# Acoustic Measurement System (AMS)

# Version 3.8.2

# User's Manual

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Users are assumed to have a good working technical knowledge of ultrasonic systems, probes and the principles of acoustic power and intensity measurements. Users will be responsible for reading and following the instructions provided. Users will also be responsible for exercising all safety precautions recommended. If you have any questions, please call us at 303-834-8413. The ultimate accuracy of acoustic measurements made with the AMS system is the responsibility of the user.

# Safety Warnings

1. Do not operate if any liquid has been spilled into the motor driver. Call Acertara Acoustic Laboratories at 303.834.8413 to arrange for servicing.

2. Shock Hazard – Motors are not hot-swappable. Do not connect or disconnect any power cables in the motor/encoder system while the power supply is plugged in

3. Do not position the equipment so that it is difficult to operate the emergency stop switch and/or remove the power cord.

4. The protection provided by the equipment may be impaired if used in a manner not specified herein.

# Product Description

The Acertara Acoustic Measurement System (AMS) shown in the figure below, is a test system consisting of hardware and software designed to measure the acoustic energy emitted by diagnostic and therapeutic ultrasound devices.   The test system utilizes a three axis servo motor control to position the hydrophone relative to the device under test (acoustic source).  The tank has hydrophone mounts designed to support both bi-laminar membrane and needle hydrophones. The hydrophone output is sampled and digitized by a digital oscilloscope.  Both the oscilloscope and the motion controller are interfaced to the AMS software via an ethernet network connection.

The system software is written in the Python programming language. Source code may be purchased if desired, and custom modifications may be possible upon discussion with Acertara. The software runs on "PC" type computers running Windows 10.   It is specifically designed to conveniently make the measurements required by U.S. and International measurement standards. Functions include probe alignment, "Z-Scan" searches for determining the spatial peak location, waveform captures, and orthogonal beam plots and raster scans to generate two-dimensional beam plots for determination of total power. Auxiliary programs have also been created to provide convenient generation of data plots as well as generation of data summaries for convenient post-processing.

The software logo is derived from a freely-distributed graphic for which attribution is required: created by rawpixel.com - www.freepik.com.

# Software Revisions

## Changes in Version 3.8.2

Features
- Added the option to user_config.txt to set a maximum size for images included in exposure reports ('exposure_max_im_dim = 1000  # max pixels in 1 direction')
- Added Ispta.0 display to the finished waveform screen

Bug Fixes
- Fixed finished waveform screen metadata when the Channel 2 signal is captured at the same time as the Channel 1 signal.
- Fixed usage of Report number in the exposure report generator (select software versions)

## Changes in Version 3.8.1

Features
- Added support for Tektronix MDO32 series scope
- Added a command-line tool for MI/TI calculation (not distributed by default)
- Added a power factor estimator to the cross-axis scan analysis (can be used in cases where there is cylindrical symmetry though raster-scan derived power factors are recommended throughout)

Bug Fixes
- Fixed the order of Pa,zs and Ispta3,zs and Pa,zb and Ispta3,zb in the spreadsheet summarizer

## Changes in Version 3.8.0

Features
- Added a guided exposure routine (including support for auto-generated reports)
- Added a warning that the secondary hydrophone is selected prior to starting a script acquisition

Bug Fixes
- Fixed a bug in multiple-TP reporting with different apertures that could affect TIC and TIS

## Changes in Version 3.7.1

Features

- Added support for using <Enter> to close the results modal (rather than having to click
- Added support for Omega HH376 thermistor

Bug Fixes
- None

# Changes in Version 3.7.0

Features
- Added plot of combined z-scan to analyze output, saves a new combined z-scan file during analysis or reporting
- Allow an alternate path to assign the output directory (if `alternate_path = True` in config.txt)
- Added a saved 'summary plot' when script execution is complete

Bug Fixes
- Fixed case where $z_{s,ns}$ depth was incorrectly assigned for some non-scanning transmit profiles
- Fixed bug where some special characters in the device serial number could break the program
- Fixed incorrect unit in the metadata in z-scan plots
- Fixed case where spacebar was disabled when it shouldn't be

# Changes in Version 3.6.0

Features
- Added option to input externally-calculated or measured power into physiotherapy results
- Added a method to capture the current waveform on the oscilloscope (without the normal autoscaling and waiting for stability)
- Added a script summary figure to the express script (non-standard feature)
- Cleaned up GUI somewhat, added a keyboard shortcut to release and re-capture the motors, changed the alignment logic slightly to be more user-friendly

Bug Fixes
- Suppress plotting the $z_b$ waveform if it is not used in the calculations (reporter, sub-set of users)
- Corrected the units of the frequency spectrum so that it properly reflects the power spectral density (previously it reflected the pressure spectral density)
- Through config flag $scope\_force\_save\_raw\_no\_fc = False$, the software will now, by default, not save waveforms for which the spectrum was not resolved. (Old behavior can be obtained by turning this flag to 'True'.)

- Changed the footer so that clicks of, e.g., 'Move motors' are not 'missed'

# Changes in Version 3.5.0

Features
- Add environmental monitor (ambient temperature and humidity) support
- Clean up of some GUI and output file elements
- Added better handling of default hydrophone (replace config.txt entry 'primaryhyd_default = <index of default>' with 'primaryhyd_default_name = <some part of the hydrophone calibration file name, e.g. 'S5-186'>'; do the same with secondaryhyd_default →secondaryhyd_default_name
- Added the ability to override the calculated power (e.g., with the power from a radiation force balance) for diagnostic reports and not require a raster scan. (in config.txt, add: 'calc_manual_Ps = True')
- Added the ability to log cross checks between a primary and secondary hydrophone to an output file. (in config.txt, add: 'crosscheck_log = <path to overall log>')

Bug fixes
- Clean up reporter (sub-set of users): fix duplicative warnings; clean up automated emails; remove $z_b$ waveform from appendix if unused
- Clean up frequency spectrum analysis for some waveforms with high DC component
- Changed how the active hydrophone is switched to avoid a case where the change hydrophone button on the GUI could lose sync with the program if it was clicked while the software was in a blocking state

# Changes in Version 3.4.0

Features
- Improved alerts during various processes (eg. near-field raster, avoid duplication of 'waiting for trigger' alert)
- Changed handling of the initial hydrophone position (defaults to 'current location')
- Added ability to change motor orientation in the 'move motors' screen

Bug fixes
- Fixed Ispta.0 and Ispta.3 in CW waveforms when a delay is applied (PII.0 and PII.3 were always correct)
- Fixed raster scan plot template to keep contents on a single page
- Improved motor stability, upgraded gclib to latest version from motor controller supplier
- Fixed bug on loading probe templates

# Changes in Version 3.3.0

Features
- Built a new web server to increase stability, reduce browser refreshing
- Added functionality to the remote control channel (scope statistics)
- Added support for automated probe alignment (hardware required)
- Added a new pdf output for IEC 60601-2-37 Table 201.103 (supersedes previous method that required MS Excel)

Bug fixes
- Fixed a bug whereby scope could get stuck collecting noisy data without an appropriate timeout

# Changes in Version 3.2.6.1

Bug fixes
- Fixed a bug in the report generator (some versions, only) where the TIB for combined modes was not calculated correctly for autoscan/non-autoscan modes
- Fixed a bug where the fine z-scan forced searching regardless of whether or not box was checked by user

# Changes in Version 3.2.6

Features
- Added support for Keysight DSO-X oscilloscopes
- Added support for Track 1 FDA results tabulation (add-on feature)
- Add number of averages to waveform capture metadata
- Added option to disable motors during scope acquisition for small signals to reduce the effects of electrical noise (config.txt→ $scope\_motoroff\_voltage\_level = 0.002$)
- Added ability to run a script to automatically move through a standard acquisition based on acceptance criteria (add-on feature)

Bug fixes
- Fixed a bug in the physiotherapy z-scan whereby certain conditions could return an error
- Fixed a bug where the motors would remain disabled if the 'move motors' screen was left with the motors in a disabled state

# Changes in Version 3.2.5

Features

- Added (optional) report generation tools (add-on feature, contact Acertara for details if not equipped)
- Added the option of using torque stops in addition to/instead of limit switches
- Increased the options for plotting
- Major refactor of motor operation (back end changes)
- Added (optional) remote control interface (see dedicated section)

Bug fixes
- Fixed a bug with the center-of-mass autosearch

# Changes in Version 3.2.4.2

Features
- None.

Bug fixes
- Changed 'y' to 'θ' for cylindrical raster scans when config parameter: plot_pars_2d_rst_theta_not_y = True

# Changes in Version 3.2.4.1

Features
- Releases motors on 'Exit'.

Bug fixes
- Fixed issue preventing cylindrical raster scans from working.
- Use nominal center frequency if the reset f_c box is clicked on the first waveform screen

# Changes in Version 3.2.4

Features
- Added interactive tool to physiotherapy z-scan: option to change the smoothing kernel and set bounds on the $z_n$ depth
- Added flexibility to job naming convention: config: jobdatespecifier
- Added automated log file purge: config: logPurgeDays
- Added A_BCS to plotted raster scans, where applicable
- Added physiotherapy Fac parameter to log file (defaults to 1.333 per IEC 61689)
- Added zscan lower limit variable to user_config: plot_pars_zscan_db_lower

Bug fixes

- Introduced threshold to prevent plotting very large rasters (resulting in memory overflow): config: rst_n_plot_lim
- Fixed R&D tool table rendering issue
- Physiotherapy summary file reported power in the wrong units. This has been corrected.

## Changes in Version 3.2.3

Features
- Changed config and user_config behavior. See section in manual
- Added support for alternate file output (xlsx, csv) and added support for simple plots (pdfs only, no additional information on image)
- Added ability to add comments to collected data
- Added xz and yz raster scans as an R&D function

Bug fixes
- Fixed bug whereby analysis tool would crash if it expected CW data and received pulsed data, and vice versa

## Changes in Version 3.2.2

Features
- Added more editable plotting parameters to user_config.py
- Waveform files now store peak compressional pressure in addition to peak negative pressure

Bug fixes
- Fixed and error whereby continuous wave data caused a problem with the summarized power reporting
- Fixed a problem when summarizer didn't find an appropriate raster scan and would crash

## Changes in Version 3.2.1

Features
- Made motor jogging smoother and more intuitive
- Automatically preserve temporary files should LaTeX file creation fail

Bug fixes
- Cross-axis scan real-time plotting excluded the points on the y-axis if the simulation mode was not used simultaneously

# Changes in Version 3.2.0

Features
- Added a physiotherapy page to collect data and make calculations per IEC 60601-2-5 and IEC 61689
- Added 2 additional autosearch methods: center of mass and RMS-based
    - RMS is faster than previous
    - Center of mass is less sensitive to fields where the peak is not well-defined
- Overhauled probe management and added a new feature whereby probe templates can be saved and loaded readily
- Added features so that end user can specify plot colors

Bug fixes
- 404 error was slowing down rendering of pages when computer was disconnected from the internet. This was fixed in the python web server
- Changed initialization order so that thermistor information is properly logged

# Changes in Version 3.1.0

Features
- Added support for a stack of rasters scans as an R&D command, with or without cross-axis scans

Bug fixes
- Fixed problem in cross-axis scan extent when initial position is far from x=0 or y=0
- Fixed how the statistics spreadsheet tab calculated means, standard deviations
- Fixed how the pressure was derated in one place (10 log vs 20 log)

# Changes in Version 3.0.3

- Added detailed description of hydrophone data file format requirements.

# Changes in Version 3.0.2

- Added description of initial setup screens, emergency stop function, and move motors screen.

# Changes in Version 3.0.1

- Software updated to include new plot and table generation options. Numerous stability fixes.

# Changes in Version 3.0.0b

- The "b" release denotes modifications to support a fourth servo motor to rotate the source during measurement. This axis is labelled Axis D in the hardware, and denoted in the software by θ.

# Software Installation and Configuration

The following sections will guide you through installing and configuring the AMS system.



## AMS Software Setup

The AMS system comes with software pre-loaded. Please contact Acertara regarding software upgrades.

## Network Configuration

The AMS system connects to your computer via Ethernet.  Both the motor controller and the oscilloscope require static IP addresses.  To look up and change these addresses, please refer to the manufacturers' literature for the Galil motion control and the Tektronix oscilloscope. Record these addresses, as you will need to enter them into the AMS program in the *Software Configuration* step below. You may need to consult your network administrator to determine appropriate addresses for your network.

If you want the tank and control computer to be on a separate local area network (by connecting an Ethernet cable from the computer directly into the tank), you need to assign the computer an appropriate Class C (/24) IP address. If the scope is 192.168.99.24 and the motor controller is 192.168.99.25, a good choice for the computer is 192.168.99.26. Note that the first three terms must be the same and the final term must be on the interval 1 to 254 inclusive.

