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## **Revision History**

Revision	Content	Date	Edited by	
1.0	Initial Release (For B2 Sample)	06.02.2020	PD	
1.0.1	Update Dimension Drawing in Appendix D Modify some not precise description	18.02.2020	PD	
1.0.2	Add the interpretation of UTC timestamp	10.03.2020	PD	

# Terminologies

MSOP	Main Data Stream Output Protocol
MEMS	Micro-Electro-Mechanical System
Pitch	The vertical angle
Yaw	The horizontal angle
Timestamp	The marker that records the system time
Header	The starting part of the protocol packet
Tail	The ending part of the protocol packet
Thermolysis	The loss of Heat from the Object

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Congratulations on your purchase of a RS-LiDAR-M1 (B2 Sample) Real-Time 3D LiDAR Sensor. Please read carefully before operating the product. Wish you a pleasurable product experience with RS-LiDAR-M1 (B2 Sample).

## **1 Safety Notices**

To reduce the risk of device damage and to avoid breach of terms, do not disassemble sensor.

• Laser Safety - The laser safety complies with following standards:

IEC 60825-1:2004;

21 CFR 1040.10 and 1040.11, except the terms in Laser Notice No. 50 that was published at 24.06.2007;

Chinese National Standard GB7247.1-2012.

- Read Instructions All safety and operating instructions should be read before operating the product.
- Follow Instructions All operating and use instructions should be followed.
- Retain Instructions The safety and operating instructions should be retained for future reference.
- Heed Warning All warnings on the product and in the operating instructions should be obeyed.
- Servicing The user should not attempt to service the product beyond what is described in the operating instructions. All other servicing should be referred to RoboSense.

## **2** Introduction

RS-LiDAR-M1 (B2 Sample) is the world leading automotive grade solid-state LiDAR with small size that is particular applied in perception of environment for autonomous driving and ADAS.

RS-LiDAR-M1 (B2 Sample), as a MEMS solid-state LiDAR, the technical details are listed as below:

- Measurement rang up to 180 meters
- Accuracy ± 5 centimeter (within 60 meter)
- Data rate up to 1,125,000 points/second
- Horizontal field of view (FOV): 120°
- Vertical field of view (FOV): -12.5°~12.5°

In comparison to RS-LiDAR-M1 (B1 Sample), not only the dimension but also the specification of B2 Sample has been further optimized.

For RS-LiDAR-M1(B2 Sample), laser beams are emitted and then sent out from sensor by a 2D MEMS Mirror, in order to scan continuously the surrounding environment. Meanwhile, advanced digital signal processing and ranging algorithms calculate point cloud data and reflectivity of objects to enable the machine to "see" the world and to provide reliable data for localization, navigation and obstacle avoidance.



Figure 1: RS-LiDAR-M1(B2 Sample) Imaging System.

Operation of device includes:

- Establish communication with RS-LiDAR-M1;
- Parse the data packets for angle, measured distance, and reported calibrated reflectivity;
- Calculate X, Y, Z coordinates from reported measured distance and angle;
- Store the data as needed;

## 3 Product Specifications(B2 Sample)<sup>1</sup>

	Table 1: Product Parameters.		
	Time of Flight Distance Measurement		
	<ul> <li>Measurement Range: 1 m to 180 m(120 m@10%)<sup>2</sup></li> </ul>		
	• Accuracy: ±5 cm (within 60 m) <sup>3</sup>		
Sensor	● Field of View (Vertical): -12.5°~+12.5°		
	Angular Resolution (Vertical): 0.2 <sup>°4</sup>		
	Field of View (Horizontal): 120°		
	<ul> <li>Angular Resolution (Horizontal/Azimuth): 0.2<sup>°4</sup></li> </ul>		
	Frame Rate: 15 Hz		
Laser	Class 1		
Eucor	Wavelength: 905 nm		
	Data Rate: ~1125k points/second		
Output	• 1000Base-T1 Ethernet		
	UDP Packet includes: Distance, Angle, Reflectivity		
	<ul> <li>Power Consumption: 28 W (B2 Sample)<sup>5</sup></li> </ul>		
	Operating Voltage: 9-36 VDC		
Mechanical/	<ul> <li>Weight: ~0.8 kg(without cable)</li> </ul>		
Electrical/	• Dimensions: L:140 mm x H:50 mm x W:110 mm		
Operational	<ul> <li>Environmental Protection: IP67, IP6K9K</li> </ul>		
	• Operation Temperature: -40 °C to +65 °C <sup>6</sup> , (Convection		
	Cooling is necessary, while device operates for a long time)		
	<ul> <li>Storage Temperature: -40 °C to +105 °C</li> </ul>		

<sup>&</sup>lt;sup>1</sup> The following data is only for mass-produced products. Any samples, testing machines and other non-mass-produced versions may not be referred to this specification. If you have any questions, please contact RoboSense sales.

<sup>&</sup>lt;sup>2</sup>The measurement target of rang 120 m is a 10% NIST Diffuse Reflectance Calibration Targets, the test performance is depending on circumstance factors, not only temperature, range and reflectivity but also including other uncontrollable factors.

<sup>&</sup>lt;sup>3</sup> The measurement target of accuracy is a 50% NIST Diffuse Reflectance Calibration Targets, the test performance is depending on circumstance factors, not only temperature, range and reflectivity but also including other uncontrollable factors.

<sup>&</sup>lt;sup>4</sup> Resolution is not always the same in the whole FOV, the mean value of the resolution is 0.2°.

<sup>&</sup>lt;sup>5</sup> The test performance of power consumption is depending on circumstance factors, not only temperature, range and reflectivity but also including other uncontrollable factors.

<sup>&</sup>lt;sup>6</sup> Device operating temperature is depending on circumstance, including but not limited to ambient lighting, air flow and pressure etc.

## **4 Electrical Interface**

## 4.1 Power Supply

The device requires a voltage input range of 9-36 VDC, and 12 VDC is recommended. The power consumption of the device is about 28 W (typical).

## 4.2 Electrical Configuration

The connectors of RS-LiDAR-M1 (B2 Sample) are shown as below:



Figure 2: Image of the two connectors on RS-LiDAR-M1(B2 Sample).

