LISST-ABS

Acoustic Backscatter Sensor

User's Manual

Version 1.1

(November 2015)

Sequoia Scientific, Inc.
2700 Richards Road Suite 107
Bellevue, WA, 98005, USA
Phone: +1 425-641-0944; Fax: +1 425-643-0595
support@SequoiaSci.com; www.SequoiaSci.com

This page intentionally left blank

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.

A list of local Sequoia distributors can be found at our website http://www.sequoiasci.com/about/contact/distributors

Sequoia Scientific, Inc. can be reached at support@sequoiasci.com or by phone +1-425-641-0944.

Contents

Section 1: Quick Start

Intro

Thank you for purchasing Sequoia's LISST-ABS acoustic sediment sensor. This Quick Start guide is intended to get you up running as quickly as possible. Detailed instructions can be found in other sections of the manual.

The LISST-ABS uses acoustic backscatter to measure the concentration of particles suspended in water. It outputs the Uncalibrated Concentration (or C_u). The Uncalibrated Concentration is converted to Concentration using standard calibration procedures such as used for turbidity sensors. For more details see Appendix B and Appendix C.

The LISST-ABS is shipped ready for use. It takes just 3 easy steps to start seeing some real measurements.

Step 1: Unpack box

Inside the box should be the following items: LISST-ABS with protective red cap and locking cap on the connector, a 5 to 50 meter long cable with underwater connector and locking sleeve on one end and an 8-pin plastic Molex connector on the other end, USB cable with mating Molex connector and three short pigtails with mating Molex connectors. The three cables can be used for connecting to dataloggers with screw terminals. There are separate pigtails for SDI-12, RS232, and Analog Output connections. Also included is a credit card style USB memory card with software installation files.

The sensor head is covered with a protective red cap to prevent accidental impact and damage of the acoustic transceiver (white disc). Be sure to remove the protective cap before use. The instrument will not work with the cap left on. The underwater connector is also covered with a protective cap.

Step 2: Install Software

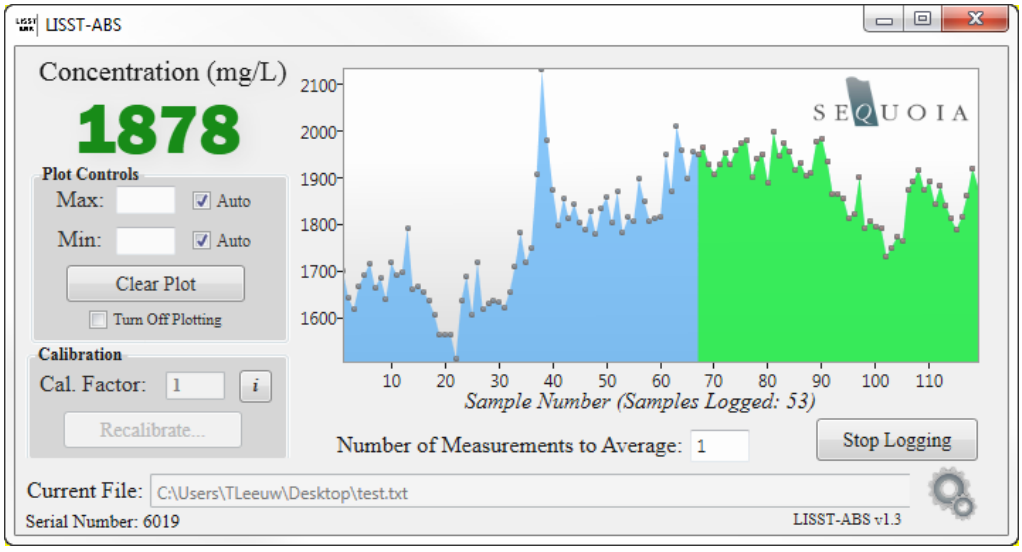
A simple program that can be used for testing the LISST-ABS is included on the USB memory card. To install the software on your computer run the LISST-ABS_installer.exe program on the memory card. This will install the LISST-ABS software. This software requires the .NET 4.0 Framework. Most computers will have this framework already installed as it is used by many other programs. A message will appear if the .NET 4.0 needs to be installed. You can install .NET using the dotNetFx40_Client.exe program on the memory card.

Step 3: Plug in USB cable and Start Program

The LISST-ABS is a sensor only and must be connected to a power source. We have designed a USB cable to provide power and communicate with the instrument via one connection to a PC. Connect the long cable to the LISST-ABS, attached the USB extension cable and then plug in the USB cable into the PC. You should see the green LED on the LISST-ABS start to blink. Every time the LISST-ABS blinks data is being sent up the cable to the PC.

If the LISST-ABS was purchased without a cable you will need to provide power to the LISST-ABS and connect the RS232 output to the PC to use the provided software.

You can now start the LISST-ABS software to see the values in real time. You can also use the software to store data. Below is a screen shot of the software while data is being logged to text file. More details on the operation of the software can be found in Section 2.5.



The Cal Factor is a calibration value that is used to convert Uncalibrated Concentration (C_u) to Concentration in mg/L. You can determine your own Cal Factor value based on the type of particles you will be measuring. The LISST-ABS is calibrated and adjusted at the factory using 63-75 micron particles so that the Cal Factor for these particles will always be 1. You may use this value for a quick approximation of concentration but proper calibration should be done to obtain the most accurate results. More information about calibrating the LISST-ABS can be found in Appendix B.

The Concentration displayed on the screen will be an average of a number of samples. The number of measurements used to create the average is set in the Average Duration box. The value displayed and plotted will update at the rate selected. To store data to a file press the Log Data button, select a location and name of a file to receive the data and then press Start Logging. Data will be stored to the file until Stop Logging is pressed. The log file contains a header with calibration constants, the Cal Factor value and the instrument serial number. Following the header is a row for each sample containing date and time, Uncalibrated Concentration, and computed Concentration. The Log file is a space delimited ASCII file that can be easily imported into programs such as Excel.

Detailed instructions on connecting the LISST-ABS to your datalogger are covered in separate sections of this manual. For SDI-12 operations see Section 2.2. For Serial/RS232 operations see Section 2.3. For Analog Output operations see Section 2.4.

Section 2: Instructions

2.1 Introduction

Thank you for your purchase of Sequoia's LISST-ABS acoustic backscatter sensor. The LISST-ABS is a single-point acoustic sediment sensor, designed to provide higher quality data than optical turbidity sensors. Its key advantages over optical turbidity sensors are:

- Superior response to particles of grain size >30 microns.
- Relatively flat sensitivity to particles from 30-400 microns in sizes.
- Greater immunity to fouling.
- Wide dynamic range of concentrations from 1mg/L to 70 g/L.

The LISST-ABS internally measures the Attenuation Corrected Backscatter(ACB). The ACB value is converted to an Uncalibrated Concentration (C_u) and then output. To convert the Uncalibrated Concentration to sediment concentration a simple multiplier is required. The multiplier, or Cal Factor, is dependent on the specific type and size of sediment being measured. When a user recalibrates an instrument, it is this multiplier that is updated. For more detailed understanding of the technology, please see Appendix C.

The LISST-ABS can output the Uncalibrated Concentration using three different methods, SDI-12, RS232, and analog output. All three of these outputs are available on the underwater connector on the end of the LISST-ABS. The output used is determined by how the instrument is connected to a datalogger.

The LISST-ABS can be powered in two ways. For testing purposes, a special USB cable is available. When using this cable, power to the instrument is provided by the USB port. When connecting to a datalogger you will need to supply a voltage between 10-18VDC. The current drain at 12V is 100 ma when actively collecting data. If the supply voltage is too low the LISST-ABS will output an Uncalibrated Concentration value of -999.

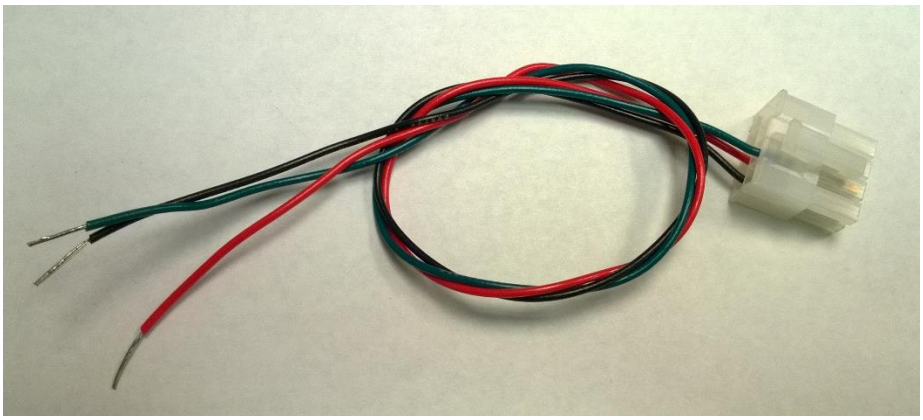
When the LISST-ABS is powered up the green LED on the endcap will start to blink at about once per second. This indicated that the instrument is powered up and operating normally. When the LISST-ABS is actively sampling it will double blink (two blinks in quick succession). When idle but still powered up it will do a single blink once per second.

2.2 SDI-12 Operations

The LISST-ABS has been designed to support SDI-12 protocol. It is compatible with SDI-12 version 1.3. This section is divided into two parts, Connecting to your datalogger and SDI-12 command summary.

SDI-12 Connections

SDI-12 only requires three wires. Power, Ground and Data. Appendix A includes detailed descriptions of the use of the individual pins of the 8-pin connector on the LISST-ABS. However, in most case you will be using a cable provided by Sequoia for connecting to your SDI-12 compatible datalogger. To make the connections easier we have provided different cable terminations designed specifically for different connection requirements. For example we provide a termination with only the three individual wires that are labeled and can be easily connected to the datalogger. The mating connector makes it easy to remove the long cable without disconnecting the wires from the datalogger. You can also easily switch between the datalogger and the USB cable if needed.



The wires are labeled and color coded. Connect the Black wire to Ground. Connect the Red wire to +12V. Connect the Green wire to SDI-12 Data.

The LISST-ABS is shipped pre-configured with an SDI-12 instrument address of 0.

The available SDI-12 commands are described below. Following the command descriptions are some suggested best practices for using the LISST-ABS with SDI-12.

