OUSTER OS0 Digital Lidar Sensor User Manual

Contents

OUSTER OS0 Digital Lidar Sensor

Important Safety Information

Safety & Legal Notices

- The OS0-128, OS0-64, and OS0-32 have been evaluated to be Class 1 laser products per 60825-1: 2014 (Ed. 3) and operate in the 865nm band.

Figure 1.1: Class 1 Laser Product

Figure 1.2: Caution "Sharp Edges"

- The OS0 is a hermetically sealed unit, and is non-user-serviceable.
- Use of controls, or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.
- Use of the OS0 is subject to the Terms of Sale that you agreed and signed with Ouster or your distributor/integrator. Included in these terms are the prohibitions of:
    - Removing or otherwise opening the sensor housing
    - Inspecting the internals of the sensor
    - Reverse-engineering any part of the sensor

    - Permitting any third party to do any of the foregoing
- Operating the sensor without the attached mount that is shipped with the sensor, or attaching the sensor to a surface of inappropriate thermal capacity runs the risk of having the sensor overheat under certain circumstances.
- This lidar sensor features a modular cap design to enable more flexible mounting and integration solutions for the sensor.
- The modular cap design increases design flexibility but it does not remove the need for thermal management on top of the sensor. The attached radial cap serves an important thermal management purpose and the sensor will not operate properly without a cap.
- Operation for extended periods of time without the cap will result in system errors and the sensor overheating. The cap can be replaced with alternative solutions but it cannot be left off altogether.
- If you wish to operate the sensor with a custom mounting solution, please contact our Field Application
- Team and we can answer your questions and provide guidance for achieving proper operations.
- This product emits Class 1 invisible laser radiation. The entire window is considered to be the laser aperture. While Class 1 lasers are considered to be “eye safe”, avoid prolonged direct viewing of the laser and do not use optical instruments to view the laser.
- When operated in an ambient temperature >40°C, the metallic surfaces of the sensor may be hot enough to potentially cause skin burn. Avoid skin contact with the sensor’s base, lid and the heatsink when the sensor is operated under these conditions. The sensor should not be used in an ambient temperature above 60°C. The maximum safety certified ambient operating temperature is 60°C.

Equipment Label: Includes model and serial number and a notice that states the unit is a Class 1 Laser Product, is affixed to the underside of the Sensor Enclosure Base. It is only visible after the attached mount with which the Sensor is shipped, is removed. For location details please refer to figure Sensor Components in the Mechanical Interface Section.

Electromagnetic Compatibility: The OS0 is an FCC 47 CfR 15 Subpart B device. This device complies with part 15 of the FCC Rules. Operation is subject to the following conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. “Ouster” and “OS0” are both registered trademarks of Ouster, Inc. They may not be used without express permission from Ouster, Inc.
If you have any questions about the above points, contact us at **legal@ouster.io**.

Proper Assembly, Maintenance and Safe Use

- The OS0 can be easily set up by following the instructions outlined in Mounting Guidelines. Any mounting orientation is acceptable. Each sensor is shipped with an attached mount that can be used for test or normal use within the specified operating conditions. The sensor may also be affixed to any other user specific mount of appropriate thermal capacity. Please contact Ouster for assistance with approving the use of user specific mounting arrangements.
- Any attempt to utilize the sensor outside the environmental parameters delineated in the OS0 datasheet may result in voiding of the warranty.
- When power is applied, the sensor powers up and commences boot-up with the laser disabled. The boot-up sequence is approximately 60s in duration, after which the internal sensor optics subassembly commences spinning, the laser is activated, and the unit operates in the default 1024 x 10 Hz mode.
- When the sensor is running, and the laser is operating, a faint red flickering light may be seen behind the

optical window.

- Note that the OS0 utilizes an 865nm infrared laser that is only dimly discernible to the naked eye. The sensor is fully Class 1 eye safe, though Ouster strongly recommends against peering into the optical window at close range while the sensor is operating. Ouster sensors are equipped with a multi-layer series of internal safety interlocks to ensure compliance to Class 1 Laser Eye Safe limits.
- The OS0 is a hermetically sealed unit, and is not user-serviceable. Any attempt to unseal the enclosure has the potential to expose the operator to hazardous laser radiation.
- The sensor user interface may be used to configure the sensor to a number of combinations of scan rates and resolutions other than the default values of 1024 x 10 Hz resolution. In all available combinations, the unit has been evaluated by an NRTL to remain within the classification of a Class 1 Laser Device as per IEC 60825-1:2014 (Ed. 3).

Sensor Cleaning
All Ouster Sensor window are made from polycarbonate. Based on the sensor usage you may see dust, bugs and/or layers of mud/debris on the window. Before you attempt to clean your sensor, please read the instructions below on best practices for cleaning Ouster Sensors.

