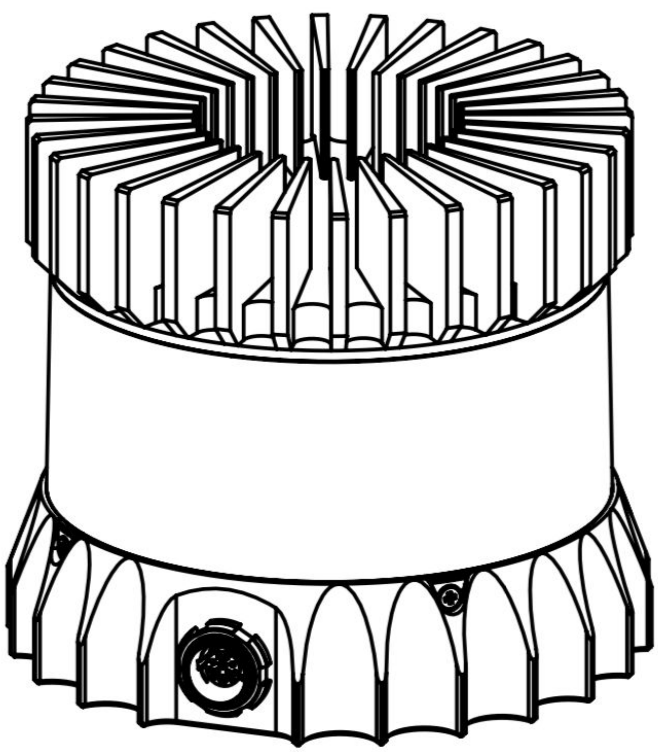
OUSTER

OS-1-64/16 High Resolution Imaging LIDAR

Software User Guide



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1. Introduction

The OS-1 family of sensors offer a market leading combination of price, performance, reliability and SWAP. They are designed for indoor/outdoor all-weather environments and long lifetime. As the smallest high performance LIDAR on the market, the OS-1 can be directly integrated into vehicle facias, windshield, side mirrors, and headlight clusters. The OS-1 family of sensors consist of two models, the OS-1-16 and OS-1-64, with differing resolution, but of identical mechanical dimensions

HIGHLIGHTS

- Fixed resolution per frame operating mode
- Camera-grade intensity, ambient, and range data
- Multi-sensor crosstalk immunity
- Simultaneous and co-calibrated 2D and 3D output
- Industry leading intrinsic calibration
- Open source drivers

For the purposes of this document, the term “OS-1” refers to the family of sensors, and only where there is a difference in performance will each model will be referred to by its specific model designation

2. Safety & Legal Notices

The OS-1-16 and OS-1-64 are Class 1 laser products per **IEC 60825-1:2014** and operate in the 850nm band.

WARNING: The OS-1 is a sealed unit, and is not user-serviceable

Your use of the OS-1 is subject to the Terms of Sale that you signed with Ouster or your distributor/integrator. Included in these terms is the prohibition on removing or otherwise opening the sensor housing, inspecting the internals of the sensor, reverse-engineering any part of the sensor, or permitting any third party to do any of the foregoing.

“Ouster” and “OS-1” are both registered trademarks of Ouster. They may not be used without express permission from Ouster.

If you have any questions about the above points, contact us at legal@ouster.io

3. Drivers & Interface

Our sample drivers can be found at: www.github.com/orgs/ouster-lidar

The sensor will automatically turn on, start scanning, obtain an IP address, and start taking measurements when provided power by the Interface Box. However it will only stream UDP data packets after receiving a destination IP address on TCP Port 7501.

The sensor is configured to dynamically obtain an IP address using a DHCP server. If the sensor is plugged into a network switch, it will automatically obtain an IP and you can find that IP by checking the DNS leases on the network switch.

