MS500 dToF Lidar

User Manual

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ORADAR

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1. Do not repair, modify, or manipulate this product without permission to prevent damage to the product or radiation exposure.
2. Do not drop or hit this product, otherwise, the internal components of the product may be damaged, resulting in abnormal operation.
3. Please check the power supply requirements of the product carefully, over-powering may result in permanent damage to the product.
4. Do not scratch the optical housing and keep it clean. Otherwise, the product measuring performance may be affected.
5. The product is certified according to laser protection Class 1 (IEC/EN 60825-1: 2014). Do not stare into laser beam. Do not point lasers at people!
6. It is strictly prohibited to use or store the product in flammable, explosive or corrosive environment to prevent damage to the product.

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1. Product Introduction

Product Brief

MS500 is a 2D light detection and ranging (LiDAR) sensor launched by Shenzhen Oradar Technology Co. Ltd. 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°/≥10m (@10% reflectivity). The LiDAR can be widely used in many fields, including robot positioning and navigation, area security, logistics, environmental scanning, and 3D reconstruction.

Working Principle

The measurement principle of MS500 is dToF. The distance is calculated as:

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

where d is the distance to be measured, c the speed of light, and t the time of flight captured by LiDAR sensor.

The LiDAR comprises a rotating ranging module on which a laser transmitter and receiver is located. When the ranging module works, the laser transmitter emits a laser pulse, the receiver captures this pulse reflected by an object. By measuring the flight time of the laser pulse in the air, the distance from the target object to the LiDAR can therefore be calculated. Through the built-in brushless motor, the distance is measured at different angles by rotating the ranging module. This working principle permits continuous scanning of the surrounding environment with a field of view of 270°.

Product Features

Long ranging capacity: Measurement range can be up to 10m@10%, 30m@90%, providing the capacity for large-scale environment usage.

High resolution: Up to 30KHz measurement frequency with high angular resolution allows tiny obstacle detection and precise edge detection.

Anti-ambient light interference: Maintains operational stability under 50,000 lx ambient light interference.

Environmental adaptability: Guaranteed stable operation in a temperature range of -10°C minimum and 55°C maximum.

High protection level: IP65 protection level, high shock resistance, suitable for logistics/security applications.

Low power consumption: Total power consumption typical value is less than 2W, permitting small heat generation and low temperature rise.

2. Specifications

General specifications

Product	MS500	Remarks
Measurement principle	dToF	
Measurement range	≥30m @90% reflectivity ≥10m @10% reflectivity	
Accuracy	typ. ±20mm max ±30mm	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 (1 sigma).
Precision	typ. ≤10mm max ≤20mm	
Output data	Distance, angle, intensity, timestamp	
Scanning angle	270°	
Measurement frequency	30KHz	Measurements per second
Rotation frequency	10Hz/15Hz/20Hz/25Hz/30Hz	default 15Hz
Emission pitch angle	0° ±1°	With the underside plane of the housing as the reference
Laser wave length	903±10nm	
Ambient light limit	50,000Lux	
Multi-device anti-interference	Yes	

Mechanical/Electronic specifications

Operating voltage	12V（9~28V DC）	
Power consumption	typ. <2W max <5W	
Interface type	100 Gigabit Ethernet RJ45 connector, Power supply and time synchronization connection cable	See interface definition for details
Dimensions	60mm×60mm×85mm	L×W×H (without connection cable)
Weight	~270g	Cable included

Environmental specifications

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	*Sinusoidal Vibration*: 0.75mm amplitude, 10~55~10Hz frequency, 1oct/min sweep speed. *Random vibration*: 10~500Hz frequency, 0.05g²/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	-10℃~55℃	
Storage temperature	-20℃~70℃	
Relative humidity	0~85%	no moisture condensation
Certification	CE-EMC/FCC/RoHS2.0, Class1, FDA registration	

- The ranging performance is derived from Oradar's 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 Oradar 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 meters with 10% and 90% reflectivity conditions under laboratory conditions.
  2. **Measurement precision**: the relative error under laboratory conditions at 10% reflectivity and working distance within 10 meters.
  3. **Measurement frequency**: output frequency of measurement data calculated with a 360° horizontal field of view.
  4. **Angular resolution**: 0.12°, 0.18°, 0.24°, 0.30°, 0.36° refer to the angular resolution values at the measurement frequency of 30KHz, corresponding to the rotation frequency of 10Hz, 15Hz, 20Hz, 25Hz, 30Hz, respectively. The actual angular resolution may vary slightly due to the fluctuation of the real-time rotation frequency under the user's usage scenario.

