HESAI

Pandar128

128–Channel Mechanical LiDAR User Manual

Website

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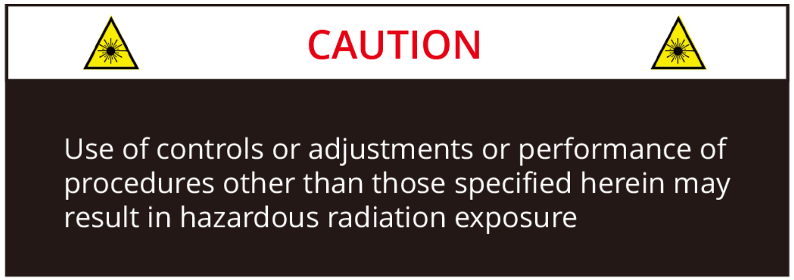
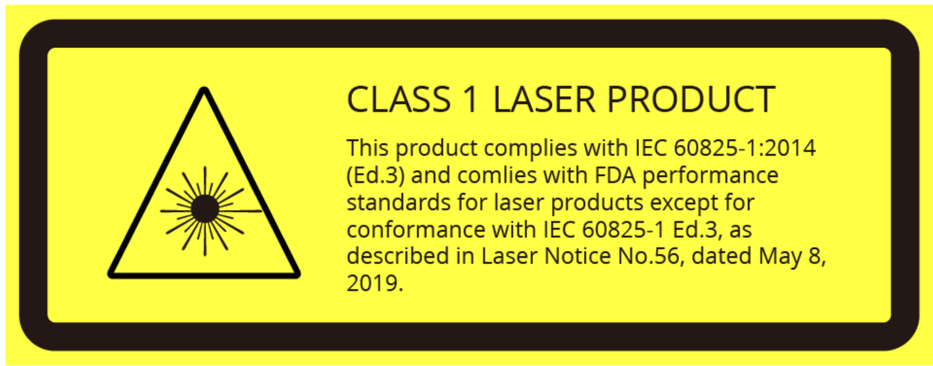
Safety Notice

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 product. The product must not be tampered with and must not be changed in any way. There are no user-serviceable parts inside the product. 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 product 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 product disposal.

Handling

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

Enclosure

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

Eye Safety

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

Repair

DO NOT open and repair the product without direct guidance from Hesai Technology. Disassembling the product 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 product'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.

Hot Surface

During or after a period of operation, DO NOT touch the product's enclosure with your skin. Such direct contact with the hot surface can result in discomfort or even burns. If you incorporate this LiDAR product into your product(s), you should also communicate the hot surface risks to the intended users of your product(s).

Vibration

Strong vibration may cause damage to the product 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 product that prohibit or restrict the use of electronic devices. Although the product is designed, tested, and manufactured to comply with the regulations on RF radiation, the radiation from the product may still influence electronic devices.

Medical Device Interference

Some components in the product 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(s) and whether you need to keep a safe distance from the product. If you suspect that the product is interfering with your medical device, stop using the product immediately.

Explosive Atmosphere and Other Air Conditions

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

Light Interference

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

1 Introduction

This manual describes the specifications, installation, and data format of Pandar128.

This manual is under constant revision. To obtain the latest version, please visit the Download page of Hesai's official website, or contact Hesai technical support.

1.1 Operating Principle

Distance Measurement: Time of Flight (ToF)

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

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

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

Figure 1.1 Distance Measurement Using Time of Flight

1.2 LiDAR Structure

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

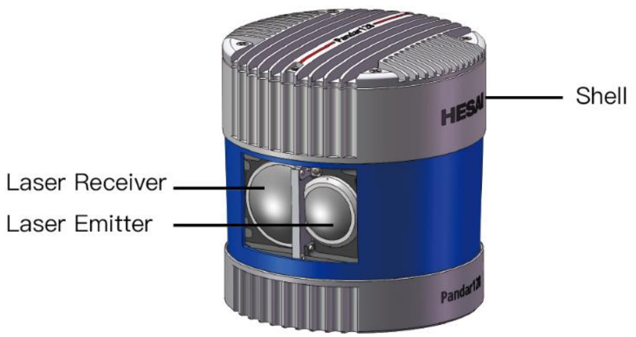


Figure 1.2 Partial Cross-Sectional Diagram

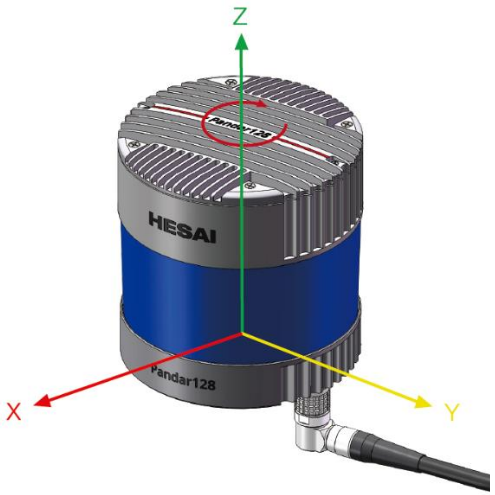


Figure 1.3 Coordinate System
(Isometric View)

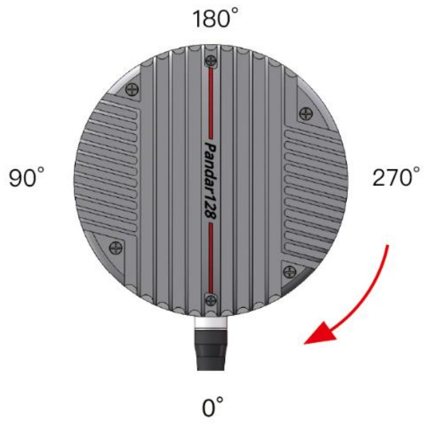


Figure 1.4 Default Rotation Direction
(Top View)

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

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

Each laser channel has an intrinsic horizontal angle offset. When Channel 42 passes the zero degree position in Figure 1.4, the azimuth data in the corresponding UDP data block will be 0°.

1.3 Channel Distribution

The vertical resolution is

- 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 (Channel Distribution)

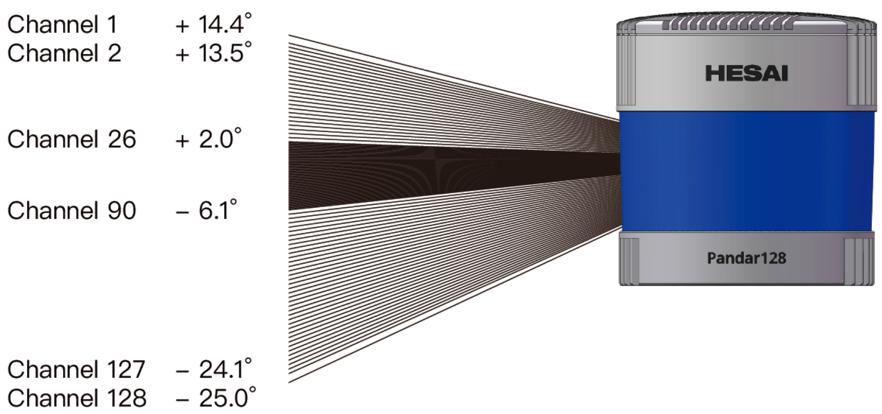


Figure 1.5 Channel Vertical Distribution

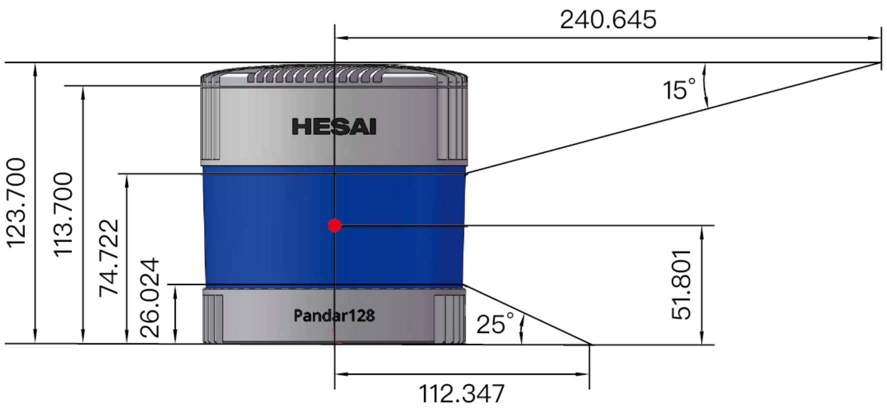


Figure 1.6 Laser Firing Position (Unit: mm)

Each channel has an intrinsic angle offset, both horizontally and vertically.
The offsets are recorded in this LiDAR unit's calibration file, which is provided when shipping the unit.

In case you need to obtain the file again:

- Send this TCP command *PTC_COMMAND_GET_LIDAR_CALIBRATION*, as described in Hesai TCP API Protocol (Chapter 6).
- Or contact a sales representative or technical support engineer from Hesai.

1.4 Specifications

SENSOR	
Scanning Method	Mechanical Rotation
Channel	128
Range Capability	0.3 to 200 m (at 10% reflectivity)
Range Accuracy	±8 cm (0.3 to 0.5 m, each channel)
	±5 cm (0.5 to 1 m, each channel)
	±2 cm (1 to 200 m, average)
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 (Last/Strongest/First)
	Dual Return (Last and Strongest)
	Dual Return (Last and First)
	Dual Return (First and Strongest)
CERTIFICATIONS	

MECHANICAL/ELECTRICAL/OPERATIONAL	
Wavelength	905 nm
Laser Class	Class 1 Eye Safe
Ingress Protection	IP6K7 & IP6K9K
Dimensions	Height: 123.7 mm
	Top/Bottom Diameter: 118.0 / 116.0 mm
Operating Voltage	DC 9 to 48 V
Power Consumption	27 W / 20 W (at 0.1°/0.2° horizonal resolution)
Operating Temperature	-40°C to 85°C
Weight	1.63 kg
DATA I/O	
Data Transmission	UDP/IP Ethernet, 1000Base-TX or 1000Base-T1
Data Outputs	Distance, Azimuth Angle, Intensity
Valid Data Points	Single Return: 3,456,000 points/sec (max)
	Dual Return: 6,912,000 points/sec (max)
Point Cloud Data Rate	Single Return: 117.28 Mbps (max)
	Dual Return: 234.56 Mbps (max)
Clock Source	GPS / PTP
PTP Clock Accuracy	⩽1 µs
PTP Clock Drift	⩽1 µs/s

NOTE Specifications are subject to change. Please refer to the latest version.

NOTE Range Capability: measured under 100 klux ambient intensity. Range accuracy may vary with range, temperature, and target reflectivity.

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

2 Setup

2.1 Mechanical Installation

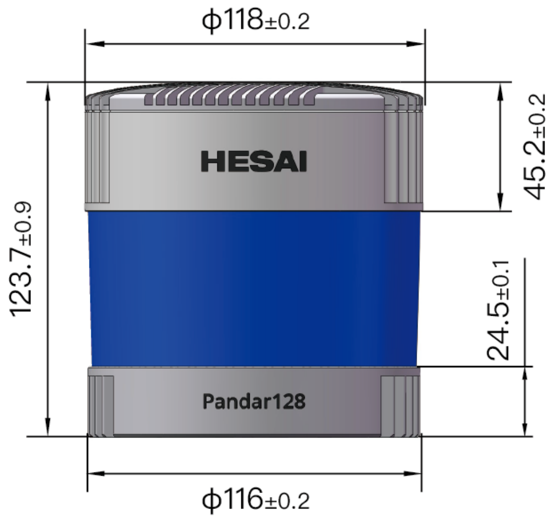


Figure 2.1 Front View (Unit: mm)

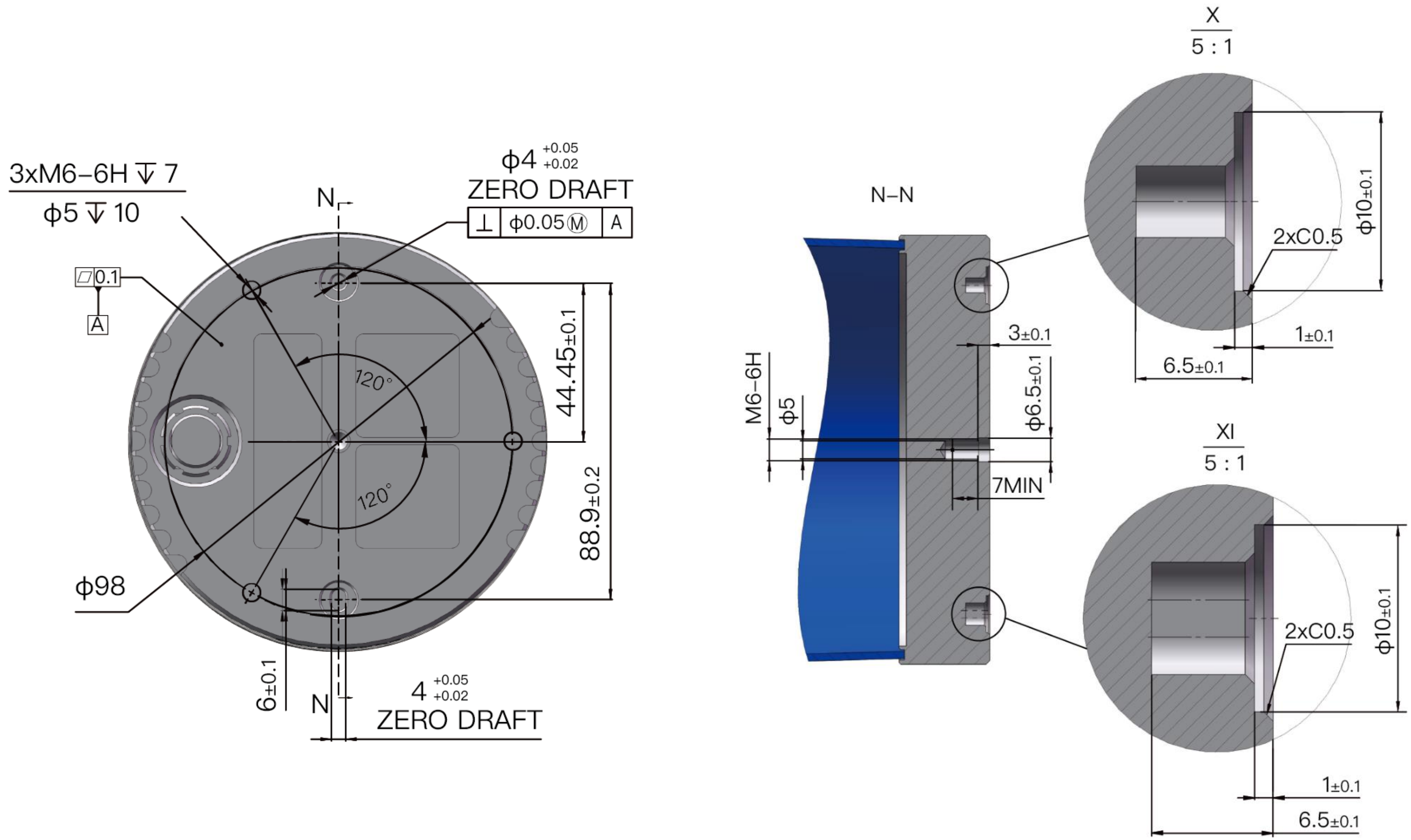


Figure 2.2 Bottom View (Unit: mm)

