and input a sync angle.
Trigger Method	Angle-Based / Time-Based
	In the angle-based trigger mode, lasers fire every 0.2 deg at 10 Hz or 0.4 deg at 20 Hz. In the time-based mode, lasers fire every 55.56 us.
Rotation Direction	Clockwise / Counterclockwise
	Rotation of the motor
Operational Mode	Dynamic / Constant
	Under the Dynamic mode, the LiDAR automatically shifts between four states (High Performance, Standard, Energy Saving, and Shutdown), according to the ambient temperature. Under the Constant mode, the LiDAR only shifts between High Performance and Shutdown states.
Standby Mode	Whether to stop the motor from running and lasers from firing



5. Clock Source and PTP Parameters

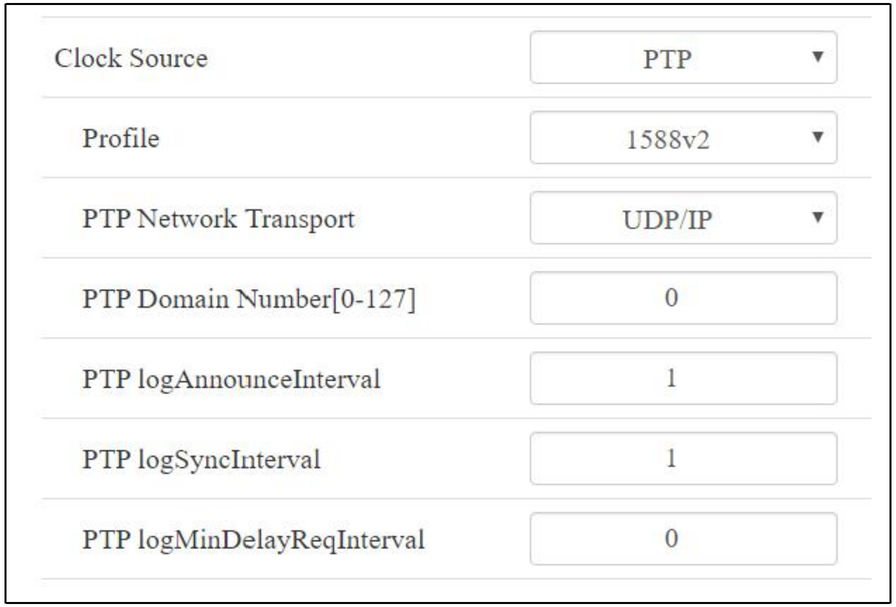
Clock Source	GPS / PTP
	In the PTP mode, LiDARs do not output GPS Data Packets, as detailed in Appendix III PTP Protocol.

- When GPS is selected as the clock source:

GPS Mode	GPRMC / GPGGA
	Format of the data received from the external GPS module. Both the NMEA sentence and the GPS positioning status are put into the GPS Data Packet. See Section 3.2.2 for details.
GPS Destination Port	10110 (default)
	Port used for sending GPS Data packets

(Continued on the next page)

(Continued)



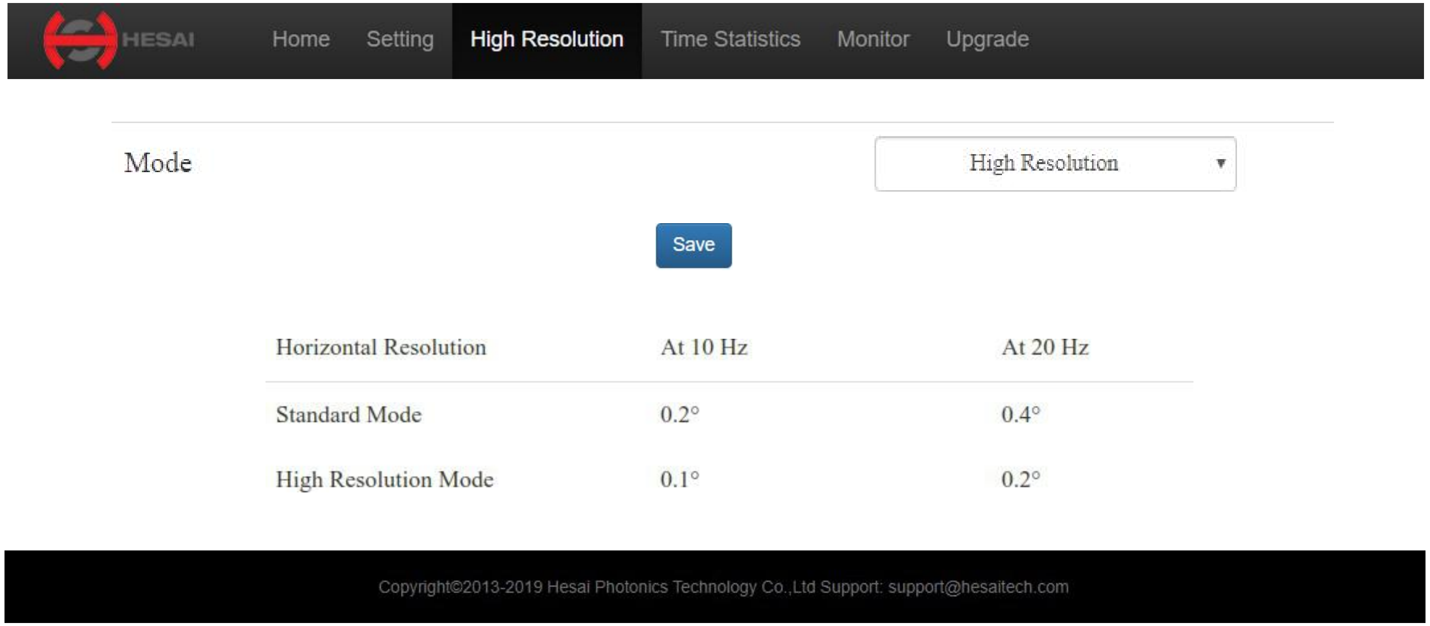
- When PTP is selected as the clock source:

Profile	1588v2 (default) or 802.1AS
	IEEE timing and synchronization standard used
PTP Network Transport	UDP/IP (default) or L2
	UDP/IP follows the PTPv2 standard defined in IEEE 1588-2008 L2 follows the gPTP standard defined in IEEE 802.1 AS
PTP Domain Number	Integer from 0 to 127
	Domain attribute of the local clock
PTP logAnnounceInter-val	-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 logMinDelayReqIn-terval	-7 to 3 log seconds
	Minimum permitted mean time between Delay_Req messages (default: 0)

4.3 High Resolution

The horizontal resolution of far field measurement is configurable on-the-fly.

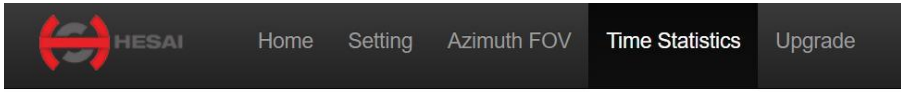
Configuration Mode	Frame Rate	Horizontal Resolution of Far Field Measurement
Standard	10 Hz	0.2° for all channels
	20 Hz	0.4° for all channels
High Resolution	10 Hz	0.1° for the 64 middle channels (Channel 27 to Channel 90) 0.2° for the other channels **NOTE** Channel # counts from 1 to 128
	20 Hz	0.2° for the 64 middle channels (Channel 27 to Channel 90) 0.4° for the other channels



NOTE The horizontal resolution of near field measurement is always 0.4° at 10 Hz and 0.8° at 20 Hz. See Appendix I for the definition of near/far field measurement.