If the sensor is plugged directly into a computer, you will have to install a DCHP server on the computer. We recommend dnsmasq for Ubuntu to dynamically assign an IP address. The basic steps are as follows:

	Step	Command
1	Install dnsmasq	
2	In a terminal window, obtain the list of interfaces on the machine, and note the interface that the sensor is plugged into	ip link
3	Edit your network connections to have a manually assigned IP e.g., 192.168.1.1 , with a Netmask of 255.255.255.0. You can keep the gateway field blank.	Right click network connections in the top-right-hand corner of your screen, and select an

		interface to edit.
4	Edit the dnsmasq config file to read the target interface	sudo vim /etc/dnsmasq.conf
5	Uncomment “#interface=” and add the interface above. dnsmasq will now search on this interface for allocating IP addresses	interface=enp0s25
6	Uncomment DHCP-range and make sure it has the same subnet as the manual IP you set above In the example to the right, dnsmasq will now allocate addresses 50-150 for leases for new devices on subnet 1	dhcp-range=192.168.1.50, 192.168.1.150, 12h” -
7	Start (or stop and start) dnsmasq	sudo systemctl stop dnsmasq sudo systemctl start dnsmasq
8	After dnsmasq is running with the proper configs per above, plug in the sensor. Check DNSMasq’s status	Use “journalctl -fu dnsmasq” to see dnsmasq’s status. You should see an IP address be allocated to the sensor after 10-15 seconds.
9	Then, either when you launch the ROS driver, you will identify the sensor by hostname or IP address (e.g., 192.168.1.50), and tell the sensor which IP address to send the data to (e.g., 192.168.1.1) NOTE: The sensor hostname does not change when you restart the sensor, whereas IP usually does with a DHCP server. We recommend using hostnames (e.g., os1-991827000891.local) instead of IP addresses for this reason. This functionally achieves the same result as a fixed sensor IP address.	

Future firmware releases will support manually setting a sensor IP address over TCP and/or GUI at a IPv6 linklocal address.

3.1. TCP API Command Set

3.1.1. Querying Sensor Info and Intrinsic Calibration

The sensor can be queried and configured using a simple plaintext protocol over TCP on port 7501. The following commands will return sensor configuration and calibration information:

Command	Description	Response
get_config_txt	Return JSON-formatted sensor configuration: auto_start_flag, tcp_port, udp_ip, udp_port_lidar, udp_port_imu, timestamp_mode, pps_out_mode, pps_out_polarity, pps_rate, pps_angle, pps_in_polarity, lidar_mode.	{"auto_start_flag": 1, "tcp_port": 7501, "udp_ip": "", "udp_port_lidar": 7502, "udp_port_imu": 7503, "timestamp_mode": "TIME_FROM_INTERNAL_OSC", "pps_out_mode": "OUTPUT_FROM_PPS_DEFINED_RATE", "pps_out_polarity": "ACTIVE_HIGH", "pps_rate": 1, "pps_angle": 360, "pps_pulse_width": 10, "pps_in_polarity": "ACTIVE_HIGH", "lidar_mode": "1024x10", "pulse_mode": "STANDARD", "window_rejection_enable": 1}
get_sensor_info	Return JSON-formatted sensor metadata: serial number, hardware and software revision, and sensor status.	{“prod_line”: “OS-1-64”, "prod_pn": "840-101396-02", "prod_sn": "991805000142", "base_pn": "000-101323-01", "base_sn": "11E0211", "image_rev": "ousteros-image-prod-aries-v1.2.0-201804232039", "build_rev": "v1.2.0", "proto_rev": "v1.1.0", "build_date": "2018-05-02T18:37:13Z", "status": "RUNNING"}
get_beam_intrinsics	Returns JSON-formatted beam altitude and azimuth offsets, in degrees.	{"beam_altitude_angles": [16.611, ..., -16.611], "beam_azimuth_angles": [3.164, …, -3.164]}

get_imu_intrinsics	Returns JSON-formatted imu transformation matrix needed to adjust to the Sensor Coordinate Frame	{"imu_to_sensor_transform": [1, 0, 0, 6, 253, 0, 1, 0, -11.775, 0, 0, 1, 7.645, 0, 0, 0, 1]}
get_lidar_intrinsics	Returns JSON-formatted lidar transformation matrix needed to adjust to the Sensor Coordinate Frame	{"lidar_to_sensor_transform": [-1, 0, 0, 0, 0, -1, 0, 0, 0, 0, 1, 36.18, 0, 0, 0, 1]}