The PINs definition of these two connectors are shown as below:

LiDAR\_Connector 1:



PIN	Definition		
B1	GPS_1PPS		
B2	DC Power Input		
B3	Ground		
B4	CANH (DISABLE)		
B5	CANL (DISABLE)		
B6	Wake-up Mode Input (DISABLE)		

Figure 3: Image of PINs Definition of LiDAR\_Connector 1(Power Source).

#### LiDAR\_Connector 2:



PIN	Definition		
A1	GMSL_P (DISABLE)		
A2	1000Base-T1_P		
A3	GMSL_N (DISABLE)		
A4	1000Base-T1_N		

Figure 4: Image of PINs Definition of Connector 2(Signal).

The connectors on the RS-LiDAR-M1(B2 Sample) can be connected to the Robosense Interface Box, the cable length from the side of LiDAR to the Interface Box is 3 m (standard).

#### 4.3 Interface Box

The interface box is connected to the RS-LiDAR-M1 by default, while the main function of the interface box is to transfer the 1000Base-T1 signal to 1000Base-TX signal.

There are also connectors for power supply and for 1000Base-TX Ethernet with RJ45 interface.

All interfaces on Interface Box are shown in the image as below:



	1PPS
Connection to external device	Wake-up
	DC_INPUT
	RJ45
Connection to LiDAR	Box_Connector 1
Connection to LIDAR	Box_Connector 2

Figure 5: Connector Definition on Interface Box

## 4.4 Connection Details of Interface Box

The details of all interfaces are shown in following image.





## **5** Communications Protocols

RS-LiDAR-M1 (B2 Sample) adopts UDP protocol and communicates with PC through Ethernet. The length of UDP packet in this user manual is fixed at 1400 bytes. The Ethernet parameters of RS-LiDAR-M1 (B2 Sample) can be changed as user wish. The factory Ethernet parameters, IP address and port number, are shown in the following table.

Device	IP Address	MSOP Packet Port Number
RS-LiDAR-M1(B2 Sample)	192.168.1.200	
PC	192.168.1.102	6699

Table 2: The IP Address and Port Number Setting at the Factory.

The default MAC Address of eachRS-LiDAR-M1 (B2 Sample) is set in the factory. The MAC Address is sole.

To establish communication between a sensor and a computer, the IP address of the computer should be set at the same network segment of that of the sensor. By default: 192.168.1.X (X can take any positive integer between 1 and 254), subnet mask: 255.255.255.0. In case of uncertainty about the internet setting of the sensor, please connect the sensor to the computer, and parse packet to get the IP and port through Wireshark.

The content of MSOP protocol is shown as below:

Protocol	Abbreviation	Function	Туре	Size	Cycle
Main data Stream	MSOP	Scan Data Output	UDP	1400bvte	~ 75 us <sup>7</sup>
Output Protocol	Meer		021	Troobyto	10 40

Table 3: Protocols Adopted by RS-LiDAR-M1(B2 Sample).

Note: The following section describes and defines the valid payload (1400 byte) of the UDP protocol packet.

### 5.1 MSOP

I/O type: device output data, computer parse data. Default port number is 6699.

MSOP outputs data information of the 3D environment in packets. Each MSOP packet is 1400 bytes long and consists of reported distance, calibrated reflectivity values, yaw and pitch values and a time stamp.

Each RS-LiDAR-M1 (B2 Sample) packet payload is 1400 bytes long and consists of a 20-byte header, a 1300-byte data field containing 25 blocks of 52-byte data block and 80 bytes for reservation.

The format of MSOP packet in single return mode is shown as below:

 $<sup>^7</sup>$  For RS-LiDAR-M1(Sample B2), the complete scan process is realized through MEMS-Mirror reflecting laser beams. Its scanning path is like a zigzag. In one complete frame, that includes 126 lines, each line contains 5 UDP packets, it will cost 75  $\mu$ s between two packets. In the transition of two lines, the time between the near two UDP packets cost about 80  $\mu$ s. After finishing the 126-line scan, there is still 17 ms time interval to start the first line scan in a new one frame.



MSOP Packet (1400 bytes)



#### 5.1.1 Header

The 20-byte Header marks the beginning of data blocks, packet command, reservation bits and time stamp. The details is shown as below:

Header(20bytes)				
header	cmd	resv	time	
4bytes	4bytes	2bytes	10bytes	

Table 4: Header of MSOP Packet.

header: 0x55,0xAA,0x05,0x5A;

- cmd: packet command, fore 16 bits are packet number (cycle count), rear 16 bits are packet length (exclude header and packet command);
- time: time stamp, which records system time, resolution 1 us, can refer to time definition in the Appendix A.1;

resv: reservation bits.

#### 5.1.2 Data Field

Data field comprises data blocks that contain valid measurement data, in total 1300 bytes. Each data filed contains 25 blocks. Each block is 52-byte long and is a complete measurement data set. The details are shown in the following table 5.

Data block n(52bytes)					
content	offset(byte)	size(bit)	instruction		
pitch	0	16	Vertical angle		
yaw	2	16	Horizontal angle		
resv	4	64	Reservation		
ch1_ref_w1	12	16	Channel 1 reflectivity for 1st return		
ch1_dist_w1	14	16	Channel 1 distance for 1st return		
ch1_ref_w2	16	16	Channel 1 reflectivity for 2nd return		
ch1_dist_w2	18	16	Channel 1 distance for 2nd return		
ch2_ref_w1	20	16	Channel 2 reflectivity for 1st return		
ch2_dist_w1	22	16	Channel 2 distance for 1st return		
ch2_ref_w2	24	16	Channel 2 reflectivity for 2nd return		
ch2_dist_w2	26	16	Channel 2 distance for 2nd return		
ch3_ref_w1	28	16	Channel 3 reflectivity for 1st return		
ch3_dist_w1	30	16	Channel 3 distance for 1st return		
ch3_ref_w2	32	16	Channel 3 reflectivity for 2nd return		
ch3_dist_w2	34	16	Channel 3 distance for 2nd return		
ch4_ref_w1	36	16	Channel 4 reflectivity for 1st return		
ch4_dist_w1	38	16	Channel 4 distance for 1st return		
ch4_ref_w2	40	16	Channel 4 reflectivity for 2nd return		
ch4_dist_w2	42	16	Channel 4 distance for 2nd return		
ch5_ref_w1	44	16	Channel 5 reflectivity for 1st return		
ch5_dist_w1	46	16	Channel 5 distance for 1st return		
ch5_ref_w2	48	16	Channel 5 reflectivity for 2nd return		
ch5_dist_w2	50	16	Channel 5 distance for 2nd return		

Tahla	5٠	Definition	of	Data	Block	in	MOSP	Packet
Table	υ.	Deminion	UI	Dala	DIOCK		IVIUSE	Fackel.

