LISST-AOBS

Super-Turbidity Sensor

Version 2

User's Manual

Version 2.1

July, 2021

Describes LISST-AOBS Version 2, serial numbers 6246 and higher.
For earlier Version 1 LISST-AOBS models, see manual version 1

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FOR TECHNICAL ASSISTANCE please contact your local Distributor, or Sequoia if the instrument was purchased directly from Sequoia. Please be sure to include the instrument serial number with any correspondence.

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INTRODUCTION

LISST-AOBS system parts

The LISST-AOBS is a system with three main parts:

1. LISST-ABS acoustic backscattering sensor
2. Turner Designs Turbidity Plus™ optical backscattering sensor
3. A Y-cable/adapter connecting the two sensors.

The combination of acoustic and optical sensors provides measurements of total sed concentration that are much less affected by particle size than standard turbidity measurements (see *How Super-Turbidity Measurement Works* on page 13)

For complete technical details of the Turbidity Plus™, see the User's Manual at https://www.turnerdesigns.com/turbidity-plus-submersible-sensor.

Data outputs

The LISST-AOBS has three outputs:

1. ABS standardized concentration in mg/liter, as calibrated with 75-90 µm microspheres.
2. Turbidity Plus output in Volts (*not* calibrated in terms of concentration or NTU).
3. AOBS concentration (Super-Turbidity) in mg/liter, a combination of the ABS and OBS measurements as described in *Pairing ABS with turbidity* on page 14.

Data interface and logging options

LISST-AOBS has two digital interfaces: RS-232 and SDI-12. Both interfaces are available for communication at any time, although normally you will communicate using only one interface at a time. NOTE: the RS-232 interface will not respond when an SDI-12 command is in progress.

Any logger that supports SDI-12 version 1.3 or higher can use the SDI-12 interface. Sequoia has teamed with NexSens Technology to integrate the LISST-AOBS with the NexSens X2 logger family, using SDI-12. The X2 can automatically detect a LISST-AOBS and deliver its data, with data from other connected sensors, through Wi-Fi, cellular, radio, or satellite channels. See more in *Operation with the NexSens X2 logger* on page 4.

If operating with a logger other than the X2 family, see *SDI-12 Operation* on page 7. For details of the RS-232 interface, see *RS-232 Operation*, starting on page 9.

Anti-fouling wiper

Optical backscattering measurements are much more sensitive to biofouling than acoustic measurements. To prevent fouling, the Turbidity Plus includes an integrated anti-fouling wiper. Operation of the wiper takes about 10 seconds, and is activated in the following ways:

1. Upon power-up,*
2. By certain SDI-12 commands,
3. By the RS-232 WI or WIPE command
4. If operating in the free-running RS-232 mode (after automatic start or GO command), every 10* minutes.

*These are the default factory settings, but can be changed via RS-232 with the OBSSET command (see *Set automatic wiping* on page 11)

Sampling modes and start-up sequence

The LISST-AOBS RS-232 interface can operate in either polled or free-running mode.

The default mode is free-running. Upon power-up, after running the Turbidity Plus wiper if applicable, the LISST-AOBS will start sending one data sample per second via RS-232, and continue indefinitely. The host data system is not required to send any commands in this mode.

The free-running mode can be stopped at any time by sending 3 control-C or carriage-return characters via RS-232, or by sending any SDI-12 command.

When not in free-running mode, the LISST-AOBS can receive other RS-232 commands, as described in the *RS-232 Operation* section, including commands for collecting and sending individual samples.

The SDI-12 interface is always polled: the logger or other data system must request a sample, then request the data from that sample.

Wiring

For SDI-12 operation, as with any SDI-12 device, only three connections are required: power (nominally 12 V), ground, and SDI-12 data. However, for compatibility with existing LISST-ABS cabling, the LISST-AOBS uses the same 8-pin connector as a standard LISST-ABS. For details, see *Connection Details* on page 16. The user must determine how to connect

the LISST-AOBS to the SDI-12 logger. Sequoia Scientific can provide cable pigtails for this purpose.

RS-232 operation requires four connections: power, ground, transmit, and receive. Typically these connections will be made to a computer COM port, or a USB adapter, or to a data logger. The user must determine to exact wiring depending on the mating device.