An example session using the unix netcat utility is shown below, with user input in **bold**:

$ nc os1-991805000142 7501
get_sensor_info
{“prod_line”: “OS-1-64”, "prod_pn": "840-101396-02", "prod_sn": "991805000142", "base_pn": "000-101323-01", "base_sn": "11E0211", "image_rev": "ousteros-image-prod-aries-v1.2.0-201804232039", "build_rev": "v1.2.0", "proto_rev": "v1.1.0", "build_date": "2018-05-02T18:37:13Z", "status": "RUNNING"}

3.1.2. Querying Active or Staged Parameters

Sensor configurations / operating modes can also be queried over TCP. Below is the latest command format:.

get_config_param active <parameter> will return the current active configuration parameter values.

get_config_param staged <parameter> will return the parameter values that will take place after issuing **reinitialize** command or after sensor reset.

get_config_param Command	Description	Response

udp_ip	Returns the ip to which the sensor sends UDP traffic..	“”(default)
udp_port_lidar	Returns the port number of Lidar UDP data packets	7502 (default)
udp_port_imu	Returns the port number of IMU UDP data packets	7503 (default)
lidar_mode	Returns a string indicating the horizontal resolution	One of “512x10”, “1024x10”, “2048x10”, “512x20”, “1024x20”
auto_start_flag	Returns “1” if sensor is on auto start, and “0” if not. [describe]	1 (default)
timestamp_mode	Get the method used to timestamp measurements. See section 5.1 for a detailed description of each option.	One of “TIME_FROM_INTERNAL_OSC”, “TIME_FROM_PPS_IN_SYNCED”, “TIME_FROM_PTP_1588”
pps_out_mode	Get the source of the the PPS signal output by the sensor. See section 5.2 for a detailed description of each option.	One of “OUTPUT_FROM_INTERNAL_OSC”, “OUTPUT_FROM_PPS_IN_SYNCED”, “OUTPUT_PPS_OFF”, “OUTPUT_FROM_PTP_1588”
pps_out_polarity	Returns the polarity of PPS output, if sensor is set as the master sensor used for time synchronization	One of “ACTIVE_HIGH” or “ACTIVE_LOW”.
pps_in_polarity	Returns the polarity of PPS input, if a sensor is set as slave sensor in time synchronization.	One of “ACTIVE_HIGH” or “ACTIVE_LOW”.
pulse_mode	STANDARD: The default. 8ns pulse. Allows sensor to achieve full spec	One of “STANDARD” or “NARROW”

	NARROW: Reduces pulse width to 4.8ns Improves spatial spatial resolution and reduces range. No sensor specs are guaranteed in this mode.	
window_rejection_enable	1: The default. Enabled. Allows the sensor to achieve full spec. 0: Disabled. Reduces the sensor range to zero meters but also causes the sensor to select the window return echo instead of a target return echo if the window echo is stronger. Depending on window cleanliness this can significantly reduce sensor range. No sensor specs are guaranteed in this mode.	1 (default)

An example session using the unix netcat utility is shown below, with user input in **bold**::

$ nc os1-991805000142 7501
get_config_param active lidar_mode
1024x10

3.1.3. Setting Configuration Parameters

set_config_param <parameter> <value> will set new values for configuration parameters, which will take effect after issuing "**reinitialize**" command, or after sensor reset.

set_config_param Command	Description	Response
lidar_mode <mode value>	Set the horizontal resolution and rotation rate of the sensor. Valid modes are "512x10", "1024x10", "2048x10"	"set_config_param" on success, "error:" otherwise