For example, the following shows the computer set for a static IP of 10.1.0.21:
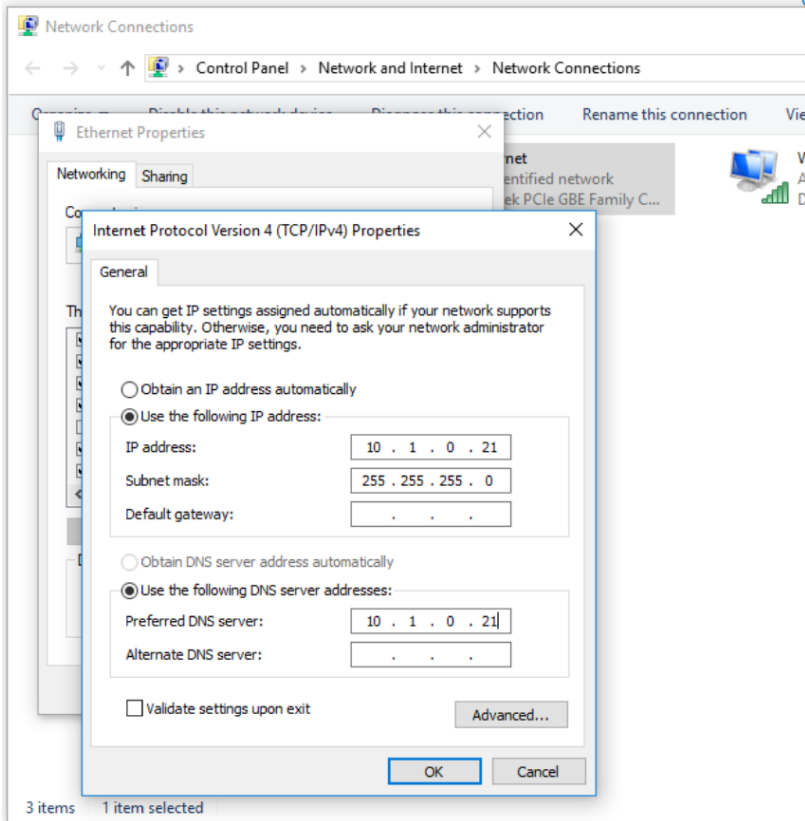


The following shows a properly-configured scope with TekVISA, with an IP of 10.1.0.27:
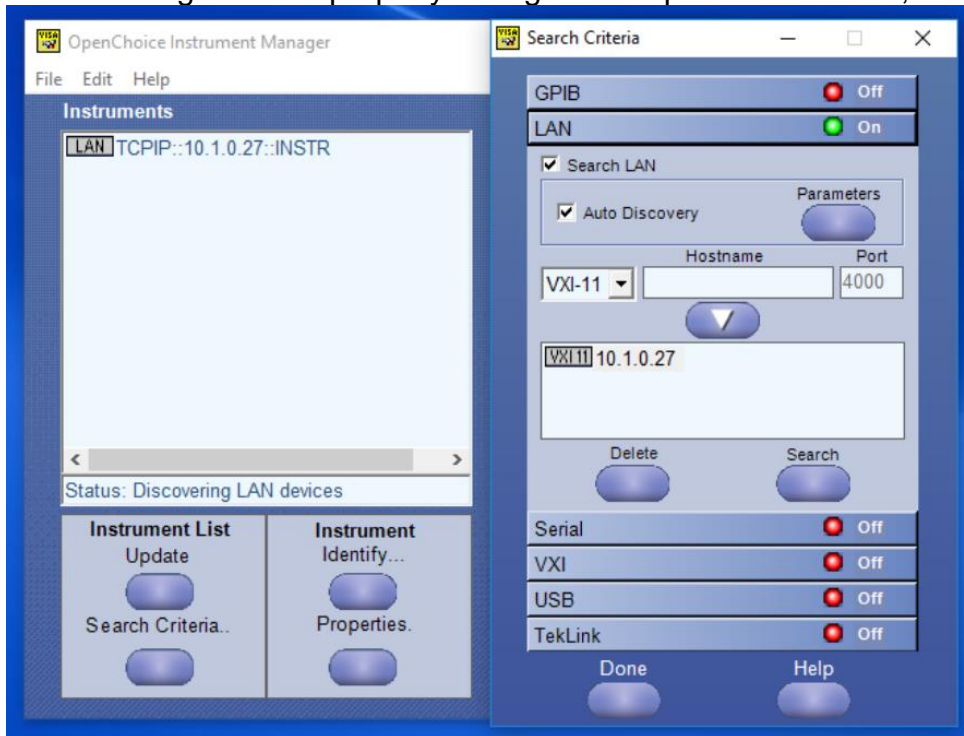
You are now ready to run the AMS software.

# Software Configuration

All user configuration parameters are stored in a pair of configuration files entitled *config.txt* and *user_config.txt*.

We recommend that you back up the original configuration files and take care when making changes. Parameters and settings that are frequently changed are at the top of the file, bracketed by lines of the '#' sign. While other parameters and settings can be changed, be aware that there are settings and combinations that may cause unexpected behavior.

*config.txt* is read once when the program is started. Accordingly, any changes will take place the next time the program is run. *user_config.txt* can be refreshed without restarting the program by clicking the 'Reload user config' button on the top ribbon of the main GUI screen.

In legacy versions of the software (pre v 3.2.3), *config.py* and *user_config.py* were used instead of these .txt variants. The software is programmed such that it should read the old configuration files and function with them, though it is recommended to move to the .txt nomenclature going forward. The beginning of the log file for each session should indicate how these files are parsed. Values after the '#' sign in [brackets] indicate the default value that will be assigned if this value is left blank or the line is omitted entirely.

# Test Setup

## Tank Preparation

The first step in tank preparation is filling it with water. Before filling verify that the "drain valve", shown in the following figure, is closed. It is recommended that de-ionized or distilled water is used. Never use "tap water" as it is always has a high concentration of gas bubbles and ions provide an electrical pathway to between the acoustic source and the hydrophone, potentially introducing noise. Use care when filling to avoid creating air bubbles. Using siphon techniques with the water outlet submerged will generally will transfer water with the minimum amount of bubble generation. Pouring or filling in any manner such that a stream of water hits the surface of the partially filled tank will generate a huge amount of gas bubbles.

In general, even the most careful filling techniques result is a significant amount of gas bubbles. Using degassed water is recommended, although de-ionized and distilled water also usually have a reduced dissolved gas concentration. High acoustic output devices should only be measured with degassed water to avoid having cavitation bubbles interfere with the measurements and possibly damaging the hydrophone. Acertara sells an optional system for water filtration and degassing. Contact Acertara for details, or see the product description online: https://www.acertaralabs.com/product-details/paratus/. Absent a degassing system, a 48 hour delay between tank filling and initial operation will allow the dissolved gas level to reach equilibrium with the surrounding atmosphere.

## Hydrophone Installation and Handling

CAUTION: Never touch the active area of any hydrophone as this will damage it. Never attempt to clean the hydrophone by touching the active area with anything!

Acertara offers hydrophone holders for membrane and needle hydrophones. Two versions of each type of holder are available: horizontal and vertical orientations for each type of hydrophone.

It is best to submerse membrane hydrophones in the measurement tank at least 30 minutes before any measurements are made. This allows any gas on the surface of the hydrophone to dissolve resulting in better measurement stability and repeatability. Some needle hydrophones trap gas near the tip and may need to be "soaked" for up to 24 hours before stable measurements can be obtained.

For membrane hydrophones, a large gas bubble can be easily trapped in the cavity on the bottom of the hydrophone formed by the case and the membrane. This is avoided by sliding the hydrophone "sideways" into the water (see photos below) and verifying that no air is trapped underneath it before attaching it to the holder. A large air bubble results in

an "air backed" configuration, which results in measurements significantly different than if no air is present.



Membrane hydrophones are attached to the holder by lifting up and rotating the "spring loaded clips" so that they overlap the surface of the case. Before installation, verify that the clips are rotated so they will not overlap the hydrophone surface (picture on left). The clips are spring loaded to hold the hydrophone in place once rotated to overlap the hydrophone case (picture on right).
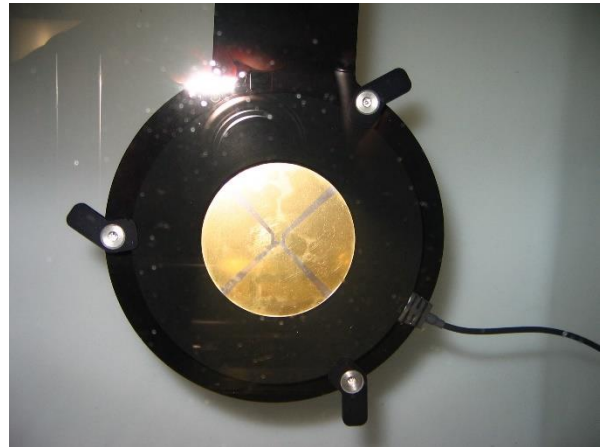


The needle hydrophones are attached by tightening a screw that "squeezes" the hydrophone holder pinching the needle hydrophone case. Two channels are provided depending on the needle hydrophone diameter. CAUTION: Do not over tighten this screw as damage to the needle hydrophone may result. Only tighten it enough so that the needle is held firmly.

Needle Hydrophones

Some tanks are sold with needle hydrophones supplied by a third party. These, in turn, are accompanied with a user manual that should be followed regarding care and handling.

In order to affix the needle hydrophone to the acoustic test tank, Acertara supplies a universal needle hydrophone holder.

To mount the needle hydrophone in the holder, the clamp is loosened with an Allen wrench and the pre-amplifier is slid into the holder as shown, below. Once the pre-amplifier is mounted and secured in the clamp by tightening the bolt, the hydrophone can be pressed gently into the pre-amplifier as shown. The holder can then be mounted to the carriage at the bottom of the vertical axis by means of a large screw (1/2" Allen wrench or finger-tightened).



The needle holder is shown below, mounted in the tank:

In order to protect hydrophones, sources, and the AMS system itself, limit switches, hard stops and software checks are employed.

**Limit switches**
There are 6 limit switches on the tank, 2 for each axis. The vertical axis has one tripped by a stop attached to the lead screw (left, below) and one tripped by an adjustable clamp on one of the rails (right, below).
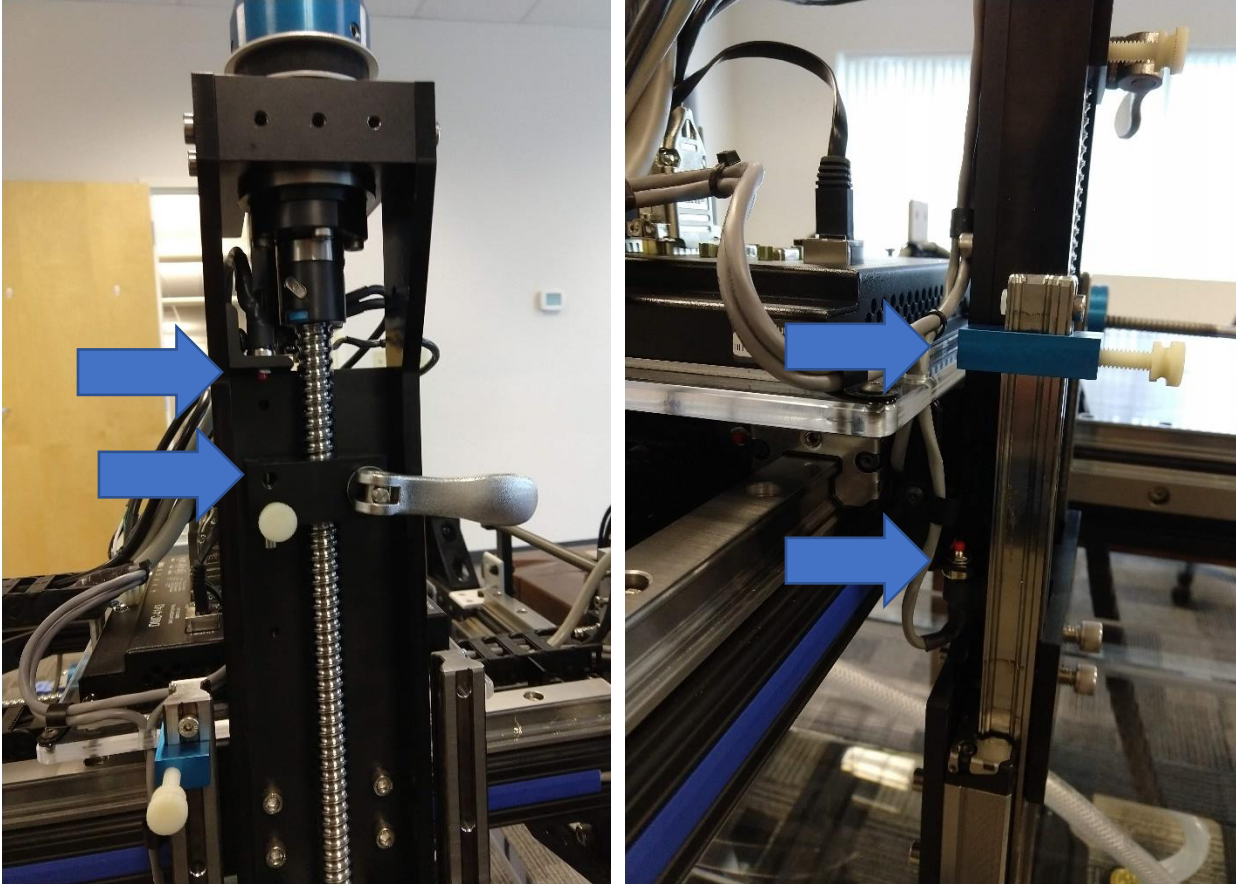


The top limit switch stop has a hole and pin that can be adjusted such that the pin extends 2 cm from the block so as to set the block exactly 2 cm from the switch, when the hydrophone is 2 cm from the source (top-down orientation). Once accomplished, the pin can be released until flush with the block by loosening and then tightening the white screw.

The other four limit switches are adjusted by moving the L-brackets along their tracks by loosening and tightening the thumb screws.

> ⚠ WARNING: Failure to use the limit switches properly dramatically increases the likelihood of collisions in the tank

In addition to the limit switches, where possible, there are hard stops to prevent the motors from driving the bearings off of their rails.

Lastly, once the motors are initialized, there is a software limit that rejects any depth with $z < z_{min}$. However, this software limit is only effective if the initial depths are set correctly. The software limit will not negate the need for limit switches.

## Mounting the Acoustic Source Under Test

In the 'b' variation of the AMS 3 tank, the standard, universal probe holder mounted to a goniometer with pitch and roll adjustments is replaced by a vertically-mounted drill chuck tethered to a fourth, rotary motor axis. The entire apparatus can be raised and lowered on a rail and is secured by a clamp. Care should be taken to avoid submerging the motor while lowering the drill chuck.