OPERATION WITH THE NEXSENS X2 LOGGER

About the X2 and X2-SDL

The NexSens X2 is a data logger that directly supports the LISST-AOBS, using the SDI-12 protocol, as well as many other SDI-12 sensors. The standard X2 is in a compact weatherproof (but not submersible) housing. The X2-SDL is functionally identical, but is submersible to a maximum depth of 60 meters.

Sequoia Scientific and NexSens offer complete packages that include an X2 or X2-SDL, and all necessary cabling.

For detailed information, see the X2 Document and Resource Library at https://www.nexsens.com/knowledge-base-v2/data-loggers/x2, and the X2-SDL resources at https://www.nexsens.com/knowledge-base-v2/data-loggers/x2-sdl.

Logging process

X2 loggers are optimized for long-term monitoring applications, in which they wake periodically, collect a sample, then return to low-power sleep mode until the next sample. The factory-default sample period is 10 minutes, but can be changed through the X2's Wi-Fi interface, or through the CONNECT software.

Data storage & transmission

The logging of LISST-AOBS data on an X2 is controlled by a script provided with the X2. The standard script

1. powers the LISST-AOBS 10 seconds before the scheduled sample time, running the anti-fouling wiper on the turbidity sensor, then
2. collects a 30-second average of LISST-AOBS data, and
3. logs the averaged values.

X2 loggers store data in their onboard memory, but also support automatic uploading through a Wi-Fi, cellular, radio, or satellite connection (depending on hardware configuration). Data then appear in near-real-time on the WQDataLive website. Raw data can also be offloaded directly to a computer through a USB port.

WQDataLIVE

WQData LIVE is a web-based platform for collecting and displaying data from Nexsens loggers. Users of X2 loggers can set up projects on this platform, free of charge. A project can have one or more X2 loggers associated with it, and those loggers can automatically deliver their data to the site through a WiFi, cellular, radio, or satellite connection

(depending on their hardware). The site aggregates the data and offers customizable graphical and tabular displays of data. See https://v2.wqdatalive.com.

CONNECT software

CONNECT is a Windows application for communicating directly to the X2 logger. It is not required for routine logging, but is often helpful for setup. It also allows copying data directly from the memory of the X2. Full information about CONNECT is available at https://www.nexsens.com/knowledge-base-v2/software/connect/user-guide. The software can be downloaded from https://www.nexsens.com/support/downloads.

Using CONNECT requires an adapter cable, Nexsens part number UW6-USB-485P, which is supplied with most X2 systems sold by Sequoia. This cable connects to any USB port on your computer or laptop, and to the waterproof connection in the center of the X2 logger's cap.

SDI-12 addressing

By default, the LISST-AOBS occupies SDI-12 address 0. If you connect other SDI-12 devices to the logger, you must ensure that they have unique addresses. The LISST-AOBS address can be changed, but the X2 logger detection script requires it to be within the range 0 to 9.

Initial setup

Please follow the latest Quick Start Guide from NexSens, available at https://www.nexsens.com/knowledge-base-v2.

If you purchased the complete X2-LISST-AOBS system as a package, the X2 logger will already be set up to with knowledge of the LISST-AOBS that is connected.

If you add sensors or otherwise change the configuration of the system, you must run the X2's process for detecting which sensors are connected. This can be initiated either with the CONNECT software, or through the X2's WiFi web interface. For instructions on running sensor detection from CONNECT, see https://www.nexsens.com/knowledge-base-v2/software/connect/user-guide/run-sensor-detection.

Parameter labels on WQDataLIVE

In a WQData LIVE project, the 3 parameters from the LISST-AOBS are, by default, labeled as follows:

1. "Suspended Particle" in mg/L—the direct output of the LISST-ABS.
2. Voltage—the direct output of the Turbidity Plus sensor

3. “Suspended Particle” in mg/L—the AOBS composite concentration, as described in *How Super-Turbidity Measurement Works* starting on page 13.

For clarity, we recommend that after setting up a project on WQDataLIVE, you change the parameter names from their defaults. To do this:

1. On your WQDataLIVE project’s dashboard, pull down the Admin menu and select Settings.
2. On the Settings page, find the Parameter Settings section.
3. Under Parameter Settings, click on the name of the logger location, then on the name of the logger.
4. Now you should see a list of all the parameters measured by the logger, including the LISST-AOBS parameters. You can edit the names as you see fit. We recommend “ABS Concentration”, “Turbidity” and “Total Concentration”.