4.4 Operation Statistics

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

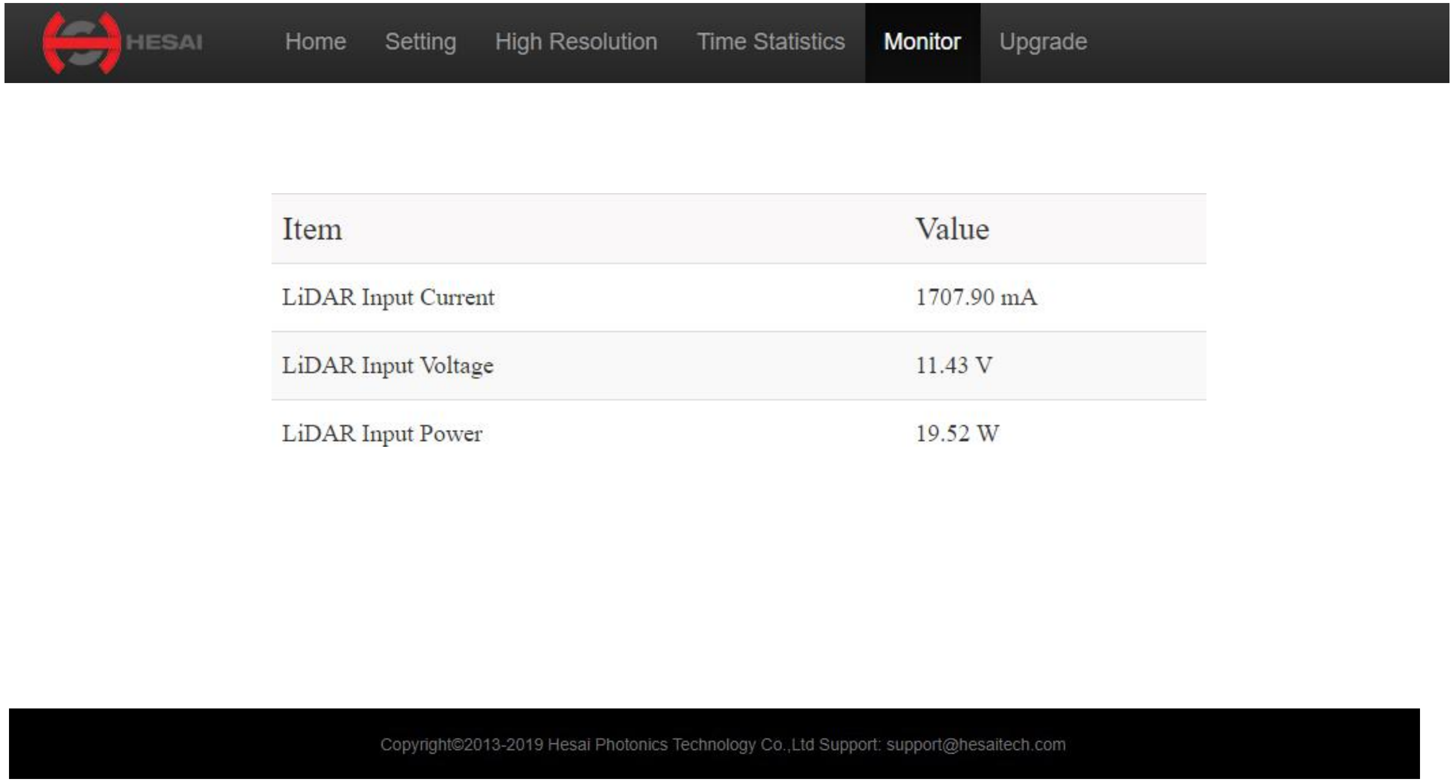


Start-up Counts	40
Internal Temperature	27.71°C
Total Operation Time	54 h 49 min

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

4.5 Monitor

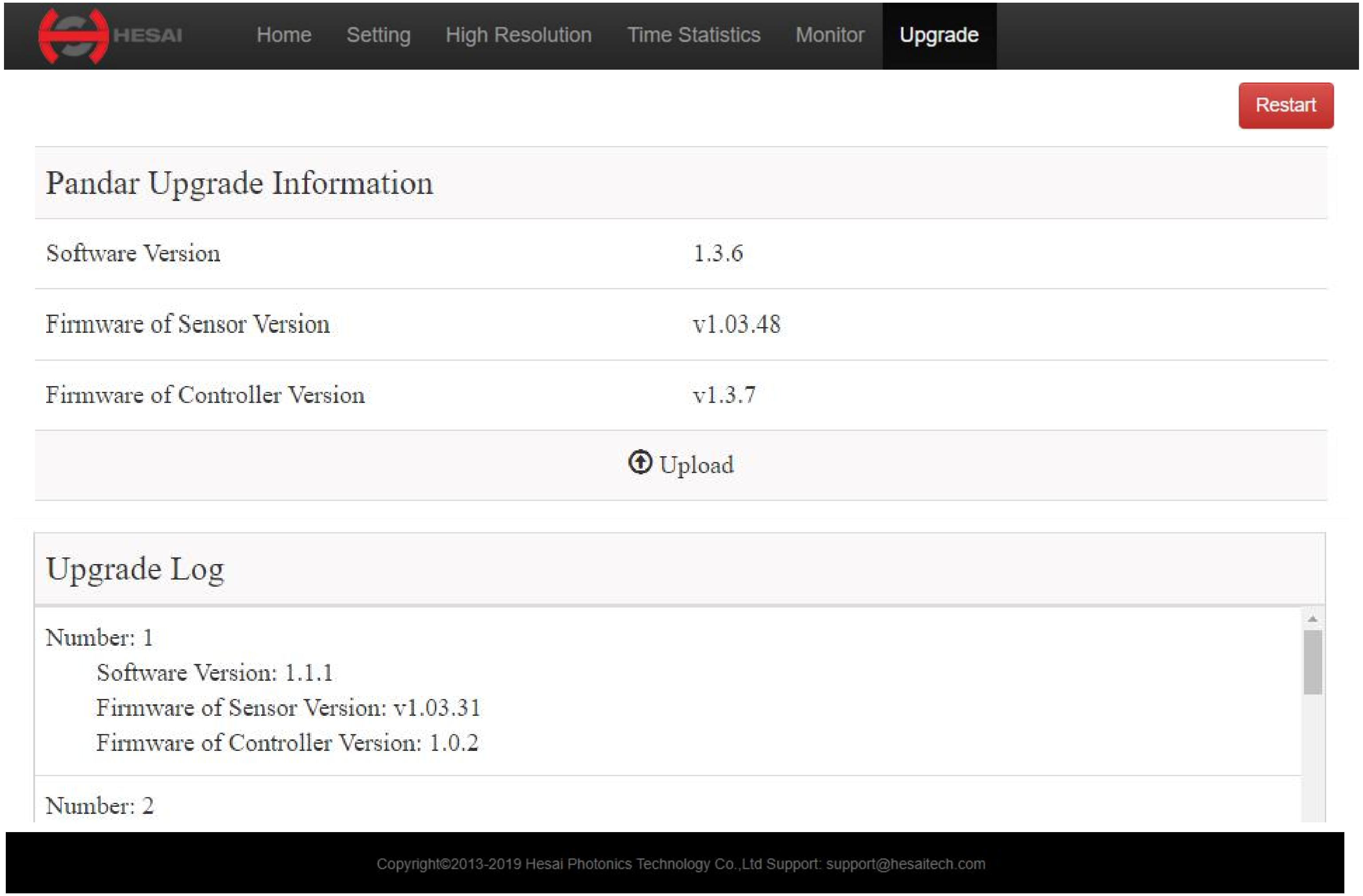
The LiDAR's input current, voltage, and power consumption are displayed.



Item	Value
LiDAR Input Current	1707.90 mA
LiDAR Input Voltage	11.43 V
LiDAR Input Power	19.52 W

4.6 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 process 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

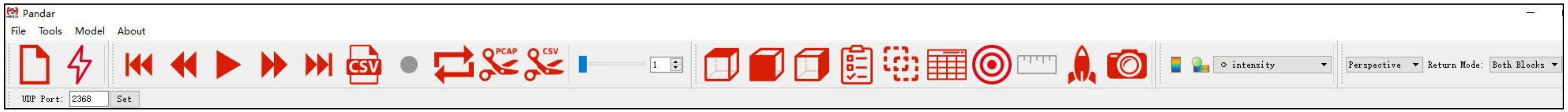
PandarView is a software that records and displays the point cloud data from Hesai LiDARs, available in 64-bit Windows 7/8/10 and Ubuntu-16.04/18.04.

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 the default settings in the setup wizard, including "install for all users"
		Double click and install PandarView_Windows using the default settings
Ubuntu-16.04	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

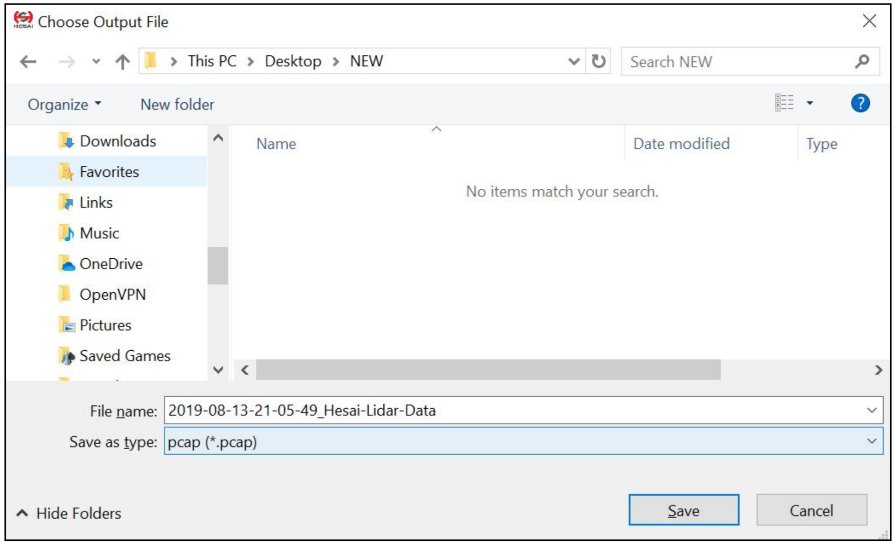
Set the PC's IP address according to Section 2.4 Use.