LISST-ABS SDI-12 Command Summary

Command Name	Command Code	Notes
Address Query	**?!**	Request address of single sensor on bus
Acknowledge Active	*a***!**	Request response from sensor at address *a*
Change Address	*a***A***b***!**	Change address of sensor at address *a* to *b*
Send Identification	*a***I!**	Send ID string including SI address, SDI version, Manufacturers ID, sensor model, sensor Firmware version and device serial number
Start Measurement	*a***M!**, *a***MC!** *a***M1!**, *a***MC1!** *a***M2!**, *a***MC2!** *a***M3!**, *a***MC3!** *a***M4!**, *a***MC4!**	Start a measurement, returns number of seconds till sample is ready to be read. Sends service request when measurement is complete. An M command returns a single 1 second average. M1, M2, M3, and M4 return a 30, 60, 120, or 300 second average. C following a command requests a CRC code in the data return (D command).
Start Concurrent Measurement	*a***C!**, *a***CC!** *a***C1!**, *a***CC1!** *a***C2!**, *a***CC2!** *a***C3!**, *a***CC3!** *a***C4!**, *a***CC4!**	Same as Start Measurement command except does not send service request.
Send Data	*a***D***b***!**	Requests output *b* (0-9) from Sensor *a*
Continuous Measurements (Read)	*a***R!**	Not supported
Start Verification	*a***V!**	Not Supported

See the next page for details of SDI-12 commands.

LISST-ABS SDI-12 Command Details

Basic Command Set

?!	**Address Query**
Syntax:	**?!**
Description:	Request address of single sensor on bus. Note: sensor must be the only sensor on the bus or multiple instruments will respond simultaneously.
Example:	Command: ?! Response: 0 (responds with address of sensor, in this case 0)

*a***!**	**Acknowledge Active**
Syntax:	*a***!**
Description:	Request response from sensor at address a.
Example:	Command: 0! (request sensor at address 0 to confirm it is active) Response: 0 (responds with address of sensor)

*a***A***b***!**	**Change Address**
Syntax:	*a***A***b***!**
Description:	Change address of sensor at address *a* to *b*
Example:	Command: 0A3! (request sensor at address 0 to change to address 3) Response: 3 (responds with new address of sensor)

*a***I!**	**Send Identification**
Syntax:	*a***I!**
Description:	Send ID string including SI address, SDI version, Manufacturers ID, sensor model, sensor Firmware version and device serial number.
Example:	Command: 3I! (request sensor at address 3 to send ID string Response: 313SequoiaSABS001001123456 Where: 3 = Sensor address (1 character) 13 = SDI Version compatibility (2 characters) SequoiaS = Manufacturers ID (8 characters) ABS001 = Sensor Model (6 characters) 001 = Sensor Firmware (3 characters) 123456 = Sensor Serial Number (6 characters)

*a***M!**	**Start Measurement**
Syntax:	***a*M!, *a*MC!, *a*M1!, *a*MC1!, *a*M2!, *a*MC2!, *a*M3!, *a*MC3!, *a*M4!, or *a*MC4!**
Description:	Start a measurement, returns number of seconds till sample is ready to be read. Sends service request when measurement is complete.
Examples:	Command: 3M! (request sensor at address 3 to make as measurement) Response: 30011 (3 is the address, 001 is # of seconds, 1 is the # of values) <after 1 second> 3 (sends address to confirm measurement is ready to be read) Command: 3M1! (request sensor at address 3 to get a 30 second average) Response: 30011 (3 is the address, 031 is # of seconds, 1 is the # of values) <after 31 seconds> 3 (sends address to confirm measurement is ready to be read) Command: 3MC1! (request sensor at address 3 to get a 30 second average with CRC in returned data) Response: 30011 (3 is the address, 031 is # of seconds, 1 is the # of values) <after 31 seconds> 3 (sends address to confirm measurement is ready to be read)

*a***C!**	**Start Concurrent Measurement**
Syntax:	***a*C!**
Description:	Start a measurement, returns number of seconds till sample is ready to be read. Does **not** send service request when measurement is complete.
Example:	Command: 3C! (request sensor at address 3 to make as measurement) Response: 30011 (3 is the address, 001 is # of seconds, 1 is the # of values) <after 1 second, measurement is ready but no response is send> Command: 3C1! (request sensor at address 3 to get a 30 second average) Response: 30011 (3 is the address, 001 is # of seconds, 1 is the # of values) <after 1 second, measurement is ready but no response is send>

*a***D***b***!**	**Send Data**
Syntax:	***a*D*b*!**
Description:	Requests output *b* (0-9) from Sensor *a*
Examples:	Command: 3D0! (request sensor at address 3 to send data block 0) Response: 3+1234.56 (responds with Uncalibrated Concentration, C_u) Note: in response to certain commands, the data returned after a D command may have a CRC value appended to it. Since the LISST-ABS has only one output only the aD0! command is required.

*a***R!**	**Continuous Measurements**
Syntax:	*a***R!**
Description:	Not supported. The LISST-ABS is not a continuous measurement device. No data will be returned. The response to this command is below.
Example:	Command: 3R! (request continuous measurement) Response: 3 (responds with address of sensor)

*a***V!**	**Start Verification**
Syntax:	*a***V!**
Description:	Not supported but the sensor will respond to the command with the response shown below.
Example:	Command: 0A3! (request sensor at address 0 to change to address 3) Response: 30000 (responds with current address of sensor)

LISST-ABS and SDI-12 Best practices

In order to obtain the most accurate results it is recommended that the LISST-ABS collect a 30 second or longer average. The LISST-ABS is more sensitive to larger particles and the sample volume is smaller. Therefore do get good representative measurements an average of a larger volume of water is recommended. Using the M1!, M2!, M3! Or M4! Commands will acquire an average of 30, 60, 120, or 300 seconds.

The LISST-ABS will remain powered between SDI-12 commands. If low power consumption is required it is suggested that the LISST-ABS be powered down between measurements to conserve power. The M commands can be immediately after power up and establishing an SDI-12 connection.

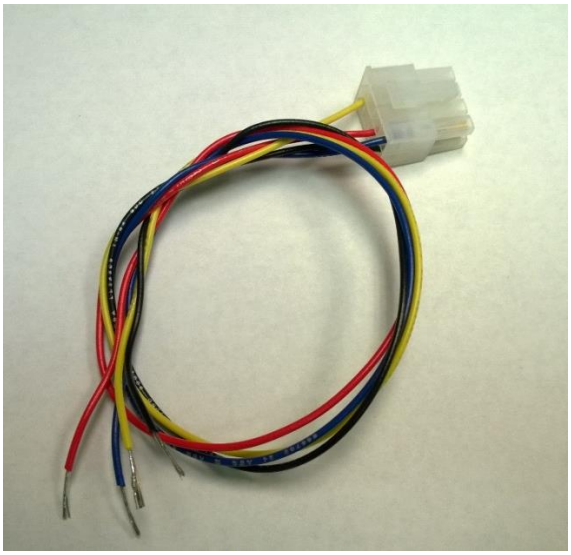
For suggestions on mounting, cleaning and maintenance please see Section 2.6.

2.3 RS232 Output Operations

The LISST-ABS has also been designed to support RS232 communication in both transmit-only and two-way communication modes.

RS232 Connections

RS232 requires four wires. Power, Ground, Transmit and Receive. Appendix A includes detailed descriptions of the use of the individual pins of the 8-pin connector on the LISST-ABS. However, in most cases you will be using a cable provided by Sequoia for connecting to your RS232 compatible datalogger. To make the connections easier we have provided different cable terminations designed specifically for different connection requirements. For example we provide a termination with only the four individual wires that are labeled and can be easily connected to the datalogger. The mating connector makes it easy to remove the long cable without disconnecting the wires from the datalogger. You can also easily switch between the datalogger and the USB cable if needed.



The wires are labeled and color coded. Connect the Black wire to Ground. Connect the Red wire to +12V. Connect the Yellow ABS Transmit wire to the datalogger Receive input and the Blue ABS Receive wire to the datalogger transmit output.

The LISST-ABS uses a baud rate of 9600 with 8 data bits, one stop bit, no parity, and no flow control.

By default, the LISST-ABS will automatically start outputting the Uncalibrated Concentration values out the RS232 connection upon power up. The values are output at once per second. The values are one value per line in scientific notation. The line is terminated with a linefeed character. We call this the Automatic Mode output.

The simplest method of collecting RS232 data is to capture and store the values being returned from the LISST-ABS as it is output. As described below in the recommended sampling procedure, the instrument should be allow to output for 30 seconds after power up before measurements are recorded.

There are also a set of commands that can be sent to the LISST-ABS to give more control of the flow of data. The available RS232 commands are described below. The commands are not case sensitive and there are multiple command codes for the same command function.

Following the command descriptions are some suggested best practices for using the LISST-ABS with RS232.

LISST-ABS RS-232 Command Summary

Command Name	Command Code	Notes
Display Status	**DS** **Status**	Display the Current Status of the instrument including instrument serial number and firmware version
Take and Transmit Sample (and hold)	**GS** **GetSample**	Instrument makes a measurement, stores it in temporary memory, and outputs the results to the RS-232.
Take Sample and hold it	**HS** **HoldSample**	Instrument makes a measurement and stores it in temporary memory. The results are NOT sent to the RS-232 output.
Transmit last sample	**SL** **SendLast**	Transmits the last sample collected by the issuing of a GS or HS command that was stored in temporary memory.
Return to Automatic Mode	**Return** **AutoMode** **Exit**	Returns the LISST-ABS to automatic mode where results are output to the RS232 every 1 second
Help	**HE** **Help**	Displays a list of commands available with brief descriptions

See the next page for details of the RS232 commands.