■ Quick Installation

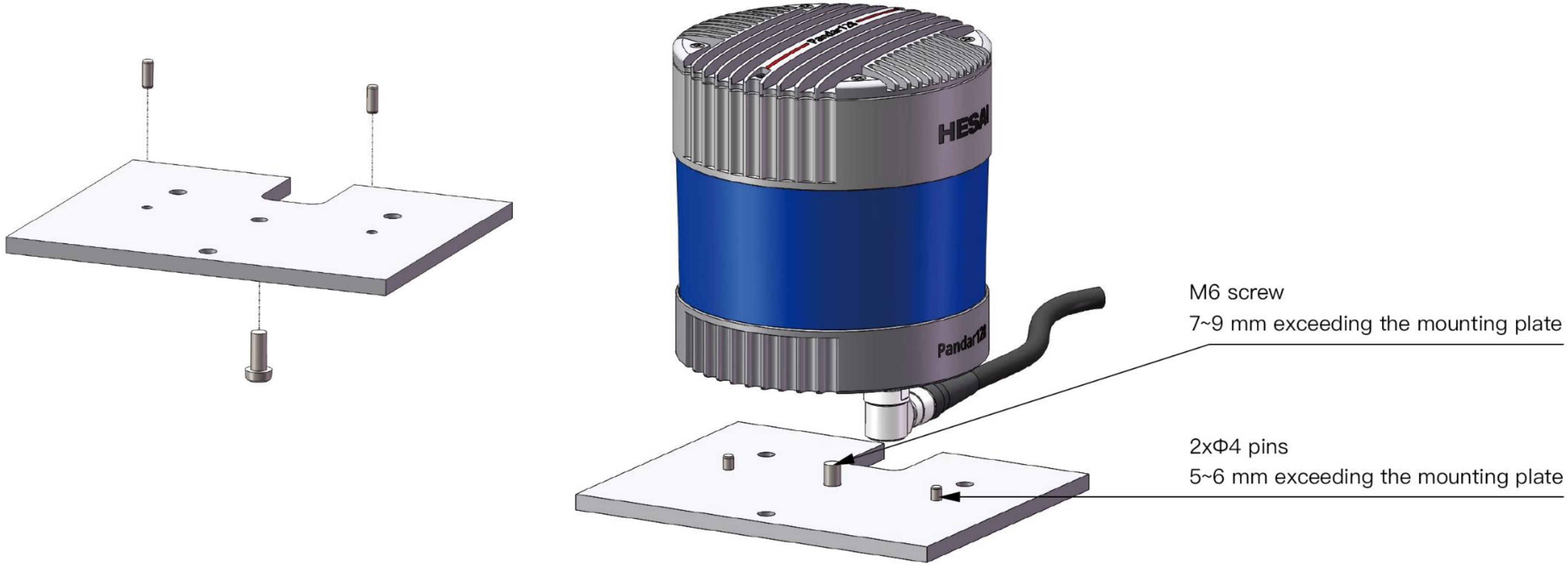


Figure 2.3 Quick Installation

■ Stable Installation

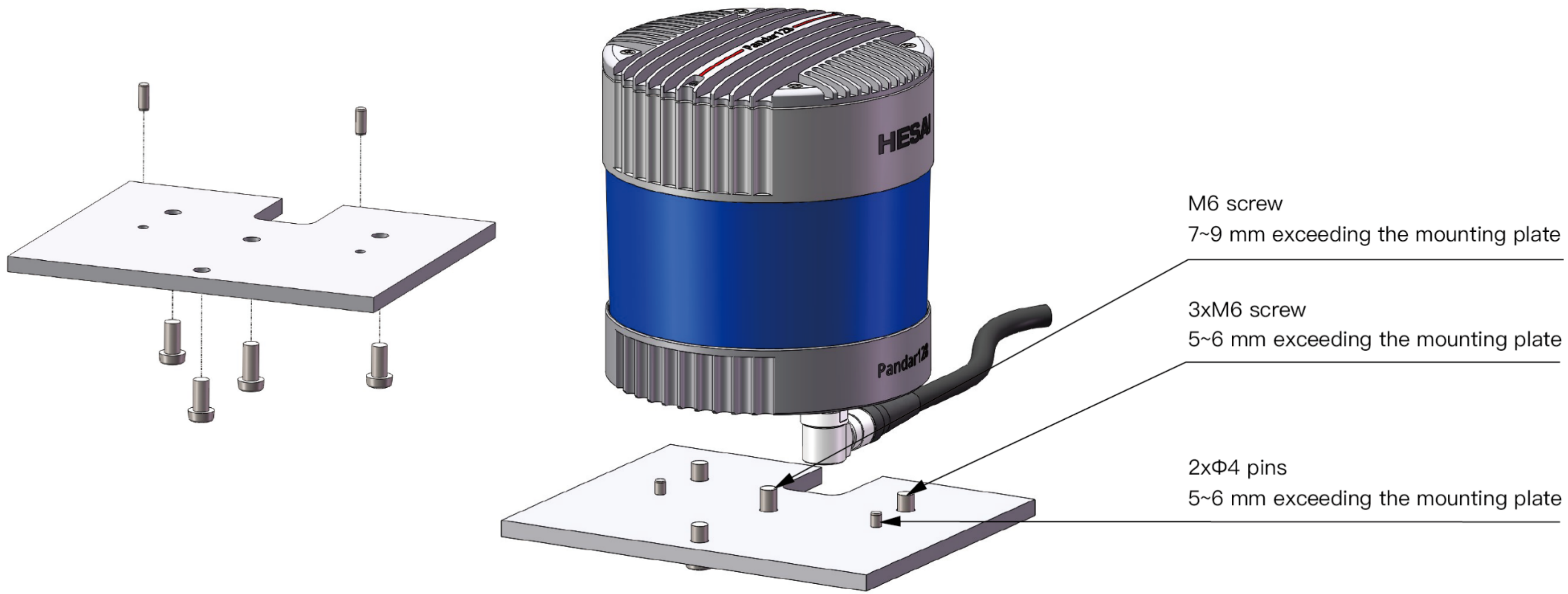


Figure 2.4 Stable Installation

2.2 Interfaces

Lemo part number: EEG.2T.316.CLN (female socket, on the LiDAR)

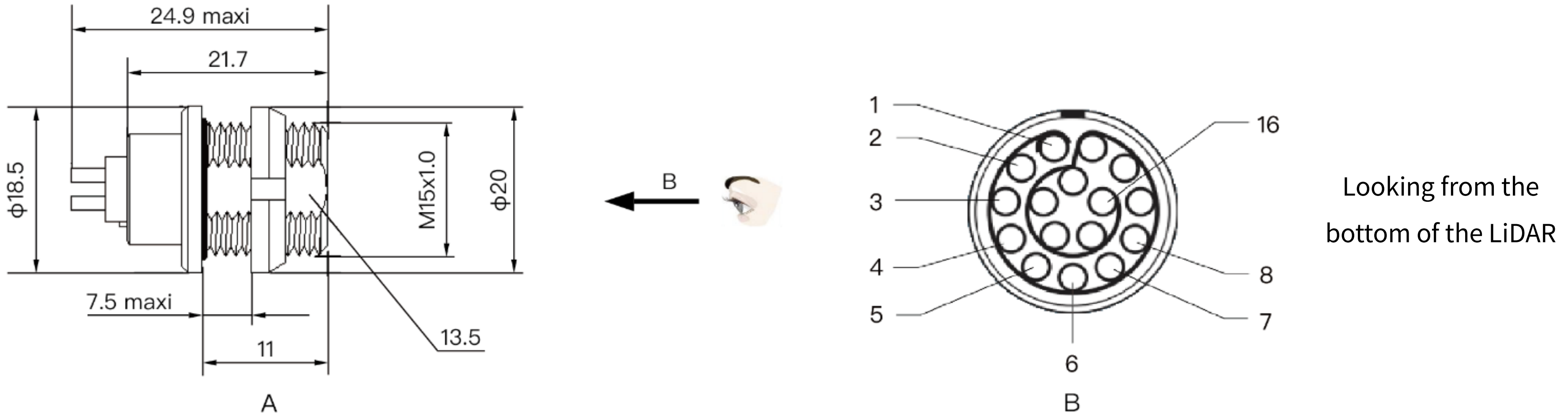


Figure 2.5 Lemo Connector (Female Socket)

2.2.1 Pin Description

■ 1000Base-TX

No.	Signal	Voltage
1	Ground (Return)	0 V
2	Ground (Return)	0 V
3	Ethernet BI_DC-	-1 to 1 V
4	Ethernet BI_DC+	-1 to 1 V
5	Ethernet BI_DB-	-1 to 1 V
6	Ethernet BI_DB+	-1 to 1 V
7	Ethernet BI_DA-	-1 to 1 V
8	Ethernet BI_DA+	-1 to 1 V

No.	Signal	Voltage
9	GPS Serial Data	-13 to +13 V
10	Power	9 to 48 V
11	Power	9 to 48 V
12	GPS PPS	3.3 / 5 V
13	Ethernet BI_DD-	-1 to 1 V
14	Ethernet BI_DD+	-1 to 1 V
15	Index	0 to 3.3 V
16	Encoder	0 to 3.3 V

■ Automotive 1000Base-T1

No.	Signal	Voltage
1	Ground (Return)	0 V
2	Ground (Return)	0 V
3	Ethernet_Data-	-1 to 1 V
4	Ethernet_Data+	-1 to 1 V
5	-	-
6	-	-
7	-	-
8	-	-

No.	Signal	Voltage
9	GPS Serial Data	-13 to +13 V
10	Power	9 to 48 V
11	Power	9 to 48 V
12	GPS PPS	3.3 / 5 V
13	-	-
14	-	-
15	Index	0 to 3.3 V
16	Encoder	0 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 bare hands

2.2.2 Cables

OD (outside diameter) = 7.70±0.30 mm

Minimum bend radius: 5 * OD

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

2.2.3 Connector Use

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

NOTE

- DO NOT attempt to force open a connection by pulling on the cables or the shells, or by twisting the connectors in any way. Doing so can loosen the connectors' shells, or even damage the contacts.
- In case a connector's shell is accidentally pulled off, stop using the connector and contact Hesai technical support.
- DO NOT attempt to assemble the connector's shell and cable collet; DO NOT connect a connector without its shell. Doing so may damage the LiDAR's circuits.

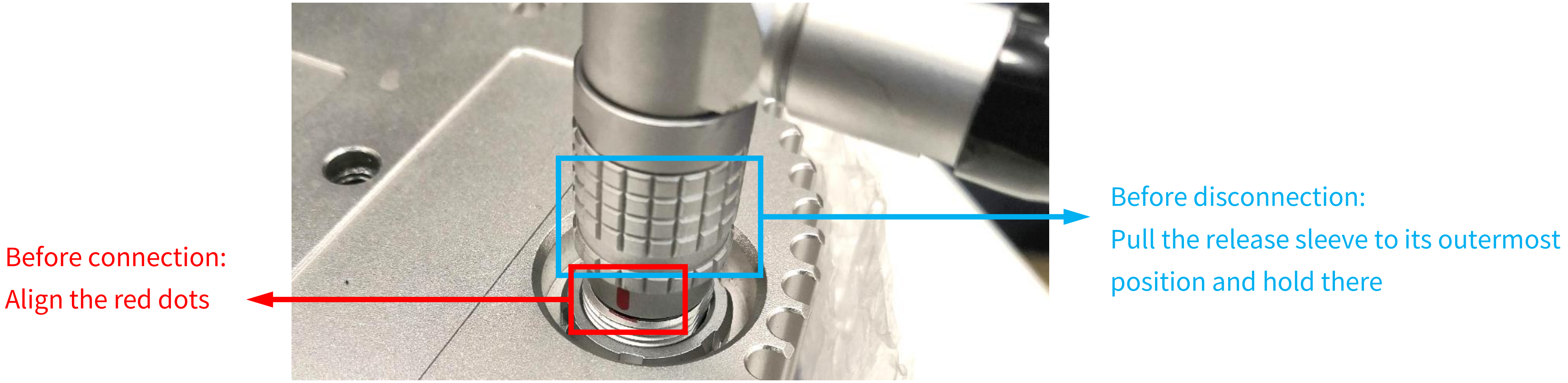


Figure 2.6 Lemo Connection/Disconnection

2.3 Connection Box (Optional)

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

The connection box has a power port, a GPS port, and a standard Ethernet port.

Lemo part number: FSG.2T.316.CLAC80Z (male plug, on the connection box)

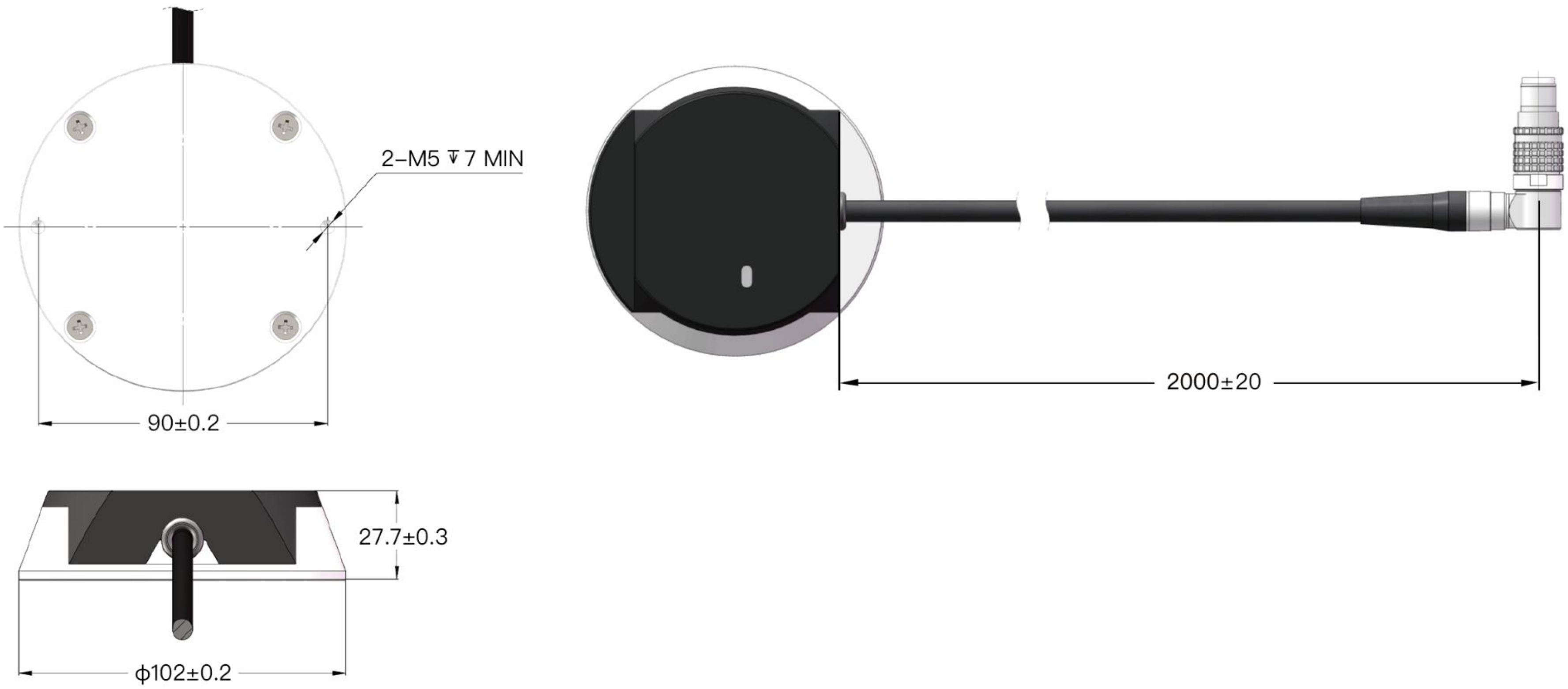


Figure 2.7 Connection Box (Unit: mm)

1000Base-TX

No.	Signal	Voltage	Wire Color
1	Ground (Return)	0 V	Black
2	Ground (Return)	0 V	White
3	Ethernet BI_DC-	-1 to 1 V	Blue
4	Ethernet BI_DC+	-1 to 1 V	Blue/White
5	Ethernet BI_DB-	-1 to 1 V	Green
6	Ethernet BI_DB+	-1 to 1 V	Green/White
7	Ethernet BI_DA-	-1 to 1 V	Orange
8	Ethernet BI_DA+	-1 to 1 V	Orange/White

No.	Signal	Voltage	Wire Color
9	GPS Serial Data	-13 to +13 V	Yellow
10	Power	9 to 48 V	Red
11	Power	9 to 48 V	Green
12	GPS PPS	3.3 / 5 V	Purple
13	Ethernet BI_DD-	-1 to 1 V	Brown
14	Ethernet BI_DD+	-1 to 1 V	Brown/White
15	Index	0 to 3.3 V	Gray
16	Encoder	0 to 3.3 V	Gray/White

Automotive 1000Base-T1

No.	Signal	Voltage	Wire Color
1	Ground (Return)	0 V	Black
2	Ground (Return)	0 V	White
3	Ethernet_Data-	-1 to 1 V	Blue
4	Ethernet_Data+	-1 to 1 V	Blue/White
5	-	-	
6	-	-	
7	-	-	
8	-	-	

No.	Signal	Voltage	Wire Color
9	GPS Serial Data	-13 to +13 V	Yellow
10	Power	9 to 48 V	Red
11	Power	9 to 48 V	Green
12	GPS PPS	3.3 / 5 V	Purple
13	-	-	
14	-	-	
15	Index	0 to 3.3 V	Gray
16	Encoder	0 to 3.3 V	Gray/White

2.3.1 Connection Box Interfaces

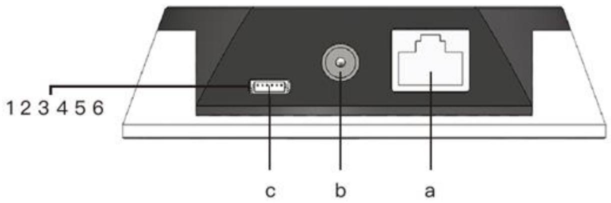


Figure 2.8 Connection Box (Front)

Port #	Port Name	Description
a	Standard Ethernet Port	RJ45, 1000 Mbps Ethernet
b	Power Port	Use DC-005 DC power adapter External power supply: 9 to 48 V, 27 W
c	GPS Port	Connector part number: 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	-	Reserved	-

For Pandar128 LiDARs with Lemo connectors, a trigger port is added to output external trigger signals.

