DATASHEET
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ORBBEC® Pulsar Series LiDAR

ORBBEC Inc.

SL450

Revision History

Version	Date	Note
V1.0	2024.12.6	● Initial release
V1.1	2024.12.27	● Modify installation instructions ● Correct some spelling and descriptive errors, optimize some formatting
V1.2	2025.3.5	● Change the product series description; ● Update the official website address.

Content

1 Description and Features

SL450 uses innovative direct Time of Flight (dToF) ranging technology. The LiDAR comprises a precise rotating-mirror optical scanning system and a high-frequency laser pulse transmitter. Sophisticated optical, mechanical and structural design permits robust and accurate scanning within 270°/≥45m (@90% reflectivity). The LiDAR can be widely used in many fields, including robot positioning and navigation, area security, logistics, environmental scanning, and 3D reconstruction.

Product Specification

Product	**SL450**	**Remarks**
Measurement principle	dToF	Direct Time of Flight
Measurement range	0.05~45.0m@90% reflectivity 0.05~15.0m@10% reflectivity	The accuracy value of 0.05 to 0.1m is out of specification and is used only for obstacle avoidance
Accuracy [1]	±20mm@90% reflectivity ±25mm@10% reflectivity	At least 100 times data statistics are collected. The accuracy is the difference between the mean and true value of the data, and the precision is the standard deviation value of the data (1σ).
Precision [2]	≤15mm@90%&10% reflectivity	
Output data	Distance, angle, intensity	
Scanning angle	270°	
Measurement frequency [3]	72kHz	Measurements per second
Rotation frequency	15Hz/20Hz/25Hz/30Hz/40Hz	Default 20Hz
Angular resolution [4]	0.075°/0.1°/0.125°/0.15°/0.2°	Angular resolution corresponds one-to-one with rotational speed
Emission pitch angle	0° ± 0.5°	With the underside plane of the housing as the reference
Laser wave length	903±10nm	
Ambient light limit [5]	60,000Lux	
Multi-device anti-interference	Yes	
Operating voltage	24V(9~28V DC)	
Power consumption	Typ. <3W Max. <5W	
Interface type	100Mbps RJ45 Ethernet connector(female port) Power supply and time synchronization connection cable(female port)	See interface definition for details
Dimensions	60mm×60mm×88mm	L×W×H (without connection cable)
Weight	~320g	Cable included

Degree of protection	IP65	IEC 60529:2013; GB/T 4208-2017
EMC		EN IEC 61000-6-1:2019 EN IEC 61000-6-3:2021
Laser class	Class1	IEC 60825-1：2014
Anti-vibration [6]	Sinusoidal Vibration: 0.75mm amplitude, 10~55~10Hz frequency, 1oct/min sweep speed. Random vibration: 10~500Hz frequency, 0.05g^2/Hz power spectral density, 7.02g root mean square, +6dB/oct (10~20Hz) Slope	GB/T 2423.10-2019 GB/T 2423.56-2018
Anti-shock	50g acceleration, 11ms pulse width, 5s interval time, ±3 one-time shocks/axis	IEC 60068-2-27：2008 GB/T 2423.5-2019
Ambient operation temperature [7]	-10°C~55°C	
Storage temperature	-20°C~70°C	
Relative humidity	0~85%	no moisture condensation
Certification	CE-EMC/FCC/RoHS2.0/REACH, Class1,FDA registration	

Notes:

The ranging performance is derived from laboratory tests, which is under standard diffuse reflective target plates, precision guide rails, temperature control at 25°C and indoor ambient light conditions. Please contact for detailed data and test reports. LiDAR is a precision photoelectric sensor, and its test results are related to the installation method, temperature, humidity, vibration, environment, and other factors. Please pay attention to protection when using the sensor and refer to the guidance given by technical support staff for operation.

1. **Measurement accuracy**: the absolute error within 10 & 30m under laboratory conditions with 10% & 90% reflectivity, respectively.
2. **Measurement precision**: the relative error under laboratory conditions at 10% and 90% reflectivity, and working distances within 10 and 30 meters, respectively. The measurement results may be affected by environmental factors such as target distance and reflectivity.
3. **Measurement frequency**: output frequency of measurement data calculated with a 360° horizontal field of view.
4. **Angular resolution**: 0.075°/0.1°/0.125°/0.15°/0.2° refer to the angular resolution values at the measurement frequency of 72 kHz, corresponding to the rotation frequency of 15Hz/20Hz/25Hz/30Hz/40Hz respectively. The actual angular resolution may vary slightly due to the fluctuation of the real-time rotation frequency under the user's usage scenario.
5. **Ambient light limit**: this refers to the ability of the LiDAR to function normally for distance measurement under the specified ambient light conditions, but the accuracy and precision of its measurement results may slightly diminish as the light intensity increases. It is also necessary to avoid direct exposure of strong light to the LiDAR's optical area.
6. **Anti-vibration**: this is the test standard passed for laboratory reliability. If the actual usage scenario involves vibrations stronger than this standard or with an acceleration greater than 2G, it will affect the performance of the LiDAR motor. It is recommended to add shock absorption measures or purchase a matching shock absorption base for use.
7. **Temperature**: this refers to the range of temperatures within which the LiDAR can ensure normal operation. At the extreme limits of this range, there is a possibility of slight deviations in accuracy performance.

2 Introduction

2.1 Purpose

This document describes the specifications and some design details of ORBBEC® Pulsar Series SL450 LiDAR products, as well as for developers to understand and use the related products.

2.2 Terminology

SL450 is a 2D light detection and ranging (LiDAR) sensor launched by ORBBEC. The LiDAR uses innovative direct Time of Flight (dToF) ranging technology. The LiDAR comprises a precise rotating-mirror optical scanning system and a high-frequency laser pulse transmitter. Sophisticated optical, mechanical and structural design permits robust and accurate scanning within 270°/≥15m (@10% reflectivity). The LiDAR can be widely used in many fields, including robot positioning and navigation, area security, logistics, environmental scanning, and 3D reconstruction.

2.3 Introduction to Working Principle

The measurement principle is the direct time of flight method (Direct Time of Flight, dToF). The distance measurement formula is:

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

Where d denotes the distance, c denotes the speed of light, and t denotes the time of flight.

When the ranging module works, the laser transmitter sends out a laser pulse, which is projected onto the surface of the object and reflected. The ranging chip receives the reflected light and accurately calculates the distance from the target object to the LiDAR by measuring the flight time of the laser beam in the air. Through the built-in brushless motor, the distance is measured at different angles by rotating the ranging module, thus scanning to obtain the point cloud outline of the surrounding environment.