Pitch: vertical angle;

Yaw: horizontal angle;

Chn\_ref\_w1: channel n the reflectivity of first return;

Chn\_dist\_w1: channel n the measured distance of first return;

Chn\_ref\_w2: channel n the reflectivity of second return;

Chn\_dist\_w2: channel n the measured distance of second return;

Here, n = 1, 2, 3, 4, 5.

### 5.1.1.1 Channel Data

Channel data is 8-byte long, respectively first return and second return. Each block is 4 bytes and include 2 set data, of which the 2 higher bytes contain reflectivity and the lower 2 bytes contain measured distance.

	Channel data n(8 byte)											
First Reflect	ivity(2 byte)	First Dista	nce(2 byte)	Second Refle	ctivity(2 byte)	Second Distance(2 byte)						
Reflectivity1	Reflectivity	Distance	Distance	Reflectivity1	Reflectivity2	Distance	Distance					
[15:8]	2[7:0]	[15:8]	[7:0]	[15:8]	[7:0]	[15:8]	[7:0]					

Table 6: Details of each Channel Data.

Distance is 2-byte, unit: cm, resolution: 0.5 cm. The following shows how to parse channel data.

In the case of Figure 8, the distance information is calculated by:

Get distance values: higher bits is 0x03 , lower bits is 0xfc; Convert to decimal: 3, 252; Formula: Distance = (higher bits \* 256 + lower bits) \* resolution = (3 \* 256 + 252) \* 0.005

= 5.10 m

Result: 5.10 m

Hence, the measured distance is 5.10 m

Reflectivity data records relative reflectivity (more definition on reflectivity, please refer to description on calibrated reflectivity in Section 9 of this manual). Reflectivity data reveals the reflectivity performance of the system in real measurement environments, it can be used in distinguishing different materials.

## 5.1.2.2 Demonstration of MSOP Packet

The following image shows the content of MSOP packet and the parsing process:

No.	Time	Source Destination	Protocol Length Info
F	1 0.000000	192.168.1.200 192.168.1.1	02 UDP 1442 6677→6699 Len=1400
	2 0.000000	192.168.1.200 192.168.1.1	02 UDP 1442 6677→6699 Len=1400
	3 0.000156	192.168.1.200 192.168.1.1	02 UDP 1442 6677→6699 Len=1400
	4 0.000157	192.168.1.200 192.168.1.1	02 UDP 1442 6677→6699 Len=1400
	5 0.000325	192.168.1.200 192.168.1.1	02 UDP 1442 6677→6699 Len=1400
	6.0.000326	192.168.1.200 192.168.1.1	02 UDP 1442 6677→6699 Len=1400
	Header checksum:	0x2af1 [validation disabled]	
	[Header checksum	status: Unverified]	
	Source: 192.168.1	1,200	
	Destination: 192	.168.1.102	
	[Source GeoIP: Un	nknown]	
0010	0 05 04 05 -0 00	00 ff 11 00 f1 c0 c0 01 c0 c0 c0	·
0010	0 05 94 06 29 00	2h 05 80 81 19 55 aa 5a a5 16 a9	f + 117
0020	05 20 00 01 19	10 25 12 11 39 00 9d 01 9a 3a b0	% 9 .
0040	3a ad 00 05 03	fc 20 5d 00 ff 00 69 02 d2 01 05	· · · · · · · · · · · · · · · · · · ·
0050	00 e4 00 2c 07	25 00 b5 00 d5 00 27 04 26 00 fe	
0060	00 e4 00 23 02	42 00 cc 00 f6 00 1d 08 ec 00 f8	Header: 0x55 0xaa 0x5a 0xa5
0070	00 e7 3a b2 38	2e 00 05 03 fc 00 5c 00 ff 00 1b	
0080	02 cf 00 82 00	e4 00 2f 07 1b 00 b9 00 d5 00 22	/"
0090	04 30 00 de 00	e4 00 22 02 48 00 c6 00 f6 00 1a	.0" <mark>.</mark> H
00a6	08 e7 00 e0 00	e7 3a b3 35 ae 00 05 03 fc 00 60	
00b6	00 ff 00 1c 02	cb 00 84 00 e4 00 2e 07 12 00 b6	Data block 0
00c0	00 d5 00 1b 04	3a 00 c7 00 e4 00 24 02 4d 00 d3	
00d0	00 f6 00 18 08	df 00 d3 00 e7 3a b4 33 39 00 05	Channel 1 data calculation
00e6	03 fc 00 59 00	ff 00 1b 02 c8 00 83 00 e4 00 28	
0010	07 08 00 ac 00	d5 00 12 04 43 00 8a 00 e7 00 1d	distance byte: 0x03, 0xfc: Atten byte:0x03
0100	02 4C 00 aa 00	to 00 1a 08 d8 00 e4 00 e7 3a b6	
0110	30 ed 00 03 03	fc 00 3D 00 ff 00 1D 02 C3 00 /f	combine the byte: $0x03fc$ ; get atten $0x03$
0130	00 67 00 13 02	3a 00 7c 00 f9 00 16 08 a0 00 bd	combine the byter onobie, get atten ionob
0140	00 e7 3a h7 2e	8e 00 05 03 fc 00 5d 00 ff 00 1a	get distance: 0x03fc: combine the byte:0x03
0150	02 c2 00 7d 00	e4 00 2e 06 f5 00 b6 00 d5 00 19	get distance. 0x051c, combine the byte .0x05
0160	04 55 00 58 00	e7 00 0e 01 9f 00 5a 00 fc 00 13	convert to decimal 1020, convert to decimal 2
0170	08 ec 00 aa 00	e7 3a b9 2c 3b 00 05 03 fc 00 5f	convert to decimal. 1020, convert to decimal.5
0180	00 ff 00 1a 02	c0 00 7c 00 e4 00 33 06 ec 00 be	
0190	00 d5 00 18 04	5e 00 b0 00 e7 00 13 01 9d 00 7b	·····^·· ······{
01a6	00 fc 00 18 0b	70 00 9d 00 e7 3a ba 29 eb 00 05	p:.)
016	03 fd 00 5e 00	ff 00 66 02 be 00 fe 00 e4 00 33	^f3
01c6	06 e6 00 bf 00	d5 00 09 04 64 00 42 00 ea 00 17	d.B
01d6	01 9d 00 95 00	fc 00 18 0b 74 00 9f 00 e7 3a bb	t

Figure 8: Example for showing Data Block in Wireshark.