■ 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.



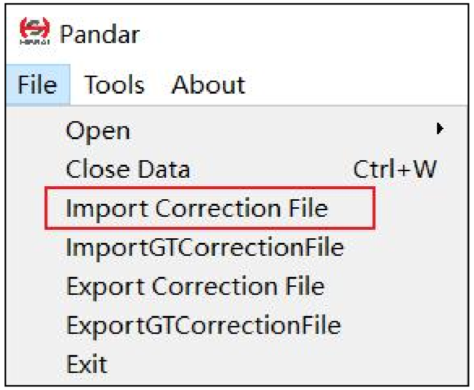
■ Open a PCAP File

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".



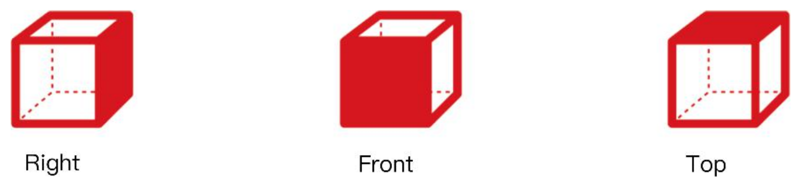
■ Play a PCAP File

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)	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 (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	
PCAP	Save multiple frames to .PCAP	Start Frame: 0 End Frame: 408 Specify the start and end frames
CSV	Save multiple frames to .CSV (the XYZ coordinates as the last three columns)	
20	Drag this progress bar or enter a frame number to jump to a specific frame	

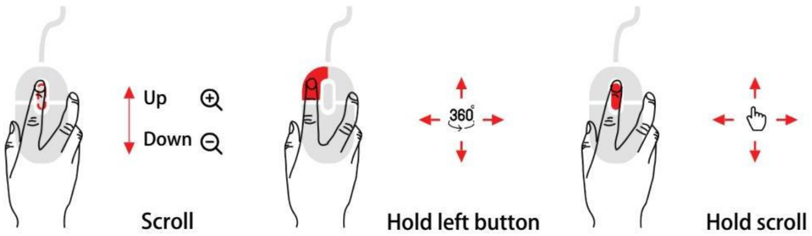
5.3 Features

■ Viewpoint Selection

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

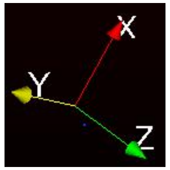


■ Mouse Shortcuts



- 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



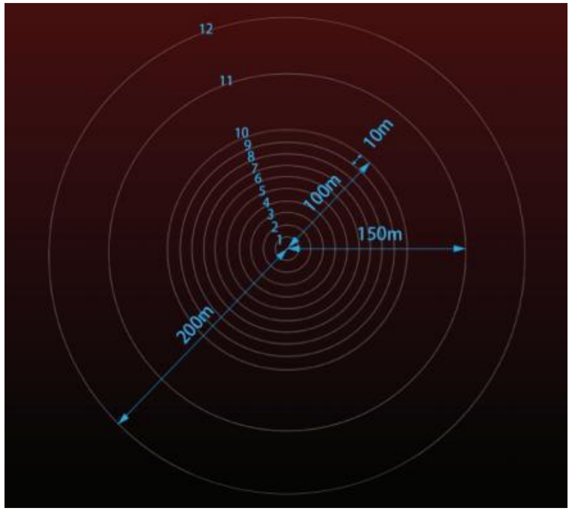
■ 3D Projection and Distance Measurement

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.

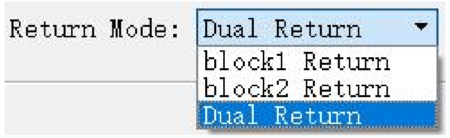
■ Distance Reference Circles

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**

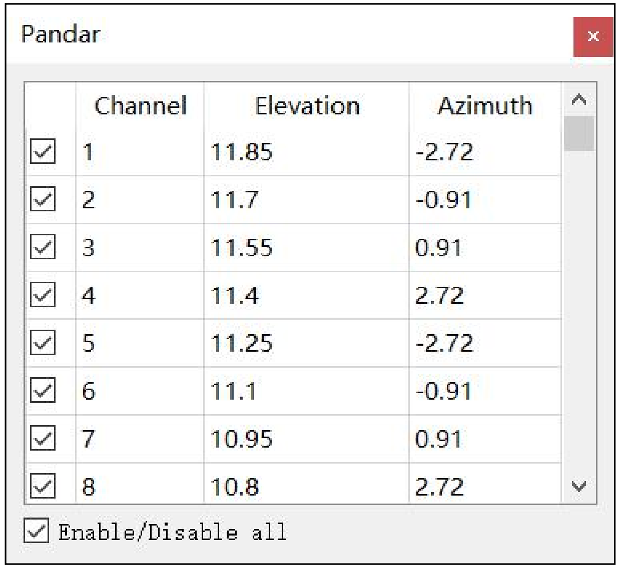
Enter the UDP port number, and click "Set" to apply it.

■ **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

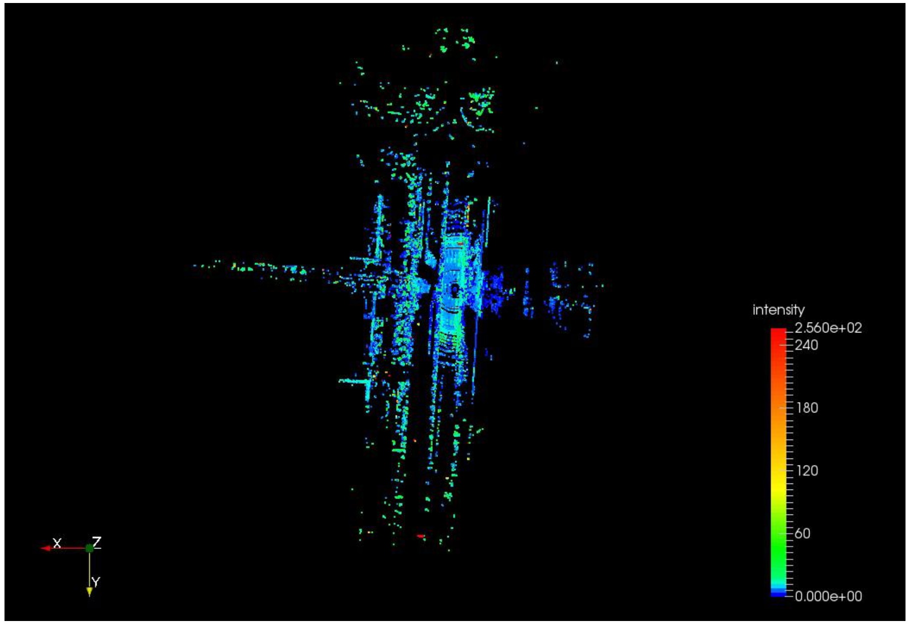
Some of the data fields are defined below:

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

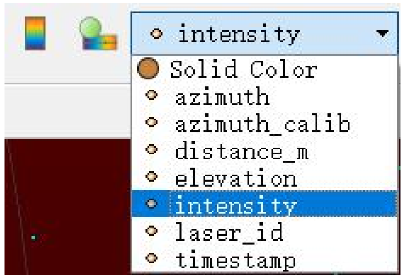
To cancel the selection, click on again and click on any place outside the selected area.