3 Product Composition

3.1 Component Composition

SL450 Component description shown in the figure below.

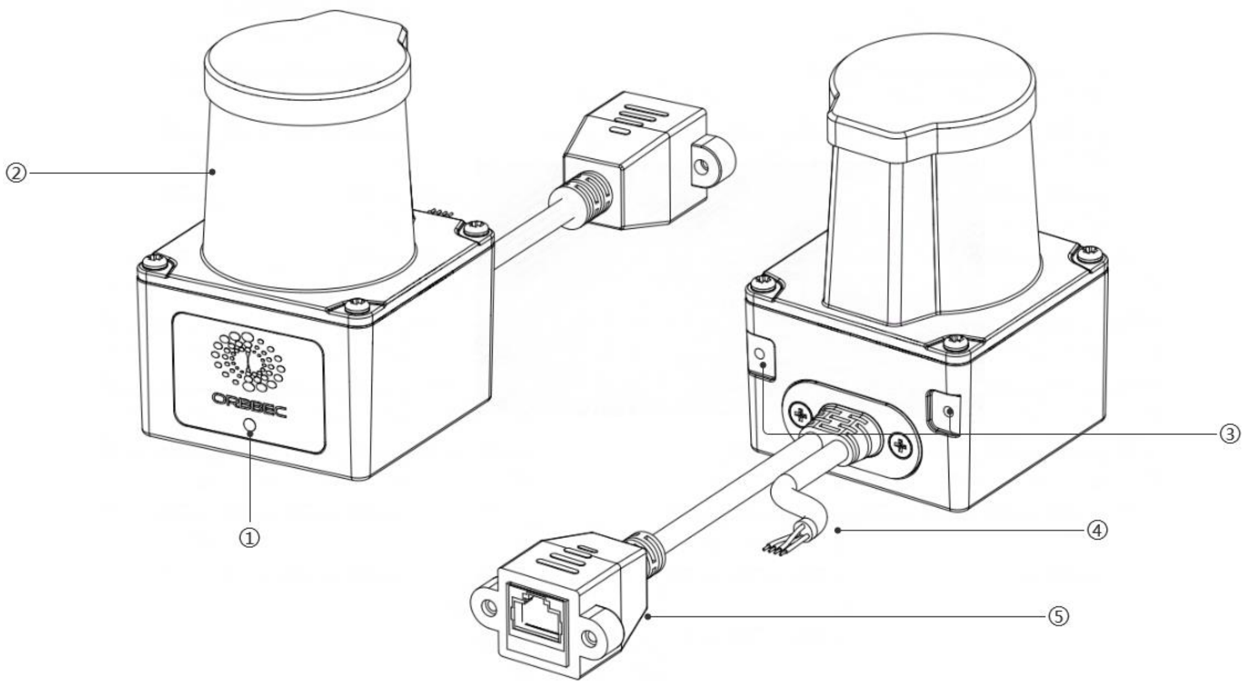

Figure 3-1-1 SL450 Component description

① **LED Indicators**

Indicate the working status of the LiDAR

- White light constantly on: Normal operating and ranging mode.
- White light flashing slowly (1 second per flash cycle): In standby mode, the motor is not rotating.
- White and pink lights flashing alternately (1 second per flash cycle): LiDAR warning, the point cloud data is considered reliable.
- Red light flashing very slowly (2 seconds per flash cycle): LiDAR network has dropped.
- Red light flashing slowly (1 second per flash cycle): LiDAR error, the point cloud data is not reliable.
- Red light flashing rapidly (0.1 second per flash cycle): FPGA anomaly detected, the LiDAR will automatically restart after 30 seconds.
- No light: Power supply issue

② **Optical window**

The laser pulse is emitted through the window to scan the object within the scanning range. When installing, please pay attention to the laser transmission and reception area to avoid blocking it, which may affect its use. For detailed dimensions, refer to the installation dimensions.

③ **Side Mounting Holes**

There are 2 M3 mounting holes on the side of the device for installation

④ **Multicore Cable**

Multicore cable is used for LiDAR power supply and synchronization signals. For the wiring sequence, please refer to Figure 3-2-3.

⑤ **Ethernet Port**

The Ethernet port (RJ45 female connector) is used for LiDAR data transmission, and is 0.58 meters long. For the wiring sequence, please refer to Figure 3-2-2。

3.2 Interface Definition

SL450 is equipped with highly reliable Ethernet cable for communication and multi-core cable with terminal connectors or open wiring for power supply, to facilitate power connection, control signals, and the transmission of data.

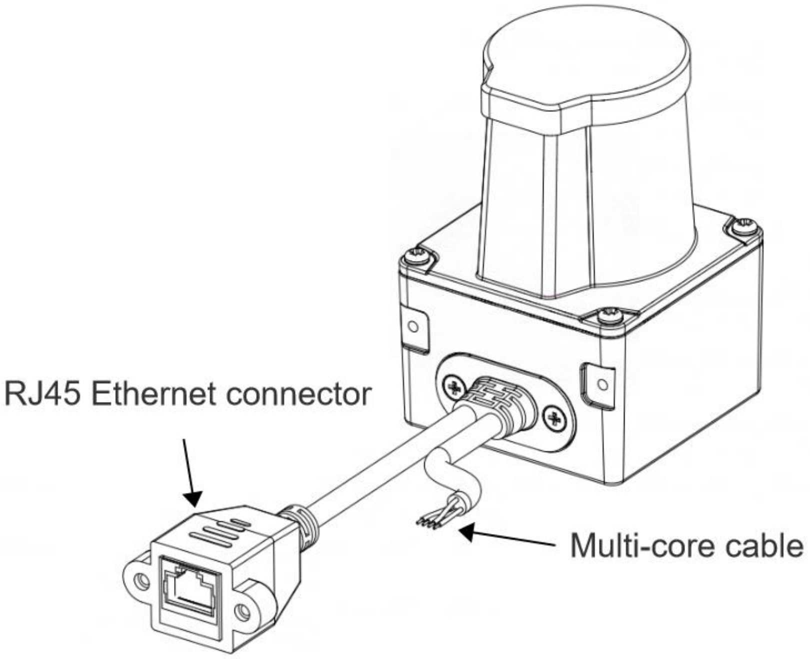

Figure 3-2-1 SL450 Interface Definition

Users can connect the PC to the LiDAR via this cable bundle for preliminary performance evaluation and early development of the LiDAR. This interface also serves as the control and data transmission interface for the target device developed by the user.