# 6 GPS Synchronization (not support now)

TBD

## 7 Key characteristics

## 7.1 Return Mode

### 7.1.1 Return Mode Principle

RS-LiDAR-M1(B2 Sample) supports multiple return modes: Strongest return, Last return, and Dual return modes. When set to dual return mode, the details of the target will be enhanced, and the number of point is twice than that of a single return.

Due to the divergence of the beam, it is possible to generate multiple laser returns with one laser emission. When the laser pulse is emitted, its light spot gradually becomes larger. Suppose a light spot is large enough to shot multiple targets and produce multiple returns. Generally, the farther away the target is, the weaker it will be at the receiver, while the high reflective surface may be the opposite.

RS-LiDAR-M1(B2 Sample) analyzes the received multiple return values and outputs the strongest, last or simultaneous output of these two return values depending on the setting. If set to the strongest return mode, only the strongest reflected return value is output. Similarly, if the setting is the last return mode, only the last return value is output; if set to double return mode, the strongest and last return information is output simultaneously.

Note: Only when the distance between two objects is greater than 1 meter, the LiDAR could distinguish these two returns.

## 7.1.2 The Strongest Return

When the LiDAR beam hits only one object, there is only the strongest return at this time.

### 7.1.3 Strongest, Last and Dual Returns

When the laser pulse hit two objects at different distances, there will be two return wave, then it will lead two situations:

(1) When the strongest return is not the last return, return the strongest and last return;

(2) When the strongest return is also the last return, return the strongest return and the second strongest return;

Note: For RS-LiDAR-M1 (B2 Sample), it is only support Strongest Return mode.

## 8 Point Cloud

## 8.1 Coordinating Mapping

Please refer to the ROS source code to get the coordinating mapping and point calculation method. The exact source code is located in the unpack function of rawdata.cc file.

More details will be replenished in later version.

## **9** Reflectivity

For RS-LiDAR-M1(B2 Sample), the reflectivity is included in the data field of MSOP packet. Reflectivity is a scale to evaluate the ability of the reflection of light from object. This value is highly related to the material of measured object. Hence, the character can be used to distinguish the different materials.

RS-LiDAR-M1(B2 Sample) reports reflectivity values from 0 to 255 with 255 being the reported reflectivity for an ideal reflector. Diffuse reflection reports values from 0 to 100, with the weakest reflectivity reported from black objects and strongest reflectivity reported from white object. Retro-reflector reports values from 101 to 255.

### **Diffuse Reflector**



Figure 9: Calibration of Reflectivity.

The value of reflectivity can be gotten from MSOP packet.

## **10 Troubleshooting**

This section provides detail on how to troubleshoot your sensor.

Problem	Solution
Interface BOX green LED doesn't light or blink.	<ul> <li>Verify the power connection and polarity</li> <li>Verify the power supply satisfy the requirement( at least 4A @19V)</li> </ul>
Unit operates but no data	<ul> <li>Verify network wiring is functional.</li> <li>Verify receiving computer's network settings.</li> <li>Verify packet output using another application (e.g. Wireshark)</li> <li>Verify no security software is installed which may block Ethernet broadcasts.</li> <li>Verify input voltage and current draw are in proper ranges</li> </ul>
Can see data in Wireshark but not RSVIEW	<ul> <li>Check no firewall is active on receiving computer.</li> <li>Check the receiving computer's IP address is the same as LiDAR destination IP address.</li> <li>Check the RSVIEW Data Port setting.</li> <li>Check if the wireshark receive the MSOP packets.</li> </ul>
Data dropouts	<ul> <li>This is nearly always an issue with the network and/or user computer.</li> <li>Check the following: <ul> <li>Is there excessive traffic and/or collisions on network?</li> <li>Are excessive broadcast packets from another service being received by the sensor? This can slow the sensor down.</li> <li>Is the computer fast enough to keep up with the packet flow coming from the sensor?</li> </ul> </li> <li>Remove all network devices and test with a computer directly connected to the sensor.</li> </ul>
No data via router	<ul> <li>Close the DHCP function in router or set the Sensor IP in router configuration</li> </ul>
Point cloud data to be a radial	<ul> <li>If the computer is windows 10 OS, then run the RSVIEW with windows 7 OS compatible mode.</li> </ul>

## **Appendix A Registers Definition**

## A.1 MSOP cmd

Cmd (4 bytes)								
Packet Numb	er(2bytes)	Packet Length(2bytes)						
Number1 [15:8]	Number2 [7:0]	Length1 [15:8]	Length1 [7:0]					

## A.2 UTC\_TIME

3 0.000216	192.168.1.21	192.168.1.255	UDP	1442 2368→2368 Len=1400
4 0.000217	192.168.1.21	192.168.1.255	UDP	1442 2368→2368 Len=1400
5 0.000410	192.168.1.21	192.168.1.255	UDP	1442 2368→2368 Len=1400
6 0.000410	192.168.1.21	192.168.1.255	UDP	1442 2368→2368 Len=1400
7 0.000604	192.168.1.21	192.168.1.255	UDP	1442 2368→2368 Len=1400
8 0.000605	192.168.1.21	192.168.1.255	UDP	1442 2368→2368 Len=1400
9 0.000605	192.168.1.21	192.168.1.255	UDP	1442 2368→2368 Len=1400
10 0.000794	192.168.1.21	192.168.1.255	UDP	1442 2368→2368 Len=1400
11 0.000794	192.168.1.21	192.168.1.255	UDP	1442 2368→2368 Len=1400
12 0.000981	192.168.1.21	192.168.1.255	UDP	1442 2368→2368 Len=1400