SDI-12 OPERATION DETAILS

Overview

The LISST-AOBS supports numerous SDI-12 commands for flexible control over the timing of samples, and over the anti-fouling wiper on the Turbidity Plus. All these commands are accessible to any logger that supports version 1.3 or higher of the SDI-12 protocol. For complete details of the LISST-AOBS commands, see *SDI-12 Command Reference* starting on page 8.

Addressing

When shipped from Sequoia Scientific, the LISST-ABS is normally set to address 0 (zero). You can change the addresses according to your own requirements, using standard SDI-12 methods. In this document, we use *a* to represent the LISST-ABS address.

Sampling and averaging

The ABS and turbidity sensors in the LISST-AOBS can be sampled every 2 to 3 seconds, using the SDI-12 *M* command. However, we recommend collecting 30-second averages in most cases, to smooth the natural variability created by turbulent motion of particles. Longer averaging intervals are also available by selecting the appropriate commands. The concurrent C commands allow the logger to communicate with other SDI-12 devices while the LISST-AOBS collects and averages its readings.

Control of the anti-fouling wiper

By default, the wiper on the Turbidity Plus runs once when power is initially applied to the LISST-AOBS. If your logger is programmed to turn off power to the LISST-AOBS between samples, the wiper will run upon power-up before each sample, without an explicit command from the logger. However, you can also turn off the automatic wiping and control the wiper with commands via RS-232 or SDI-12. See *Set automatic wiping* on page 11.

SDI-12 COMMAND REFERENCE

The following commands comply with the SDI-12 standard version 1.3. The address of the LISST-AOBS is represented by *a*.

Command Function	SDI-12 Command	Action
Address query	?!	Request address (requires that only one device is connected to the SDI-12 bus)
Acknowledge active	*a***!**	Request response from sensor at address *a*
Change address	*a***A***x***!**	Change address of sensor at address *a* to *x*
Send identification	*a*I!	Send ID string including SI address, SDI version, Manufacturers ID and sensor model
Start measurement	*a*M! *a*M1! *a*M2! *a*M3! *a*M4!	Sample once Average for 30 seconds Average for 60 seconds Average for 120 seconds Average for 300 seconds
Run wiper, then start measurement	*a*M5! *a*M6! *a*M7! *a*M8! *a*M9!	Run the wiper, then average for 30 seconds Run the wiper, then average for 60 seconds Run the wiper, then average for 120 seconds Run the wiper, then average for 300 seconds Run the wiper only; no sampling
Start concurrent measurement	*a*C! *a*C1! *a*C2! *a*C3! *a*C4!	Sample once Average for 30 seconds Average for 60 seconds Average for 120 seconds Average for 300 seconds
Run wiper, then start concurrent measurement	*a*C5! *a*C6! *a*C7! *a*C8! *a*C9!	Run the wiper, then average for 30 seconds Run the wiper, then average for 60 seconds Run the wiper, then average for 120 seconds Run the wiper, then average for 300 seconds Run the wiper only; no sampling
Send data	*a*D0!	Requests output data from the preceding M or C command. The data reply contains three values: ABS in mg/l, Turbidity in V, and AOBS in mg/l.

RS-232 OPERATION

Overview

The LISST-AOBS can communicate through RS-232, or through USB with an appropriate adapter (see *USB-powered operation* below).

With factory-default settings, upon power-up the LISST-AOBS will automatically run the anti-fouling wiper for 10 seconds, then send data, once per second, via RS-232.

NOTE: the LISST-AOBS will not respond to RS-232 commands when an SDI-12 command is in progress.

USB-powered operation

The 2-meter adapter cable from Sequoia, part number SEQ-AC-ABS-CBL02, provides both power and communication through a USB port. However, the Turbidity Plus sensor draws a brief surge of current when it is first powered, which can trigger a shutdown of the USB power. To prevent this:

1. disconnect the Turbidity Plus from the Y-cable,
2. connect the cable to the USB port (which will power the LISST-ABS),
3. connect the Turbidity Plus to the Y-cable.

Port parameters

The RS-232 port parameters are 9600 baud, 8-bit data, no parity, one stop bit, no flow control.

Command prompt

When the LISST-AOBS is ready to accept commands, it will display the `LISST-AOBS>` prompt.