3. Interface Description

Learn about MS500

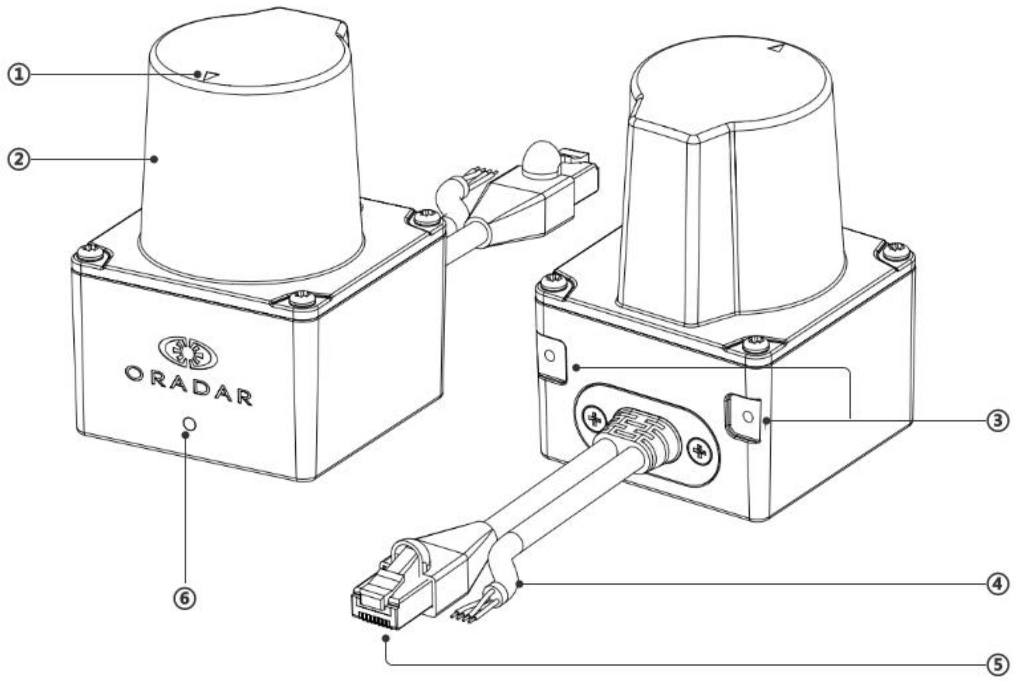


Figure 3-1 MS500 Parts Description

① **Identifier**
Indicate the direction in front of the LiDAR, the corresponding angle is 180°.

② **Optical window**
The laser pulse is emitted through the window to scan the object within the scanning range.

③ **Mounting hole**
The LiDAR has two M3 mounting holes for installation. For detailed dimensions, see Dimension Details.

④ **Multi-core cable**
The multi-core cable is used for LiDAR power supply and time synchronization signal. The length is 1.0m. Please refer to the Interface Definition for the wire sequence.

⑤ **Ethernet connector**
The Ethernet connector (RJ45) is used for LiDAR data transmission, the length is 1.0m. Please refer to the Interface Definition for the wire order.

⑥ **Indicators**
Indicate the system status of the LiDAR.
Red: The LiDAR is powered on, lasting for 2s.
Flashing in white: The LiDAR is in the initialization state, and the indicator flashes once every 1s.
White: LiDAR is in normal operation with ranging status.
Flashing in red: LiDAR is running fault, and the indicators flashes once every 1s.
Off: If the indicator is off, it means abnormal power supply.

Interface Definition

MS500 has high-reliability Ethernet wire communication and power supplied via multi-core cable. It realizes power supply, control signal transmission and data transmission.