Required Materials:

- Few clean microfiber cloths
- Warm water
- Mild liquid dishwashing soap
- Spray bottle with clean water
- Spray bottle with mild soapy water
- 99% Isopropyl alcohol

Warning:

- Avoid getting water into the power connector.
- Avoid using hard water when cleaning the sensor.
- Do not use acetone to clean the window. It will embrittle the polycarbonate.
- Do not wipe dirt directly from the sensor. Spray it off with warm water first.

Procedure:

- Using the 99% isopropyl alcohol and a clean microfiber towel, wipe away bugs/mud/debris from the sensor.
- Spray the sensor with warm, mild-soapy water and gently wipe the sensor with a clean microfiber towel. Wipe along the curve of the sensor, not top-to-bottom (think moving with the grain).
- Spray the sensor with clean water to rinse off the soap and dry with a second microfiber towel.
- Enjoy your clean window.

OS0 Overview

The OS0 offers an ultra-wide 90º vertical field-of-view with an industry-leading combination of price, performance, reliability, size, weight, and power. It is designed for indoor/outdoor all-weather environments and long lifetime. As the smallest high performance lidar on the market, the OS0 can be easily integrated into autonomous vehicles,

heavy machinery, robots, drones, and mapping solutions. The OS0 family of sensors consist of three models, the OS0-128, OS0-64, and OS0-32, with differing resolution, but of identical mechanical dimensions.

HIGHLIGHTS

- Fixed resolution per frame operating mode
- Camera-grade intensity, near infrared, and range data
- Multi-sensor crosstalk immunity
- Simultaneous and co-calibrated 2D and 3D output
- Industry leading intrinsic calibration
- Example client code available

For the purposes of this documwent, the term “OS0” refers to the family of sensors, and only where there is a difference in performance will each model be referred to by its specific model designation.

OS0 Product Models
The OS0 is available with 128, 64, or 32 beams of vertical resolution and with Uniform, Gradient, Above Horizon, or Below Horizon beam spacing options. Product specs and more information on these configurations can be found on the OS0 product page.

Mechanical Interface

Included Components
The OS0 is shipped with the following items:

- OS0-128, OS0-64, or OS0-32
- Sensor to interface box cable/connector
- Interface Box and 24V AC/DC power supply (2 meters)
- RJ45 cable (1 meter)
- **Optional:** Heat sink