COMMAND LIST (see detailed Command Reference on following pages) Commands are not case-sensitive	
DS *or* **status**	Display the identity and status of the LISST-AOBS.
GO	Starts free-running mode.
GS *or* **GetSample**	Makes a measurement and sends it via RS-232.
HS *or* **HoldSample**	Instrument makes a measurement and stores it in temporary memory. The results are NOT sent to the RS-232 output.
SL *or* **SendLast**	Transmits the last sample collected by the issuing of a GS or HS command that was stored in temporary memory.
WI *or* **Wipe**	Run the anti-fouling wiper on the Turbidity Plus sensor.
HE *or* **Help**	Displays a brief list of commands.
OBSSET OBSI	Controls automatic wiping.

RS-232 COMMAND REFERENCE

Display Status	
Syntax:	**DS** *or* **status**
Description:	Display the identity and status of the LISST-AOBS. NOTE: future firmware versions may include more information in the response.

Example:	`LISST-AOBS>DS`
	`Serial number: 6260`
	`SDI-12 address: 0`
	`Version 2.10 Apr 13 2021 22:59:53`
	`Input voltage is 12.46`
	`LISST-AOBS>`

Get and Transmit Sample	
Syntax:	**GS** *or* **getsample**
Description:	Instrument makes a measurement (for approximately 1 second) and returns the ABS, OBS and AOBS values.

Example:	`LISST-AOBS>GS`
	`+4.66e+01,+1.004,+8.78e+02`
	`LISST-AOBS>`

Start free-running data	
Syntax:	**GO** *or* **GO** ***period***
Description:	Starts free-running mode. If a numeric *period* value is included, that will set the time between samples, in seconds. If no *period* is included, the period is 1 second. Data will continue indefinitely, until stopped by 3 ctrl-C or carriage-return characters are received, or an SDI-12 command is received.

Examples:	`LISST-AOBS>GO`
	`+4.66e+01,+1.004,+8.78e+02`
	`+4.66e+01,+1.004,+8.78e+02`
	`+4.66e+01,+1.004,+8.78e+02`
	…
	
	`LISST-AOBS>GO 3`
	`+4.66e+01,+1.004,+8.78e+02` *[3-second pause]*
	`+4.66e+01,+1.004,+8.78e+02` *[3-second pause]*
	`+4.66e+01,+1.004,+8.78e+02` *[3-second pause]*
	…

Help (list commands)	
Syntax:	**HE** *or* **help**
Description:	Displays a list of commands available with brief descriptions

```
**** LISST-ABS help menu ****
DS or Status      Display status.
GS or GetSample   Take a sample and return the result.
HE or Help        This menu.
HS or HoldSample  Take a sample and hold the value (nothing returned).
GO or GO x        Start sampling once per second or every x seconds.
                  Send <cr> or ^C three times to stop.
SL or SendLast    Display the previous sample taken by GS or HS.
WI or Wipe        Run the OBS wiper.

Commands are not case sensitive.
LISST-AOBS>
```

Get and Hold a Sample (do not transmit it)	
Syntax:	**HS** *or* **holdsample**
Description:	Instrument makes a measurement (for approximately 1 second) and stores it in memory. The results are NOT sent to the RS-232 output. Use the SL command to get the result.
Example:	`LISST-AOBS>HS` `LISST-AOBS>`

Set automatic wiping	
Syntax:	**OBSSET OBSI *interval***
Description:	Controls whether the wiper will automatically run at power-up, and also how often it will run during free-running sampling (started by the GO command). • If *interval* is not included, the command simply indicates the present value of *interval*. The factory default is 10 minutes. • If *interval* is non-zero, the wiper will run automatically at power-up, and during free-running sampling it will run every *interval* minutes. The maximum *interval* is 255 minutes. • If *interval* is zero, the wiper will run **only** when explicitly commanded with the WI command or an SDI-12 command.

Example:	`LISST-AOBS>OBSSET OBSI`
	`OBS wipe interval (obsi)= 10 min` [*the factory default*]
	`LISST-AOBS>OBSSET OBSI 60`
	`OBS wipe interval (obsi)= 60 min`
	`LISST-AOBS>OBSSET OBSI 0`
	`OBS wipe interval (obsi)= 0 min` [*automatic wiping is off*]

Transmit last sample	
Syntax:	**SL** *or* **sendlast**
Description:	Transmits the last sample collected by the issuing of a GetSample or HoldSample command. This can be called multiple times and will return the same result each time until a new sample is collected.