■ Color Schemes

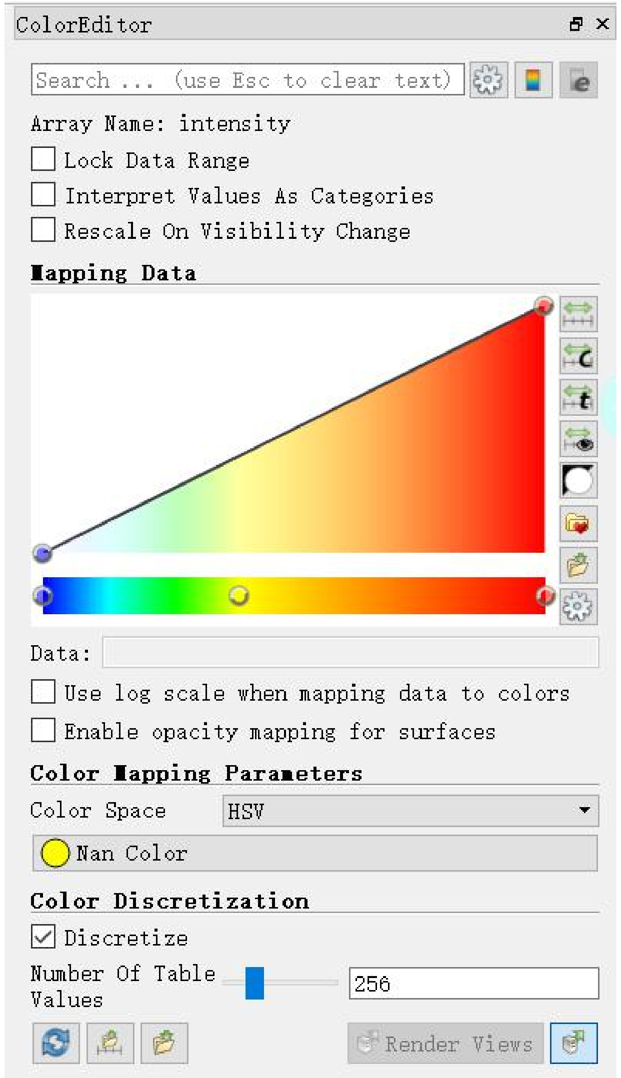
Click on to show the color legend at the lower right corner.



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

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

6.1 Packet Structure

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

Table 6.1 Command Message Sent from Client to LiDAR

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

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

Table 6.2 Feedback Message from LiDAR to Client

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

6.2 Frequently Used Commands

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

6.2.1 PTC_COMMAND_GET_LIDAR_CALIBRATION

Command message payload

None

Feedback message payload

LiDAR's calibration file in CSV Format (ASCII)

Including 3 fields: LaserID, Elevation, and Azimuth Offset

6.2.2 PTC_COMMAND_PTP_DIAGNOSTICS

Command message payload

1-byte PTP Query Type

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

Feedback message payload

a. PTP STATUS

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

b. PTP TLV PORT_DATA_SET

Per IEEE-1588 standard management TLV PORT_DATA_SET

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

c. LinuxPTP TLV TIME_STATUS_NP(0xc000)

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

d. LinuxPTP TLV GRANDMASTER_SETTINGS_NP(0xc001)

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

6.2.3 PTC_COMMAND_GET_INVENTORY_INFO

Command message payload

None

Feedback message payload

Field	Length	Description
sn	18 bytes	Serial number of the device
date_of_manufacture	16 bytes	Date of manufacture in ASCII (yyyy-mm-dd)
mac	6 bytes	MAC address of the device
sw_ver	16 bytes	Software version in ASCII (xx.xx.xx)
hw_ver	16 bytes	Hardware version in ASCII
control_fw_ver	16 bytes	Controller firmware version in ASCII
sensor_fw_ver	16 bytes	Sensor firmware version in ASCII
angle_offset	2 bytes	Zero-angle offset, as an unsigned short value in network byte order (big endian)
model	1 byte	0 – Pandar40P 2 – Pandar64 3 - Pandar128 5 - Pandar40 15 - PandarQT 17 - Pandar40M
motor_type	1 byte	0 – single direction 1 – dual direction **NOTE** Not supported on Pandar40
num_of_lines	1 byte	Number of channels
reserved	11 bytes	-

6.2.4 PTC_COMMAND_GET_CONFIG_INFO

Command message payload

None

Feedback message payload

Table 6.10 PTC_COMMAND_GET_CONFIG_INFO (continued on the next page)

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

Table 6.10 PTC_COMMAND_GET_CONFIG_INFO (continued)

udp_seq	1 byte	Whether the point cloud data will include a UDP sequence number field 0 - UDP sequence OFF (default) 1 - UDP sequence ON #1 (UDP sequence increments only when UDP packets are generated) 2 - UDP sequence ON #2 (UDP sequence increments even though no UDP packet is generated outside the specified azimuth FOV) **NOTE** Not applicable to PandarQT and Pandar128. These two models always have the UDP sequence ON.
trigger_method	1 byte	0 – angle based 1 – time based (default)
return_mode	1 byte	0 – last return 1 – strongest return 2 – dual return
standby_mode	1 byte	0 – in operation 1 – standby
motor_status	1 byte	0x0* – cannot reverse the rotation direction 0x1* – supports reversing the rotation direction 0x*0 – currently rotating clockwise 0x*1 – currently rotating counterclockwise
vlan_flag	1 byte	0 – VLAN not in use 1 – VLAN in use
vlan_id	2 bytes	VLAN ID
clock_data_fmt	1 byte	0 – GPRMC 1 – GPGGA **NOTE** Not applicable to PandarQT and Pandar128
noise_filtering	1 byte	0 – OFF 1 – ON **NOTE** Not applicable to PandarQT and Pandar128
reflectivity_mapping	1 byte	0 – Linear Mapping 1 – Non-linear Mapping **NOTE** Not applicable to PandarQT and Pandar128
reserved	6 bytes	-

6.2.5 PTC_COMMAND_GET_LIDAR_STATUS

Command message payload

None

Feedback message payload

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

7 Sensor Maintenance

Storage

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

Transport

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

Cleaning

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

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

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

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

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

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

8 Troubleshooting

Table 8.1 Troubleshooting (To Be Continued)

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

Table 8.1 Troubleshooting (Continued)

Symptoms	Points to Check
Abnormal point cloud (misaligned points, flashing points, or incomplete FOV)	▪ Make sure the LiDAR's enclosure is clean. If not, refer to Chapter 7 Sensor Maintenance for the cleaning method ▪ Make sure the LiDAR's calibration file is imported. (Pandar40P automatically imports the calibration file, while Pandar40 requires manual importing) ▪ 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	▪ Make sure the GPS receiver is properly connected ▪ Make sure the PPS signal is connected to the LiDAR ▪ Make sure the Destination GPS Port is correct on the Settings page of web control ▪ Make sure the input GPS signals satisfy the electrical requirements in Section 2.2 Interface and Section 2.3.1 Connection Box Interfaces in the user manual

Appendix I Channel Distribution

■ 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 TableI.1
- Define clockwise in the top view as positive

■ Vertical Angle

Each channel's vertical angle is a constant, listed in Table I.1

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

■ Near/Far Field Measurement

- All the 128 channels fire laser pulses that measure the far field (>2.85 m in range)
- Additionally, 32 of the 128 channels (marked in bold in Table I.1) also fire laser pulses that measure only the near field (0.3~2.85 m), at a time other than the channel's far field firings

- The horizontal resolution of far field measurement is listed below. User can select Standard or High Resolution mode from the web control page (see Section 4.3)

Configuration Mode	Frame Rate	Horizontal Resolution of Far Field Measurement
Standard	10 Hz	0.2° for all channels
	20 Hz	0.4° for all channels
High Resolution	10 Hz	0.1° for the 64 middle channels (Channel 27 to Channel 90) 0.2° for the other channels **NOTE** Channel # counts from 1 to 128
	20 Hz	0.2° for the 64 middle channels (Channel 27 to Channel 90) 0.4° for the other channels

- The horizontal resolution of near field measurement is always 0.4° at 10 Hz and 0.8° at 20 Hz

Table I.1 Pandar128 Channel Distribution (To Be Continued)

Channel #	Horizontal Angle Offset (Azimuth, in degrees)	Vertical Angle (Elevation, in degrees)	Instrument Range (in meters)	Range (in meters) with Reflectivity	
				Min	Max
01 (Top Beam)	3.257	14.436	100	**0.3@10**	140@10
02	3.263	13.535	100	2.85@10	140@10
03	1.091	13.082	100	**0.3@10**	140@10
04	3.268	12.624	100	2.85@10	140@10
05	1.093	12.165	100	2.85@10	140@10
06	3.273	11.702	100	**0.3@10**	140@10
07	1.094	11.239	100	2.85@10	140@10
08	3.278	10.771	100	2.85@10	140@10
09	1.095	10.305	100	**0.3@10**	140@10
10	3.283	9.830	100	2.85@10	140@10
11	1.096	9.356	100	2.85@10	140@10
12	3.288	8.880	100	**0.3@10**	140@10
13	1.097	8.401	100	2.85@10	140@10
14	3.291	7.921	100	2.85@10	140@10
15	1.098	7.438	100	**0.3@10**	140@10
16	-1.101	6.953	100	2.85@10	140@10
17	1.1	6.467	100	2.85@10	140@10
18	-1.104	5.978	100	**0.3@10**	140@10
19	-3.306	5.487	100	2.85@10	140@10
20	-1.106	4.996	100	2.85@10	140@10

Table I.1 Pandar128 Channel Distribution (To Be Continued)