**To reduce electrical noise, the drill chuck should not be allowed to touch the water and conductive devices should be shielded from the drill chuck with some sort of sheath or simply electrical tape.**

## Oscilloscope Setup

The goal of initial oscilloscope setup is to make sure the oscilloscope is triggering from the desired source, which MUST be a signal synchronous with transmit excitation for the acoustic source. Having a transmit trigger signal—even for CW sources—is critical to making accurate measurements. The following steps assume the user is familiar with the oscilloscope function. If not, the user should thoroughly review the oscilloscope manual before making any measurements. To begin setup, the hydrophone and acoustic source must be installed (and under water) with the hydrophone positioned approximately at the focus depth of the acoustic source and centered on the source acoustic axis "by eye". The acoustic source must be transmitting. Setup the Oscilloscope with the following steps:

1. Connect the trigger source to scope channel 2 and make sure the coupling and input impedance selections are appropriate for the source.
2. View the signal on the screen and adjust the scale and time base for a reasonable display.
3. Select the scope trigger source to channel 2 and adjust the level to the desired point on the waveform.
4. Disable display of channel 2. This is usually done to make viewing of the hydrophone output voltage clearer.
5. Select the coupling and input impedance for channel 1 to appropriate values for the hydrophone being used. The input should be set to 50 Ohms for hydrophones with pre-amps and set at high impedance for hydrophones without preamps. Do not select AC coupling with an input of 50 Ohms unless there is no other option.

Doing so can compromise the low frequency response of the measurement. The software now sets the impedance based on the hydrophone data file.

6. Connect the hydrophone output to channel 1 and modify the scale to be sensitive to small signals.

## Motor setup

The motors do not require any special setup, other than ensuring that they are powered by plugging in the power supply.

The motors are equipped with an emergency stop button:
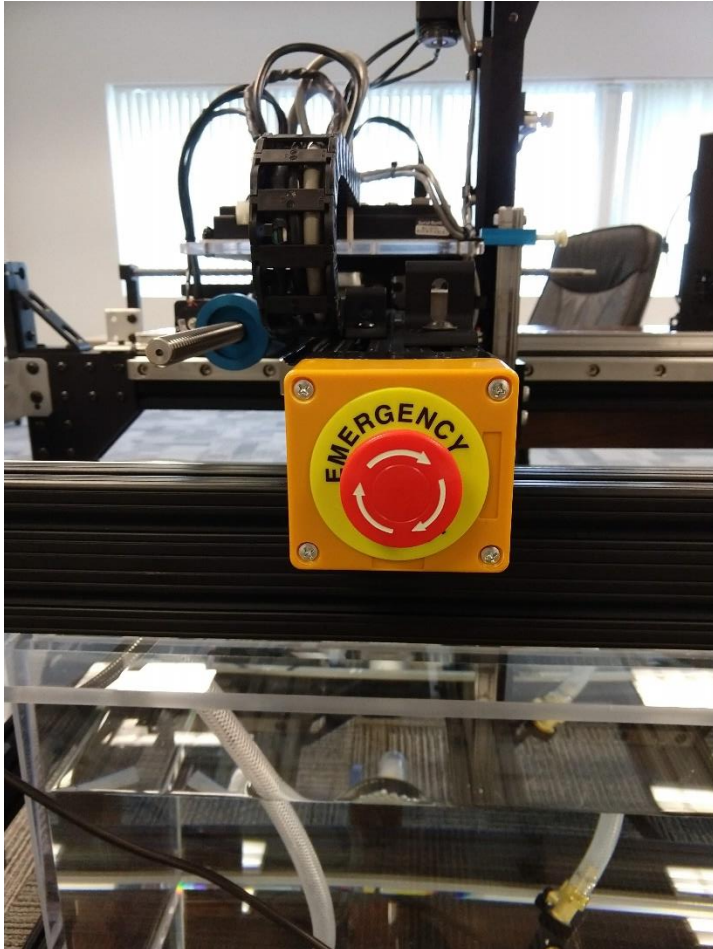


The button is activated by pushing it. It will stop the motors immediately and abort the active command. The emergency top switch is deactivated by rotating the red knob clockwise until it releases. The motors can then be used again without further re-initialization (though the command being executed will have aborted.)

The emergency stop button will not release the hold on the motors, only stop motion with rapid deceleration.

# Software Initialization

The AMS program can be initialized by running 'main.exe' in C:/AMS. A shortcut, called 'AMSPy' can be found on the computer desktop. The first time running the software after bootup may result in a substantial delay where activity is not evident. Please be patient. Once the software begins to run, it will launch a web browser instance (specified in the config.py file). All operations are performed via web browser input. Because of the way commands are passed between the web browser and python web server, it is not recommended to use the browser's *back* or *refresh* commands.

The main window should appear:
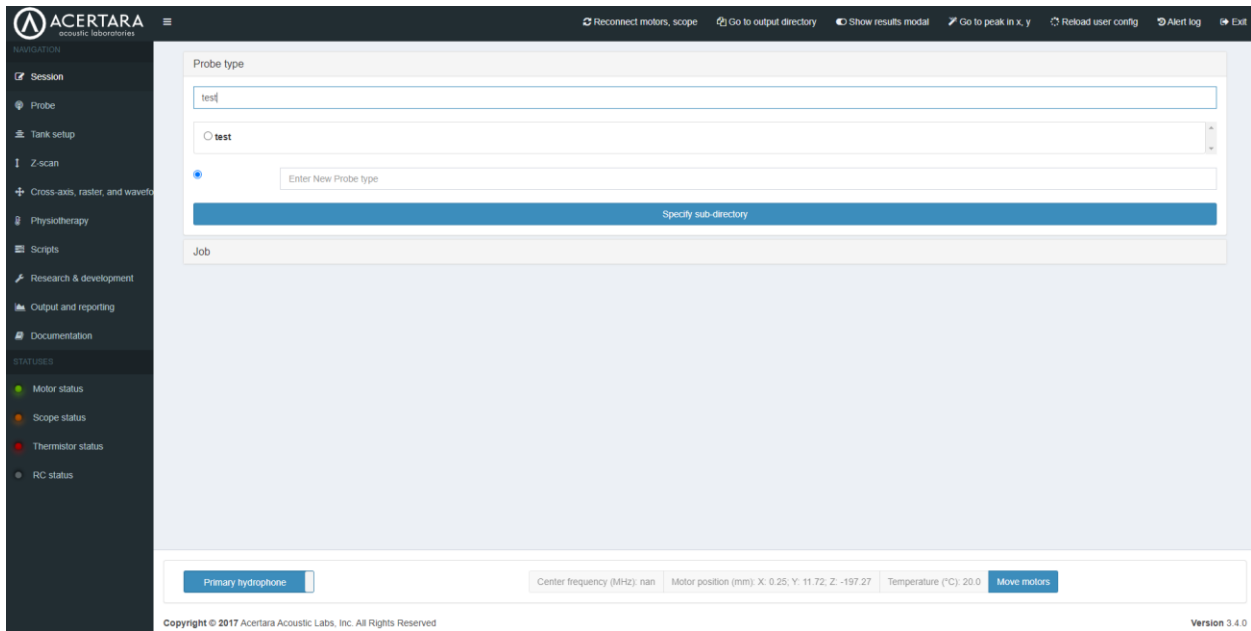


The bottom left corner gives the status of the various connections:
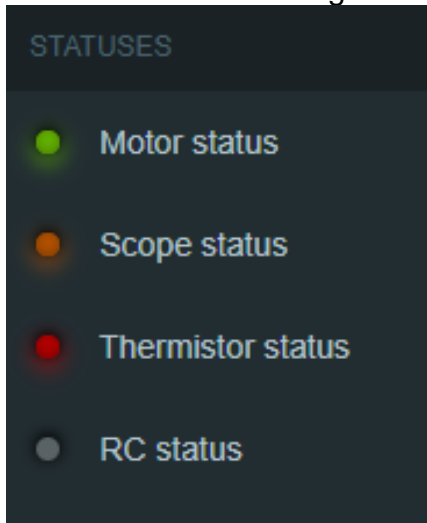
## Motors

The top-most 'LED' in the status area shows the connection status to the motion controller. Green indicates that the software believes that there is an appropriate connection. Yellow indicates that the software is attempting to connect to the motion controller. Red indicates a failure to connect. Orange indicates that the motors are being emulated and that no real motion will occur. (This mode can be activated in config.txt by setting `emulate_motors = True`. It is useful for learning the software.)

The software will automatically attempt to connect to the motion controller when it is run, using the IP address specified in config.txt.

If connection fails (red LED), consider the following:
1. Check that the motor power supply is plugged in and the indicator lights on the motor control board are lit.
2. Check the motor IP address by 'pinging' it from a windows command window:
    a. Start → cmd.exe
    b. Type `ping xx.xx.xx.x`
    c. Should see something like this:

```
Microsoft Windows [Version 10.0.18363.1379]
(c) 2019 Microsoft Corporation. All rights reserved.

C:\Users\nellens.ACERTARA>ping 10.1.0.27

Pinging 10.1.0.27 with 32 bytes of data:
Reply from 10.1.0.27: bytes=32 time<1ms TTL=64
Reply from 10.1.0.27: bytes=32 time<1ms TTL=64
Reply from 10.1.0.27: bytes=32 time<1ms TTL=64
Reply from 10.1.0.27: bytes=32 time<1ms TTL=64

Ping statistics for 10.1.0.27:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Users\nellens.ACERTARA>
```

3. If 'pinging' is successful but the software will not connect, open the **Galil Design Kit** (Start → GDK) through the Windows start menu and attempt to connect to the controller, observing any error messages generated.
4. Beyond these, please contact Acertara for support.

Two motor orientations are available: 'top-to-bottom' and 'right-to-left'. The default orientation is set in config.txt. This setting can be changed in the `Move motors` window, discussed later.

By convention, the tank uses a left-handed co-ordinate system (in either orientation).

**CAUTION: If difficulties are encountered with the motors or motor controller, it is recommended that probes and hydrophones be removed from the water during troubleshooting. If there are mechanical malfunctions with, eg. a motor encoder, it is possible, though unlikely, that unexpected motion could occur during operation that would jeopardize sensitive test equipment.**

**Oscilloscope**

The second LED indicates the connection status of the oscilloscope. Green indicates that the software believes that there is an appropriate connection. Yellow indicates that the software is attempting to connect to the oscilloscope. Red indicates a failure to connect. Orange indicates that the oscilloscope is being emulated and that no real data acquisition will occur. (This mode can be activated in config.txt by setting `emulate_scope = True`. It is useful for learning the software.)

The software will automatically attempt to connect to the oscilloscope when it is run. If connection fails, consider the following:
1. Check that the oscilloscope is powered on and connected to the ethernet switch
2. Check the IP address on the oscilloscope by selecting 'Utility' → 'I/O' → Ethernet settings
3. Enter the oscilloscope IP address directly into a browser address window. If the scope is connected, a Tektronix web interface will be displayed.
4. If '3' is successful but the AMS software cannot communicate with the oscilloscope, open the TekVISA Instrument Manager or Keysight Connection Expert. The oscilloscope should be listed as an active device. See figure below (example for Tektronix).
5. If you cannot locate the device, point a browser at the IP address of the oscilloscope. A control screen should be presented with information about the oscilloscope.
6. If the instrument manager and browser cannot locate the oscilloscope, it might be necessary to restart the computer and/or the oscilloscope.
7. If ping and/or browser access to the oscilloscope are possible, but the software cannot reach the oscilloscope, consider re-installing either TekVisa or IOLibSuite and the NI VISA run-time utility. These should have come pre-installed on the AMS computer.
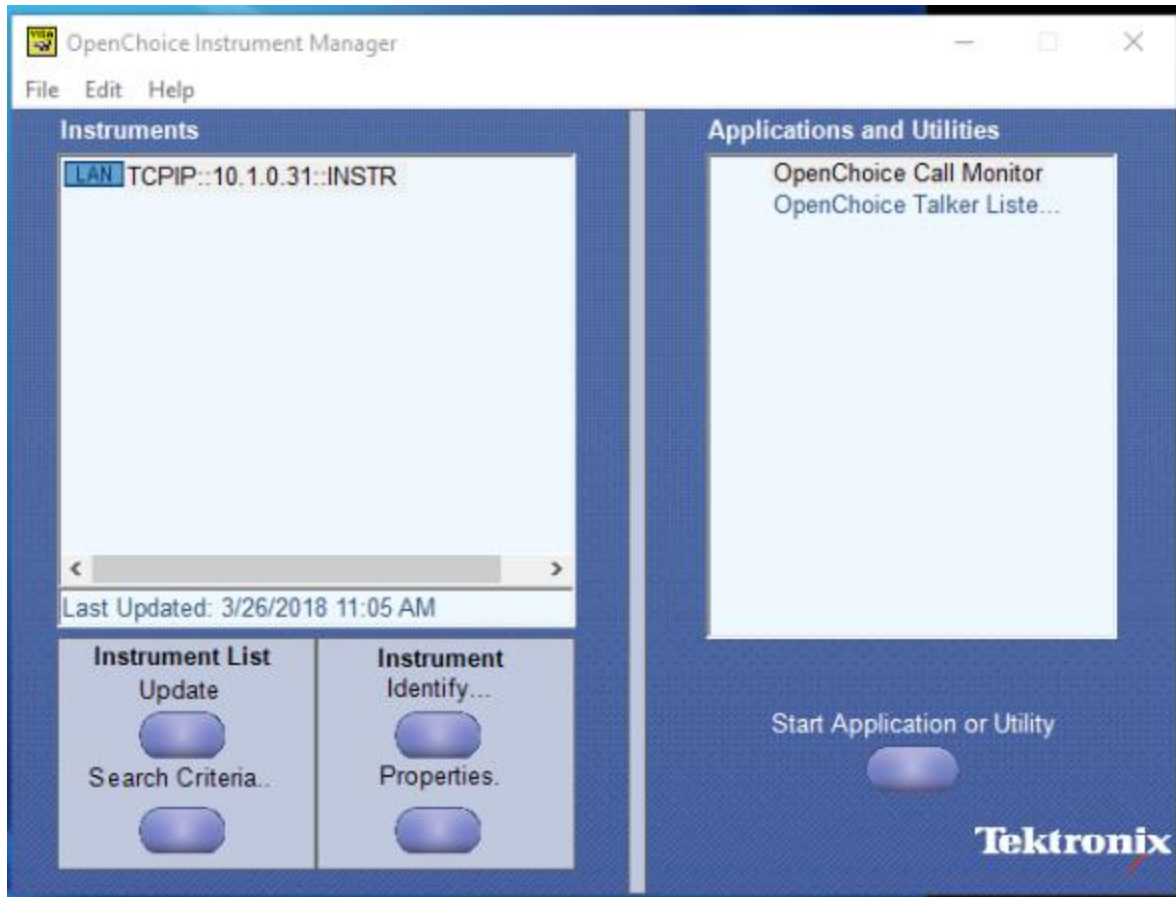
**Thermistor**

The third LED indicates the connection status of the USB thermistor. Green indicates that the software believes that there is an appropriate connection. Red indicates a failure to connect. Orange indicates that the thermistor is being emulated and that no real data acquisition will occur. If emulated or if the indicator is red, the `temp_default` temperature (e.g. 20°C) in config.txt will be used in the place of a real temperature value.