Example:	`LISST-AOBS>SL`
	`+4.66e+01,+1.004,+8.78e+02`
	`LISST-AOBS>`

Run anti-fouling wiper	
Syntax:	**WI** *or* **wipe**
Description:	Runs the wiper on the Turbidity Plus. The command prompt returns immediately, but if you send another command while the wipe is in progress, the second command will be delayed until the wipe is completed. If it is another WI command, the reply indicates the remaining time.

Example:	`LISST-AOBS>WI`
	`Wiping for 10 seconds.`
	`LISST-AOBS>WI`
	`Wipe in progress, 4 s remaining.`

HOW SUPER-TURBIDITY MEASUREMENT WORKS

The LISST-AOBS combines two measurement techniques: acoustic (ultrasonic) and optical, to measure suspended sediment concentration, providing data superior to either technique alone.

Acoustic

The acoustic measurement is provided by the LISST-ABS, which measures backscattering with 8 MHz ultrasonic pulses. The LISST-ABS works best for particles with diameters from 30 to 400 µm. For more details, see the LISST-ABS User's Manual.

Optical

The optical measurement is provided by a Turner Designs Turbidity Plus™ sensor with integrated anti-fouling wiper. The Turbidity Plus's sensitivity to particles, like that of any turbidity sensor, is inversely related to the size of the individual particles. That makes turbidity a poor proxy for total particle mass, because turbidity from small particles can be the same as for a much larger mass of large particles.

Figure 1 shows the contrast between the ABS (blue curve) and turbidity (red) sensor responses versus particle size. For particles larger than about 30 µm, the ABS response is relatively flat, while the response of the turbidity (OBS) sensor is strongest for smaller sizes.

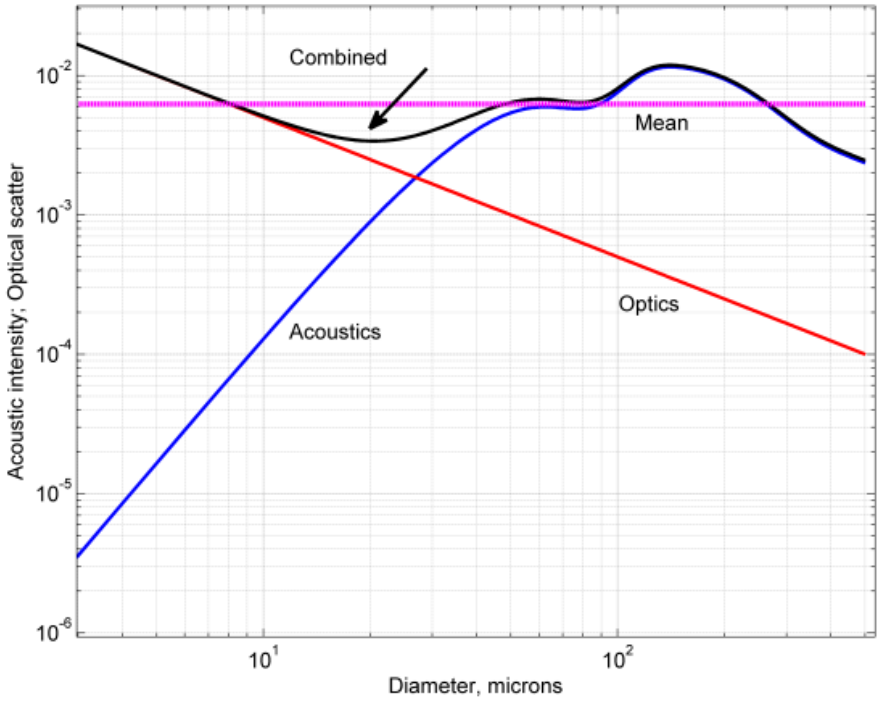


Figure 1: ABS and OBS response versus particle size

Pairing ABS with turbidity

By combining the complementary characteristics of the optical and acoustic measurements, the LISST-AOBS provides better tracking of total sediment concentration than either measurement alone. We can define a combined concentration measurement, C_{AOBS}, as follows:

$$C_{AOBS} = C_{ABS} + P * (V_{OBS} - V_0)$$

where

C_{ABS} is the concentration reported by the LISST-ABS, in mg/l
V_{OBS} is the voltage from the turbidity sensor
V_o is the voltage from the turbidity sensor in clean water
P is the pairing factor in mg/l/V

Intuitively, we can see from Figure 1 that adding the two sensor responses will produce a curve that is "flatter" than either curve alone, but it is not obvious what value of P is optimum. From a combination of theory and experiment, we find that the optimum pairing factor is

$$P = C_{ABS}/V_{OBS}$$

when measured with particles of 30 µm diameter, and with a high enough concentration to make the clean-water offset V_0 negligible. Put another way, P should have the value that equalizes the acoustic and optical contributions to C_{AOBS} from 30 µm particles.

