Pandar64

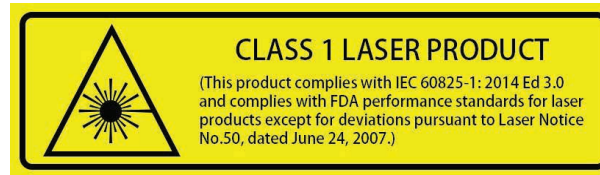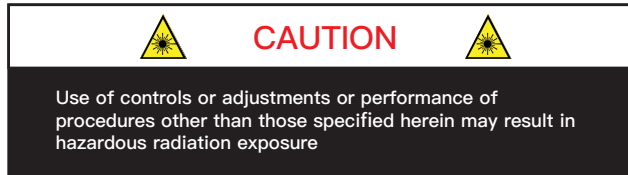## 64–Channel Mechanical LiDAR User's Manual

HESAI Wechat

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 on your own accord. 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 Technologies service personnel.

⚠ 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 3.0 and complies with FDA performance standards for laser products except for deviations pursuant to Laser Notice No.50, dated June 24, 2007.)

■ Laser Safety Notice — Laser Class 1

The device satisfies the requirements of:
- IEC 60825–1:2014;
- 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No.50, dated June 24, 2007;
- GB7247.1–2012

DISCLAIMER The information contained within this user's manual and the functions offered are intended to provide information about products. All reasonable efforts have been made to ensure the accuracy of the information. However, Hesai cannot be held responsible for any errors. Hesai does not warrant the accuracy and reserves the right to make changes to the catalog and its functions at any time without notice.

Contents

1 Introduction

Pandar64 is a 64–channel mechanical LiDAR. It creates 3D imaging by 360˚ mechanical rotating through 64 laser diodes inside the housing. Pandar64's unique channel distribution makes it more suitable for autonomous driving applications.

In addition to the specifications of Pandar64, this manual also describes the mechanical installation, data outputs format, and GPS timestamp synchronization.

This manual is undergoing constant revision and improvement, please ask Hesai for the latest version of the user's manual.

1.1 Operational Principles

1.1.1 Distance Measurement: Time of Flight (ToF)

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

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

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

Figure 1.1 ToF Formula

1.1.2 Structure Description

64 pairs of laser emitters and receivers are attached to a rotating motor inside the LiDAR housing that perform horizontal scans in 360 degrees.

Figure 1.2 Partial Cross–Sectional Diagram
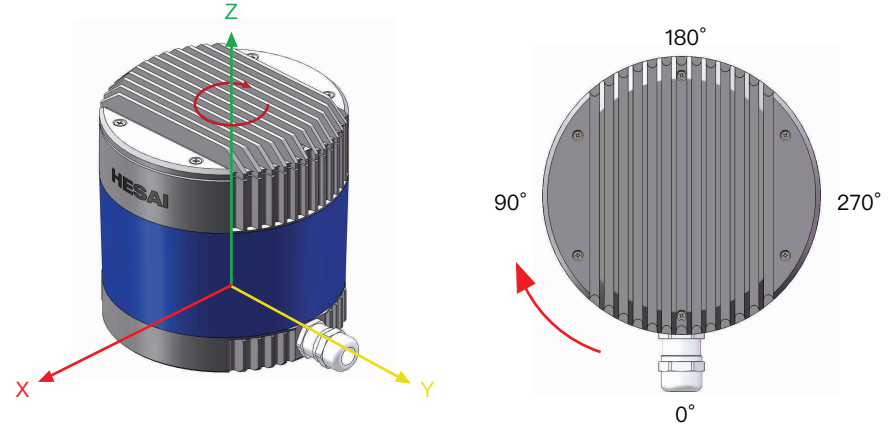
Figure 1.3 LiDAR Coordinate System and Rotation Direction

NOTE

1) Figure 1.3 shows the coordinate system and the z axis is along the rotation center of the LiDAR. The origin of the coordinate system is shown as a red dot in Figure 1.5 (side view of the LiDAR). All the LiDAR measurement data are relative to the origin after geometry transformation according to LiDAR's optical and mechanical design.

2) Because of the intrinsic angle offset of each laser channel, the zero degree is defined as the azimuth angle in the corresponding block in UDP packet when channel 18 passes y axis defined in Figure 1.3.

1.1.3 Pandar64 Channel Vertical Distribution

The vertical angular resolution is 0.167˚ between Channel 6 and Channel 54;
The vertical angular resolution is 1˚ between Channel 5 and Channel 6, Channel 54 and Channel 62;
The vertical angular resolution of the remaining channels is not evenly distributed.
Please see Appendix I for detailed channel distribution.

Channel 1   + 15˚
Channel 5   + 3˚
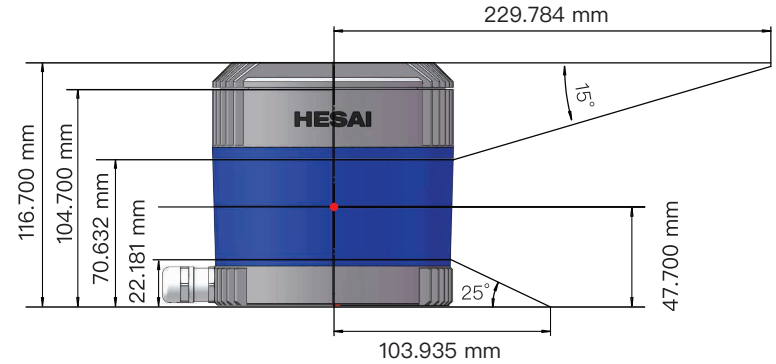Channel 6   + 2˚
Channel 18   0˚
Channel 54   – 6˚
Channel 62   – 14˚
Channel 64   – 25˚
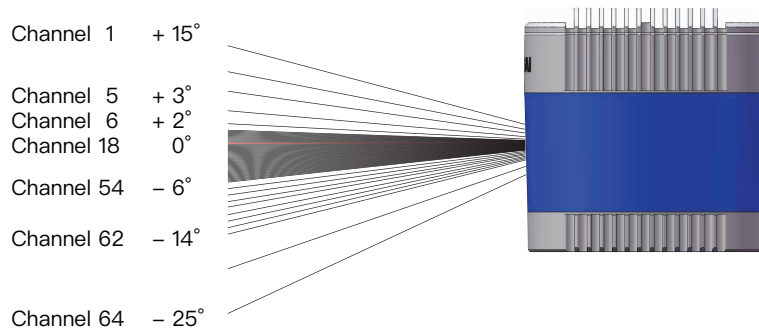
Figure 1.4 Channel Vertical Distribution

229.784 mm
15˚
116.700 mm
104.700 mm
70.632 mm
22.181 mm
103.935 mm
47.700 mm
25˚
HESAI

Figure 1.5 Laser Firing Position

1.2 Specifications

Scanning Method	Mechanical Rotating	Angular Resolution (Vertical)	0.167° (−6° to +2°); 1° (+2° to +3°, −14° to −6°); 2° (+3° to +5°); 3° (+5° to +11°); 4° (+11° to +15°); 5° (−19° to −14°); 6° (−25° to −19°)
Channel	64		
Wavelength	905 nm		
Laser Class	Class 1 Eye Safe	Data Transmission Method	UDP/IP Ethernet (100 Mbps)
Enclosure Level	IP6K7	Data Outputs	UDP: distance, azimuth angle, intensity
Measurement Range	0.3 m to 200 m (at 10% reflectivity)	Operating Voltage	9 V to 48 V
Returns (Configurable)	Single and Dual Returns (Strongest, Last)	Power Consumption	22 W
Data Points Generated	Single Return Mode: 1,152,000 points per second Dual Return Mode: 2,304,000 points per second	Operating Temperature	−40℃ to +65℃
Frame Rate (Configurable)	10 Hz, 20 Hz	Clock Source	GPS/PTP
Measurement Accuracy	±5 cm (0.3 m to 0.5 m), ±2 cm (0.5 m to 200 m)	PTP Clock Accuracy	≤1 μs
FOV (Horizontal)	360°(default)	PTP Clock Drift	≤1 μs/s
Angular Resolution (Horizontal)	0.2° (10 Hz), 0.4° (20 Hz)	Weight	1.520 kg
FOV (Vertical)	40° (−25° to +15°)	Dimensions	Height: 116.70 mm; Top Diameter: 116.00 mm; Bottom Diameter: 115.00 mm

Table 1.1 Prototype Specifications of Pandar64

*Specifications are subject to change without notice.

2 Installation Guide

2.1 Mechanical Installation (Metric System)

Figure 2.1 Pandar64 Side View
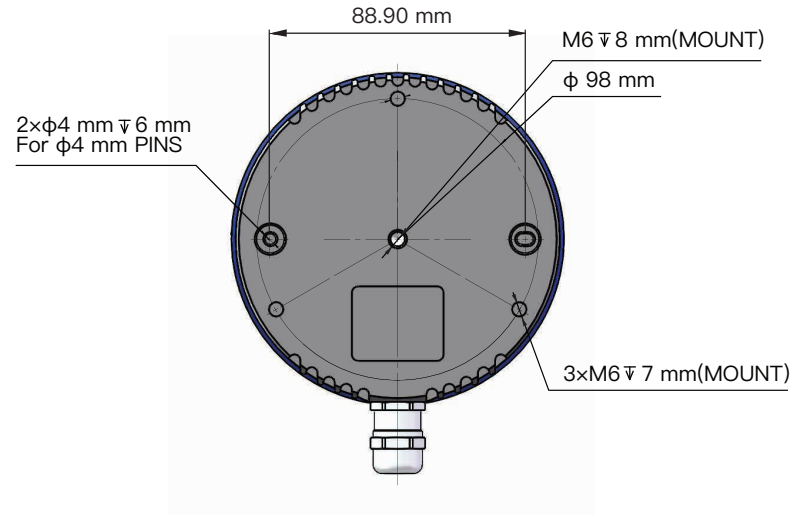
Figure 2.2 Pandar64 Mounting Base

■ Quick Installation

M6 screw
7~9 mm over mounting base

2xΦ4PINS
5~6 mm over mounting base

Figure 2.3 Diagram of Quick Installation

■ Stable Installation

M6 screw
7~9 mm over mounting base

3xM6 screw
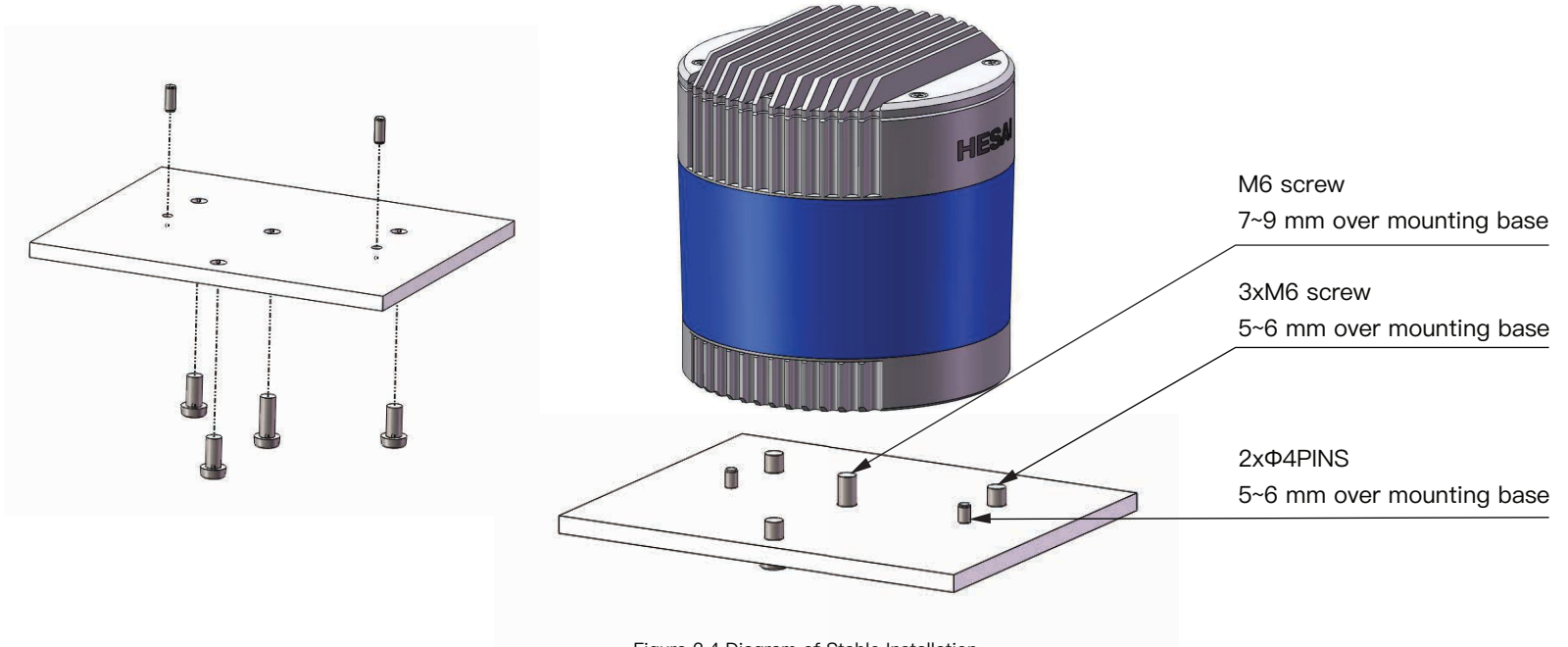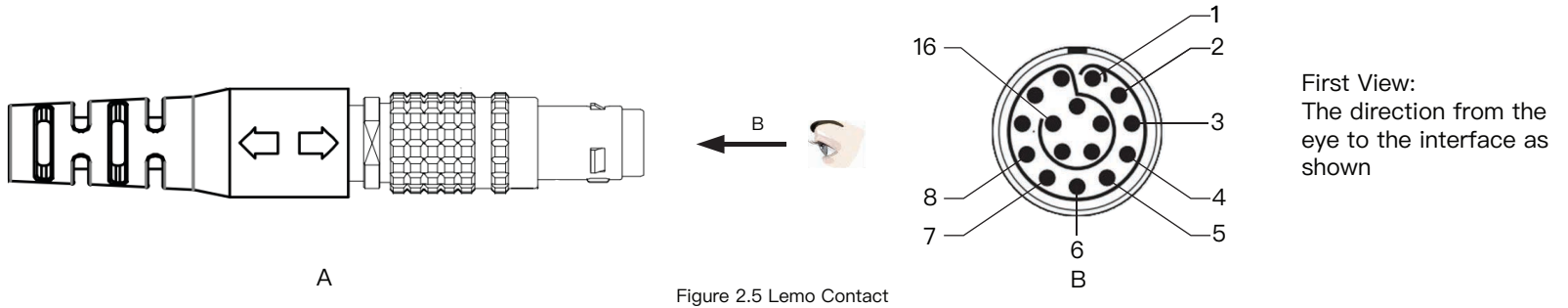5~6 mm over mounting base