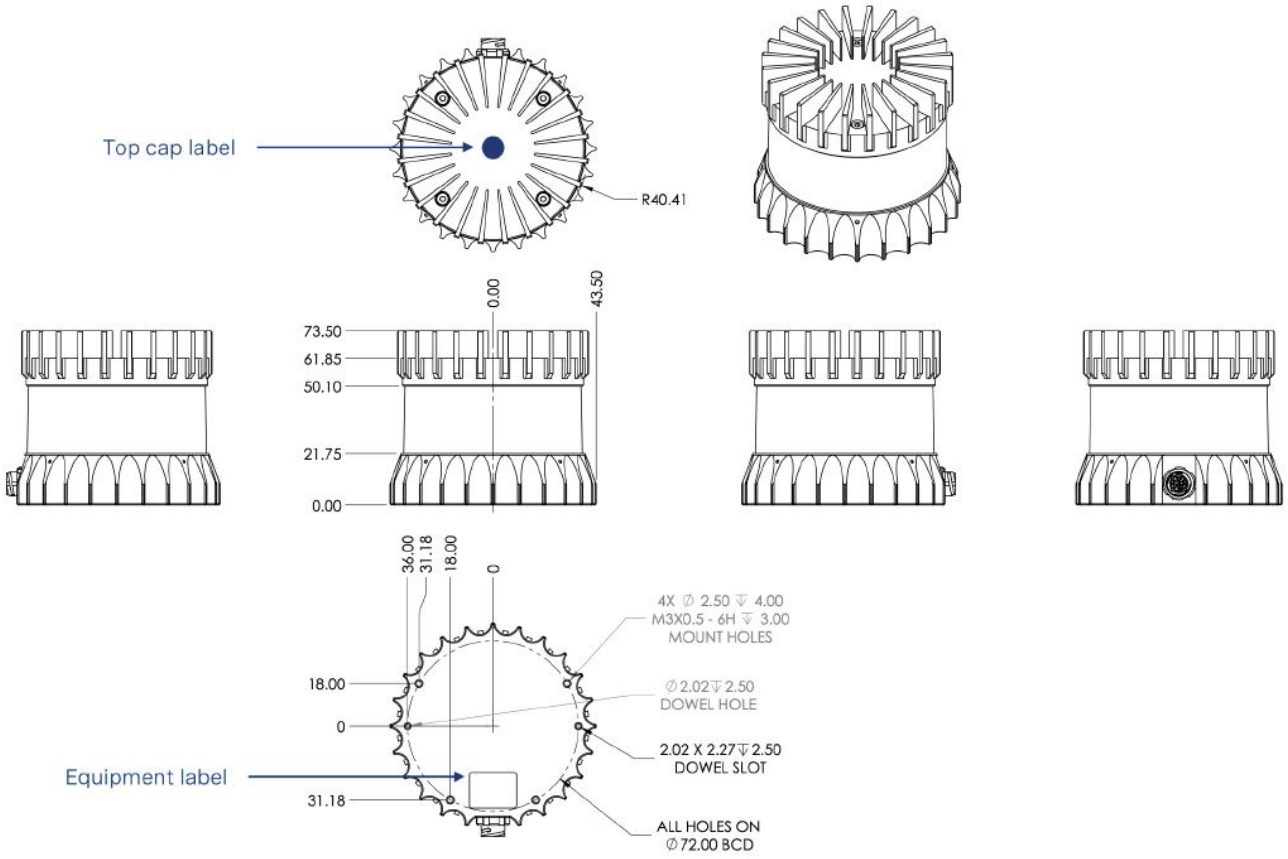


Figure 4.1: Sensor Components

Downloadable CAD files for the OS0 can be found online at **www.ouster.com/lidar-product-details**.

Warning: Water ingress protection: The sensor ingress protection rating is only valid if the I/O cable is plugged into the panel mount connector on the base of the sensor, and the locking collet rotated past the detent click to the properly locked condition i.e past the détente position. The cable and plug are an element of the sensor ingress protection system. Without this the ingress protection rating may be compromised. Bending the cable at a sharp angle directly after egress from the plug over mold should also be avoided. Sharp bends and high axial stresses on the cable immediately adjacent to the plug over mold may create a moisture ingress path into the connector. Please note the cable minimum bend radius requirements below:

I/O Cable type	**O.D.**	**Cable Minimum Bend Radius**	
		Fixed Bend	**Flexing Bend**
Ouster Thick Cable	10.5mm	79mm (7.5*OD)	158mm (15*OD)
Ouster Thin Cable (Standard)	8mm	50mm (5*OD)	80mm (10*OD)

Mounting Guidelines
Our sensors ship with modular mounting options. Proper mounting will ensure optimal sensor performance, reducing noise from vibration and providing efficient heat dissipation.

- Mount to a material with high thermal conductivity. The following are recommended aluminum alloys and their thermal conductivity:
    1. **6061:** 167 W/m-K
    2. **7075:** 130 W/m-K

3. **2024:** 121 W/m-K

- Ensure interfaces are clean and free from debris
- Torque bolts appropriately for the mount material and bolts
- Use TIM (Thermal Interface Material) for any irregular or unmachined surfaces
- Do not overconstrain the sensor if mounting to both the top and the bottom
- Use a thermally conductive pad to ensure good conductivity while not overconstraining.
- Ensure your implementation maintains the base and top of the sensor at no greater than 25ºC above ambient with an ambient less than 50ºC
- The shape of any heatsink should maximize the surface area for free and forced convection while being thick enough to allow the heat to conduct through the material

If you have questions about your specific mounting situation please contact the Ouster at **support@ouster.io**.