Channel #	Horizontal Angle Offset (Azimuth, in degrees)	Vertical Angle (Elevation, in degrees)	Instrument Range (in meters)	Range (in meters) with Reflectivity	
				Min	Max
21	−3.311	4.501	100	**0.3@10**	140@10
22	−1.109	4.007	100	2.85@10	140@10
23	−3.318	3.509	100	2.85@10	140@10
24	−1.111	3.013	100	**0.3@10**	140@10
25	−3.324	2.512	100	2.85@10	140@10
26	−1.113	2.013	200	**0.3@10**	140@10
27	7.72	1.885	200	2.85@10	140@10
28	5.535	1.761	200	2.85@10	140@10
29	3.325	1.637	200	2.85@10	140@10
30	−3.33	1.511	200	2.85@10	140@10
31	1.107	1.386	200	2.85@10	140@10
32	−5.538	1.258	200	2.85@10	140@10
33	−7.726	1.130	200	**0.3@10**	140@10
34	−1.115	1.008	200	2.85@10	200@10
35	7.731	0.880	200	2.85@10	200@10
36	5.543	0.756	200	2.85@10	200@10
37	3.329	0.630	200	2.85@10	200@10
38	−3.336	0.505	200	2.85@10	200@10
39	1.108	0.379	200	2.85@10	200@10
40	−5.547	0.251	200	**0.3@10**	200@10

Table I.1 Pandar128 Channel Distribution (To Be Continued)

Channel #	Horizontal Angle Offset (Azimuth, in degrees)	Vertical Angle (Elevation, in degrees)	Instrument Range (in meters)	Range (in meters) with Reflectivity	
				Min	Max
41	-7.738	0.124	200	2.85@10	200@10
42 (Horizontal Beam)	-1.117	0.000	200	2.85@10	200@10
43	7.743	-0.129	200	2.85@10	200@10
44	5.551	-0.254	200	2.85@10	200@10
45	3.335	-0.380	200	2.85@10	200@10
46	-3.342	-0.506	200	2.85@10	200@10
47	1.11	-0.632	200	**0.3@10**	200@10
48	-5.555	-0.760	200	2.85@10	200@10
49	-7.75	-0.887	200	2.85@10	200@10
50	-1.119	-1.012	200	2.85@10	200@10
51	7.757	-1.141	200	2.85@10	200@10
52	5.56	-1.266	200	2.85@10	200@10
53	3.34	-1.393	200	2.85@10	200@10
54	-3.347	-1.519	200	**0.3@10**	200@10
55	1.111	-1.646	200	2.85@10	200@10
56	-5.564	-1.773	200	2.85@10	200@10
57	-7.762	-1.901	200	2.85@10	200@10
58	-1.121	-2.027	200	2.85@10	200@10
59	7.768	-2.155	200	2.85@10	200@10
60	5.569	-2.282	200	2.85@10	200@10

Table I.1 Pandar128 Channel Distribution (To Be Continued)

Channel #	Horizontal Angle Offset (Azimuth, in degrees)	Vertical Angle (Elevation, in degrees)	Instrument Range (in meters)	Range (in meters) with Reflectivity	
				Min	Max
61	3.345	-2.409	200	**0.3@10**	200@10
62	-3.353	-2.535	200	2.85@10	200@10
63	1.113	-2.663	200	2.85@10	200@10
64	-5.573	-2.789	200	2.85@10	200@10
65	-7.775	-2.916	200	2.85@10	200@10
66	-1.123	-3.044	200	2.85@10	140@10
67	7.78	-3.172	200	2.85@10	140@10
68	5.578	-3.299	200	**0.3@10**	140@10
69	3.351	-3.425	200	2.85@10	140@10
70	-3.358	-3.552	200	2.85@10	140@10
71	1.115	-3.680	200	2.85@10	140@10
72	-5.582	-3.806	200	2.85@10	140@10
73	-7.787	-3.933	200	2.85@10	140@10
74	-1.125	-4.062	200	2.85@10	140@10
75	7.792	-4.190	200	**0.3@10**	140@10
76	5.586	-4.318	200	2.85@10	140@10
77	3.356	-4.444	200	2.85@10	140@10
78	-3.363	-4.571	200	2.85@10	140@10
79	1.116	-4.699	200	2.85@10	140@10
80	-5.591	-4.824	200	2.85@10	140@10

Table I.1 Pandar128 Channel Distribution (To Be Continued)

Channel #	Horizontal Angle Offset (Azimuth, in degrees)	Vertical Angle (Elevation, in degrees)	Instrument Range (in meters)	Range (in meters) with Reflectivity	
				Min	Max
81	-7.799	-4.951	200	2.85@10	140@10
82	-1.127	-5.081	200	**0.3@10**	140@10
83	7.804	-5.209	200	2.85@10	140@10
84	5.595	-5.336	200	2.85@10	140@10
85	3.36	-5.463	200	2.85@10	140@10
86	-3.369	-5.589	200	2.85@10	140@10
87	1.118	-5.718	200	2.85@10	140@10
88	-5.599	-5.843	200	2.85@10	140@10
89	-7.811	-5.968	200	2.85@10	140@10
90	-1.129	-6.100	100	**0.3@10**	140@10
91	-3.374	-6.607	100	2.85@10	140@10
92	-1.13	-7.117	100	2.85@10	140@10
93	-3.379	-7.624	100	**0.3@10**	140@10
94	-1.132	-8.134	100	2.85@10	140@10
95	-3.383	-8.640	100	2.85@10	140@10
96	3.381	-9.149	100	**0.3@10**	140@10
97	-3.388	-9.652	100	2.85@10	140@10
98	3.386	-10.160	100	2.85@10	140@10
99	1.129	-10.665	100	**0.3@10**	140@10
100	3.39	-11.170	100	2.85@10	140@10

Table I.1 Pandar128 Channel Distribution (To Be Continued)

Channel #	Horizontal Angle Offset (Azimuth, in degrees)	Vertical Angle (Elevation, in degrees)	Instrument Range (in meters)	Range (in meters) with Reflectivity	
				Min	Max
101	1.129	-11.672	100	2.85@10	140@10
102	3.395	-12.174	100	**0.3@10**	140@10
103	1.131	-12.673	100	2.85@10	140@10
104	3.401	-13.173	100	2.85@10	140@10
105	1.133	-13.670	100	**0.3@10**	140@10
106	3.406	-14.166	100	2.85@10	140@10
107	1.135	-14.660	100	2.85@10	140@10
108	3.41	-15.154	100	**0.3@10**	140@10
109	1.137	-15.645	100	2.85@10	140@10
110	3.416	-16.135	100	2.85@10	140@10
111	1.139	-16.622	100	**0.3@10**	140@10
112	-1.142	-17.106	100	2.85@10	140@10
113	1.142	-17.592	100	2.85@10	140@10
114	-1.143	-18.072	100	**0.3@10**	140@10
115	-3.426	-18.548	100	2.85@10	140@10
116	-3.426	-19.030	100	2.85@10	140@10
117	-1.144	-19.501	100	**0.3@10**	140@10
118	-3.429	-19.978	100	2.85@10	140@10
119	-1.145	-20.445	100	2.85@10	140@10
120	-3.433	-20.918	100	**0.3@10**	140@10

Table I.1 Pandar128 Channel Distribution (Continued)

Channel # in UDP Data	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range (in meters)with Reflectivity	
				Min	Max
121	-1.145	-21.379	100	2.85@10	140@10
122	-3.436	-21.848	100	2.85@10	140@10
123	-1.146	-22.304	100	**0.3@10**	140@10
124	-3.44	-22.768	100	2.85@10	140@10
125	-1.146	-23.219	100	2.85@10	140@10
126	-3.443	-23.678	100	**0.3@10**	140@10
127	-3.446	-24.123	100	2.85@10	140@10
128 (Bottom Beam)	-3.449	-25.016	100	**0.3@10**	140@10

Appendix II Absolute Time and Laser Firing Time

II.1 Absolute Time of Point Cloud Data Packets

For Pandar128, there are 2 blocks of ranging data in the Body of each Point Cloud Data Packet, as shown below. Each block contains the ranging data from 128 channels, one return per channel.

Point Cloud Data Packet – Body: 772 bytes (2 blocks)	
Block 1	**Block 2**
Azimuth 1	Azimuth 2
Channel 1	Channel 1
Channel 2	Channel 2
…	…
Channel 128	Channel 128

■ **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 2**.

■ **Dual Return Mode**

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

- Block 1 is the last return, and Block 2 is the strongest return
- If the last and strongest returns coincide, the second strongest return will be placed in Block 2
- The start time of Block1 and Block 2 is the same

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

■ **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.