2xΦ4PINS
5~6 mm over mounting base
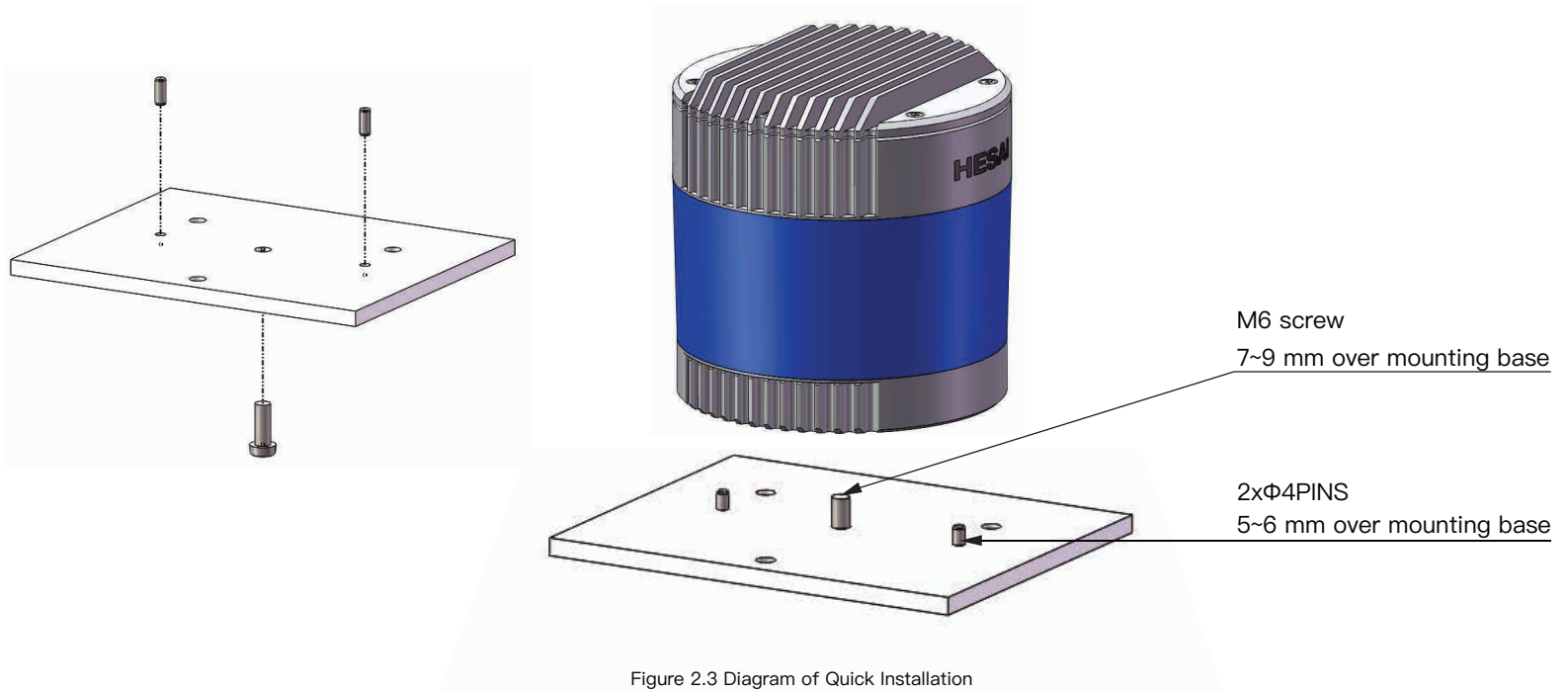
Figure 2.4 Diagram of Stable Installation

2.2 Interface

Pandar64 uses Lemo Contact as the communication connector. The cable length from LiDAR exit to the tip of the connector is 0.3 m.

First View:
The direction from the eye to the interface as shown

Figure 2.5 Lemo Contact

Pin #	Function	Color	Voltage (V)	Pin #	Function	Color	Voltage (V)
1	N.A	N.A	N.A	9	GPS Serial Data	WHITE	–13 V to +13 V
2	N.A	N.A	N.A	10	GPS PPS	YELLOW	3.3 V/5 V
3	N.A	N.A	N.A	11	P12V	RED	12 V
4	N.A	N.A	N.A	12	P12V	GRAY	12 V
5	Ethernet RX–	BLUE	–1 V to 1 V	13	Ground (Return)	BLACK	0
6	Ethernet RX+	BLUE/WHITE	–1 V to 1 V	14	Ground (Return)	GRAY/WHITE	0
7	Ethernet TX–	ORANGE	–1 V to 1 V	15	Index	PURPLE	0 V to 3.3 V
8	Ethernet TX+	ORANGE/WHITE	–1 V to 1 V	16	Encoder	PURPLE/WHITE	0 V to 3.3 V

Table 2.1 Communication Connector Description

NOTE Pandar64 can also use Phoenix Contact as the communication connector. Please refer to Appendix VI for more details.

2.3　Connecting Box (Optional Component)

Connecting box is the optional component of Pandar64. Users can choose to connect LiDAR using the connecting box.
The connecting box comes equipped with a power port, a GPS port, and a standard ethernet port.
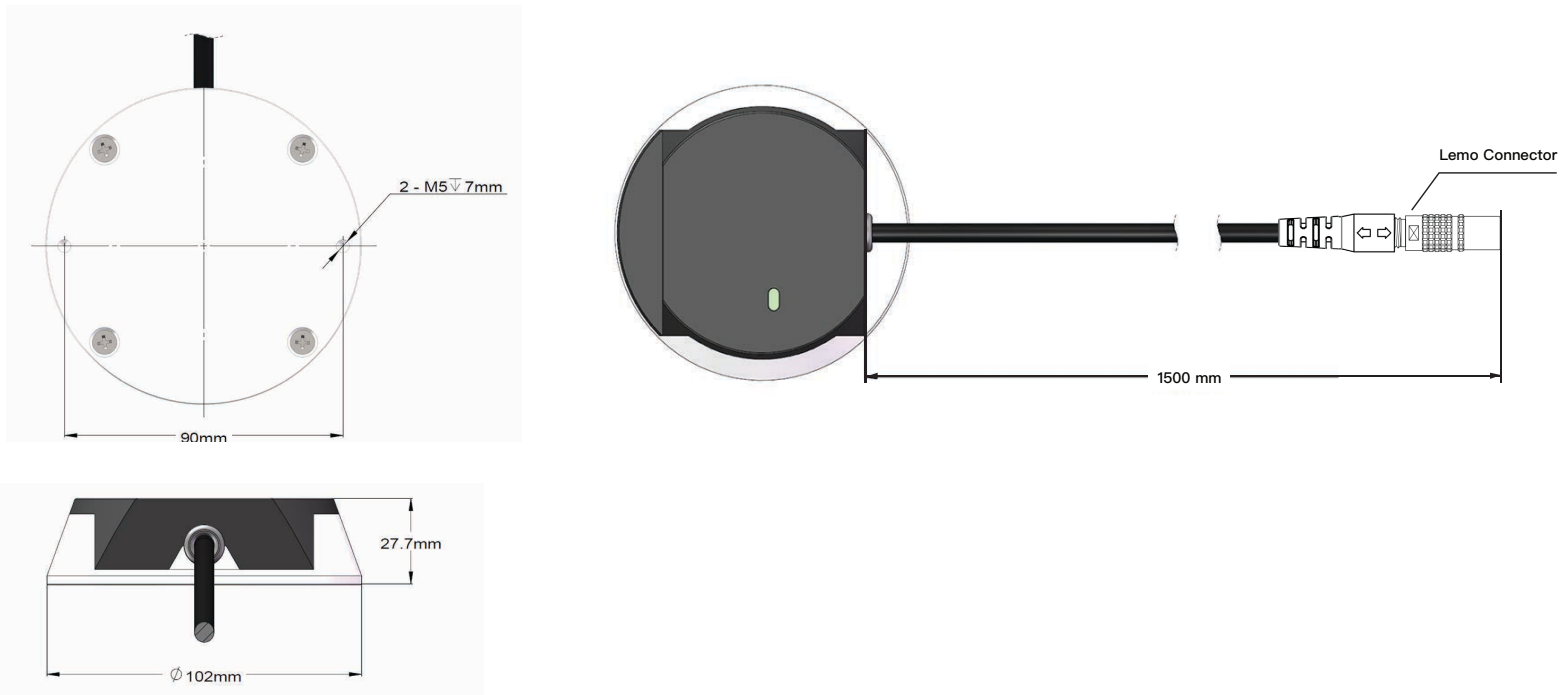The cable length from Lemo connector to the connecting box is 1.5 m.

2 - M5 ▽ 7mm

90mm

27.7mm

Ø 102mm

Lemo Connector

1500 mm

Figure 2.6 Connecting Box

2.3.1 Connecting Box Interfaces

1 2 3 4 5 6

c   b   a
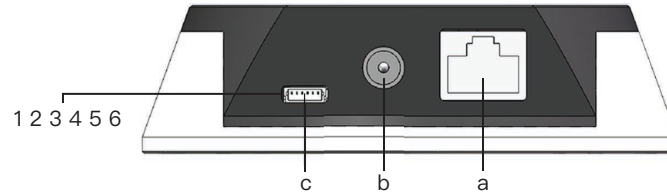
Figure 2.7 Connecting Box (1)

No.	Name	Interface Description
a	GPS Port	Connector type: JST SM06B–SRSS–TB Recommended connector for external GPS module: JST SHR–06V–S–B Voltage standard: RS232 Baud rate: 9600 bps
b	Power Port	Use DC–005 DC power adapter Input voltage ranges from 9 V to 48 V Power consumption is 22 W
c	Standard Ethernet Port	RJ45, 100 Mbps Ethernet

Table 2.2 Connecting Box Interface Description (To Be Continued)

GPS port pin number from left to right is 1 to 6, and the specific definition of each pin is shown as follows:

| Pin No.	Direction	Pin Description
1	Input	PPS synchronizing signal, to receive synchronized pulses from the GPS module TTL 3.3 V/5 V
2	Output	5 V power, to provide power for external GPS module
3	Output	GND, to ground external GPS module
4	Input	Receiving signal of serial port, to receive serial data from external GPS module, RS232 level
5	Output	GND, to ground external GPS module
6	Output	Transmitting signal of serial port, to send serial data to the external GPS module, RS232 level

Table 2.3 GPS Pin Definition
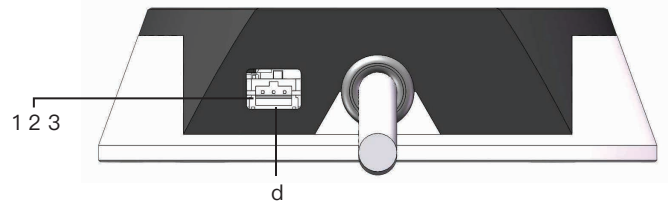
Figure 2.8 Connecting Box (Continued)

No.	Name	Name
d	Trigger Port	Connector type: Molex, LLC 5023520300 Recommended connector: Molex, LLC 5023510300 Voltage: 0 V to 3.3 V Signal type: pulse Max current output level: 12 mA

NOTE Only the Pandar64 LiDARs with Lemo communication connectors support the feature of outputting external trigger signal.

Table 2.4 Connecting Box Interfaces Description (Continued)

Pin No.	Direction	Pin Description
1	Input	GND, to ground the external trigger signal
2	Output–Encoder	Trigger signal output: outputs one pulse when the LiDAR rotates 0.05 degrees 7 µs@600RPM, 3.5 µs@1200RPM
3	Output–Index	Trigger signal output: outputs one pulse when the LiDAR rotates one revolution 4 µs@600RPM, 2 µs@1200RPM

Table 2.5 Trigger Port Pin Definition

2.3.2   How to Connect using Connecting Box

Connect the power port to the adapter.