Measuring Pairing Factor

To determine the pairing factor P in practice, we immerse the AOBS sensors in a suspension of natural particles (Arizona Test Dust) filtered to a range of 20 to 40 µm, that is, centered on the 30 µm optimum size cited above. The outputs of the two sensors provide C_{ABS} and V_{OBS}, and the ratio of those values is the pairing factor P.

Pairing Results

Figure 2 shows the response of a properly paired AOBS sensor to a wide range of particle sizes and concentrations. While obviously imperfect (perfect data would lie on the diagonal blue line), these results are vastly superior to what could be expected from a simple turbidity measurement.

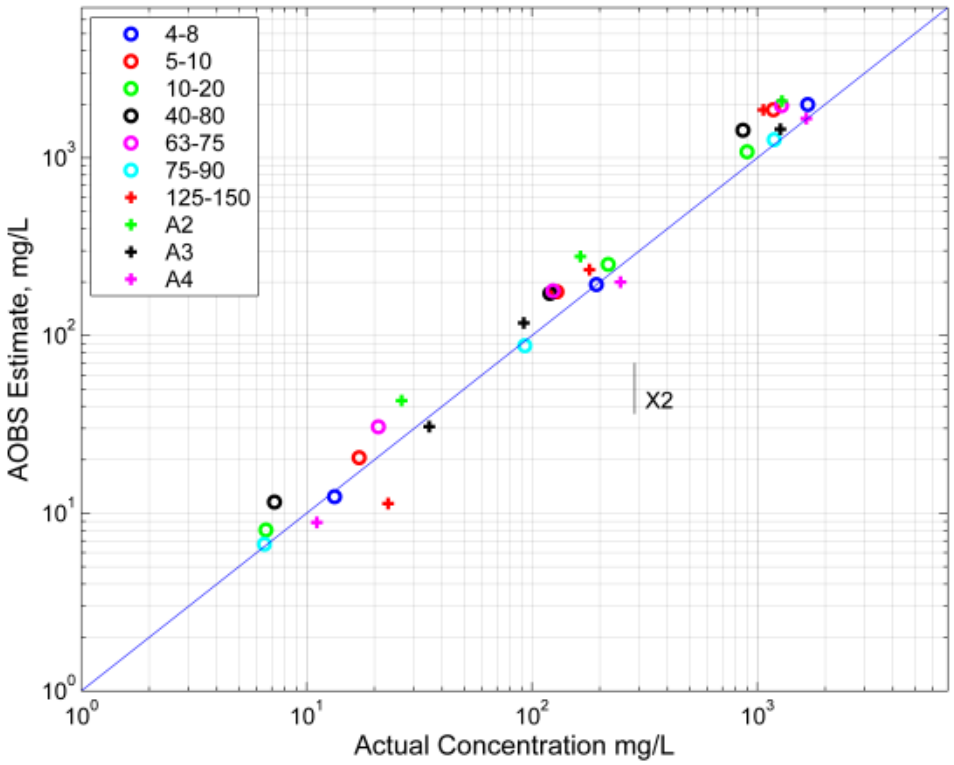


Figure 2: Response of combined AOBS sensor for various particle sizes

Interpreting LISST-AOBS Data

Although the AOBS or Super-Tubidity value is optimum in terms of estimating total concentration across a wide range of particle sizes, the separate ABS and OBS data have value beyond their contribution to the AOBS quantity. Because they have different responses to particle size, the ABS and OBS data can also provide insight into the particle size distribution (PSD). If the ratio of OBS to ABS increases, that indicates the PSD skewing toward smaller particles. If it decreases, the PSD is favoring larger particles. And, in some installations the turbidity from the OBS may also be an important parameter on its own. Therefore, it is generally worthwhile to log all three values.