LISST-ABS RS232 Command Details

Basic Command Set

DisplayStatus	Display Status
Syntax:	**DS or ds or status**
Description:	Display the Current Status of the instrument including instrument serial number and firmware version
Example:	Command: DS Response: Serial number: 6014 SDI-12 address: 0 Version Jul 8 2015 15:01:34 LISST-ABS>

GetSample	Take and Transmit Sample (and hold)
Syntax:	**GS or gs or getsample**
Description:	Instrument makes a measurement, stores it in memory, and outputs the averaged Uncalibrated Concentration value to the RS-232 output.
Example:	Command: GS 30 Response: <delay of 30 seconds> 1.23456E3 LISST-ABS> Command: GS Response: <delay of 1 second> 1.23456E3 LISST-ABS>

HoldSample	Take Sample and hold it
Syntax:	**HS or hs or holdsample**
Description:	Instrument makes a measurement and stores it in memory. The results are NOT sent to the RS-232 output. Only a LISST-ABS> prompt is returned.
Example:	Command: HS 30 Response: LISST-ABS> <Value in memory will be updated in 30 seconds> Command: HS Response: LISST-ABS> <Value in memory will be updated in 1 second>

SendLast	Transmit last sample
Syntax:	**SL or sl or sendlast**
Description:	Transmits the last sample collected by the issuing of a GetSample or HoldSample command.
Example:	Command: SendLast Response: 1.23456E3 LISST-ABS>

Return	Return to Automatic Mode
Syntax:	**GO or go or return or exit**
Description:	Returns the LISST-ABS to automatic mode where results are output to the RS232 every 1 second
Example:	Command: Exit Response: <delay of 1 second> 1.23456E3 <delay of 1 second> 1.23456E3 …

Help	Display Help
Syntax:	**HE or help**
Description:	Displays a list of commands available with brief descriptions
Example:	Command: help Response: **** LISST-ABS help menu **** DS or Status Display status. GS or GetSample Take a sample and return the ACB. HE or Help This menu. HS or HoldSample Take a sample and hold the ACB (nothing returned). AutoMode, Exit, or Return Return to 1hz sampling. Press <cr> three times to halt sampling. SL or ShowLast Display the previous sample taken by GS or HS. Commands are not case sensitive. LISST-ABS>

LISST-ABS and RS232 Best practices

In order to obtain the most accurate results it is recommended that the LISST-ABS be powered up and allowed to sample in the automatic mode (green LED double blinking) for 30 seconds or more before issuing a Start Measurement command. This 30 second wait should be done every time power is applied. During these 30 seconds the LISST-ABS is obtaining a running average of attenuation that is used internally to compute the ACB value that is output. Shorter waits will result in noisier measurements.

It is also recommended that bursts of 30 measurements or more be recorded and averaged to obtain the best results. Because of the small measurement volume of the LISST-ABS the ACB measurements can be vary sample to sample as clouds of turbidity pass by. In order to obtain a representative value some averaging of these clouds should be done.

For example if measurements every 15 minutes are desired we recommend the following procedure:

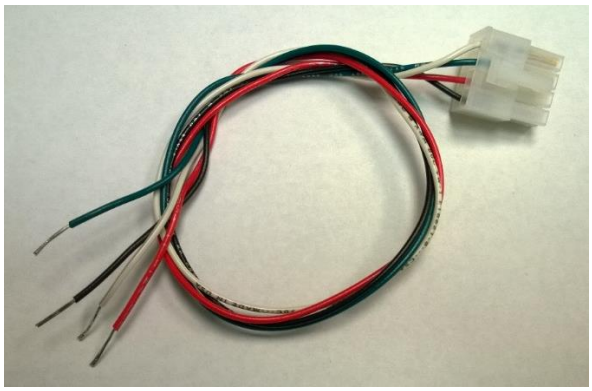
1) Power up the LISST-ABS 45 seconds before the beginning of the desired sample time and allow it to sample.
2) Option 1: Start recording the values being output by the LISST-ABS to record 60 measurements 1 second apart. Option 2: Issue GetSample commands to record 60 measurements 1 second apart.
3) Power down the LISST-ABS and wait till the next sample time.

For suggestions on mounting, cleaning and maintenance please see Section 2.6.

2.4 Analog Output Operations

The LISST-ABS has a third output option. The digital Uncalibrated Concentration value is converted to a voltage and output on the underwater connector. This voltage can be recorded and converted back to Uncalibrated Concentration values. It is highly recommended to use either SDI-12 or RS232 to obtain the most accurate measurements of Uncalibrated Concentration. However, for some applications it may be desirable to use the analog output.

Using the Analog Output requires four wires. Power, Power Ground, Signal and Signal Ground. Appendix A includes detailed descriptions of the use of the individual pins of the 8-pin connector on the LISST-ABS. However, in most cases you will be using a cable provided by Sequoia for connecting to your datalogger. To make the connections easier we have provided different cable terminations designed specifically for different connection requirements. For example we provide a termination with only the four individual wires that are labeled and can be easily connected to the datalogger. The mating connector makes it easy to remove the long cable without disconnecting the wires from the datalogger. You can also easily switch between the datalogger and the USB cable if needed.



The wires are labeled and color coded. Connect the Black wire to Power Ground. Connect the Red wire to +12V. Connect the Green wire to Analog input and the White wire to the Signal Ground.

LISST-ABS and Analog Output Best Practices

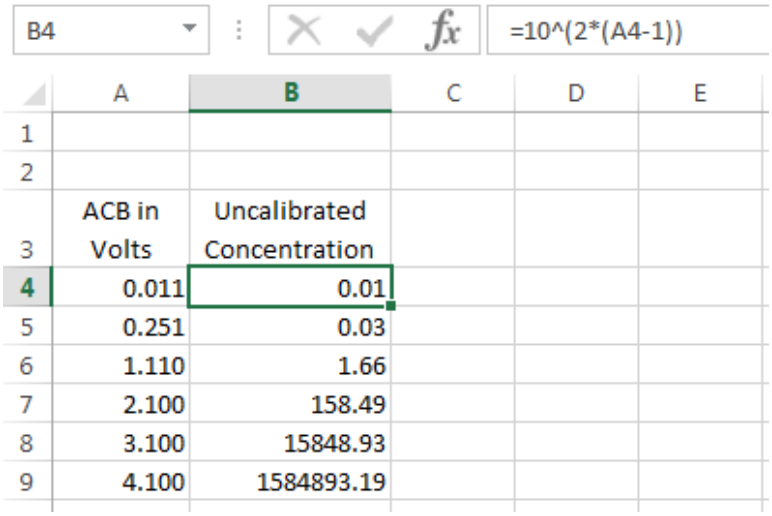
Because the LISST-ABS has a very large dynamic range a simple linear relationship between Uncalibrated Concentration and voltage is not sufficient. Therefore the Attenuated Corrected Backscatter (ACB) value is output instead. The ACB can be converted to Uncalibrated Concentration with a simple equation.

The Analog Output of the LISST-ABS is configured such that 1mv of output is equal to 1 ACB count. Therefore if the output of the LISST-ABS is 1234 ACB counts then the analog voltage would be set to 1234 mV or 1.234 volts.

To convert the ACB value to Uncalibrated Concentration use the following formula: Uncalibrated Concentration = $10^{2*(V-1)}$

where V is the ACB in volts.

The formula for Excel is shown below.



	A	B	C	D	E
1					
2					
3	ACB in Volts	Uncalibrated Concentration			
4	0.011	0.01			
5	0.251	0.03			
6	1.110	1.66			
7	2.100	158.49			
8	3.100	15848.93			
9	4.100	1584893.19			

In order to obtain the most accurate results it is recommended that the LISST-ABS be powered up and allowed to sample in the automatic mode (green LED double blinking) for 30 seconds or more before recording the analog voltage output. This 30 second wait should be done every time power is applied. During these 30 seconds the LISST-ABS is obtaining a running average of attenuation that is used internally to compute the ACB value that is output. Shorter waits will result in noisier measurements.

It is also recommended that bursts of 30 measurements or more be recorded and averaged to obtain the best results. Because of the small measurement volume of the LISST-ABS the ACB measurements can be vary sample to sample as clouds of turbidity pass by. In order to obtain a representative value some averaging of these clouds should be done.

For example if measurements every 15 minutes are desired we recommend the following procedure:

1) Power up the LISST-ABS 45 seconds before the beginning of the desired sample time and allow it to sample.
2) Record 60 measurements of the analog voltage 1 second apart.
3) Power down the LISST-ABS and wait till the next sample time.

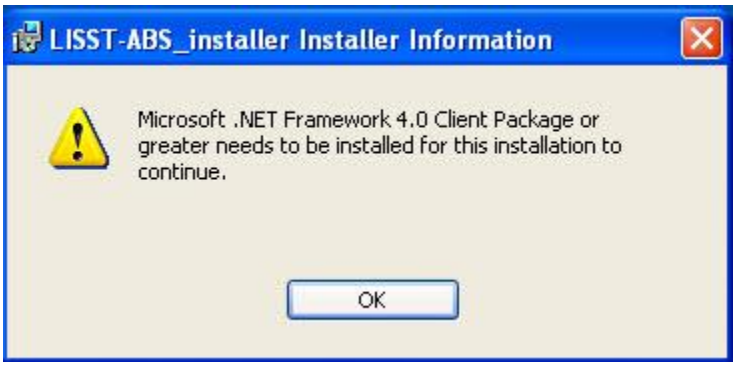
For suggestions on mounting, cleaning and maintenance please see Section 2.6.

2.5 USB Operations via PC software

The LISST-ABS is shipped with a simple windows application that allows for viewing and logging of data. The application also provides a feature that allows for easy calibration of the LISST-ABS.

Installation

The installer and related software files are located in the Software folder on your instruments ship disk. Open the installer by double clicking on 'LISST-ABS_installer.exe.' The software requires that you have windows .NET framework 4.0 or later installed on your computer. You can determine if the framework is installed on your computer by simply running the LISST-ABS installer. If the framework is missing, a warning message will appear:



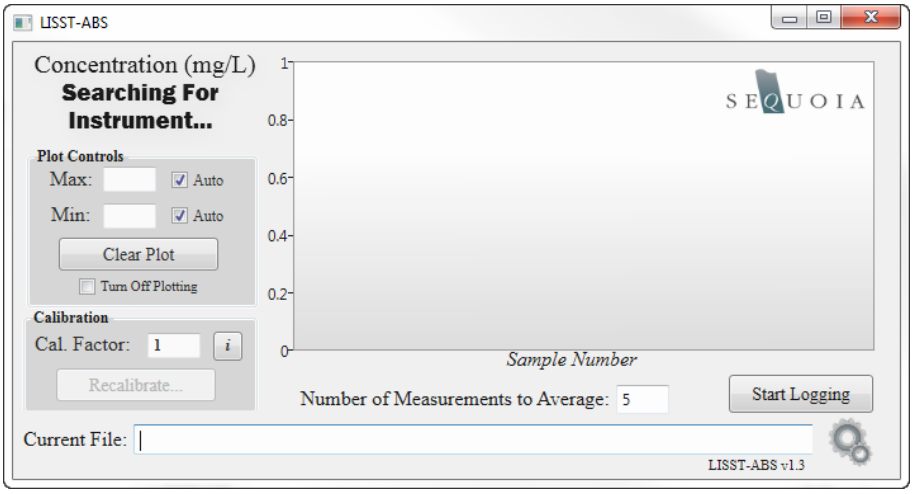
Should you receive this message, return to the ship disk and run the 'dotNetFx40_Client.exe' installer. This will install the .NET framework on your computer. Once that is completed, relaunch the 'LISST-ABS_installer.exe' and follow the installation instructions. The installer will place a LISST-ABS shortcut on your start menu as well as your desktop.