Power port and standard Ethernet port

Pandar64

Use an Ethernet cable to connect the LiDAR's and computer's Ethernet ports.
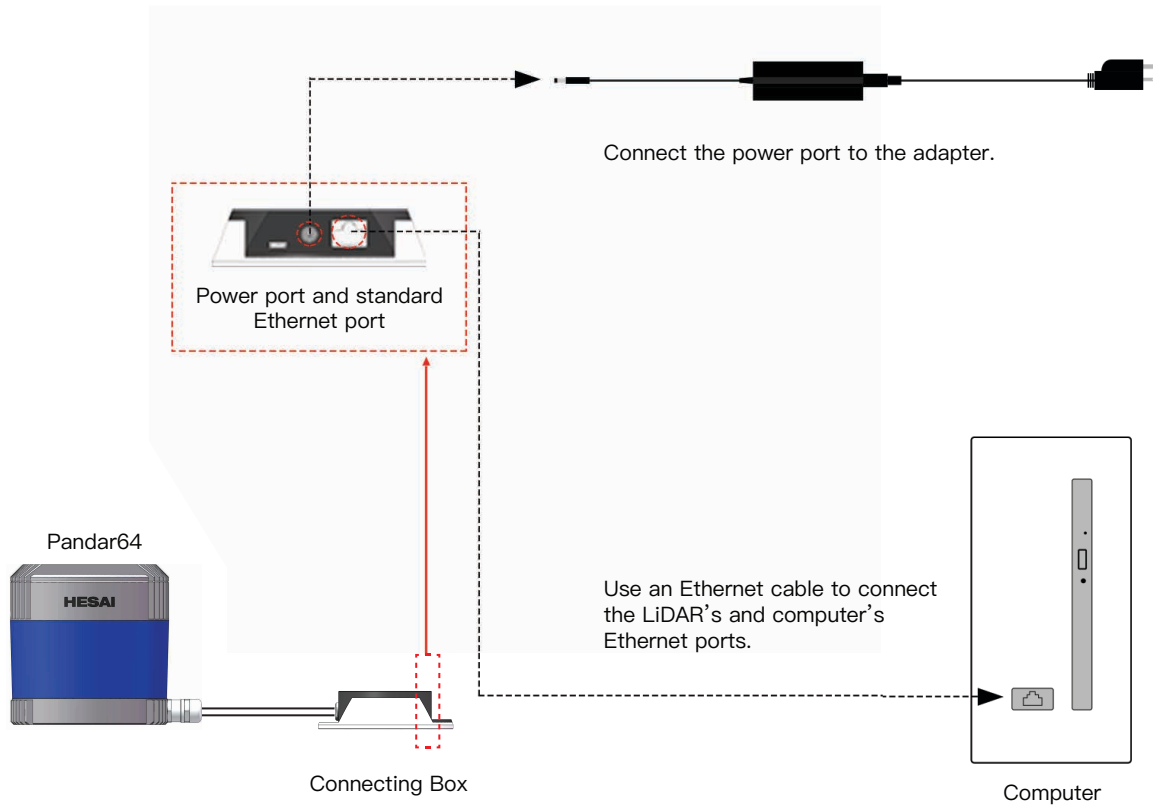
Connecting Box

Computer

Figure 2.9 How to Connect Using Connecting Box

NOTE Please refer to Appendix III for the connection using PTP protocol.

2.4   Get Ready to Use

Pandar64 begins to scan and transmit data automatically once it is wired and powered up.
To receive the data on your PC, please set the PC IP address to 192.168.1.100 and Subnet mask to 255.255.255.0.
Point cloud data can be quickly viewed or recorded by using PandarView, the point cloud data viewer software developed by Hesai. For more on PandarView installation and usage, see Appendix VI PandarView.

NOTE Pandar64 does not have a power switch. It starts to operate whenever power is applied.
NOTE Web control can be used to set up the configurable parameters of the LiDAR before using. For more on web control functions, see Chapter 4.
NOTE SDK (Software Development Kit) of our LiDAR can be found on Hesai official GitHub.

3 LiDAR Data Structure

The communication protocol for data output of Pandar64 is Fast Ethernet UDP/IP. The output data includes point cloud data packet and GPS data packet. Each data packet consists of an ethernet header and a UDP data.
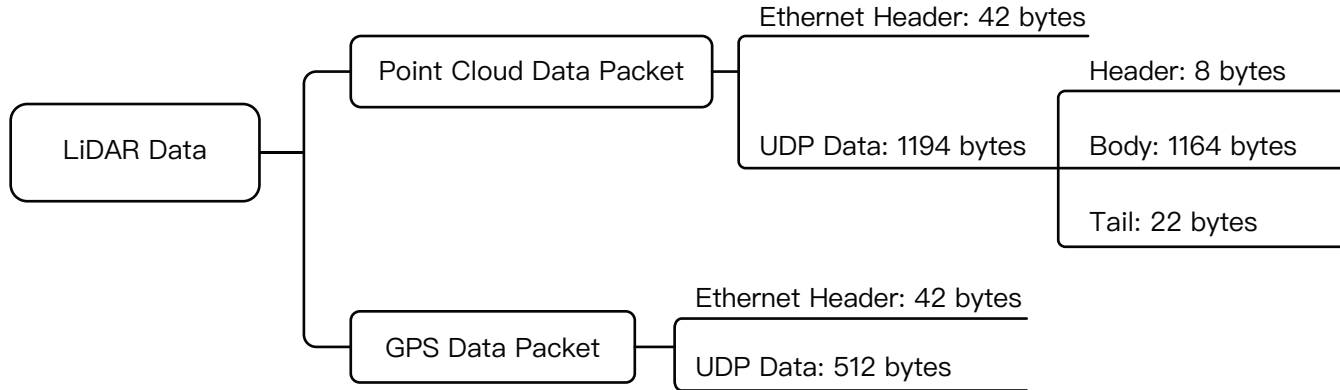

Figure 3.1 LiDAR Data Structure Illustration

NOTE Please refer to Appendix V for details about data structure with UDP Sequence on.

3.1 Point Cloud Data Packet Ethernet Header/ UDP Data

Each Pandar64 point cloud data packet has a 42 bytes ethernet header and 1194 bytes UDP data.

3.1.1 Point Cloud Data Packet ─ Ethernet Header

Here is an example of point cloud data packet ethernet header definition:

Ethernet Header: 42 bytes		
Ethernet II MAC	12 bytes	Destination: Broadcast (0xFF: 0xFF: 0xFF: 0xFF: 0xFF: 0xFF), Source: (xx:xx:xx:xx:xx:xx)
Ethernet Data Packet Type	2 bytes	0x08, 0x00
Internet Protocol	20 bytes	Version, Header Length, Differentiated Services, Field, Total Length, Identification, Flags, Fragment Offset, Time to Live, Protocol, Header Checksum, Source IP Address, Destination IP Address
UDP Port Number	4 bytes	UDP source port (0x2710, represents 10000), destination port (0x0940, represents 2368)
UDP Length and Checksum	4 bytes	Length 2 bytes (0x04b2, represents 1202 bytes), checksum 2 bytes

Table 3.1 Point Cloud Data Packet Ethernet Header Definition

IP Address

Each Pandar64 has a unique MAC address.
The destination IP address is 0xFF and in broadcast form.
The default source IP address is 192.168.1.201.
Taking "Internet Protocol (20 bytes)" as an example, it is described as Figure 3.2.

Figure 3.2 Point Cloud Data Ethernet Header Internet Protocol Illustration

3.1.2 Point Cloud Data Packet–UDP Data

The UDP Data of Pandar64 includes the areas of Header, Body and Tail. All the multi–byte values are the unsigned type and in Little Endian format.

■ Header

Header: 8 bytes		
0xee 0xff	2 bytes	SOP (start of packet)
Laser N	1 byte	0x40 (64 lines)
Block N	1 byte	0x06 (6 blocks per packet)
RT Start	1 byte	Return type start, the first block's return number; (when dual return) 0–single return 1–the first block is the last return when dual return type is selected 2–the first block is the strongest return when dual return type is selected
Dis Unit	1 byte	4 mm
Reserved	1 byte	–
Reserved	1 byte	–

Table 3.2 UDP Data–Header Definition

■ Body

Body: 1164 bytes (6 blocks)				
Block 1	**Block 2**	**Block 3**	······	**Block 6**
Azimuth	Azimuth	Azimuth	······	Azimuth
Unit 1	Unit 1	Unit 1	······	Unit 1
Unit 2	Unit 2	Unit 2	······	Unit 2
······	······	······	······	······
Unit 64	Unit 64	Unit 64	······	Unit 64

Table 3.3 UDP Data–Body Definition

The size of each block equals to (64*Unit Size+Azimuth Size).

Each Block 194 bytes			
Azimuth	2 bytes	Represents the current reference angle of the rotor. Azimuth [15:0]: lower byte Azimuth_L [7:0] is in the front, upper byte Azimuth_H [15:8] is in the back. Azimuth Angle=[Azimuth_H, Azimuth_L]/100°=Azimuth/100°	
Unit	3 bytes	2 bytes distance data	Distance Value = Distance*4 mm Maximum Distance Value = (2^16−1)*4 mm = 262.14 m
		1 byte reflectivity data	

Table 3.4 Definition of Each Block

NOTE Under dual return mode, azimuth angle changes every two blocks. The odd number block is the last return, and the even number block is the strongest return. If the last and strongest return coincides, the second strongest return will be placed to the even number block.

Tail

Tail: 22 bytes		
Reserved	5 bytes	reserved data, meaningless
High Temperature Shutdown Flag	1 byte	0x01 means high temperature; 0x00 means normal operation · during normal operation, shutdown flag keeps being 0x00 · if high temperature is detected and system needs to be shut down, the shutdown flag will be set to 0x01, and the system will be shut down after 60 seconds. The flag keeps being 0x01 during the 60 seconds and shutdown period · after the high temperature shutdown, the LiDAR temperature will decrease. When the system is not in high temperature status, the shutdown flag will be reset to 0x00 and the system can return to normal operation
Reserved	2 bytes	reserved data, meaningless
Motor Speed	2 bytes	speed_2_bytes [15:0] = speed (RPM)
GPS Timestamp	4 bytes	the packing time of this data packet, the unit is 1 µs, value range 0 µs–1000000 µs (1 s)
Return Mode Information	1 byte	the strongest return (0x37), the last return (0x38), dual return (0x39)
Factory Information	1 byte	0x42 (or 0x43)
UTC	6 bytes	year, month, date, hour, minute, second, decimal digit

Table 3.5 Point Cloud Data UDP Data–Tail

Example of UDP Data Analysis

Taking Pandar64's Channel 5 in block 3 of a UDP Data Packet as an example:

1) Horizontal angle offset of the laser is –1.042°, and vertical angle of the laser is 3.04° for Channel 5.

2) Horizontal angle is the current reference angle of the rotor plus horizontal angle offset, so the result is (Azimuth 3+(–1.042)) degree .
(NOTE We define clockwise as a positive direction of the angle from top view)

3) Analyze the "Channel 5 Unit 3" from the UDP Data Packet, and the distance formed by upper 2 bytes multiplied by 4mm is the actual distance in millimeters in the real world.

By now, the direction and distance of this point have been decided, and this obstacle point could be drawn in the polar or rectangular coordinate system. The real–time point cloud data of Pandar64 can be drawn by analyzing every data in the UDP Data Packet using the above method.

3.2　GPS Data Packet Ethernet Header/UDP Data

Each GPS Data Packet has a 42 bytes ethernet header and 512 bytes UDP Data. All the multi–byte values are the unsigned type and in Little Endian format. GPS UDP Data Packet will be triggered every second, and the port is 10110.

Before receiving the GPS module data, the rising edge of the internal 1Hz signal of the LiDAR will trigger a GPS Data Packet. The initial GPS time data in the packet will be counted from 000101000000 (yymmddhhmmss, year, month, day, hour, minute, second) and this unreal GPS time can also increase according to internal 1Hz signal of LiDAR as long as GPRMC information is not available at the beginning. If LiDAR receives PPS signal and GPRMC data from GPS module, the local 1Hz signal of the LiDAR will be locked to the PPS signal. GPS Data Packet is still triggered by the rising edge of the internal 1Hz signal. Meantime, the GPS time data in the Packet will be reset to actual GPS time by GPRMC information from GPS module.

GPS module sends firstly the PPS signal, then the GPRMC information. The LiDAR can extract the UTC information and stamp 6 bytes UTC time (Year:Month:Day:Hour:Minute:Second) into Point Cloud UDP Packet. User can then add 4 bytes timestamp and 6 bytes UTC time in Point Cloud UDP to achieve absolute time for the UDP packet.

As long as the GPS signal is available, the GPS time in the packet will update according incoming GPRMC information. If GPS module stops sending data, LiDAR will still trigger a GPS Data Packet following the internal 1Hz signal and GPS time data in the Packet will be counted on the base of previously actual GPS time.

3.2.1　GPS Data Packet — Ethernet Header

Ethernet Header: 42 bytes		
Ethernet II MAC	12 bytes	Destination: Broadcast (0xFF: 0xFF: 0xFF: 0xFF: 0xFF: 0xFF), Source: (xx:xx:xx:xx:xx:xx)
Ethernet Data Packet Type	2 bytes	0x08, 0x00
Internet Protocol	20 bytes	Version, Header Length, Differentiated Services, Field, Total Length, Identification, Flags, Fragment Offset, Time to Live, Protocol, Header Checksum, Source IP Address, Destination IP Address
UDP Port Number	4 bytes	UDP source port (0x2710, represents10000), destination port (0x277E, represents 10110)
UDP Length and Checksum	4 bytes	Length 2 bytes (0x208, represents 520 bytes), checksum 2 bytes

Table 3.6 GPS Data Packet Ethernet Header Definition

IP Address

The destination IP address is 0xFF FF FF FF and in broadcast form.

The default source IP address is 192.168.1.201. Taking "Internet Protocol (20 bytes)" as an example, it is described as follows:

```
⊟ 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 Data Ethernet Header Internet Protocol Illustration

3.2.2 GPS Data Packet – UDP Data

Every second, one UDP data will be triggered by one GPS PPS. UDP data has 512 bytes, and the port is 10110. In a locked state, the GPS packet outputs per second continuously.

GPS UDP data: 512 bytes				
GPS Time Data	18 bytes	Header	2 bytes	0xFFEE, 0xFF first
		Date	6 bytes	Year month and day in order (2 bytes each), lower byte first, ASCII code
		Time	6 bytes	Second minute and hour in order (2 bytes each), lower byte first, ASCII code
		µs Time	4 bytes	Unit is µs, lower byte first
GPRMC Data	77 bytes	ASCII code, valid till 2 bytes after '*'		
Reserved Data	411 bytes	Filled with 411 0xDF		
Location valid or not	1 byte	From GPRMC information, ASCII code, A=valid, V=invalid		
Flag of PPS lock	1 byte	1=locked, 0=unlocked		
Reserved Data	4 bytes	Reserved meaningless data		

Table 3.7 GPS Data Packet–UDP Data Definition

Example of GPS Data Packet UDP Data Analysis


```
⊞ User Datagram Protocol, Src Port: ndmp (10000), Dst Port: nmea-0183 (10110)
⊟ Data (512 bytes)
    Data: ffee37313231303232353534323100300084a4244750524d43...