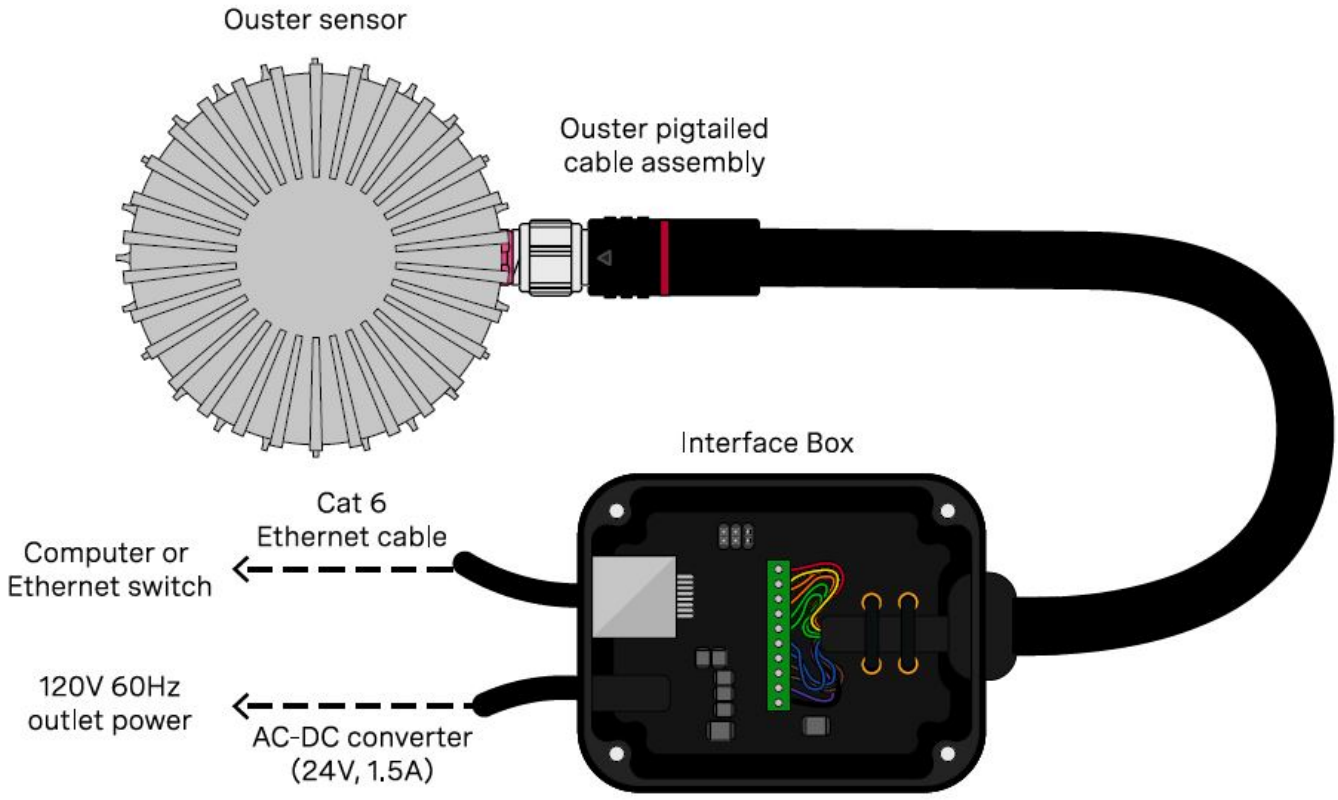
Thermal Requirements
Thermal requirements for Rev C OS0 are listed below. Please contact support@ouster.io or with your sensor serial number if you do not know what revision your sensor is.

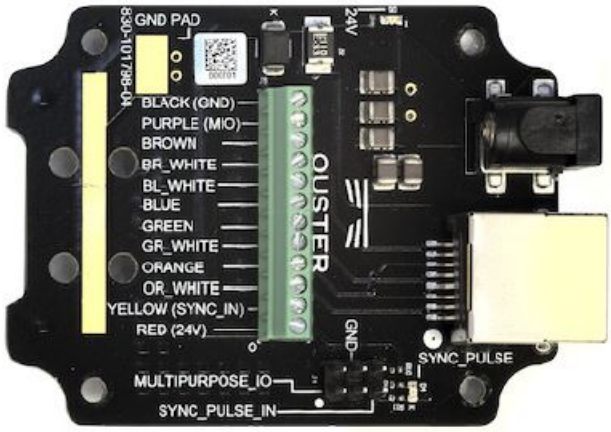
Table 4.1: Thermal requirements for OS0 with modular cap

	Require- ment s	**Example Test Case**
	Chassis Temp (ºC)	Convective Air Temp with Radial Heatsink and Standard Base (ºC)
Max Temp before shot limit- ing	52	47
Temp that shot limiting sat- urat es	60	55
Max Temp before sensor may s hut off	65	60

Electrical Interface

Interface Box
The Interface Box that accompanies the OS0 is designed to allow the sensor to be operated for test and evaluation purposes. It terminates the interface cable from the sensor, allows it to be powered up and provides access to the sensor gigabit Ethernet Interface via a standard RJ45 connector. DC Power to the sensor is provided to the Interface Box by the accompanying 24V DC supply.
Note: The Ouster Interface Box is a support tool for use in laboratory environments to assist customers in evaluating Ouster's LiDAR sensor products and in the development of software. The Interface Box is not protected from ingress of moisture or solid particles and is not intended for use outdoors.





Direct Cable Connection and Pinout
The OS0 can be operated without the use of an Interface Box.

Warning: Ouster is not responsible for any errors in wiring as a result of bypassing the Interface Box and this activity may result in a voiding of your warranty if it results in damage to the sensor. The following guidelines for direct cable connection assume use of the Ouster-provided 24V 1.5A power supply. Ouster cannot be held responsible for damage to the device if alternate is used.