The thermistor should be plugged into one of the computer USB ports, either directly or through the supplied extension cable. The thermistor functions as a serial port and establishes itself with the computer on one of the COM ports. The COM port (eg. 'COM3') must be added to the config.txt file in order for the software to read the temperature of the water. The thermistor connection is automatic. If one suspects that it is not working, one can observe the footer of the main software (described below) to be sure that the temperature is changing.

### RC status

For systems so equipped, the RC status LED will indicate if AMSPy believes that there is an active remote control connection to the software. This is discussed elsewhere.

# Main AMS Program

## Top ribbon
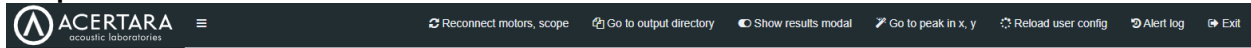


The top ribbon allows the following commands to be easily accessible at all times:

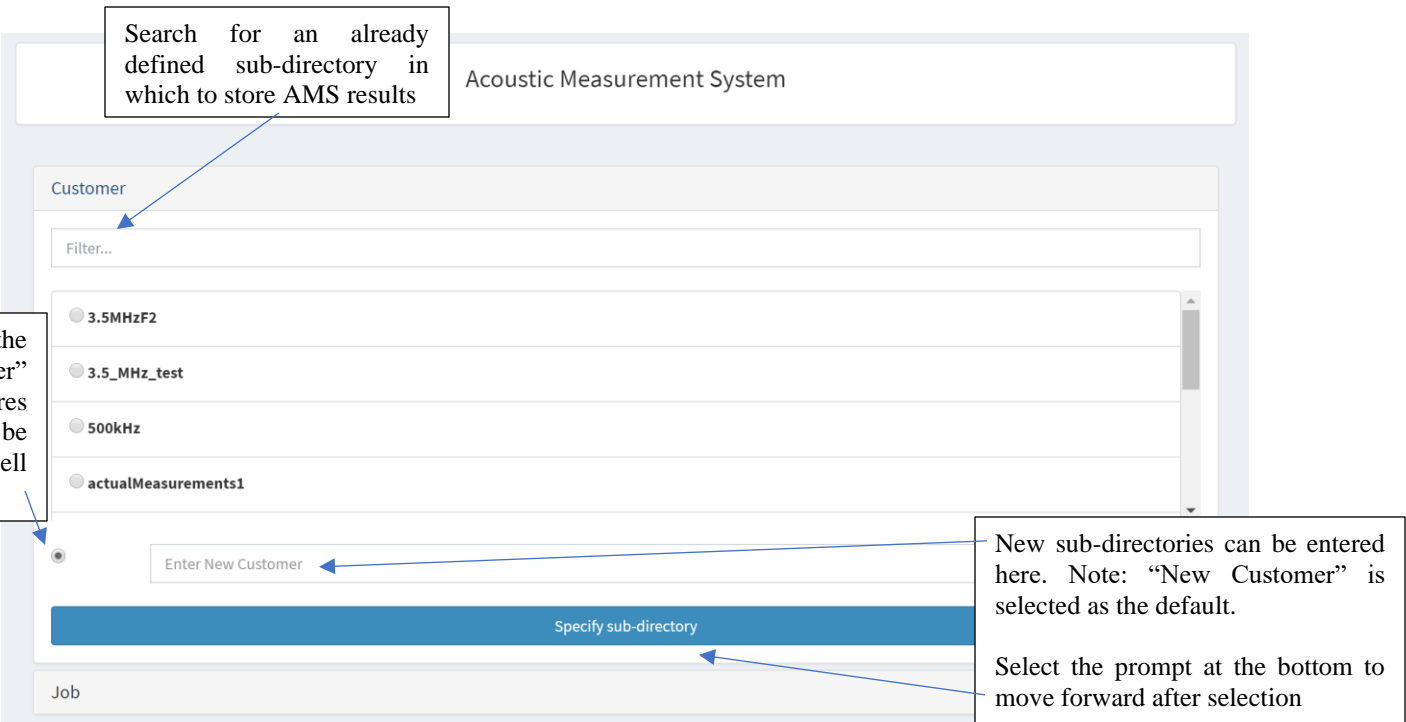| Name | Description |
|---|---|
| Utilities<br>Reconnect motors, scope | The software will attempt to re-establish connections to both the motors and the oscilloscope. This is to be used if there is some sort of drop in communication. The success of this endeavor will be assessed via the colors of the status LEDs. |
| Utilities<br>Reload user config | Refreshes the user_config.py file, making those parameters immediately effective. An alert should indicate if this command is executed correctly. |
| Utilities<br>Current scope waveform | After the probe has been defined and the hydrophone set, this button can be used to launch a waveform acquisition that will skip the normal autoscaling and assessment of RMS stability. It allows one to transfer data from a 'stopped' oscilloscope to the AMSPy software. |
| Go to output directory | Software will attempt to launch a Windows Explorer window that begins in the current, active output directory. |
| Show results modal | Bring the results modal to the foreground. This can be used if one inadvertently closes the results modal. |
| Go to peak in x, y | The software tracks the highest measured PII.0 location. Assuming the probe is correctly aligned, this serves as an effective means to bring the hydrophone back to the acoustic axis in case one gets lost |
| Alert log | Opens a separate tab that lists the alerts that have popped up since the program began. The list can be filtered using the checkboxes at the top. |
| Exit | Stops the program. **Please make every attempt to terminate the program using the 'Exit' button. Unscheduled 'killing' of the program could result in leaving the motor and/or oscilloscope connections in an undesirable state. When in doubt, restart computer and cycle power to the motor controller, leaving it off for at least 30 seconds.** |

The following sections discuss the command categories found on the left side of the list the AMS commands found along the left side of the main window, from top to bottom. These commands are arranged in the order that they will normally be used in making an acoustic measurement. The side bar is shown, below.
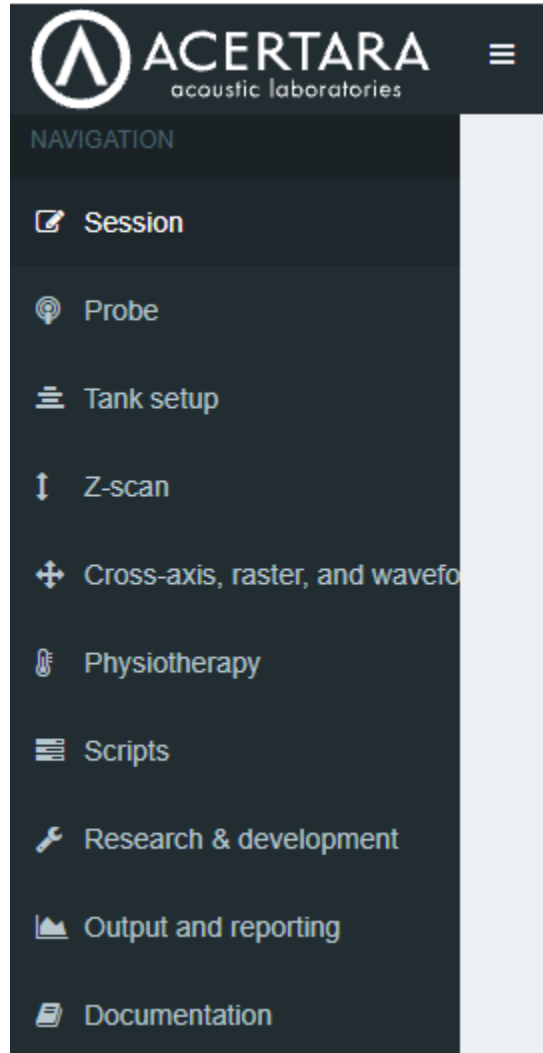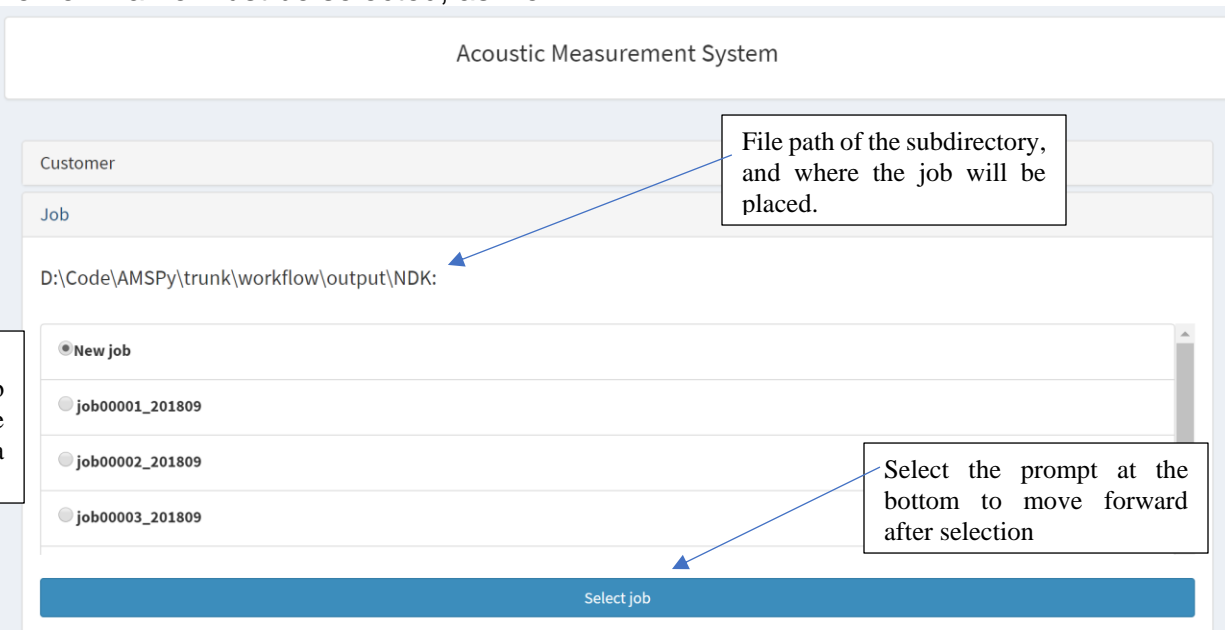


## Session

The sub-directories in the 'output' directory are listed first in the session menu. (A shortcut to the output directory is found in the AMSPy desktop folder.) It is recommended that these sub-directories be given descriptive names to organize collected data.

The label of the sub-directory by the software (shown here as 'Customer') is set in the config file: config.output_subdir_description.

Acoustic Measurement System

Customer

Filter...

○ **3.5MHzF2**

○ **3.5_MHz_test**

○ **500kHz**

○ **actualMeasurements1**

○ Enter New Customer

Specify sub-directory

Job

The top input box allows one to filter the sub-directories in order to locate a known name. Otherwise, the list can be scrolled through and selected with the radio buttons. New sub-directories can be created by typing the name at the bottom, though the radio button with the new name must be selected, as well.

Acoustic Measurement System

Customer

Job

D:\Code\AMSPy\trunk\workflow\output\NDK:

⦿ New job

○ job00001_201809

○ job00002_201809

○ job00003_201809

Select job

After a sub-directory is selected, the 'Job' panel opens. Here, there is less flexibility. One can initiate a new job, or continue a previous, listed job.

Selecting a job should advance the software to the next screen

# Probe



The overall screen for the probe definition characteristics, which are explained separately below, splitting them into categories for Probe Characteristics, Probe Specifics, Aperture Characteristics, and Probe Templates.

## Probe Characteristics



Define a probe name to refer to this specific probe choice.

Define focusing depths relative to azimuthal (x-direction) and elevational (y-direction) depths

Define additional mode identifier such as "b-mode"

Signal transmission type

Define the nominal center frequency

The upper left section of the 'probe characteristics and specifics' screen is used to set specifics about the probe and a specific set of transmit characteristics such as focal depth, nominal center frequency, and a mode identifier field (eg. 'b-mode'). Please note that these fields must match each other exactly for different acquisitions if the settings are to be properly read by the table and plot generators.

## Probe Specifics

**Serial number:**

Unknown20180809-075411

Probe serial number dropdown menu. Should be automatic, but may be overridden.

**Operator:**

Users may put the name of the probe operator in this field, but not required.

**Oscilloscope serial number:**

**Thermistor serial number:**

N/A

**Oscilloscope** serial number input and **thermistor** serial number input

The upper-right section of the 'probe characteristics and specifics' screen is used to set the specific probe serial number, record the name of the operator (optional), and record the thermistor and oscilloscope serial numbers. These serial numbers should be automatically populated, but they may be overridden.

## Aperture Characteristics

Circular **outer diameter** and **inner diameter**

Aperture

| ⦿ Circle | Outer diameter (mm): | 10.0 | Inner diameter (mm): | 0.0 |
| ◯ Rectangle | Length (mm): | 6.0 | Height (mm): | 4.0 |
| ◯ Other | Aperture (mm²): | 3.1 | | |

Rectangular **x-direction** size and **y-direction** size

Select to switch geometry type

Other **aperture area**

The bottom section of the 'probe characteristics and specifics' screen is used to set the transducer aperture geometry. This includes selection entries for circular or rectangular geometric categories, with respective size arguments for each. 'Circle' utilizes entries for inner and outer diameter arguments in mm. If a whole piston face is utilized, then use the default inner diameter size at 0. 'Rectangle' uses entries for length (x-direction) and height (y-direction) in mm. Rectangular geometries also maintain the additional classification of linear or phased focusing, which is controlled by the 'geom_type' variable in *config.py*. 'Other' is also defined based on the aperture area in mm².