Frame 4: 1442 bytes on wire (11536 bits), 1442 bytes captured (11536 bits) on interface 0
 Ethernet II, Src: Xilinx\_00:01:02 (00:0a:35:00:01:02), Dst: Broadcast (ff:ff:ff:ff:ff:ff)
 Internet Protocol Version 4, Src: 192.168.1.21, Dst: 192.168.1.255

> User Datagram Protocol, Src Port: 2368, Dst Port: 2368

	5E.		00	45	3 00	2 0	01 0	00	35	0a	00	ff	ff	ff	ff	ff	ff	0000
	V		a8	c0	1 15	8 0	c0 a	e8	56	11	ff	00	00	0b	db	94	05	0010
	@@U.Z^	@.@	5e	bf	a a5	a 5	55 a	40	40	80	05	40	09	40	09	ff	01	0020
	9.f.X.	. Y Z.	eb	K	5 8a	9 6	39 f	h7	d1	dh	5a	00	00	01	59	20	05	0030
head		q	2d	00	9 9c	9 0	00 0	ff	00	00	00	00	00	00	00	d2	71	0040
	H.!	Z.?	ac	00	4 21	∕∧	00 4	d9	00	4	00		03	5a	00	ff	00	0050
	X./	:	2f	00	4 58	5 04	00 0		00	94	00	91	03		00	d4	00	0060
	natatatatatatang	X.n	0a	00	ð ff	0 0	00 0	00	00	30	00	c0	6e	e7	58	f7	00	0070
sec		···/···T	4a	00	<del>) d9</del>	1 0	<del>00</del> e	3e	03	54	00	ff	00	2f	00		00	0080
		. # =	06	00		B Ø	00 9	91	03	3d	00	d4	00	af	00	23	04	0090
	k	X.	00	00	00 6	ð Ø	00 0				58	ff	00		00	<b>b</b> 8	00	00a0
	R.>		cb	00		2 0	00 5	ff	00	2d	00	97	00		00	ff	00	0060
ns	=	F.\$	98	00	3 92	10	00 3	d4	00		00	24	04		00		00	00c0
	X.h	0	00	00		a 6	58 e	ff	00	4f	00	ad	00		00		00	00d0
			4f	00	) ff	7 0	00 2	e6	03	07	00	ff	00	00	00	00	00	00e0

Figure A - 1: UTC Data Block.

(1) The timestamps are divided into second part and nanosecond part. The second part shown in Figure A-1 is 0x005adbd1b7 (1524355511); the nanosecond part is 0x39f9668a (972646026);

(2) The second part is UTC timestamp, which indicates the incremental count of seconds from 0:00 (London time) on January 1, 1970 to the current time. Figure A-1 shows the identification of London time 2018 / 4 / 22 00:05:11;

(3) The maximum value of the nanosecond part is 0x3b9ac9ff (99999999), after the maximum value is increased by 1, the nanosecond returns to zero and the second will be added to 1, as shown in Figure A-1 is 972646026 nanosecond;

(4) Most PC development environments have time conversion functions, such as including system library < time.h >, time.gmtime (&t) function can convert timestamp to London time.

UTC Time (10bytes)									
Byte No.	byte1	byte2	byte3	byte4	byte5	byte6	byte7	byte8	
Function				ns					
Byte No.	byte9	byte10							
Function	n	IS							

Note: ns[7:0]: 0~999999999;

## Appendix B RSView

This appendix gets you started with RSView. It shows you how to use the application to acquire, visualize, save, and replay sensor data.You can examine sensor data with other free tools, such as Wireshark or tcp-dump. But to visualize the 3D data, use RSView. It's free and relatively easy to use.The version of RSView is RSView2.0.

### **B.1 Features**

RSView provides real-time visualization of 3D LiDAR data from RoboSense LiDAR sensors. RSView can also playback pre-recorded data stored in "PCAP" (Packet Capture) files, but RSView still does not support .PCAPNG files.

In RSView, each measurement from RS-LiDAR- M1 (B2 Sample) can be recognized as a point cloud data. A cloud point data could include different information such as distance, reflectivity, pitch and yaw value. According to these values, software can display the measured points in terms of different colors as user wish. The function of RSView:

- Visualize live streaming sensor data over Ethernet.
- Record real-time measured data in PCAP files.
- Replay the data from recorded PCAP files.
- Different vitalization mode, according to distance, pitch and yaw etc..
- Tabular inspection of point cloud data.
- Tools for distance measuring.

### **B.2 RSView Installation**

Installer for RSView is provided for Windows 64-bit system and it doesn't need other dependencies packet. The executable installer **RSView\_2.0.0\_Setup.exe** can be found in the U disk in the RS-LiDAR-M1 (B2 Sample) box.

### **B.3 Set up Network**

The default IP address of the computer from factory should be set as 192.168.1.102, sub-net mask should be 255.255.255.0. And the RSView should not be shielded by operating firewall in the computer.

### **B.4 Visualization of Sensor Data**

- 1. Connect RS-LiDAR- M1(B2 Sample) to power source and through crossover cable to PC.
- 2. Right Click the symbol of RSView, to start it with Run as administrator(Fig. B-1).



Figure B - 1: Open RSView with Run as administrator.

3. Click File > Open then select Sensor Stream (Fig. B-2).

🙆 R	SView				
File	Tools Help				
	Open	٠	-	Capture File	Ctrl+O
	Recent Files	•		Sensor Stream	
٩	Save As Export To KiwiViewer Save Screenshot	÷	Ø	Choose Calibration Fi	e
	Close Data	Ctrl+W			
	Exit	Ctrl+Q			

Figure B - 2: Open Sensor Stream for displaying real-time Data.

4. The Sensor Configuration dialog will appear. A default configuration folder of RS-LiDAR-M1 called "RSIidarM1CorrectionFile" for reference, but please add the right configuration files folder of the RS-LiDAR-M1 in USB stick, which should include all three csv files (angle.csv, ChannelNum.csv, curves.csv). That can be found in the configuration files folder named "configuration\_data", otherwise point cloud display will be chaos with the default configuration files. Select the configuration files folder of corresponding LiDAR and then click **OK**.



Figure B - 3: Import Configuration\_data of RS-LiDAR-M1(B2 Sample).

5. RSView begins displaying the real-time sensor data stream. The stream can be paused by pressing the **Play/Pause** button. Press it again to resume stream play.