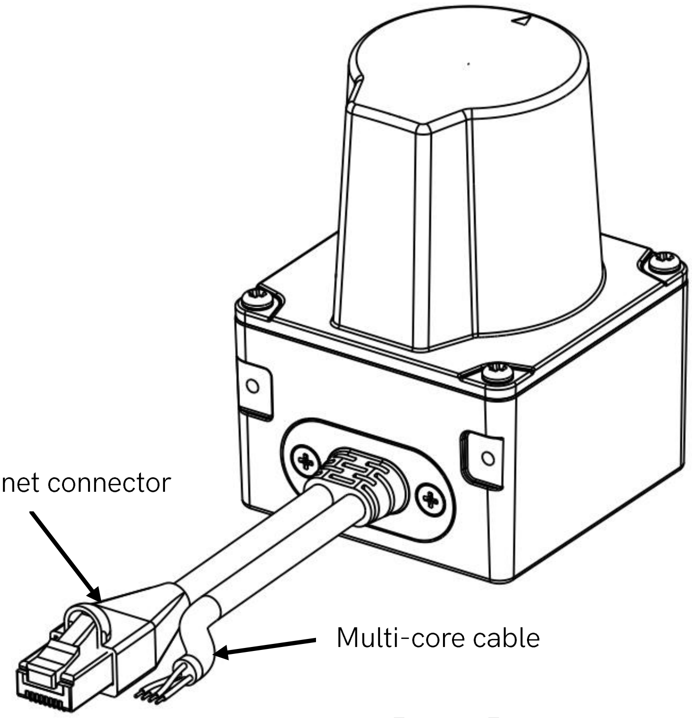


Figure 3-2 MS500 Interface Definition

Ethernet connector

There is a RJ45 Ethernet connector on the rear of the housing for connecting the Ethernet interface. The following figure shows the pinout:

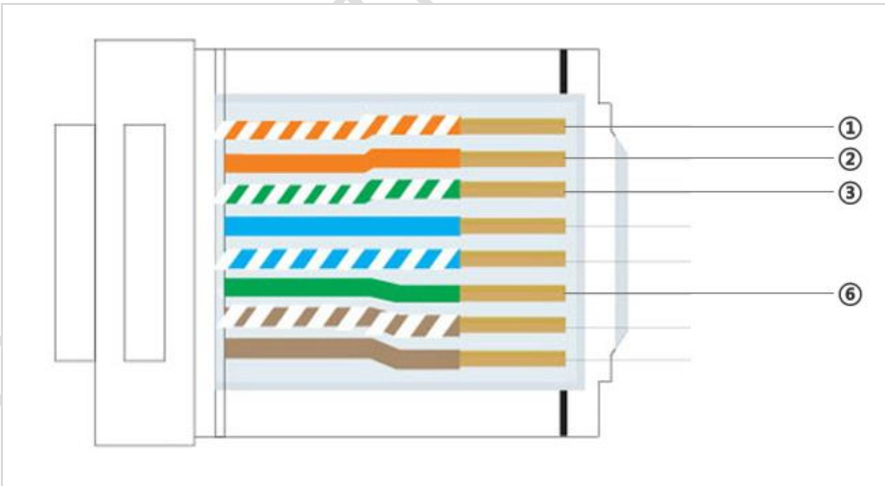


Figure 3-3 Ethernet connector layout

Table 3-1 Ethernet connector pinout

Pin No.	Signal	Description	Color
1	TxData+	Data output+	White orange
2	TxData-	Data output -	Orange
3	RxData+	Data input+	White green
6	RxData-	Data input -	Green

Multi-core cable

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

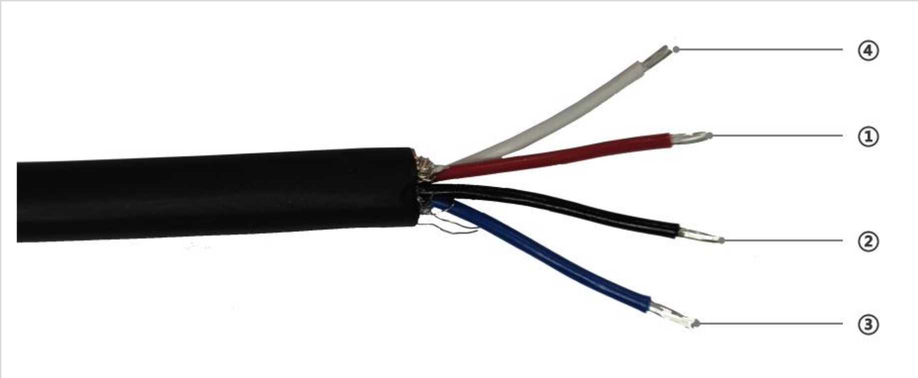


Figure 3-4 Multi-core cable layout

Table 3-2 multi-core cable pinout

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

4. Installation

Installation Dimensional Structure Diagram

Oradar MS500 supports two mounting methods. There are four M3 mounting holes with a depth of 7mm on the underside. There are two M3 mounting holes with a depth of 3.5mm on the rear of the housing. There are two positioning holes at the bottom with a depth of 6.0mm. Mount the LiDAR from the underside or rear to the right location.