USB Drivers

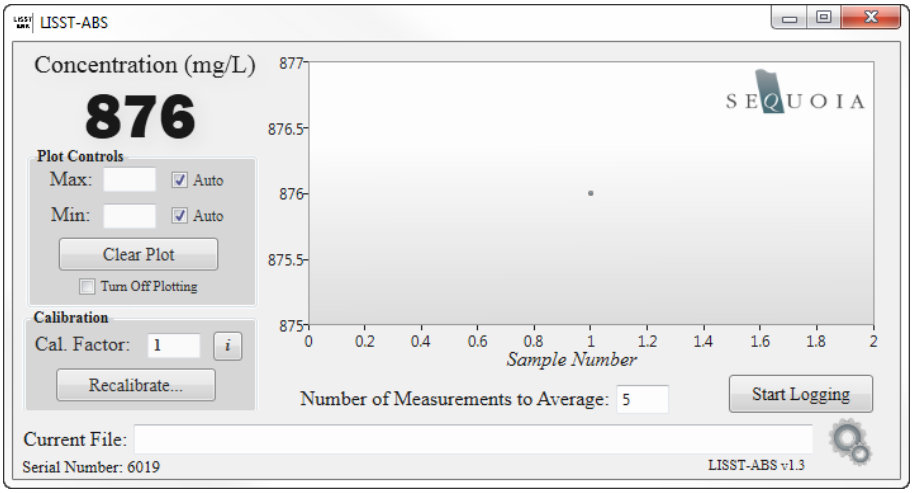
Before launching the LISST-ABS software, plug the USB cable into your computer. If the computer has an internet connection it should automatically install the correct drivers. A notification will appear on the screen if the drivers are being installed automatically. If the drivers are not installed, go back to the ship disk and run 'CDM USB Driver.exe.' Follow the on screen instructions to install the drivers.

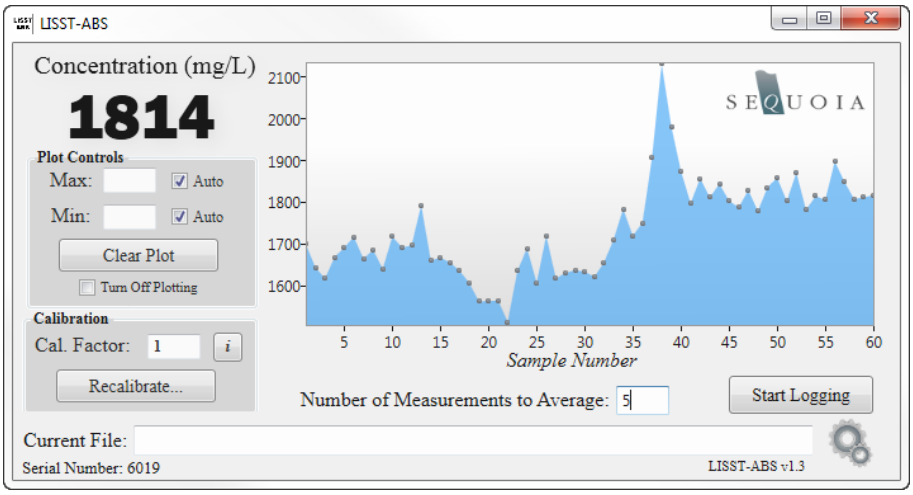
Automatic Instrument Detection

When the LISST-ABS software is launched, it will begin searching for the instrument on the ports of your computer.



Ensure the instrument is connected to the computer via the USB cable. Within a few seconds the software will find the instrument and begin displaying uncalibrated concentration values (default calibration factor of 1). The instrument serial number will also be displayed at the bottom left of the screen. The software will automatically start plotting the uncalibrated concentration as function of sample number.



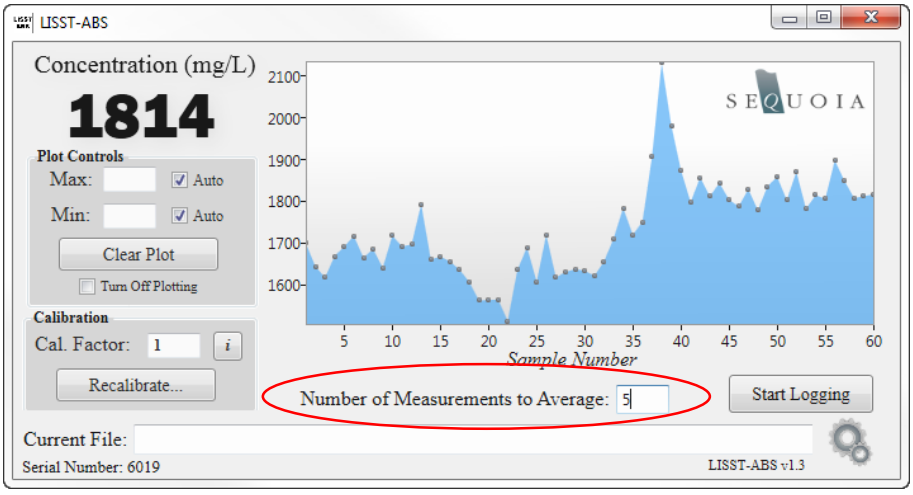


If the Sequoia USB cable is not available you can still use the software via any RS232 connection to the PC. You will need to power the instrument separately. See Appendix A for wiring instructions.

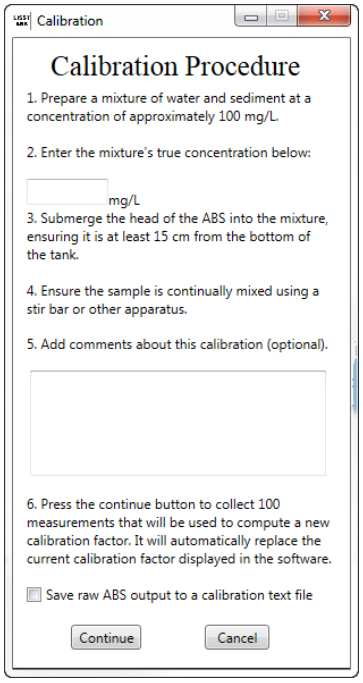
Should you have more than one ABS instrument plugged into your computer, the software will interface with the first instrument it finds while searching your computer's ports. To change to a different port, see the 'Settings/Tools' section on page 26.

Sampling Parameters

Just below the concentration plot, you have the ability to adjust the number of measurements to average per data point. The ABS samples once per second (1 hz), so this number will also represent the amount of time, in seconds, between each data point. For example, if you set the measurement average to 10, the ABS would collect 10 measurements over a period of 10 seconds. The software then averages the 10 samples together and displays the resulting concentration on the screen. If you do not want any averaging of the ABS output, simply set the measurement average to 1.



Calibration

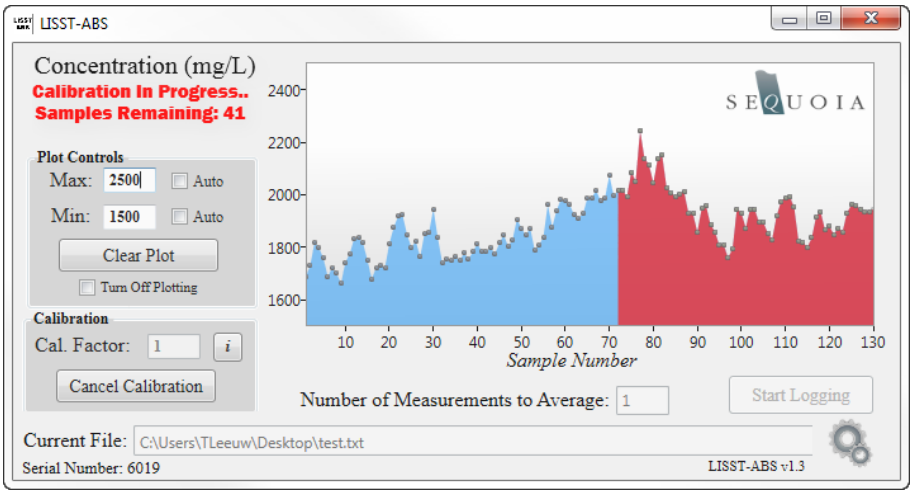


The concentration displayed in the software will be incorrect until an accurate calibration factor is entered in the software (see Appendix B for an explanation of calibration constants). If you are only interested in viewing and logging uncalibrated concentration, you can skip this section.

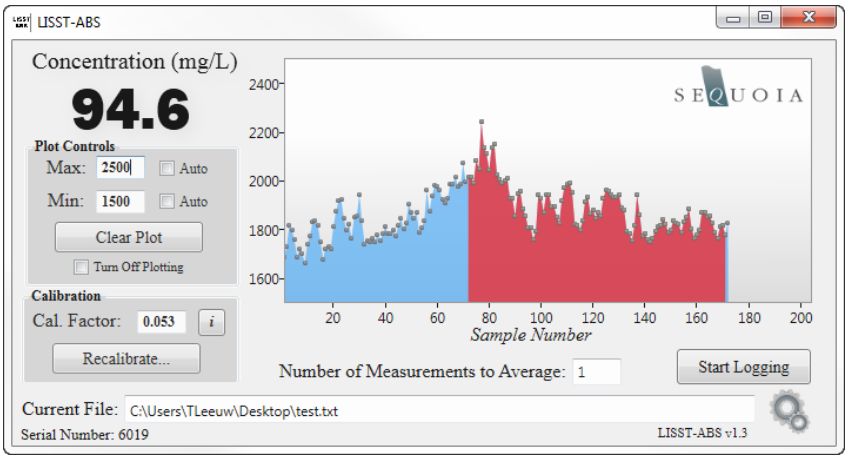
If you already have a calibration factor for your instrument, you can simply type it into the 'Cal. Factor' text box. The ABS output is multiplied by this value to calculate the true concentration, which will then be displayed to the screen.

