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.

CAUTION

Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure

CLASS 1 LASER PRODUCT
This product complies with IEC 60825-1:2014 (Ed.3) and complies with FDA performance standards for laser products except for conformance with IEC 60825-1 Ed.3., as described in Laser Notice No.56, dated May 8, 2019.
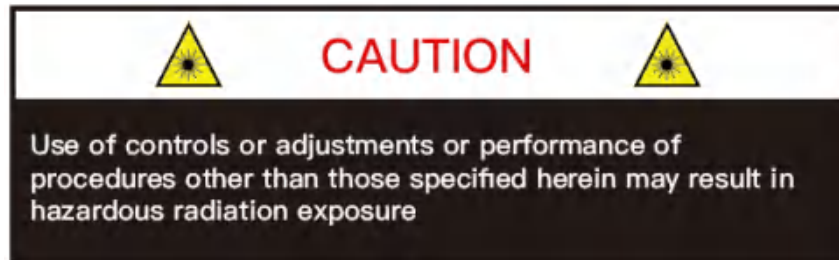
■ **Laser Safety Notice – Laser Class 1**

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 Pandar40M.

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.

$$d = \frac{1}{2}ct \qquad \begin{array}{l} d: \text{ Distance} \\ c: \text{ Speed of light} \\ t: \text{ Laser beam travel time} \end{array}$$

Figure 1.1 ToF Formula

1.2   LiDAR Structure

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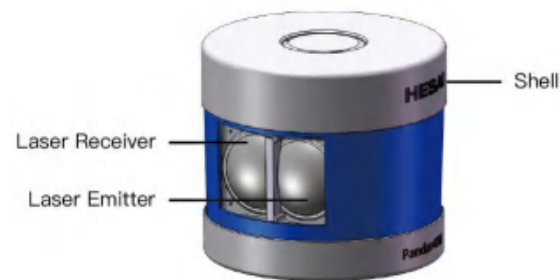

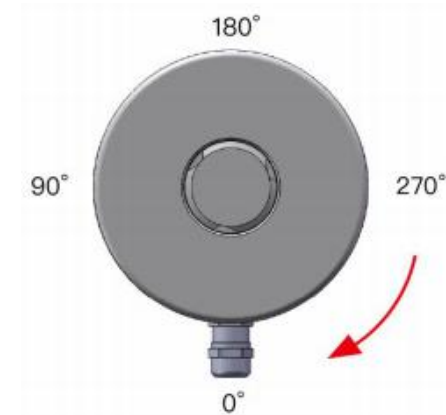Figure 1.2 Partial Cross-Sectional Diagram   Figure 1.3 Coordinate System (Isometric View)   Figure 1.4 Rotation Direction (Top View)

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 12 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
- 0.33° between Channel 6 and Channel 30
- 1° between Channel 5 and Channel 6, Channel 30 and Channel 38
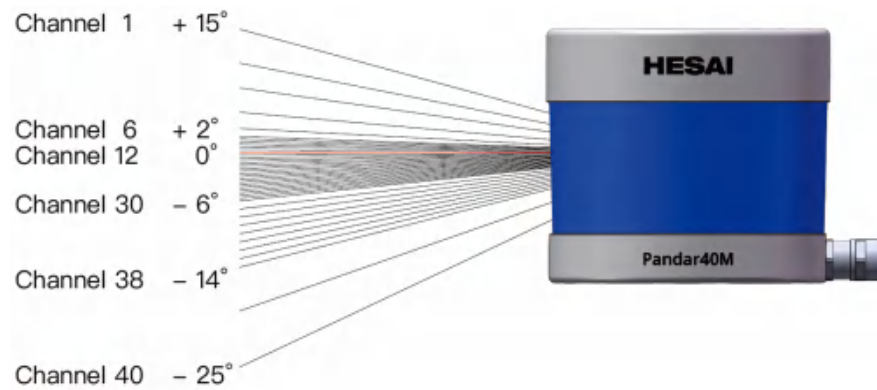- not evenly distributed in the remaining channels, as detailed in Appendix I

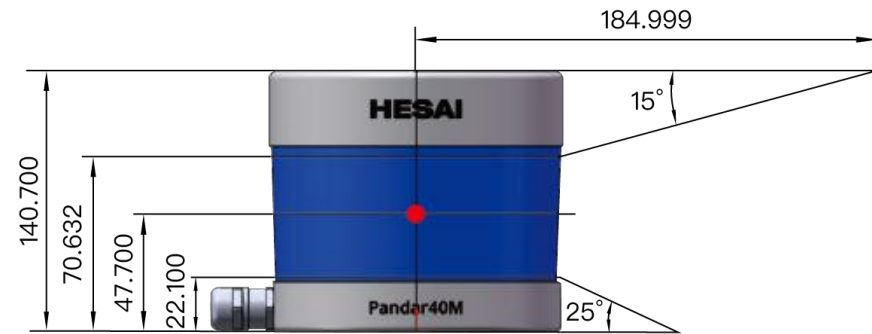Figure 1.5 Channel Vertical Distribution

Figure 1.6 Laser Firing Position

1.4   Specifications

SENSOR	
Scanning Method	Mechanical Rotation
Channel	40
Range	0.3 to 120 m (at 10% reflectivity)
Range Accuracy	±5 cm (0.3 to 1 m)
	±2 cm (1 to 120 m)
FOV (Horizontal)	360°
Resolution (Horizontal)	0.2° (10 Hz), 0.4° (20 Hz)
FOV (Vertical)	40° (-25° to +15°)
Resolution (Vertical)	0.33° (-6° to +2°)
	1° (+2° to +3°, -14° to -6°)
	2° (+3° to +5°)
	3° (+5° to +11°)
	4° (+11° to +15°)
	5° (-19° to -14°)
	6° (-25° to -19°)
Frame Rate	10 Hz, 20 Hz
Returns	Single Return
	Dual Return (Strongest, Last)

CERTIFICATIONS	
	FDA, KCC

MECHANICAL/ELECTRICAL/OPERATIONAL	
Wavelength	905 nm
Laser Class	Class 1 Eye Safe
Ingress Protection	IP6K7
Dimensions	Height: 104.7 mm
	Top/Bottom Diameter: 118.00 / 116.00 mm
Operating Voltage	DC 9 to 48 V
Power Consumption	15 W
Operating Temperature	-20℃ to 65℃
Weight	1.4 kg

DATA I/O	
Data Transmission	UDP/IP Ethernet (100 Mbps)
Data Outputs	Distance, Azimuth Angle, Intensity
Data Points Generated	Single Return Mode: 720,000 points/sec
	Dual Return Mode: 1,440,000 points/sec
Clock Source	GPS / PTP
PTP Clock Accuracy	≤1 μs
PTP Clock Drift	≤1 μs/s

NOTE Specifications are subject to change without notice.

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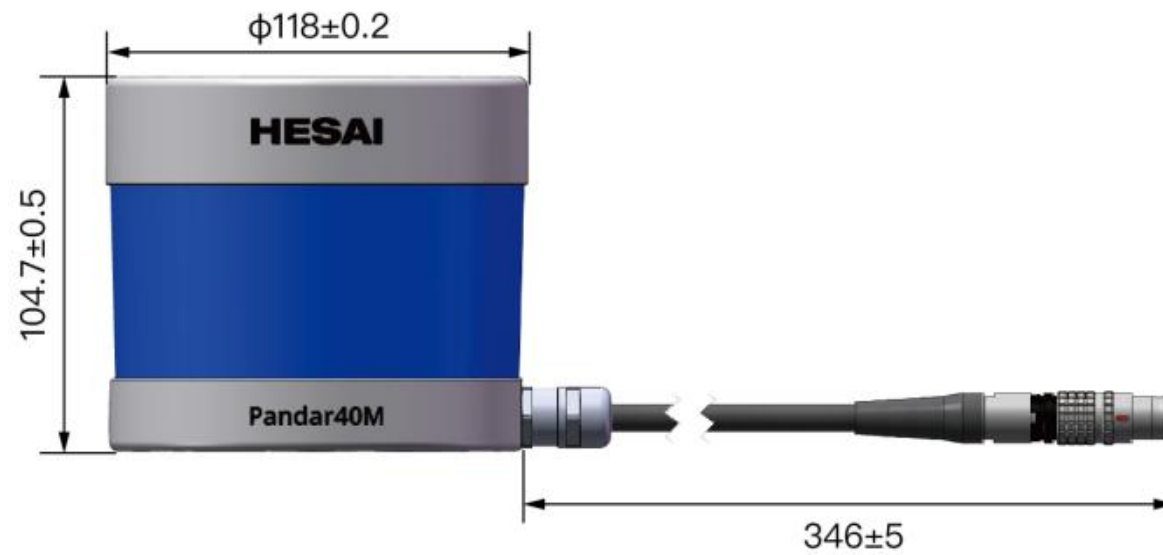
2 Setup