**Probe Template**

Select to open path directory and read in a saved probe template

Drop probe template file here or click to upload

**OR** drop an existing probe template onto the page

Save current settings as probe template

Select to current save settings as a *.csv* for later use
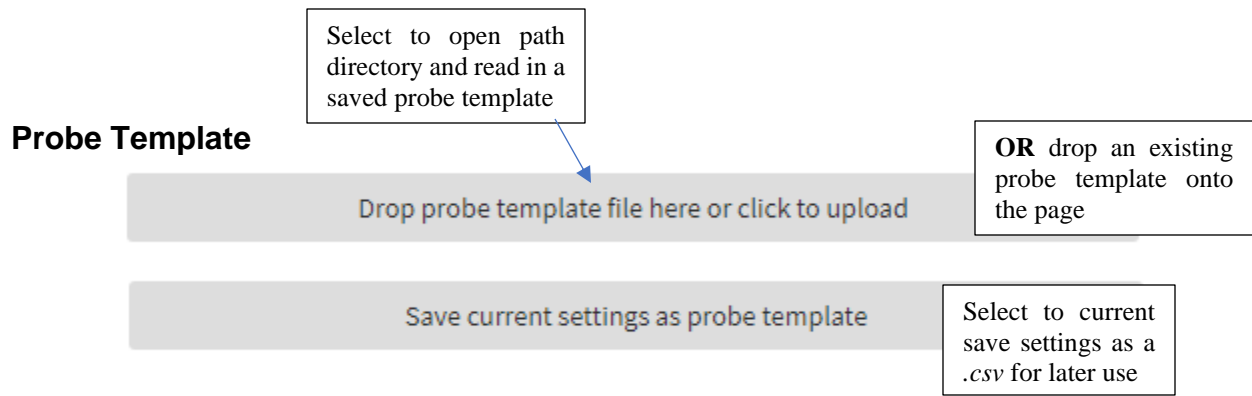
Once the geometry of a probe is established, using the criteria and entries above, the current settings can be saved as a *.csv* extension file. Once 'Save current settings as probe template' is selected, a prompt at the top of the screen will request a filename. Once provided, the *.csv* file will be stored in the `templatedir` specified in config.txt; 'ProbeTemplates', by default.

In order to upload a saved template, drag and drop the *.csv* file onto the page, or click the upload option and trace the file path back through AMSPy's *ProbeTemplates* sub-directory in the *workflow* directory. In addition to this, any exterior probe templates may be drag and dropped into AMSPy, but it must match the format of the standard probe template *.csv* files.

When all parameters are successfully and correctly defined, select the blue 'Specify Probe' prompt in the bottom right to proceed.

**Other features**

Systems equipped with the 'Scripts' option can input acceptance criteria in this screen that are evaluated at run time to determine if the script should continue or pause.

The 'Presest' dropdown allows for several probe templates to be loaded at once. To use this, format the presets as in "..\TableGeneratorTemplates\SeveralSettingsTest.xlsx". This xlsx file can be dragged and dropped onto the 'Drop probe template file here or click to upload' and these templates will be accessible through the dropdown preset menu.

# Tank Setup

**Hydrophone(s)**



The left-most panel provides drop down menus to select the primary (required) and secondary (optional) hydrophones. These lists are populated by files with the extension *.hyd* in the ActiveHydrophones directory. Default values can be specified in the *config.py* file. Finally, the initial offset distance between the active sensor of the hydrophone and the face of the transducer being measured is specified. **If no hydrophone offset is specified, the system will assume that the current motor position is correct.**
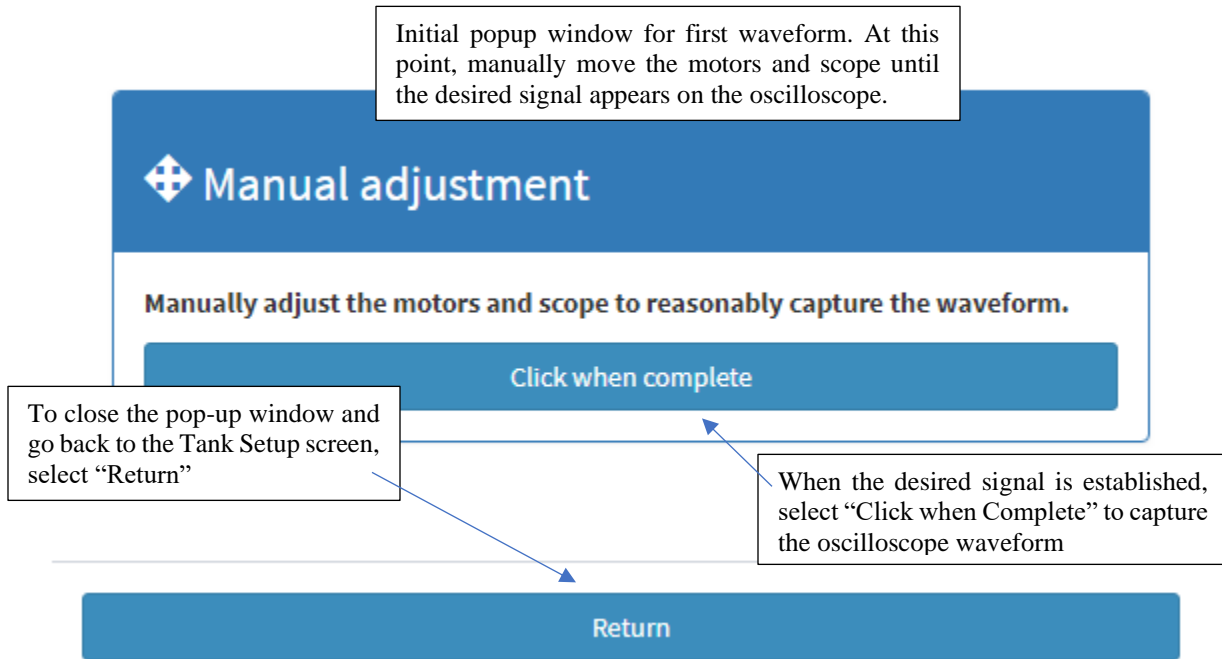
> ⚠️ WARNING: setting the hydrophone offset incorrectly will corrupt subsequently-acquired data and risks a collision between the hydrophone and device under test.

Hydrophone data are discussed in appendix A. Hydrophone data files can be edited with a text editor or MS Excel, though they must retain the same format as the ones included with the software. Details about the essential elements of the hydrophone data file can be found in the appendix.
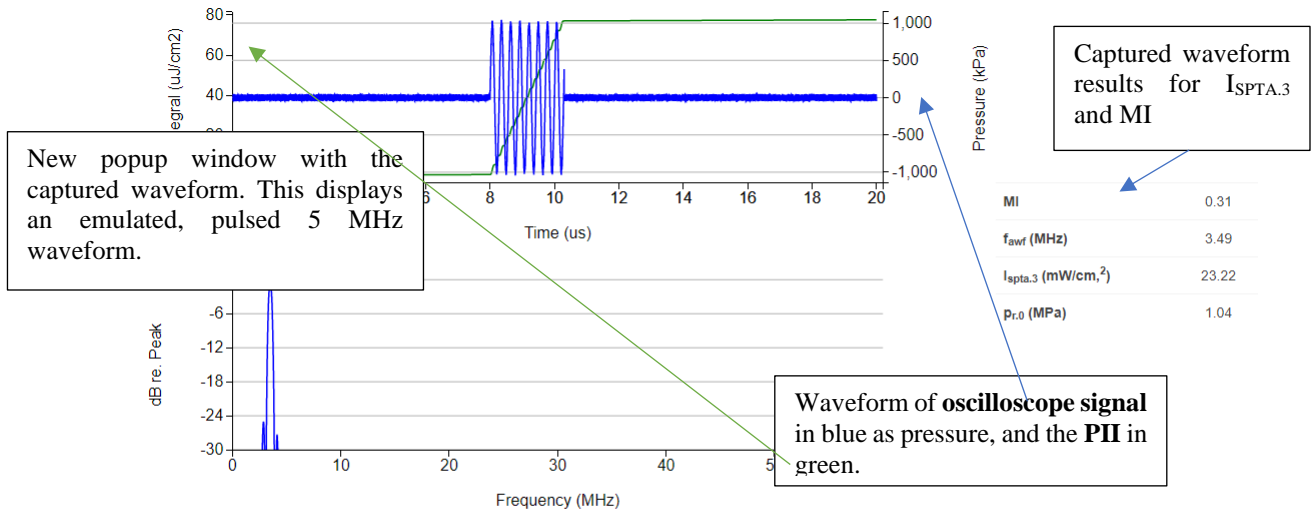
**First waveform**
Clicking 'Acquire waveform' will move the hydrophone from its start position (specified in 'hydrophone', above) to the nominal azimuthal focal depth and open a popup window.

**Note: it is important that the nominal azimuthal focal depth be realistic.** If, for instance, the nominal azimuthal depth is set to 600 mm, the motors will run the hydrophone out to 600 mm, unless a limit switch engages or 600 exceeds the motor z limit (config: motor_maxZ_default). **This behavior can be over-ridden by setting dut_override{'firstwavedepth': np.nan} to a value that is not '-1'.**

Initial popup window for first waveform. At this point, manually move the motors and scope until the desired signal appears on the oscilloscope.

**✛ Manual adjustment**

Manually adjust the motors and scope to reasonably capture the waveform.

Click when complete

To close the pop-up window and go back to the Tank Setup screen, select "Return"

When the desired signal is established, select "Click when Complete" to capture the oscilloscope waveform

Return

The hold of the motors will be released for manual adjustment. Move the motors in x, y, and, optionally, z in order to find the ultrasound pulse. At the point, the oscilloscope can be adjusted to move the pulse into the center of the screen. When you are happy with the waveform displayed, click the 'click when complete' button and the software will capture the waveform displayed on the oscilloscope.

New popup window with the captured waveform. This displays an emulated, pulsed 5 MHz waveform.

Captured waveform results for I$_{SPTA.3}$ and MI

| | |
|---|---|
| MI | 0.31 |
| f$_{awf}$ (MHz) | 3.49 |
| I$_{spta.3}$ (mW/cm$^2$) | 23.22 |
| p$_{r.0}$ (MPa) | 1.04 |

Waveform of **oscilloscope signal** in blue as pressure, and the **PII** in green.

Fast Fourier Transform Plot of signal to determine functional nominal frequency

Delete captured data? ☐ or append comment:

Reset center frequency going forward? (3.49 MHz) ☑

Return

Options for first waveform results

To close the pop-up window, finalize checked categories, and go back to the Tank Setup screen, select "Return"

The software will calculate the center frequency from the captured waveform and give the user the option to accept this value (used to determine the waveform for subsequent step sizes).

Optionally, clicking 'Specify f$_c$' will skip the movement and acquisition and set the current working frequency for the software to the value specified in the box above this button.

**Probe alignment**

↓↑ Probe alignment

**Click to run through probe alignment**
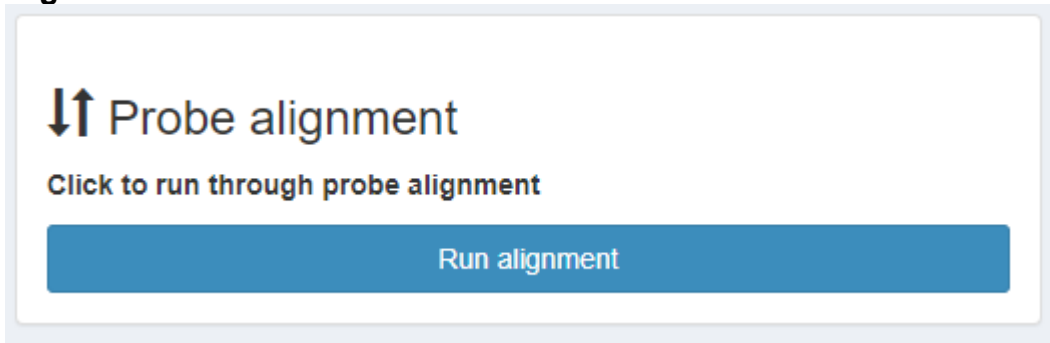
Run alignment

Clicking this button will open an alignment window.

Two depths are selected on either side of the nominal focal depth, z$_{min}$ and z$_{max}$. When run, searches for the peak are performed at each of these depths with the assumption that the highest intensity in each plane corresponds to the center of the beam. From these

peak locations, a vector is calculated and angles and/or offsets are supplied to indicate how far the source is angled from the tank's z-axis. This command can be run repeatedly after adjusting the angle of the source until the offset is satisfactorily small. If the 'Search method' is changed to 'Center-of-mass', the search methology is changed so that each search looks for the calculated center of mass, rather than an absolute peak. This is more appropriate for some types of transducer geometry.



Options available for adjusting motor-driven goniometers (automatic alignment variant, only)

**NOTE:** The default depths selected for the alignment follow one of three patterns, specified in user_config.py:

```
alignmentmethod = 'physioshallow'  # 'physiodeep' (2 * A_ERN / (pi *
lambda)) or 'physioshallow' (A_ERN / (3 * pi * lambda)) or 'plus25'
(1.25 * focal depth)
```

The following are the definitions used to interpret these three options:

| Method | Proximal depth | Distal depth |
|---|---|---|
| 'plus25' | Mean of breakpoint depth and focal depth | 1.25 × focal depth |
| 'physiodeep' | $A_{ERN} / (\pi \times \lambda)$ | $2 \times A_{ERN} / (\pi \times \lambda)$ |
| 'physioshallow' | $A_{ERN} / (3 \times \pi \times \lambda)$ | $A_{ERN} / (\pi \times \lambda)$ |

It should be noted that the assumption that the peaks at each depth lie along the center of the ultrasound beam is not true for all transducers, particularly those with large apertures and tight foci. (These tend to produce a bifurcated 1D pressure profile with two peaks of approximately equivalent magnitude.)