If you don't have a calibration factor, you will need to calibrate the instrument. This can be easily achieved by pressing the 'Recalibrate…' button. A new window will appear. It will list the steps you need to follow to calibrate the instrument (left). A check box at the bottom of the window allows you to save a calibration text file that contains the 100 uncalibrated ABS measurements that were used to calculate the new calibration factor value. You may wish to save this file for your records, but it is not required for the calibration to proceed.

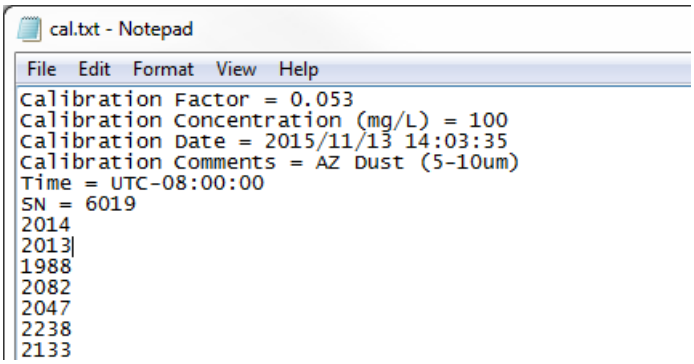
After following the calibration steps the software will begin collecting 100 measurements (If you elected to save a calibration file, you will be prompted for a location to save the file before the calibration begins).



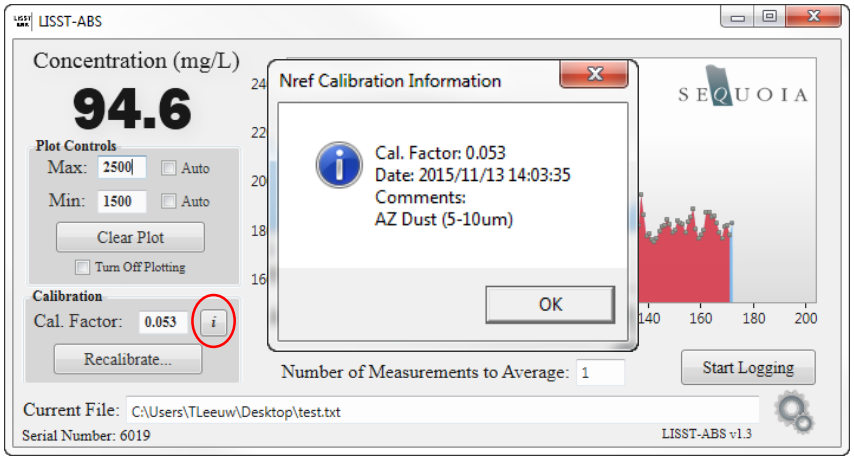
The sample number will count down from 100. Once completed, a new calibration factor will be calculated and entered into the text box. This calibration factor will be saved in the software between sessions (i.e. next time you open the software, 'Cal. Factor' from your previous session will be filled in automatically).



If you elected to save the uncalibrated ABS values, a text file will be saved at the location you specified before starting the calibration. It will contain a header with calibration information, followed by the 100 uncalibrated ABS measurements used to calculate the new calibration factor.



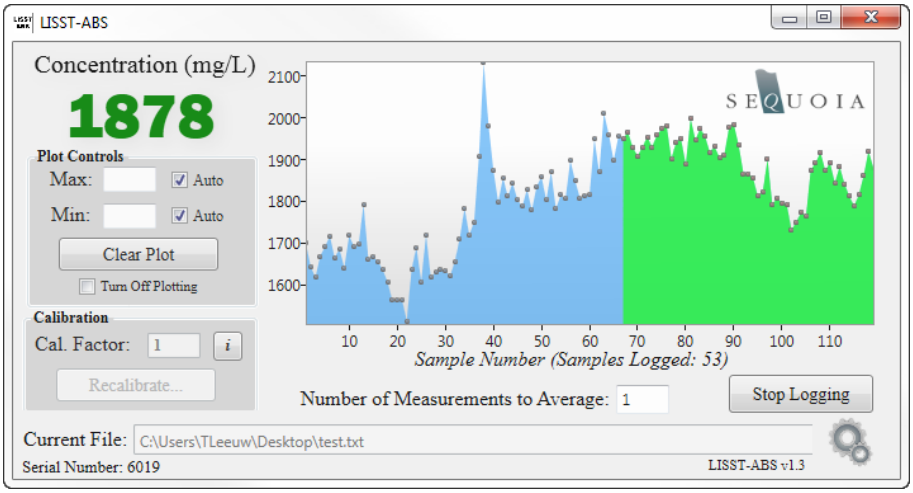
Should you need to remind yourself where a calibration factor came from, you can click the info button located next to the calibration factor textbox.



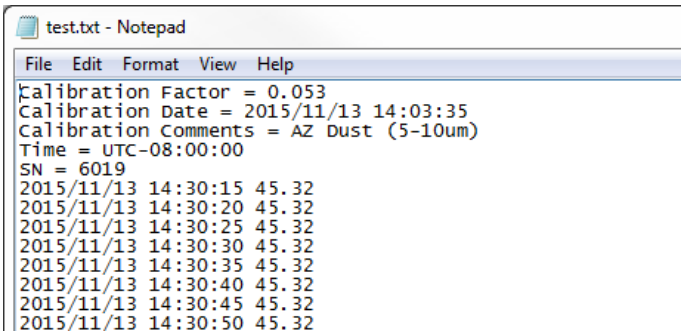
Logging

Logging is initiated by pressing the ‘Start Logging’ button. A browser will open that allows you to specify a location and name for the log file. Once that is complete, the location of the log file will be displayed at the bottom of the screen (note: the location displayed at the bottom of the screen can also be edited by hand, which is handy for incrementing file names).

After selecting a file, data logging begins immediately. The number of logged measurements is shown just below the concentration plot.



The log file header contains calibration information, the computers current time zone, and the instrument serial number. The header is followed by three columns of data: date, time, and concentration (mg/L).

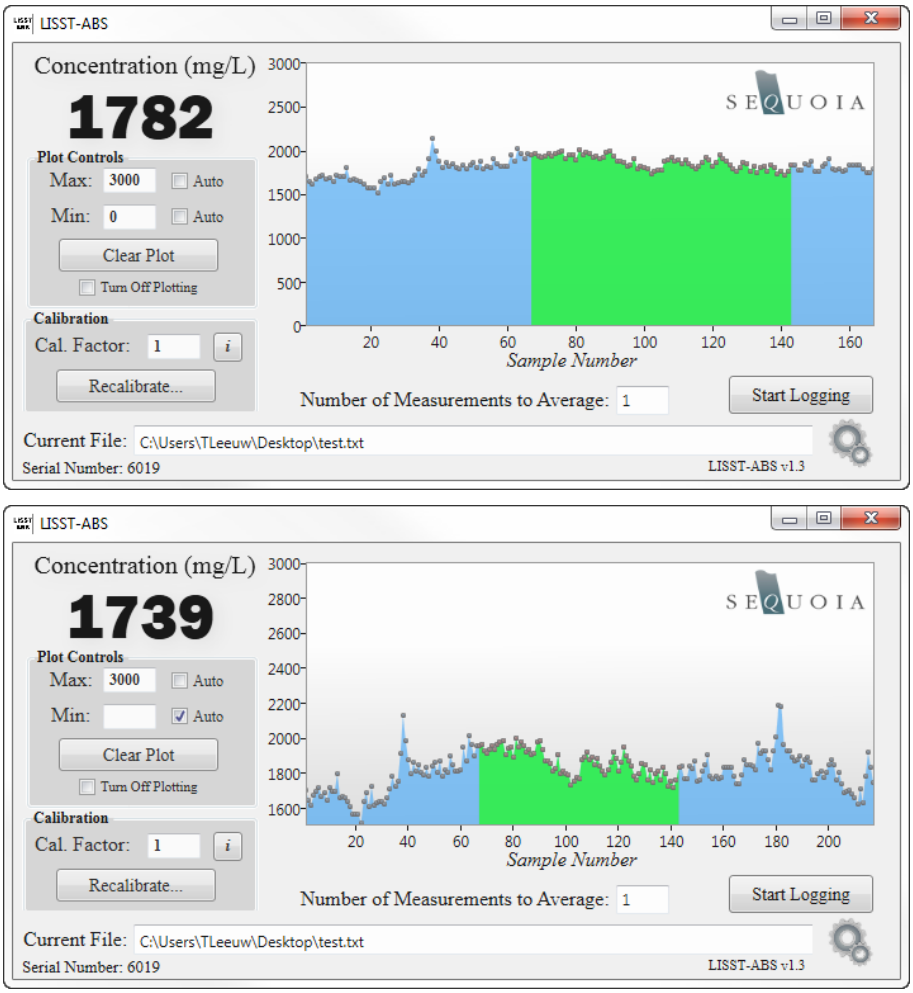


Data Plotting

The LISST-ABS software automatically plots concentration as a function of sample number.

Data shown in the plot is color coded to indicate what operation the software is preforming. If the concentration is simply being displayed with no logging or calibration being performed, data are plotted in blue. If concentration is actively being logged to a text file, data are plotted in green. If the instrument is currently being calibrated, data are plotted in red.

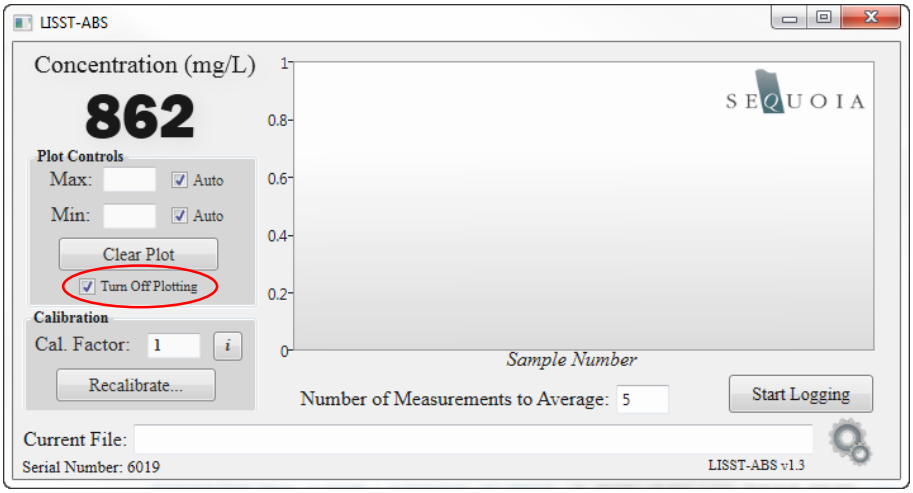
Scaling of the y-axis is handled automatically by default. However, if you wish to lock the y-axis limits at a specific value, enter a number in the text box next to ‘Min’ or ‘Max’ in the ‘Plot Controls’ box. You can switch back to auto scaling by checking the ‘Auto’ checkbox.