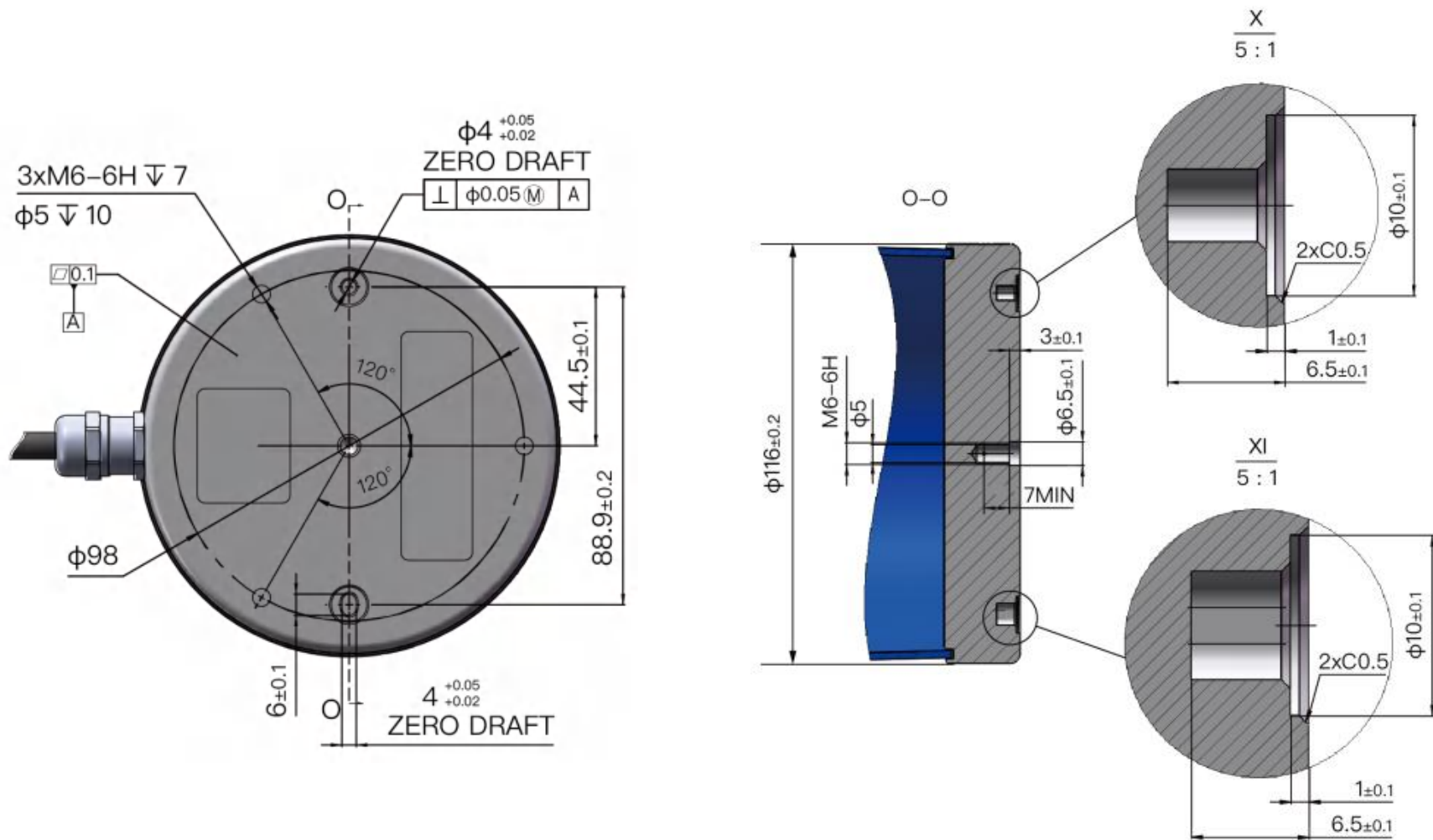## 2.1 Mechanical Installation

Figure 2.1 Front View

Figure 2.2 Bottom View

■ Quick Installation

M6 screw
7~9 mm exceeding the mounting plate

2xΦ4PINS
5~6 mm exceeding the mounting plate

■ **Stable Installation**

M6 screw
7~9 mm exceeding the mounting plate

3xM6 screw
5~6 mm exceeding the mounting plate

2xΦ4PINS
5~6 mm exceeding the mounting plate
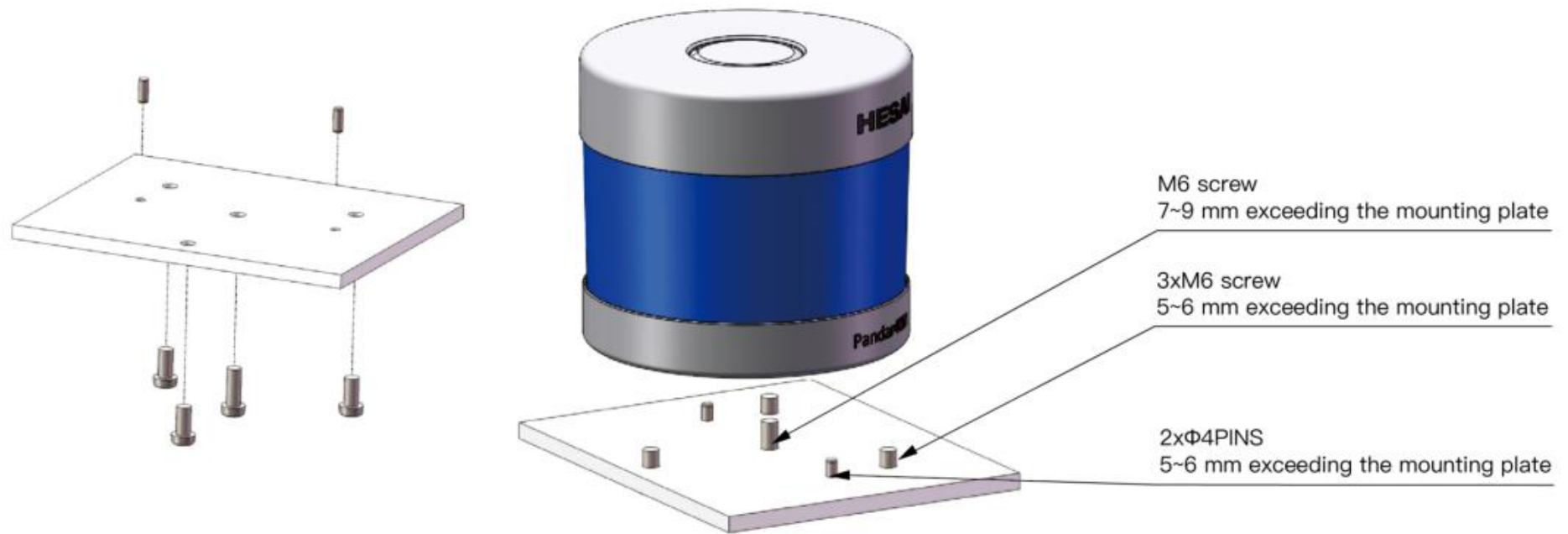
2.2   Interfaces

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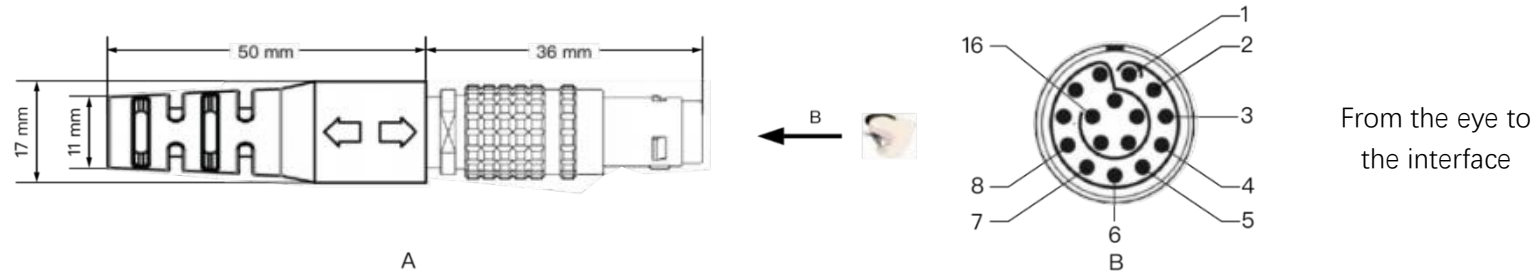Lemo part number: FGG.2T.316.CLAC75Z (male, on the LiDAR)

From the eye to the interface

Figure 2.3 Lemo Connector (Male)

Pin Description of the Lemo Connector:

| Pin #	Function	Color	Voltage
1 ~ 4	-	-	-
5	Ethernet RX-	BLUE	-1 V to 1 V
6	Ethernet RX+	BLUE/WHITE	-1 V to 1 V
7	Ethernet TX-	ORANGE	-1 V to 1 V
8	Ethernet TX+	ORANGE/WHITE	-1 V to 1 V
9	GPS Serial Data	WHITE	-13 V to +13 V
10	GPS PPS	YELLOW	TTL level 3.3 V/5 V Pulse width: 1 ms or longer is recommended Cycle: 1 s (from rising edge to rising edge)
11	P12V	RED	12 V
12	P12V	GRAY	12 V
13	Ground (Return)	BLACK	0
14	Ground (Return)	GRAY/WHITE	0
15	-	PURPLE	-
16	-	PURPLE/WHITE	-

2.3 Connection Box (Optional)

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

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

The cable length between the connector and the connection box is 1.7 m by default, and the cable diameter is 7.5±0.3 mm.