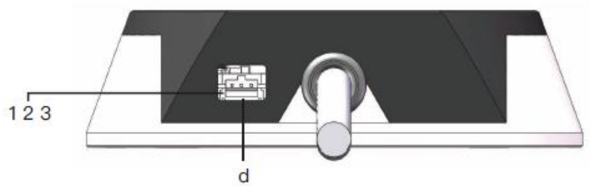


Figure 2.9 Connecting Box (Back)

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: outputs one pulse when the LiDAR rotates 0.05° Pulse width: 8.31 µs @ 600 RPM, 4.17 µs @ 1200 RPM
3	Output-Index	Trigger signal: outputs one pulse when Channel 42 passes the LiDAR's 180° position (see Figure 1.4) Pulse width: 2.87 µs @ 600 RPM, 1.44 µs @ 1200 RPM

2.3.2 Connection

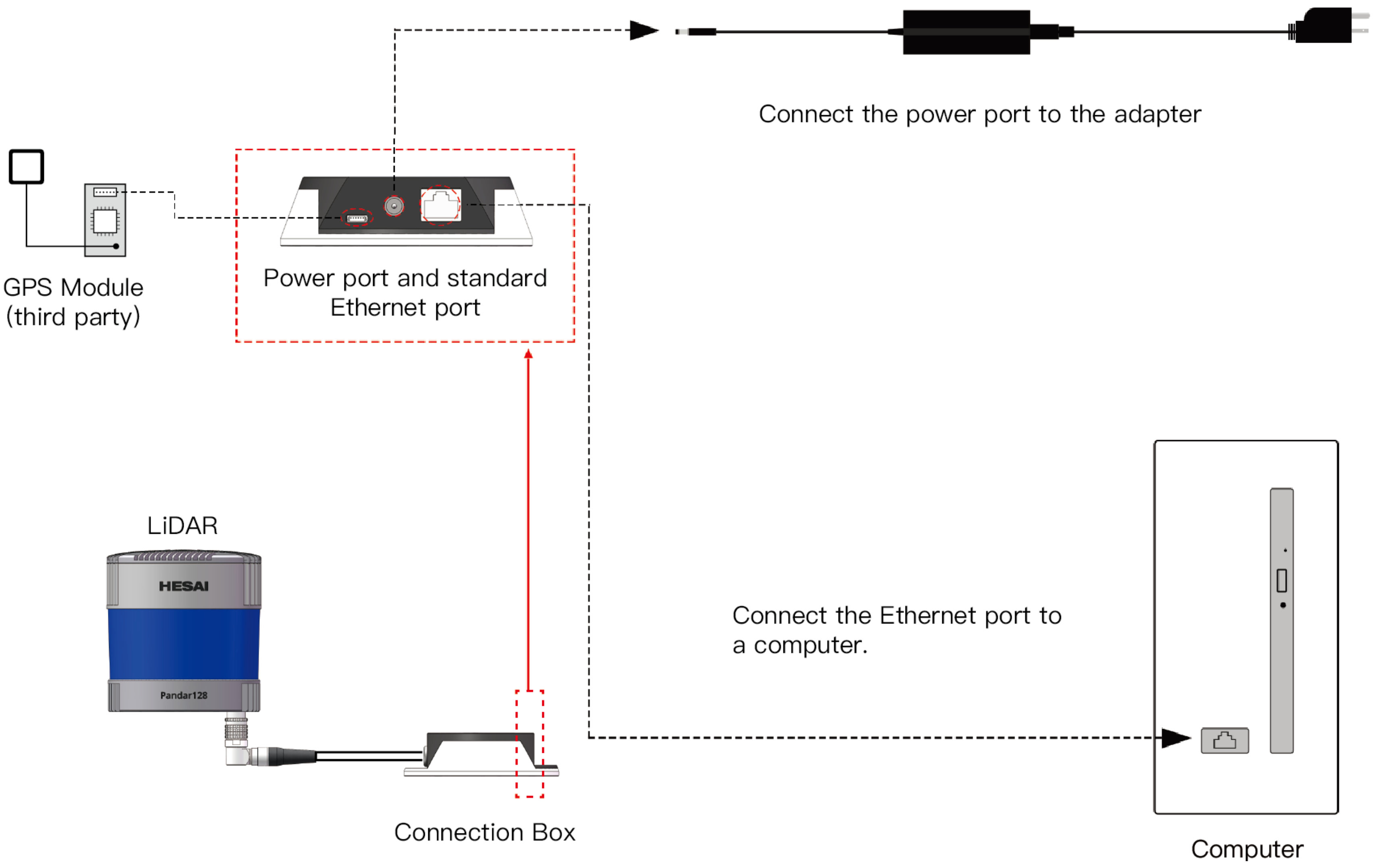


Figure 2.10 Connection Box - Connection

NOTE Refer to Appendix III (PTP Protocol) when PTP is used.

2.4 Get Ready to Use

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

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

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

For Ubuntu:	For Windows:
Input this ifconfig command in the terminal: ~$ sudo ifconfig enp0s20f0u2 192.168.1.100 (replace enp0s20f0u2 with the local Ethernet port name)	Open the Network Sharing Center, click on "Ethernet" In the "Ethernet Status" box, click on "Properties" Double-click on "Internet Protocol Version 4 (TCP/IPv4)" Configure the IP address to 192.168.1.100 and subnet mask to 255.255.255.0

To record and display point cloud data, see 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

The LiDAR outputs Point Cloud Data Packets and GPS Data Packets using 1000 Mbps Ethernet UDP/IP.

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

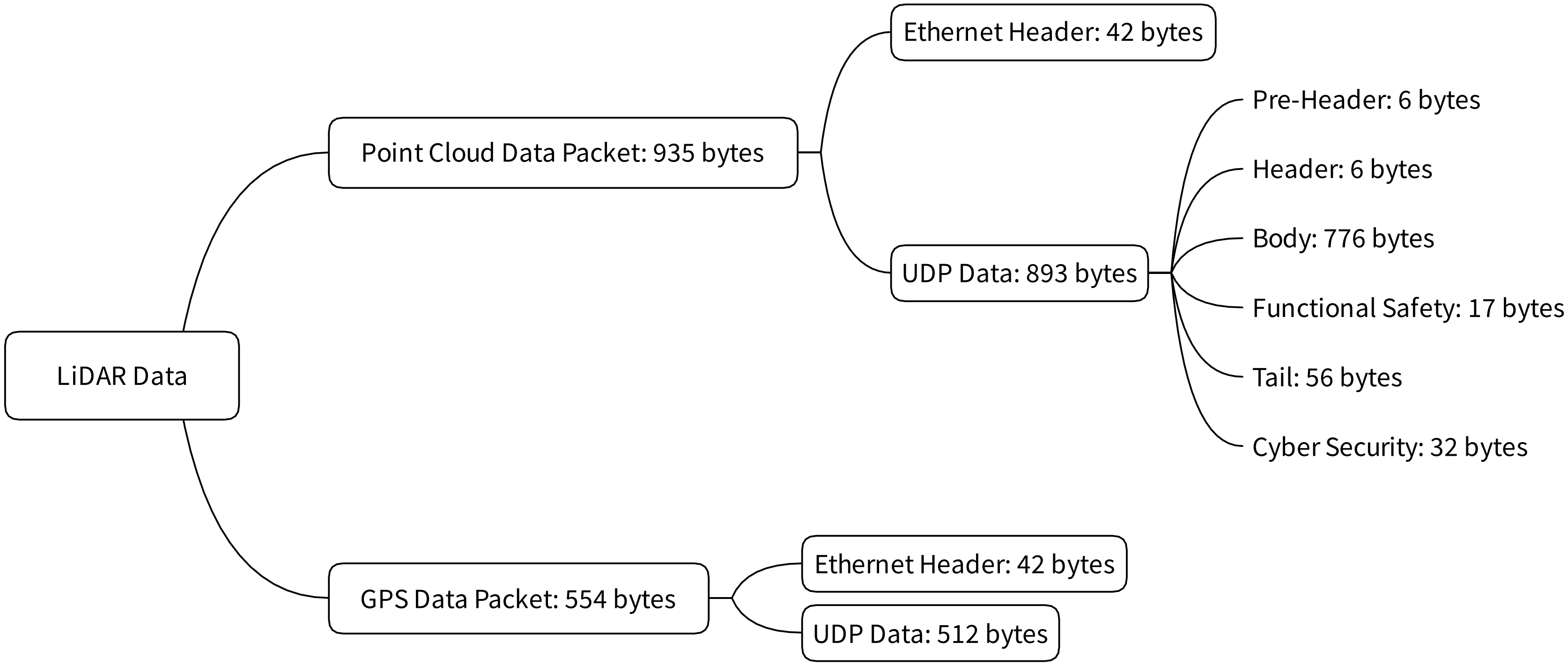


Figure 3.1 Data Structure

3.1 Point Cloud Data Packet

3.1.1 Ethernet Header

Each LiDAR has a unique MAC address. The source IP is 192.168.1.201 by default, and the destination IP is 255.255.255.255 (broadcast).

Point Cloud Ethernet Header: 42 bytes		
Field	Bytes	Description
Ethernet II MAC	12	Destination: broadcast (0xFF: 0xFF: 0xFF: 0xFF: 0xFF: 0xFF) Source: (xx:xx:xx:xx:xx:xx)
Ethernet Data Packet Type	2	0x08, 0x00
Internet Protocol	20	Shown in the figure below
UDP Port Number	4	UDP source port (0x2710, representing 10000) Destination port (0x0940, representing 2368)
UDP Length	2	0x0385, representing 901 bytes (8 bytes more than the size of the Point Cloud UDP Data, shown in Figure 3.1)
UDP Checksum	2	-

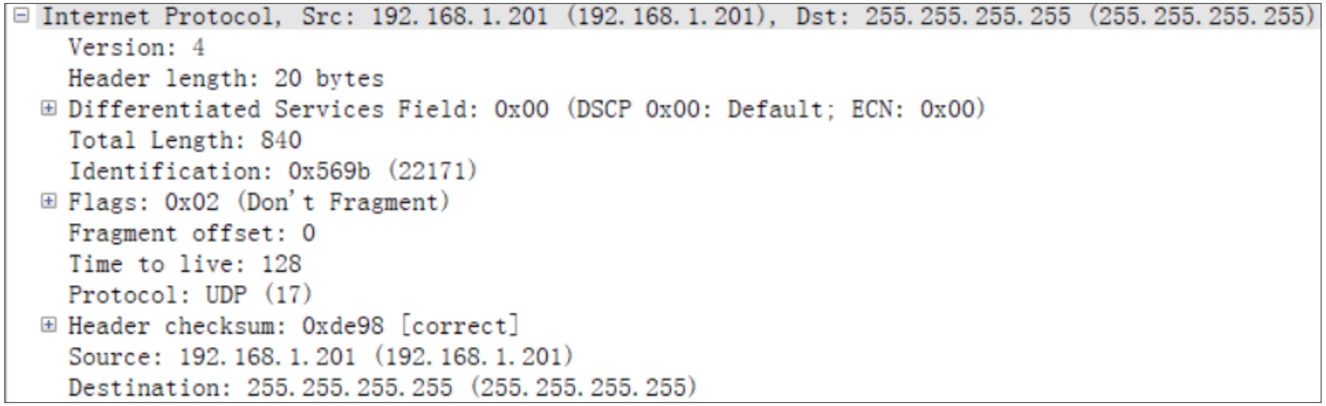


Figure 3.2 Point Cloud Ethernet Header - Internet Protocol

3.1.2 UDP Data

■ **Pre-Header**

Pre-Header: 6 bytes		
Field	Bytes	Description
0xEE	1	SOP (start of packet)
0xFF	1	SOP (start of packet)
Protocol Version Major	1	To distinguish between product models 0x01 for Pandar128
Protocol Version Minor	1	For each product model, to indicate the current protocol version Currently 0x04 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)
First Block Return	1	The first block in this data packet 0x00 - Single Return 0x01 - Return 1 in a Dual Return mode, i.e., Last Return in 0x39 or 0x3B mode, or First Return in 0x3C mode
Dis Unit	1	0x04 (4 mm)
Return Num	1	Number of returns that each channel generates 0x01 - one return 0x02 - two returns
Flags	1	[7:5] is reserved [4:0] shows whether this data packet contains the following information [4] confidence 1 - YES 0 - NO [3] digital signature 1 - YES 0 - NO [2] functional safety 1 - YES 0 - NO [1] IMU 1 - YES 0 - NO [0] UDP sequence 1 - YES 0 - NO

■ Body

Body: 776 bytes (2 blocks)		
Field	Bytes	Description
Azimuth 1	2	For Block 1: current reference angle of the rotor, in little endian format (lower byte first) azimuth angle = Azimuth / 100°
Block 1	384	For Block 1: measurements made by Channels 1 to 128, see table below
Azimuth 2	2	For Block 2
Block 2	384	For Block 2
CRC 1	4	CRC-32 checksum of the Body

Each Block in the Body: 3 * 128 = 384 bytes			
Field	Bytes	Description	
Channel XX	3	2-byte Distance	In little endian format (lower byte first) Distance Value = Distance * 4 mm
		1-byte Reflectivity	Reflectivity, in percentage (0 to 255%)

Pandar128 supports three single-return modes and three dual-return modes, see the Return Mode field in the Tail of Point Cloud UDP Data.
In a dual-return mode,

- the measurements from each round of firing are stored in the two blocks of one packet (see table below);
- Azimuth 1 and Azimuth 2 are the same.

Return Mode field	Block 1	Block 2	Note
0x39	Last return	Strongest return	If the last return is also the strongest, then Block 2 stores the second strongest return.
0x3B	Last return	First return	If there is only one return, then Block 1 and Block 2 store the same data.
0x3C	First return	Strongest return	If the first return is also the strongest, then Block 2 stores the second strongest return.

Functional Safety

Functional Safety: 17 bytes		
Field	Bytes	Description
FS Version	1	Version number of the functional safety module (currently 0x00)
Lidar State	1	[7:5] is the LiDAR's current state, see table below
Fault Code Type		[4:3] is the type of the fault code in this data packet b-01: current fault b-10: past fault
Rolling Counter		[2:0] indicates whether the fault reporting system gets stuck Starting from 0, the rolling counter increments by 1 every time the fault message is updated Normally, the fault message is updated every 5 ms
Total Fault Code Num	1	[7:4] counts the total number of fault codes in this queue
Fault Code ID		[3:0] is the sequence number of the fault code in this queue, starting from 1
Fault Code	2	Fault code sent by this data packet
Reserved	8	-
CRC 2	4	CRC-32 checksum of Functional Safety (from the Lidar State field to the Fault Code field)

Lidar State field	LiDAR State	Definition
d-0 (b-000)	Init	Initiating the system. Configuration in progress.
d-1 (b-001)	Normal	In operation. No fault detected.
d-2 (b-010)	Report Failure	Non-safety-related fault(s) detected. Record the fault code(s).
d-3 (b-011)	Pre-Performance Degradation	Warning state: safety-related fault(s) detected; will transition to Performance Degradation.
d-4 (b-100)	Performance Degradation	Safety-related fault(s) detected. Operating below normal performance.
d-5 (b-101)	Pre-Shutdown	Warning state: significant fault(s) detected; will transition to Shutdown.
d-6 (b-110)	Shutdown	Significant fault(s) detected. Laser emission, motor rotation, and point cloud data output have stopped; communication remains.

■ **Tail**

Tail: 24 bytes		
Field	Bytes	Description
Reserved	9	-
Azimuth Flag	2	Azimuth flag is used to determine the laser firing time of a channel, see Appendix II. [15:14] is the azimuth flag of Block 1, and [13:12] the azimuth flag of Block 2. Range: 0~3 (High Performance mode), 0~1 (Standard mode, Energy Saving mode) [11:0] is reserved
Operational State	1	0 - High Performance (i.e. High Resolution) 1 - Shutdown 2 - Standard 3 - Energy Saving (measurement range reduced)
Return Mode	1	0x33 - First Return 0x37 - Strongest Return 0x38 - Last Return 0x39 - Dual Return (Last, Strongest) 0x3B - Dual Return (Last, First) 0x3C - Dual Return (First, Strongest)
Motor Speed	2	speed_2_bytes [15:0] = speed (RPM)
Date & Time	6	Year (current year minus 1900), month, date, hour, minute, second Binary, 1 byte each
Timestamp	4	The "µs time" part of the absolute time of this data packet (defined in Appendix II) Unit: µs Range: 0 to 1000000 µs (1 s)

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Field	Bytes	Description
Factory Information	1	0x42
UDP Sequence	4	Sequence number of this UDP packet 1 to 0xFF FF FF FF in little endian format
IMU Temperature	2	Temperature provided by the IMU (inertial measurement unit), as a signed integer Unit: 0.01°C
IMU Acceleration Unit	2	Conversion factor of acceleration, as an unsigned integer Currently 488 (0x01e8) Unit of acceleration: 0.001 *mg* * 488 = 0.488 *mg* (*g* : standard gravity)
IMU Angular Velocity Unit	2	Conversion factor of angular velocity, as an unsigned integer Currently 14000 (0x36b0) Unit of angular velocity: 0.01 mdps * 14000 = 140 mdps (millidegree per second)
IMU Timestamp	4	Timestamp of the IMU data Counting from 0 after powering on the LiDAR or after an overflow Unit: 25 μs Range: 0 to approx. 1.24 days
IMU X Axis Acceleration	2	Acceleration of the X-axis, measured by the IMU as a signed integer Measurement range: ±16 *g* Unit of acceleration: currently 0.488 *mg*, see the IMU Acceleration Unit field **E.g.** When IMU_X_Axis_Acceleration_2_bytes = 5, X-axis acceleration = 5 * 0.488 *mg* = 2.44 *mg*
IMU Y Axis Acceleration	2	Acceleration of the Y-axis

(Continued on the next page)

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Field	Bytes	Description
IMU Z Axis Acceleration	2	Acceleration of the Z-axis
IMU X Axis Angular Velocity	2	Angular velocity of the X-axis, measured by the IMU as a signed integer Measurement range: ±4000 dps Unit of angular velocity: currently 140 mdps, see the IMU Angular Velocity Unit field **E.g.** When IMU_X_Axis_Angular_Velocity_2_bytes = 5, X-axis angular velocity = 5 * 140 mdps = 700 mdps
IMU Y Axis Angular Velocity	2	Angular velocity of the Y-axis
IMU Z Axis Angular Velocity	2	Angular velocity of the Y-axis
CRC 3	4	CRC-32 checksum of the Tail

■ **Cyber Security**

Cyber Security: 32 bytes		
Field	Bytes	Description
Signature	32	Signature calculated using the whole Point Cloud Data Packet Algorithm: HMAC-SHA256