Please install according to the size of Oradar MS500 and the size of the mounting holes shown in the figure below.

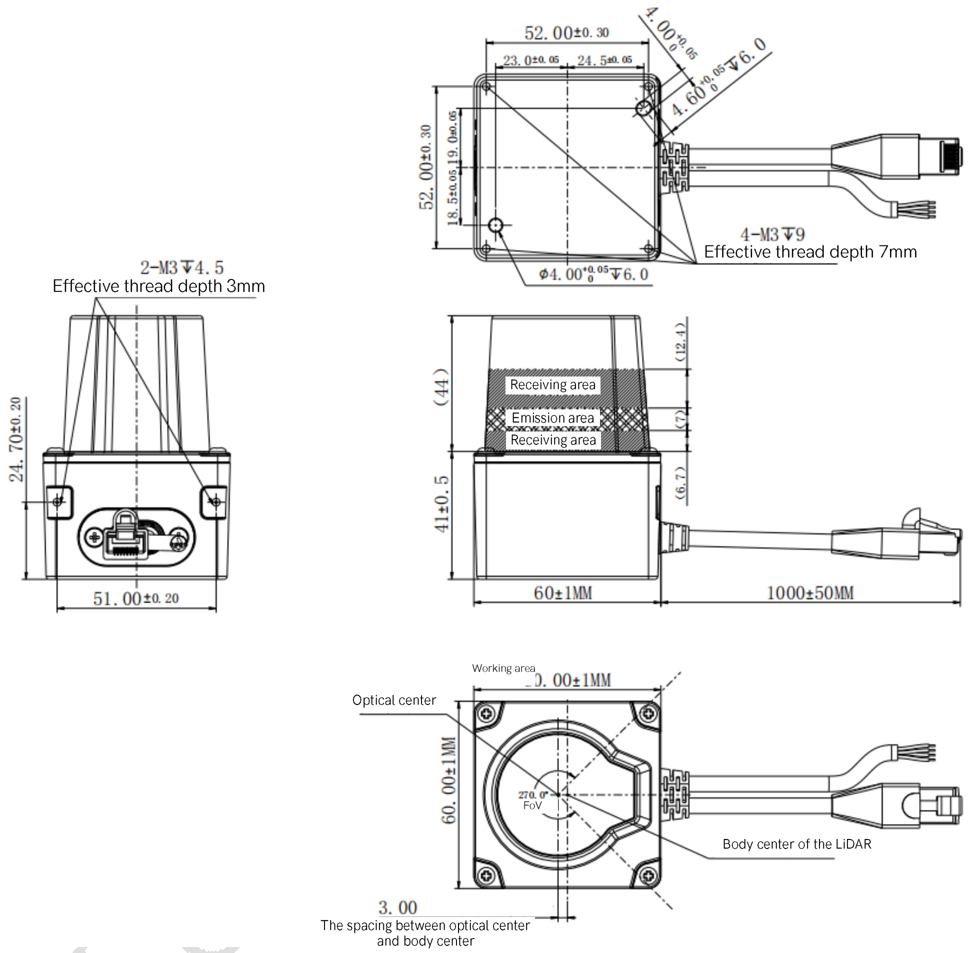
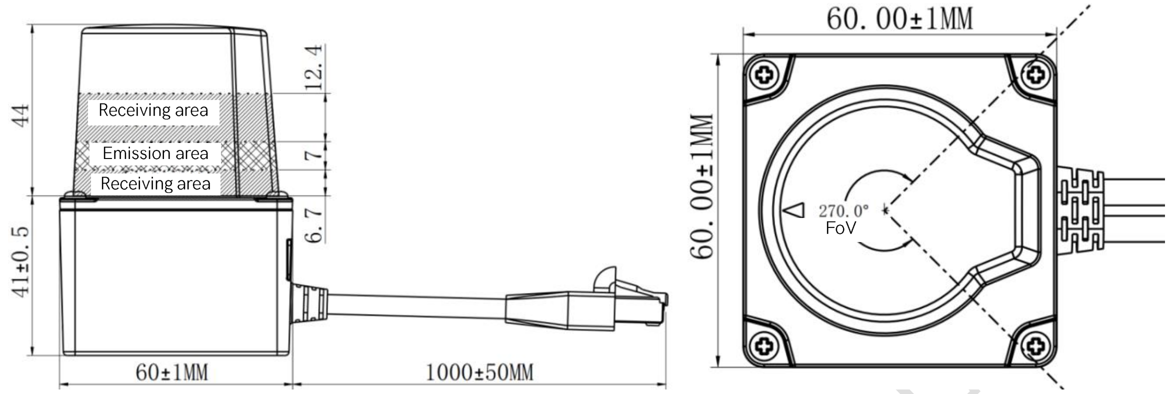