Lemo part number: PHG.2T.316.CLLC75Z (female, on the connection box)
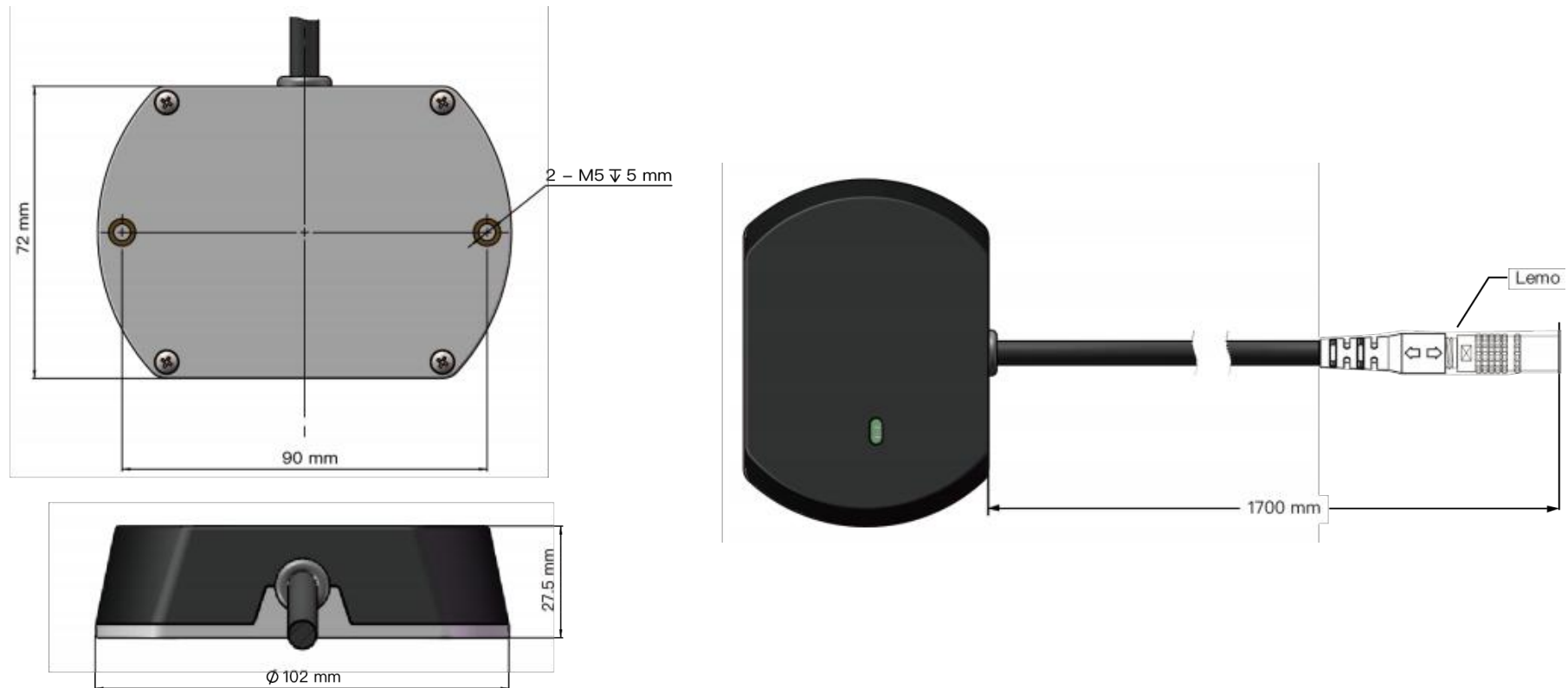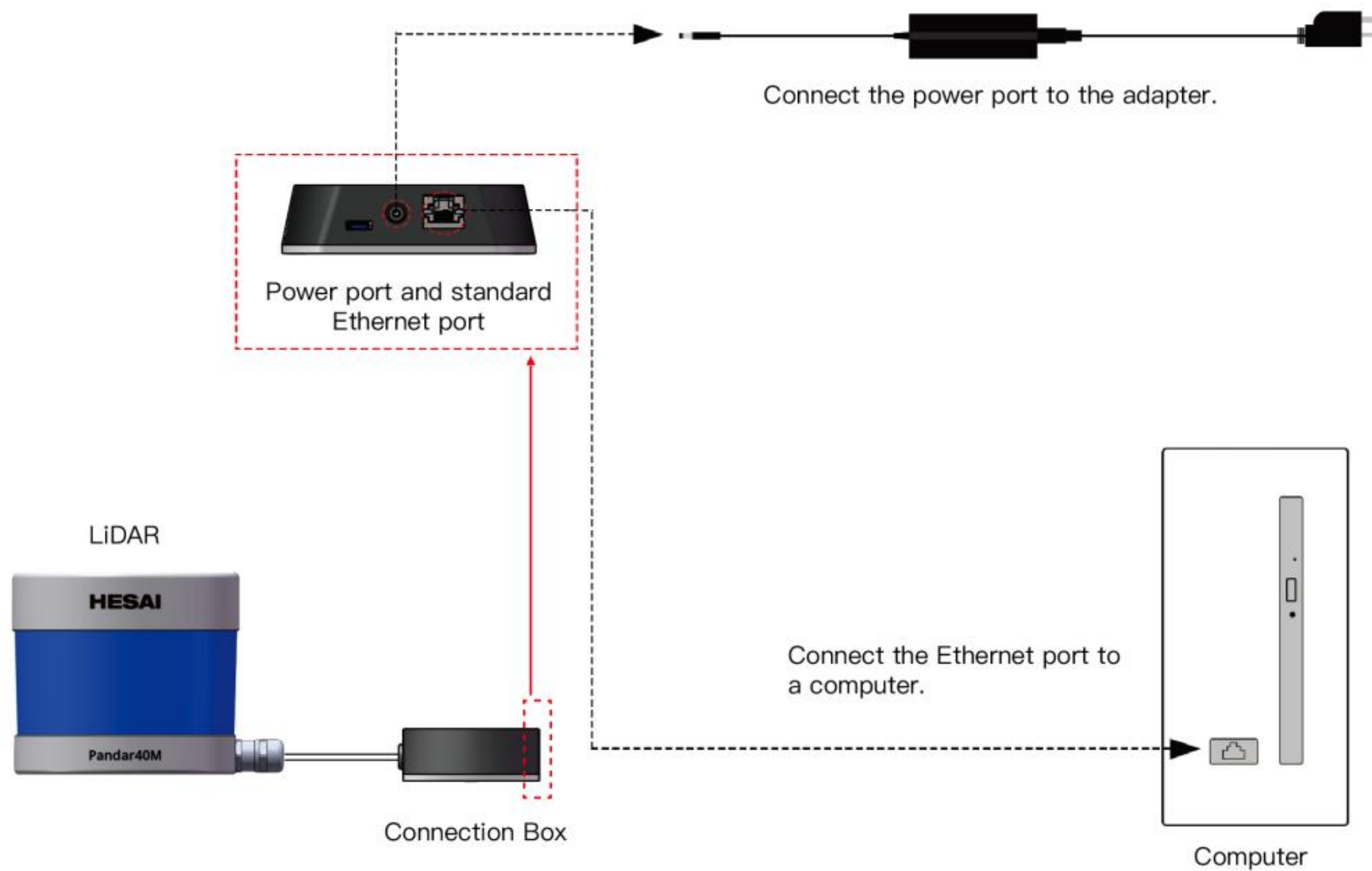
2.3.1   Connection Box Interfaces

Port #	Port Name	Description
a	Standard Ethernet Port	RJ45, 100 Mbps Ethernet
b	Power Port	Use DC-005 DC power adapter Input voltage ranges from 9 V to 48 V. Power consumption is 15 W
c	GPS Port	Connector type: JST SM06B-SRSS-TB Recommended connector for the external GPS module: JST SHR-06V-S-B Voltage standard: RS232 Baud rate: 9600 bps

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

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

2.3.2 Connection

Connect the power port to the adapter.

Power port and standard Ethernet port

LiDAR

HESAI

Pandar40M

Connection Box

Connect the Ethernet port to a computer.

Computer

NOTE Refer to Appendix III when PTP protocol is used.