As referenced above, Acertara sells a variant of the probe holder that is equipped with three, IPX7-rated motors that electronically control the goniometers, shown below. These motors can be submerged without damage for up to 30 minutes, though the intent for use with this tank is that they be used above water with the knowledge that splashes will not have any adverse effects.
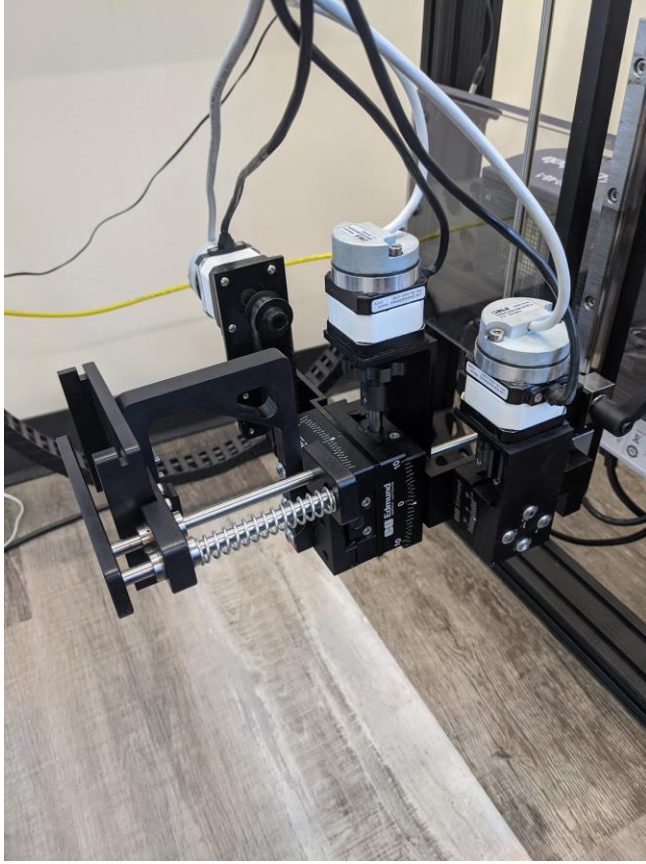
This holder is designed to work with custom-manufactured, probe-specific holders. Please contact Acertara for more information.
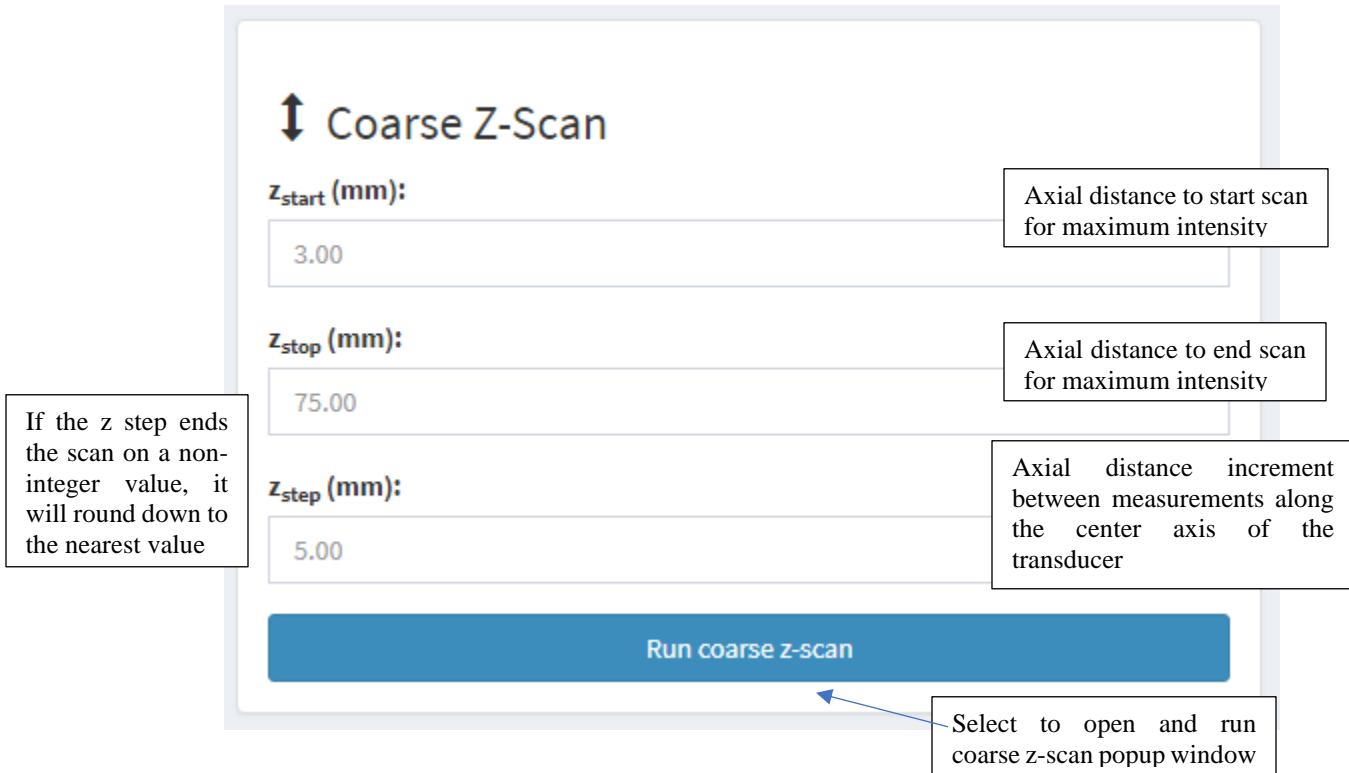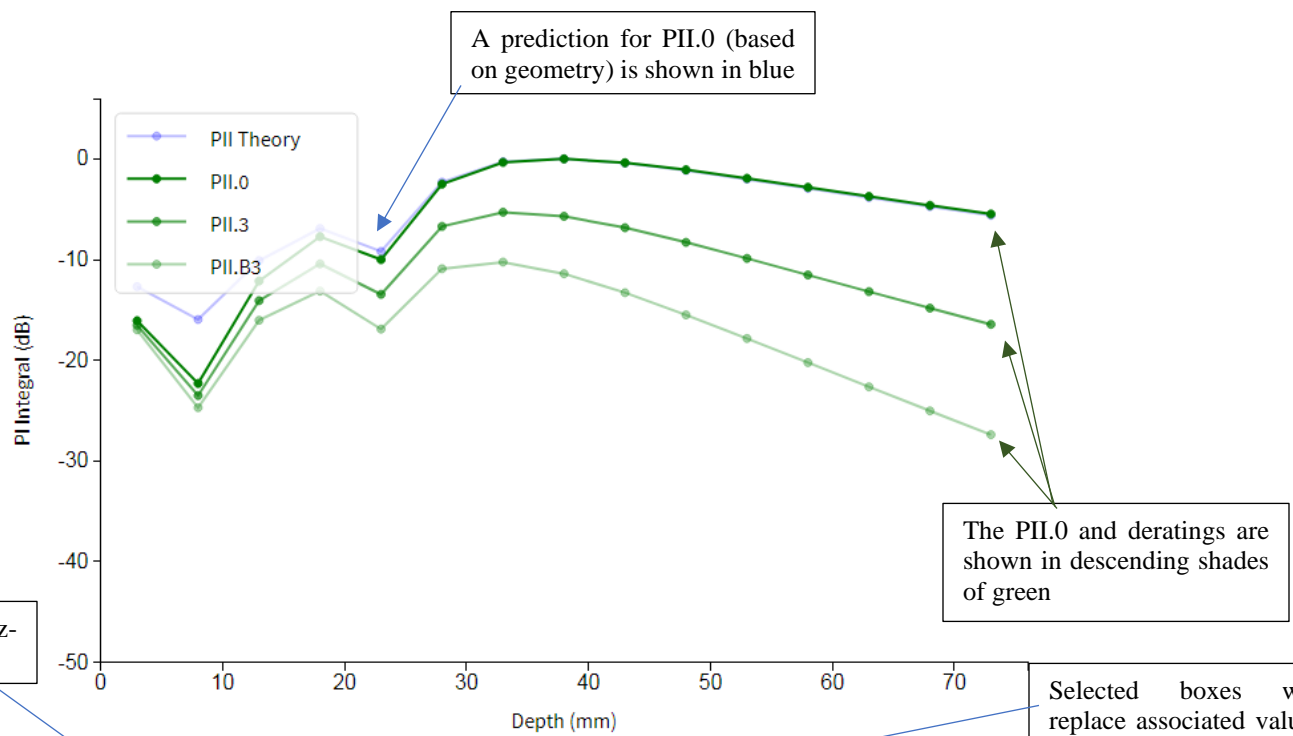
# Z-scan
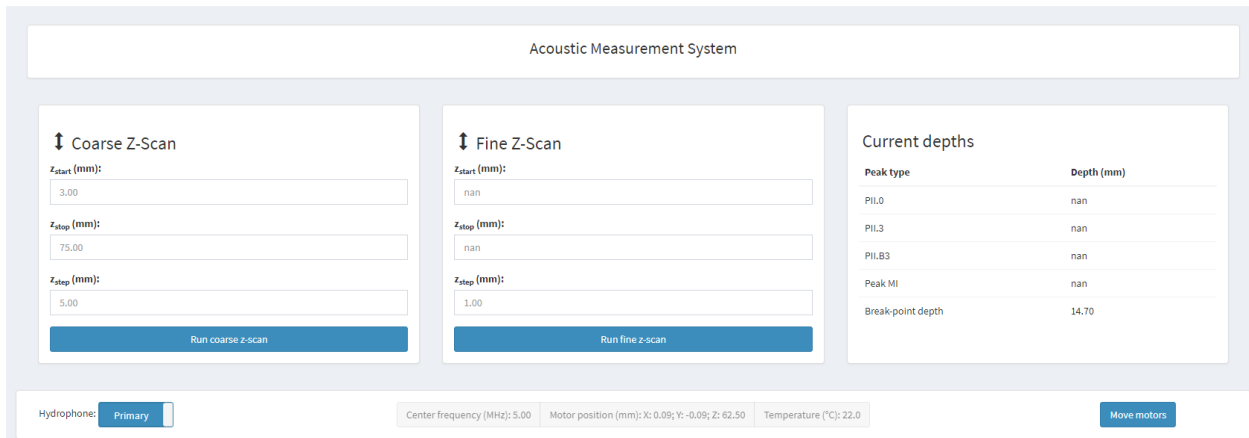


Z-scans prescribe sampling the acoustic axis at specified intervals, starting proximal to the probe and moving distally. There are two variants, intended—but not required—to be run successively.

## Coarse Z-Scan



If the z step ends the scan on a non-integer value, it will round down to the nearest value

$z_{start}$ (mm): Axial distance to start scan for maximum intensity

$z_{stop}$ (mm): Axial distance to end scan for maximum intensity

$z_{step}$ (mm): Axial distance increment between measurements along the center axis of the transducer

Select to open and run coarse z-scan popup window

1. $z_{start}$, $z_{stop}$, and $z_{step}$ parameters are specified. The hydrophone will be moved to depth $z_{start}$, acquire a waveform, move deeper the distance $z_{step}$, and acquire another waveform until reaching $z_{stop}$. `Do autosearch?` checkbox determines if an in-plane search will be performed at each point.

2. Output is displayed in real-time (log of the intensity, with deratings of 0.3 dB/cm/MHz and 0.6 dB/cm/MHz)
3. At the end of the sequence, user is prompted to accept or decline the depths that the software recognize as the different peaks. Whether a substitution is recommended (defaulted) depends on what has been acquired previously: if nothing has been previously acquired or subsituted, the substitution is recommended; if the previously substituted value is lower than the newly-acquired value, the substitution is recommended. The four depths are at the following peaks:
    a. PII.0: highest intensity past $z_{min}$
    b. PII.3: highest 0.3 dB/cm/MHz derated intensity past $z_{min}$
    c. PII.3 (MI): highest 0.3 dB/cm/MHz derated intensity at any sampled depth
    d. PII.B3: highest 0.6 dB/cm/MHz derated intensity past $z_{min}$

A prediction for PII.0 (based on geometry) is shown in blue

The PII.0 and deratings are shown in descending shades of green

Options for z-scan results

Selected boxes will replace associated values on the main z-scan page, under current depths

Delete captured data? ☐

Replace PII.0 depth (nan with 38.0)? ☑  Replace PII.3 depth (nan with 33.0)? ☑  Replace PII.3(MI) depth (nan with 33.0)? ☑

Replace PII.B3 depth (nan with 33.0)? ☑

Return

Select to return to the main z-scan page

**Fine Z-Scan**



↕ Fine Z-Scan

$z_{start}$ (mm):

28.00

Axial distance to start scan for maximum intensity

$z_{stop}$ (mm):

43.00

Axial distance to end scan for maximum intensity

$z_{step}$ (mm):

1.00

Axial distance increment between measurements along the center axis of the transducer

**Run fine z-scan**

Select to open and run fine z-scan popup window

1. Behaves in the same way that the coarse z-scan behaves
   a. The default depths are determined from the most recently-run coarse z-scan