The following figure shows the pinout:

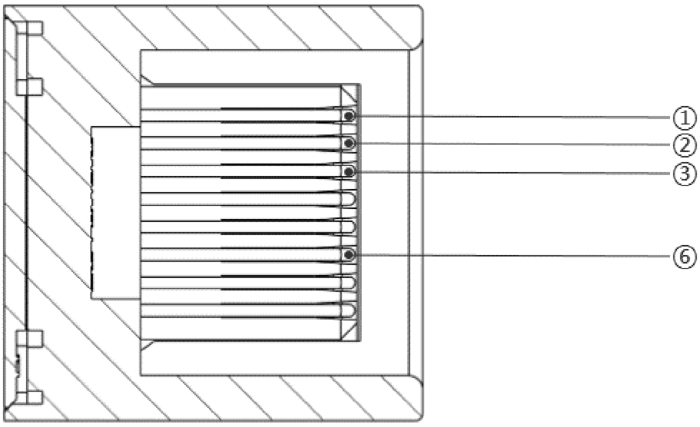

Figure 3-2-2 Ethernet connector layout

Table 3-2-1 Ethernet connector pinout

Pin No.	Signal	Description
1	Tx Data+	Data output+
2	Tx Data-	Data output -
3	Rx Data+	Data input+
6	Rx Data-	Data input -

There is a 4-core cable on the rear of the housing for power supply and time synchronization signal.

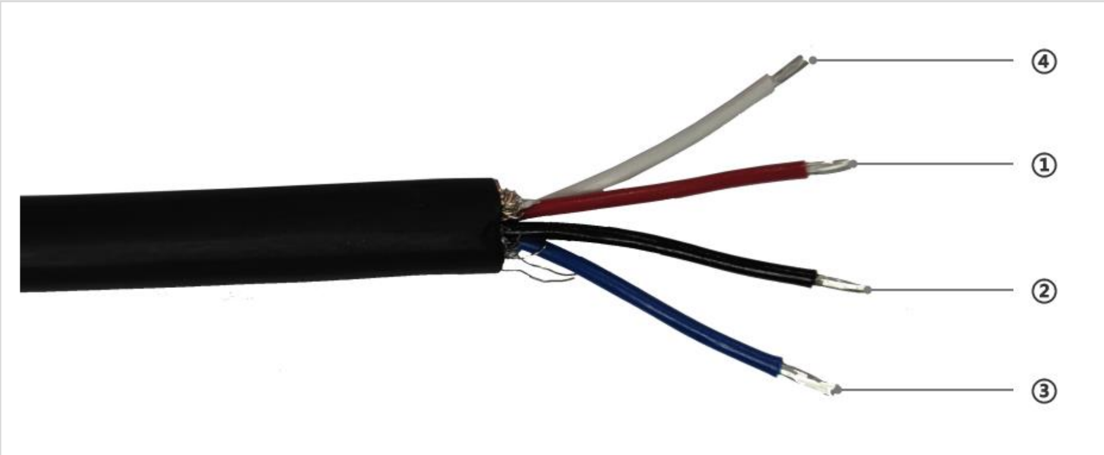

Figure 3-2-3 Multi-core cable layout

Table 3-2-2 multi-core cable pinout

Pin No.	Signal	Description	Color
1	Power	Input power supply+, DC 9~28V	Red
2	Ground	Input power supply-, ground	Black
3	GPS_PPS	Input 3.3V TTL level, pulse per second	Blue
4	Sync	Output open-drain pulse over zero-angle	White

Based on the 4-core cable, we have added a FHG connector at the end, so users can design a corresponding connector on their own machines to directly plug in for power supply and signal use. If users have their own alternative design, they can also simply cut off the connector and use it, which means the cable end will be bare wires.

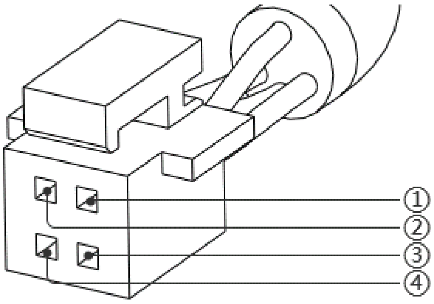

Figure 3-2-4 Connector style and pin NO.

3.3 Installation

3.3.1 Installation Dimension

SL450 has two M3 mounting holes with an effective thread depth of 7mm on its bottom, as well as two positioning holes with a depth of 6mm for installation. Users can install the LiDAR in the appropriate position based on the size and mounting hole dimensions of the SL450 shown in the figure below.