	“512x20”, “1024x20” Each 50% the total number of points gathered is reduced - e.g., from 2048x10 to 1024x10 - extends range by 15-20%.	
timestamp_mode <mode value>	Set the method used to timestamp measurements. Valid modes are “TIME_FROM_INTERNAL_OSC”, “TIME_FROM_PPS_IN_SYNCED”, or “TIME_FROM_PTP_1588	“set_config_param” on success, “error:” otherwise
udp_ip <ip>	Specifies the ip to which the sensor sends UDP traffic. On boot, the sensor will not output data until this is set.	“set_config_param” on success, “error:” otherwise
udp_port_lidar <port>	Lidar data will be sent to <udp_ip>:<port>	“set_config_param” on success, “error:” otherwise
udp_port_imu <port>	Imu data will be sent to <udp_ip>:<port>	“set_config_param” on success, “error:” otherwise
pps_out_mode <mode value>	Set the source of the PPS signal. Valid modes are “OUTPUT_FROM_INTERNAL_OSC”, “OUTPUT_FROM_PPS_IN_SYNCED”, “OUTPUT_PPS_OFF”, or “OUTPUT_FROM_PTP_1588”	“set_config_param” on success, “error:” otherwise
pulse_mode	STANDARD: The default. 8ns pulse. Allows sensor to achieve full spec NARROW: Reduces pulse width to 4.8ns Improves spatial spatial resolution while reducing signal/range. No sensor specs are guaranteed in this mode.	One of “STANDARD” or “NARROW”
window_rejection_enable	1: The default. Enabled. Allows the sensor to achieve full spec. 0: Disabled. Reduces the sensor range to zero meters but also causes the sensor to select the	1 (default)

	window return echo instead of a target return echo if the window echo is stronger. Depending on window cleanliness this can significantly reduce sensor range. No sensor specs are guaranteed in this mode.	

write_config_txt will write new values of parameters into a configuration file, so they will take effect after sensor reset.

reinitialize will reinitialize the sensor so the staged values of the parameters will take effect immediately.

set_config_param Command	Description	Response
write_config_txt	Make the current settings persist until the next reboot.	“write_config_txt” on success
reinitialize	Restarts the sensor. Changes to lidar, pps, and timestamp modes will only take effect after reinitialization.	“reinitialize” on success

$ nc os1-991805000142 7501
set_config_param lidar_mode 512x20
set_config_param
set_config_param udp_ip 192.168.11.1
set_config_param
write_config_txt
write_config_txt
reinitialize
reinitialize

For FW 1.5.1 and earlier:

Command	Description	Response
get_sensor_info	Return JSON-formatted sensor metadata: serial number, hardware and software revision, and sensor status.	{"prod_pn": "840-101396-02", "prod_sn": "991805000142", "base_pn": "000-101323-01", "base_sn": "11E0211", "image_rev": "ousteros-image-prod-aries-201804232039", "build_rev": "v1.2.0-21-g337de76", "proto_rev": "v1.1.0", "build_date": "2018-05-02T18:37:13Z", "status": "RUNNING"}
get_beam_intrinsics	Returns JSON-formatted beam altitude and azimuth offsets, in degrees.	{"beam_altitude_angles": [16.611, ..., -16.611], "beam_azimuth_angles": [3.164, …, -3.164]}
set_udp_ip <ip>	Specifies the ip to which the sensor sends UDP traffic. On boot, the sensor will not output data until this is set.	“set_udp_ip” on success, “error:” otherwise
set_udp_port_lidar <port>	Lidar data will be sent to <udp_ip>:<port>	“set_udp_port_lidar” on success, “error:” otherwise
set_udp_port_imu <port>	Imu data will be sent to <udp_ip>:<port>	“set_udp_port_imu” on success, “error:” otherwise
get_lidar_mode	Returns a string indicating the horizontal resolution	One of “512x10”, “1024x10”, “2048x10”, “512x20”, “1024x20”
set_lidar_mode <lidar_mode>	Set the horizontal resolution and rotation rate of the sensor. Valid modes are “512x10”, “1024x10”, “2048x10”, “512x20”, “1024x20”.	“set_lidar_mode” on success, “error:” otherwise
get_timestamp_mode	Get the method used to timestamp measurements. See section 5.1 for a detailed description of each option.	One of “TIME_FROM_INTERNAL_OSC”, “TIME_FROM_PPS_IN_SYNCED”, “TIME_FROM_PTP_1588”