Figure 4-1 Dimensional drawing of Oradar MS500

Effective Field of View

The scanning angle of Oradar MS500 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 Oradar MS500 provided by Oradar when designing the installation structure.



Oradar MS500 is designed with a rotating mirror structure, with a blind zone of 90°, located in the area of 45°-0°-315°. The △ identifier on the front side of the LiDAR means the angle of 180°.

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.

The emission pitch angle of MS500 is slightly different. With underside plane of the housing as the reference, the pitch angle is within ±1°, 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.

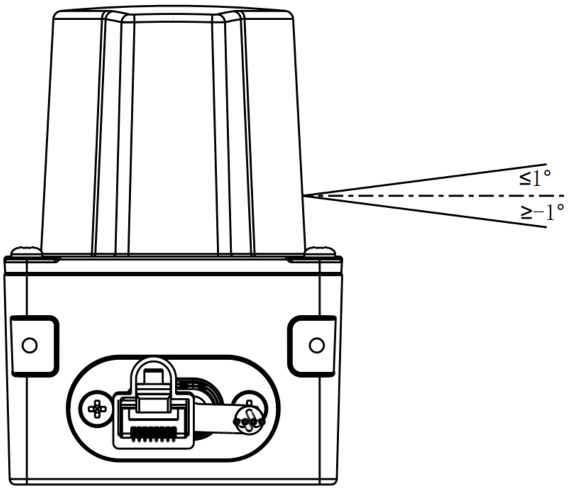


Figure 4-2 Oradar MS500 emission pitch angle

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

5. Operation Mechanism

The MS500 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.