0020  ff ff 27 10 27 7e 02 08  a2 2c ff ee 37 31 32 31   ..'.'~...,..7121
0030  30 32 32 35 35 34 32 31  00 30 08 a4 24 47 50 52   02255421 .0..$GPR
0040  4d 43 00 2c 31 32 34 35  35 32 2e 30 30 2c 41 2c   MC.,1245 52.00,A,
0050  33 31 32 31 2e 38 36 37  37 32 2c 4e 2c 31 32 31   3121.867 72,N,121
0060  31 34 2e 36 37 33 31 38  2c 45 2c 30 2e 30 37 34   14.67318 ,E,0.074
0070  2c 2c 32 30 31 32 31 37  2c 2c 2c 44 2a 37 35 35   ,,201217 ,,,D*755
0080  35 35 35 35 35 35 35 35  35 35 35 35 35 35 35 35   55555555 55555555
0090  df df df df df df df df  df df df df df df df df   ........ ........
00a0  df df df df df df df df  df df df df df df df df   ........ ........
00b0  df df df df df df df df  df df df df df df df df   ........ ........
00c0  df df df df df df df df  df df df df df df df df   ........ ........
00d0  df df df df df df df df  df df df df df df df df   ........ ........
00e0  df df df df df df df df  df df df df df df df df   ........ ........
00f0  df df df df df df df df  df df df df df df df df   ........ ........
0100  df df df df df df df df  df df df df df df df df   ........ ........
0110  df df df df df df df df  df df df df df df df      ........ .......
```

Figure 3.4 GPS Data Packet UDP Data Illustration

Date
Year: 0x37, 0x31, convert ASCII code to '7', '1'; means 17
Month: 0x32, 0x31, convert ASCII code to '2', '1'; means 12
Day: 0x30, 0x32, convert ASCII code to '0', '2'; means 20

Time
Second: 0x32, 0x35, convert ASCII code to '2', '5'; means 52
Minutes: 0x35 0x34 convert ASCII code to '5', '4; means 45
Hour: 0x32 0x31, convert ASCII code to '2', '1'; means 12 (UTC time)

μs Time
4 bytes, the μs time value of each GPS PPS pulse, and timestamp will be set as 0 μs.
The μs time of GPS PPS and the timestamp from the point cloud data have the same data source, and the unit is 1 μs.

GPRMC Data Format

The standard GPRMC data format is as follows:
$GPRMC, <01>, <02>, <03>, <04>, <05>, <06>, <07>, <08>, <09>, <10>, <11>, <12>*hh

Detailed descriptions are as follows：

<01> UTC Time, hhmmss (hour, minute, second) format

<02> Location Status, A=Valid Position, V=Invalid Position

<03> Latitude ddmm.mmmm (degree, minute) format

<04> Latitude Northern (N) or Southern (S) Hemisphere

<05> Longitude dddmm.mmmm (degree, minute) format

<06> Longitude Eastern (E) or Western (W) Hemisphere

<07> Ground Rate (000.0 to 999.9 knots)

<08> Ground Direction (000.0~359.9 degrees, referencing true north)

<09> UTC Date, ddmmyy (day, month, year) format

<10> Declination (000.0 to 180.0 degrees)

<11> Declination Direction, E (east) or W (west)

<12> Mode (only on version NMEA0183 3.00, A=Automatic Positioning, D=Differential, E=Estimation, N=Invalid Data)

The GPS interface of Pandar64 is compatible with a variety of data formats. The external GPS module GPRMC data format needs to meet the following conditions:
the data in <01> is the hour, minute, and second information; the data in <09> is the date information.

The following two formats are both admissible:
1) $GPRMC,072242,A,3027.3680,N,11423.6975,E,000.0,316.7,160617,004.1,W*67
2) $GPRMC,065829.00,A,3121.86377,N,12114.68322,E,0.027,,160617,,,A*74

4 Web Control

Web Control can be used to set Pandar64 parameters, check device info, and upgrade.
Before setting, please connect LiDAR and the computer using Ethernet cable. Set IP address to 192.168.1.25.

4.1 Open Web Control

After setting, open browser and type URL: 192.168.1.201/index.html to enter the web control homepage.
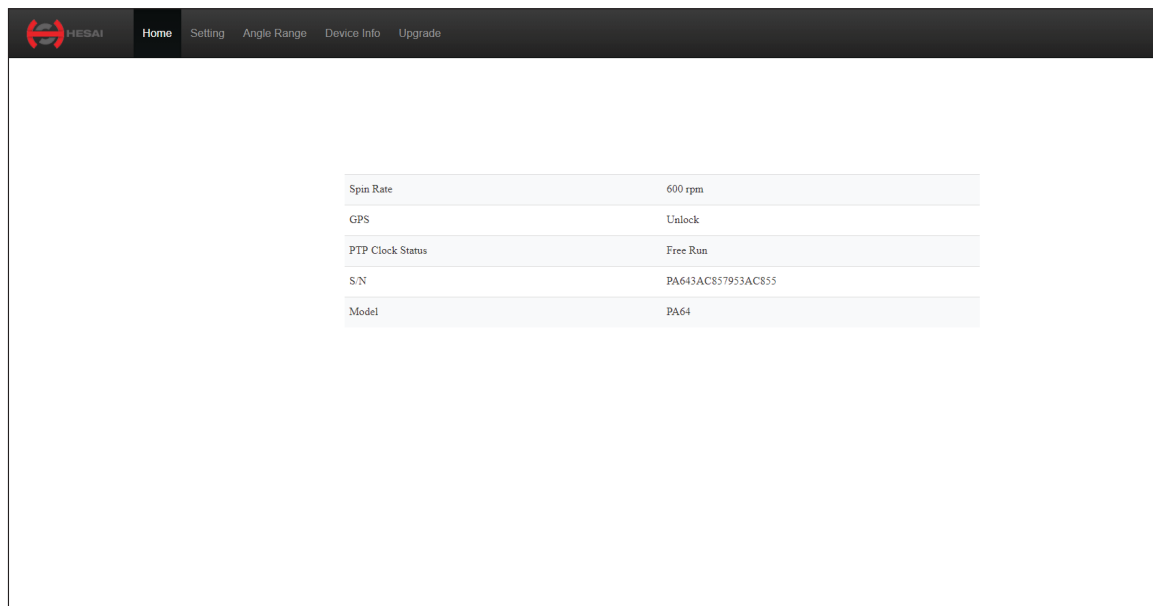**NOTE** Please use Google Chrome or Firefox. IE is not supported.

Spin Rate	600 rpm
GPS	Unlock
PTP Clock Status	Free Run
S/N	PA643AC857953AC855
Model	PA64

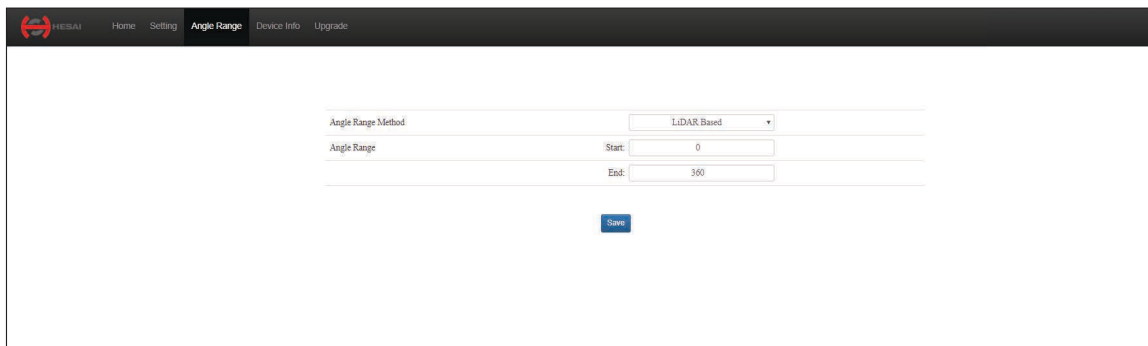Figure 4.1 Home Page of Web Control

4.2   Setting

Figure 4.2 Setting Page of Web Control

1) Pandar64 supports both broadcast (default setting) and unicast.
   To use broadcast, please set Destination IP as 255.255.255.255. To use unicast, please set Destination IP as the same as PC IP address.

2) Users can choose the spinning rate from 600 rpm and 1200 rpm.

3) Users can choose the GPS sync angle. If set as 0, then the 0 degree angle is in sync with PPS.

4) Users can choose the dual return type from the last return, the strongest return, and the dual return.

5) Users can choose clock source between GPS or PTP. When PTP clock source is selected, LiDAR sends only Point Cloud UDP Packet, but NO GPS UDP PACKET, please refer to Appendix III for details.

6) Users can turn on or off UDP sequence. UDP sequence is used to label the sequence number for UDP packet. Please refer to Appendix V for details about data structure changes.

7) Users can choose the trigger method from angle based and time based.

   NOTE In Time Based Trigger Mode, lasers fire every 55.56 us. In Angle Based Trigger Mode, lasers fire every 0.2° (at 10 Hz) or 0.4° (at 20 Hz).

4.3 Angle Range

Users can set azimuth angle range on this page. There are two methods to set angle range: LiDAR based angle range method and laser based angle range method.
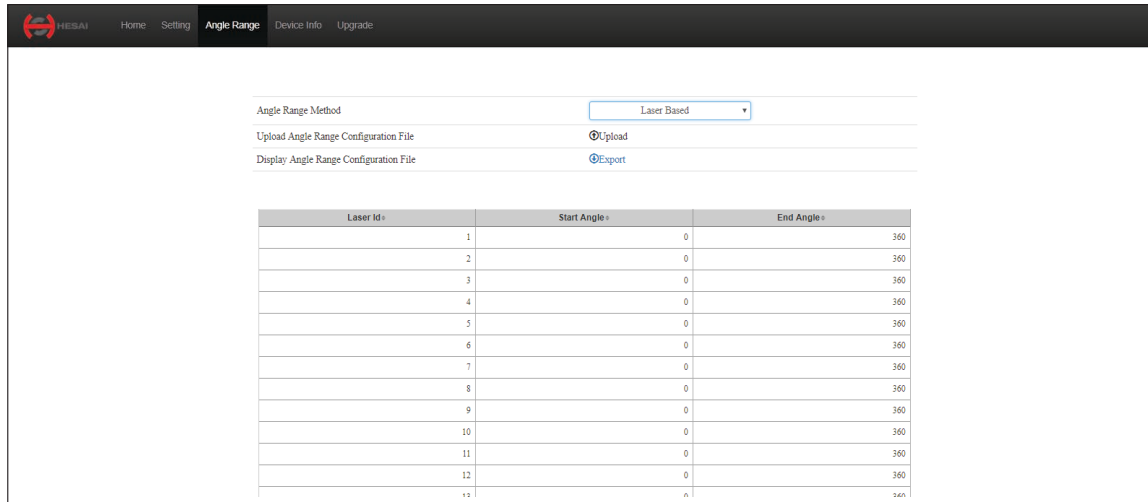

Figure 4.3 Angle Range Page

■ LiDAR Based

If LiDAR based angle range method is selected, the start and end angles that users enter will be applied to all 64 channels. In other words, all 64 channels will have the same angle range. There will be no laser firing or data generated outside the specified angle range. After setting, click "Save".

NOTE Please do not forget to click "Save" after finishing setting. Otherwise, angle range will not be applied.

■ Laser Based

If laser based angle range method is selected, users can see a table as in Figure 4.4. The start and end angles of each laser can be configured individually.

Figure 4.4 Angle Range Page–Laser Based
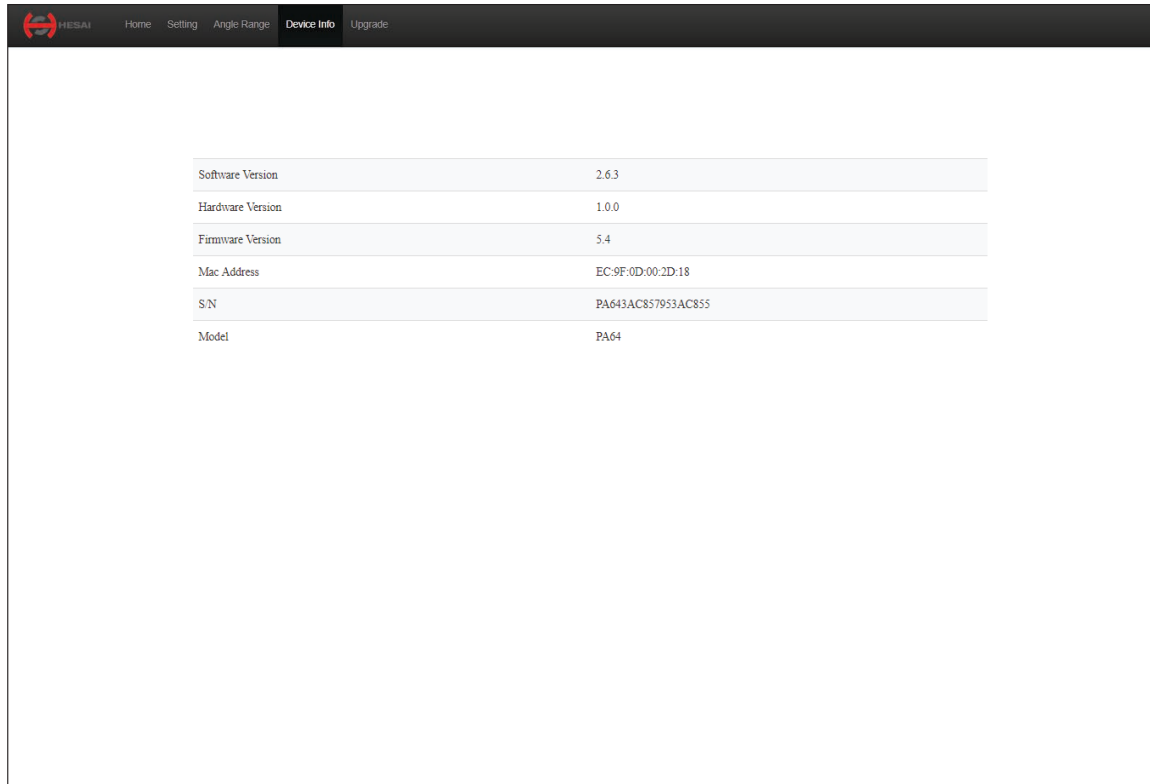
Users can edit the start and end angles by first downloading the angle range configuration file and then upload the edited configuration file. Please click "Save" to apply your settings.

NOTE

1) Use LiDAR Based Method if the same angle range is expected on all 64 channels. Outside the specified range, no laser will be firing and no data will be generated.

2) If Laser Based Method is chosen and the angle range varies channel by channel, there will be no data generated only outside the union of all specified angle ranges.

4.4   Device Info

Software version, hardware version, firmware version can be viewed from device information page.

Software Version	2.6.3
Hardware Version	1.0.0
Firmware Version	5.4
Mac Address	EC:9F:0D:00:2D:18
S/N	PA643AC857953AC855
Model	PA64

Figure4.5 Device Info Page of Web Control

4.5   Firmware Upgrade

Please ask Hesai for the latest upgrade file if needed. Click on "Upload" button to upload the upgrade file. Please reboot the LiDAR after finishing upgrading.
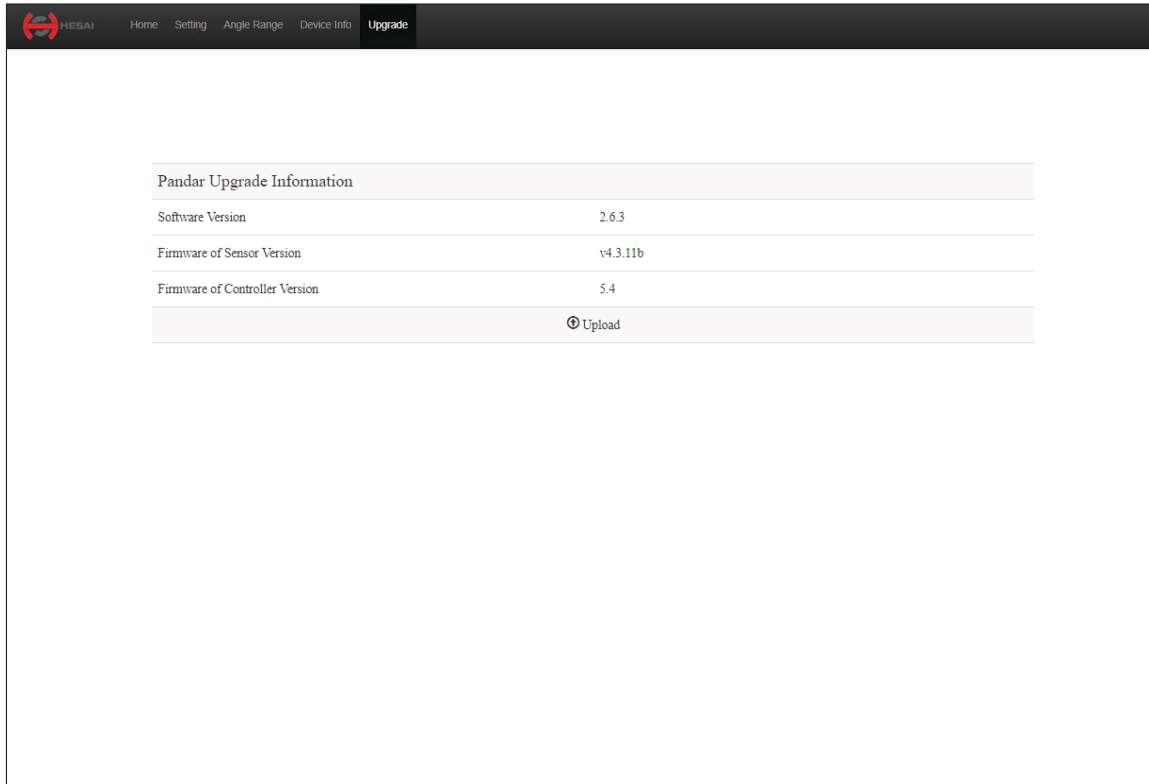

Figure4.6 Upgrade Page of Web Control

Appendix I

Pandar64 Channel Distribution

Channel Number of Laser	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range Capability vs. Reflectivity (in meters)
Channel number in UDP Data Packet	The horizontal angle of each line is the sum of current reference angle of the rotor and the angle below. Define clockwise as positive.	The vertical angle of each line is constant, and 0° represents horizontal direction. Define upward as positive.	Instrument range capability	Range capability at objects with specific reflectivity
01	−1.042	14.882	130	200@20%
02	−1.042	11.032	130	200@20%
03	−1.042	8.059	130	200@20%
04	−1.042	5.057	130	200@20%
05	−1.042	3.040	130	200@20%
06	−1.042	2.028	130	200@20%
07	1.042	1.860	130	200@20%
08	3.125	1.688	230	200@20%
09	5.208	1.522	130	200@20%
10	−5.208	1.351	230	200@20%
11	−3.125	1.184	230	200@20%
12	−1.042	1.013	230	200@10%
13	1.042	0.846	230	200@10%
14	3.125	0.675	230	200@10%

Channel Number of Laser	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range Capability vs. Reflectivity (in meters)
15	5.208	0.508	230	200@10%
16	−5.208	0.337	230	200@10%
17	−3.125	0.169	230	200@10%
18	−1.042	0.000	230	200@10%
19	1.042	−0.169	230	200@10%
20	3.125	−0.337	230	200@10%
21	5.208	−0.508	230	200@10%
22	−5.208	−0.675	230	200@10%
23	−3.125	−0.845	230	200@10%
24	−1.042	−1.013	230	200@10%
25	1.042	−1.184	230	200@10%
26	3.125	−1.351	230	200@10%
27	5.208	−1.522	230	200@10%
28	−5.208	−1.688	230	200@10%
29	−3.125	−1.860	230	200@10%
30	−1.042	−2.028	230	200@10%