set_timestamp_mode <timestamp_mode>	Set the method used to timestamp measurements. Valid modes are "TIME_FROM_INTERNAL_OSC", "TIME_FROM_PPS_IN_SYNCED", or "TIME_FROM_PTP_1588"	"set_timestamp_mode" on success, "error:" otherwise
get_pps_out_mode	Get the source of the the PPS signal output by the sensor. See section 5.2 for a detailed description of each option.	One of "OUTPUT_FROM_INTERNAL_OSC", "OUTPUT_FROM_PPS_IN_SYNCED", "OUTPUT_PPS_OFF", "OUTPUT_FROM_PTP_1588"
set_pps_out_mode <pps_out_mode>	Set the source of the PPS signal. Valid modes are "OUTPUT_FROM_INTERNAL_OSC", "OUTPUT_FROM_PPS_IN_SYNCED", "OUTPUT_PPS_OFF", or "OUTPUT_FROM_PTP_1588"	"set_pps_out_mode" on success, "error:" otherwise
write_config_txt	Make the current settings persist until the next reboot.	"write_config_txt" on success
reinitialize	Restarts the sensor. Changes to lidar, pps, and timestamp modes will only take effect after reinitialization.	"reinitialize" on success

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3.2. LIDAR Data Format

By default UDP data is forwarded to Port 7502. Lidar data packets consist of 16 azimuth blocks and are always 12608 Bytes in length. The packet rate is dependent on the output mode. Words are 32 bits in length.

Word	Azimuth Block 0	Azimuth Block 1	...	Azimuth Block 15
(Word 0,1)	(64 bit unsigned int) Timestamp (ns)	(64 bit unsigned int) Timestamp (ns)	...	(64 bit unsigned int) Timestamp (ns)
(Word 2)	Measurement ID	Measurement ID	...	Measurement ID
(Word 3)	Encoder Count (0 to 90111)	Encoder Count (0 to 90111)	...	Encoder Count (0 to 90111)
(Word 4,5,6)	Channel 0 Data Block	Channel 0 Data Block	...	Channel 0 Data Block
(Word 7,8,9)	Channel 1 Data Block	Channel 1 Data Block	...	Channel 1 Data Block
	. . .	. . .		. . .
(Word 193, 194, 195)	Channel 63 Data Block	Channel 63 Data Block	...	Channel 63 Data Block
(Word 196)	Packet Status	Packet Status	...	Packet Status

Each azimuth block contains:

- **Timestamp** [64 bits] - Unique time in nanoseconds.
- **Measurement ID** [32 bits] - a sequentially incrementing azimuth measurement counting up from 0 to 511, or 0 to 1023, or 0 to 2047 depending on lidar_mode.

- **Encoder Count** [32 bits] - an azimuth angle as a raw encoder count, starting from 0 with a max value of 90111 - incrementing 44 ticks every azimuth angle in x2048 mode, 88 ticks in x1024 mode, and 176 ticks in x512 mode.
- **Data Block** [96 bits] - 3 data words for each of the 16 or 64 pixels. See Table below for full definition.
  - **Range** [20 bits] - Range in millimeters, discretized to the nearest 12 millimeters.
  - **Reflectivity** [16 bits] - Sensor signal_photon measurements are scaled based on measured range and sensor sensitivity at that range, providing an indication of target reflectivity. Calibration of this measurement has not currently been rigorously implemented, but this will be updated in future a future firmware release.
  - **Signal Photons** [16 bits] - Signal photons in the signal return measurement are reported
  - **Noise Photons** [16 bits] - Noise photons in the noise return measurement are reported.
- **Packet Status** - indicates whether the azimuth block is good or bad. Good = 0xFFFFFFFF, Bad = 0x0. If a packet is bad Measurement ID, Encoder Count, and Data Bock:Range and Data Block:Reflectivity will also be set to 0x0.