CONNECTION DETAILS

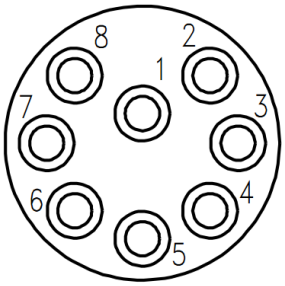
Pin functions

The connector on the LISST-AOBS Y-adapter is a Subconn MCBH8M, wired as shown below. Mating connector is Subconn MCIL8F.

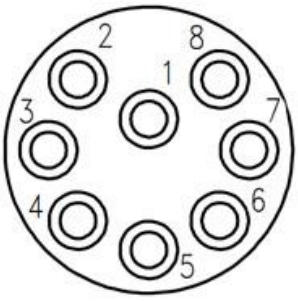
1. Common*
2. Supply voltage, 10 to 15 V
3. Common*
4. RS232 transmit (from AOBS to computer)
5. RS232 receive (to AOBS from computer)
6. SDI-12 input/output
7. No connection
8. Common*

* Common pins are connected inside the Y-cable.

Male connector numbering



Female mating connector numbering



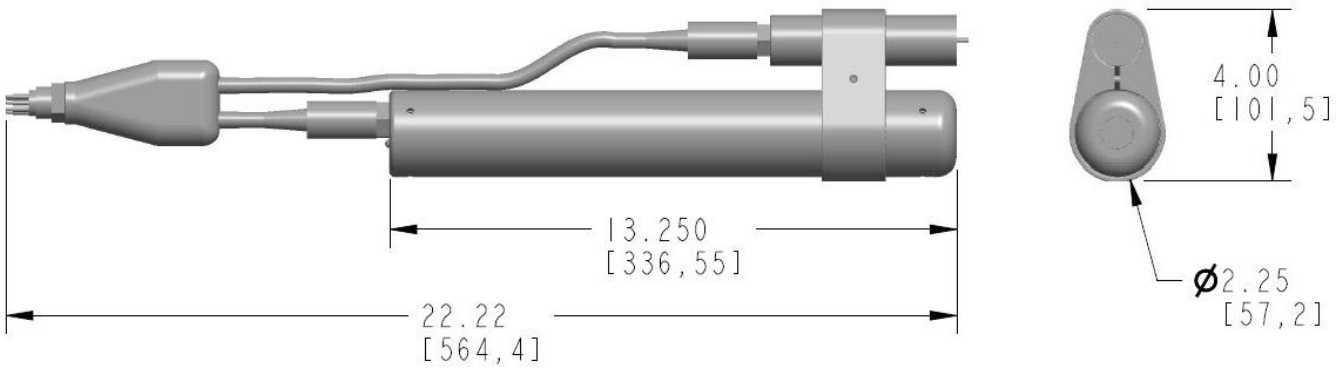
Cables

Green-jacketed cables supplied by Sequoia Scientific for the LISST-ABS are compatible with the LISST-AOBS adapter. See the LISST-ABS manual for details.

SPECIFICATIONS

NOTE: these specifications apply to version 2 of the LISST-AOBS (starting with serial number 6246) and are significantly different from the previous version.

- Power Consumption (typical, 12 V input):
    - Idle: 60 mA
    - Sampling: 75 mA
    - Wiper running (sampling pauses): 68 mA
- Input voltage: 10 to 15 VDC (maximum limited by Turbidity Plus™)
- Maximum depth: 100 meters (limited by LISST-ABS)
- Dimensions: see drawing below
- Concentration measurement range:
    - 1 mg/liter minimum
    - 10 g/liter maximum for particles of any size
    - 30 g/liter maximum for particles 20 µm or smaller
- Weight: 0.9 kg in air; buoyant in water
- Housing materials: Acetal and ABS plastic



Dimensions in inches [mm]

Revision history

Version 2.1	Add note about *USB-powered operation* on page 9.
Version 2.0	Major revision to describe new LISST-AOBS version 2 (Manual version 1.3 still applies to older LISST-AOBS).
Version 1.3	Remove incorrect warranty statement. For warranty information see www.sequoiasci.com/support/warranty
Version 1.2	General revision and formatting, add information about X2 loggers, May 2020
Version 1.1	Improved figure 1. March, 2020
Version 1.0	First released version, March 2020