31	1.042	−2.198	230	200@20%
32	3.125	−2.365	230	200@20%
33	5.208	−2.536	230	200@20%

Channel Number of Laser	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range Capability vs. Reflectivity (in meters)
34	–5.208	–2.700	230	200@20%
35	–3.125	–2.873	230	200@20%
36	–1.042	–3.040	230	200@20%
37	1.042	–3.210	230	200@20%
38	3.125	–3.375	230	200@20%
39	5.208	–3.548	130	200@20%
40	–5.208	–3.712	230	200@20%
41	–3.125	–3.884	130	200@20%
42	–1.042	–4.050	230	200@20%
43	1.042	–4.221	130	200@20%
44	3.125	–4.385	130	200@20%
45	5.208	–4.558	130	200@20%
46	–5.208	–4.720	130	200@20%
47	–3.125	–4.892	130	200@20%
48	–1.042	–5.057	130	200@20%
49	1.042	–5.229	130	200@20%
50	3.125	–5.391	130	200@20%
51	5.208	–5.565	130	200@20%
52	–5.208	–5.726	130	200@20%

Channel Number of Laser	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range Capability vs. Reflectivity (in meters)
53	−3.125	−5.898	130	200@20%
54	−1.042	−6.061	130	200@20%
55	−1.042	−7.063	130	200@20%
56	−1.042	−8.059	130	200@20%
57	−1.042	−9.060	130	200@20%
58	−1.042	−9.885	130	200@20%
59	−1.042	−11.032	130	200@20%
60	−1.042	−12.006	130	200@20%
61	−1.042	−12.974	130	200@20%
62	−1.042	−13.930	130	200@20%
63	−1.042	−18.889	130	200@20%
64	−1.042	−24.897	130	200@20%

Table I.1 Pandar64 Channel Distribution

Appendix II

Point Cloud Data Packet Absolute Time and Laser Firing Time Calculations

Pandar64 transmits two types of UDP Data Packet, including the point cloud UDP Data Packet and the GPS UDP Data Packet, hereafter referred to as Point Cloud Data Packet and GPS Data Packet.

1 Absolute Time Calculation of Point Cloud Data Packet

LiDAR transmits a GPS Data Packet and a Point Cloud Data Packet chronologically with μs timestamps from the same data source. The μs timestamp in the Point Cloud Data Packet (GPS Timestamp) is used to calculate the packing time of this data packet.

There are two methods to calculate the absolute packing time of Point Cloud Data:
1) Retrieve the μs timestamp and the time information (UTC, decimal number) from the Point Cloud Data Packet. The absolute time of Point Cloud Data Packet can be calculated by combining 2 parts: a) the 4 bytes μs timestamp; b) the 6 bytes UTC time information (decimal number) in Point Cloud Data Packet.
2) First retrieve timestamp from the Point Cloud Data Packet, then retrieve time information (UTC) from the previous GPS Data Packet. The absolute time of Point Cloud Data Packet can be calculated by combining 2 parts: a) the 4 bytes μs timestamp; b) the UTC time information (decimal number) in previous GPS Data Packet.

NOTE
1) Because LiDAR GPS Data Packet is triggered by PPS rising edge, the corresponding GPRMC information (real absolute time) from GPS module after PPS rising edge is not available at that time.
2) The UTC time in LiDAR GPS Data Packet and following Point Cloud Data Packet can only utilize previous GPRMC information, which is 1 full second older than the absolute time of the triggering PPS rising edge. But the LiDAR can automatically adjust and the user can simply add the 4 bytes timestamp and 6 bytes UTC time to get absolute time.
3) Since every GPS Data Packet matches an internal 1Hz signal, the GPS Data Packet will be exported continuously in every second with or without GPRMC information. If GPRMC is available, UTC time in data packets are updated according to GPRMC and avoid drift of internal 1Hz signal; if GPRMC is not available, UTC time in data packets are updated according to internal 1Hz signal and keep the mechanism.

NOTE Please refer to Appendix III for the calculation of absolute time using PTP protocol.

2 Laser Firing Time Calculation

The laser firing time of every laser channel can be calculated by using the absolute time in Point Cloud Data Packet.
Assuming the Point Cloud Data Packet's absolute time is t0.

Body: 1164 bytes (6 blocks)				
Block 1	**Block 2**	**Block 3**	· · · · · · ·	**Block 6**
Azimuth	Azimuth	Azimuth	· · · · · · ·	Azimuth
Unit 1	Unit 1	Unit 1	· · · · · · ·	Unit 1
Unit 2	Unit 2	Unit 2	· · · · · · ·	Unit 2
· · · · · · ·	· · · · · · ·	· · · · · · ·	· · · · · · ·	· · · · · · ·
Unit 64	Unit 64	Unit 64	· · · · · · ·	Unit 64

Table II.1 Point Could Data UDP Data–Body

■ Single Return Mode

There are 6 Blocks in every Point Cloud UDP Data Packet.
In the single return mode, each block consists 64 laser channels ranging data. The end time of the Block means all the 64 channels laser finished the firing.

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

01) End time of Block6: (t0−42.58) µs;

02) End time of BlockN: (t0−42.58−55.56*(6−N)) µs;   04) End time of Block2: (t0−42.58−55.56*4) µs;

03) End time of Block3: (t0−42.58−55.56*3) µs;   05) End time of Block1: (t0−42.58−55.56*5) µs.

■ Dual Return Mode

There are 6 Blocks in every Point Cloud UDP Data Packet.

In the dual return mode, Block (1, 2) are corresponding to dual return ranging data for the same 64 channels laser firing, so they have the same firing time for each laser and the same end time for the Block. Similarly, Block (3, 4) and so on have same firing and end time.

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

01) End time of Block6: (t0−42.58) μs;

02) End time of Block5: (t0−42.58) μs;

03) End time of Block4: (t0−42.58−55.56*1) μs;

04) End time of Block3: (t0−42.58−55.56*1) μs;

05) End time of Block2: (t0−42.58−55.56*2) μs;

06) End time of Block1: (t0−42.58−55.56*2) μs;

Through the Block's end time, it is possible to calculate the laser firing time for every channel in the Block.

Take Block 6 for example, assuming Block 6's end time is t6, then:

01) Laser ID 51's firing time: (t6−(1.304*00 + 1.968*00 + 3.62)) μs;

02) Laser ID 61's firing time: (t6−(1.304*00 + 1.968*00 + 3.62)) μs;

03) Laser ID 45's firing time: (t6−(1.304*01 + 1.968*00 + 3.62)) μs;

04) Laser ID 60's firing time: (t6−(1.304*01 + 1.968*00 + 3.62)) μs;

05) Laser ID 39's firing time: (t6−(1.304*02 + 1.968*00 + 3.62)) μs;

06) Laser ID 57's firing time: (t6−(1.304*02 + 1.968*00 + 3.62)) μs;

07) Laser ID 09's firing time: (t6−(1.304*03 + 1.968*00 + 3.62)) μs;

08) Laser ID 55's firing time: (t6−(1.304*03 + 1.968*00 + 3.62)) μs;

09) Laser ID 49's firing time: (t6−(1.304*04 + 1.968*00 + 3.62)) μs;

10) Laser ID 63's firing time: (t6−(1.304*04 + 1.968*00 + 3.62)) μs;

11) Laser ID 43's firing time: (t6−(1.304*05 + 1.968*00 + 3.62)) μs;

12) Laser ID 59's firing time: (t6−(1.304*05 + 1.968*00 + 3.62)) μs;

13) Laser ID 07's firing time: (t6−(1.304*06 + 1.968*00 + 3.62)) μs;

14) Laser ID 56's firing time: (t6−(1.304*06 + 1.968*00 + 3.62)) μs;

15) Laser ID 53's firing time: (t6−(1.304*07 + 1.968*00 + 3.62)) μs;

16) Laser ID 64's firing time: (t6−(1.304*07 + 1.968*00 + 3.62)) μs;

17) Laser ID 47's firing time: (t6−(1.304*08 + 1.968*00 + 3.62)) μs;

18) Laser ID 62's firing time: (t6−(1.304*08 + 1.968*00 + 3.62)) μs;

19) Laser ID 41's firing time: (t6−(1.304*09 + 1.968*00 + 3.62)) μs;

20) Laser ID 58's firing time: (t6−(1.304*09 + 1.968*00 + 3.62)) μs;

21) Laser ID 06's firing time: (t6–(1.304*10 + 1.968*00 + 3.62)) µs;
22) Laser ID 54's firing time: (t6–(1.304*10 + 1.968*00 + 3.62)) µs;
23) Laser ID 05's firing time: (t6–(1.304*11 + 1.968*00 + 3.62)) µs;
24) Laser ID 48's firing time: (t6–(1.304*11 + 1.968*00 + 3.62)) µs;
25) Laser ID 04's firing time: (t6–(1.304*12 + 1.968*00 + 3.62)) µs;
26) Laser ID 50's firing time: (t6–(1.304*12 + 1.968*00 + 3.62)) µs;
27) Laser ID 03's firing time: (t6–(1.304*13 + 1.968*00 + 3.62)) µs;
28) Laser ID 52's firing time: (t6–(1.304*13 + 1.968*00 + 3.62)) µs;
29) Laser ID 02's firing time: (t6–(1.304*14 + 1.968*00 + 3.62)) µs;
30) Laser ID 46's firing time: (t6–(1.304*14 + 1.968*00 + 3.62)) µs;

31) Laser ID 01's firing time: (t6–(1.304*15 + 1.968*00 + 3.62)) µs;
32) Laser ID 44's firing time: (t6–(1.304*15 + 1.968*00 + 3.62)) µs;
33) Laser ID 24's firing time: (t6–(1.304*15 + 1.968*01 + 3.62)) µs;
34) Laser ID 33's firing time: (t6–(1.304*15 + 1.968*01 + 3.62)) µs;
35) Laser ID 27's firing time: (t6–(1.304*15 + 1.968*02 + 3.62)) µs;
36) Laser ID 42's firing time: (t6–(1.304*15 + 1.968*02 + 3.62)) µs;
37) Laser ID 21's firing time: (t6–(1.304*15 + 1.968*03 + 3.62)) µs;
38) Laser ID 36's firing time: (t6–(1.304*15 + 1.968*03 + 3.62)) µs;
39) Laser ID 15's firing time: (t6–(1.304*15 + 1.968*04 + 3.62)) µs;
40) Laser ID 30's firing time: (t6–(1.304*15 + 1.968*04 + 3.62)) µs;
41) Laser ID 22's firing time: (t6–(1.304*15 + 1.968*05 + 3.62)) µs;