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

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

2) Horizontal angle = current reference angle of the rotor + horizontal angle offset + firing time offset
- Current reference angle of the rotor is the Azimuth field of Block 2
- Horizontal angle offset: 1.093° for Channel 5 , according to Appendix I (Channel Distribution)
- Firing time offset = Laser Firing Time of Channel 5 (See Appendix II) * Spin Rate of the Motor (see Section 4.1 Web Control - Home)
- Define clockwise in the top view as positive

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

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

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

(Continued on the next page)

(Continued)

- Draw the data point in a polar or rectangular coordinate system
- Obtain the real-time point cloud data by analyzing and drawing every data point in each 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)
- GPS Data Packets: 6-byte Date (year, month, day) and 6-byte Time (second, minute, hour)

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

When GPS signal is lost

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

3.2.1 Ethernet Header

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

GPS Ethernet Header: 42 bytes		
Field	Bytes	Description
Ethernet II MAC	12	Destination: broadcast (0xFF: 0xFF: 0xFF: 0xFF: 0xFF: 0xFF) Source: (xx:xx:xx:xx:xx:xx)
Ethernet Data Packet Type	2	0x08, 0x00
Internet Protocol	20	Shown in the figure below
UDP Port Number	4	UDP source port (0x2710, represents 10000) Destination port (0x277E, represents 10110)
UDP Length	2	0x208, representing 520 bytes (8 bytes more than the size of the GPS UDP Data, shown in Figure 3.1)
UDP Checksum	2	-

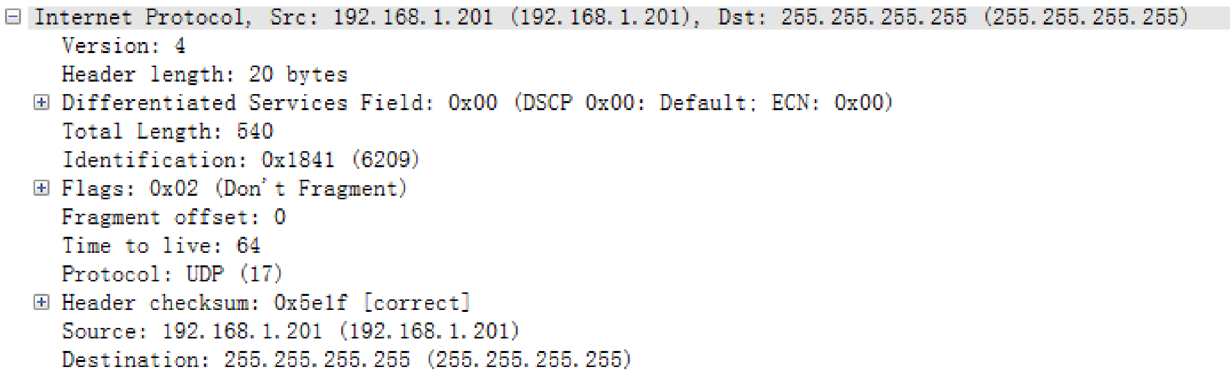


Figure 3.3 GPS Ethernet Header - Internet Protocol

3.2.2 UDP Data

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

■ GPRMC Data Format

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

Field #	Field	Description
<01>	UTC Time	Hour, minute, and second 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 Typically 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

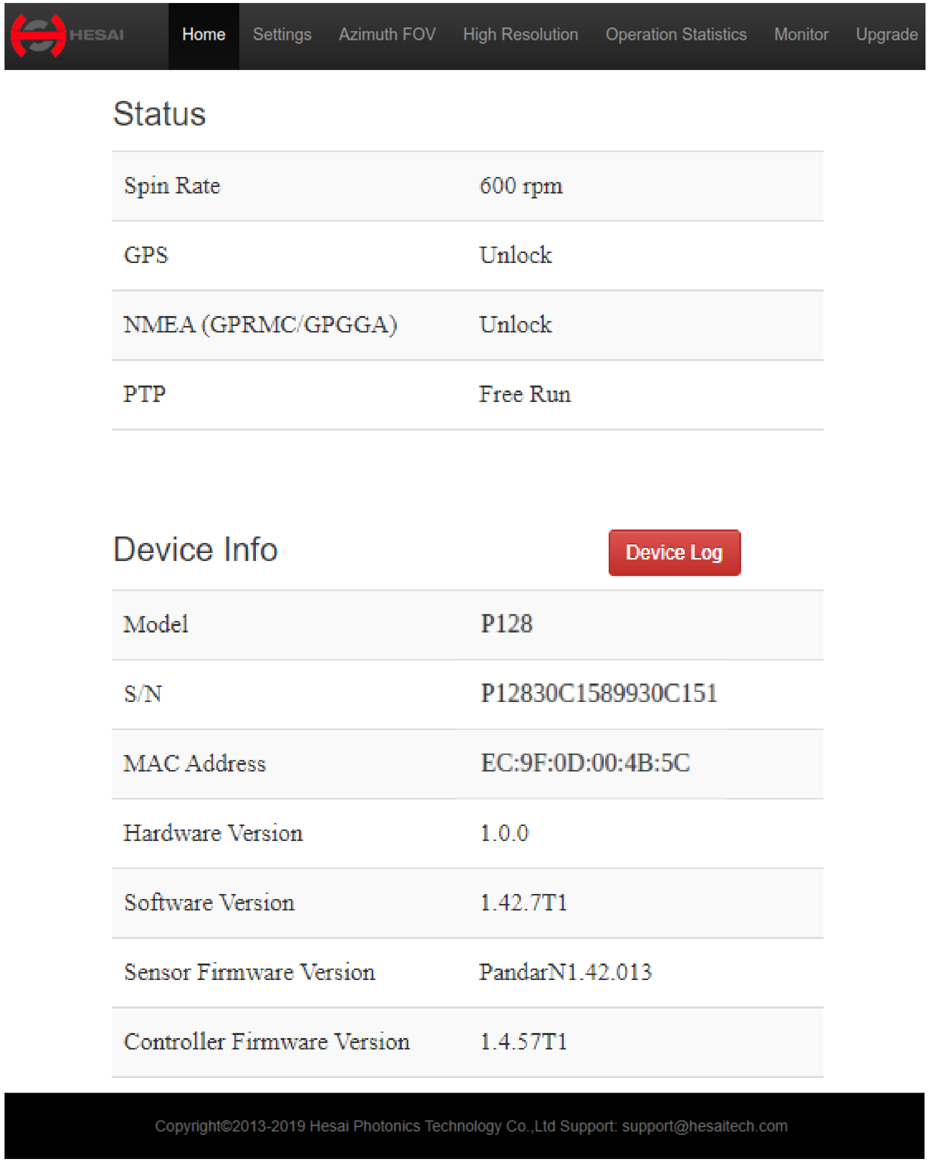
Web control is used for setting parameters, checking device info, and upgrading.

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 GPS
Unlock	Not in sync

NMEA (GPRMC/GPGGA) Status

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

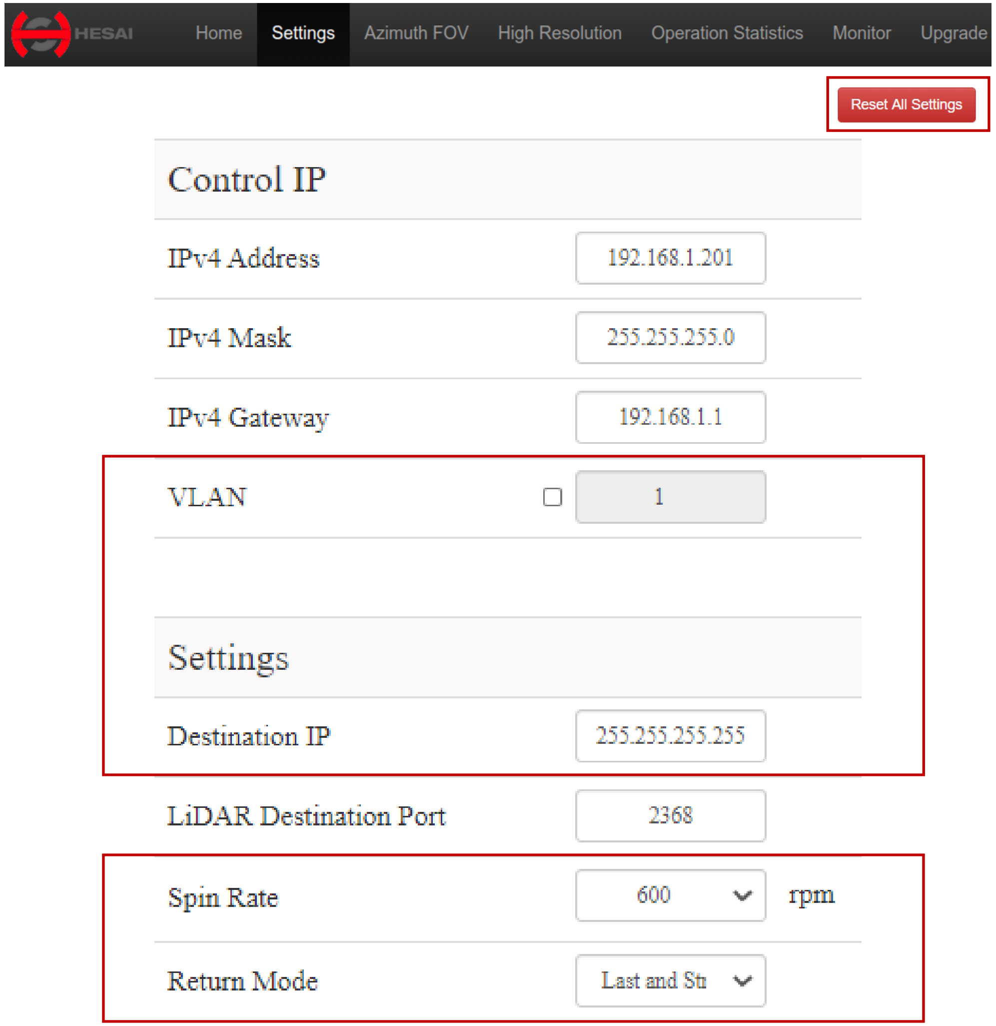
PTP Status

Free Run	No PTP master selected
Tracking	Slave is trying to sync with the selected PTP Master, but the absolute offset is over 1 μs
Locked	Absolute offset between Slave and Master is < 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



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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 factory defaults.
The default values are shown in the screenshots in Section 4.2 and Section 4.3.1.

2. 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

3. 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. LiDAR Functions

Spin Rate	600 rpm / 1200 rpm
Return Mode	Single Return (Last/Strongest/First), Dual Return (Last and Strongest, Last and First, First and Strongest)

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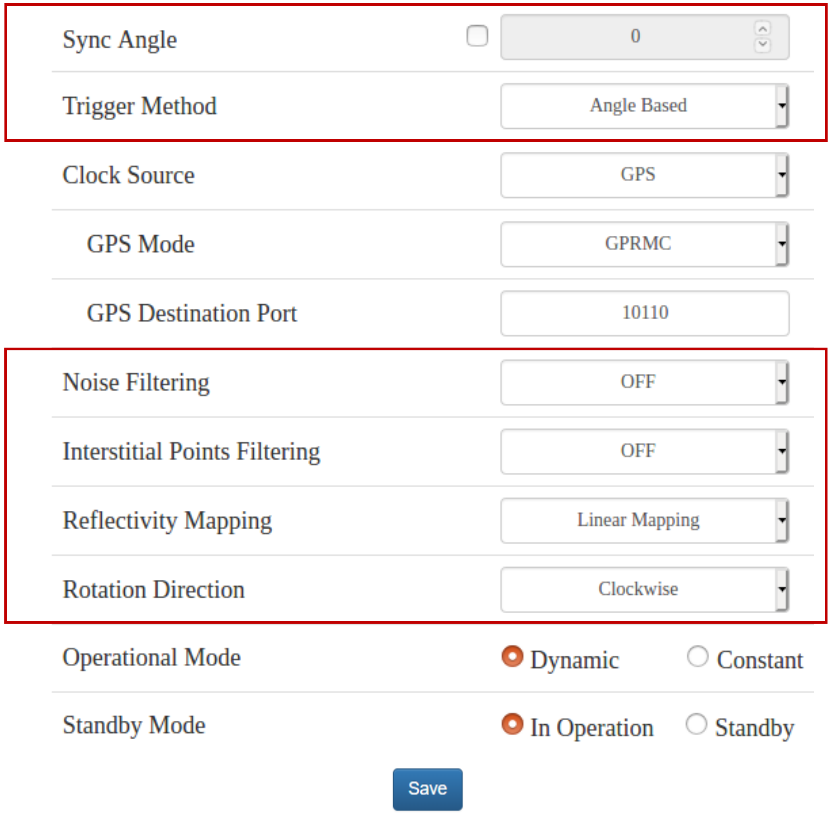

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Sync Angle	0~360 degrees
	By default, the LiDAR's 0° position (see Section 1.2) is not in sync with GPS PPS or the whole second of the PTP clock. If syncing is needed, check the checkbox and input a sync angle.
Trigger Method	Angle-Based / Time-Based
	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
Interstitial Points Filtering	Interstitial point: when a beam partially hits on a front target's edge and further hits on a rear target, the return signal can result in a false point located between both targets. Such points can be mitigated.
Reflectivity Mapping	Linear / Nonlinear Mapping
	Linear: 1-byte reflectivity data linearly represents target reflectivity (0 ~ 255%). **Nonlinear**: increases the contrast in low-reflectivity region, see Appendix IV.
Rotation Direction	Clockwise / Counterclockwise

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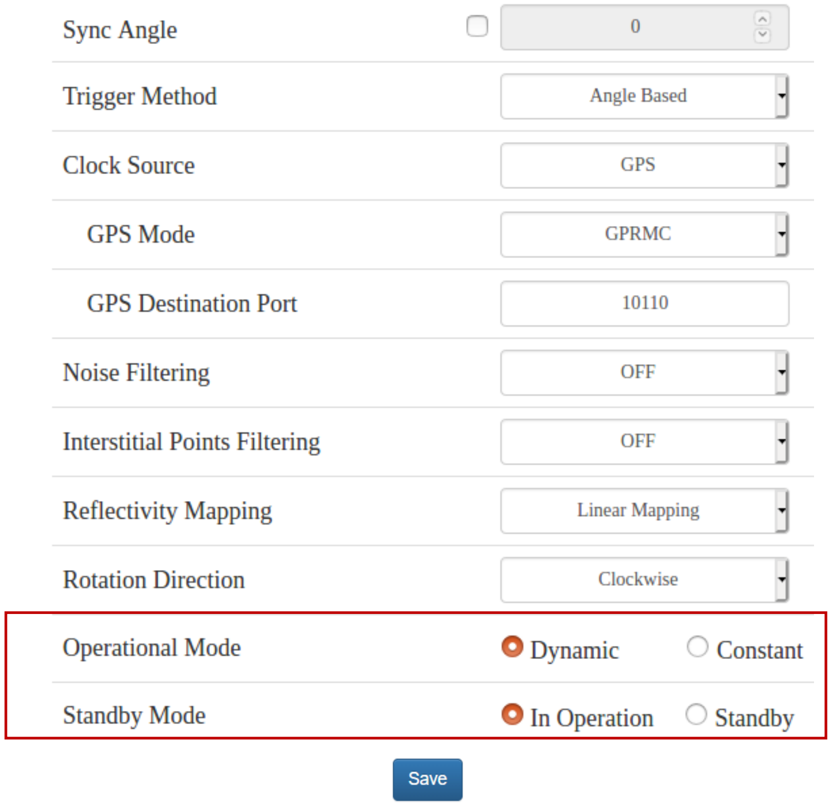

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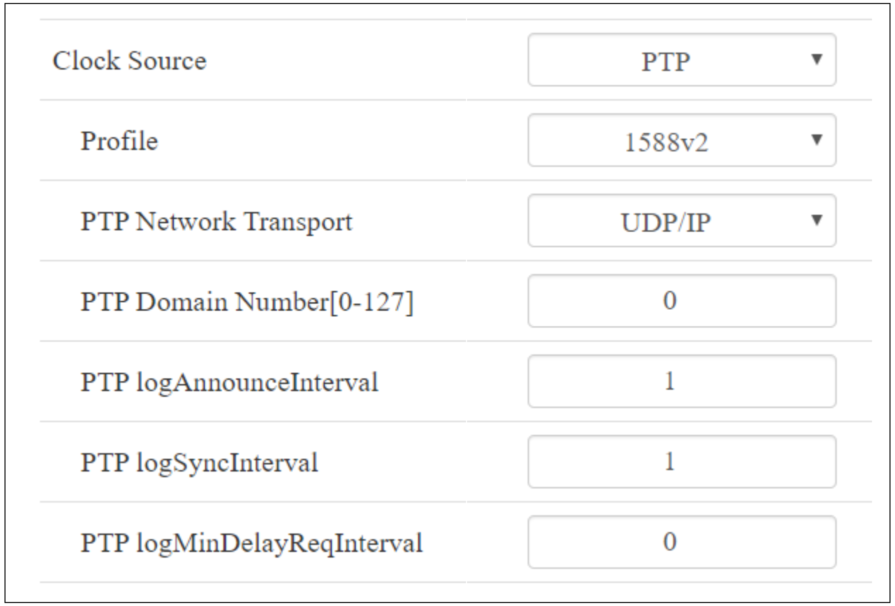
Operational Mode	Dynamic / Constant **Dynamic**: automatic shifting between four states according to ambient temperature - High Performance, Standard, Energy Saving, and Shutdown. See the table below. **Constant**: shifting only between High Performance and Shutdown.
Standby Mode	Motor not running and lasers not firing

Definition of operational states:

Operational States	Horizontal Resolution	Laser Power
High Performance	High Resolution Mode	Normal
Standard	Standard Mode	Normal
Energy Saving	Standard Mode	Half of normal value (measurement range reduced by 30%)
Shutdown	Motor not running and lasers not firing	Shutdown

5. Clock Source and PTP Parameters

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



- 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

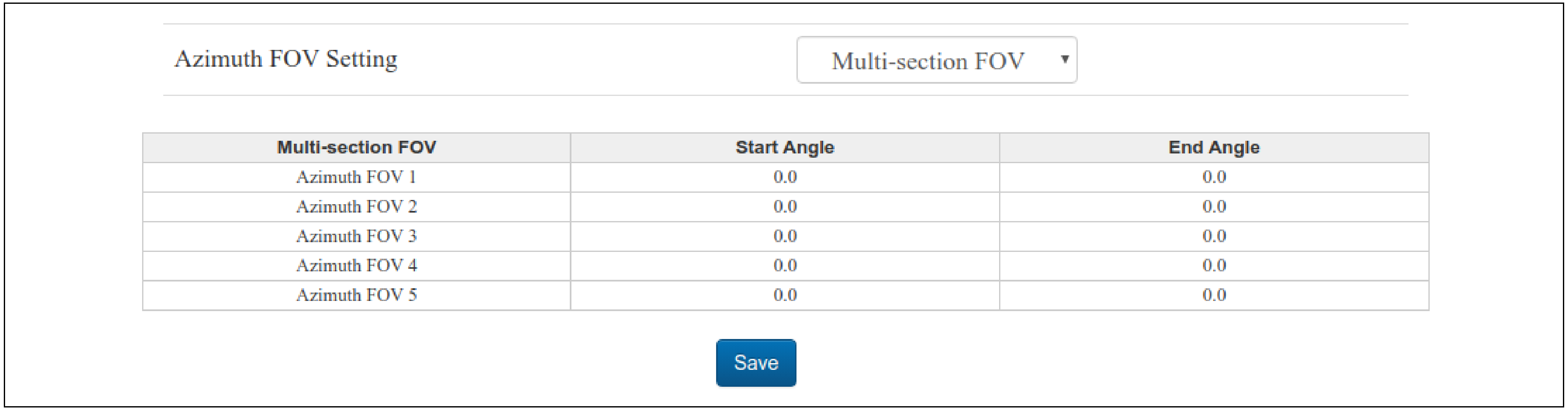
To set the Azimuth FOV, users can select one of the two modes: for all channels, or multi-section FOV.