The data currently in the plot can be cleared by pressing the ‘Clear Plot’ button. This will only clear the display and will have no effect on data logging or calibration. If the software is left to run for a long period of time, the plot will show a maximum of 900 data points (15 minutes at a measurement average of 1). After 900 points, the x-axis will scroll, showing only the most recent 900 points.

Plotting of data can be disabled by checking the ‘Turn Off Plotting’ checkbox. This is recommended if you will be leaving the ABS unattended to log data for long periods of time. In these cases there is no need to tie up computer resources generating

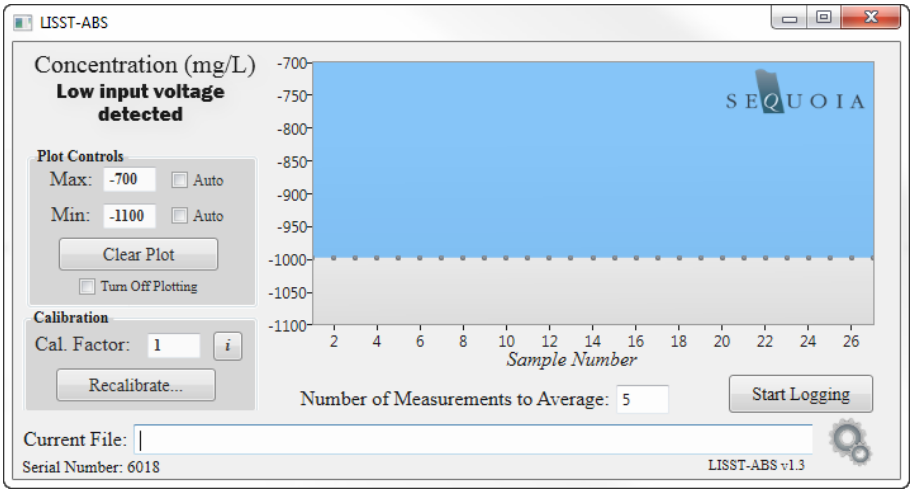
a plot that will not be viewed. To resume plotting data, simply uncheck the box.

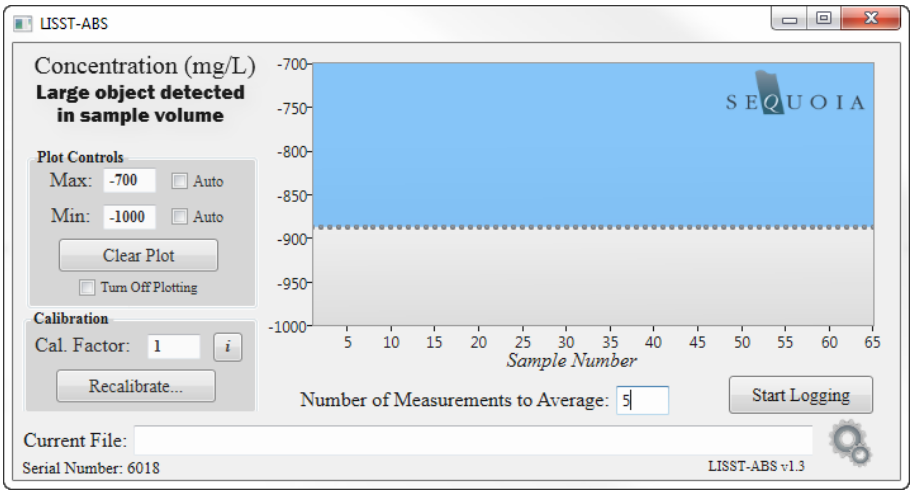


Errors/Disconnection

Should there be a power interruption or momentary disconnection, the LISST-ABS software will automatically reconnect when the power or connection is reestablished. If the disconnection occurs while logging data, the logging will pause and resume automatically when the instrument is reconnected.

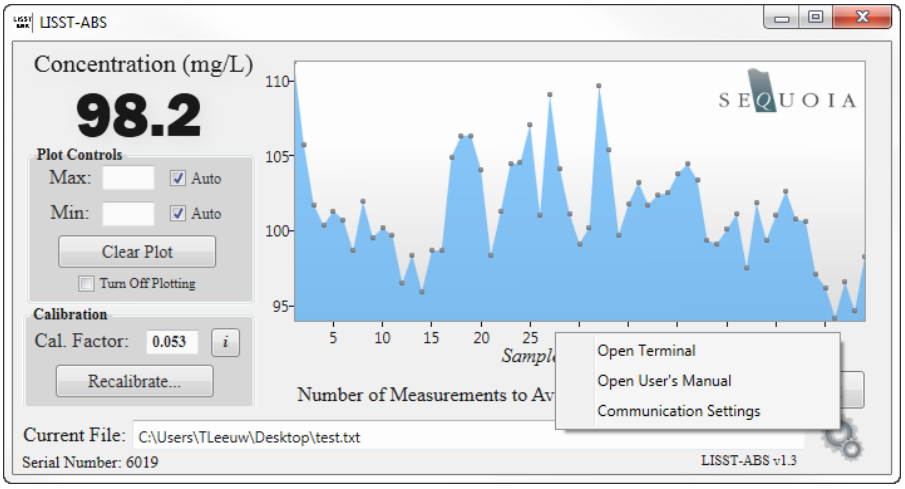
Should one of the two error codes be produced by the ABS, a brief description of the problem will be shown. A value of -999 means low power supply voltage and the instrument cannot operate. A value of -888 implies obstruction within sample volume, or the second sample volume is at a boundary (see Appendix C). In either case, this error is triggered when backscatter from the second range cell is stronger than the first.



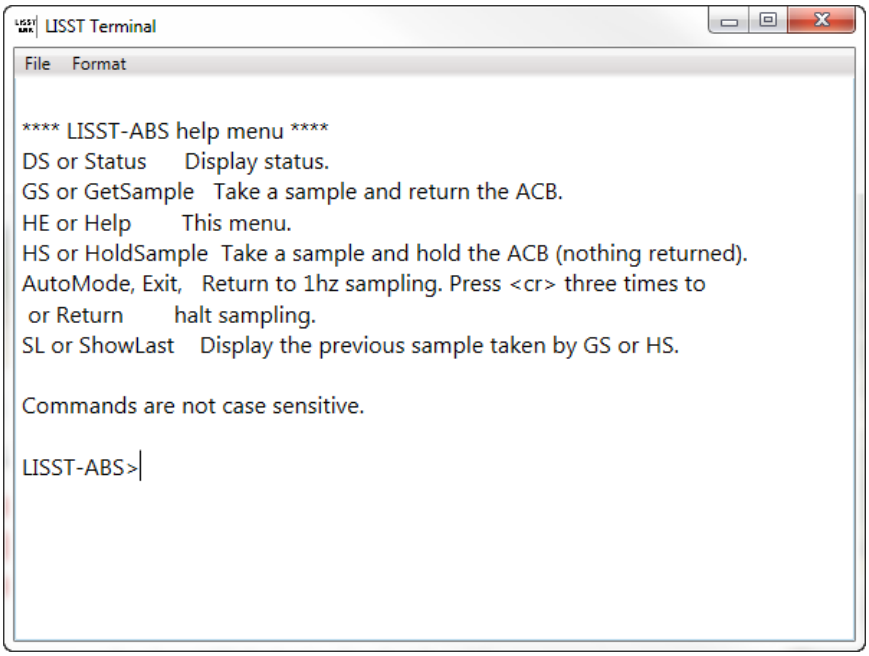


Settings/Tools

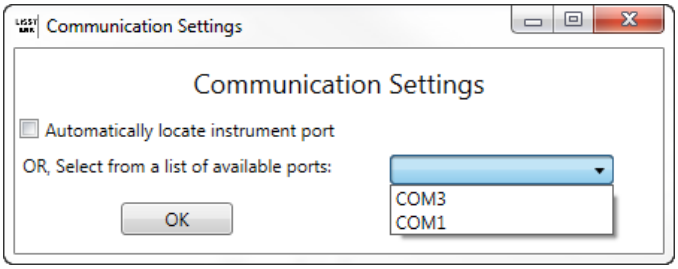
Program settings and tools can be accessed by clicking the gear icon in the lower right corner. This will provide access to a terminal window, the users manual, and communication settings.



The terminal window will allow you communicate directly with the instrument. This can be useful for retriving information about your sensor or exploring the instruments serial communication features. Text from this window can be saved to file by selecting ‘Save’ from the ‘File’ menu.



Communication Settings allows you to disable the automatic port searching feature. If you know what port your LISST-ABS is connected to, you can specify the port in this window. This can be useful if you are on a computer with many ports, or have multiple LISST-ABS's connected to one computer.



2.6 Field Deployment Suggestions

The mounting and orientation of the LISST-ABS is similar to that of optical backscatter and turbidity sensor. The suggestions below may help when determining how to mount or orientate the LISST-ABS

The LISST-ABS measures backscatter from two cells at approximately 5 and 10 cm from the sensor head. The two locations are used to measure the attenuation that is used in the internal computation of ACB.

Mounting Orientation

For reduced drag, mount the LISST-ABS horizontally facing into a flow. In this orientation, it may be placed very close to a boundary (e.g. a river bed), limited only by considerations of bed scour.

The instrument may also be mounted vertically. To avoid interference from bottom reflection, the sensor head must be at least 15 cm above the hard bottom. The computation of Uncalibrated Concentration assumes that the concentration is similar between the range cells. If there is a strong vertical gradient causing significant differences between them the Uncalibrated Concentration will not be accurate.

The sensor housing is made of plastic. DO NOT apply excessive force while mounting. The diameter of the main body is just under 2 inches. There are many different types of clamps available for this diameter.

BioFouling reduction

Biofouling can be a problem for any sensor deployed in the water. Even though the LISST-ABS is more tolerant to biofouling it is still recommended to use some anti-fouling procedures to reduce the chance of fouling effecting the measurements.

Do not apply anti-fouling paint directly to the transducer face as it will affect the instrument performance.