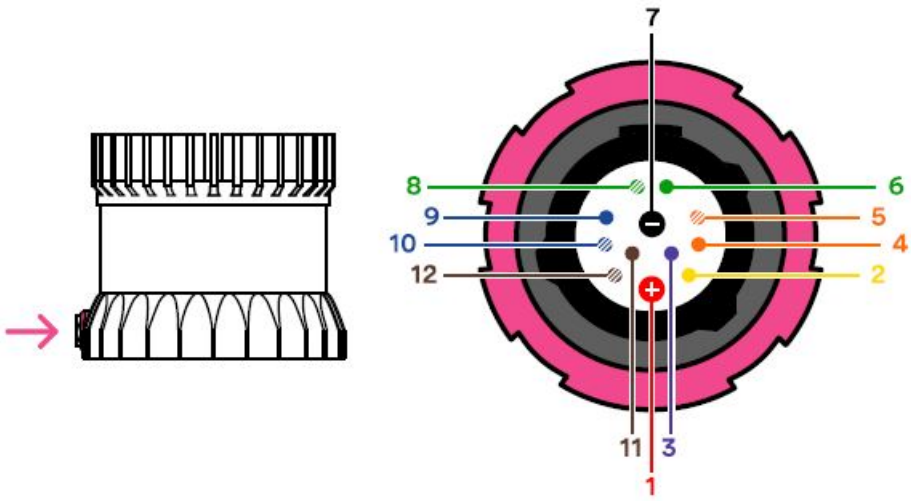


Figure 5.1: cable pinout of on-sensor receptacle

Table5.1: Ouster Cable Pinout: Connector, Sensor P/Ns: 840_101855, 840_102144, 840_102145, 840_102146

Net Name	Pin Number	Wire	Twisted With
MULTIPURPOSE_IO	3	Purple, 26 AWG	N/A
SYNC_PULSE_IN	2	Yellow, 26 AWG	N/A
VCC_24	1	Red, 22 AWG	N/A
GROUND	7	Black, 22 AWG	N/A
TRP_1_P (Ethernet)	5	White/Orange, 26 AWG	Orange
TRP_1_N (Ethernet)	4	Orange, 26 AWG	White/Orange
TRP_2_P (Ethernet)	8	White/Green, 26 AWG	Green
TRP_2_N (Ethernet)	6	Green, 26 AWG	White/Green
TRP_3_P (Ethernet)	9	Blue, 26 AWG	White/Blue
TRP_3_N (Ethernet)	10	White/Blue, 26 AWG	Blue
TRP_4_P (Ethernet)	12	White/Brown, 26 AWG	Brown
TRP_4_N (Ethernet)	11	Brown, 26 AWG	White/Brown

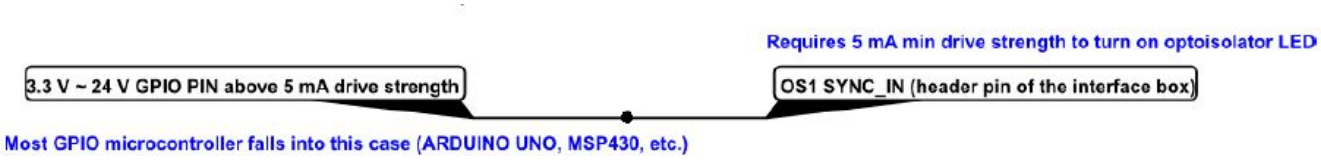
Digital IO

SYNC_PULSE_IN
SYNC_PULSE_IN is a dedicated input channel that is accessible within the Interface Box Jumper J4. This channel expects an input pulse sequence which can be used for time synchronization. See the Software User Manual for more information on configuring this input. Any references to pulse polarity in this document references the signal polarity on the SYNC_PULSE_IN pin of the sensor. This input channel is protected by an optoisolator which will draw 10mA at full turn on.