4.3.1 For all channels

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

4.3.2 Multi-section FOV

Users can configure up to five continuous angle ranges for all channels.
Each channel outputs valid data only within its specified range.



4.3.3 Note

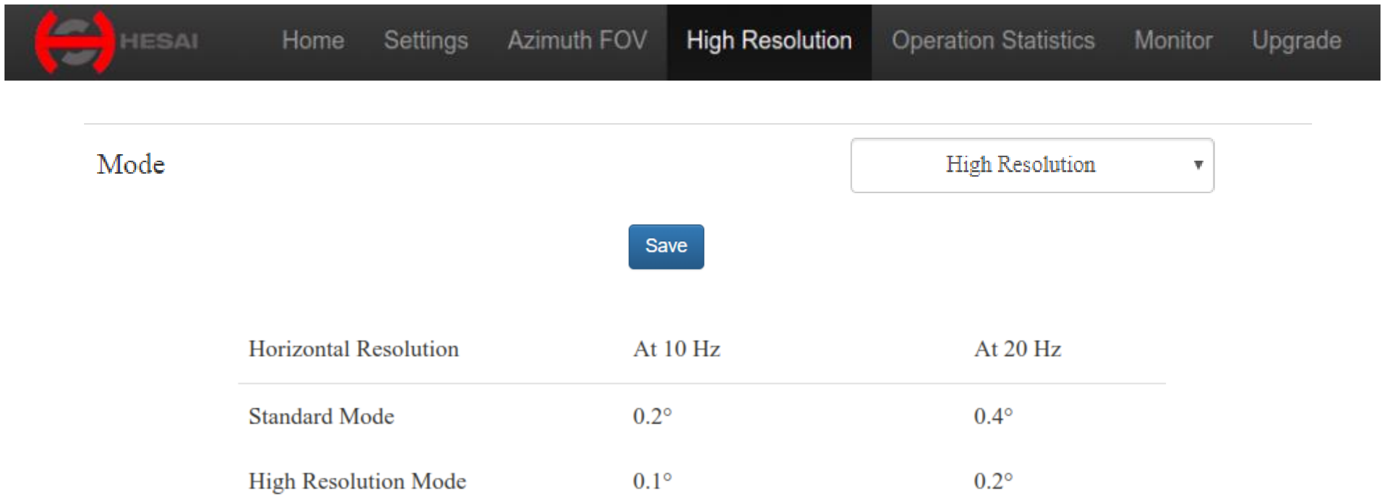
- Click "Save" to apply your settings.
- The angles in degrees are accurate to the first decimal place.
- If the Start Angle is larger than the End Angle, then the actual azimuth FOV is the union of [Start Angle, 360°] and [0°, End Angle].

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

4.4 High Resolution

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

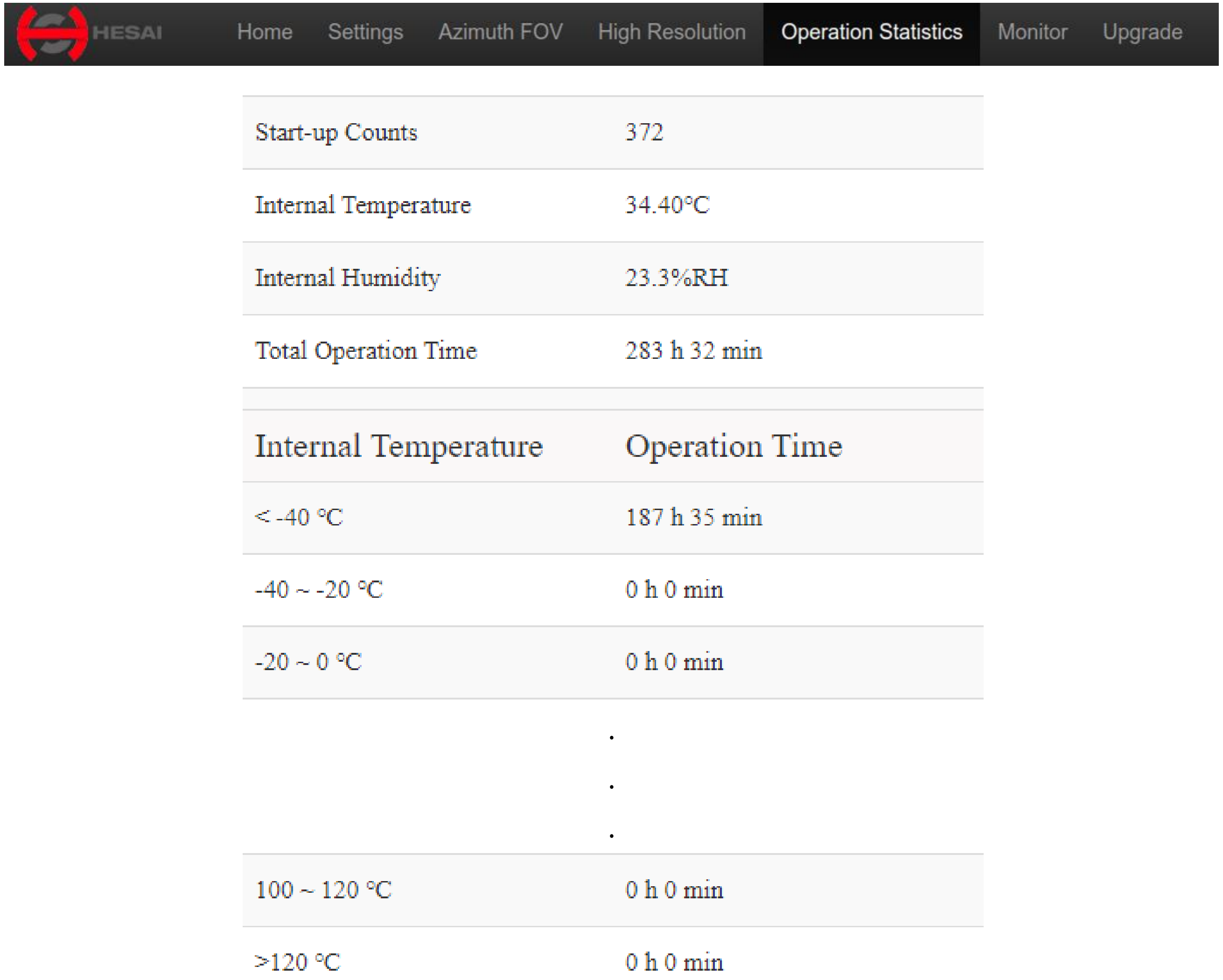
Configuration Mode	Frame Rate	Horizontal Resolution of Far Field Measurement
Standard	10 Hz	0.2° for all channels
	20 Hz	0.4° for all channels
High Resolution	10 Hz	0.1° for the 64 high-res channels (Channel 26 to Channel 89) 0.2° for the other channels **NOTE** Channel # counts from 1 to 128
	20 Hz	0.2° for the 64 high-res channels (Channel 26 to Channel 89) 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 (Channel Distribution) for the definition of near/far field measurement.

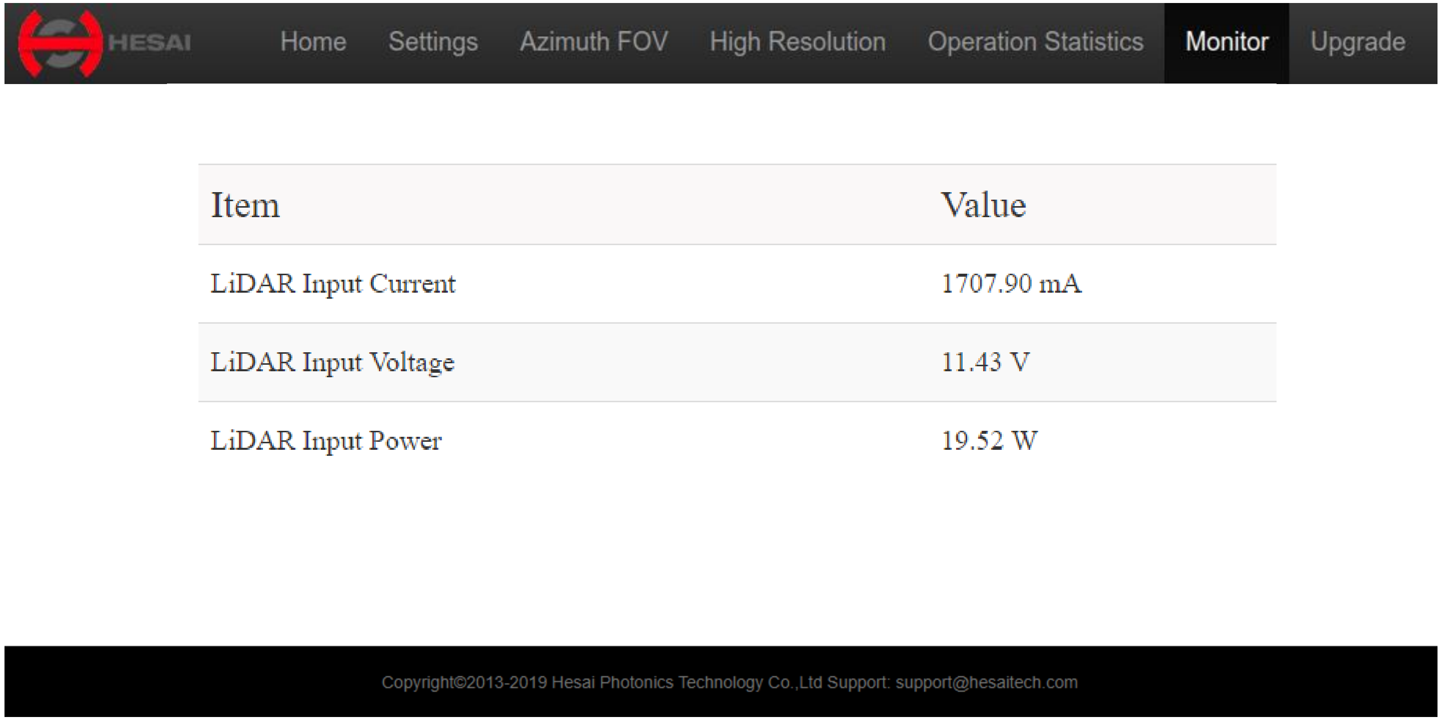
4.5 Operation Statistics

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



4.6 Monitor

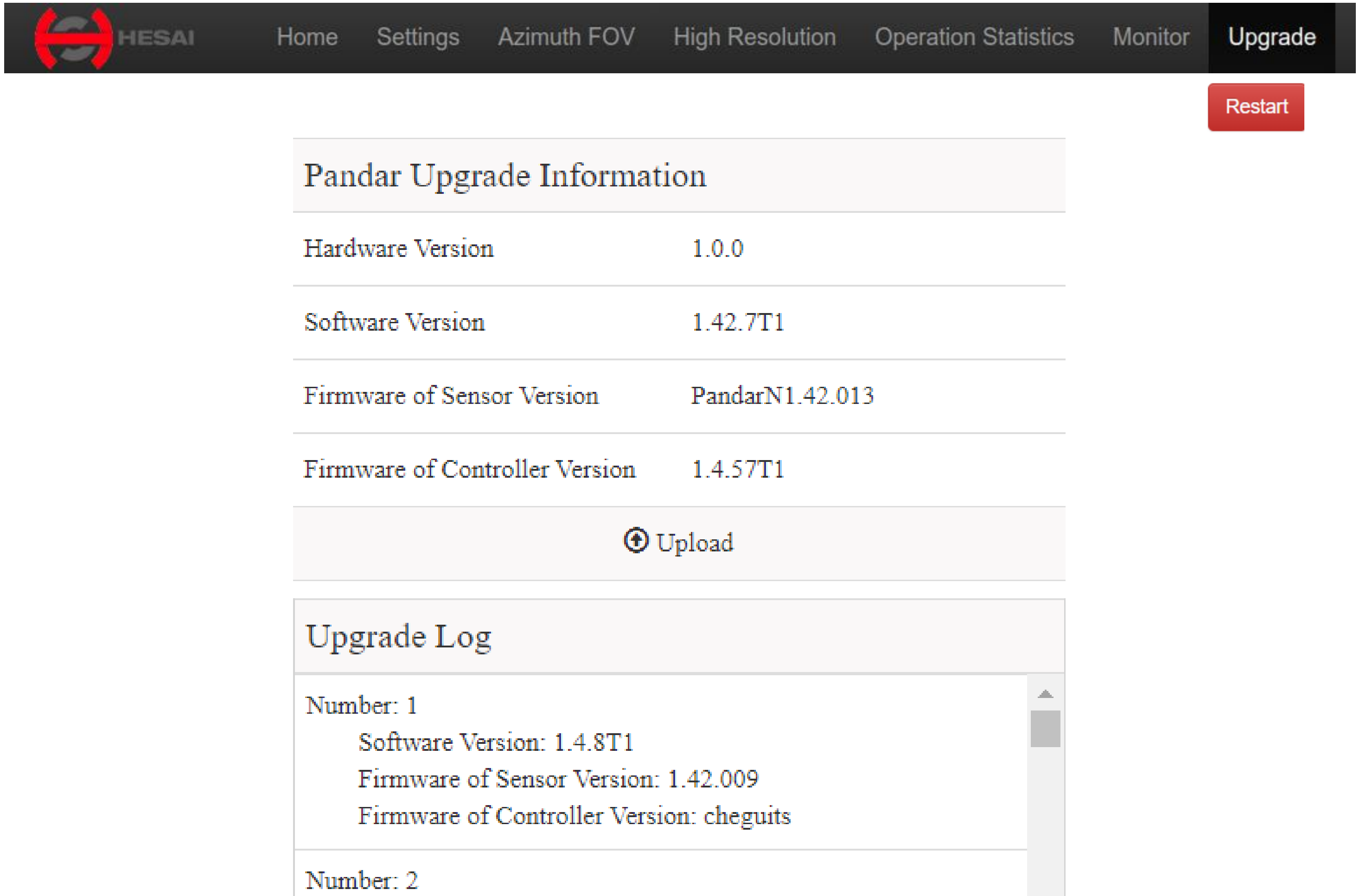
The LiDAR's input current, voltage, and power consumption are displayed.



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

4.7 Upgrade

Click the "Upload" button, select an upgrade file (provided by Hesai), and confirm your choice in the pop-up window.
When the upgrade is complete, the LiDAR will automatically reboot, and the past versions will be logged in the Upgrade Log.



A software reboot is triggered by clicking the "Restart" button on the top right corner.

Afterwards, the start-up counts in the Operation Statistics page increments by 1.

NOTE The screenshot may not display the most current version numbers.

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 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 the software version from "About" in the menu bar.