Figure B - 4: Point Cloud Image of R-LiDAR-M1(B2 Sample).

## **B.5 Capture Streaming Sensor Data to PCAP File**

RSView as packet capture tool (the RSView for RS-LiDAR-M1 doesn't support this function):

1. Display real-time stream data, and then click **Record** button (Fig. B-5).



Figure B - 5: The Record Button in RSView

2. A Choose Output File dialog will pop up. Navigate to where you want the file to be saved and click the **Save** button (Fig. B-6). RSView begins writing packets to your pcap file. (Note: RS-LiDAR-32 sensors generate a lot of data. The pcap file can become quite large if the recording duration is lengthy. Also, it is best to record to a fast, local HDD or SSD, not to a slow subsystem such as a USB storage device or network drive.).

$ ightarrow \star \uparrow$ 🏪 > Thi	s PC → Local Disk (C:)			5 V	Search Local Dis	k (C:)	2
rganize 🔻 New folde	r:						1
📰 Pictures 🛛 🖈 ^	Name	Date modified	Туре	Size			
MEMS	PerfLogs	9/15/2018 3:33 PM	File folder				
wps	Program Files	1/18/2020 9:56 AM	File folder				
	Program Files (x86)	1/18/2020 8:51 AM	File folder				
This PC	Users	1/15/2020 10:03 AM	File folder				
3D Objects	Windows	1/18/2020 11:11 AM	File folder				
Desktop							
Documents							
Downloads							
Music							
Pictures							
Videos							
Local Disk (C)							
V V							
File name: 2017-0	7-29-11-43-02-RS-16-Data.pcap						_
Coursesting Lange (	*						_
Save as type: pcap (	".pcap)						

Figure B - 6: Dialogue after clicking Record Button.

3. Recording will continue until the **Record** button is clicked again, which stops the recording and closes the .pcap file.

Wireshark as packet capture tool:

1. Download software Wireshark (Fig. B-7).



Figure B - 7: Icon of Wireshark.

2. Double left click Wireshark, then select the LiDAR corresponding Network.

The Wireshark Network Analyzer		- 0	×
File Edit View Go Capture Analyze Statistics Telephony Wireless To	, Hep		
Apply a display filter ** @trl-/?		1	
Velcome to Vireshark			
Capture			
	err in * All interfaces shows*		
Ethernet0 J.			
Adapter for loopback traffic capture			

Figure B - 8: Start Software Wireshark.

3. When the data is shown like following image, it means that LiDAR operates normally. "LiDAR IP", "PC IP", "MSOP Port Number", "DIFO Port Number" can be checked in the red box.



Figure B - 9: The Information Display of Ethernet Packet.

4.	Click	Files	>	Save	(Fig.	B-10)	).
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Op	en Rec	lecent									,																	•
M	erge										Dest	inati	ion		Protocol		ol Length Info											
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Cl	ose				C	trl+W		90	)		192	.16	3.1.	102	U	IDP				Len=1248								
C .					0	aut. C		-10	)		192	. 16	3.1.	102	U	IDP	1290	3836	→ 38	36	Len=1248							
Save Save Ar			111+3		- 6	0 192.168.1.1		.102 UDP	1290	7788	+ 77	88	Len=1248															
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					90	9		192	. 161	3.1.	102	U	IDP	1290	3836	+ 38	36	Len=1248										
-								- 96	,		192	.16	3.1.	102	U	IDP	129	3836	→ 38	36	Len=1248							
Exq	port Spe	cified	Packe	:ts				pe	)		192	. 16	3.1.	102	U	IDP	1296	3836	→ 38	36	Len=1248							
Exq	port Pad	ket Dis	secti	ons			•	90	)		192	.16	3.1.	102	U	IDP	1290	3836	→ 38	36	Len=1248							
Exe	port Pag	ket By	tes		C	trl+Sh	ift+X	90	)		192	. 161	3.1.	102	U	IDP	1290	3836	→ 38	36	Len=1248							
Export PDUs to File					90	)		192	. 161	8.1.	102	U	IDP	1290	3836	+ 38	36	Len=1248										
Export TLS Session Keys				90	)		192	. 16	3.1.	102	U	IDP	1296	3836	→ 38	36	Len=1248											
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								-E																				
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Qu	uit				c	trl+Q		(6	00:10	:23	:17:	b8:	36),	Dst: 1	LCFCHe	Fe_bf	10:32	(c8:5	b:76:	bf:	10:32)							
Qu	uit n. Dat		. De	oto	C	trl+Q	. Do	(*	192.	.168	:17: .1.2	b8: 00,	36), Dst	Dst: 1	LCFCHe	EFe_bf: 102	10:32	(c8:5	b:76:	bf:	:10:32)							
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Qu Use	r Dat	agra	n Pr	oto 10	col 32	trl+Q , Sr 00 1	c Po	(e : : : : : : :	00:10 192. 3830 7 b8	:23 .168 5, D	:17: .1.2 st P 08 0	68: 00, ort	36), Dst : 38 5 06	Dst: 1 t: 192.1 336 0 ·[v	LCFCHe 168.1.	#··6·	:10:32	(c8:5	b:76:	bf:	10:32)							
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Figure B - 10: Save Data of Capturing Packet.



5. Select type of files as "Wireshark/tapdump/ pcap".

Figure B - 11: Save Data as PCAP Packet using Wireshark.

6. The saved PCAP data will appear in corresponding save path, the data can be visualized in RSView or ROS driver (the instruction of RSView can be referred in this Appendix of above section).

Name	Date modified	Туре	Size
RS-LiDAR	2/5/2020 5:24 PM	Wireshark capture	1,515,342 KB

Figure B - 12: Data saved in selected Document.

#### **B.6 Replay Captured Sensor Data from PCAP File**

To replay (or examine) a pcap file, open it with RSView. You can press **Play** to let it run, or scrub through the data frames with the Scrub slider. Select a set of 3D rendered data points with your mouse and examine the numbers with a Spreadsheet sidebar.

1. Click on File > Open and select Capture File (Fig. B-13).

💿 R File	SView Tools Help						
	Open	•	-	Capture File Ctrl+0			
	Recent Files	۲		Sensor Stream			
0	Save As Export To KiwiViewer Save Screenshot	+	0	Choose Calibration File			
	Close Data	Ctrl+W					
	Exit	Ctrl+Q					

Figure B - 13: Open recorded PCAP File.