II.2 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**

The start time of each block depends on the horizontal resolution – whether the LiDAR is operating in High Resolution mode or Standard mode (defined in Section 4.4 High Resolution).

Block	Start Time (μs) in High Resolution Mode	Start Time (μs) in Standard Mode
Block 1	t0 + 3.148 – 27.778	t0 + 3.148 – 27.778 * 2
Block 2	t0 + 3.148	t0 + 3.148

■ **Dual Return Mode**

The start time of each block is independent of the horizontal resolution.

Block	Start Time (μs)
Block 1 & Block 2	t0 + 3.148

II.3 Laser Firing Time of Each Channel

Assume that the start time of Block i is T(i), $i \in \{1, 2\}$.
The laser firing time of Channel j in Block i is **t(i, j) = Ti + Δt(j)**, $j \in \{1, 2, ..., 128\}$.

■ **Analysis**

The time difference Δt(j) depends on three factors.

1) horizontal resolution

Whether the LiDAR is operating in High Resolution mode or Standard mode (defined in Section 4.4 High Resolution)

2) azimuth angle of the block

Obtained from the Azimuth field of Block i

3) distance of the data point

Obtained from the Distance field of Channel j in Block i

■ **Calculation**

To determine the Δt(j) of Channel j

1) Check whether the LiDAR is operating in High Resolution mode or Standard mode

2) Analyze the k value of the azimuth angle

Under High Resolution mode, represent the azimuth angle of Block i as **α(i) = 0.4° * N + 0.1° * k**

- N is a positive integer, and $k \in \{0, 1, 2, 3\}$
- For example, 46.2° = 0.4 * 115 + 0.1 * 2. Therefore N = 115, k = 2

Under Standard mode, represent the azimuth angle of Block i as **α(i) = 0.4° * N + 0.2° * k**

- N is a positive integer, and k ∈ {0, 1}
- For example, 46.2° = 0.4 * 115 + 0.2 * 1. Therefore N = 115, k = 1

3) Analyze the Near-Range Flag of the data point

- For a data point whose distance d > 2.85 m (i.e. generated from a far-field firing), the Near-Range Flag is set to 0
- For a data point whose distance d ≤ 2.85 m (i.e. generated from a near-field firing), the Near-Range Flag is set to 1

4) Look up Δt(j) in the tables below.

Check the resolution mode and k value in the table titles, and check the Near-Range Flag in the third column of each table.

Δt(j) – Time Difference between the Channel's Laser Firing Time and the Block's Start Time

Table II.1 High Resolution mode, k = 0 (To Be Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
1	1	4	0	0.275	5	19	0	3.925	11	41	0	8.455
2	1	13	0	0.275	5	24	0	3.925	11	42	0	8.455
3	1	23	0	0.275	5	100	0	3.925	11	60	0	8.455
4	1	92	0	0.275	5	109	0	3.925	11	64	0	8.455
5	1	96	0	0.275	5	120	0	3.925	11	71	0	8.455
6	1	105	0	0.275	5	127	0	3.925	11	86	0	8.455
7	1	114	0	0.275	6	24	1	5.035	12	36	0	10.48
8	1	121	0	0.275	7	12	1	5.475	12	40	0	10.48
9	2	105	1	1.385	8	8	0	6.19	12	47	0	10.48
10	3	6	0	2.1	8	17	0	6.19	12	54	0	10.48
11	3	15	0	2.1	8	21	0	6.19	12	67	0	10.48
12	3	25	0	2.1	8	94	0	6.19	12	73	0	10.48
13	3	90	0	2.1	8	102	0	6.19	12	77	0	10.48
14	3	98	0	2.1	8	111	0	6.19	12	82	0	10.48
15	3	107	0	2.1	8	115	0	6.19	13	31	0	12.505
16	3	116	0	2.1	8	122	0	6.19	13	38	0	12.505
17	3	125	0	2.1	9	21	1	7.3	13	49	0	12.505
18	4	6	1	3.21	10	102	1	7.74	13	51	0	12.505
19	5	5	0	3.925	11	27	0	8.455	13	61	0	12.505
20	5	12	0	3.925	11	37	0	8.455	13	66	0	12.505

Table II.1 High Resolution mode, k = 0 (Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
21	13	80	0	12.505	16	45	0	18.58	19	63	0	23.07
22	13	84	0	12.505	16	50	0	18.58	19	78	0	23.07
23	14	30	0	14.53	16	68	0	18.58	19	83	0	23.07
24	14	43	0	14.53	16	70	0	18.58	20	40	1	25.82
25	14	53	0	14.53	16	79	0	18.58				
26	14	57	0	14.53	16	81	0	18.58				
27	14	58	0	14.53	17	68	1	20.33				
28	14	72	0	14.53	18	26	0	21.045				
29	14	76	0	14.53	18	44	0	21.045				
30	14	87	0	14.53	18	48	0	21.045				
31	15	28	0	16.555	18	55	0	21.045				
32	15	39	0	16.555	18	62	0	21.045				
33	15	46	0	16.555	18	75	0	21.045				
34	15	59	0	16.555	18	85	0	21.045				
35	15	65	0	16.555	18	89	0	21.045				
36	15	69	0	16.555	19	29	0	23.07				
37	15	74	0	16.555	19	33	0	23.07				
38	15	88	0	16.555	19	34	0	23.07				
39	16	32	0	18.58	19	52	0	23.07				
40	16	35	0	18.58	19	56	0	23.07				

Table II.2 High Resolution mode, k = 1 (To Be Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
1	1	2	0	0.275	6	9	0	4.365	11	41	0	8.455
2	1	11	0	0.275	6	16	0	4.365	11	42	0	8.455
3	1	20	0	0.275	6	95	0	4.365	11	60	0	8.455
4	1	93	0	0.275	6	101	0	4.365	11	64	0	8.455
5	1	104	0	0.275	6	108	0	4.365	11	71	0	8.455
6	1	113	0	0.275	6	119	0	4.365	11	86	0	8.455
7	1	118	0	0.275	6	126	0	4.365	12	36	0	10.48
8	1	128	0	0.275	7	9	1	5.475	12	40	0	10.48
9	2	93	1	1.385	8	1	1	5.915	12	47	0	10.48
10	3	3	0	2.1	9	7	0	6.63	12	54	0	10.48
11	3	10	0	2.1	9	14	0	6.63	12	67	0	10.48
12	3	22	0	2.1	9	18	0	6.63	12	73	0	10.48
13	3	91	0	2.1	9	97	0	6.63	12	77	0	10.48
14	3	99	0	2.1	9	103	0	6.63	12	82	0	10.48
15	3	106	0	2.1	9	110	0	6.63	13	31	0	12.505
16	3	117	0	2.1	9	112	0	6.63	13	38	0	12.505
17	3	124	0	2.1	9	123	0	6.63	13	49	0	12.505
18	4	3	1	3.21	10	18	1	7.74	13	51	0	12.505
19	5	99	1	3.65	11	27	0	8.455	13	61	0	12.505
20	6	1	0	4.365	11	37	0	8.455	13	66	0	12.505

Table II.2 High Resolution mode, k = 1 (Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
21	13	80	0	12.505	16	45	0	18.58	19	63	0	23.07
22	13	84	0	12.505	16	50	0	18.58	19	78	0	23.07
23	14	30	0	14.53	16	68	0	18.58	19	83	0	23.07
24	14	43	0	14.53	16	70	0	18.58	20	47	1	25.82
25	14	53	0	14.53	16	79	0	18.58				
26	14	57	0	14.53	16	81	0	18.58				
27	14	58	0	14.53	17	26	0	20.605				
28	14	72	0	14.53	17	44	0	20.605				
29	14	76	0	14.53	17	48	0	20.605				
30	14	87	0	14.53	17	55	0	20.605				
31	15	28	0	16.555	17	62	0	20.605				
32	15	39	0	16.555	17	75	0	20.605				
33	15	46	0	16.555	17	85	0	20.605				
34	15	59	0	16.555	17	89	0	20.605				
35	15	65	0	16.555	18	75	1	22.355				
36	15	69	0	16.555	19	29	0	23.07				
37	15	74	0	16.555	19	33	0	23.07				
38	15	88	0	16.555	19	34	0	23.07				
39	16	32	0	18.58	19	52	0	23.07				
40	16	35	0	18.58	19	56	0	23.07				