5.2 Use

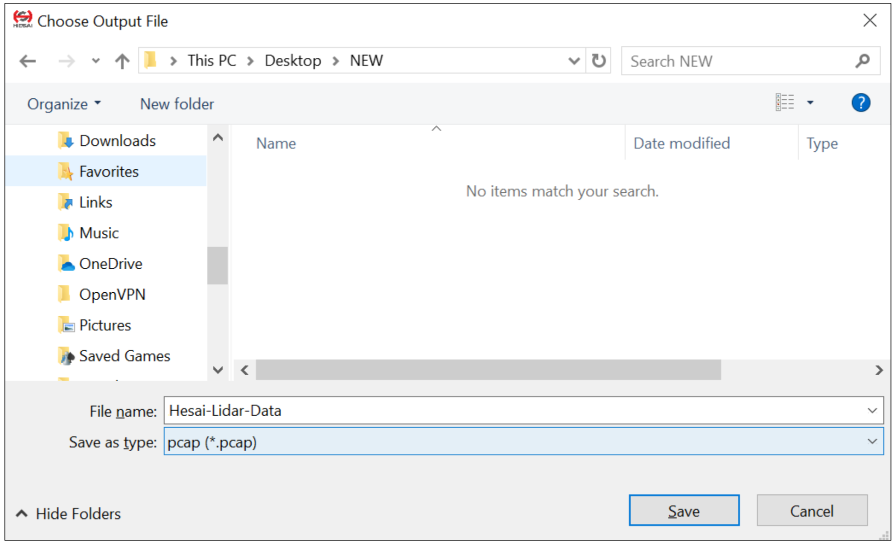
Set the PC's IP address according to Section 2.4 (Get Ready to Use)

■ Check Live Data

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

■ Record 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

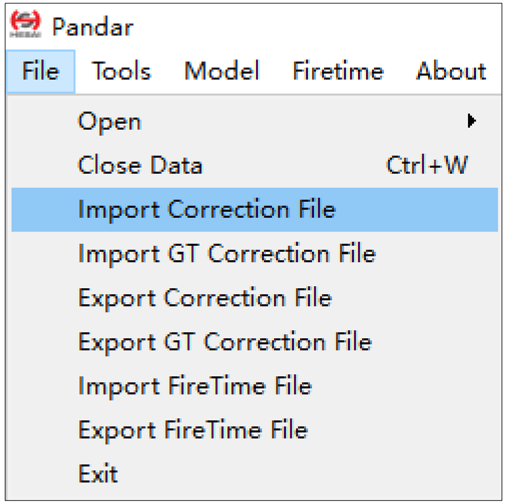
1) Open a .PCAP File

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

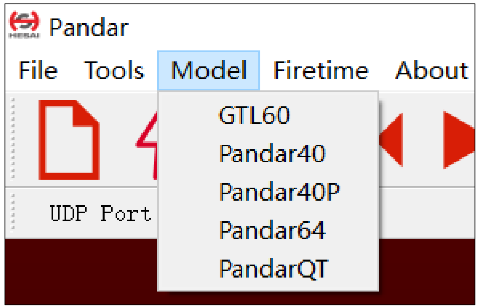
2) Import a Correction File

Each LiDAR unit has a corresponding calibration file (.CSV), see Section 1.3 (Channel Distribution).

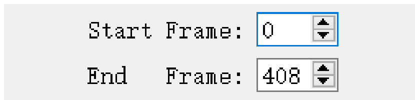
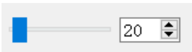
We recommend importing the calibration file of this LiDAR unit into PandarView (File -- Import Correction File), in order to display the point cloud most accurately.



If the calibration file of this LiDAR unit is temporarily not at hand, select the LiDAR model in the "Model" menu. Thus 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)	
 / 	After loading a point cloud file, click to play the file While playing, click to pause	
	While paused, jump to the next frame. While playing, forward. May click again to adjust the forward speed (2x, 3x, 1/2x, 1/4x, and 1x)	
	Jump to the end of the file	
	Save a single frame to .CSV	
	While playing, this Record button will be gray and unclickable	
	While playing, click to loop playback. Otherwise the player will stop at the end of the file	
	Save multiple frames to .PCAP	 Specify the start and end frames
	Save multiple frames to .CSV	
	Drag this progress bar or enter a frame number to jump to a specific frame	

5.3 Features

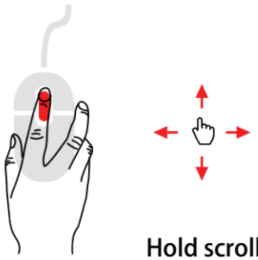
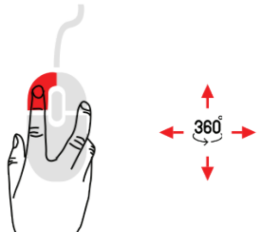
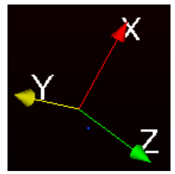
■ Standard Viewpoints


Right


Front


Top

■ Mouse Shortcuts

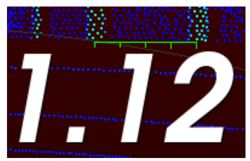
 Scroll	 Hold scroll	 Hold left button	
Scroll the mouse wheel up/down to zoom in/out	Press the mouse wheel and drag to pan the view	Hold the left button and drag to adjust the point of view	The bottom-left coordinate axes show the current point of view

■ 3D Projection and Distance Measurement

PandarView supports perspective projection (default) and orthographic projection.

The distance ruler is available only under orthographic projection:

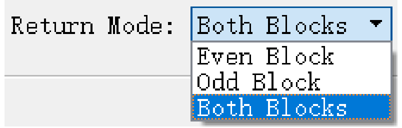
- Click on  to enter measurement mode. Hold the Ctrl key and drag the mouse to make a measurement in units of meters
- Click on  again to quit



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-number blocks

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

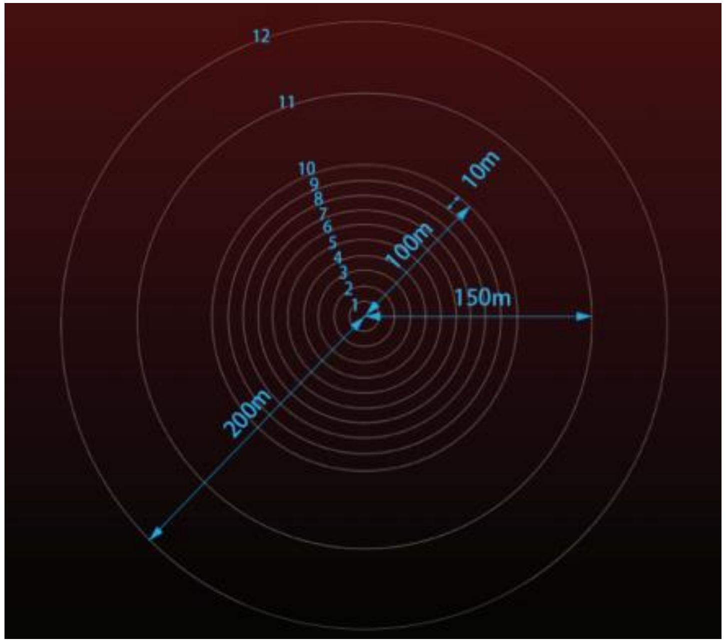


UDP Port

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

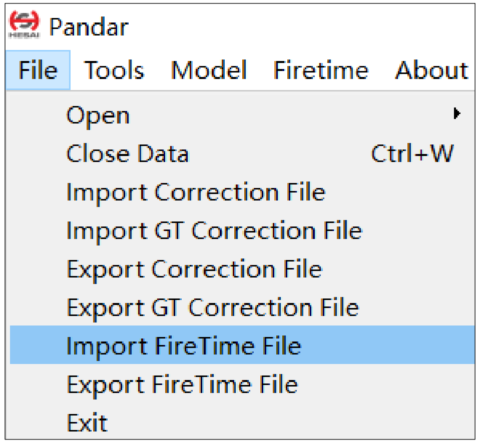
Distance Reference Circles

Click on  to show/hide the 12 distance reference circles. 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, import the fire time correction file of this LiDAR model into PandarView (File -- Import FireTime File).



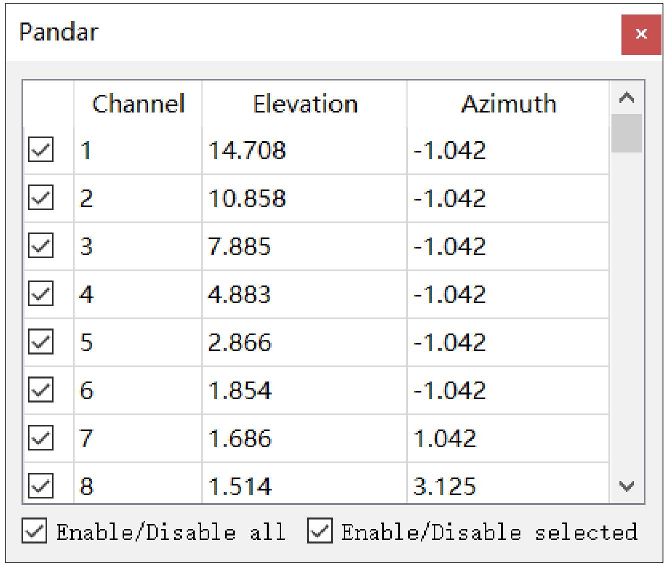
Afterwards, click on to finetune point cloud display using the fire time correction file.

Click on again to cancel the finetuning effects.

Channel Selection

Click on to open the Channel Selection box.

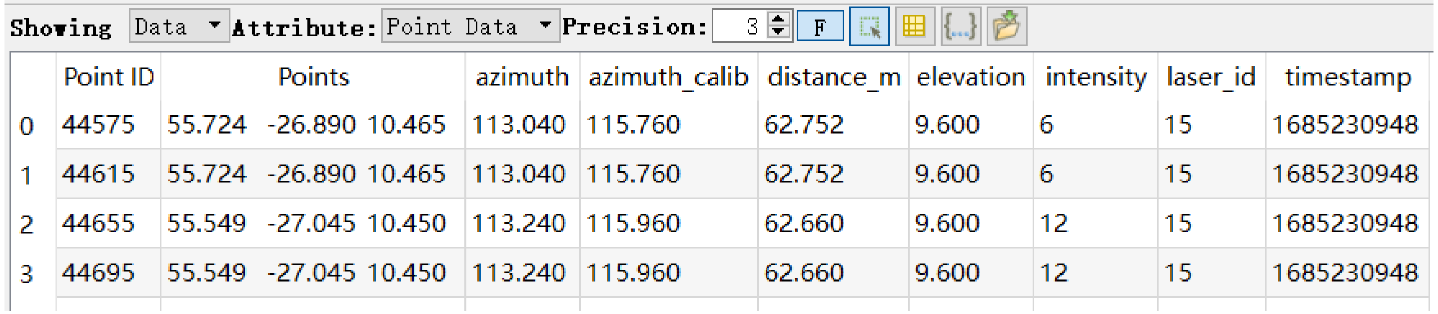
- Check/Uncheck the boxes on the left to show/hide each channel. By default, the point cloud data from all channels are shown.
- Check/Uncheck the "Enable/Disable all" option at the bottom of the table to show/hide all channels.
- When multiple channels are selected by holding the Shift or Ctrl key,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



Click on again to close the Channel Selection box.

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

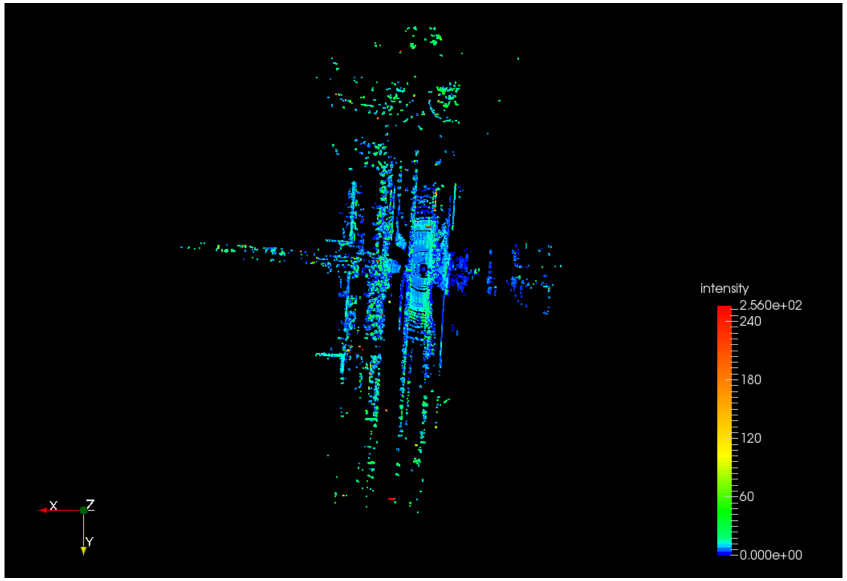
Some of the data fields are defined below:

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

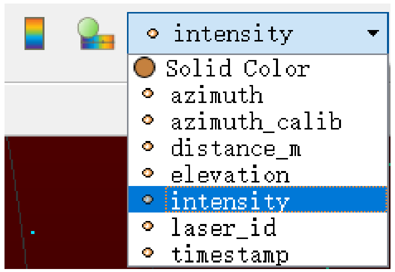
To cancel the selection, click on again and click on any place outside the selected point cloud area.

Color Schemes

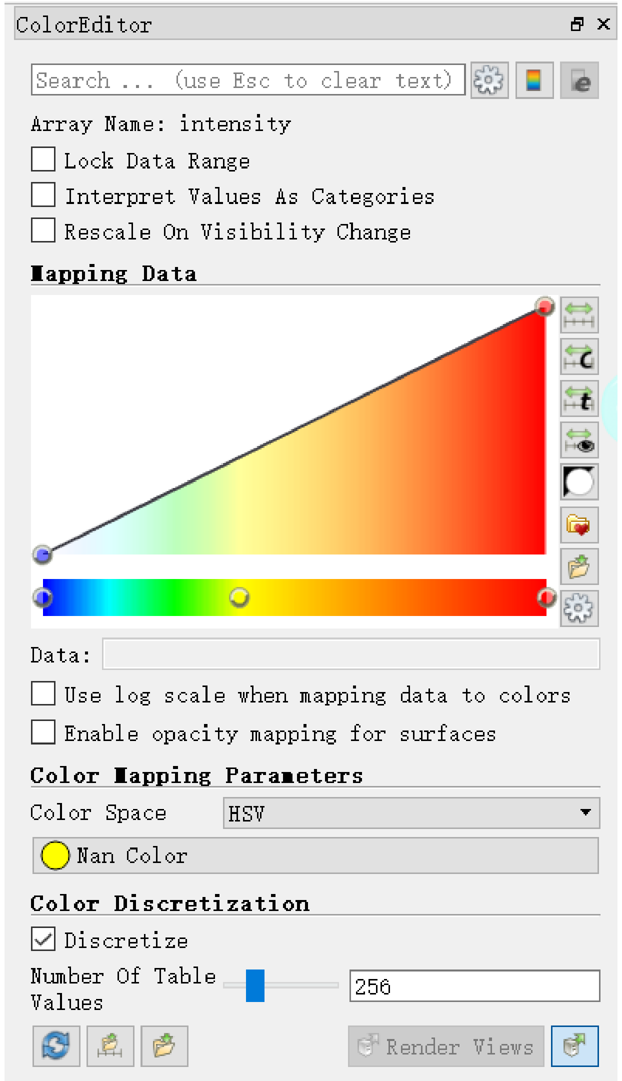
Click on to show the color legend at the lower right corner.



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 product in a dry, well ventilated place. The ambient temperature shall be between -40°C and +85°C, and the humidity below 85%.
Please check Section 1.4 (Specifications) for product IP rating, and avoid any ingress beyond that rating.

■ Transport

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

■ Cleaning

Stains on the product's enclosure, such as dirt, fingerprints, and oil, can negatively affect point cloud data quality.
Please perform the following 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

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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 **NOTE** When using IPA or alcohol, please ensure adequate ventilation and keep away from fire.
Solvent temperature	20 to 25°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 • power adapter is properly connected and in good condition • connection box is intact • input voltage and current satisfy the requirements in Section 2.3 (Connection Box) Power on again to check if the symptom persists.
Motor is not running	Verify that • power adapter is properly connected and in good condition • if a connection box is used, the connection box is intact • input voltage and current satisfy the requirements in Section 1.4 (Specifications) and 2.3 (Connection Box) • web control can be accessed (see "cannot open web control" on the next page) Power on again to check if the symptom persists.
Motor is running but no output data is received, neither on Wireshark nor on PandarView	Verify that • Ethernet cable is properly connected (by unplugging and plugging again) • LiDAR's IP is in the same subnet with the PC's • horizontal FOV is properly set on the Azimuth FOV page of web control • firmware version of the sensor is correctly shown on the Upgrade page of web control • LiDAR is emitting laser light. This can be checked by using an infrared camera, an infrared sensor card, or a phone camera without infrared filter Power on again to check if the symptom persists.