2.4 Get Ready to Use

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

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

For Ubuntu-16.04:	For Windows:
Use the ifconfig command in the terminal: ~$ sudo ifconfig enp0s20f0u2 192.168.1.100 (replace enp0s20f0u2 with the local network port name)	Open the Network Sharing Center, click on "Ethernet" In the "Ethernet Status" interface, click on "Properties" Double-click on "Internet Protocol Version 4 (TCP/IPv4)" Configure the IP address to 192.168.1.100 and subnet mask to 255.255.255.0

To record and display point cloud data, see Chapter 5 PandarView

To set parameters, check device info, or upgrade firmware, see Chapter 4 Web Control

The SDK (Software Development Kits) download links can be found at www.hesaitech.com/en/download

3   Data Structure

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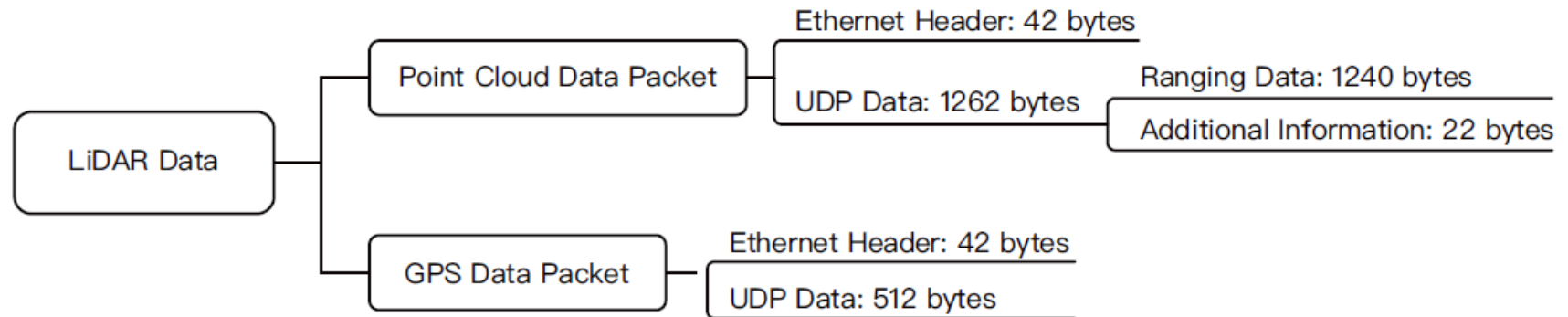

Figure 3.1 Data Structure with UDP Sequence OFF

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

3.1 Point Cloud Data Packet

3.1.1 Ethernet Header

Each LiDAR has a unique MAC address.