System Workflow

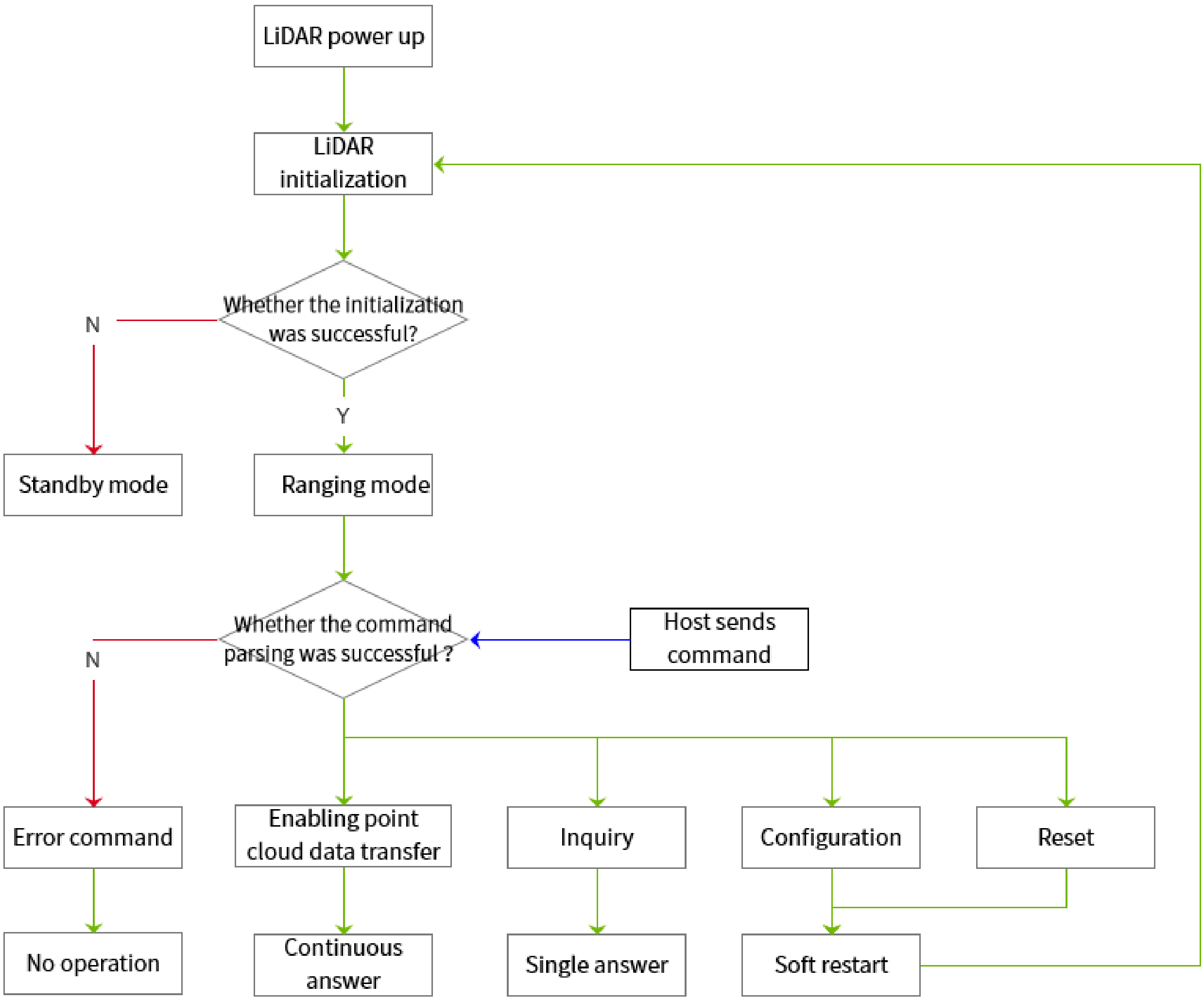


Figure 5-1 LiDAR system workflow diagram

Ethernet Communication Protocol

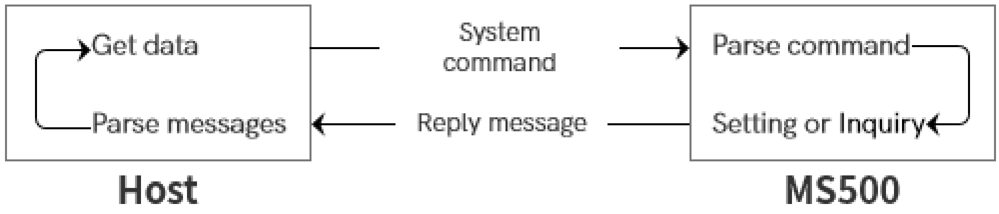
The MS500 point cloud data is transmitted outward via Ethernet UDP protocol with factory default IP address *192.168.1.100* and default network port number *2007*.

The scan data is received from the LiDAR using a UDP/IP channel. The detailed operation is as follows:

1. After the LiDAR powered up and initialized, the internal ranging module starts to work normally. The host computer needs to send a connection command to establish a connection with the LiDAR first.
2. After the host computer establishes a connection with the LiDAR, the point cloud data can be acquired.

The point cloud transmission can be turned on or off, and the host computer can send system commands to parametrize and control the LiDAR.

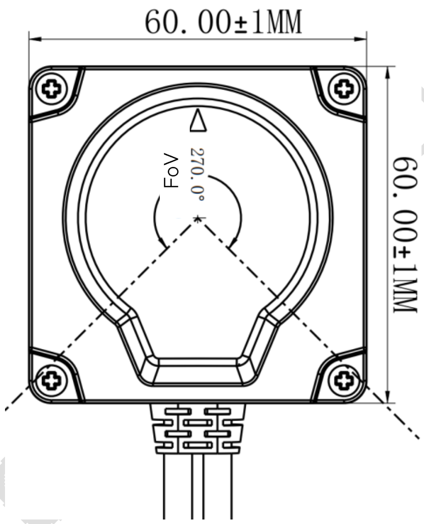
3. the LiDAR will answer with a reply message after each system command is received, parsed, and executed.