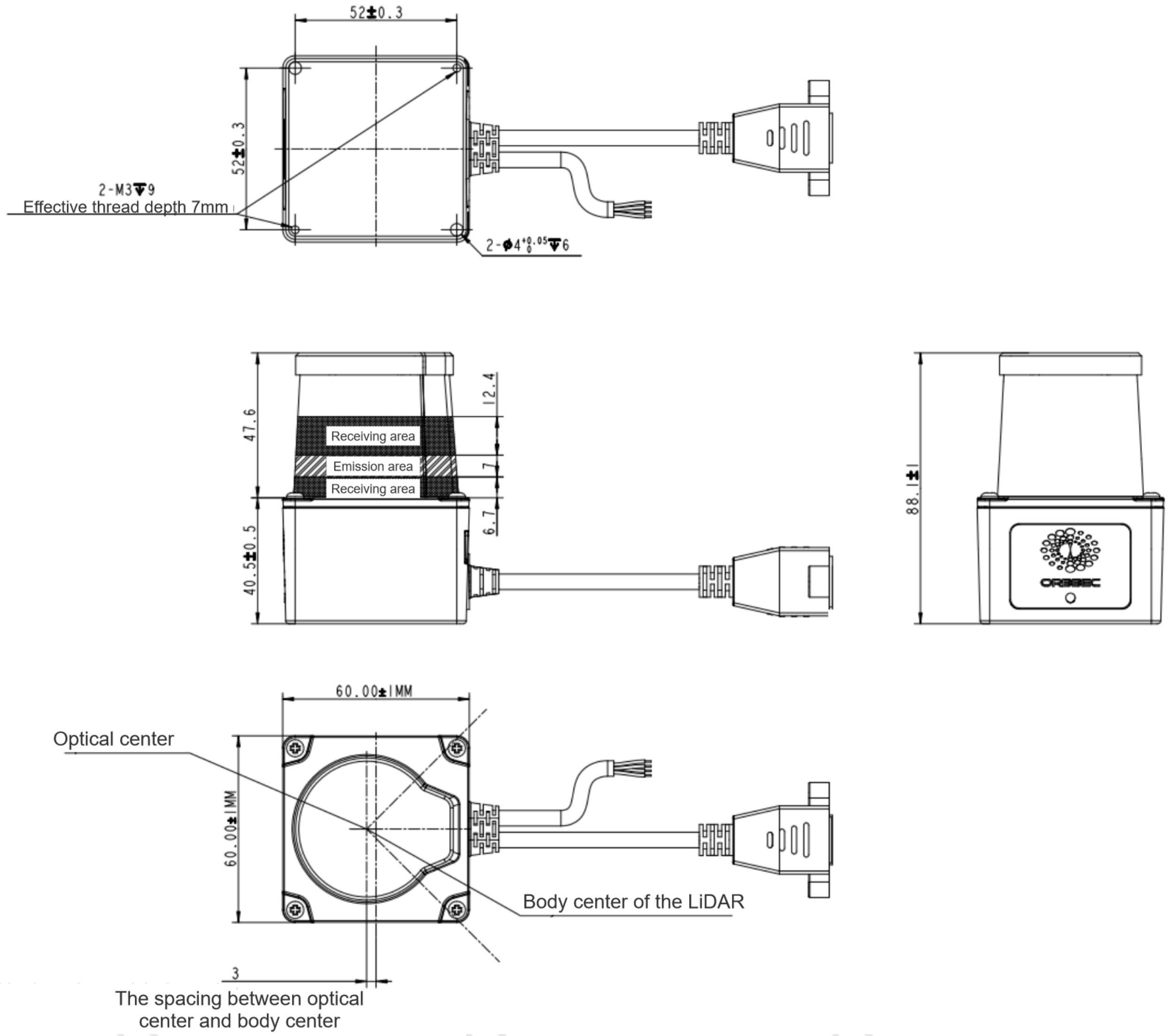

Figure 3-3-1 SL450 Dimensional Structure

The emission pitch angle of SL450 is slightly different. With underside plane of the housing as the reference, the pitch angle is within ±0.5°, as shown in the figure below. When mounting, the emission pitch angle should be considered to make sure that the emitting laser pulse points to the target objects

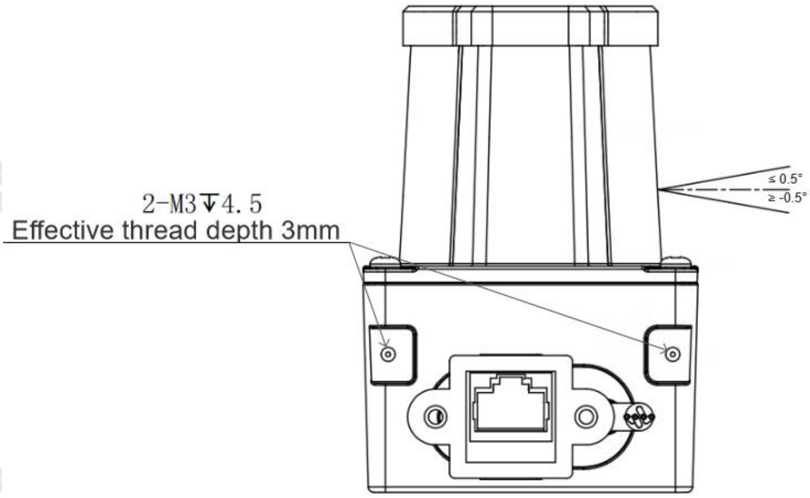

Figure 3-3-2 SL450 emission pitch angle and back mounting hole

The scanning angle of SL450 is 270°, and the laser emission and receiving area is shown in the figure below. When mounting, make sure the effective field of view (scanning angle and laser emission and receiving area) is not obstructed visually, e.g., blocked by a cover. Please refer to the 3D model of SL450 when designing the installation structure.

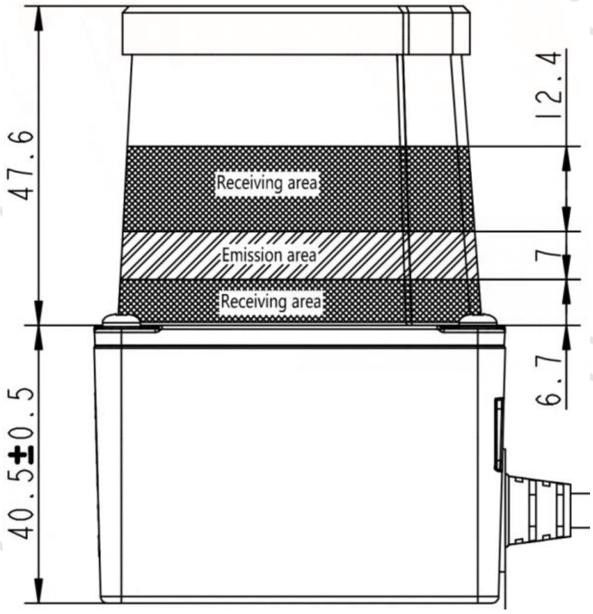

Figure 3-3-3 SL450 optical region

SL450 is designed with a rotating mirror structure, with a blind zone of 90°, located in the area of 45°-0°-315°. When mounting, make sure the laser emission and receiving area are kept clean and not blocked. With the upper edge of the receiving area horizontal plane as the reference, at least 5mm of vertical open space should be reserved on the upper part, and the emission and reception area should not be blocked within the 31.1mm vertical area.

Notes:

When mounting, make sure that the effective field of view is not blocked and the impact of the emission pitch angle is considered.

3.3.2 Installation Instructions

If the final surface used is uneven, the sensor will be exposed to vibrations and impacts, thereby increasing the possibility of damage to the lidar. When used in environments with severe vibrations or impacts, such as in industrial and logistics applications, for heavy-duty mobile robots like Autonomous Mobile Robots (AMRs) and unmanned forklifts, it is **essential** to use the mounting points on the bottom in conjunction with a shock-absorbing base.

SL450 is provided with a matching shock-absorbing base. The upper surface of the base is secured to the lidar with screws, and the lower surface is fixed to the robot's mounting surface with screws. The following figure shows the schematic and dimensional drawings of the provided base.