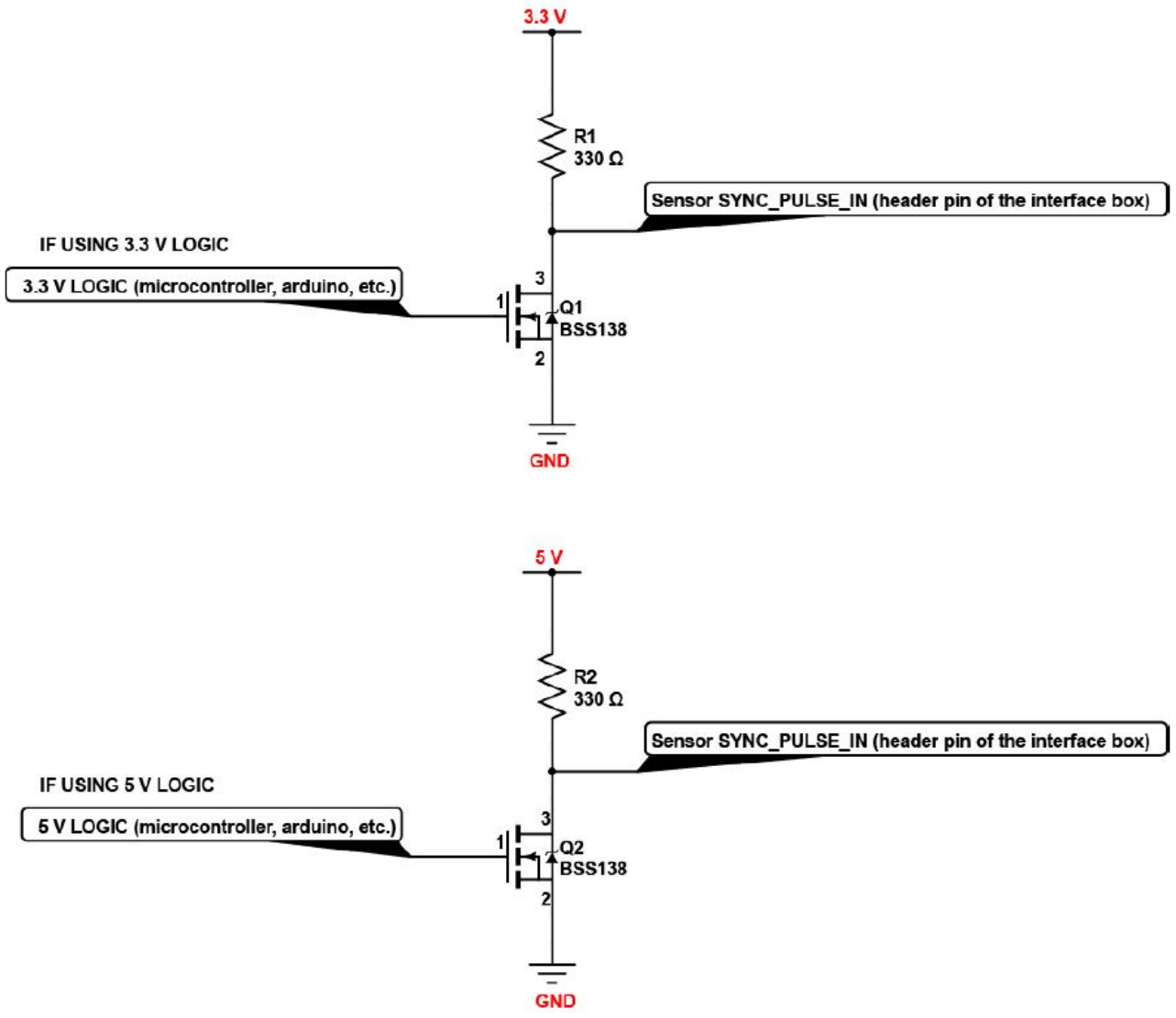
Parameter	Min Voltage	Max Voltage	Min Driver Current
LOGIC LOW	0 V	1 V	N/A
LOGIC HIGH	3.3 V	15 V	5 mA

SYNC_PULSE_IN Interface Requirements were tested with 2 m cable Interface Box connection at 2 MHz.

- When GPIO has 5 mA drive strength minimum, GPIO can be directly connected to the SYNC_PULSE_IN pin of the interface box header. This is the most common case and has been tested to work on common Arduino microcontroller series. Typical common logic levels of 3.3 V, 5 V GPIO of microcontrollers can produce drive strength of 5 mA min (Arduino, MSP430, etc.).



- If the 5 mA drive strength minimum cannot be met, a buffer circuit is required to drive SYNC_PULSE_IN. Example circuits are provided for common 3.3 V and 5 V logic.



MULTIPURPOSE_IO (M_IO)
MULTIPURPOSE_IO (M_IO) is a configurable input or output channel accessible within the Interface Box Jumper J4 connected to the MULTIPURPOSE_IO pin of the Interface Box. Detailed information on how to configure this channel using the sensor TCP interface can be found in the API Guide. By default this channel is disabled. When

this channel is configured as an OUTPUT, the M_IO sends a pulse sequence that can be used for timesynchronization or event triggering outside the sensor. For a full description of output pulse triggering options, see the Software User Manual section. This output is an optoisolated open collector circuit, relying on an externally provided pull-up resistor. This resistor is not provided as part of the Interface Box.