Table II.3 High Resolution mode, k = 2 (To Be Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
1	1	4	0	0.275	7	5	0	4.725	11	41	0	8.335
2	1	13	0	0.275	7	12	0	4.725	11	42	0	8.335
3	1	23	0	0.275	7	19	0	4.725	11	60	0	8.335
4	1	92	0	0.275	7	24	0	4.725	11	64	0	8.335
5	1	96	0	0.275	7	100	0	4.725	11	71	0	8.335
6	1	105	0	0.275	7	109	0	4.725	11	86	0	8.335
7	1	114	0	0.275	7	120	0	4.725	12	36	0	10.36
8	1	121	0	0.275	7	127	0	4.725	12	40	0	10.36
9	2	114	1	1.385	8	120	1	5.835	12	47	0	10.36
10	3	96	1	1.805	9	8	0	6.53	12	54	0	10.36
11	4	6	0	2.5	9	17	0	6.53	12	67	0	10.36
12	4	15	0	2.5	9	21	0	6.53	12	73	0	10.36
13	4	25	0	2.5	9	94	0	6.53	12	77	0	10.36
14	4	90	0	2.5	9	102	0	6.53	12	82	0	10.36
15	4	98	0	2.5	9	111	0	6.53	13	31	0	12.385
16	4	107	0	2.5	9	115	0	6.53	13	38	0	12.385
17	4	116	0	2.5	9	122	0	6.53	13	49	0	12.385
18	4	125	0	2.5	10	111	1	7.64	13	51	0	12.385
19	5	90	1	3.61	11	27	0	8.335	13	61	0	12.385
20	6	15	1	4.03	11	37	0	8.335	13	66	0	12.385

Table II.3 High Resolution mode, k = 2 (Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
21	13	80	0	12.385	16	45	0	18.46	19	63	0	22.93
22	13	84	0	12.385	16	50	0	18.46	19	78	0	22.93
23	14	30	0	14.41	16	68	0	18.46	19	83	0	22.93
24	14	43	0	14.41	16	70	0	18.46	20	54	1	25.68
25	14	53	0	14.41	16	79	0	18.46				
26	14	57	0	14.41	16	81	0	18.46				
27	14	58	0	14.41	17	26	0	20.485				
28	14	72	0	14.41	17	44	0	20.485				
29	14	76	0	14.41	17	48	0	20.485				
30	14	87	0	14.41	17	55	0	20.485				
31	15	28	0	16.435	17	62	0	20.485				
32	15	39	0	16.435	17	75	0	20.485				
33	15	46	0	16.435	17	85	0	20.485				
34	15	59	0	16.435	17	89	0	20.485				
35	15	65	0	16.435	18	26	1	22.235				
36	15	69	0	16.435	19	29	0	22.93				
37	15	74	0	16.435	19	33	0	22.93				
38	15	88	0	16.435	19	34	0	22.93				
39	16	32	0	18.46	19	52	0	22.93				
40	16	35	0	18.46	19	56	0	22.93				

Table II.4 High Resolution mode, k = 3 (To Be Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
1	1	2	0	0.275	5	16	0	3.925	10	42	0	8.015
2	1	11	0	0.275	5	95	0	3.925	10	60	0	8.015
3	1	20	0	0.275	5	101	0	3.925	10	64	0	8.015
4	1	93	0	0.275	5	108	0	3.925	10	71	0	8.015
5	1	104	0	0.275	5	119	0	3.925	10	86	0	8.015
6	1	113	0	0.275	5	126	0	3.925	11	36	0	10.04
7	1	118	0	0.275	6	126	1	5.035	11	40	0	10.04
8	1	128	0	0.275	7	108	1	5.475	11	47	0	10.04
9	2	128	1	1.385	8	7	0	6.19	11	54	0	10.04
10	3	3	0	2.1	8	14	0	6.19	11	67	0	10.04
11	3	10	0	2.1	8	18	0	6.19	11	73	0	10.04
12	3	22	0	2.1	8	97	0	6.19	11	77	0	10.04
13	3	91	0	2.1	8	103	0	6.19	11	82	0	10.04
14	3	99	0	2.1	8	110	0	6.19	12	82	1	11.79
15	3	106	0	2.1	8	112	0	6.19	13	31	0	12.505
16	3	117	0	2.1	8	123	0	6.19	13	38	0	12.505
17	3	124	0	2.1	9	123	1	7.3	13	49	0	12.505
18	4	117	1	3.21	10	27	0	8.015	13	51	0	12.505
19	5	1	0	3.925	10	37	0	8.015	13	61	0	12.505
20	5	9	0	3.925	10	41	0	8.015	13	66	0	12.505

Table II.4 High Resolution mode, k = 3 (Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
21	13	80	0	12.505	16	45	0	18.58	18	78	0	22.63
22	13	84	0	12.505	16	50	0	18.58	18	83	0	22.63
23	14	30	0	14.53	16	68	0	18.58	19	33	1	24.38
24	14	43	0	14.53	16	70	0	18.58	20	61	1	25.82
25	14	53	0	14.53	16	79	0	18.58				
26	14	57	0	14.53	16	81	0	18.58				
27	14	58	0	14.53	17	26	0	20.605				
28	14	72	0	14.53	17	44	0	20.605				
29	14	76	0	14.53	17	48	0	20.605				
30	14	87	0	14.53	17	55	0	20.605				
31	15	28	0	16.555	17	62	0	20.605				
32	15	39	0	16.555	17	75	0	20.605				
33	15	46	0	16.555	17	85	0	20.605				
34	15	59	0	16.555	17	89	0	20.605				
35	15	65	0	16.555	18	29	0	22.63				
36	15	69	0	16.555	18	33	0	22.63				
37	15	74	0	16.555	18	34	0	22.63				
38	15	88	0	16.555	18	52	0	22.63				
39	16	32	0	18.58	18	56	0	22.63				
40	16	35	0	18.58	18	63	0	22.63				

Table II.5 Standard mode, k = 0 (To Be Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
1	1	4	0	0.275	5	19	0	3.925	11	41	0	8.455
2	1	13	0	0.275	5	24	0	3.925	11	42	0	8.455
3	1	23	0	0.275	5	100	0	3.925	11	60	0	8.455
4	1	92	0	0.275	5	109	0	3.925	11	64	0	8.455
5	1	96	0	0.275	5	120	0	3.925	11	71	0	8.455
6	1	105	0	0.275	5	127	0	3.925	11	86	0	8.455
7	1	114	0	0.275	6	24	1	5.035	12	36	0	10.48
8	1	121	0	0.275	7	12	1	5.475	12	40	0	10.48
9	2	105	1	1.385	8	8	0	6.19	12	47	0	10.48
10	3	6	0	2.1	8	17	0	6.19	12	54	0	10.48
11	3	15	0	2.1	8	21	0	6.19	12	67	0	10.48
12	3	25	0	2.1	8	94	0	6.19	12	73	0	10.48
13	3	90	0	2.1	8	102	0	6.19	12	77	0	10.48
14	3	98	0	2.1	8	111	0	6.19	12	82	0	10.48
15	3	107	0	2.1	8	115	0	6.19	13	32	0	12.505
16	3	116	0	2.1	8	122	0	6.19	13	35	0	12.505
17	3	125	0	2.1	9	21	1	7.3	13	45	0	12.505
18	4	6	1	3.21	10	102	1	7.74	13	50	0	12.505
19	5	5	0	3.925	11	27	0	8.455	13	68	0	12.505
20	5	12	0	3.925	11	37	0	8.455	13	70	0	12.505

Table II.5 Standard mode, k = 0 (To Be Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
21	13	79	0	12.505	18	93	1	29.163	24	1	1	33.693
22	13	81	0	12.505	19	3	0	29.878	25	7	0	34.408
23	14	68	1	14.255	19	10	0	29.878	25	14	0	34.408
24	15	29	0	14.97	19	22	0	29.878	25	18	0	34.408
25	15	33	0	14.97	19	91	0	29.878	25	97	0	34.408
26	15	34	0	14.97	19	99	0	29.878	25	103	0	34.408
27	15	52	0	14.97	19	106	0	29.878	25	110	0	34.408
28	15	56	0	14.97	19	117	0	29.878	25	112	0	34.408
29	15	63	0	14.97	19	124	0	29.878	25	123	0	34.408
30	15	78	0	14.97	20	3	1	30.988	26	18	1	35.518
31	15	83	0	14.97	21	99	1	31.428	27	31	0	36.233
32	16	40	1	17.72	22	1	0	32.143	27	38	0	36.233
33	17	2	0	28.053	22	9	0	32.143	27	49	0	36.233
34	17	11	0	28.053	22	16	0	32.143	27	51	0	36.233
35	17	20	0	28.053	22	95	0	32.143	27	61	0	36.233
36	17	93	0	28.053	22	101	0	32.143	27	66	0	36.233
37	17	104	0	28.053	22	108	0	32.143	27	80	0	36.233
38	17	113	0	28.053	22	119	0	32.143	27	84	0	36.233
39	17	118	0	28.053	22	126	0	32.143	28	30	0	38.258
40	17	128	0	28.053	23	9	1	33.253	28	43	0	38.258