The source IP is 192.168.1.201 by default. 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	0x04F6 when UDP sequence is OFF, representing 1270 bytes (8 bytes more than the size of the Point Cloud UDP Data, shown in Figure 3.1)
		0x04FA when UDP sequence is ON, representing 1274 bytes
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: 1290
     Identification: 0x8e3d (36413)
  ⊞ Flags: 0x02 (Don't Fragment)
     Fragment offset: 0
     Time to live: 64
     Protocol: UDP (17)
  ⊞ Header checksum: 0xe534 [correct]
     Source: 192.168.1.201 (192.168.1.201)
     Destination: 255.255.255.255 (255.255.255.255)
```

Figure 3.2 Point Cloud Ethernet Header – Internet Protocol

3.1.2 UDP Data

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

■ **Ranging Data**

Ranging Data: 1240 bytes (10 blocks)				
Block 1	**Block 2**	**Block 3**	⋯	**Block 10**
0xFFEE	0xFFEE	0xFFEE	⋯	0xFFEE
Azimuth 1	Azimuth 2	Azimuth 3	⋯	Azimuth 10
Channel 1	Channel 1	Channel 1	⋯	Channel 1
Channel 2	Channel 2	Channel 2	⋯	Channel 2
...	...	...	⋯	...
Channel 40	Channel 40	Channel 40	⋯	Channel 40

Each block in the Ranging Data: 124 bytes			
Field	Bytes	Description	
0xFFEE	2	Header, meaningless, 0xFF first	
Azimuth	2	Current reference angle of the rotor Azimuth[15:0]: lower byte Azimuth_L[7:0], upper byte Azimuth_H[15:8] Azimuth Angle (in degrees) = [Azimuth_H, Azimuth_L] / 100° = Azimuth / 100°	
Channel XX	3	2-byte Distance	Distance[15:0]: lower byte Distance_L[7:0], upper byte Distance_H[15:8] Distance Value = [Distance_H, Distance_L] * 4 mm = Distance * 4 Maximum Distance Value = $(2 \wedge 16 - 1) * 4$ mm = 262.14 m
		1-byte Reflectivity	Reflectivity, in percentage (0 to 255%)

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

■ Additional Information

Additional Information: 22/26 bytes when UDP sequence is OFF/ON		
Field	Bytes	Description
Reserved	5	–
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	2	–
Motor Speed	2	speed_2_bytes[15:0] = speed (RPM)
GPS Timestamp	4	Packing time of this data packet, in units of 1 μs Range: 0 to 1000000 μs (1 s)
Return Mode Information	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
UDP Sequence	4	Added only when UDP sequence is ON Label the sequence number of Point Cloud UDP packets 1 to 0xFF FF FF FF in little endian format

3.1.3 Point Cloud Data Analysis

The analysis of point cloud UDP data consists of three steps.

■ **Analyze the vertical angle, horizontal angle, and distance of a data point**

Take Pandar40M's Channel 5 in Block 3 as an example:

1) Vertical angle of Channel 5 is 3.00°, 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 -1.042°, according to Appendix I Channel Distribution

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

3) Actual distance in real world millimeters = distance measurement * Distance Unit (4 mm)
Distance measurement is the Distance field of Channel 5 in Block 3

■ **Draw the data point in a polar or rectangular coordinate system**

■ **Obtain the real-time point cloud data by analyzing and drawing every data point in a frame**

3.2 GPS Data Packet

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

Before NMEA messages are available from the external GPS module

Each rising edge of the LiDAR's internal 1 Hz signal triggers a GPS Data Packet.

The time and date in the GPS Data Packets are unreal, starting from 00 01 01 00 00 00 (year, month, day, hour, minute, second) and increasing with the internal 1 Hz signal.

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

The internal 1 Hz signal will be locked to the PPS. Each rising edge still triggers a GPS Data Packet.

Meanwhile, the LiDAR will extract the actual date and time from NMEA messages ($GPRMC or $GPGGA), and stamp them into both Point Cloud Data Packets and GPS Data Packets.

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

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

When GPS signal is lost

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

3.2.1 Ethernet Header

The source IP is 192.168.1.201 by default. The destination IP address is 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

3.2.2 UDP Data

GPS UDP data: 512 bytes				
Field	Bytes	Description		
GPS time data	18	Header	2 bytes	0xFFEE, 0xFF first
		Date	6 bytes	Year, month, and day (2 bytes each, lower byte first) in ASCII
		Time	6 bytes	Second, minute, and hour (2 bytes each, lower byte first) in ASCII
		µs Time	4 bytes	In units of µs (lower byte first)
GPRMC/GPGGA data	84	ASCII code, valid till 2 bytes after '*' NMEA sentence that contains the date and time information Users can select either GPRMC or GPGGA in the Settings page of web control, as shown in Section 4.2		
reserved	404	404 bytes of 0xDF		

GPS positioning status	1	ASCII code, obtained from $GPRMC or $GPGGA
		
		When $GPRMC is selected: When $GPGGA is selected:
		A (hex = 41) for Valid Position 0 = invalid
		V (hex = 56) for Invalid Position 1 = GPS fix (SPS)
		NUL (hex = 0) for GPS being unlocked 2 = DGPS fix
		  3 = PPS fix
		  6 = estimated (dead reckoning)		

flag of PPS lock	1	1 – locked 0 – unlocked		
reserved	4	-		

■ GPRMC Data Format

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

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

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

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

For example, the following two formats are both acceptable:

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

■ **GPGGA Data Format**

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

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

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

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

For example, the following two formats are both acceptable:

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

3.2.3 GPS Data Analysis
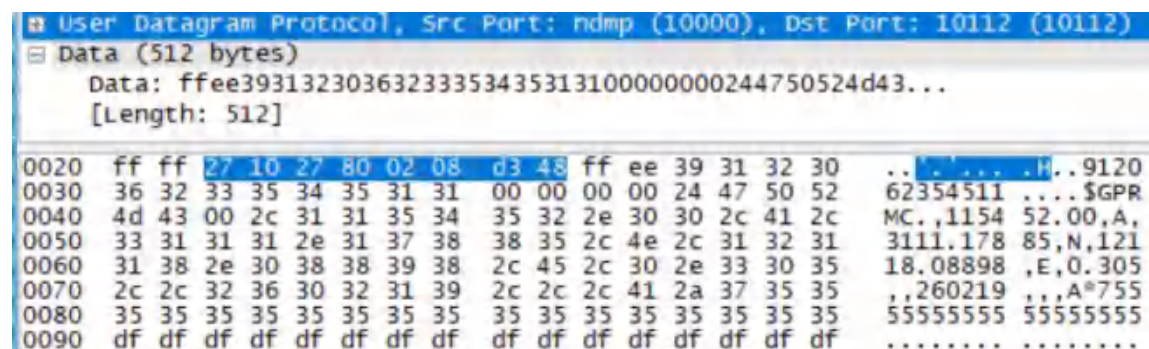
Figure 3.4 GPS Data Packet – UDP Data (Example)

Date

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

Time