Table6.2: MULTIPURPOSE_IO – OUTPUT Interface Requirements

Parameter	**Min**	**Max**
Pull Up Voltage	N/A	15 V
Sinking Current	N/A	25 mA

When this channel is configured as an INPUT, the M_IO can accept a standard NMEA $GPRMC UART message. These messages are a common way for GPS systems to share timestamp information in UTC time format. More information on this packet structure and supported baud rates can be found in the Time Synchronization section of the Software User Manual.

Table6.3: MULTIPURPOSE_IO – INPUT Interface Requirements

Parameter	**Min Voltage**	**Max Voltage**	**Min Driver Current**
LOGIC LOW	0 V	1 V	N/A
LOGIC HIGH	1.7 V	15 V	10 mA

Above are tested with 2 m cable interface box connection at 2 MHz.

GPS/GNSS Synchronization Guide

This guide will explain how to physically connect a GPS to your Ouster sensor and synchronize the Ouster sensor timestamp to an NMEA sentence.

Setting up your GPS/GNSS
It is important to ensure you have configured your GPS according to the manufacturer's specifications. The Ouster sensor accepts the following:

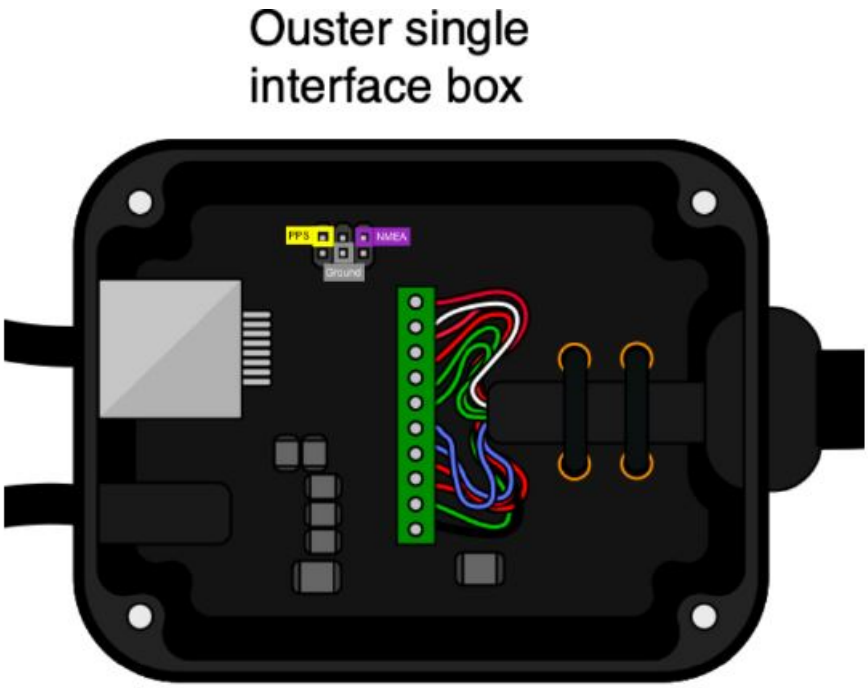
- **NMEA sentence type:** GPRMC only (future support for other sentence types)
- **Baud Rates:** 9600 or 115200
- **Polarity:** Normal or Reversed (ACTIVE_HIGH or ACTIVE_LOW)
- **Voltage:** 3.3 – 15 V logic with a minimum drive current of 5 mA.
    - If your GPS can't meet these minimums you will need to buffer the voltage with an additional circuit. Details in the Digital IO section of the Ouster Hardware User Manual.

Note: Once you have configured your GPS, it is good practice to verify the signals using an oscilloscope. This will ensure you have the correct baud rate, polarity, voltage, and message type being output.

Connecting the Hardware
The next step to successfully connecting your GPS is ensuring that you have connected the outputs from your GPS to the correct inputs of the sensor. For lab applications where you will use the interface box, it is

recommended to use terminated jumper wires like these to ensure a solid connection.

- Connect the PPS output from your GPS to the sync_pulse_in pin of the Ouster Interface Box, pictured below in yellow.
- Connect the NMEA UART output from your GPS to the multipurpose_io pin of the Ouster Interface Box, pictured below in magenta.
- Connect the ground output from your GPS to the GND pin of the Ouster Interface Box, pictured below in gray.



Note: Please note the Voltage and Current requirements from the Hardware User Manual in the tables below.