A prediction for PII.0 (based on geometry) is shown in blue

The PII.0 and deratings are shown in descending shades of green

**PIIntegral (dB)** — vertical axis, values: 0, -10, -20, -30, -40, -50

**Depth (mm)** — horizontal axis, values: 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46

Legend:
- PII Theory
- PII.0
- PII.3
- PII.B3

Options for z-scan results

Selected boxes will replace associated values on the main z-scan page, under current depths
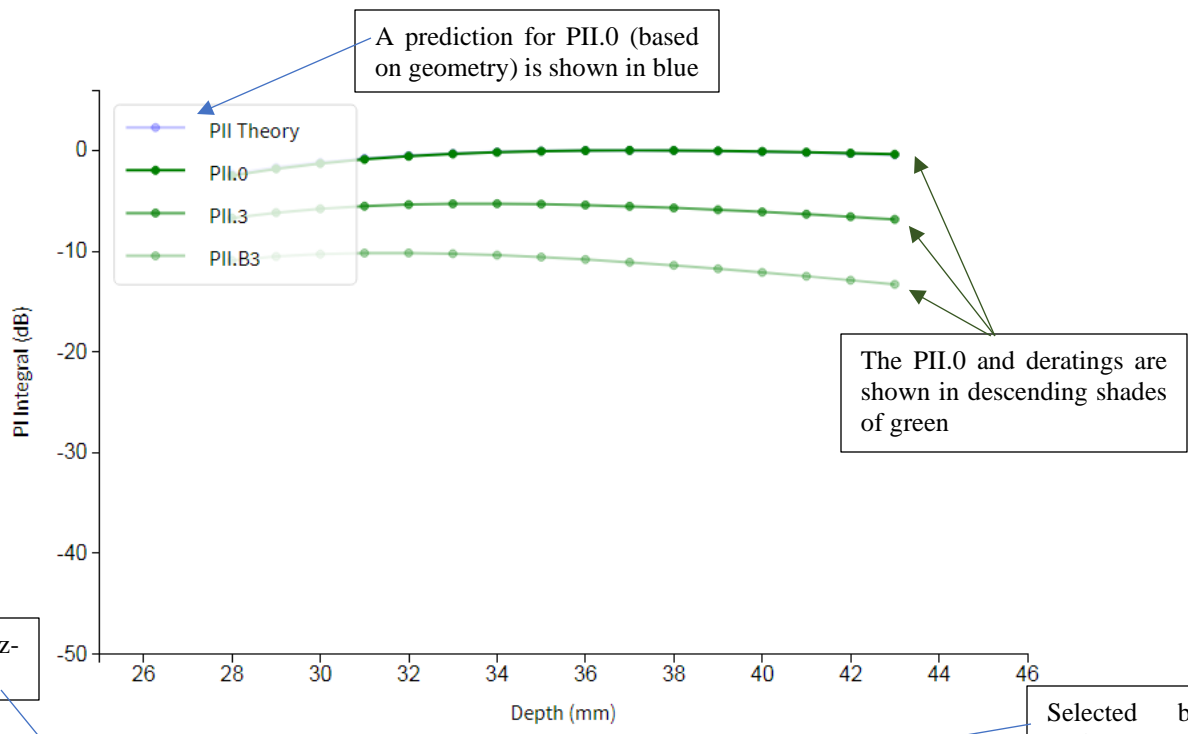
Delete captured data? ☐

Replace PII.0 depth (38.0 with 37.0)? ☑ Replace PII.3 depth (33.0 with 34.0)? ☑ Replace PII.3(MI) depth (33.0 with 34.0)? ☑
Replace PII.B3 depth (33.0 with 32.0)? ☑

**Return**

Select to return to the main z-scan page

**Current depths**

## Current depths

| Peak type | Depth (mm) |
|---|---|
| PII.0 | 37.00 |
| PII.3 | 34.00 |
| PII.B3 | 32.00 |
| Peak MI | 34.00 |
| Break-point depth | 14.70 |

This is where selected values of the z-scan results appear, and determined $z_{bp}$ values

1. This panel displays the currently-accepted list of depths, specific to this probe serial number and setting. This list is for reference only.

# Cross-axis, raster, and waveform
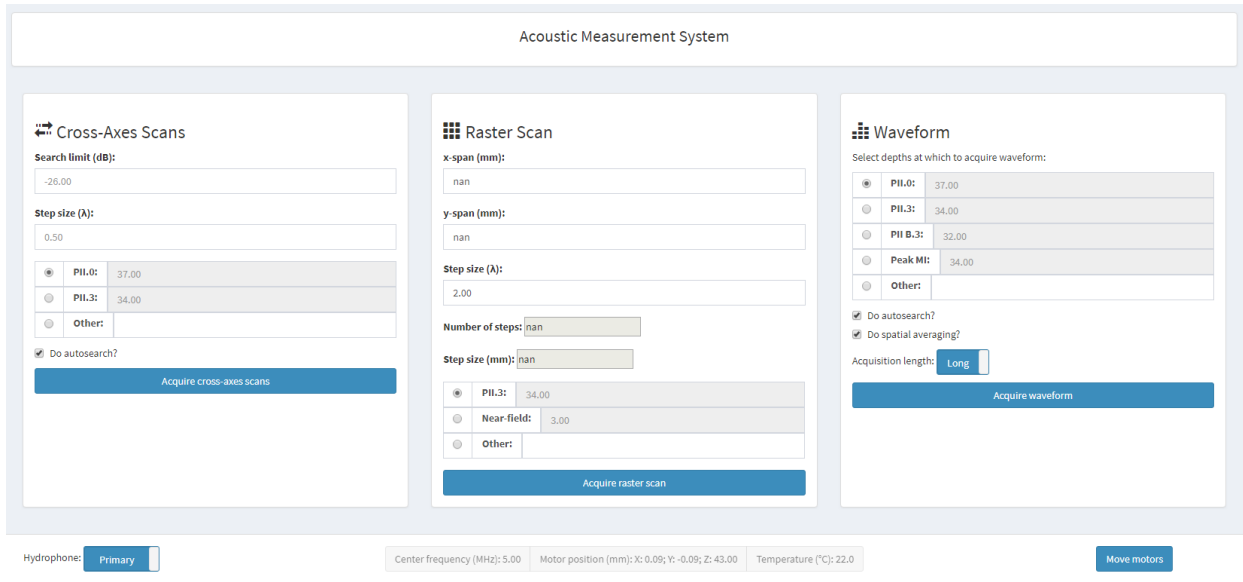


This page prescribes measuring the beam along two orthogonal axes (cross-axes scans), in a 2D rectilinear fashion, or to acquire high-resolution waveforms. It is recommended, but not required, that they be acquired from left-to-right on the screen. As actions are completed, they will be outlined in bright green. Depending on the z-scan, one acquisition may indirectly negate the need for another acquisition.
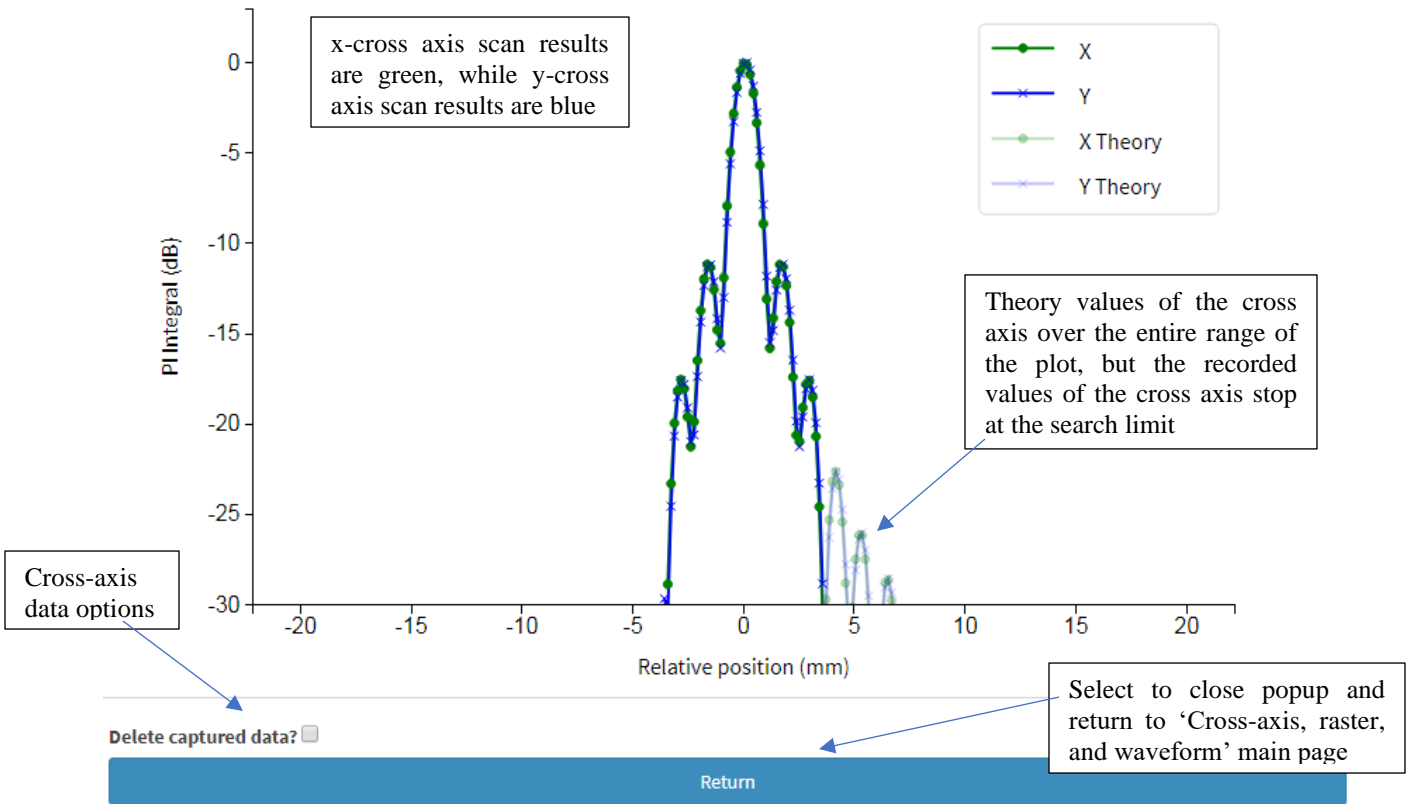
**Cross-Axes Scans**



1. Radio buttons allow the rapid selection of the PII.0 and PII.3 depths, along with a user-specified depth

2. An autosearch is performed if checked; the hydrophone is scanned in 4λ steps in the negative X direction until the "search limit (dB)" is reached
3. From the "search limit (dB)" level, the system will move back along the axis of travel in λ/2 steps, recording a waveform at each step until the "search limit (dB)" limit is reached on the other side of the peak
4. This process is repeated along the Y axis



Cross-axes scans complete: -12 dB diameters are 3.68 mm in x, 3.68 mm in y.

Results of the $d_{eq}$ from the cross axis scan listed at the top, for each cross-axis

x-cross axis scan results are green, while y-cross axis scan results are blue

Theory values of the cross axis over the entire range of the plot, but the recorded values of the cross axis stop at the search limit

Cross-axis data options

Select to close popup and return to 'Cross-axis, raster, and waveform' main page

Delete captured data? ☐

Return

**Raster Scan**

### ⦿ Raster Scan

**x-span (mm):**

8.30

Total x-direction size of the raster scan

**y-span (mm):**

8.31

Total y-direction size of the raster scan

**Step size (λ):**

2.00

Size per step in terms of the wavelength

**Number of steps:** 225.00

**Step size (mm):** 0.59

Calculated values for the **number of steps** over the x-span and y-span, given the step size and the **absolute step-size** measurement

| ⦿ | **PII.3:** | 34.00 |
| ○ | **Near-field:** | 3.00 |
| ○ | **Other:** | |

Select switch the location of interest for the raster scan popup screen

This is the location of the **derated PII.3** as a choice for the raster, the other is the near field, which is the $z_{min}$ **value**

**Acquire raster scan**

Select to open raster popup screen and begin the raster

1. Radio buttons allow the rapid selection of the PII.3 depth, the closest-allowable depth (used to calculate the ultrasound entry beam diameter), or a user-specified depth
2. At the depth specified, centered at the starting location, the system will acquire a 2D array of waveforms in a rectangle specified by the x- and y-spans, with the step size specified

Raster scan complete: power factor is 0.023 cm².

Once complete, raster scan provides a power factor value

Options for the raster data

**Delete captured data?** ☐

**Return**

Select to close popup window and return to the 'cross-axis, raster, and waveform' main page

**Waveform**



Select to decide which depth's waveform should be captured

Select depths at which to acquire waveform:

| | | |
|---|---|---|
| ⦿ | **PII.0:** | 37.00 |
| ○ | **PII.3:** | 34.00 |
| ○ | **PII B.3:** | 32.00 |
| ○ | **Peak MI:** | 34.00 |
| ○ | **Other:** | |

☑ Do autosearch?

☑ Do spatial averaging?

Acquisition length: Long

Acquire waveform

Select to enact an autosearch near the depth of choice, to find the peak

Select to average several waveforms near the depth

Determines length of the oscilloscope screen record

Select to open the waveform popup screen and capture the waveform

1. Radio buttons allow the rapid selection of recommended depths at which to acquire waveforms (PII.0, PII.3, PII.B3, and MI), along with a user-specified depth
2. "Do autosearch?", if checked, will perform a peak search at the specified depth prior to acquiring the waveform
3. "Do spatial averaging?", if checked, will acquire a series of waveforms around the peak and calculate an estimate of the error introduced by spatial averaging of the finite-sized hydrophone
4. "Acquisition length" toggles between screen record lengths specified in the *config.py* file
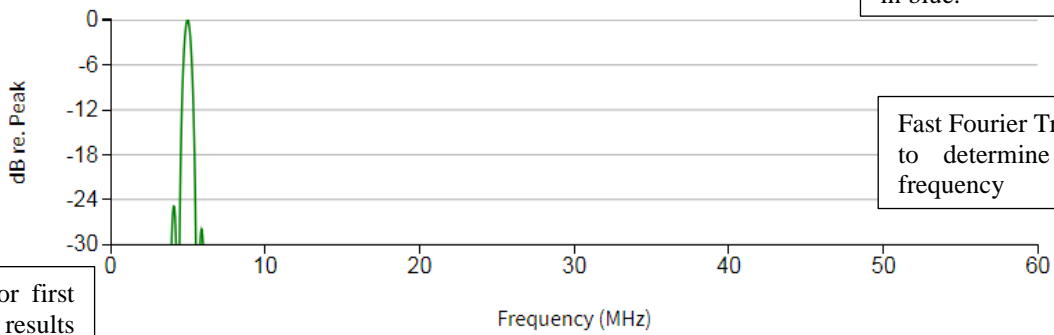
Captured waveform results for $I_{SPTA.3}$ and MI

First waveform capture complete. MI: 0.29; $I_{SPTA.3}$@1.0kHz: 2.25e+01 mW/cm$^2$.
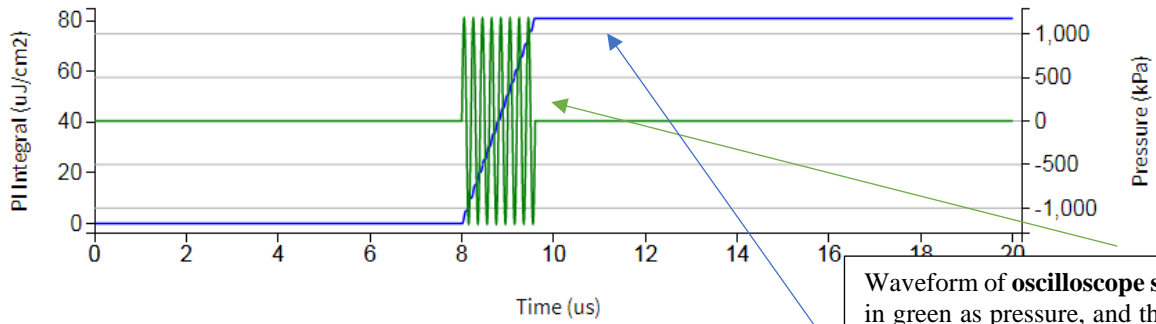
Waveform of **oscilloscope signal** in green as pressure, and the **PII** in blue.