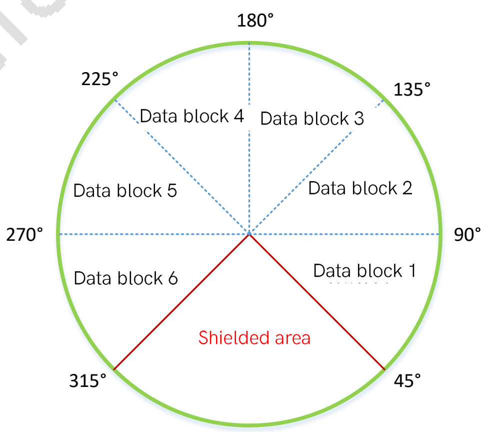


Output Data

The Oradar MS500 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 6 data blocks of point cloud data, as shown in the following figure:





Communication Protocol

Point Cloud Data Protocol

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 6 data blocks, and the measurement frequency is fixed at 30kHz, 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 5-1 The relationship between rotation frequency and data block parameters

Rotation frequency	Measurement frequency	Angular resolution	Point count per rotation cycle	Point count per data block	Bytes per data block
10Hz	30KHz	0.12°	2268	378	1154
15Hz	30KHz	0.18°	1512	252	776
20Hz	30KHz	0.24°	1152	192	596
25Hz	30KHz	0.30°	900	150	470
30Hz	30KHz	0.36°	756	126	398

Each point cloud data block comprises frame header information, timestamp, and scan point data. The byte order for all binary data is *Big Endian*. The format of the point cloud data block is shown in the following figure:

Table 5-2 The format of the point cloud data block

Frame header	Reserved	Block information	Timestamp information	Scan point_1	Scan point_2	…	Scan point_N-1	Scan point_N
8Bytes	2Bytes	4Bytes	6Bytes	3Bytes	3Bytes	…	3Bytes	3Bytes

The length of the frame header is 8 Bytes, the first 6 bytes are fixed as 4D 53 01 F4 EB 90 (hexadecimal), the next 2 bytes indicate the frame length.

The timestamp contains 4 bytes of timestamp information, 1 byte of timestamp synchronization mode information and 1 reserved byte.

The number of scan point in the point cloud data block is N, and N varies with the rotation frequency. Each scan point contains 2 bytes of distance information and 1 byte of intensity information.

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

Table 5-3 The detailed structure of the point cloud data block

Byte	Name	Description	Byte contents	Byte length
1-6	Frame header	Fixed magic bytes	4D 53 01 F4 EB 90	6
7-8		Frame length of the whole data block	10Hz: 0x0482 15Hz: 0x0308 20Hz: 0x0254 25Hz: 0x01D6 30Hz: 0x018E	2
9	Reserved	-	-	1
10	Reserved	-	-	1
11	Block information	Information type	04: Scan data for 10Hz rotation frequency 05: Scan data for 15Hz rotation frequency 06: Scan data for 20Hz rotation frequency 07: Scan data for 25Hz rotation frequency 08: Scan data for 30Hz rotation frequency	1
12		Data block number	01: Scan data for 45~90° range 02: Scan data for 90~135° range 03: Scan data for 135~180° range 04: Scan data for 180~225° range 05: Scan data for 225~270° range 06: Scan data for 270~315° range	1
13-14		Data block sequence	1~65535	2
15-18	Timestamp information	Timestamp	The range is 0~3600e6 with unit as 1us	4
19		Time sync mode	0: free-running mode 1: external sync mode	1
20		Reserved		1
21-22	Scan point information	Distance of point_1	Unit is 2mm	2
23		Intensity of point_1	0~255	1
24-25		Distance of point_2	Unit is 2mm	2
26		Intensity of point_2	0~255	1
...		Distance of point_n	Unit is 2mm	
...		Intensity of point_n	0~255	
18+N*3-19+N*3		Distance of point_N	Unit is 2mm	2
20+N*3		Intensity of point_N	0~255	1

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:

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., 0.18°.
3. Extract the data block number in this point cloud data block: e.g., 0x03.
4. Multiply the data block number by 45 to obtain the starting angle of the point cloud data block: 3 × 45 = 135°.

5. For the *n*th 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 100, the corresponding angle is then: 135° + (100-1) × 0.18° = 152.82°.

Distance and Intensity Information Extraction

The byte length of every scan point is 3, with 2 bytes for distance information and 1 byte for intensity information. The unit of distance information is 2mm. The range of intensity is 0~255, which is the relative intensity level. The distance and intensity information extraction are as follows:

1. Extract the scan point information of the *n*th scan point from the point cloud data block: e.g. 0x13,0x25,0x37.
2. Extract the first two bytes of this scan point information, which is the distance: 0x13, 0x25.
3. Extract the third byte of the point cloud data information and convert it to decimal, which is the intensity information: 0x37→55.
4. Combine the distance information bytes into 16 bits of data 0x1325.
5. Converting the distance information to decimal to obtain: 0x1325→4901.
6. Multiply with the distance information unit (2mm) to get the absolute distance: 9802mm, i.e. 9.802m.