Table7.1: SYNC_PULSE_IN Interface Requirements

Parameter	Min Voltage	Max Voltage	Min Driver Current
LOGIC LOW	0 V	1 V	N/A
LOGIC HIGH	3.3 V	15 V	5 mA

Table7.2: MULTIPURPOSE_IO – INPUT Interface Requirements

Parameter	Min Voltage	Max Voltage	Min Driver Current
LOGIC LOW	0 V	1 V	N/A
LOGIC HIGH	1.7 V	15 V	10 mA

Configuring the Ouster Sensor
Now that everything is configured and verified on the GPS side and you have connected everything to the Ouster sensor, it is time to configure the Ouster sensor to synchronize its timestamp with the GPS.

- **Set the timestamp_mode to TIME_FROM_SYNC_PULSE_IN**
  - **TCP command:** set_config_param timestamp_mode TIME_FROM_SYNC_PULSE_IN
- **Set the multipurpose_io_mode to INPUT_NMEA_UART**
  - **TCP command:** set_config_param multipurpose_io_mode INPUT_NMEA_UART
- **Set the polarity of the sync_pulse_in pin to match the GPS PPS polarity**
  - **TCP command:** set_config_param sync_pulse_in_polarity <ACTIVE_HIGH or ACTIVE_LOW>
- **Set the polarity of the multipurpose_io pin to match the GPS NMEA UART polarity**
  - **TCP command:** set_config_param nmea_in_polarity <ACTIVE_HIGH or ACTIVE_LOW>
- **Set the nmea_baud_rate to match the GPS NMEA baud rate**
  - **TCP command:** set_config_param nmea_baud_rate <BAUD_11520 or BAUD_9600>
- **Set the nmea_leap_seconds to match the current leap seconds as defined by TIA at this website, at time of writing this the leap seconds are 37**
  - **TCP command:** set_config_param nmea_leap_seconds 37
- **Reinitialize and write the configuration**
  - **TCP command:** reinitialize
  - **TCP command:** save_config_params

Checking for Sync
Once you have completed all the above you should be able to check for synchronization:

- Check the output from the TCP command: get_time_info
  - Verify that the sensor is locked onto the PPS signal
    - ”sync_pulse_in”: { “locked”: 1
      - if not check the polarity and change it if necessary
- Verify that the sensor is locked on the NMEA signal
  - “nmea”: { “locked”: 1
    - if not check the polarity and baud rate and change them if necessary
- Verify that last_read_message looks like a valid GPRMC sentence
  - “decoding”: {“last_read_message”: “GPRMC,024041.00,A,5107.0017737,N,11402.3291611,W,0.080,323.3,020420,0.0,
- Verify that timestamp time has updated to a reasonable GPS time
- “timestamp”: { “time”: 1585881641.96139565999999, “mode”: “TIME_FROM_SYNC_PUSLE_IN”, “time_options”: { “sync_pulse_in”: 1585881641

Example output from get_time_info:


```
{
   "timestamp":{
      "time":1585881641.96139565999999,
      "mode":"TIME_FROM_SYNC_PUSLE_IN",
      "time_options":{
         "sync_pulse_in":1585881641,
         "internal_osc":302,
         "ptp_1588":309
      }
   },
   "sync_pulse_in":{
      "locked":1,
      "diagnostics":{
         "last_period_nsec":10,
         "count_unfiltered":832,
         "count":832
      },
      "polarity":"ACTIVE_HIGH"
   },
   "multipurpose_io":{
      "mode":"INPUT_NMEA_UART",
      "sync_pulse_out":{
         "pulse_width_ms":10,
         "angle_deg":360,
         "frequency_hz":1,
         "polarity":"ACTIVE_HIGH"
      },
      "nmea":{
         "locked":1,
         "baud_rate":"BAUD_9600",
         "diagnostics":{
            "io_checks":{
               "bit_count":2938457,
               "bit_count_unfilterd":2938457,
               "start_char_count":832,
               "char_count":66526
            },
            "decoding":{
               "last_read_message":"GPRMC,024041.00,A,5107.0017737,N,11402.3291611,W,0.080,323.3,020420,0.0,
↪E,A*20",
               "date_decoded_count":832,
               "not_valid_count":0,
               "utc_decoded_count":832
            }
         },
         "leap_seconds":37,
         "ignore_valid_char":0,
         "polarity":"ACTIVE_HIGH"
      }
   }
}
```


OS0 CAD files

All the most up-to-date CAD files of our products can be found on our Lidar Product Details page.

Documents / Resources

	OUSTER OS0 Digital Lidar Sensor [pdf] User Manual Rev C OS0 Sensors, OS0, OS0 Digital Lidar Sensor, Digital Lidar Sensor, Lidar Sensor, Sensor

References

- GPS, UTC, and TAI Clocks
- Ouster Download Center | Ouster | Ouster
- Jira Service Management
- Ouster Download Center | Ouster | Ouster
- OS0 Ultra-wide field-of-view lidar sensor for autonomous vehicles and robotics | Ouster