Appendix A: LISST-ABS Cable Wiring and Connector Pinouts

This appendix details the configuration of the LISST-ABS connectors and cables so that it can be connected to the dataloggers. We will start at connector on the LISST-ABS and work toward the end of the long cable.

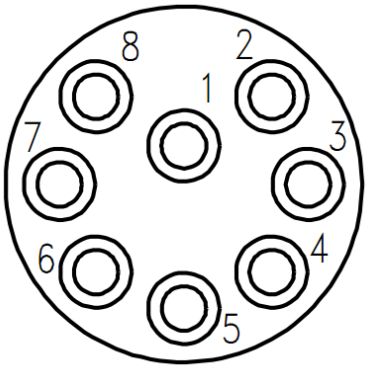
Details of Underwater connector on LISST-ABS

The endcap connector on the LISST-ABS is an Impulse MCBH8-M-P, wired as shown below. Mating connector is MCIL8-F-S.

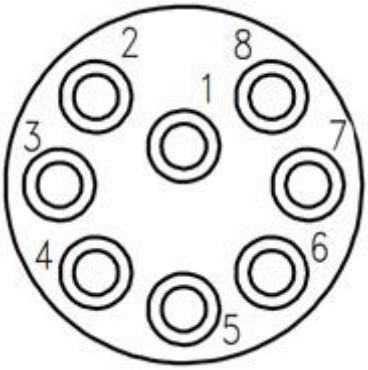
1. Common
2. Supply voltage, 10 to 18 V
3. Common
4. RS232 transmit
5. RS232 receive
6. SDI-12 input/output
7. Analog output
8. Common

The Common pins are interchangeable and connected to each other inside the ABS.

Bulkhead Connector numbering

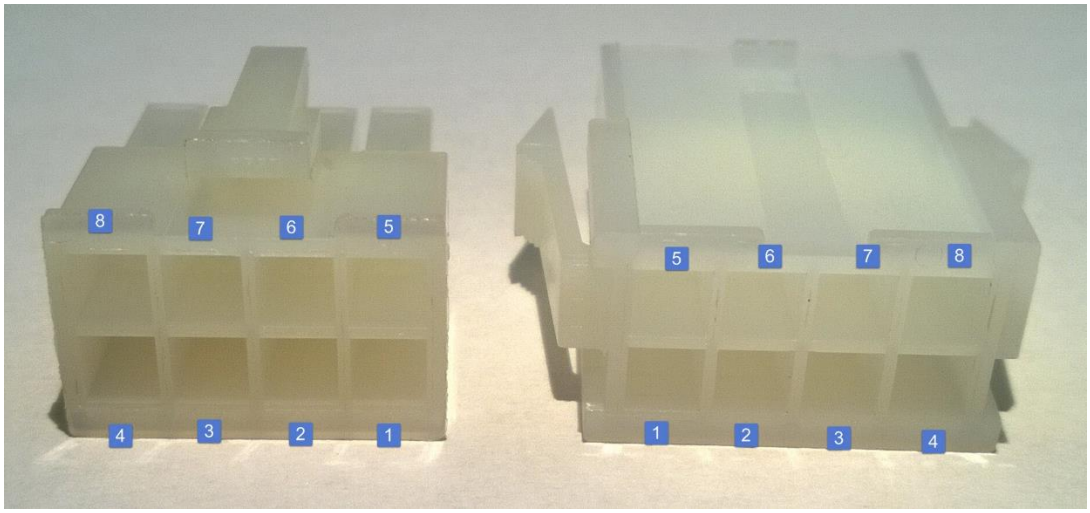


Cable Connector Numbering



Sequoia offers cables for the LISST-ABS in lengths from 5 to 50 meters. These cables include an underwater connector is spliced to a longer cable which is terminated with a white plastic Molex connector. When purchasing the long cable multiple mating cables are provided for different datalogger connections. There are pigtail ends for SDI-12 connections, RS232 connections, Analog Output connections, and a USB Cable for use with a PC. The table below shows the details of the wiring of the different cables.

MCBH8M on ABS			Sequoia long cable	RS232 pigtail	SDI-12 pigtail	Analog pigtail
Pin	**Function**	**Wire color**	**Wire color**	**Wire color**	**Wire color**	**Wire color**
1	Common	Black	White	Black	Black	Black
2	V+ (10 to 18V)	White	Red	Red	Red	Red
3	Common	Red	-	-	-	-
4	RS232 transmit	Green	Yellow	Yellow	-	-
5	RS232 receive	Blue	Blue	Blue	-	-
6	SDI-12 data	Grey	Black	-	Green	-
7	Analog out	Yellow	Green	-	-	Green
8	Common	Orange	shield	-	-	White



The long cable is terminated with a Molex Mini-Fit Jr Female connector (Molex # 0039012081 with Molex # 0039000431 pins). The mating pigtail cables use a male connector with a latch (Molex 0039012080 with Molex #0039000073 sockets). Both connector have labels for the pin numbering molded into the plastic body of the connector. The pin number is also shown above.

Appendix B: Converting Uncalibrated Concentration to Concentration

Formula The relationship between Uncalibrated Concentration (C_u) and suspended concentration (C) is

$$C = Cu * Cal\ Factor$$

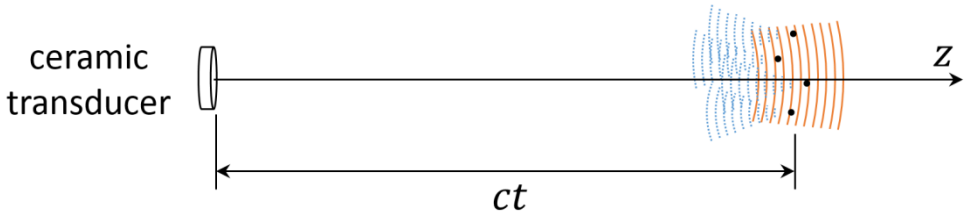
Where CalConst is characteristic of a sediment size and type. All LISST-ABS instruments are calibrated using glass spheres between 63 and 90 microns. They are configured so that Cal Const = 1 for these particles. This makes all LISST-ABS sensor interchangeable.

Note that Cal Factor is the only variable that changes upon recalibration.

Recalibration Recalibration of the sensor for different size or types of particles involves finding a new value for Cal Factor. Recalibration can be done by using the provided Windows software. You will need to prepare a known concentration of your suspension, in a very well-mixed chamber. Insert the instrument, apply power. The instrument displays Uncalibrated Concentration at the previously held value of Cal Factor. At any time, Press the Recalibrate button and follow instructions. At the end of about a minute, the software computes the new Cal Factor and loads it into the designated box. The measurements that follow use this value of Cal Factor to convert Uncalibrated Concentration to Concentration in mg/L. *This value is not saved on the instrument*. It is only used in the Windows software. Record this value in your notes for future reference. For detailed instructions on using the LISST-ABS software see Section 2.5.

Appendix C: How the LISST-ABS works

Basics The LISST-Acoustic Backscatter Sensor, LISST-ABS operates in a manner similar to radar. A short pulse of high-frequency sound is transmitted by a ceramic transducer (see Figure).



The pulse travels outward, and its location at any time is at a distance equal to the product of speed of sound in water *c*, and time *t* after transmission, *ct*. Particles in the pulse (called 'cell', 'range cell', ' range bin', or 'sample volume') scatter sound in all directions. Some of this sound travels backward toward the transducer. This scattered sound takes the same amount of time *t* to reach back to the transmitter. This is the backscatter signal. The total time for this signal out and back is 2*t*. Thus the signal sensed at time *2t* after pulse transmission corresponds to scattering from a range cell a distance *ct* from the transmitter. This is the essence of acoustic backscatter. The strength of the backscatter pressure P at the transducer from a range R = *ct* is related to the outgoing pressure pulse P_o, the geometric spreading G(R), and attenuation by the combination of water and sediments. It is helpful now to consider the signal via the sonar equation:

$$\log_{10}[P/P_o] = -G(R) - 2[\alpha_w + \alpha_s]R + \log_{10}(\sigma) + N(R) \qquad (1)$$

This equation shows the weakening of the signal due to geometric spreading G(R), attenuation by absorption by water (α_w) and sediment (α_s), and a noise floor N(R). The signal of interest is the scattering by particles, σ. The LISST-ABS actually measures the backscatter signal from two range cells located at ct_1 and ct_2 from the transducer, so that it can compensate for attenuation by particles in water. To understand, consider the difference of two signals such as above, but with assumption of equal concentration. By difference, we have:

$$\log_{10}[P_1] - \log_{10}[P_2] = [-\Delta G(R) - 2\alpha_w \Delta R] - \alpha_s \Delta R \qquad (2)$$

This shows that the difference in signals from two range bins is equal to the geometric spreading factor, and attenuation. The attenuation term is usually very small for LISST-ABS until sediment concentration becomes high, >1g/L. [we ignore noise floor, it is small]. Thus the two-point backscatter determines the quantity in square bracket. Any increase in the difference determines water attenuation term.

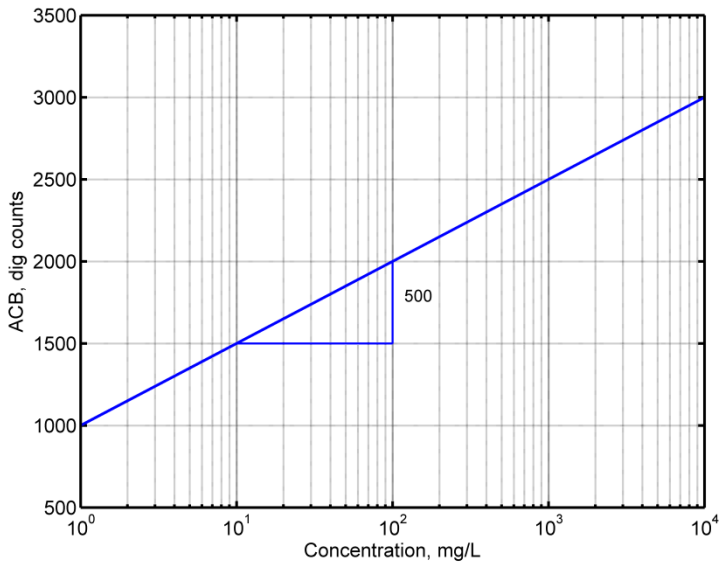
Knowing the terms in Eq.(2), we simply project the measurement to a small distance from the transducer, i.e. at R ~0 in Eq.(1), yielding the concentration term $\log_{10}(\sigma)$. With a little more arithmetic, that is ACB.