2. An Open File dialog will pop up. Navigate to a PCAP file, select it, and click the **Open** button.

→ • • • •	> This P	C > Desktop >	New folder			5 V	Search New folder	م
ganize 🔻 Ne	w folder							
🔜 Desktop	* ^ 1	lame	^	Date modified	Туре	Size		
👆 Downloads	*	🔓 back_lidar		2/5/2020 5:24 PM	Wireshark capture	1,515,342 K	B	
Documents	*							
Pictures	*							
MEMS								
S WPS网盘								
This PC								
3D Objects								
Desktop								
Documents								
🖶 Downloads								
Music								
Pictures								
Videos	~							
	File name	back_lidar				~	Supported Files (*.inp *.txt	*.cr

Figure B - 14: Select and open PCAP File.

- 3. The Sensor Configuration dialog will pop-up. Select your sensor configuration folder and click **OK**.
- 4. Press **Play** to replay/pause the data stream. Use the Scrub slider tool (it looks like an old-fashioned volume slider) to move back and forth through the data frames. Both controls are in the same toolbar as the **Record** button.

🙆 RS	View															- • ×
File	Tools	He	lp													
		Ø	4				2			int 🔿 🛱	ensity	•				
X	0	<b>Lund</b>		+X	<b>1</b> -X	<b>1</b> +¥	¥1	+Z <b>1</b>	-Z	Relative RAW			) DDI 🛱	TF: 0	Skip: 0	477 🜲
Ŧ												Play				X
-																California de la companya de la comp

Figure B - 15: The Position of Play Button and Scrub Tool.

5. To get more detailed data, scrub to an interesting frame and click the **Spreadsheet** button (Fig. B-16). A sidebar of tabular data is displayed to the right of the rendered frame, containing all data points in this frame.

- File Tools Help								
1 0 4		📘 🎴 🛱						
	+X Spreadsheet	Rela						

Figure B - 16: Spreadsheet Tools in RSView.

6. Adjust the width of columns or sort the parameter per different physical quantity can get a much better view of those data.

Showing	ng Data 🔹 Attribute: Point Data 💌 Precision: 3 🐳 💽 🔛 🔛												
	Point ID	Points_m_XYZ	adjustedtime	azimuth	distance_m	intensity	laser_id	timestamp					
0	D	0.003	12320919.000	3	6.170	1	0	12320919					
1	1	0.005	12320922.000	4	7.600	3	1	12320922					
2	2	0.008	12320925.000	5	9.210	2	2	12320925					
3	3	0.012	12320928.000	6	11.520	1	3	12320928					
4	4	0.108	12320958.000	17	36.690	1	13	12320958					
5	5	0.022	12320969.000	21	6.160	1	0	12320969					
6	6	0.029	12320972.000	22	7.660	3	1	12320972					
7	7	0.036	12320975.000	23	9.230	3	2	12320975					
8	В	0.048	12320978.000	24	11.520	1	3	12320978					
9	9	0.222	12321008.000	35	36.540	2	13	12321008					
10	10	0.041	12321019.000	39	6.170	1	0	12321019					
11	11	0.052	12321022.000	40	7.650	2	1	12321022					

Figure B - 17: Tabular Info Display of all selected Point Cloud.

7. Click **Show only selected elements** in the Spreadsheet. Since no points are selected, the table will be empty.



Figure B - 18: RSView show-olny-elements Tool.

8. Click the **Select All Points** tool. This will turn your mouse into a point selection mode (Fig. 19).

File Tools	Help			
1	04		i 🥐 🛛	• H
8		+X Select Al	l Points	Re
X		1-1-		1

Figure B - 19: RSView Select-All-Points Tool.

9. In the 3D rendered data pane, press left mouse to draw a rectangle around amount of points. The additional information of box selected points will immediately show the data table (Fig. B-20).



Figure B - 20: RSView can list all of selected Points.

10. At any point you can save a subset of data frames by doing **File > Save As > Select Frames.** 

## Appendix C RS-LiDAR- M1(B2 Sample) ROS Package

This appendix will describe how to use Ubuntu 16.04 + ROS Kinetic to view the measured data from RS-LiDAR-M1(B2 Sample).

## C.1 Prerequisite

- 1. Please download and install the Ubuntu 16.04.
- Please refer the link (<u>http://wiki.ros.org/kinetic/Installation/Ubuntu</u>) to install ROS Kinetic.
- 3. Download and install libpcap-dev.

#### C.2 compile ROS Package for RS-LiDAR- M1(B2 Sample)

1. Create the work space for ros:

cd ~ mkdir -p catkin\_ws/src

2. Copy the ros\_rslidar\_package into the work space ~/catkin\_ws/src. The latest version of the ros\_rslidar driver can be downloaded from

https://github.com/RoboSense-LiDAR/ros\_rslidar.

If any problem appears, please ask Robosense for help to get these files.

3. Build:

cd ~/catkin\_ws catkin\_make

### C.3 Configuration of PC IP

For factorial default firmware of RS-LiDAR- M1(B2 Sample), the static IP of PC is "192.168.1.102", subnet mask: "255.255.255.0", gate way doesn't need to set.

After configuring, the command "ifconfig" in command prompt can check, whether the static PC IP is worked.

### C.4 Display the real-time data with ros\_rslidar packet

1. Connect the RS-LiDAR-M1 to your PC via RJ45 cable, and power on it.

2. In ros\_rslidar packet, the launch files, e.g. "rs\_lidar\_m6.launch", can start the "rslidar\_pointcloud" node to visualize the real-time point cloud data. Open a terminal and run the following code:

cd ~/catkin\_ws

source devel/setup.bash

roslaunch rslidar\_pointcloud rs\_lidar\_m6.launch

Figure C - 1: Point Could Display of RS-LiDAR-M1(B2 Sample) using rivz.

3. Set the Fixed Frame to "rslidar". Add a pointcloud2 type and set the topic to "rslidar points".

### C.5 View the recorded pcap file offline

The ros\_rslidar ROS package can also visualize the recorded .PCAP data.