Full Description of Data block:

Word in Data Block	Byte 3	Byte 2	Byte 1	Byte 0
Data Word 0	unused[31:24]	unused[23:20] range_mm[19:16]	range_mm[15:8]	range_mm[7:0]
Data Word 1	signal_photons[31:24]	signal_photons[23:16]	reflectivity[15:8]	reflectivity[7:0]
Data Word 2	unused[31:24]	unused[23:16]	noise_photons[15:8]	noise_photons[7:0]

3.3. IMU Data Format

UDP Packets - 48 Bytes - Port 7503 - at 100 Hz

Word	IMU and Gyro Data Block
(Word 0,1)	64 bit unsigned int for IMU Start Read Time (ns)
(Word 2,3)	64 bit unsigned int for Accel Read Time (ns)
(Word 4,5)	64 bit unsigned int for Gyro Read Time (ns)
(Word 6)	32 bit float for Acceleration in X (g)
(Word 7)	32 bit float for Acceleration in Y (g)
(Word 8)	32 bit float for Acceleration in Z (g)
(Word 9)	32 bit float for Angular Acceleration About in X-axis (deg per sec)
(Word 10)	32 bit float for Angular Acceleration About in Y-axis (deg per sec)
(Word 11)	32 bit float for Angular Acceleration About in Z-axis (deg per sec)

3.4. Data Rates

Based on 12,608 Bytes/packet and 1280 packets/sec, in 2048x10 or 1048x20 mode the OS-1 outputs 16.138 MB/s (129 Mbps). For this reason a gigabit ethernet network is required for reliable performance.

4. Coordinate Frames

4.1. Sensor Coordinate Frame

The Sensor Coordinate Frame follows the right-hand rule convention and is defined at the center of the sensor housing on the bottom, with the x-axis pointed forward, y-axis pointed to the left and z-axis pointed towards the top of the sensor. The external connector is located in the negative x direction.

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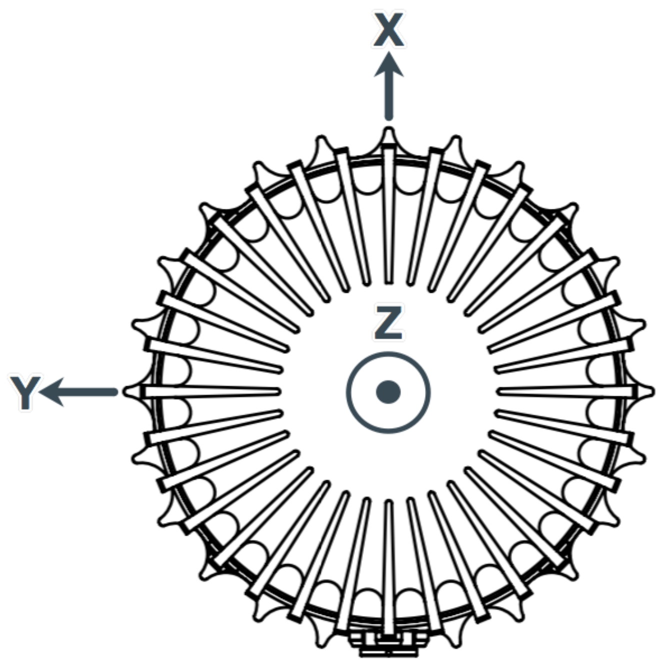

4.2. LIDAR Intrinsic Beam Angles

The intrinsic beam angles for each beam may be queried with a TCP command (see OS-1 Software User Guide) and provide an azimuth and elevation adjustment to the each beam. The azimuth adjustment is referenced off of the current encoder angle and the elevation adjustment is referenced from the XY plane in the Sensor and LIDAR Coordinate Frames.

4.3. LIDAR Range Data To XYZ LIDAR Coordinate Frame

The origin and axes of the LIDAR Coordinate Frame are defined by the position of the LIDAR lens aperture stop in the sensor and the 0º position of the rotary encoder, which is aligned with the sensor connector and the negative X axis of the Sensor Coordinate Frame.

For many applications, it is sufficient to calculate the XYZ point cloud in the LIDAR Coordinate Frame using a combination of the intrinsic beam angles and the encoder reading. The intrinsic azimuth and elevation beam angles may be queried over TCP as two vectors each 64 elements

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long.