42) Laser ID 37's firing time: (t6–(1.304*15 + 1.968*05 + 3.62)) µs;

43) Laser ID 16's firing time: (t6–(1.304*15 + 1.968*06 + 3.62)) µs;
44) Laser ID 31's firing time: (t6–(1.304*15 + 1.968*06 + 3.62)) µs;
45) Laser ID 10's firing time: (t6–(1.304*15 + 1.968*07 + 3.62)) µs;
46) Laser ID 25's firing time: (t6–(1.304*15 + 1.968*07 + 3.62)) µs;
47) Laser ID 19's firing time: (t6–(1.304*15 + 1.968*08 + 3.62)) µs;
48) Laser ID 34's firing time: (t6–(1.304*15 + 1.968*08 + 3.62)) µs;
49) Laser ID 13's firing time: (t6–(1.304*15 + 1.968*09 + 3.62)) µs;
50) Laser ID 28's firing time: (t6–(1.304*15 + 1.968*09 + 3.62)) µs;
51) Laser ID 20's firing time: (t6–(1.304*15 + 1.968*10 + 3.62)) µs;
52) Laser ID 35's firing time: (t6–(1.304*15 + 1.968*10 + 3.62)) µs;

53) Laser ID 14's firing time: (t6–(1.304*15 + 1.968*11 + 3.62)) µs;
54) Laser ID 29's firing time: (t6–(1.304*15 + 1.968*11 + 3.62)) µs;
55) Laser ID 08's firing time: (t6–(1.304*15 + 1.968*12 + 3.62)) µs;
56) Laser ID 23's firing time: (t6–(1.304*15 + 1.968*12 + 3.62)) µs;
57) Laser ID 17's firing time: (t6–(1.304*15 + 1.968*13 + 3.62)) µs;
58) Laser ID 32's firing time: (t6–(1.304*15 + 1.968*13 + 3.62)) µs;
59) Laser ID 11's firing time: (t6–(1.304*15 + 1.968*14 + 3.62)) µs;
60) Laser ID 26's firing time: (t6–(1.304*15 + 1.968*14 + 3.62)) µs;
61) Laser ID 18's firing time: (t6–(1.304*15 + 1.968*15 + 3.62)) µs;
62) Laser ID 38's firing time: (t6–(1.304*15 + 1.968*15 + 3.62)) µs;
63) Laser ID 12's firing time: (t6–(1.304*15 + 1.968*16 + 3.62)) µs;
64) Laser ID 40's firing time: (t6–(1.304*15 + 1.968*16 + 3.62)) µs;

Appendix III

PTP Protocol

The Precision Time Protocol (PTP), also referred as IEEE 1588 standard, is a protocol used to synchronize clocks throughout a computer network. It can achieve clock accuracy in the sub−microsecond range, and is suitable for measurement and control systems.
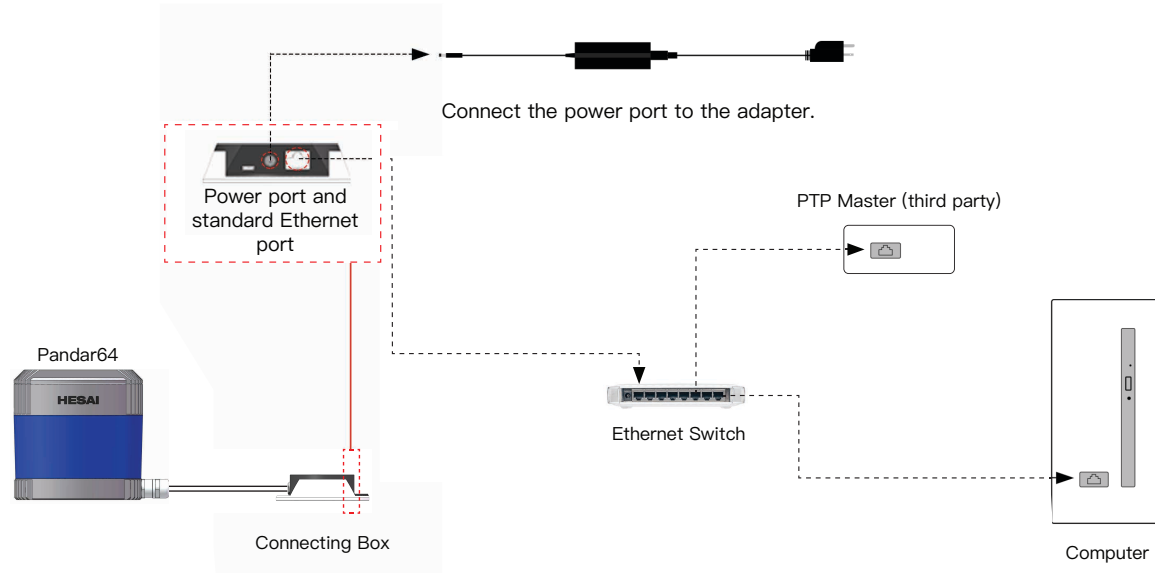
1 How to connect LiDAR using PTP protocol

Figure III.1 How to Connect LiDAR Using PTP Protocol

2 Absolute Time Calculation of Point Cloud Data Packet

In case of clock source from PTP, the user needs to connect a PTP master device to get the absolute time.

If PTP clock source is selected, LiDAR transmits only Point Cloud Data Packet with μs timestamps and 6 bytes UTC time. The μs timestamp and UTC time in the Point Cloud Data Packet are used to calculate the packing time of this data packet.

The user can calculate the absolute time by the following method:
Retrieve the μs timestamp and the time information (UTC, decimal number) from the Point Cloud Data Packet. The absolute time of Point Cloud Data Packet can be calculated by combining 2 parts: a) the 4 bytes μs timestamp; b) the 6 bytes UTC time information (decimal number) in Point Cloud Data Packet.

NOTE
1) The PTP master device is a third–party product and not included in LiDAR Package. The LiDAR clock just follow the PTP master device by PTP protocol.
2) The timestamp and 6 bytes UTC time in Point Cloud Data Packet strictly follow the PTP time from PTP master device. There may have offset with UTC time for certain PTP master device. Please verify the PTP master device configuration and calibration in order to get precise UTC time from PTP master device.
3) The LiDAR works as PTP slave device and the PTP protocol is Plug&Play. No additional setup is required.
4) If PTP clock source is selected but no PTP master device available, the LiDAR will have an increasing time from invalid past time. If PTP clock source was supplied and later stopped, the LiDAR will continue to count the time with internal clock.

NOTE
The calculation of laser firing time remains the same whether PTP is used or not. Please refer to Appendix II for details.

Appendix IV

Communication Protocol

This part describes the communication protocol supported by Pandar64 and detailed implementation.
1) Binary format is used to improve the communication performance.
2) Disabled Nagle's algorithm to improve the real–time performance.
3) Simple protocol includes fixed 8 bytes header and variable command specific payload size.

1 Packet Structure

The protocol includes the header and the payload. The header describes type of the command and the length of the payload. The load may differ in length/content by different type of command.
Following is the command message sent from client to server (LiDAR):

Type	Length	Field Description
0×47	1 byte	fixed content
0×74	1 byte	fixed content
Cmd	1 byte	the code for command, see command description for details
Return Code	1 byte	useless
Payload Length	4 bytes	the data length for the command, 0x00 means that the command does not need additional data
Payload	data length bytes	the additional data for the command, its length is indicated by "payload length" field

Table IV.1 Command Message Sent from Client to LiDAR

Following is the response message format sent from server (LiDAR) to client:

Type	Length	Field Description
0×47	1 byte	fixed content
0×74	1 byte	fixed content
Cmd	1 byte	the code for command, see command description for details
Return Code	1 byte	return code from server
Data Length	4 bytes	the additional data length for the command, 0x00 means that the command does not have payload
Payload	data length bytes	the payload data for the command, its length is indicated by "payload length" field

Table IV.2 Feedback Message Format from LiDAR to Client

NOTE LiDAR echos feedback message to every command it received.

2 Command Description

Command list is shown as Table IV.3.

Command	Command Code	Additional Data	Description
PTC_COMMAND_GET_LIDAR_CALIBRATION	0x5	None	to retrieve the LiDAR's calibration files
PTC_COMMAND_PTP_DIAGNOSTICS	0x6	PTP Query Type	to retrieve PTP-diagnostic for specified PTP Query Type
PTC_COMMAND_GET_INVENTORY_INFO	0x7	None	to retrieve the LiDAR inventory information
PTC_COMMAND_GET_CONFIG_INFO	0x8	None	to retrieve the LiDAR configuration parameters
PTC_COMMAND_GET_LIDAR_STATUS	0x9	None	to retrieve the LiDAR temperature, system uptime etc information

Table IV.3 Type of Command

■ PTC_COMMAND_GET_LIDAR_CALIBRATION

1) Function Description:
   To retrieve LiDAR calibration files

3) LiDAR Feedback Message Payload Content:
   The LiDAR calibration file data
   Format: CSV Format (ASCII) Including 3 fields
           (LaserID, Elevation, Azimuth Offset)

2) Description for Sending Data Package:
   Command Code: 0x5
   Payload Length: 0 byte

■ PTC_COMMAND_PTP_DIAGNOSTICS

1) Function Description:
   Obtain PTP diagnostics information from server

2) Description for Sending Data Package:
   Command Code: 0x6
   Payload Length: 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

Table IV.4 PTP Query Type

3) LiDAR Response Message Payload Content

a. PTP STATUS

PTP Query Type	Length	Description
master_offset	8 bytes	the offset between master/salve
ptp_state	4 bytes	"NONE", /*0*/ "INITIALIZING", /*1*/ "FAULTY", /*2*/ "DISABLED", /*3*/ "LISTENING", /*4*/ "PRE_MASTER"/*5*/ "MASTER", /*6*/ "PASSIVE", /*7*/ "UNCALIBRATED", /*8*/ "SLAVE", /*9*/ "GRAND_MASTER", /*10*/
elapsed_millisec	4 bytes	time elapsed in milliseconds since last handshake between master/slave

<div align="center">Table IV.5 PTP STATUS</div>

b. PTP TLV PORT_DATA_SET

Per IEEE–1588 standard management TLV PORT_DATA_SET

Fields	Length	Description
portIdentity	10 bytes	the port identity, including 8 bytes clock identity and 2 bytes port number
portState	1 byte	same as ptp_state in above message
logMinDelayReqInterval	1 byte	the minimum permitted mean time interval between Delay_Req messages it is specified as a power of two in seconds. The default is 0 (1 second).
peerMeanPathDelay	8 bytes	the peer mean path delay value in ns
logAnnounceInterval	1 byte	the mean time interval between Announce message of the portDS set
announceReceiptTimeout	1 byte	the number of missed Announce messages before the last Announce messages expires of the portDS set
logSyncInterval	1 byte	the mean time interval between Sync messages. It's specified as a power of two in seconds
delayMechanism	1 byte	the delay mechanism, possible values are E2E, P2P and Auto
logMinPdelayReqInterval	1 byte	the minimum permitted mean time interval between Pdelay_Req messages
versionNumber	1 byte	PTP version number, 2 as v2

<div align="center">Table IV.6 PTP TLV PORT_DATA_SET</div>

c. LinuxPTP TLV TIME_STATUS_NP (0xc000)

LinuxPTP specific TLV