Table II.5 Standard mode, k = 0 (Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
41	28	53	0	38.258
42	28	57	0	38.258
43	28	58	0	38.258
44	28	72	0	38.258
45	28	76	0	38.258
46	28	87	0	38.258
47	29	28	0	40.283
48	29	39	0	40.283
49	29	46	0	40.283
50	29	59	0	40.283
51	29	65	0	40.283
52	29	69	0	40.283
53	29	74	0	40.283
54	29	88	0	40.283
55	30	26	0	42.308
56	30	44	0	42.308
57	30	48	0	42.308
58	30	55	0	42.308
59	30	62	0	42.308
60	30	75	0	42.308

Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
30	85	0	42.308
30	89	0	42.308
31	75	1	44.058
32	47	1	45.498

Table II.6 Standard mode, k = 1 (To Be Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
1	1	4	0	0.275	7	5	0	4.805	11	49	0	8.455
2	1	13	0	0.275	7	12	0	4.805	11	51	0	8.455
3	1	23	0	0.275	7	19	0	4.805	11	61	0	8.455
4	1	92	0	0.275	7	24	0	4.805	11	66	0	8.455
5	1	96	0	0.275	7	100	0	4.805	11	80	0	8.455
6	1	105	0	0.275	7	109	0	4.805	11	84	0	8.455
7	1	114	0	0.275	7	120	0	4.805	12	30	0	10.48
8	1	121	0	0.275	7	127	0	4.805	12	43	0	10.48
9	2	114	1	1.385	8	120	1	5.915	12	53	0	10.48
10	3	96	1	1.825	9	8	0	6.63	12	57	0	10.48
11	4	6	0	2.54	9	17	0	6.63	12	58	0	10.48
12	4	15	0	2.54	9	21	0	6.63	12	72	0	10.48
13	4	25	0	2.54	9	94	0	6.63	12	76	0	10.48
14	4	90	0	2.54	9	102	0	6.63	12	87	0	10.48
15	4	98	0	2.54	9	111	0	6.63	13	28	0	12.505
16	4	107	0	2.54	9	115	0	6.63	13	39	0	12.505
17	4	116	0	2.54	9	122	0	6.63	13	46	0	12.505
18	4	125	0	2.54	10	111	1	7.74	13	59	0	12.505
19	5	90	1	3.65	11	31	0	8.455	13	65	0	12.505
20	6	15	1	4.09	11	38	0	8.455	13	69	0	12.505

Table II.6 Standard mode, k = 1 (To Be Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
21	13	74	0	12.505	18	128	1	29.163	24	7	0	33.968
22	13	88	0	12.505	19	3	0	29.878	24	14	0	33.968
23	14	26	0	14.53	19	10	0	29.878	24	18	0	33.968
24	14	44	0	14.53	19	22	0	29.878	24	97	0	33.968
25	14	48	0	14.53	19	91	0	29.878	24	103	0	33.968
26	14	55	0	14.53	19	99	0	29.878	24	110	0	33.968
27	14	62	0	14.53	19	106	0	29.878	24	112	0	33.968
28	14	75	0	14.53	19	117	0	29.878	24	123	0	33.968
29	14	85	0	14.53	19	124	0	29.878	25	123	1	35.078
30	14	89	0	14.53	20	117	1	30.988	26	27	0	35.793
31	15	26	1	16.28	21	1	0	31.703	26	37	0	35.793
32	16	54	1	17.72	21	9	0	31.703	26	41	0	35.793
33	17	2	0	28.053	21	16	0	31.703	26	42	0	35.793
34	17	11	0	28.053	21	95	0	31.703	26	60	0	35.793
35	17	20	0	28.053	21	101	0	31.703	26	64	0	35.793
36	17	93	0	28.053	21	108	0	31.703	26	71	0	35.793
37	17	104	0	28.053	21	119	0	31.703	26	86	0	35.793
38	17	113	0	28.053	21	126	0	31.703	27	36	0	37.818
39	17	118	0	28.053	22	126	1	32.813	27	40	0	37.818
40	17	128	0	28.053	23	108	1	33.253	27	47	0	37.818

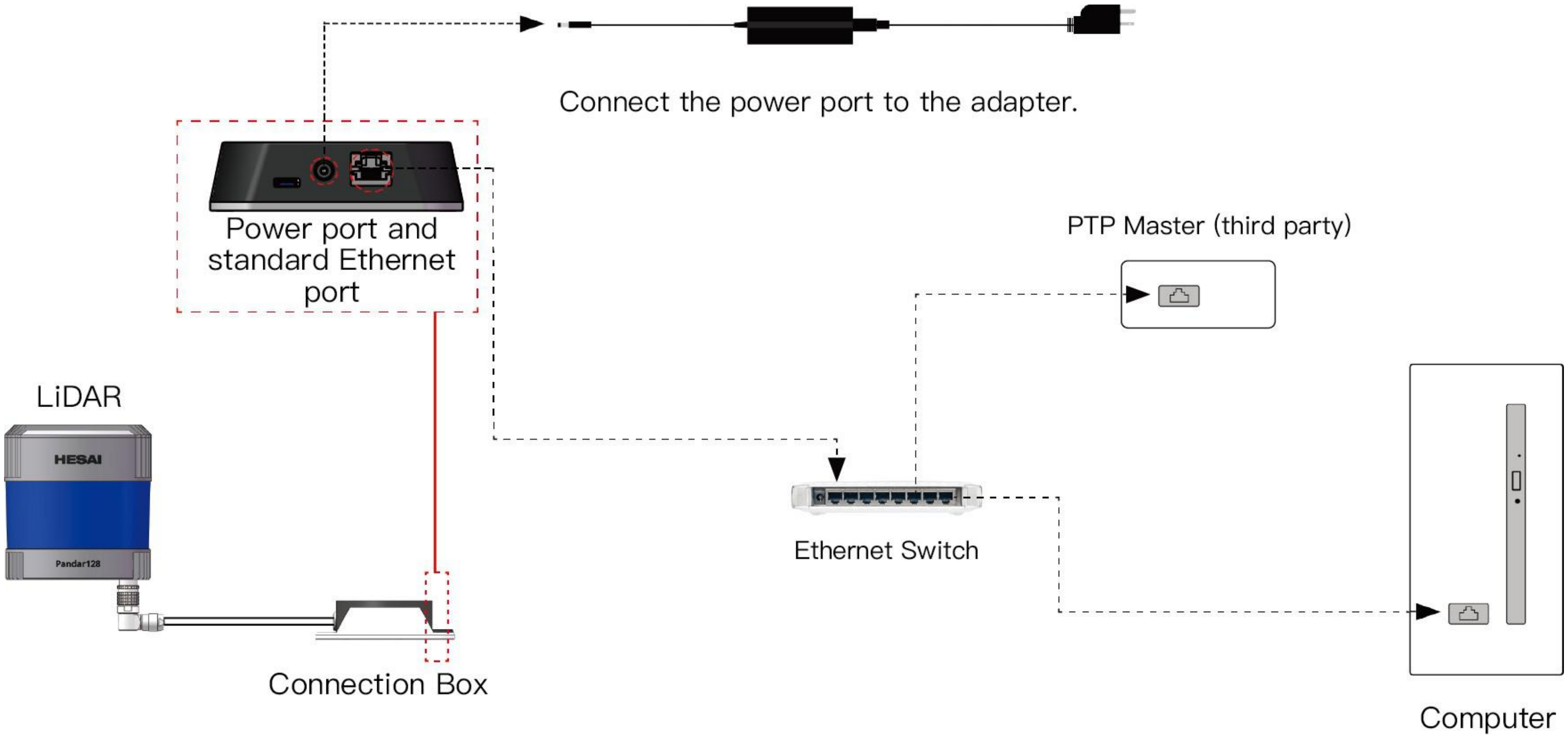
Table II.6 Standard mode, k = 1 (Continued)

Row No.	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)	Firing Sequence	Channel #	Near-Range Flag	Δt(j) (μs)
41	27	54	0	37.818	30	78	0	42.308
42	27	67	0	37.818	30	83	0	42.308
43	27	73	0	37.818	31	33	1	44.058
44	27	77	0	37.818	32	61	1	45.498
45	27	82	0	37.818				
46	28	82	1	39.568				
47	29	32	0	40.283				
48	29	35	0	40.283				
49	29	45	0	40.283				
50	29	50	0	40.283				
51	29	68	0	40.283				
52	29	70	0	40.283				
53	29	79	0	40.283				
54	29	81	0	40.283				
55	30	29	0	42.308				
56	30	33	0	42.308				
57	30	34	0	42.308				
58	30	52	0	42.308				
59	30	56	0	42.308				
60	30	63	0	42.308				

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**



■ 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.

NOTE 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: 2ASO2PANDAR128

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.

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.

■ Legal Notice

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