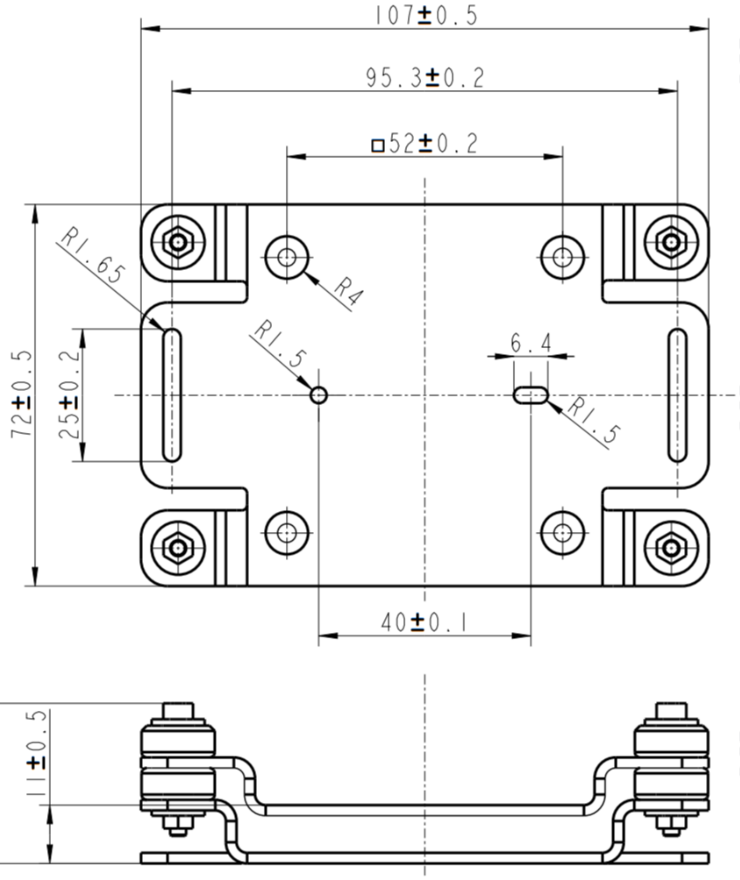

Figure 3-3-4 Schematic and dimensions of the shock-absorbing base for SL450

4 Operation Mechanism

4.1 System Workflow

The SL450 LiDAR is set up with 2 operating modes: ranging mode and standby mode.
Ranging mode: LiDAR is activated and working properly;
Standby mode: LiDAR is activated but has not yet emitted the ranging laser pulse.
The brief workflow diagram of LiDAR is shown in the figure below.

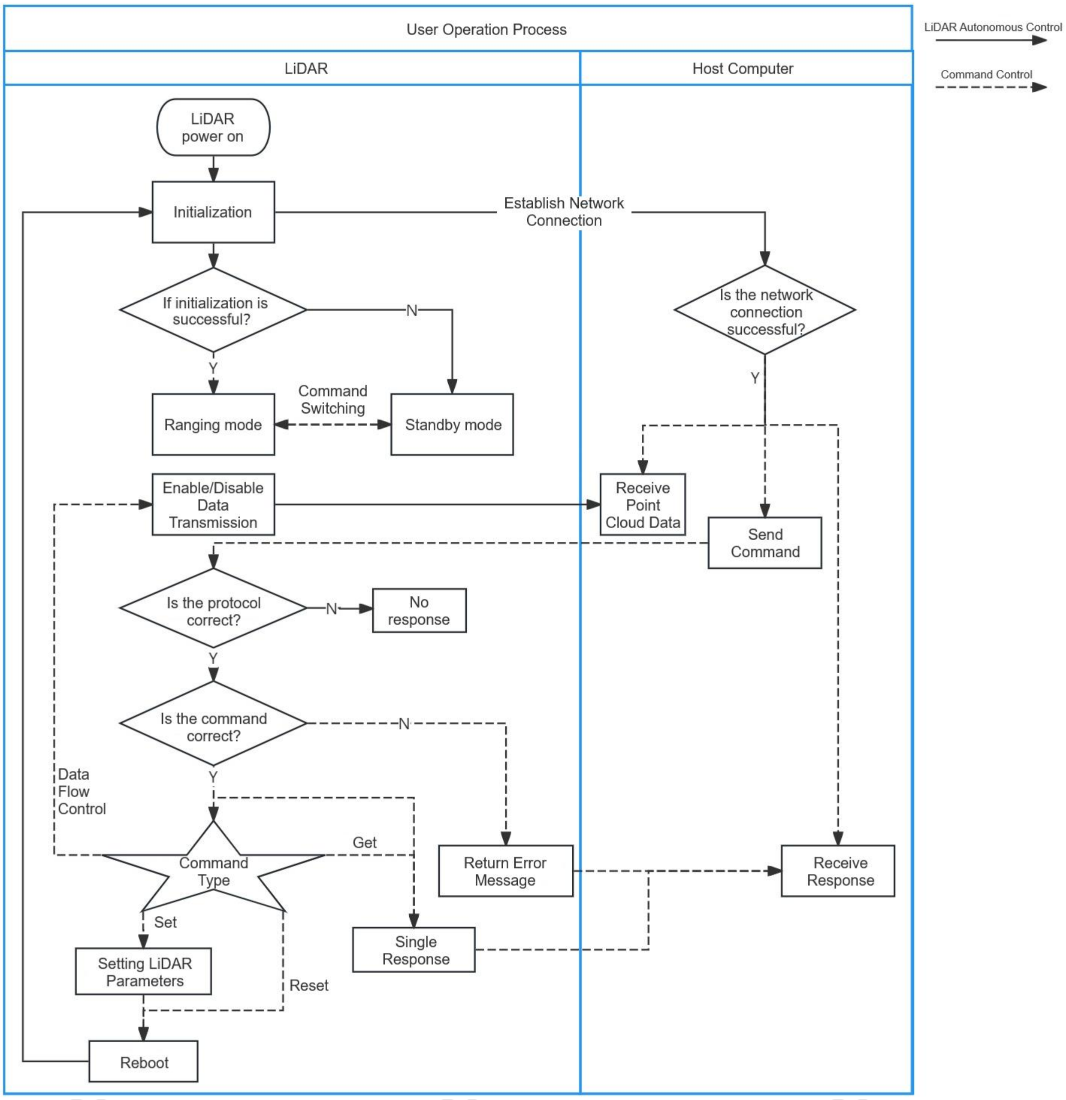

Figure 4-1-1 LiDAR system workflow diagram

4.2 LiDAR Communication

The SL450 point cloud data is transmitted outward via Ethernet UDP protocol with factory default IP address 192.168.1.100 and default network port number 2228.