In short, the combined geometrical and water attenuation are measured once and are fixed. [Temperature related changes in α_w are small and applied subsequently.] The sediment attenuation is measured by the change in the difference between two range cells. And then, the measurement is projected to the transducer to get ACB which is then converted to Uncalibrated Concentration.

This is a simplified explanation. The precise description of the computations is to be published separately. Here, we simply note that near-field effect has been considered.

Recalibration

The relationship between ACB and sediment concentration is shown in the figure below for 5-10 micron AC dust. Note that this is a log-linear relationship. ACB counts depend on $\log_{10}(C)$. The slope of the calibration line K_o is fixed by electronics. The offset at 1mg/L (where $\log_{10}(1) = 0$) is called N_{ref}.. For all instruments, N_{ref} =1000.



A change in sediment grain-size or other properties does not change K_o. Only N_{ref} is recalibrated, so that all sediment calibration lines are parallel. To find the new calibration factor, we recommend using our provided Windows software. Prepare a mixture in a well-mixed chamber [Use of Sequoia's mixing chamber is strongly recommended]. Insert the instrument tip at the surface. Be sure to leave 15 cm gap between sensor and chamber bottom. Press the Recalibrate button. After completion in ~1 minutes, a new value will appear.

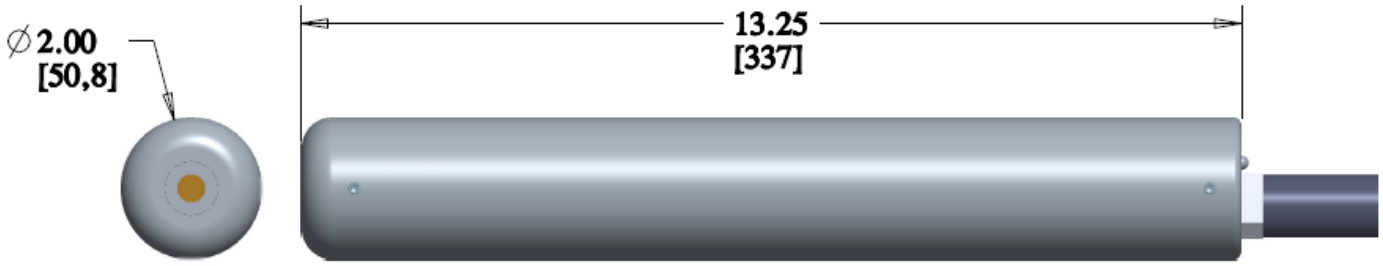
Specifications:

Technical:

- Acoustic Frequency: 8 MHz
- Sample Volume: 10 dia x 15 L (mm) (located 5.5 cm in front of sensor)
- Outputs:
  - 0-5 V analog
  - SDI-12
  - RS-232
- Range: 1 mg/L to 70 g/L (7 μm) or <50 g/L (200 μm sand)
- Calibration: Recommended with *in-situ* samples

Mechanical and Electrical:

- Sensor Dia.: 2.00 in (5.08 cm)
- Length: 13.25 in (33.65 cm)
- Weight: 1 lb. (0.5 Kg) in air;
  0.5 lb. (0.22Kg) buoyant in water.
- Transducer: 10mm dia, ceramic
- External supply : 10-18 Vdc
- Current drain: 100 mA
- Max. Depth: 100 m (check with factory for deeper rating)
- Material: ABS Plastic
- Connector: Impulse MCBH-8- MP-SS
- Power on LED: Green, blink on update
- Sample update rate: 1Hz [average of 1000 measurements(pings)]



Warranty

STATEMENT OF LIMITED WARRANTY AND LIABILITY

This Statement of Limited Warranty applies to all Sequoia Scientific, Inc. (“SEQUOIA”) products ("Products"). Any additional or different terms, including any terms in any purchase order, will be of no effect unless agreed to in writing by an authorized representative of SEQUOIA as reflected in a written SEQUOIA quotation.

1. Limited Warranty

SEQUOIA warrants that upon delivery by SEQUOIA (a) the Products will be free from defects in materials and workmanship, (b) the Products will perform substantially in accordance with SEQUOIA's applicable specifications, and (c) any Products (or components or parts thereof) that are manufactured by SEQUOIA do not infringe any U.S. patent or copyright.

2. Correction of Non-Compliance

If, during the twenty-four months after installation, or thirty months after delivery, whichever comes first (the “Warranty Period”), any Product does not comply with the warranties set forth in 1(a) and 1(b) above, SEQUOIA will, at its option, either (a) repair the Product, (b) replace the Product, or (c) refund the purchase price paid by Customer to SEQUOIA for the Product; provided that Customer gives SEQUOIA written notice of the noncompliance within the Warranty Period and ships the Product to SEQUOIA within one month after the end of the Warranty Period. As to any Product repaired or replaced by SEQUOIA, the Warranty Period will end upon the later of the end of the original Warranty Period or 90 days after SEQUOIA's delivery of the repaired or replacement Product to Customer. Any Product, component, part or other item replaced by SEQUOIA becomes the property of SEQUOIA. SEQUOIA may use refurbished components in the repair of Products supplied hereunder.

SEQUOIA's warranties shall be void and not apply if the Product has been subjected to misuse or alteration or repaired by a party not approved by SEQUOIA or the serial number on a product (if applicable) has been altered or defaced. SEQUOIA shall not be liable for normal wear and tear (such as replacement of consumables), nor for defects or failure caused by maintenance, misuse, negligence or failure resulting from non-compliance with SEQUOIA’s specifications, operating or maintenance manuals.

3. Infringement Indemnification

If any Product does not comply with the warranty set forth in 1(c) above, SEQUOIA will defend and indemnify Customer against any third-party claim asserted in any proceeding against Customer based on this noncompliance; provided that Customer gives SEQUOIA prompt written notice of the claim, SEQUOIA has exclusive control over the defense and settlement of the claim, Customer provides such assistance as SEQUOIA may request in connection with the defense and settlement of the claim (in which event SEQUOIA will reimburse the reasonable out-of-pocket costs incurred by Customer to provide such assistance), Customer does not settle the claim without the prior written consent of SEQUOIA and, upon SEQUOIA's request, Customer returns the Non-Complying Product to SEQUOIA for modification, replacement or a refund of the purchase price paid by Customer to SEQUOIA for the Non-Complying Product, less a reasonable allowance for Customer's use prior to return.

4. Exclusive Warranties

THE WARRANTIES SET FORTH IN PARAGRAPH 1 ABOVE ARE EXCLUSIVE AND IN LIEU OF ALL OTHER

WARRANTIES, EXPRESS OR IMPLIED. SEQUOIA DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS OR IMPLIED (INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, AND ANY IMPLIED WARRANTY ARISING FROM COURSE OF PERFORMANCE, COURSE OF DEALING, OR USAGE OF TRADE) OTHER THAN THOSE SPECIFICALLY SET FORTH IN PARAGRAPH 1.

5. Exclusive Remedies

CUSTOMER'S RIGHTS AND REMEDIES SET FORTH IN PARAGRAPHS 2 AND 3 ABOVE ARE EXCLUSIVE AND IN LIEU OF ANY AND ALL OTHER RIGHTS AND REMEDIES FOR ANY BREACH OF OR OTHER FAILURE TO COMPLY WITH ANY WARRANTY WITH REGARD TO ANY PRODUCT.

6. No Consequential Damages

SEQUOIA will not be liable for any indirect, incidental, special or consequential damages, any cover, or any loss of revenue, profit, data or use.

7. Limitations of Liability

SEQUOIA's liability (whether in contract, tort, or otherwise; and notwithstanding any fault, negligence, strict liability or product liability) with regard to any Product (including, but not limited to, any breach of or default by SEQUOIA) will in no event exceed the purchase price paid by Customer to SEQUOIA for such Product. Further, SEQUOIA will not be liable for, or be in breach of or default on account of, any delay or failure to perform as a result of any cause, condition or circumstance beyond SEQUOIA's reasonable control.

8. Indemnification by Customer

Customer acknowledges that the Products are designed and manufactured for use in non-critical, monitoring situations. If Customer chooses to purchase a Product or Products for use in applications that could result in damages in excess of the price of the Product if the Product does not operate properly or otherwise fails, Customer acknowledges and agrees that it is Customer's responsibility to provide for redundancy and/or other safety or back-up measures sufficient to assure that failure of a Product(s) will not cause such damages. Customer agrees that it will defend and hold SEQUOIA harmless from any and all claims and costs (including but not limited to attorney's fees and other costs of defense against such claims) in excess of the price of the Products arising directly or indirectly from such Customer's use of the Products. Such indemnification is a critical part of the consideration being provided by Customer (over and above the price paid for the Product(s)) for the right to use the Products for such purposes and Customer shall not use a Product or Products for such purposes if it is unwilling or unable to provide such indemnification.

9. Statute of Limitations

Customer will not commence any action based on breach of warranty with respect to any Product more than 30 months after SEQUOIA's delivery of such Product.

10. Software

The Products may include or be delivered with certain computer programs, databases or other software that is proprietary to SEQUOIA. SEQUOIA hereby grants Customer a nonexclusive license to use such software solely for the purpose of operating Products. Customer will not: use any such software for any other purpose; modify, adapt, translate, or create derivative works based on any such software; or disassemble, decompile or reverse engineer any such software. No title to or ownership of any software or intellectual property rights are transferred to Customer.

11. U.S. Government Restricted Rights Notice

All software, data, technical information, and written materials provided by SEQUOIA are provided with restricted rights. Use,

duplication, or disclosure by the government is subject to restrictions as set forth in subparagraph (c)(1)(ii) of the Rights in Technical Data and Computer Software clause at 48 C.F.R. § 252.227-7013 or in subparagraph (c)(2) of the Commercial Computer Software-Restricted Rights clause at 48 C.F.R. § 52.227-19, as applicable. Portions of these items may be unpublished. SEQUOIA reserves all rights under applicable copyright laws.

12. Controlling Document

In the event of any conflict or inconsistency between any provision of this Statement of Limited Warranty and any other provision of the Order, the provision of this Statement of Limited Warranty will control.

13. Controlling Law

This Statement of Limited Warranty will be governed by the laws of the State of Washington without reference to its rules relating to choice of law for the purpose of applying another jurisdiction's law. The U.N. Convention on Contracts for the International Sale of Goods will not apply.