1. Modify the "rs\_lidar\_m6.launch" file like below (please pay attention to the red line):

```
<launch>
```

<node name="rslidar\_node" pkg="rslidar\_driver" type="rslidar\_node" output="screen" >

<param name="model" value="MEMS"/>

<param name="pcap" value="the absolute path to your .pcap file"/>

<param name="device\_ip" value="192.168.1.200"/>

<!-- Set the Lidar data port on the PC side, default is 6699 -->

<param name="port" value="6699"/>

<param name="start\_from\_edge" value="true"/>

</node>

<node name="cloud\_node" pkg="rslidar\_pointcloud" type="cloud\_node" output="screen" >

<param name="model" value="MEMS"/>

<param name="angleT\_path" value="\$(find rslidar\_pointcloud)/data/rs\_lidar\_m6/angleT.csv" />

<param name="slow\_path" value="\$(find rslidar\_pointcloud)/data/rs\_lidar\_m6/real\_slow\_axis.csv"</pre>

<param name="channel\_path" value="\$(find rslidar\_pointcloud)/data/rs\_lidar\_m6/ChannelNum.csv"</pre>

</node>

/>

#### 2. Open a new terminal and run the following codes:

cd ~/catkin\_ws source devel/setup.bash roslaunch rslidar\_pointcloud rs\_lidar\_m6.launch

## Appendix D Dimension Image



\_Optical window without blockage(Including 2~3mm outward offset)







Figure D - 1: Dimension Drawing of RS-LiDAR-M1(B2 Sample).

Dimension	Measurement (mm)				
Length( along X direction, main body)	119.6				
Length(along X direction, include fastener )	131.6				
Width( along Y direction)	110.0				
Height( along Z direction)	50.0				

## Appendix E Suggestion of Mounting

## E.1 Suggestion of Mounting Position

Recommend mounting position on the vehicle:



Figure E - 1: Image of Mounting Position of RS-LiDAR-M1 (B2 Sample).

Recommend positions are shown in the following table:

Table E - 1: The recommend Mounting Position on the Vehicle.

Position	Mount	Height	Requirements
			1. Reserve space for clean from outside.
		600mm-1000mm	2. The thermolysis and heating device should be outside of 100mm around sensor.
A	Air Grille		<ol><li>Not recommend offset mount. If needed, the offset should be inside of 100mm.</li></ol>
			4. Angle offset with X-Y-Z axis should be smaller 1°.
в			1. Reserve space for clean from outside.
	Poor Bumpor	600mm-1000mm	2. The thermolysis and heating device should be outside of 100mm around sensor.
			3. Not recommend offset mount. The offset should be inside of 100mm.
			4. Angle offset with X-Y-Z axis should be smaller 1°.
			1. Reserve space for clean from outside.
6	Fender	600mm-1000mm	2. The thermolysis and heating device should be outside of 100mm around sensor.
	i ender		3. Do not cover FOV.
			4. Angle offset with X-Y-Z axis should be smaller 1°.
			1. Reserve space for clean from outside.
D	Front Vehicle		2. Needs to do some heat Insulation and ventilation, to ensure operating temperature inside of 85 $$ $^\circ$ C .
	ROOT		3. Angle offset with X-Y-Z axis should be smaller 1°.



Figure E - 2: Interpretation of Mounting Deviation.

In the above image, the red arrows are X-Y-Z axis in the Cartesian coordinate system. The green arrows are the offset direction. The angle offset between corresponding red and green arrow should be inside of 1°.

Besides, the RS-LiDAR should not be mounted behind windshield. It will cause the descent of LiDAR performance and the increase of LiDAR temperature.

### **E.2 Product Fixing Requirements**

At present, RS-LiDAR-M1(B2 Sample) should be fixed on the bracket with binder bolt, the relative position of fixed hole is shown in the following image.



Figure E - 3: Image of Mounting Holes of RS-LiDAR-M1 (B2 Sample).

The current fixed holes are symmetrically distributed threaded holes (those with counterbore structure on the side are housing fastening and non-structural element), which are connected by M5 bolts. The depth of the bolts into the housing is 8mm, and the actual length is compared and confirmed according to the thickness of the bracket.

The current installation method of B2 sample requires that it must be placed in the positive direction, i.e. the fixed hole should be placed downward. It is not allowed to place the B2 sample sideways or upside down. The specific arrangement can be assisted by RoboSense to ensure the stability of LiDAR.

## E.3 Product Dimension Tolerance

The following image shows the dimension tolerance of B2 Sample:



The requirements of accessories suiting for bracket should be considered according to the actual installation position. In this manual, it won't be normalization.

### E.4 Request of Thermolysis

At present, B2 Sample is a primer product. Thermolysis must be considered as an important variable while estimation of mount position.

For Thermolysis, we recommend as below:

- 1. Avoid heating source inside of 100 mm around B2 Sample.
- 2. Provide insulation measures for B2 Sample if possible.
- 3. Provide air circulation (forced convection) of at least 6m/s under long operating.
- 4. The bracket should cover the bottom radiator as much as possible to improve the heat transfer efficiency.

## Appendix F Sensor Clean

In order to exactly perceiving environment, RS-LiDAR needs to keep clean, specially fore filter part.

## F.1 Attention

Please read through this entire Appendix E content before clean the RS-LiDAR. Improper handling can permanently damage it.

### F.2 Require Materials

- 1. Clean microfiber cloths;
- 2. Mild, liquid dish-washing soap;
- 3. Spray bottle with warm, clean water;
- 4. Spray bottle with warm, mildly soapy water;
- 5. Isotropy alcohol;

## F.3 Clean Method

If the sensor is just covered by dust, use a clean microfiber cloth with a little Isotropy alcohol to clean the sensor directly, then dry with another clean microfiber cloths.

If the sensor is caked with mud or bugs, use a spray bottle with clean, warm water to loosen any debris from it. Do not wipe dirt directly off the sensor. Doing so may abrade the surface. Then use warm, mildly-soapy water and gently wipe the sensor with a clean microfiber cloth. Wipe the ring lens gently along the curve of the sensor, not top-to-bottom. To finish, spray the sensor with clean water to rinse off any remaining soap ( if necessary, use lsotropy alcohol and a clean microfiber cloth to clean any remaining dirt from the sensor ), then dry with another clean microfiber cloth.

2 0755-86325830

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