The SL450 LiDAR adopts a passive point cloud data upload method with the host computer. That is, under the condition that the host computer and the LiDAR can communicate normally over the network, the host computer opens the LiDAR according to the LiDAR's IP to obtain point cloud data. The specific operation method is as follows:

1. After the LiDAR is powered on and initialized, the internal ranging engine starts working normally. The host computer must first send a connection command to establish a connection with the LiDAR;
2. After the connection is established between the host computer and the , point cloud data can be obtained. The host computer can send commands to control the start and stop of point cloud transmission;
3. Each time the LiDAR receives a control command, it will reply with an acknowledgment message as the result of the command execution.

Figure 4-2-1 Command Interaction Diagram

4.3 Data Composition and Protocol

4.3.1 Data Composition

SL450 outputs point cloud data, which is the collection of all points of the target object in the environment scanned by the LiDAR. Each scanned point includes distance and target reflection intensity information.

When the LiDAR is mounted, as shown below (top view), the LiDAR rotates counterclockwise, i.e. θ45° indicates the initial angle and θ315° indicates the end angle, and the data is sent in the order of θ45°-θ180°-θ315. Each scan cycle (270°) is divided into 18 data blocks of point cloud data, as shown in the following figure:

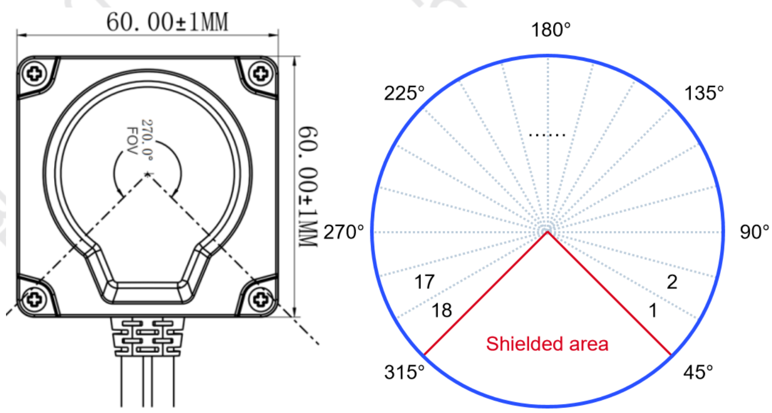

Figure 4-3-1 Point Cloud Data Blocks Segmentation

The LiDAR output point cloud angle range is 45°~315° (total 270° range), and no point cloud data block is output in the shielded angle range (0~45°, 315°~360°). Each scan cycle (270°) is divided into 18 data blocks, and the measurement frequency is fixed at 72 kHz, so the length of the point cloud data block varies with the rotation frequency.

The relationship between the specific parameters of the point cloud data block and the rotation frequency is shown in the following table:

Table 4-3-1 the relationship between rotation frequency and data block parameter

Rotation frequency	Measurement frequency	Angular resolution	Point count per rotation cycle	Point count per data block	Bytes per data block
15 Hz	72 kHz	0.075°	3600	200	844
20 Hz	72 kHz	0.1°	2700	150	644
25 Hz	72 kHz	0.125°	2160	120	524
30 Hz	72 kHz	0.15°	1800	100	444
40 Hz	72 kHz	0.2°	1350	75	344

4.3.2 Point Cloud Data Protocol

The detailed structure of the point cloud data block is described in the following table:

Table 4-3-2 the detailed structure of the point cloud data block

Byte	Name	Description	Byte contents	Byte length
1-6	Frame header	Fixed byte	4D 53 02 F4 EB 90	6
7-8		Frame length of the whole data block	15Hz: 0x034C 20Hz: 0x0284 25Hz: 0x020C 30Hz: 0x01BC 40Hz: 0x0158	2
9-10	Angular information	Start Angle	Unit is 0.01°	2
11-12		End Angle	Unit is 0.01°	2
13-14		Angular Resolution	Unit is 0.001°	2
15	Data block information	Information type	01: point cloud frame at 15Hz 02: point cloud frame at 20Hz 03: point cloud frame at 25Hz 04: point cloud frame at 30Hz 05: point cloud frame at 40Hz	1
16		Data block number	1~18	1
17-18		Data block sequence	1~65535	2
19-22	Timestamp information	Timestamp	The range is 0~3600e6 with unit as 1us	4
23		Time sync mode	0: free-running mode 1: external sync mode	1
24	Ranging Mode	Ranging Mode	0: Normal Ranging Mode; 1: Fog Penetration Mode	1
25-28	Status Information	Warning Message	Reference warning information instructions	4
29-30		Soiling Angle	45-315°，unit is 0.01°	2
31		Soiling Level	0-10	1
32-33		Temperature	Unit is 0.01°C	2
34-35		Rotation Speed	Unit is RPM	2
36-40		Reserved	-	5
41-42	Scan point information	Distance of point_1	Unit is 2mm	2
43-44		Intensity of point_1	0~2000	2
45-46		Distance of point_2	Unit is 2mm	2

47-48		Intensity of point_2	0~2000	2
…		Distance of point_n-1	Unit is 2mm	2
…		Intensity of point_n-1	0~2000	2
37+N*4-38+N*4		Distance of point_n	Unit is 2mm	2
39+N*4-40+N*4		Intensity of point_n	0~2000	2
41+N*4-44+N*4	Frame footer	Fixed byte	FE FE FE FE	4

4.3.3 Angle Information Extraction

The point cloud data block does not contain the angle information directly. The angle information of every scan point should be calculated from the extracted block information, data block number and scan point number n. The calculation is as follows:

Angle Information Calculation Method:

1. Extract the information type from the point cloud data block: e.g., 0x05;
2. Obtain the angular resolution according to the correspondence between rotation frequency and horizontal angular resolution: e.g., 0.075°;
3. Extract the start angle in this point cloud data block: e.g., 45.0°;
4. For the nth scan point, the corresponding angle of this point is: the starting angle of this data block + (scan point number - 1) × angular resolution. If n is 10, the corresponding angle is then: 45°+ (10-1) × 0.075°=45.675°.

4.3.4 Distance and Intensity Information Extraction

The byte length of every scan point is 4, with 2 bytes for distance information and 2 bytes for intensity information. The unit of distance information is 2mm. The range of intensity is 0~65535, which is the relative intensity level.