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: 0~3600×106, i.e., 1h range.
4. Timestamp meaning: the laser emitting time of the last scan point in current data block.

The LiDAR can achieve high precision time synchronization by receiving the PPS signal from external time synchronization devices, in which case the LiDAR runs in external sync mode.

When there is no external PPS signal, the LiDAR timestamp is in free-running mode, which timing from 0 according to the LiDAR internal clock.

The LiDAR automatically switches to external sync mode when there is an external input PPS signal. The period of PPS signal is 1000ms. When the rising edge of the PPS signal is received, the timestamp of current scan point is synchronized to the PPS signal. Then the timing continues using internal clock until the next PPS arrives. 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.

6. Quick Start

For a quick performance evaluation of the LiDAR or customization development based on the product, you can use the *Oradar Viewer* software, SDK and ROS package provided by Oradar.

Device Connection

The RJ45 Ethernet connector of Oradar MS500 is used to transmit scanning data, and the multi-core cable is for external power supply. Please refer to the Interface Definition for detailed description. For first-time commissioning, a 12V/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 250.250.250.0.

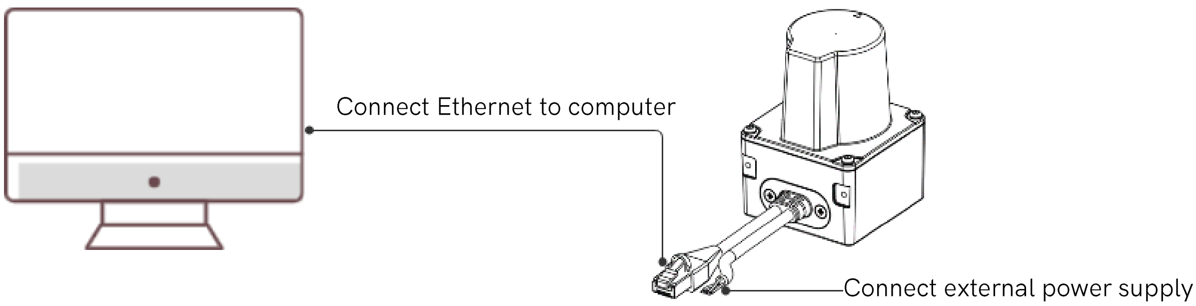


Figure 6-1 Device Connection

a. Connect the RJ45 Ethernet connector of the LiDAR to the PC.
b. Use a 12V/1A power supply to power the lidar.

IP setting of host computer

The setting method for Windows system is as follows:

a. In Control Panel, enter "Network and Sharing Center".
b. Click "Ethernet" to jump to the Ethernet status interface and click the "Attribute" button to enter the Ethernet attribute setting interface.
c. Double-click "Internet Protocol Version 4 (TCP/IPV4)".
d. 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 250.250.250.0, and click the "Confirm" button to complete setting the static address of the computer.

It is recommended to use computer with Windows 10 (64-bit) and above operating system, 4-core 2.0GHz and above CPU, and more than 4GB of memory.

Oradar Viewer

Oradar Viewer is an operation software that can display, record, and analyze point clouds in real time. It is convenient for users to evaluate the LiDAR performance and observe the point cloud data scanned in the environment on the PC.

Oradar Viewer currently supports Windows 10 (64-bit) operating system. Unzip the file, and open the program named *Oradar Viewer* in the unzipped file to use it.

Check out the "Oradar Viewer User Manual" for usage details.

Oradar SDK

In addition to the above-mentioned real-time point cloud data using the *Oradar Viewer*, users can also apply the LiDAR acquired point cloud data to various custom scenarios through the software development kit *Oradar SDK*. The *Oradar SDK* supports development in Windows/Linux environments and is available as a ROS/ROS2 package.

Please contact your technical support staff for *Oradar SDK* and related usage manual.

7. Version Revisions

Version	Revised by	Reviewed by	Release time	Revisions
A0	Xiongmaowang	Xiongmaowang	2021-09-14	Initial release
A1	Baixiao	Xiongmaowang	2022-3-5	Update some indicators.
A2	Baixiao	Xiongmaowang	2022-5-12	Increase the timestamp and Update some indicators.
A3	Lubinxun	Lubinxun	2023-01-29	Add operation mechanism

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