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

μs Time

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

Reset to 0 at the rising edge of each PPS signal

4 Web Control

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

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

NOTE Google Chrome or Firefox is recommended.

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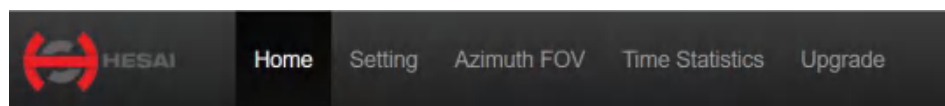
Spin Rate of the motor (revs per minute) = frame rate (Hz) * 60

GPS (PPS) Status

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

NMEA (GPRMC/GPGGA) Status

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

PTP Status

Free Run	No PTP master is selected; 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. Control IP

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.

2. Destination IP

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

3. LiDAR Functions

Spin Rate	600 rpm / 1200 rpm
Return Mode	Last / Strongest / Dual Return
UDP Sequence	OFF / ON #1 / ON #2
	OFF by default. When UDP Sequence is ON, UDP packets are labeled with a sequence number. See Section 3.1 for changes in data structure. **ON #1**: UDP sequence increments even though no UDP packet is generated outside the FOV specified in Section 4.3. **ON #2**: UDP sequence increments only when UDP packets are generated.

(continued on the next page)

30

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.
Noise Filtering	Noise points mitigation in rain and fog
Reflectivity Mapping	Linear / Nonlinear Mapping
	By default, the 1-byte reflectivity data in the Point Cloud Data Packet linearly represents target reflectivity from 0 to 255%. Users can alternatively choose Nonlinear Mapping to increase the contrast in the low-reflectivity region. See Appendix V Nonlinear Reflectivity Mapping.
Standby Mode	Whether to stop the motor from running and lasers from firing

4. Reset All Settings

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

The default values are shown on Figure 4.2 and Figure 4.5.

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.

When PTP is selected as the clock source:

PTP Domain Number	Integer from 0 to 127	Domain attribute of the local clock
PTP Network Transport	UDP/IP (default) or L2	UDP/IP follows the PTPv2 standard defined in IEEE 1588-2008
PTP logAnnounceInterval	-2 to 3 log seconds	Time interval between Announce messages (default: 1)
PTP logSyncInterval	-7 to 3 log seconds	Time interval between Sync messages (default: 1)
PTP logMinDelayReqInterval	-7 to 3 log seconds	Minimum permitted mean time between Delay_Req messages (default: 0)

4.3　Azimuth FOV

For Azimuth FOV Setting, users can select one of the three modes.

4.3.1　For all channels

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

4.3.2 For each channel

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

By default, the status button for each channel is green, indicating that angle range configuration is active.
To deactivate the angle range configuration for one channel, click the corresponding button to make it gray. Thus the angle range for this channel becomes [0°，360°].

Click the "Enable/Disable All" button to activate/deactivate the angle range configuration for all channels.

4.3.3 Multi-section FOV

Users can configure up to ten continuous angle ranges (i.e. sections) for each channel.
Outside the specified range for each channel, there will be no laser firing or data generated in that channel.

By default, the status button for each channel is green, indicating that angle range configuration is active.
To deactivate the angle range configuration for one channel, click the corresponding button to make it gray. Thus the angle range for this channel becomes [0°，360°].

Click the "Enable/Disable All" button to activate/deactivate the angle range configuration for all channels.

4.3.4 Note

Click "Save" to apply your settings.

4.4 Operation Statistics

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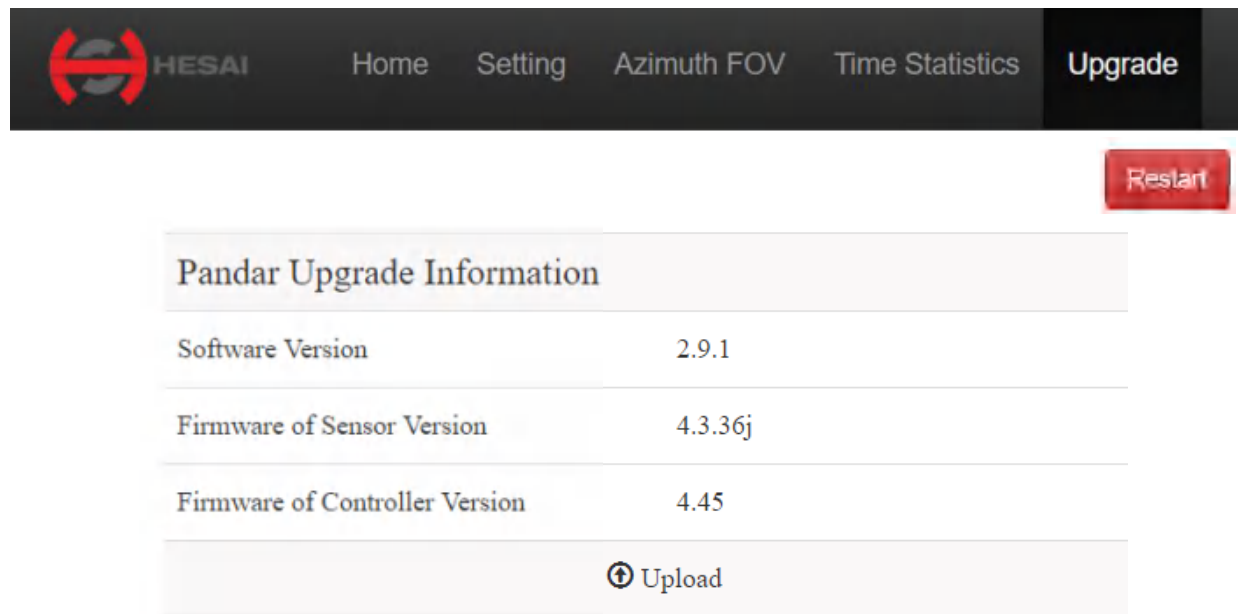

Start-up Counts	40
Internal Temperature	27.71℃
Total Operation Time	54 h 49 min

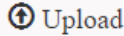| Internal Temperature	Operation Time
< -40 ℃	0 h 0 min
-40 ~ -20 ℃	0 h 0 min
-20 ~ 0 ℃	0 h 0 min
0 ~ 20 ℃	0 h 0 min
20 ~ 40 ℃	5 h 12 min
40 ~ 60 ℃	49 h 37 min
60 ~ 80 ℃	0 h 0 min
80 ~ 100 ℃	0 h 0 min
100 ~ 120 ℃	0 h 0 min
>120 ℃	0 h 0 min

4.5   Upgrade

Click the "Upload" button and select an upgrade file (provided by Hesai). Reboot the LiDAR when the upgrade is complete.

NOTE 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.

Below shows the software and firmware versions described in this manual.

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.

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	PandarView_Windows_V1.6.9.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	PandarView_Installer_V1.6.9.tar.gz	Enter the following command in the terminal: sudo apt-get install qt4-default libboost-all-dev
		Unzip PandarView_Installer.tar.gz and run PandarView_Installer.bin

This manual describes PandarView 1.6.9. 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.
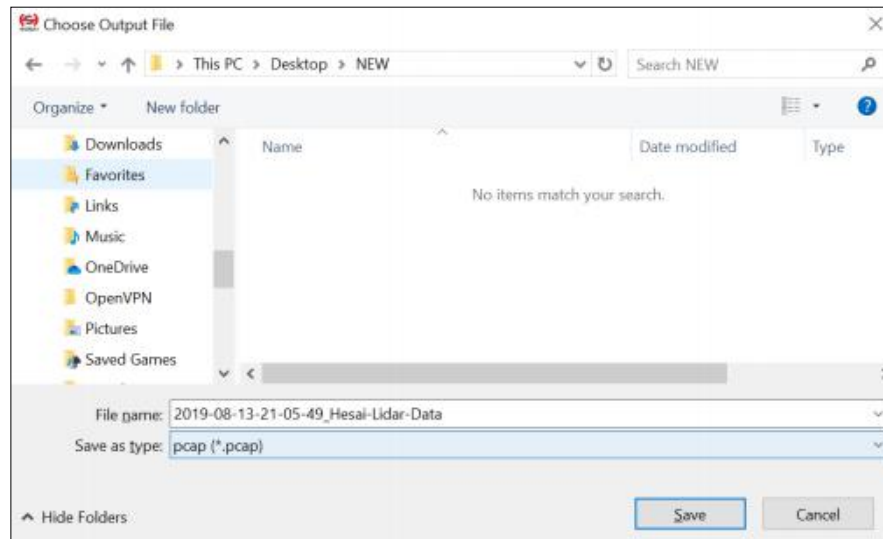
■ **Open a PCAP File**

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".

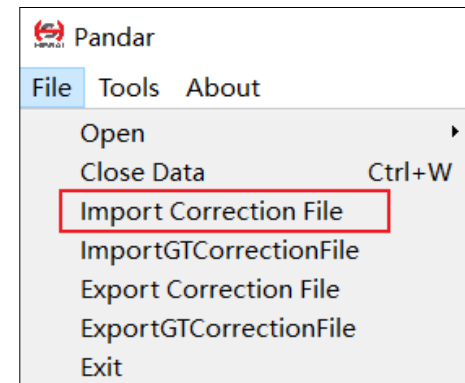■ **Play a PCAP File**

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)	
/	After loading a point cloud file, click to play the file While playing, click to pause	
	While paused, jump to the next frame. While playing, forward. May click again to adjust the forward speed (2x, 3x, 1/2x, 1/4x, and 1x)	
	Jump to the end of the file	
	Save a single frame to .CSV (the XYZ coordinates as the first three columns)	
	While playing, this Record button will be gray and unclickable	
	While playing, click to loop playback. Otherwise the player will stop at the end of the file	
	Save multiple frames to .PCAP	Start Frame: 0 End Frame: 408 Specify the start and end frames
	Save multiple frames to .CSV (the XYZ coordinates as the last three columns)	