1 LIDAR Data Format

LIDAR data may be transformed into 3D Cartesian x, y, z coordinates in the coordinate frame described in Section 4.1. Given:

- `encoder_count` of the azimuth block,
- `range` from the data block of the i-th channel,
- `beam_altitude_angles` and `beam_azimuth_angles` from `get_beam_intrinsics` in the TCP interface described in Section 3.1,

the corresponding 3D point may be computed thus:

$$r = \texttt{range}\ \mathrm{mm} \tag{1}$$

$$\theta = 2\pi\left(\frac{\texttt{encoder\_count}}{90112} + \frac{\texttt{beam\_azimuth\_angles[i]}}{360}\right) \tag{2}$$

$$\phi = 2\pi\frac{\texttt{beam\_altitude\_angles[i]}}{360} \tag{3}$$

$$x = r\cos(\theta)\cos(\phi) \tag{4}$$

$$y = -r\sin(\theta)\cos(\phi) \tag{5}$$

$$z = r\sin(\phi) \tag{6}$$

4.4. LIDAR Range Data To Sensor XYZ Coordinate Frame

For applications that require calibration against a precision mount or use the IMU data in combination with the LIDAR data, the xyz points should be adjusted to the Sensor Coordinate Frame. This requires a z translation and a rotation of the x,y,z points about the z axis. The z translation is the height of the lidar aperture stop above the sensor origin, which is 36.180 mm, and the data must be rotated 180° around the z axis. This information can be queried over TCP in the form of an intrinsic transformation matrix:

M_lidar_to_sensor = [[X, X, X, X], [X, X, X, X], [X, X, X, X], [0, 0, 0, 1]

4.5. IMU Data To Sensor XYZ Coordinate Frame

The IMU is slightly offset in the Sensor Coordinate Frame for practical reasons. The IMU origin in the Sensor Coordinate Frame can be queried over TCP in the form of an intrinsic transformation matrix:

M_imu_to_sensor = [[X, X, X, X], [X, X, X, X], [X, X, X, X], [0, 0, 0, 1]

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5. Time Synchronization

- All LIDAR and IMU data are timestamped to a common timer with 10 nanosecond precision.
- The common timer can be programmed to run off one of three clock sources:
    - An internal clock derived from a high accuracy, low drift oscillator
    - An opto-isolated digital input from the external connector for timing off an external hardware trigger such as a GPS. The polarity of this input signal is programmable. For instance, both a GPS PPS pulse and a 30 Hz frame sync from an industrial camera can supply a timing signal to the OS-1.
    - Using the IEEE 1588 Precision Time Protocol. PTP provides the convenience of configuring timing over a network that supports IEEE 1588 with no additional hardware signals.

5.1. Internal Clock Source

The source for measurement timestamps can be configured using the “set_timestamp_mode” TCP command (see Section 3.1). The available modes are described below:

TIME_FROM_INTERNAL_OSC	Use the internal clock. Measurements are time stamped with ns since power-on Free running counter based on the OS-1’s internal oscillator. Counts seconds and nanoseconds since OS-1 turn on, reported at ns resolution (both a second and nanosecond register in every UDP packet), but min increment is on the order of 10 ns Accuracy is +/- 90ppm
TIME_FROM_PPS_IN_SYNCED	Use the internal clock, disciplined by an external PPS signal. A free running counter synced to the PPS-input to the OS-1. Counts seconds (# of PPS pulses) and nanoseconds since OS-1 turn on. Reported at ns resolution (both a second and nanosecond register in every UDP packet), but min increment is on the order of 10 ns Accuracy is +/- 1 μs from a perfect PPS source
TIME_FROM_PTP_1588	Synchronize with an external PTP master A monotonically increasing counter that will begin counting seconds and nanoseconds since startup. As soon as a 1588 sync event happens, the time will be updated to seconds and nanoseconds since 1970. The counter must always count forward in time. If another 1588 sync event happens the counter will either jump forward to match the new

	time, or slow itself down. It is reported at ns resolution (there is both a second and nanosecond register in every UDP packet), but the minimum increment varies. Accuracy is +/- <50 us from the 1588 master.

5.2. External Trigger Clock Source

Additionally, the OS-1 can be configured to output a PPS signal from a variety of sources. See the “set_pps_out_mode” TCP command in Section 3.1.