(Continued on the next page)

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

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Symptoms	Points to Check
Abnormal point cloud (obviously misaligned points, flashing points, or incomplete FOV)	Verify that • LiDAR's enclosure is clean. If not, refer to Chapter 7 (Sensor Maintenance) for the cleaning method • LiDAR's calibration file is imported, see Section 5.2 (PandarView - Use) • horizontal FOV is properly set on the Azimuth FOV page of web control • motor's spin rate is steady on the Home page of web control • LiDAR's internal temperature is between -20°C and 95°C on the Operation Statistics page of web control Afterwards, check for packet loss • If no packet is missing while the point cloud flashes, please update PandarView to the latest version (see the Download page of Hesai's official website) and restart the PC If the point cloud is still abnormal • Try connecting the LiDAR to another PC • Power on again to check if the symptom persists
GPS cannot be locked	Verify that • GPS receiver is properly connected • PPS signal is connected to the LiDAR • Destination GPS Port is correct on the Settings page of web control • input GPS signals satisfy the electrical requirements in Section 2.2 (Interface) and Section 2.3.1 (Connection Box) Power on again to check if the symptom persists

Appendix I Channel Distribution

Channel #	Angular Position		Instrument Range		Near Field Enabled?	Max. Range @10% Reflectivity	Far Field Enhanced?	Min. Reflectivity @ Max. Instrument Range	High-Res?
	Horiz. Offset	Vertical	Min	Max					
①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩

①	Channel # counts from 1, from the topmost to bottom
②③	Design values of each channel's horizontal (azimuth) angle offset and vertical (elevation) angle. ・ The accurate values are recorded in this LiDAR's unit's calibration file ・ Refer to Section 3.1.3 (Point Cloud Data Analysis) for the data parsing scheme
④⑤	Actual measurement range, confined by the allocated Time of Flight (ToF) for each channel
⑥	The 32 channels with ④ = 0.3 m are **NF-enabled channels** ・ All the 128 channels fire laser pulses that measure the far field (>2.85 m) ・ Additionally, the NF-enabled channels also fire laser pulses that measure only the near field (0.3~2.85 m), at a time other than these channels' far field firings ・ The horizontal resolution of NF measurement is always 0.4° at 10 Hz and 0.8° at 20 Hz
⑦	Probability of Detection (PoD) = 70% The values in brackets only indicate detection capability, while the actual measurement range is cut off to ⑤. Channels 98~128 have enhanced near- and mid-field detection, since these channels typically point to the ground in the far field.
⑧	Channels 34~65 are **FF-enhanced channels**, able to detect 200 m@10%
⑨	Probability of Detection (PoD) = 70%
⑩	Channels 26~89 are **high-res channels**, characterized by ・ 0.125° vertical resolution ・ enhanced horizontal resolution in High Resolution Mode, see Section 4.4 (Web Control - High Resolution) ・ ⑤ = 200 m

Pandar128 Channel Distribution (To Be Continued)

Channel #	Angular Position		Instrument Range		Near Field Enabled?	Max. Range @10% Reflectivity	Far Field Enhanced?	Min. Reflectivity @ Max. Instrument Range	High-Res?
	Horiz. Offset	Vertical	Min	Max					
01	3.257°	14.436°	0.3 m	100 m	YES	100 m	-	100 m @ **10%**	-
02	3.263°	13.535°	2.85 m	100 m	-	100 m	-	100 m @ **10%**	-
03	1.091°	13.082°	0.3 m	100 m	YES	100 m	-	100 m @ **10%**	-
04	3.268°	12.624°	2.85 m	100 m	-	100 m	-	100 m @ **10%**	-
05	1.093°	12.165°	2.85 m	100 m	-	100 m	-	100 m @ **10%**	-
06	3.273°	11.702°	0.3 m	100 m	YES	(120 m)	-	100 m @ **6%**	-
07	1.094°	11.239°	2.85 m	100 m	-	(120 m)	-	100 m @ **6%**	-
08	3.278°	10.771°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
09	1.095°	10.305°	0.3 m	100 m	YES	(140 m)	-	100 m @ **3%**	-
10	3.283°	9.830°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
11	1.096°	9.356°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
12	3.288°	8.880°	0.3 m	100 m	YES	(140 m)	-	100 m @ **3%**	-
13	1.097°	8.401°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
14	3.291°	7.921°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
15	1.098°	7.438°	0.3 m	100 m	YES	(140 m)	-	100 m @ **3%**	-
16	-1.101°	6.953°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
17	1.100°	6.467°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
18	-1.104°	5.978°	0.3 m	100 m	YES	(140 m)	-	100 m @ **3%**	-
19	-3.306°	5.487°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
20	-1.106°	4.996°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-

Pandar128 Channel Distribution (To Be Continued)

Channel #	Angular Position		Instrument Range		Near Field Enabled?	Max. Range @10% Reflectivity	Far Field Enhanced?	Min. Reflectivity @ Max. Instrument Range	High-Res?
	Horiz. Offset	Vertical	Min	Max					
21	-3.311°	4.501°	0.3 m	100 m	YES	(140 m)	-	100 m @ **3%**	-
22	-1.109°	4.007°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
23	-3.318°	3.509°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
24	-1.111°	3.013°	0.3 m	100 m	YES	(140 m)	-	100 m @ **3%**	-
25	-3.324°	2.512°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
26	-1.113°	2.013°	0.3 m	200 m	YES	140 m	-	200 m @ **37%**	YES
27	7.72°	1.885°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
28	5.535°	1.761°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
29	3.325°	1.637°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
30	-3.33°	1.511°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
31	1.107°	1.386°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
32	-5.538°	1.258°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
33	-7.726°	1.13°	0.3 m	200 m	YES	140 m	-	200 m @ **37%**	YES
34	-1.115°	1.008°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
35	7.731°	0.88°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
36	5.543°	0.756°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
37	3.329°	0.63°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
38	-3.336°	0.505°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
39	1.108°	0.379°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
40	-5.547°	0.251°	0.3 m	200 m	YES	200 m	YES	200 m @ **10%**	YES

Pandar128 Channel Distribution (To Be Continued)

Channel #	Angular Position		Instrument Range		Near Field Enabled?	Max. Range @10% Reflectivity	Far Field Enhanced?	Min. Reflectivity @ Max. Instrument Range	High-Res?
	Horiz. Offset	Vertical	Min	Max					
41	-7.738°	0.124°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
42	-1.117°	0.000°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
43	7.743°	-0.129°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
44	5.551°	-0.254°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
45	3.335°	-0.380°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
46	-3.342°	-0.506°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
47	1.110°	-0.632°	0.3 m	200 m	YES	200 m	YES	200 m @ **10%**	YES
48	-5.555°	-0.760°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
49	-7.750°	-0.887°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
50	-1.119°	-1.012°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
51	7.757°	-1.141°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
52	5.560°	-1.266°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
53	3.340°	-1.393°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
54	-3.347°	-1.519°	0.3 m	200 m	YES	200 m	YES	200 m @ **10%**	YES
55	1.111°	-1.646°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
56	-5.564°	-1.773°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
57	-7.762°	-1.901°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
58	-1.121°	-2.027°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
59	7.768°	-2.155°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
60	5.569°	-2.282°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES

Pandar128 Channel Distribution (To Be Continued)

Channel #	Angular Position		Instrument Range		Near Field Enabled?	Max. Range @10% Reflectivity	Far Field Enhanced?	Min. Reflectivity @ Max. Instrument Range	High-Res?
	Horiz. Offset	Vertical	Min	Max					
61	3.345°	-2.409°	0.3 m	200 m	YES	200 m	YES	200 m @ **10%**	YES
62	-3.353°	-2.535°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
63	1.113°	-2.663°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
64	-5.573°	-2.789°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
65	-7.775°	-2.916°	2.85 m	200 m	-	200 m	YES	200 m @ **10%**	YES
66	-1.123°	-3.044°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
67	7.780°	-3.172°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
68	5.578°	-3.299°	0.3 m	200 m	YES	140 m	-	200 m @ **37%**	YES
69	3.351°	-3.425°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
70	-3.358°	-3.552°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
71	1.115°	-3.680°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
72	-5.582°	-3.806°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
73	-7.787°	-3.933°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
74	-1.125°	-4.062°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
75	7.792°	-4.190°	0.3 m	200 m	YES	140 m	-	200 m @ **37%**	YES
76	5.586°	-4.318°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
77	3.356°	-4.444°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
78	-3.363°	-4.571°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
79	1.116°	-4.699°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
80	-5.591°	-4.824°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES

Pandar128 Channel Distribution (To Be Continued)

Channel #	Angular Position		Instrument Range		Near Field Enabled?	Max. Range @10% Reflectivity	Far Field Enhanced?	Min. Reflectivity @ Max. Instrument Range	High-Res?
	Horiz. Offset	Vertical	Min	Max					
81	-7.799°	-4.951°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
82	-1.127°	-5.081°	0.3 m	200 m	YES	140 m	-	200 m @ **37%**	YES
83	7.804°	-5.209°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
84	5.595°	-5.336°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
85	3.360°	-5.463°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
86	-3.369°	-5.589°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
87	1.118°	-5.718°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
88	-5.599°	-5.843°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
89	-7.811°	-5.968°	2.85 m	200 m	-	140 m	-	200 m @ **37%**	YES
90	-1.129°	-6.100°	0.3 m	100 m	YES	140 m	-	200 m @ **37%**	-
91	-3.374°	-6.607°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
92	-1.130°	-7.117°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
93	-3.379°	-7.624°	0.3 m	100 m	YES	(140 m)	-	100 m @ **3%**	-
94	-1.132°	-8.134°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
95	-3.383°	-8.640°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
96	3.381°	-9.149°	0.3 m	100 m	YES	(140 m)	-	100 m @ **3%**	-
97	-3.388°	-9.652°	2.85 m	100 m	-	(140 m)	-	100 m @ **3%**	-
98	3.386°	-10.160°	2.85 m	100 m	-	100 m	-	100 m @ **10%**	-
99	1.129°	-10.665°	0.3 m	100 m	YES	100 m	-	100 m @ **10%**	-
100	3.390°	-11.170°	2.85 m	100 m	-	100 m	-	100 m @ **10%**	-

Pandar128 Channel Distribution (To Be Continued)

Channel #	Angular Position		Instrument Range		Near Field Enabled?	Max. Range @10% Reflectivity	Far Field Enhanced?	Min. Reflectivity @ Max. Instrument Range	High-Res?
	Horiz. Offset	Vertical	Min	Max					
101	1.129°	-11.672°	2.85 m	100 m	-	100 m	-	100 m @ **10%**	-
102	3.395°	-12.174°	0.3 m	100 m	YES	100 m	-	100 m @ **10%**	-
103	1.131°	-12.673°	2.85 m	100 m	-	100 m	-	100 m @ **10%**	-
104	3.401°	-13.173°	2.85 m	100 m	-	100 m	-	100 m @ **10%**	-
105	1.133°	-13.67°	0.3 m	100 m	YES	100 m	-	100 m @ **10%**	-
106	3.406°	-14.166°	2.85 m	100 m	-	50 m	-	100 m @ **120%**	-
107	1.135°	-14.66°	2.85 m	100 m	-	50 m	-	100 m @ **120%**	-
108	3.410°	-15.154°	0.3 m	100 m	YES	50 m	-	100 m @ **120%**	-
109	1.137°	-15.645°	2.85 m	100 m	-	50 m	-	100 m @ **120%**	-
110	3.416°	-16.135°	2.85 m	100 m	-	50 m	-	100 m @ **120%**	-
111	1.139°	-16.622°	0.3 m	100 m	YES	50 m	-	100 m @ **120%**	-
112	-1.142°	-17.106°	2.85 m	100 m	-	50 m	-	100 m @ **120%**	-
113	1.142°	-17.592°	2.85 m	100 m	-	50 m	-	100 m @ **120%**	-
114	-1.143°	-18.072°	0.3 m	100 m	YES	50 m	-	100 m @ **120%**	-
115	-3.426°	-18.548°	2.85 m	100 m	-	50 m	-	100 m @ **120%**	-
116	-3.426°	-19.030°	2.85 m	100 m	-	25 m	-	100 m @ **1600%**	-
117	-1.144°	-19.501°	0.3 m	100 m	YES	25 m	-	100 m @ **1600%**	-
118	-3.429°	-19.978°	2.85 m	100 m	-	25 m	-	100 m @ **1600%**	-
119	-1.145°	-20.445°	2.85 m	100 m	-	25 m	-	100 m @ **1600%**	-
120	-3.433°	-20.918°	0.3 m	100 m	YES	25 m	-	100 m @ **1600%**	-

Pandar128 Channel Distribution (Continued)

Channel #	Angular Position		Instrument Range		Near Field Enabled?	Max. Range @10% Reflectivity	Far Field Enhanced?	Min. Reflectivity @ Max. Instrument Range	High-Res?
	Horiz. Offset	Vertical	Min	Max					
121	-1.145°	-21.379°	2.85 m	100 m	-	25 m	-	100 m @ **1600%**	-
122	-3.436°	-21.848°	2.85 m	100 m	-	25 m	-	100 m @ **1600%**	-
123	-1.146°	-22.304°	0.3 m	100 m	YES	25 m	-	100 m @ **1600%**	-
124	-3.440°	-22.768°	2.85 m	100 m	-	25 m	-	100 m @ **1600%**	-
125	-1.146°	-23.219°	2.85 m	100 m	-	25 m	-	100 m @ **1600%**	-
126	-3.443°	-23.678°	0.3 m	100 m	YES	25 m	-	100 m @ **1600%**	-
127	-3.446°	-24.123°	2.85 m	100 m	-	25 m	-	100 m @ **1600%**	-
128	-3.449°	-25.016°	0.3 m	100 m	YES	25 m	-	100 m @ **1600%**	-

Appendix II Absolute Time and Laser Firing Time

■ Absolute Time of Point Cloud Data Packets

The Body of each Point Cloud Data Packet contains 2 data blocks, detailed in Section 3.1.2 (Point Cloud UDP Data).

Single Return Mode

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

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

Dual Return Mode

The measurements from one round of firing are stored in the two blocks of one packet.

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 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 of Date & Time), 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 When using a PTP clock source, the LiDAR does not output GPS Data Packets.

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

Laser Firing Time of Each Channel

Assume that the start time of Block m is T(m), $m \in \{0, 1\}$, then
the laser firing time of Channel n in Block m is $t(m, n) = T(m) + \Delta t(n)$, $n \in \{1, 2, \ldots, 128\}$.

$\Delta t(n)$ is determined below:

1) Check the Operational State field in the Tail of the Point Cloud Data Packet

Operation states: high performance, standard, energy saving, shutdown

2) Check the Azimuth Flag field in the Tail of the Point Cloud Data Packet: obtain azimuth flag of Block m

- Range in High Performance mode: 0, 1, 2, 3
- Range in Standard or Energy Saving mode: 0, 1

3) Check the Distance of Channel n in Block m, in the Body the Point Cloud Data Packet

- If Distance > 2.85 m, the data point is generated from a far-field firing
- If Distance ⩽ 2.85 m, the data point is generated from a near-field firing

4) Look up $\Delta t(n)$ in the tables below

Δt(n) – Time Difference between the Channel's Laser Firing Time and the Block's Start Time (Unit: ns)

Sorted by Channel (continued on the next page)

Operational State		High Performance								Standard or Energy Saving			
Angle State		0		1		2		3		0		1	
Firing Type		Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near
	1	4436	5201	0	0	4436	4436	0	0	4436	5201	4436	4436
	2	0	0	776	776	0	0	776	776	28554	28554	28554	28554
	3	776	1541	0	0	776	776	0	0	776	1541	776	776
	4	2431	2431	0	0	2781	2781	0	0	2431	2431	2781	2781
	5	4436	4436	0	0	4436	4436	0	0	4436	4436	4436	4436
	6	0	0	2781	4026	0	0	2431	2431	30559	31804	30209	30209
	7	6441	6441	0	0	6091	6091	0	0	6441	6441	6091	6091
	8	0	0	4786	4786	0	0	4086	4086	32564	32564	31864	31864
	9	0	0	6441	7206	0	0	6091	6091	34219	34984	33869	33869
Channel #	10	776	776	0	0	776	776	0	0	776	776	776	776
	11	2431	2431	0	0	2781	2781	0	0	2431	2431	2781	2781
	12	6441	6441	0	0	6091	7336	0	0	6441	6441	6091	7336
	13	0	0	776	776	0	0	776	776	28554	28554	28554	28554
	14	0	0	6441	6441	0	0	6091	6091	34219	34219	33869	33869
	15	0	0	2781	3546	0	0	2431	2431	30559	31324	30209	30209
	16	0	0	776	776	0	0	776	776	28554	28554	28554	28554
	17	0	0	4786	4786	0	0	4086	4086	32564	32564	31864	31864
	18	6441	7206	0	0	6091	6091	0	0	6441	7206	6091	6091
	19	0	0	4786	4786	0	0	4086	4086	32564	32564	31864	31864
	20	776	776	0	0	776	776	0	0	776	776	776	776

Δt(n) – Time Difference between the Channel's Laser Firing Time and the Block's Start Time (Unit: ns)

Sorted by Channel (continued on the next page)

Operational State		High Performance								Standard or Energy Saving			
Angle State		0		1		2		3		0		1	
Firing Type		Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near
Channel #	21	2431	3196	0	0	2781	2781	0	0	2431	3196	2781	2781
	22	0	0	2781	2781	0	0	2431	2431	30559	30559	30209	30209
	23	0	0	6441	6441	0	0	6091	6091	34219	34219	33869	33869
	24	0	0	4786	4786	0	0	4086	4851	32564	32564	31864	32629
	25	4436	4436	0	0	4436	4436	0	0	4436	4436	4436	4436
	26	10381	10381	10731	12126	10381	10381	10031	10031	38509	39904	37809	37809
	27	14951	14951	15301	15301	14951	14951	14601	14601	43079	43079	42379	42379
	28	12666	12666	13016	13016	12666	12666	12316	12316	12666	12666	12666	12666
	29	14951	14951	15301	15301	14951	14951	14601	14601	43079	43079	42379	42379
	30	19521	19521	19871	19871	19521	19521	19171	19171	19521	19521	19521	19521
	31	19521	19521	19871	19871	19521	19521	19171	19171	19521	19521	19521	19521
	32	8096	8096	8446	8446	8096	8096	7746	7746	36224	36224	35524	35524
	33	12666	12666	13016	13016	12666	14061	12316	12316	12666	12666	12666	14061
	34	12666	12666	13016	13016	12666	12666	12316	12316	12666	12666	12666	12666
	35	10381	10381	10731	10731	10381	10381	10031	10031	38509	38509	37809	37809
	36	24091	24091	24441	24441	24091	24091	23741	23741	52219	52219	51519	51519
	37	17236	17236	17586	17586	17236	17236	16886	16886	17236	17236	17236	17236
	38	24091	24091	24441	24441	24091	24091	23741	23741	52219	52219	51519	51519
	39	14951	14951	15301	15301	14951	14951	14601	14601	43079	43079	42379	42379
	40	14951	27056	15301	15301	14951	14951	14601	14601	43079	27056	42379	42379