	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.

Right   Front   Top

■   **Mouse Shortcuts**

↑ Up ⊕
↓ Down ⊖

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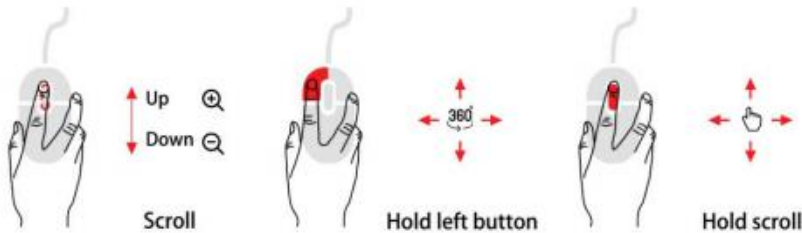
·   Slide the scroll wheel up/down to magnify/minimize
·   Drag while holding the left button to adjust the point of view
·   Drag while holding the scroll wheel to pan

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

X
Y
Z

■
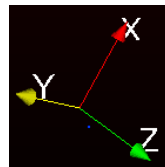
■   **3D Projection and Distance Measurement**

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

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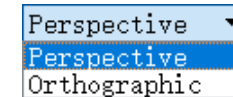
The distance ruler is available only under orthographic projection. After clicking on [ruler], drag your mouse while holding the Ctrl key to make a measurement in units of meters. Click on [ruler] again to quit.

■   **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".
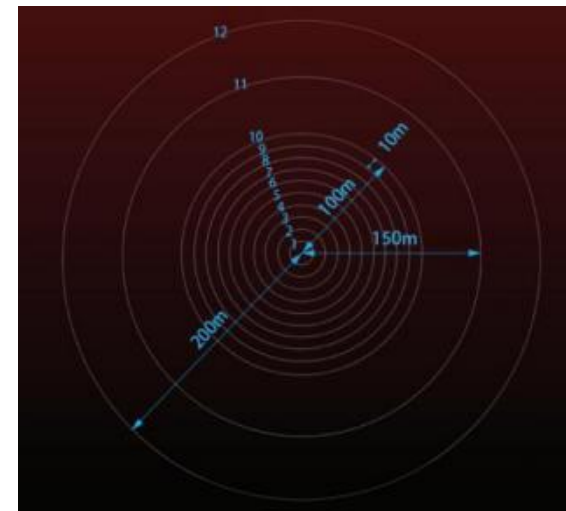
■ **Return Mode**

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

Return Mode: Dual Return
block1 Return
block2 Return
Dual Return

■ **UDP Port**

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

UDP Port: 2368 Set

■ **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.

	Channel	Elevation	Azimuth
☑	1	11.85	-2.72
☑	2	11.7	-0.91
☑	3	11.55	0.91
☑	4	11.4	2.72
☑	5	11.25	-2.72
☑	6	11.1	-0.91
☑	7	10.95	0.91
☑	8	10.8	2.72

Pandar

☑ Enable/Disable all

■ Point Selection and Data Table

Click on [icon] and drag the mouse over the point cloud to highlight an area of points.

Click on [icon] to view the data of the highlighted points, as shown below.

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

Showing Data ▼ Attribute: Point Data ▼ Precision: 3 ↕ F

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 [icon] again and click on any place outside the selected area.

■ **Color Schemes**

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

Click on 🎨 to open or close the Color Editor.

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.
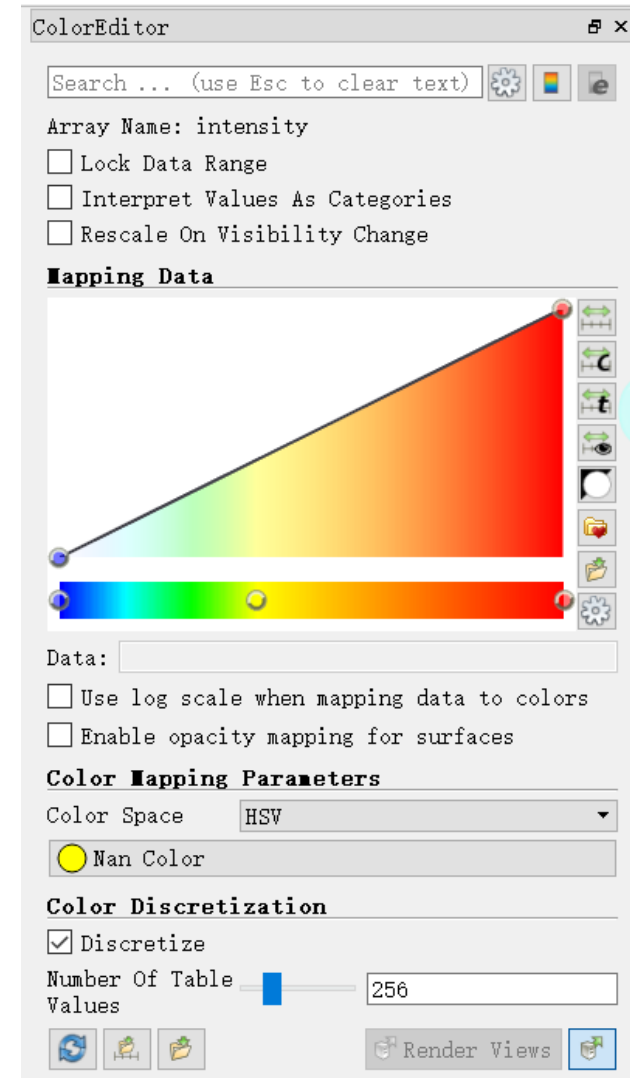
6 Communication Protocol

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*/	"MASTER", /*6*/
		"INITIALIZING", /*1*/	"PASSIVE", /*7*/
		"FAULTY", /*2*/	"UNCALIBRATED", /*8*/
		"DISABLED", /*3*/	"SLAVE", /*9*/
		"LISTENING", /*4*/	"GRAND_MASTER", /*10*/
		"PRE_MASTER"/*5*/	
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	12 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**

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

1) Thoroughly wash your hands or wear a pair of powder-free PVC gloves.

2) Analyze the type of stains on the enclosure

Dust	Blow dry air onto the enclosure
	Or, use a piece of lint-free wipe to lightly brush across the dusty area
Persistent stains	Move on to the next step

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.

(Continued)

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

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

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

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 the table below

· Define clockwise in the top view as positive

■   **Vertical Angle**

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

· 0° represents the horizontal direction

· Define upward as positive

· The Channel # from the uppermost starts from 1

Table 1.1 Pandar40M Channel Distribution (To Be Continued)

Channel # in UDP Data	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range (in meters) with Reflectivity
01 (Top Beam)	-1.042	15.00	120	120@10%
02	-1.042	11.00	120	120@10%
03	-1.042	8.00	120	120@10%
04	-1.042	5.00	120	120@10%
05	-1.042	3.00	120	120@10%
06	-1.042	2.00	120	120@10%
07	3.125	1.67	120	120@10%
08	-5.208	1.33	120	120@10%
09	-1.042	1.00	120	120@10%
10	3.125	0.67	120	120@10%
11	-5.208	0.33	120	120@10%
12 (Horizontal Beam)	-1.042	0.00	120	120@10%
13	3.125	-0.33	120	120@10%
14	-5.208	-0.67	120	120@10%
15	-1.042	-1.00	120	120@10%
16	3.125	-1.33	120	120@10%
17	-5.208	-1.67	120	120@10%
18	-1.042	-2.00	120	120@10%
19	3.125	-2.33	120	120@10%

Table 1.1 Pandar40M Channel Distribution (Continued)

Channel # in UDP Data	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range (in meters) with Reflectivity
20	-5.208	-2.67	120	120@10%
21	-1.042	-3.00	120	120@10%
22	3.125	-3.33	120	120@10%
23	-5.208	-3.67	120	120@10%
24	-1.042	-4.00	120	120@10%
25	3.125	-4.33	120	120@10%
26	-5.208	-4.67	120	120@10%
27	-1.042	-5.00	120	120@10%
28	3.125	-5.33	120	120@10%
29	-5.208	-5.67	120	120@10%
30	-1.042	-6.00	120	120@10%
31	-1.042	-7.00	120	120@10%
32	-1.042	-8.00	120	120@10%
33	-1.042	-9.00	120	120@10%
34	-1.042	-10.00	120	120@10%
35	-1.042	-11.00	120	120@10%
36	-1.042	-12.00	120	120@10%
37	-1.042	-13.00	120	120@10%
38	-1.042	-14.00	120	120@10%
39	-1.042	-19.00	120	120@10%
40 (Bottom Beam)	-1.042	-25.00	120	120@10%

Appendix II   Absolute Time and Laser Firing Time

II.1   Absolute Time of Point Cloud Data Packets

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

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

· µs time can be retrieved from the current Point Cloud Data Packet (4 bytes of Timestamp)

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

II.2   End Time of Each Block

Assuming that the absolute packing time of a Point Cloud Data Packet is t0 (detailed in II.1), the end time of each block (the time when all the lasers finish firing) can be calculated.

There are 10 blocks of ranging data in each Point Cloud Data Packet, as shown below. Each block contains the ranging data from 40 channels, one return per channel.

Poind Cloud Data Packet – Ranging Data: 1240 bytes (10 blocks)				
Block1	**Block2**	**Block3**	**···**	**Block10**
0xFFEE	0xFFEE	0xFFEE	···	0xFFEE
Azimuth 1	Azimuth 2	Azimuth 3	···	Azimuth 10
Channel 1	Channel 1	Channel 1	···	Channel 1
Channel 2	Channel 2	Channel 2	···	Channel 2
···	···	···	···	···
Channel 40	Channel 40	Channel 40	···	Channel 40

■ **Single Return Mode**