OUTPUT_FROM_INTERNAL_OSC	Output a PPS signal synchronized with the internal clock
OUTPUT_FROM_PPS_IN_SYNCED	Output a PPS signal synchronized with an an external PPS source
OUTPUT_PPS_OFF	Do not output a PPS signal
OUTPUT_FROM_PTP_1588	Output a PPS signal synchronized with an external PTP master

Configuring the sensor to time off of an external hardware trigger requires sending a series of TCP commands. To set the sensor into external hardware clock source the user must send the following TCP commands:

- set_timestamp_mode “TIME_FROM_PPS_IN_SYNCED”
- reinitialize
- [set the polarity of the external trigger] - not yet implemented, to be added in firmware update
- [set the frequency of the external trigger] - not yet implemented, to be added in firmware update
- [set timebase source to either an external SPI NEMA GPS message or to the seconds since the first hardware trigger] - Available on sensors shipping September 2018

If configured to an external UART NEMA message, the following additional commands must be sent:

- [set the polarity of the UART data] - Available on sensors shipping September 2018

- [set the frequency of the UART data] - Available on sensors shipping September 2018

If configured to count seconds from the first hardware trigger, this counter may be reset to any arbitrary integer value of seconds with the following commands

- [command] [seconds value] - not yet implemented, to be added in firmware update

6. Updating Firmware

Sensor firmware can be updated with an Ouster-provided firmware file at www.ouster.io/downloads (or directly from the deployment engineering team) by accessing the sensor over http - e.g., http://os1-991805000155.local/ and uploading the file as prompted.

Always check your firmware version before attempting to update firmware. Only update to a equal or higher version number. Do not "roll back" firmware to lower numbered versions without having been instructed to by Ouster deployment engineering.

7. Troubleshooting

Most problems we get contacted about are associated with the sensor not properly being assigned an IP address by a network switch or DHCP server on a client computer. Check your networking settings, the steps in Section 3, and that all wires are firmly connected if you suspect this problem.

NOTE: If the sensor is not connected to Gigabit ethernet, it will stop sending data and will output an error code if the cabling is wired incorrectly and fails to achieve a 1000Mb/s + full duplex link.

To check for hardware errors, use the "get_sensor_info" command as described above.

If the watchdog is triggered (various temperatures limits exceeded, uplink/downlink status), an error code (up to 8) will be appended to the end of TCP command get_sensor_info. The sensor has an 8 deep buffer that will record the first 8 errors detected by the sensor with the code itself, timestamp, and an info field (temperature that caused it to trip for temp failures, true/false for uplink/downlink).

Example showing forced temp sensor failures being sampled at 1 Hz (Three fails at 1533579080, Three at 1533579801, and the last two at 153379082 time):

- {"prod_pn": "840-101396-03", "prod_sn": "991827000111", "base_pn": "000-101323-02", "base_sn": "101823000127", "image_rev": "ousteros-image-prod-aries-v1.5.2-20180720031809", "build_rev": "v1.5.2-71-g43c87c6", "proto_rev": "v1.1.1", "build_date": "2018-08-04T23:43:55Z", "status":
- "ERROR", "errors": [{"error_code": "BASE_A_OVERTEMP", "error_timestamp": "1533579080", "error_info": "30.000000"}, {"error_code": "BASE_B_OVERTEMP", "error_timestamp": "1533579080", "error_info": "29.801411"}, {"error_code": "STATOR_OVERTEMP", "error_timestamp": "1533579080", "error_info": "30.000000"}, {"error_code": "BASE_A_OVERTEMP", "error_timestamp": "1533579081", "error_info": "30.000000"}, {"error_code": "BASE_B_OVERTEMP", "error_timestamp": "1533579081", "error_info": "29.975849"}, {"error_code": "STATOR_OVERTEMP", "error_timestamp": "1533579081", "error_info": "30.000000"}, {"error_code": "BASE_A_OVERTEMP", "error_timestamp": "1533579082", "error_info": "30.000000"}, {"error_code": "BASE_B_OVERTEMP", "error_timestamp": "1533579082", "error_info": "29.997059"}]}