The distance and intensity information extraction are as follows:

1. Extract the scan point information of the nth scan point from the point cloud data block: e.g. 0x13,0x24,0x01,0x37;
2. Extract the first two bytes of this scan point information: 0x13，0x24; combine them into 16 bits of data 0x1324 = 4900, multiply with the distance information unit (2mm) to get the absolute distance: 9800mm, i.e. 9.8m, which is the distance;
3. Extract the third byte of the point cloud data information and convert it to decimal: 0x01, 0x37; combine them into 16 bits of data 0x0137 = 311, which is the intensity information.

4.3.5 Timestamp Information Extraction

Each point cloud data block has its related timestamp information, and the current timestamp information indicates the laser emitting time of the last scan point.

The timestamp information is defined is as follows:

1. Length: 4 bytes.

2. Minimum time unit: 1us.
3. Time range: 0~3600×10^6, i.e. 1h range.
4. Timestamp meaning: the laser emitting time of the last scan point in current data block.

The timestamp extraction is as follows:

1. Extracting 4 bytes of timestamp information from the point cloud data block: e.g., 0x37, 0x5a, 0xb3, 0xe3;
2. Combine the timestamps into 32 bits of data to obtain: 0x375ab3e3;
3. Convert the timestamp information to decimal to get: 928,691,171µs.

4.3.6 Temperature Information Extraction

For temperature, which occupies 2 bytes, the unit is 0.01°C, and the calculation method is as follows:

1. If the bytes read are 0x12 and 0xf9;
2. They combine to form 0x12f9, which when converted to decimal gives 4857;
3. Multiplying by the unit 0.01°C indicates that the current internal temperature is 48.57°C.

4.3.7 Status Information Extraction

LiDAR Warning Information is appended to the point cloud data packet, with four bytes representing a total of 32 bits. The meaning of each bit for the warning is as follows:

Table 4-3-3 the meaning of the warning code

Byte	Byte length	Description
LiDAR State	1	status d-0 initial d-1 normal d-2 warning d-3 error
Fault Code	2	The status code sent this time is detailed in the fault code reference table(Appendix I)
Reserved	1	Reserved

1. If the read bytes from bits 25 to 28 are 0x02, 0x03, 0x13, and 0x00 respectively;
2. Then 0x02 represents the LiDAR State, indicating a warning condition;
3. The combination of 0x03 and 0x13 forms 0x0313, which, when compared to the fault code table, indicates a contamination level of 8;

0x00 is a reserved bit, which defaults to 0.

5 Use Instructions

5.1 Device Connection

The RJ45 Ethernet connector of SL450 is used to transmit scanning data, and the multi-core cable is for external power supply. Connect the RJ45 Ethernet connector of the LiDAR to the PC, and use power supply to power the LiDAR.

For first-time commissioning, a 24V/1A power supply is recommended. The LiDAR can be directly connected to the computer with its IP address as 192.168.1.100 and the subnet mask as 255.255.255.0.

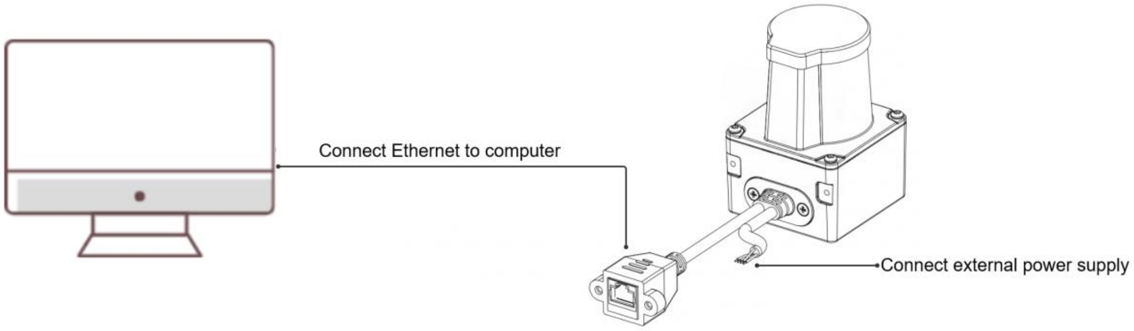

Figure 5-1-1 Device Connection

When using it for the first time, the host computer IP should be configured. The setting method for Windows system is as follows:

1. In Control Panel, enter "Network and Sharing Center";
2. Click "Ethernet" to jump to the Ethernet status interface and click the "Attribute" button to enter the Ethernet attribute setting interface;
3. Double-click "Internet Protocol Version 4 (TCP/IPV4)";
4. Set the IP address to 192.168.1.XX (e.g., 192.168.1.10, not the LiDAR address 192.168.1.100), set the subnet mask to 255.255.255.0, and click the "Confirm" button to complete setting the static address of the computer.

5.2 Viewer

Orbbec provides users with operational software that can display, record, and analyze point clouds in real-time, allowing users to conveniently assess the performance of the LiDAR and observe the scanned point cloud data in the environment on their PCs when they receive the device.

The software currently supports Windows 10/11 (64-bit) operating systems. The software installation package can be obtained through sales personnel or online links. After installing the software, it is ready for use upon completion of the process.

5.3 SDK

In addition to the above-mentioned real-time point cloud data using the Viewer, users can also apply the point cloud data obtained from the LiDAR to various custom scenarios through the Software Development Kit (SDK). Users can perform algorithm development based on the Orbbec_lidar_SDK to improve development efficiency. The Orbbec_lidar_SDK is a cross-platform (Windows, Linux) software development kit designed for Orbbec LiDAR products, providing device parameter configuration, data stream reading, and processing. It also includes ROS/ROS2 wrapper to help users quickly and conveniently understand and use Orbbec LiDARs. After purchasing the hardware, users can obtain the accompanying SDK from the Orbbec official website

6 Regulatory Compliance

The products is certified as follows:

1. RoHS Certification

Figure 6-1 RoHS Certification

2. FDA registration

Figure 6-2 FDA registration

3. Class 1 Laser Product under the EN/IEC 60825-1:2014

CLASS 1
LASER PRODUCT

Figure 6-3 Class 1

4. CE Certification

Figure 6-4 CE Certification

5. FCC Certification

Figure 6-5 FCC Certification

6. Reach Certification

7 System Integration Guide

Before choosing Pulsar Series for development, users should contact Orbbec sales staff to obtain the user manual and apply for the SDK development kit; through evaluation, debugging and verification steps to confirm whether the solution meets the mass production requirements.