The ranging data generated by one round of firing is stored in one block. The calculation of each Block's end time is as follows:

Block	End Time (μs)
Block 10	t0 - 28.58
Block N	t0 - 28.58 - 55.56 * (10 - N)
Block 3	t0 - 28.58 - 55.56 * 7
Block 2	t0 - 28.58 - 55.56 * 8
Block 1	t0 - 28.58 - 55.56 * 9

■ **Dual Return Mode**

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

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

Block	End Time (μs)
Block 10 & Block 9	t0 - 28.58
Block 8 & Block 7	t0 - 28.58 - 55.56 * 1
Block 6 & Block 5	t0 - 28.58 - 55.56 * 2
Block 4 & Block 3	t0 - 28.58 - 55.56 * 3
Block 2 & Block 1	t0 - 28.58 - 55.56 * 4

II.3   Laser Firing Time of Each Channel

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

Firing Sequence	Channel #	Firing Time (µs)
1	8	t6 - 54.67
2	20	t6 - 52.7
3	15	t6 - 50.73
4	27	t6 - 48.76
5	7	t6 - 47.46
6	19	t6 - 45.49
6	5	t6 - 45.49
7	33	t6 - 43.52
8	37	t6 - 42.22
8	1	t6 - 42.22
9	11	t6 - 40.91
10	23	t6 - 38.95
11	18	t6 - 36.98
12	30	t6 - 35.01
13	10	t6 - 33.71
14	22	t6 - 31.74
14	6	t6 - 31.74
15	34	t6 - 29.77
16	38	t6 - 28.47
16	2	t6 - 28.47

Firing Sequence	Channel #	Firing Time (µs)
17	14	t6 - 27.16
18	26	t6 - 25.19
19	21	t6 - 23.89
20	31	t6 - 21.92
21	13	t6 - 20.62
21	9	t6 - 20.62
22	25	t6 - 18.65
23	35	t6 - 17.35
24	39	t6 - 16.04
24	3	t6 - 16.04
25	17	t6 - 14.74
26	29	t6 - 12.77
27	24	t6 - 11.47
28	32	t6 - 9.5
29	16	t6 - 8.19
29	12	t6 - 8.19
30	28	t6 - 6.23
31	36	t6 - 4.92
32	40	t6 - 3.62
32	4	t6 - 3.62

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**

Connect the power port to the adapter.

Power port and standard Ethernet port

PTP Master (third party)

LiDAR

HESAI

Pandar40M

Connection Box

Ethernet Switch

Computer
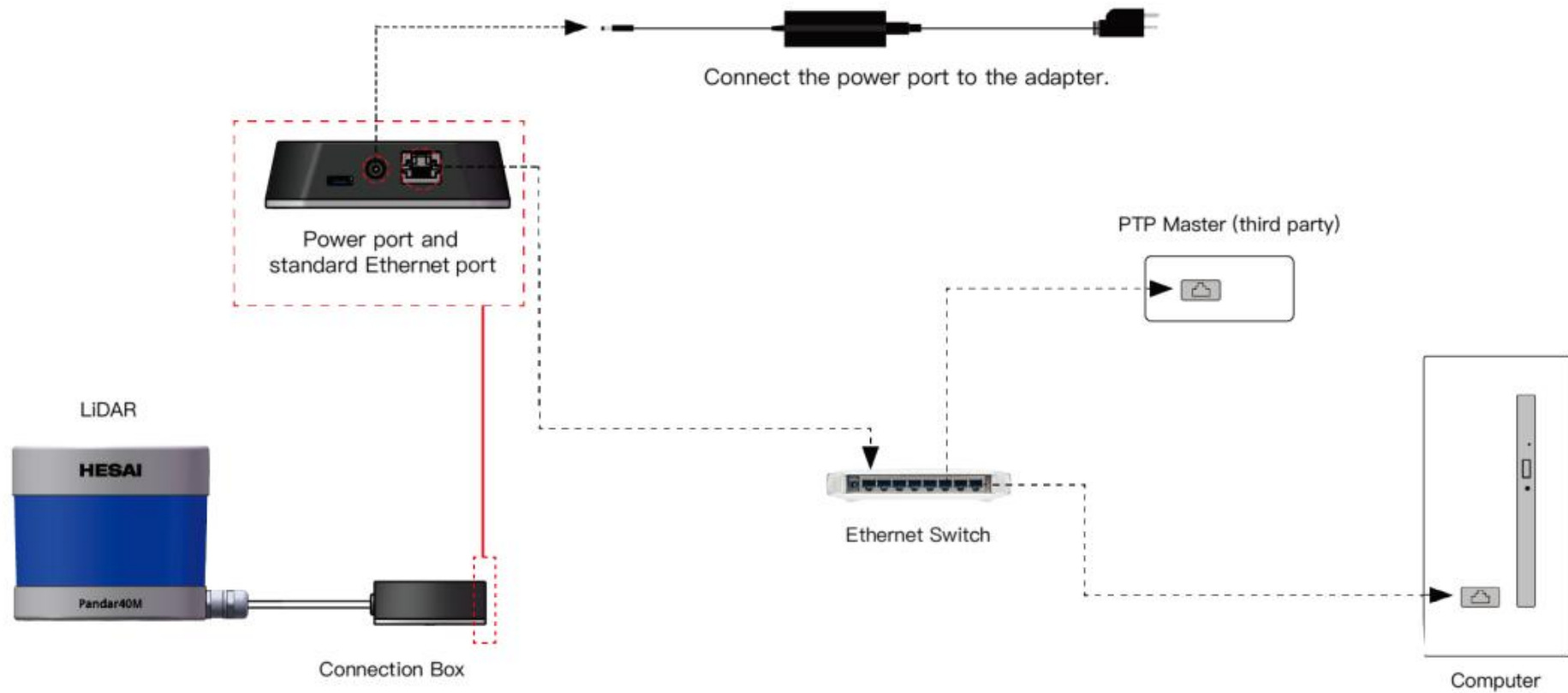
■ Absolute Packing Time When Using PTP

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   Phoenix Contact

Phoenix Contact can be used as the LiDAR's communication connector, in place of the default Lemo Contact in Section 2.2 Interfaces.

Phoenix part number: SACC-M12MS-8CON-PG 9-SH - 1511857 (male, on the LiDAR), SACC-M12FS-8CON-PG 9-SH – 1511860 (female, on the connecting box)

From the eye to the interface
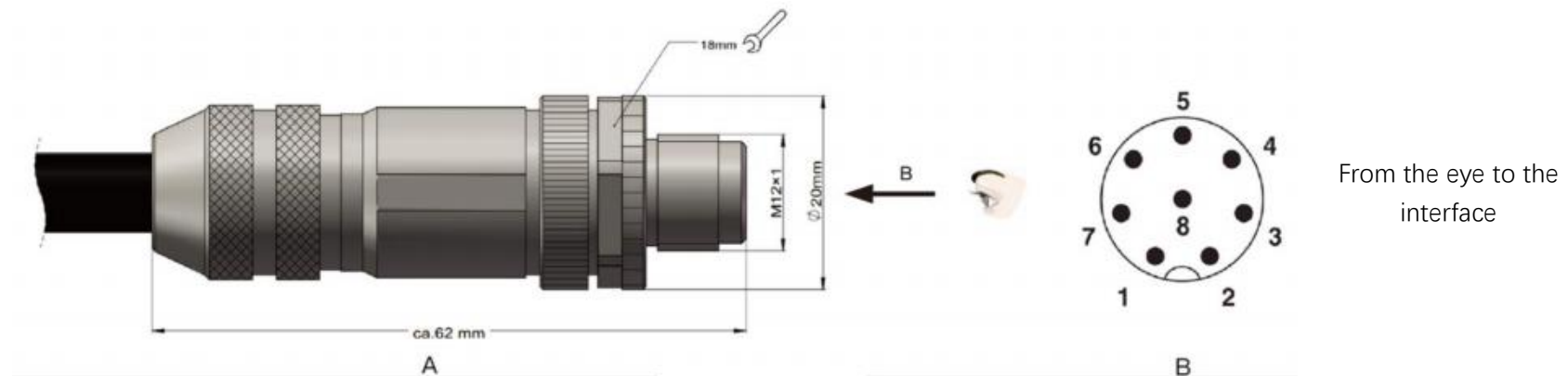
Figure IV.1 Phoenix Connector (Male)

Pin definition:

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

Appendix V Nonlinear Reflectivity Mapping

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

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

The nonlinear relationship is detailed below.

Figure V.1 Nonlinear Reflectivity Mapping

Table V.1 Nonlinear Reflectivity Mapping (To Be Continued)

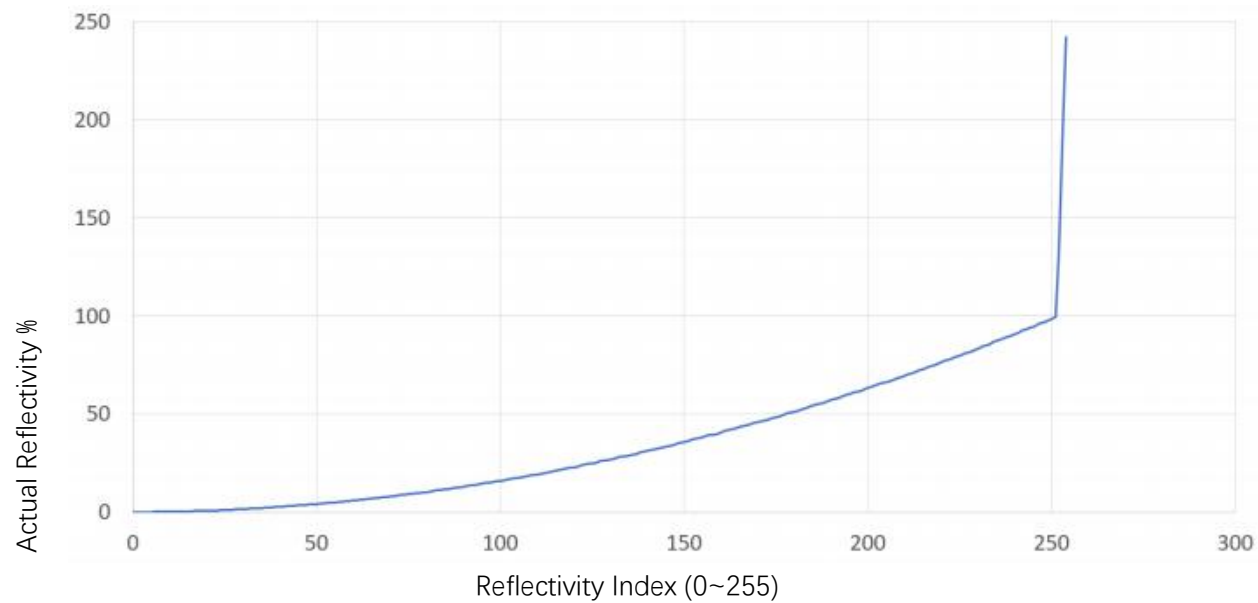| Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)
0	0	65	6.9	130	26.83	195	60.25
1	0.01	66	7.1	131	27.25	196	60.75
2	0.02	67	7.3	132	27.75	197	61.25
3	0.03	68	7.5	133	28.17	198	61.75
4	0.04	69	7.7	134	28.5	199	62.5
5	0.05	70	7.9	135	28.83	200	63.25
6	0.08	71	8.12	136	29.25	201	63.75
7	0.11	72	8.37	137	29.75	202	64.5
8	0.13	73	8.62	138	30.25	203	65.25
9	0.15	74	8.87	139	30.75	204	65.75
10	0.19	75	9.1	140	31.17	205	66.25
11	0.23	76	9.3	141	31.5	206	66.75
12	0.26	77	9.5	142	31.83	207	67.5
13	0.29	78	9.7	143	32.25	208	68.25
14	0.34	79	9.9	144	32.75	209	68.75
15	0.39	80	10.17	145	33.25	210	69.5
16	0.44	81	10.5	146	33.75	211	70.25
17	0.5	82	10.83	147	34.25	212	70.75
18	0.56	83	11.12	148	34.75	213	71.5
19	0.61	84	11.37	149	35.25	214	72.25
20	0.67	85	11.62	150	35.75	215	72.75
21	0.75	86	11.87	151	36.25	216	73.5
22	0.81	87	12.12	152	36.75	217	74.25
23	0.87	88	12.37	153	37.25	218	74.75
24	0.95	89	12.62	154	37.75	219	75.5

Table V.1 Nonlinear Reflectivity Mapping (To Be Continued)

Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)
25	1.05	90	12.87	155	38.25	220	76.5
26	1.15	91	13.17	156	38.75	221	77.25
27	1.25	92	13.5	157	39.17	222	77.75
28	1.35	93	13.83	158	39.5	223	78.5
29	1.45	94	14.17	159	39.83	224	79.25
30	1.55	95	14.5	160	40.5	225	79.75
31	1.65	96	14.83	161	41.25	226	80.5
32	1.75	97	15.12	162	41.75	227	81.25
33	1.85	98	15.37	163	42.25	228	81.75
34	1.95	99	15.62	164	42.75	229	82.5
35	2.06	100	15.87	165	43.25	230	83.5
36	2.19	101	16.17	166	43.75	231	84.25
37	2.31	102	16.5	167	44.25	232	84.75
38	2.44	103	16.83	168	44.75	233	85.5
39	2.56	104	17.17	169	45.25	234	86.5
40	2.69	105	17.5	170	45.75	235	87.25
41	2.81	106	17.83	171	46.25	236	87.75
42	2.94	107	18.17	172	46.75	237	88.5
43	3.07	108	18.5	173	47.25	238	89.25
44	3.21	109	18.83	174	47.75	239	89.75
45	3.36	110	19.17	175	48.25	240	90.5
46	3.5	111	19.5	176	48.75	241	91.5
47	3.64	112	19.83	177	49.5	242	92.5
48	3.79	113	20.25	178	50.25	243	93.25
49	3.93	114	20.75	179	50.75	244	93.75

Table V.1 Nonlinear Reflectivity Mapping (Continued)

Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)	Reflectivity Index (0~255)	Reflectivity (%)
50	4.08	115	21.17	180	51.25	245	94.5
51	4.25	116	21.5	181	51.75	246	95.5
52	4.42	117	21.83	182	52.25	247	96.25
53	4.58	118	22.17	183	52.75	248	96.75
54	4.75	119	22.5	184	53.5	249	97.5
55	4.92	120	22.83	185	54.25	250	98.5
56	5.1	121	23.25	186	54.75	251	99.5
57	5.3	122	23.75	187	55.25	252	132
58	5.5	123	24.17	188	55.75	253	196
59	5.7	124	24.5	189	56.5	254	242
60	5.9	125	24.83	190	57.25		
61	6.1	126	25.25	191	57.75		
62	6.3	127	25.75	192	58.25		
63	6.5	128	26.17	193	58.75		
64	6.7	129	26.5	194	59.5		

Appendix VI   Certification Info

■   **FCC Declaration**

FCC ID: 2ASO2PANDAR64

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 VII   Support and Contact

■   **Technical Support**

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

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

NOTE Please leave your questions under the corresponding GitHub projects.

■   **Legal Notice**

Copyright 2020 by Hesai Technology. All rights reserved. Use or reproduction of this manual in parts or its entirety without the authorization of Hesai is prohibited.

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

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

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

HESAI Wechat