Fields	Length	Description
master_offset	8 bytes	the time difference between master/slave at the last handshake
ingress_time	8 bytes	the hw ingress time stamp of the last sync message received by the slave
cumulativeScaledRateOffse	4 bytes	relative information in the last received follow_up message
scaledLastGmPhaseChange	4 bytes	relative information in the last received follow_up message
gmTimeBaseIndicator	2 bytes	relative information in the last received follow_up message
lastGmPhaseChange	10 bytes	relative information in the last received follow_up message
gmPresent	4 bytes	whether grandmaster is present
gmIdentity	8 bytes	the grandmaster identity if gmPresent is 1

Table IV.7 LinuxPTP TLV TIME_STATUS_NP

d. LinuxPTP TLV GRANDMASTER_SETTINGS_NP (0xc001)

Fields	Length	Description
clockQuality	4 bytes	the clock quality of the current grand master clock the slave selected
utc_offset	2 bytes	the UTC_Offset value set by the grand master clock
time_flags	1 byte	the time flag of the grand master
time_source	1 byte	the time source of the grand master

Table IV.8 LinuxPTP TLV GRANDMASTER_SETTINGS_NP

■ PTC_COMMAND_GET_INVENTORY_INFO

1) Function Description:
   To retrieve the LiDAR inventory information

2) Description for Sending Data Package:
   Command Code: 0x7
   Payload length: 0 byte

3) LiDAR Response Message Payload Content

Fields	Length	Description
sn	18 bytes	the serial number of the device
date_of_manufacture	16 bytes	the date of manufacture string of the device in ASCII format yyyy–mm–dd
mac	6 bytes	the mac address of the device.
sw_ver	16 bytes	the software version of the device in ASCII format xx.xx.xx
hw_ver	16 bytes	the hardware version of the device in ASCII format
control_fw_ver	16 bytes	the control firmware version of the device in ASCII format
sensor_fw_ver	16 bytes	the sensor firmware version of the device in ASCII format
reserved	16 bytes	–

Table IV.9 LiDAR Response Message Payload Content

■ PTC_COMMAND_GET_CONFIG_INFO

1) Function Description:
   To retrieve the LiDAR configuration parameters

2) Description for Sending Data Package:
   Command Code: 0x8
   Payload length: 0 byte

3) LiDAR Response Message Payload Content

Fields	Length	Description
ipaddr	4 bytes	default 192.168.1.201 the configure IP address of the device
mask	4 bytes	default 255.255.255.0 the IP Mask of the device
gateway	4 bytes	default the default gateway of the device
dest_ipaddr	4 bytes	default 255.255.255.255 the destination IP address of the LiDAR point cloud data UDP packet
dest_lidar_udp_port	2 bytes	default 2368 the destination UDP port of the point could data packet
dest_gps_udp_port	2 bytes	default 10110 the destination UDP port of the GPS packet when the LiDAR is working with GPS input, valid only when 'clock_source' is 'GPS'
spin_rate	2 bytes	the configured rotation speed of the device
sync	1 byte	default 0 synchronizing the given angle (sync_angle) with the PPS of GPS or not 0–disabled 1–enabled
sync_angle	2 bytes	defulat 0
start_angle	2 bytes	default 0. the device device will report point cloud data with angle ranges between 'start_angle' and 'stop_angle'
stop_angle	2 bytes	default 36000, in unit of 100th degree

Fields	Length	Description
clock_source	1 byte	default 0–GSP the configure clock source, 0–GPS, 1–PTP
udp_seq	1 byte	default 0–off 0–off, 1–on. whether the point cloud data will include a UDP sequence number field
reserved	16 bytes	reserved for future

Table IV.10 LiDAR Response Message Payload Content

■ PTC_COMMAND_GET_LIDAR_STATUS

1) Function Description:
   To retrieve the LiDAR temperature, system uptime etc information

2) Description for Sending Data Package:
   Command Code: 0x9
   Payload length: 0 byte

3) LiDAR Response Message Payload Content

Fields	Length	Description
system_uptime	4 bytes	the system uptime in seconds
motor_speed	2 bytes	the real–time motor speed
temperature	4*8 bytes	the real–time temperature array (unit: 0.01°C) 0 – bottom circuit board T1 4 – receiving board RT2 1 – bottom circuit board T2 5 – Top circuit RT3 2 – laser emitting board RT_L 6 – Top circuit RT4 3 – receiving board RT_R 7 – Top circuit RT5
reserved	16 bytes	–

Table IV.11 LiDAR Response Message Payload Content

Appendix V

Data Structure with UDP Sequence On

When UDP sequence is ON, Point Cloud UDP Packet size changes from 1194 bytes to 1198 bytes, with Tail changes from 22 bytes to 26 bytes.
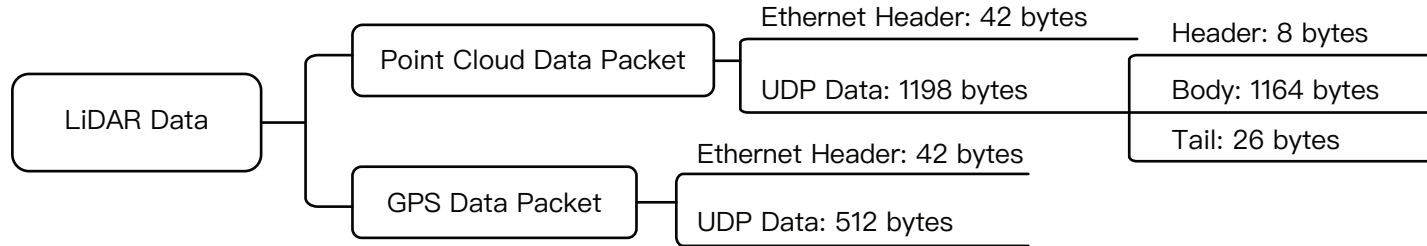
Figure V.1 Data Structure with UDP Sequence On

Here is the definition of point cloud data packet ethernet header, in which the UDP length 2 bytes changes to 0x4b6 representing 1206 bytes.

Ethernet Header: 42 bytes		
Ethernet II MAC	12 bytes	Destination: Broadcast (0xFF: 0xFF: 0xFF: 0xFF: 0xFF: 0xFF), Source: (xx:xx:xx:xx:xx:xx)
Ethernet Data Packet Type	2 bytes	0x08, 0x00
Internet Protocol	20 bytes	Version, Header Length, Differentiated Services, Field, Total Length, Identification, Flags, Fragment Offset, Time to Live, Protocol, Header Checksum, Source IP Address, Destination IP Address
UDP Port Number	4 bytes	UDP source port (0x2710, represents 10000), destination port (0x0940, represents 2368)
UDP Length and Checksum	4 bytes	Length 2 bytes (0x04b6, represents 1206 bytes), checksum 2 bytes

Table V.1 Point Cloud Data Packet Ethernet Header Definition

Tail changes to 26 bytes, adding 4 bytes UDP sequence number.

Tail: 26 bytes		
Reserved	5 bytes	reserved data, meaningless
High Temperature Shutdown Flag	1 byte	0x01 means high temperature; 0x00 means normal operation · during normal operation, shutdown flag keeps being 0x00 · if high temperature is detected and system needs to be shut down, the shutdown flag will be set to 0x01, and the system will be shut down after 60 seconds. The flag keeps being 0x01 during the 60 seconds and shutdown period · after the high temperature shutdown, the LiDAR temperature will decrease. When the system is not in high temperature status, the shutdown flag will be reset to 0x00 and the system can return to normal operation
Reserved	2 bytes	reserved data, meaningless
Motor Speed	2 bytes	speed_2_bytes [15:0] = speed (RPM)
GPS Timestamp	4 bytes	the packing time of this data packet, the unit is 1 µs, value range 0 µs–1000000 µs (1 s)
Return Mode Information	1 byte	the strongest return (0x37), the last return (0x38), dual return (0x39)
Factory Information	1 byte	0x42 (or 0x43)
UTC	6 bytes	year, month, date, hour, minute, second, decimal digit
UDP Sequence	4 bytes	added when UDP sequence feature is ON label the sequence number for UDP packet when LiDAR is sending point cloud data packet, the sequence number will label from 1 to 0xFFFFFFFF, the sequence is stored in Little Endian format

Table V.2 Point Cloud Data UDP Packet–Tail

Appendix VI Phoenix Contact

Pandar64 can use Phoenix Contact (PN: SACC–M12FS–8CON–PG 9–SH) as the communication connector. The cable length from LiDAR exit to the tip of the connector is 0.3 m.

Figure VI.1 Phoenix Contact

First View:
The direction from the eye to the interface as shown
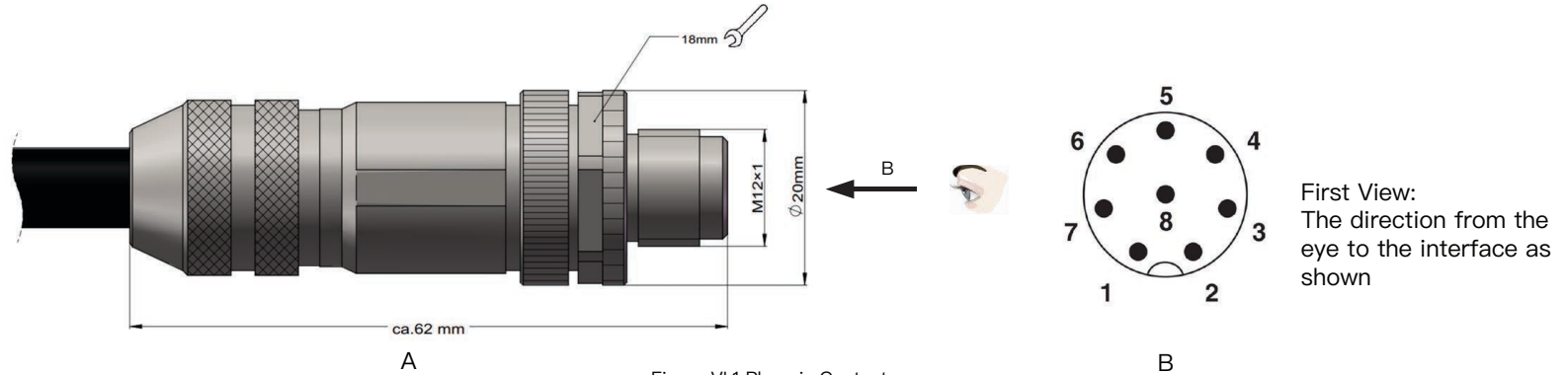
Pin #	Function	Color	Voltage
1	Ethernet RX–	Blue	–1V to 1V
2	Ethernet RX+	Light Blue (Blue/White)	–1V to 1V
3	Ethernet TX–	Orange	–1V to 1V
4	Ethernet TX+	Light Orange (Orange/White)	–1V to 1V
5	GPS Serial Data	White	–13V to +13V
6	GPS PPS	Yellow	3.3V/5V
7	+12V	Red	12V
8	Ground (Return)	Black	

Table VI.1 Phoenix Contact Description

Appendix VII

PandarView

PandarView is a software that is used to play and record the point cloud data. Installations are available on platforms: Windows 7x64/ Windows 8x64/Windows 10x64/Ubuntu−16.04. The installation package can be found in the provided USB disk in the LiDAR box.

1 PandarView Installation

Please install the PandarView and set the computer static IP address to 192.168. 1.100 before running.

■ Installation

System	Installation Files	Installation Steps	Finish Installation
Windows	PandarView_Windows_V1.5.5.msi python-2.7.13.msi	1. Double−click on python_2.7.13 2. Double−click on PandarView_v1.5.5_Windows (install with default settings)	Pandar.exe shortcut will show on the desktop after installation:
Ubuntu−16.04	PandarView_Installer_V1.5.5.tar.gz	1. Enter the following command at the terminal: sudo apt−get install qt4−default libboost−all−dev. 2. Unzip the installation file 3. Run PandarView_Installer.bin	

Table VII.1 PandarView Installation Steps

■ IP Configuration

Ubuntu−16.04:
The IP address can be configured on the terminal by using the ifconfig command:
~$ sudo ifconfig enp0s20f0u2 192.168.1.100
Replace enp0s20f0u2 with the local network port name.

Windows:
① Open the Network Sharing Center, click on "Ethernet".
② In the "Ethernet Status" interface, click on "Properties" to proceed to the next interface.
③ Double−click on "Internet Protocol Version 4 (TCP/IPv4)".
④ Configure the IP address to 192.168.1.100 and the subnet mask to 255.255.255.0, then click "OK" to finish configuration.

2 PandarView Instructions

■ Check Live Data

Run PandarView, click on ⚡ and select your LiDAR model to begin receiving data over Ethernet.
Windows：Double-click shortcut "Pandar" 🔴 and you will see an initial interface.
Ubuntu-16.04: Double-click the shortcut on the desktop (if you set "Run executable text files when they are opened"), or open the terminal, enter:
~/Desktop/PandarView to open the software.
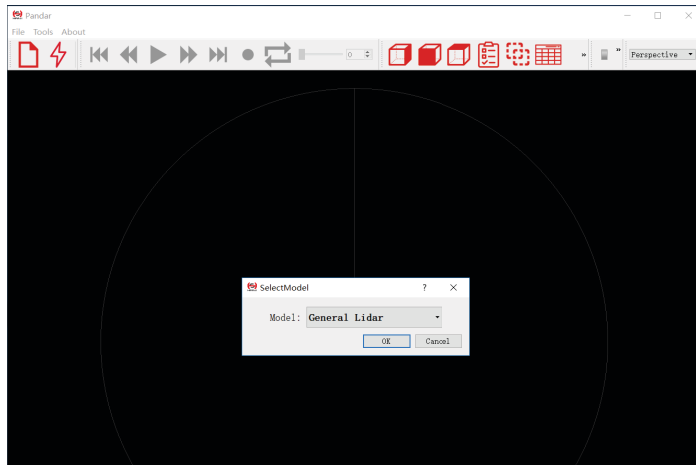
Figure VII.1 Select LiDAR Model

■ Record Pcap Files

In real-time play mode, click on the icon ● to pop up the "Choose Output File" window. Click on "Save" to begin recording a pcap file.
After recording, click on ● again to stop recording the pcap file.
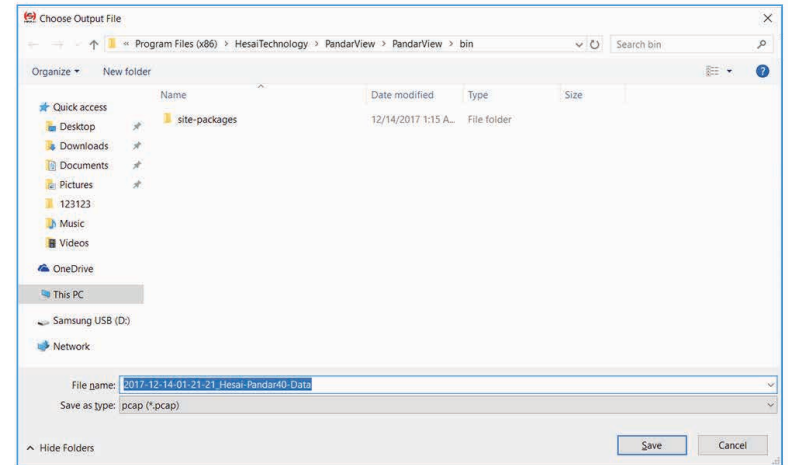
Figure VII.2 Choose Output File Window

■ Play Pcap Files

Click on the icon ▯ to open the "Choose Open File" window. Select the pcap file and click on the icon Open .

Click on ▶ to play the pcap file and visualize point cloud data.
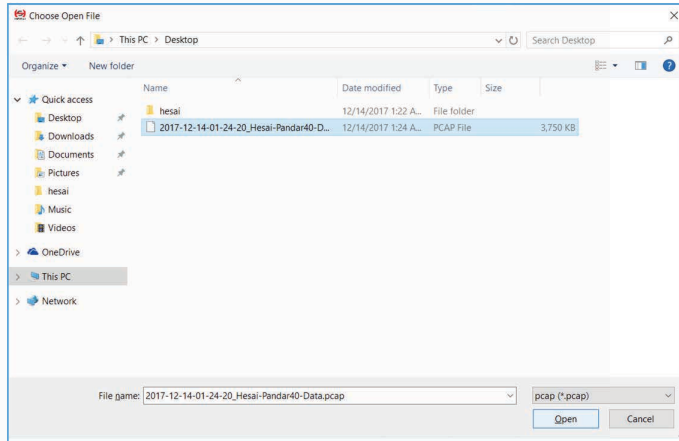
Figure VII.3 Choose Open File Window
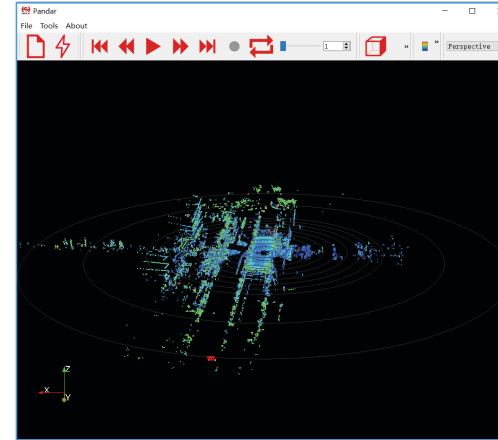
Figure VII.4 Ready to Play the Pcap File

■ Import Correction File
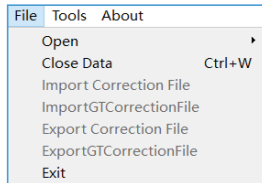
Figure VII.5 File Menu

Each LiDAR comes with a correction file (CSV) in the provided USB disk.
In the play mode, click on "File" in the upper left corner. Choose "Import Correction File" in the drop-down menu, select and open the correction file to display the calibrated point cloud.

NOTE PandarView 1.4.2 and above support to retrieve correction file from LiDAR automatically.

■ Play Buttons

Button	Description					
⏮	Jump to beginning of the file.					
⏪	1. While paused, click to view point cloud data from previous frame. 2. While playing, rewind (click again for different speeds, such as 2x, 3x, 1/2x, 1/4x, 1x speeds).	⏪ 2X	⏪ 3X	⏪ 1/2X	⏪ 1/4X	⏪
▶	1. After the point cloud file has finished loading, click on ▶ to play. 2. While playing, click on ❚❚ to pause.					
⏩	1. While paused, click to view point cloud data in next frame. 2. While playing, forward (click again for different speeds, such as 2x, 3x, 1/2x, 1/4x, 1x speeds).	⏩ 2X	⏩ 3X	⏩ 1/2X	⏩ 1/4X	⏩
⏭	Jump to end of the file.					
⬤	While playing pcap file, the recording button will be gray and unclickable.					
⟲	While playing pcap file, click on this button to loop playback, else playback will stop at the end of file.					
▭ 3210 ⏶⏷	Progress bar: drag to control playback speed, or enter frame number to jump to the desired frame.					

Table VII.2 Play Buttons Description

3 PandarView Features

■ View Direction Selection

Click on the following buttons to view the point cloud data from different directions.

Right POV   Front POV   Top POV

Figure VII.6 View Direction Selection

■ Mouse Shortcuts
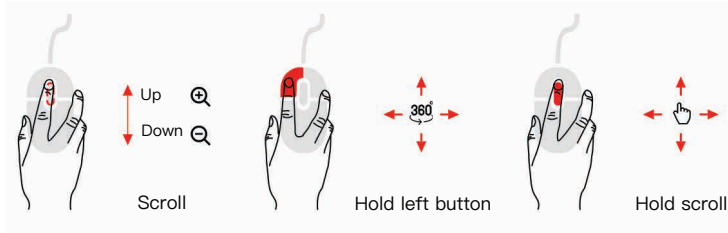
Figure VII.7 Mouse Shortcuts

01. Slide scroll wheel to magnify/minimize
02. Drag while holding left button to adjust view angle
03. Drag while holding scroll wheel to pan

■ 3D Projection Mode Switching
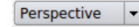
PandarView enables switching between two types of 3D projection methods (Orthogonal Projection and Perspective Projection) through the drop–down menu.

In Orthogonal Projection view, click on ▭ , thereafter while holding "Control" on the keyboard, select a point and hold down the left mouse button in order to create a spatial distance reference, in units of meters. Click on ▭ again to cancel the distance reference.

■ Distance Reference Circle

Click on ◉ to show/hide 12 gray distance reference circles. The corresponding actual distances are as shown above. The lower left axis shows the current viewing position. Click "Tools" to open "Grid Properties", where you can change the color and width of the circles.
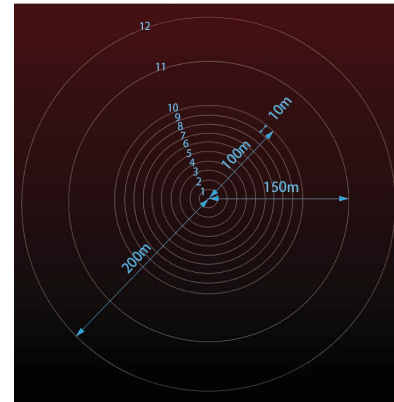
Figure VII.8 Distance Reference Circle
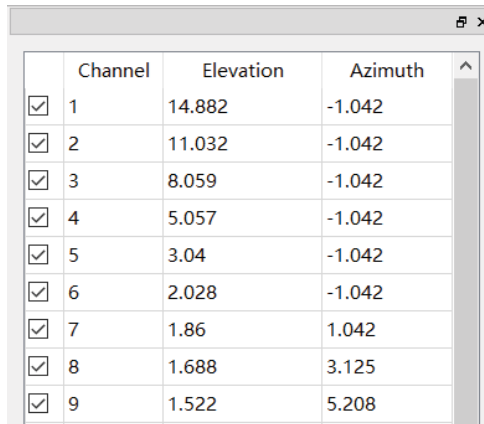
■ Return Mode

Return Mode: block1 Return ▼

Users can switch to different return modes using the "Return Mode" drop–down list: block1 return, block 2 return, and dual return.

■ Point Cloud Data Selection

Users can click on 📋 to display or hide point cloud data from any selected laser channels. Clicking on this icon will pop up the following interface. Click on 📋 again to close the interface.
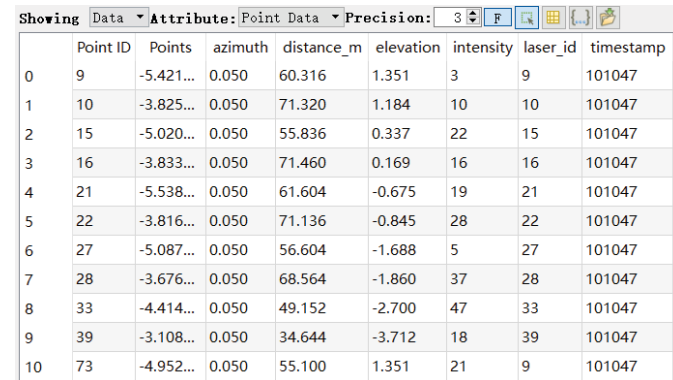
	Channel	Elevation	Azimuth
☑	1	14.882	-1.042
☑	2	11.032	-1.042
☑	3	8.059	-1.042
☑	4	5.057	-1.042
☑	5	3.04	-1.042
☑	6	2.028	-1.042
☑	7	1.86	1.042
☑	8	1.688	3.125
☑	9	1.522	5.208

Figure VII.9 Channel Display

Click on the left–side checkboxes to show/hide any given channel's display. Check the "Enable/Disable all" option in the bottom left corner to show/hide all channels at once.

Click on ⬚ to select visible points. Users can hold down the left button to box a certain area for selection. The selected points will be highlighted. Click on ▦ to view detailed data of the selected point cloud. Click on ⬚ again, select an area outside of the point cloud data to deselect.

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

	Point ID	Points	azimuth	distance_m	elevation	intensity	laser_id	timestamp
0	9	-5.421...	0.050	60.316	1.351	3	9	101047
1	10	-3.825...	0.050	71.320	1.184	10	10	101047
2	15	-5.020...	0.050	55.836	0.337	22	15	101047
3	16	-3.833...	0.050	71.460	0.169	16	16	101047
4	21	-5.538...	0.050	61.604	-0.675	19	21	101047
5	22	-3.816...	0.050	71.136	-0.845	28	22	101047
6	27	-5.087...	0.050	56.604	-1.688	5	27	101047
7	28	-3.676...	0.050	68.564	-1.860	37	28	101047
8	33	-4.414...	0.050	49.152	-2.700	47	33	101047
9	39	-3.108...	0.050	34.644	-3.712	18	39	101047
10	73	-4.952...	0.050	55.100	1.351	21	9	101047

Figure VII.10 Detailed Data of Selected Point Cloud

The main data shown about the points are their id, x, y and z values, angle, distance, reflectivity, corresponding channel id and timestamp (μs) information.

■ **Click** 🚀 **to compensate the azimuth error caused by the delay of laser activation.**

■ **Color Schemes**
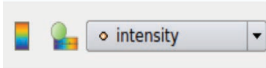
By clicking on ▮, users can see the current color scheme in the lower right corner. The drop−down list is used to choose different color schemes. The default color scheme of point cloud is drawing according to the intensity. Users can choose azimuth, distance, laser_id, or timestamp as the color scheme as well.
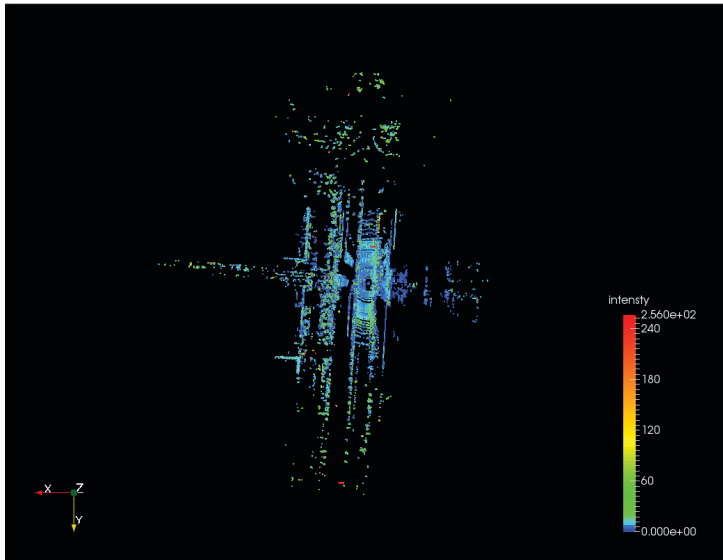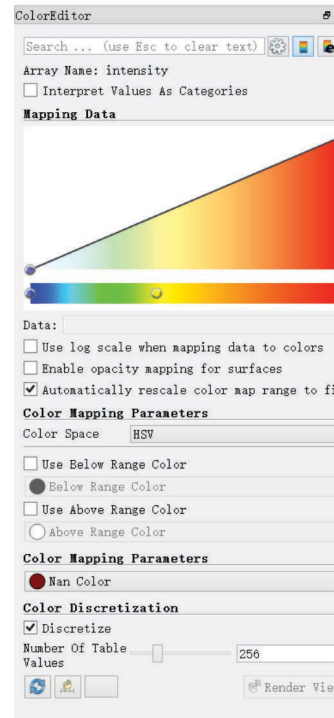

Figure VII.11 Current Color Scheme

Figure VII.12 Color Editor

Click on 🎨 to open "Color Editor", where users can customize colors. Click the button again to close the color editor.

■ PandarView Software Version

Click "About" in the upper left corner to check the software version.

Figure VII.13 PandarView Softeware Version

Appendix VIII

FCC Statement

FCC ID: 2ASO2PANDAR

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.

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 IV

Support and Contact

■ **Technical Support**

If you have any problems, and cannot find the solution in this manual please contact us:
E-mail: service@hesaitech.com
Website: www.hesaitech.com
GitHub: https://github.com/HesaiTechnology
NOTE If you have any questions about the open source we provide on GitHub, please leave your questions under corresponding projects.

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2) The defect is caused by abuse or misuse of the product or by environmental conditions that are not in conformance with the recommended operating condition of the product.
3) Repairs or product modifications, alterations and disassemble have been carried out by unauthorized personals.
4) The unit was stolen, lost or discarded.
5) The damage to the unit is caused by the event of force majeure, including but not limited: abnormal voltage, water or fire, natural disaster or transport accident.

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