We provide SDK compatible with various software platforms for the Pulsar series LiDARs. You will need the SDK for the corresponding platform to develop and use the hardware. The LiDAR SDK supports Windows and Linux operating systems. The LiDAR SDK is a secondary development package specifically designed for Orbbec's LiDAR products. After purchasing the product, users can obtain the SDK package from the Orbbec official website and directly acquire point cloud data from the LiDAR. With the driver and SDK suite, users can further develop applications for the product.

Suggested Process:

1. Read the product specification
2. Buy the product from the WEB store online
3. Before development, you should get in touch with the sales staff of Orbbec to obtain the user manual and apply for the SDK development kit.
4. Choose the right development platform
5. According to the function of product development, encounter technical problems, please contact with Orbbec staff in time
6. Confirm the mass production plan of the product
7. Mass production of the products according to mass production plan

8 Cautions

1. Please follow the guidelines to operate the device correctly, such as illegal operation may lead to damage to internal components.
2. Do not drop or hit this product to prevent damage to the internal components and loss of accuracy.
3. Do not attempt to modify or disassemble this product in any way during assembly and use, as this may cause damage to the LiDAR and loss of accuracy and precision.
4. The product temperature rises after a period of use, which is a normal phenomenon.
5. Please do not dirty or scrape the optical cover, so as not to leave a foreign objects or marks on it and thus affect the effect of laser ranging.
6. Do not place the product in a place where children or animals can touch it to avoid accidents.
7. If you can't recognize the device, please check whether the cable meets the power supply requirements and re-plug to check.
8. Although this product uses a Class 1 laser (a harmless, control-free laser), we do not recommend looking directly at the laser emitter for more than 20 seconds to avoid discomfort.

Appendix I LiDAR internal self-diagnostics items and fault code reference table

System Functional Monitoring Item	Error Code	Performance
Motor Speed	0x0301(Over-Speed) 0x0302(Under-Speed)	LiDAR Flashing Pink Light Warning
Motor Status	0x0303(Motor Blockage)	LiDAR Flashing Red Light Unreliable Output
Encoder Detection	0x0304(Encoder Signal Anomaly)	LiDAR Flashing Red Light Unreliable Output
Code Tooth Signal	0x0305(Code Tooth Signal Anomaly)	LiDAR Flashing Red Light Unreliable Output
Point Cloud Data	0x0306(Point Cloud Data Anomaly)	LiDAR Flashing Red Light Unreliable Output
Ranging Status	0x0307(Ranging Anomaly)	LiDAR Flashing Red Light Unreliable Output
FPGA and MCU Handshake During Startup	0x0308(Handshake Failure During Startup)	LiDAR Flashing Red Light Initialization
FPGA and MCU Handshake During Operation	0x0309(Handshake Failure During Operation)	LiDAR Flashing Red Light Unreliable Output
FPGA Initialization	0x030A(F FPGA Initialization Anomaly)	LiDAR Flashing Red Light Initialization
FPGA and MCU Version	0x030B(Version Matching Anomaly)	LiDAR Flashing Pink Light Warning
Dirt Obstruction Fault	0x030C(Dirt Level 1) 0x030D(Dirt Level 2) 0x030E(Dirt Level 3) 0x030F(Dirt Level 4) 0x0310(Dirt Level 5) 0x0311(Dirt Level 6) 0x0312(Dirt Level 7) 0x0313(Dirt Level 8) 0x0314(Dirt Level 9) 0x0315(Dirt Level 10)	LiDAR Flashing Red Light Warning
MCU Clock Frequency Detection	0x0316(MCU Clock Frequency Anomaly)	LiDAR Flashing Red Light Unreliable Output
MCU Input Voltage Detection	0x0317(MCU Input Voltage Anomaly)	LiDAR Flashing Pink Light Warning

LiDAR Internal Packet Loss Detection	0x0318(LiDAR Internal Packet Loss)	LiDAR Flashing Red Light Unreliable Output

Main Board Monitoring Item	Error Code	Performance
MCU_TEMP	0x0201(MCU Over-Temperature) 0x0202(MCU Under-Temperature)	LiDAR Flashing Pink Light Warning
FPGA_TEMP	0x0203(FPGA Over-Temperature) 0x0204(FPGA Under-Temperature)	LiDAR Flashing Pink Light Warning
VIN_ADC	0x0205(Overvoltage) 0x0206(Undervoltage)	LiDAR Flashing Pink Light Warning
IIN_ADC	0x0207(Overcurrent) 0x0208(Undercurrent)	LiDAR Flashing Red Light Unreliable Output/ Entering Sleep Mode Due to Overcurrent

RX Board Monitoring Item	Error Code	Performance
APD_TEMP	0x0101(APD Over-Temperature) 0x0102(APD Under-Temperature)	LiDAR Flashing Pink Light Warning
LD_TEMP	0x0103(LD Over-Temperature) 0x0104(LD Under-Temperature)	LiDAR Flashing Pink Light Warning
RXHV_ADC	0x0105(APD Voltage Anomaly)	LiDAR Flashing Red Light Unreliable Output
TXHV_ADC	0x0106(High Power Transmission Voltage Anomaly)	LiDAR Flashing Pink Light Warning
TXLV_ADC	0x0107(Low Power Transmission Voltage Anomaly)	LiDAR Flashing Pink Light Warning

Logical Function Monitoring Item	Error Code	Performance
FPGA Initialization	0x0401(Code Density Initialization Calculation Anomaly) 0x0402(Ranging Module Initialization Calibration Failure) 0x0403(Code Tooth Signal or Encoder Calibration Data Anomaly) 0x0404(ITF Board Initialization Distance Measurement Anomaly) 0x0405(e2prom Initialization Read Anomaly) 0x0406(Serial Communication Failure)	1. e2prom Initialization Read Anomaly: LiDAR Flashing Pink Light; Warning 2. Other Anomaly Occur Consecutively Three Times: LiDAR Flashing Red Light; Unreliable Output
FPGA Encoder Anomaly	0x0407(FPGA Detects Motor Blockage) 0x0408(FPGA Detects Encoder Glitches)	When the MCU Encoder Detection is Normal, But the FPGA Encoder Detection is Abnormal: Motor Stops Rotating, LiDAR Flashing Red Light; Unreliable Output
FPGA Status Monitoring	0x0409(FPGA Status Anomaly)	LiDAR Flashing Red Light Unreliable Output
FPGA Point Cloud Status	0x040A (FPGA Point Cloud Anomaly)	LiDAR Flashing Red Light Unreliable Output