Δt(n) – Time Difference between the Channel's Laser Firing Time and the Block's Start Time (Unit: ns)

Sorted by Channel (continued on the next page)

Operational State		High Performance								Standard or Energy Saving			
Angle State		0		1		2		3		0		1	
Firing Type		Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near
Channel #	41	19521	19521	19871	19871	19521	19521	19171	19171	19521	19521	19521	19521
	42	17236	17236	17586	17586	17236	17236	16886	16886	17236	17236	17236	17236
	43	12666	12666	13016	13016	12666	12666	12316	12316	12666	12666	12666	12666
	44	21806	21806	22156	22156	21806	21806	21456	21456	21806	21806	21806	21806
	45	8096	8096	8446	8446	8096	8096	7746	7746	36224	36224	35524	35524
	46	21806	21806	22156	22156	21806	21806	21456	21456	21806	21806	21806	21806
	47	10381	10381	10731	27406	10381	10381	10031	10031	38509	55184	37809	37809
	48	10381	10381	10731	10731	10381	10381	10031	10031	38509	38509	37809	37809
	49	21806	21806	22156	22156	21806	21806	21456	21456	21806	21806	21806	21806
	50	8096	8096	8446	8446	8096	8096	7746	7746	36224	36224	35524	35524
	51	8096	8096	8446	8446	8096	8096	7746	7746	36224	36224	35524	35524
	52	19521	19521	19871	19871	19521	19521	19171	19171	19521	19521	19521	19521
	53	12666	12666	13016	13016	12666	12666	12316	12316	12666	12666	12666	12666
	54	12666	12666	13016	13016	12666	27056	12316	12316	12666	12666	12666	27056
	55	24091	24091	24441	24441	24091	24091	23741	23741	52219	52219	51519	51519
	56	24091	24091	24441	24441	24091	24091	23741	23741	52219	52219	51519	51519
	57	17236	17236	17586	17586	17236	17236	16886	16886	17236	17236	17236	17236
	58	21806	21806	22156	22156	21806	21806	21456	21456	21806	21806	21806	21806
	59	17236	17236	17586	17586	17236	17236	16886	16886	17236	17236	17236	17236
	60	14951	14951	15301	15301	14951	14951	14601	14601	43079	43079	42379	42379

Δt(n) – Time Difference between the Channel's Laser Firing Time and the Block's Start Time (Unit: ns)

Sorted by Channel (continued on the next page)

Operational State		High Performance								Standard or Energy Saving			
Angle State		0		1		2		3		0		1	
Firing Type		Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near
Channel #	61	10381	10381	10731	10731	10381	10381	10031	26706	38509	38509	37809	54484
	62	14951	14951	15301	15301	14951	14951	14601	14601	43079	43079	42379	42379
	63	17236	17236	17586	17586	17236	17236	16886	16886	17236	17236	17236	17236
	64	17236	17236	17586	17586	17236	17236	16886	16886	17236	17236	17236	17236
	65	8096	8096	8446	8446	8096	8096	7746	7746	36224	36224	35524	35524
	66	19521	19521	19871	19871	19521	19521	19171	19171	19521	19521	19521	19521
	67	19521	19521	19871	19871	19521	19521	19171	19171	19521	19521	19521	19521
	68	10381	10381	10731	10731	10381	10381	10031	11426	38509	38509	37809	39204
	69	24091	24091	24441	24441	24091	24091	23741	23741	52219	52219	51519	51519
	70	10381	10381	10731	10731	10381	10381	10031	10031	38509	38509	37809	37809
	71	21806	21806	22156	22156	21806	21806	21456	21456	21806	21806	21806	21806
	72	12666	12666	13016	13016	12666	12666	12316	12316	12666	12666	12666	12666
	73	10381	10381	10731	10731	10381	10381	10031	10031	38509	38509	37809	37809
	74	14951	14951	15301	15301	14951	14951	14601	14601	43079	43079	42379	42379
	75	21806	23201	22156	22156	21806	21806	21456	21456	21806	23201	21806	21806
	76	8096	8096	8446	8446	8096	8096	7746	7746	36224	36224	35524	35524
	77	19521	19521	19871	19871	19521	19521	19171	19171	19521	19521	19521	19521
	78	17236	17236	17586	17586	17236	17236	16886	16886	17236	17236	17236	17236
	79	8096	8096	8446	8446	8096	8096	7746	7746	36224	36224	35524	35524
	80	19521	19521	19871	19871	19521	19521	19171	19171	19521	19521	19521	19521

Δt(n) – Time Difference between the Channel's Laser Firing Time and the Block's Start Time (Unit: ns)

Sorted by Channel (continued on the next page)

Operational State		High Performance								Standard or Energy Saving			
Angle State		0		1		2		3		0		1	
Firing Type		Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near
Channel #	81	24091	24091	24441	24441	24091	24091	23741	23741	52219	52219	51519	51519
	82	24091	24091	24441	24441	24091	24091	23741	25136	52219	52219	51519	52914
	83	24091	24091	24441	24441	24091	24091	23741	23741	52219	52219	51519	51519
	84	17236	17236	17586	17586	17236	17236	16886	16886	17236	17236	17236	17236
	85	21806	21806	22156	22156	21806	21806	21456	21456	21806	21806	21806	21806
	86	8096	8096	8446	8446	8096	8096	7746	7746	36224	36224	35524	35524
	87	12666	12666	13016	13016	12666	12666	12316	12316	12666	12666	12666	12666
	88	21806	21806	22156	22156	21806	21806	21456	21456	21806	21806	21806	21806
	89	14951	14951	15301	15301	14951	14951	14601	14601	43079	43079	42379	42379
	90	2431	3676	0	0	2781	2781	0	0	2431	3676	2781	2781
	91	776	776	0	0	776	776	0	0	776	776	776	776
	92	4436	4436	0	0	4436	4436	0	0	4436	4436	4436	4436
	93	6441	6441	0	0	6091	6856	0	0	6441	6441	6091	6856
	94	0	0	6441	6441	0	0	6091	6091	34219	34219	33869	33869
	95	0	0	2781	2781	0	0	2431	2431	30559	30559	30209	30209
	96	776	776	0	0	776	2021	0	0	776	776	776	2021
	97	0	0	776	776	0	0	776	776	28554	28554	28554	28554
	98	2431	2431	0	0	2781	2781	0	0	2431	2431	2781	2781
	99	2431	2431	0	0	2781	3546	0	0	2431	2431	2781	3546
	100	4436	4436	0	0	4436	4436	0	0	4436	4436	4436	4436

Δt(n) – Time Difference between the Channel's Laser Firing Time and the Block's Start Time (Unit: ns)

Sorted by Channel (continued on the next page)

Operational State		High Performance								Standard or Energy Saving			
Angle State		0		1		2		3		0		1	
Firing Type		Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near
Channel #	101	0	0	4786	4786	0	0	4086	4086	32564	32564	31864	31864
	102	0	0	776	2021	0	0	776	776	28554	29799	28554	28554
	103	0	0	2781	2781	0	0	2431	2431	30559	30559	30209	30209
	104	6441	6441	0	0	6091	6091	0	0	6441	6441	6091	6091
	105	4436	5681	0	0	4436	4436	0	0	4436	5681	4436	4436
	106	0	0	2781	2781	0	0	2431	2431	30559	30559	30209	30209
	107	0	0	776	776	0	0	776	776	28554	28554	28554	28554
	108	0	0	4786	4786	0	0	4086	5331	32564	32564	31864	33109
	109	6441	6441	0	0	6091	6091	0	0	6441	6441	6091	6091
	110	0	0	6441	6441	0	0	6091	6091	34219	34219	33869	33869
	111	0	0	6441	7686	0	0	6091	6091	34219	35464	33869	33869
	112	0	0	4786	4786	0	0	4086	4086	32564	32564	31864	31864
	113	776	776	0	0	776	776	0	0	776	776	776	776
	114	4436	4436	0	0	4436	5201	0	0	4436	4436	4436	5201
	115	0	0	4786	4786	0	0	4086	4086	32564	32564	31864	31864
	116	2431	2431	0	0	2781	2781	0	0	2431	2431	2781	2781
	117	0	0	2781	2781	0	0	2431	3196	30559	30559	30209	30974
	118	0	0	6441	6441	0	0	6091	6091	34219	34219	33869	33869
	119	776	776	0	0	776	776	0	0	776	776	776	776
	120	0	0	776	1541	0	0	776	776	28554	29319	28554	28554

Δt(n) – Time Difference between the Channel's Laser Firing Time and the Block's Start Time (Unit: ns)

Sorted by Channel (continued)

Operational State		High Performance								Standard or Energy Saving			
Angle State		0		1		2		3		0		1	
Firing Type		Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near
Channel #	121	4436	4436	0	0	4436	4436	0	0	4436	4436	4436	4436
	122	6441	6441	0	0	6091	6091	0	0	6441	6441	6091	6091
	123	0	0	6441	6441	0	0	6091	6856	34219	34219	33869	34634
	124	0	0	2781	2781	0	0	2431	2431	30559	30559	30209	30209
	125	2431	2431	0	0	2781	2781	0	0	2431	2431	2781	2781
	126	776	776	0	0	776	1541	0	0	776	776	776	1541
	127	6441	6441	0	0	6091	6091	0	0	6441	6441	6091	6091
	128	0	0	776	776	0	0	776	1541	28554	28554	28554	29319
Total Firings		96	96	96	96	96	96	96	96	128	128	128	128

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**

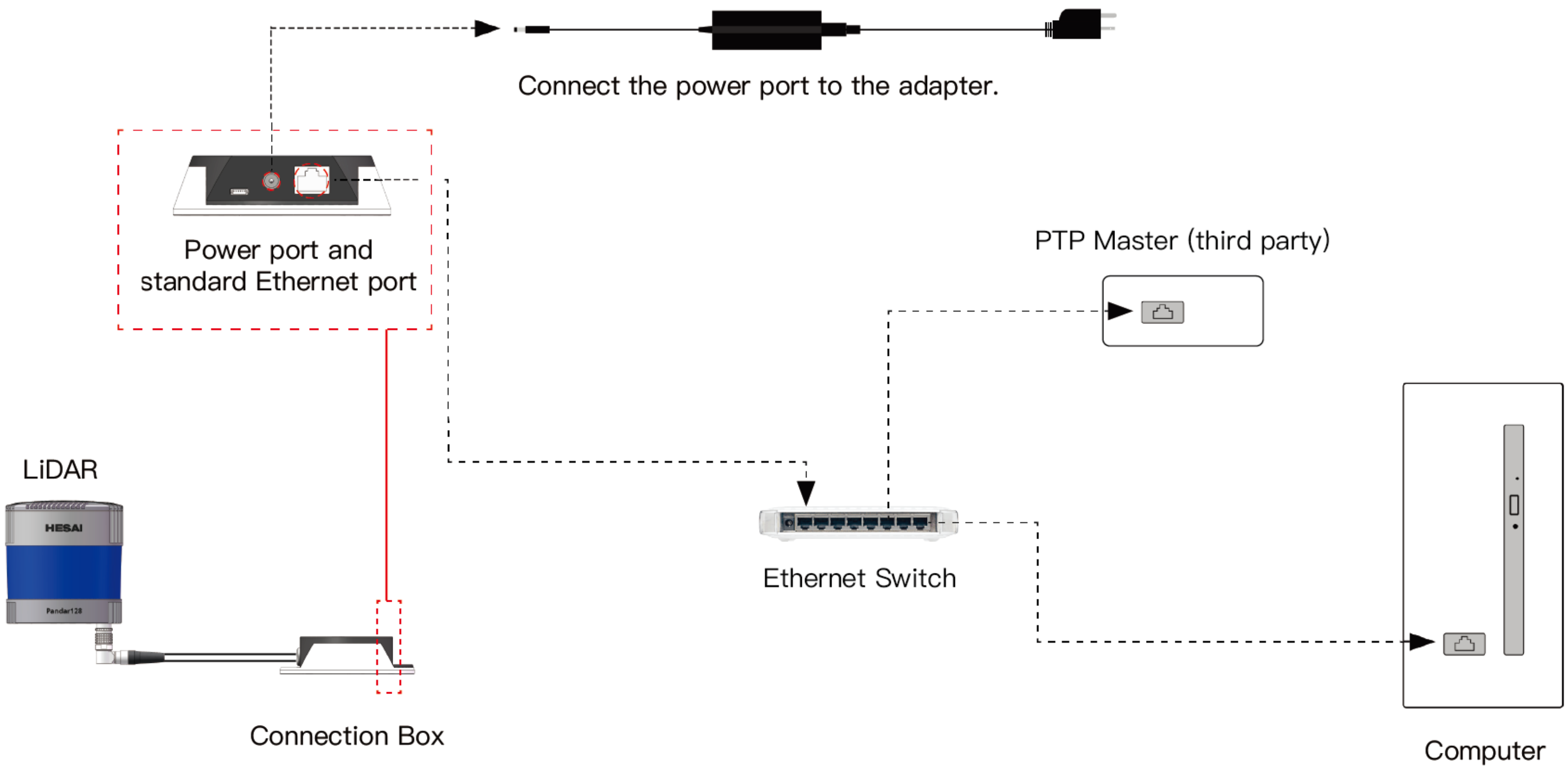

Figure III.1 Connection When Using PTP

■ Absolute Packing Time When Using PTP

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

NOTE

- PTP master is a third-party device and is not included with the LiDAR.
- The LiDAR works as a PTP slave device and the PTP protocol is Plug&Play. No additional setup is required.
- When using a PTP clock source, the LiDAR does not output GPS Data Packets.
- The timestamps and Date & Time fields in Point Cloud Data Packets strictly follow the PTP master device. Certain PTP master devices may have a specified offset from the Date & Time output by the LiDAR. Please verify the configuration and calibration of your PTP master device.
- If a PTP clock source is selected but no PTP master device is available, the LiDAR will count the time from an invalid past time. If a PTP clock source is supplied and later stopped, the LiDAR will continue to count the time with an internal clock.

Appendix IV Nonlinear Reflectivity Mapping

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

Alternatively, users may choose the Nonlinear Mapping mode, see Section 4.2 (Web Control - Settings).

The nonlinear relationship is detailed below.

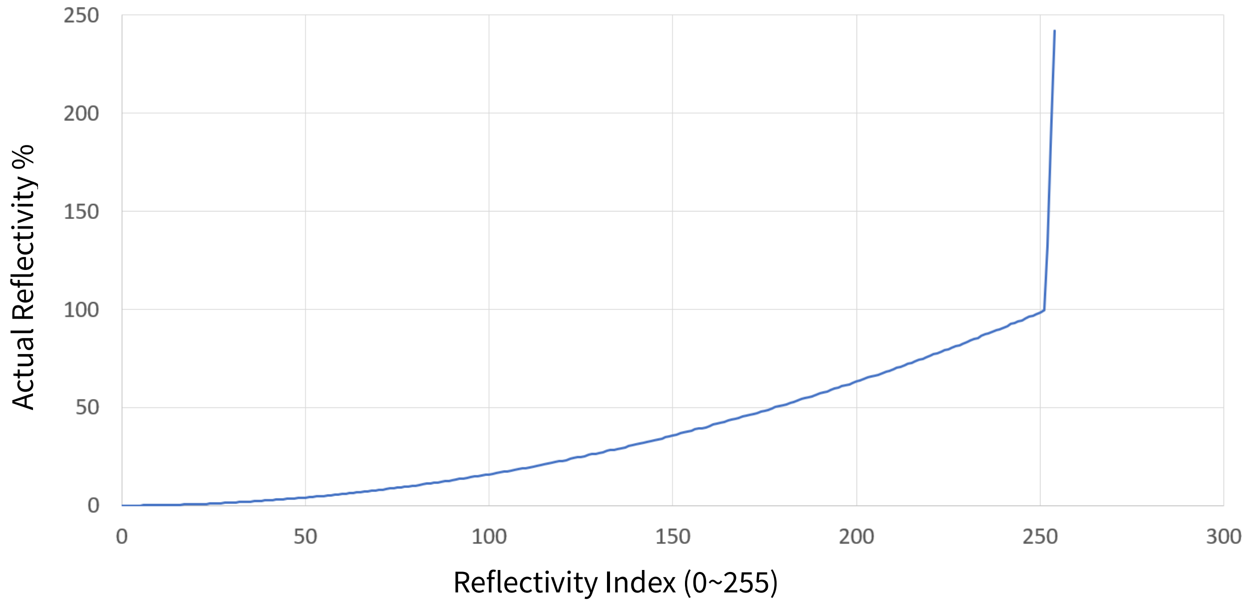

Figure IV.1 Nonlinear Reflectivity Mapping

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 V Support and Contact

■ Technical Support

If your question is 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

MAP IV, Inc.

sales: contact@map4.jp
Website: https://www.map4.jp
Address: #2702 JR Gate Tower, 1-1-3 Meieki, Nakamura-ku, Nagoya

Website