Fast Fourier Transform Plot of signal to determine functional nominal frequency

Options for first waveform results

Delete captured data? ☐

Reset functional center frequency? (5.00 MHz) ☐

Return

To close the pop-up window, finalize checked categories, and go back to the Tank Setup screen, select "Return"

# Physiotherapy

This page includes tools that are designed to collect data from physiotherapy devices.



Z-scan:



$z_{start}$: Default is set to 3 mm, per IEC 61689

$z_{stop}$: Depth suggested is the aperture area divided by λ

$z_{step}$: Suggested increment is 2 mm, the largest allowable step size in IEC 61689. Because of the number of steps, it is not recommended to autosearch at each depth as this would make the scan very long. A good alignment should negate the need for searching at each depth.
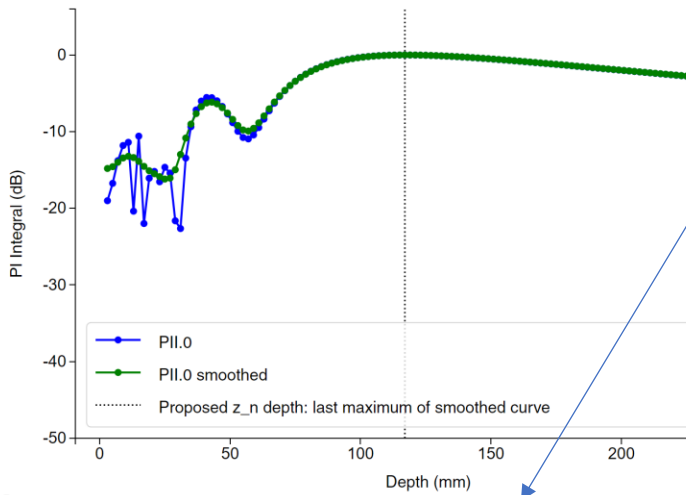
Interactive controls:
Lower and upper bounds limit where z_n is located. If both are not a number (NaN), the last axial maximum of the z-scan will be set as z_n. If one or both bounds is specified, z_n will be set as the absolute maximum between those bounds.

Curve smoothing kernel: odd number indicating how many points are used to smooth the function.

Re-process: applies the interactive controls and refreshes the screen
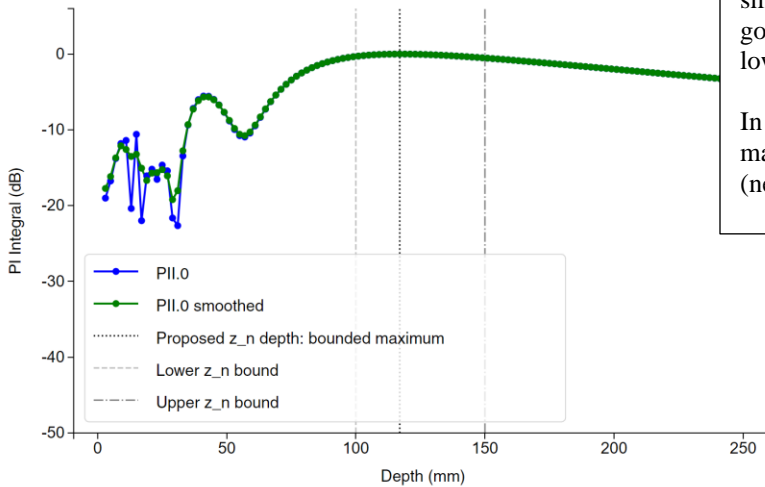


Re-processed curve with 5 points in the smoothing kernel (note that the green curve goes deeper at z=35 mm) and an upper and lower bound applied

In this case, the proposed z_n depth is the maximum between those two limits, not (necessarily) the last axial maximum.

Normal functions at the end of an acquisition

Rasters:

Select to decide at which depth to acquire a raster scan

Specifies in-plane sampling. (31 × 31 is the minimum number of points allowed in IEC 61689

**Depth**

| | | |
|---|---|---|
| ⦿ | Near-field: | 3 |
| ○ | $Z_n$: | nan |
| ○ | Other: | |

**In-plane sample spacing**

| | | |
|---|---|---|
| ⦿ | Samples per direction: | 31 |
| ○ | Step size (λ): | 0.5 |
| ○ | Step size (mm): | 0.10 |

**In-plane raster extent**

| | | | | |
|---|---|---|---|---|
| ⦿ | Cross axis to dB limit: | -26.0 | | |
| ○ | X-span (mm): | 10.0 | Y-span (mm): | 10.0 |

Specifies in-plane raster size: cross axis to dB limit will perform a cross axis scan to determine the raster size; X-span and Y-span allow the size to be specified directly

Acquire raster

Waveforms:

### ⣿ Waveform

| | | |
|---|---|---|
| ⦿ | $Z_p$: | nan |
| ○ | Other: | |

☑ Do autosearch?

Capture waveform

Select to decide at which depth to acquire a waveform. Autosearch will toggle whether or not the waveform is collected at the point the hydrophone is at when the button is clicked (no autosearch) or following an autosearch routine (do autosearch).

# Research & development

This page includes tools that are in development or allows for other measurement trajectories to be prescribed.

**XZ, YZ Rasters**
1. This allows the user to run raster scans in the xz and yz planes

**Stack of Rasters**
1. This allows one to run a series of in-plane (fixed z) raster scans at the depths specified. The in-plane sample spacing can be set as a function *n* samples, step size in λ, or step size in mm. The in-plane dimensions can be fixed (in mm) or defined as a cross-axis dB limit for which the system will do a cross-axis scan prior to each raster plane.

**Run from File**
1. This function allows the user to load an excel file into the system that prescribes a custom trajectory along which the hydrophone will move and acquire waveforms
   a. An example excel file called *RandDexample.xlsx* is included in the 'TableGeneratorTemplates' sub-directory

| Parameter | Units | Description/comment |
|---|---|---|
| x | mm | x location |
| y | mm | y location |
| z | mm | z location |
| t | ° | θ location: not used |
| hyd_sens | dB re. 1V/MPa | Override default with this hydrophone sensitivity |
| f_c_force | MHz | Override measured center frequency with this center frequency (supercedes hyd_sens) |
| tracelength | integer | Must be a value accepted by the scope or the scope will not change (eg. 1000, 10000, 100000) |
| acq_chan | integer | Usually 1 or 2 |
| do_spatial_avg | boolean | |
| do_autosearch | boolean | |
| save_raw | boolean | Will save the voltage trace if TRUE (otherwise just the analysis of the data) |
| gen_plot | boolean | Will generate real-time waveform plot, if TRUE |

2. After such a file is selected, the software will parse it and display a table indicating the measurement trajectory it will follow.
3. If 'proceed' is clicked, a progress bar will advance as the trajectory is performed, line-by-line
   a. Lines where 'gen_plot' is true will display a waveform in real-time

# Output and reporting

This page generates summaries, analysis, and plots of the output.

**Analyze results**

Clicking 'Analyze results' will allow the summary and analysis of the current acquisition; adding an absolute path to a different results directory will allow analysis of previsouly-acquired data.

The program will parse the files in the directory and, if more than one acquisition combination is present, will give you a screen in which you can select the acquisition you would like to analyze. If only one acquisition type is found, the program will proceed to the next step.



Next, based on the z-scans identified, the software will suggest what files be used for the waveforms, cross-axis, and raster scans necessary to generate output tables. The waveform files will be listed with a delta depth (eg Δ=3mm) to indicate the difference in the acquisition depth between that waveform acquisition and the depth determined in the z-scan; and either a check mark (✓), cross (x), or question mark (?), indicating if that waveform has been confirmed with a secondary hydrophone successfully, unsucessfully, or neither, respectively. The success of a secondary cross-check is determined by the maximum axial separation (config.py: crosscheck_zlim (in mm)) and the difference in PII (config.py: crosscheck_dblim (in dB)).

After each specific probe has been assigned, you will be prompted to specify if the probe is used in a scanning or non-scanning configuration, and the parameters for each.

If, in config.txt, calc_manual_Ps = True, it is possible to enter a power manually into the 'Raster scan' selector. This value, in mW, will be used for subsequent calculations and a raster scan is not required.

**Calculation parameters**

Output mode: [Non-scanning]  → Scanning/non-scanning toggle

Common parameters:

Bounded power (within 1 cm²):

1.00 (3.5 MHz f2 depth50 f45 cycles sn 0154LH seq00007 RST NearField.json) → Obtained from a near-field raster scan, or can be manually overriden

Non-scanning parameters → Parameters specific to non-scanning modes

| ⦿ | Pulse repetition frequency (Hz): | 1000.0 | | |
| ◯ | Long pulse length (ms): | 100 | Pulse repetition frequency (Hz): | 1 |

Scanning parameters → Parameters specific to scanning modes

Image rate (Hz):
20

Number of lines:
128

Line averages:
1

Linear array
⦿ Array length (mm): 40

Sector array
◯ Scan angle (°): 60    Offset (mm): 30

☑ Generate plots of table data

[Specify parameters] [Cancel]

75% → Progress bar

At this point, one may also select to produce plots, or simply the numerical results.

Note: the bounded power fraction should be between 0 and 1: the fraction of the total power that passes through a 1 cm × 1 cm aperture.

On continue, an MS excel spreadsheet and a completed pdf version of the IEC 60601-2-37:Table 201.103 form, optionally, a pdf of plots will be generated in the relevant output sub-directory. The 'TableGeneratorTemplates' directory contains an excel template for IEC-formatted output tables. It is recommended that the output excel file be opened, and the desired template file. From the template, right-click on the sheet (bottom-left corner) and say 'move or copy', copying the template to the AMS-generated summary spreadsheet. An example of this dialog is shown below:

| 9 | | $I_{TA.3}(z_1)]$ | (mW) | |
|---|---|---|---|---|
| 10 | | $z_1$ | (cm) | |
| 11 | Assoc Acoustic | $z_{bp}$ | (cm) | |
| 12 | Parameters | $z_{sp}$ | (cm) | |

Move or Copy dialog:

**Move or Copy** ? ✕

Move selected sheets

To book:

TableGen20180627-094107.xlsx ▾

Before sheet:

Identifiers and constants
Measured data
Calculated values
Statistical analysis
(move to end)

☑ Create a copy

[ OK ]  [ Cancel ]

Sheet tab: **Track 3** ⊕

#RE appears in several rows (13, 15, 18, 19, 20, 24, 26)
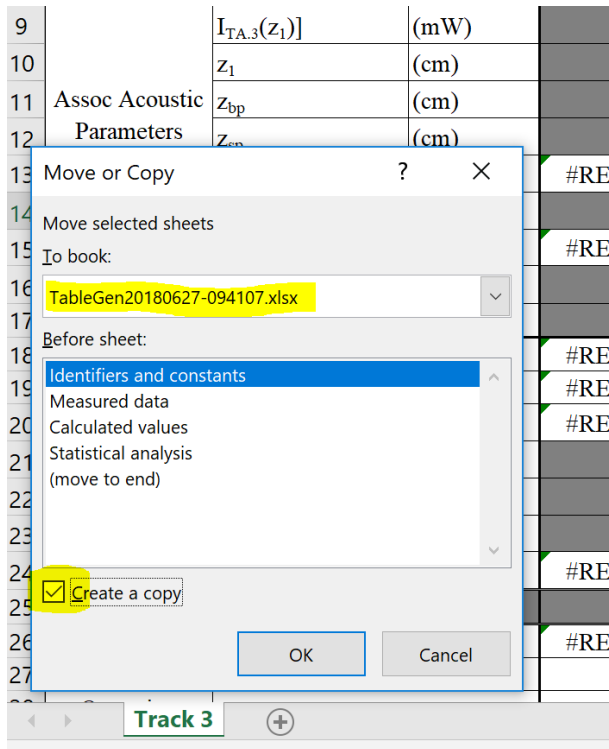
## Analyze physiotherapy results

Clicking 'Analyze physiotherapy results' will perform a similar routine to the 'Analyze results' button but will perform calculations specific to IEC 61689 and IEC 60601-2-5.

## Summarize results

Summarize results lists the output files in either the current directory, or the directory specified and allows the user to select files to summarize

1. Available files
   a. Sequences that have been acquired
2. Files to process
   a. Drag, drop, and re-order the collected data you would like summarized and/or plotted
3. 'Generate plots' and 'Generate spreadsheet summary'
   a. Checkboxes indicate the type or types of output that will be created.
4. PDF plots and XLSX summary files are created in the output subdirectory

# Documentation

Links to this document

# Footer
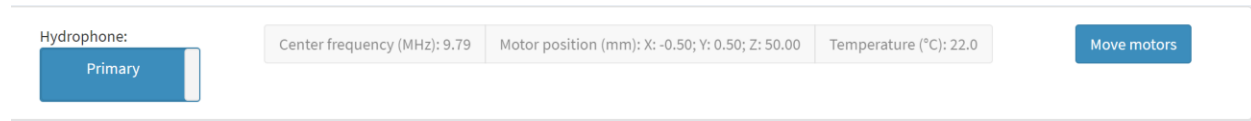


The footer has several functions:

<u>Hydrophone:</u> toggles between the calibrations of the primary and secondary hydrophones

<u>Center frequency, motor position, and temperature:</u> displays the current values

<u>Move motors:</u> opens the move motors window (see below)

## Move motors

Clicking 'Move motors' in the footer brings up the following page:

# config.txt and user_config.txt

config.txt and user_config.txt contain many variables that can be modified to change the behavior of the program.

Acertara recommends that you create copies of these files before changing parameters so that you can change back if there is unexpected behavior.

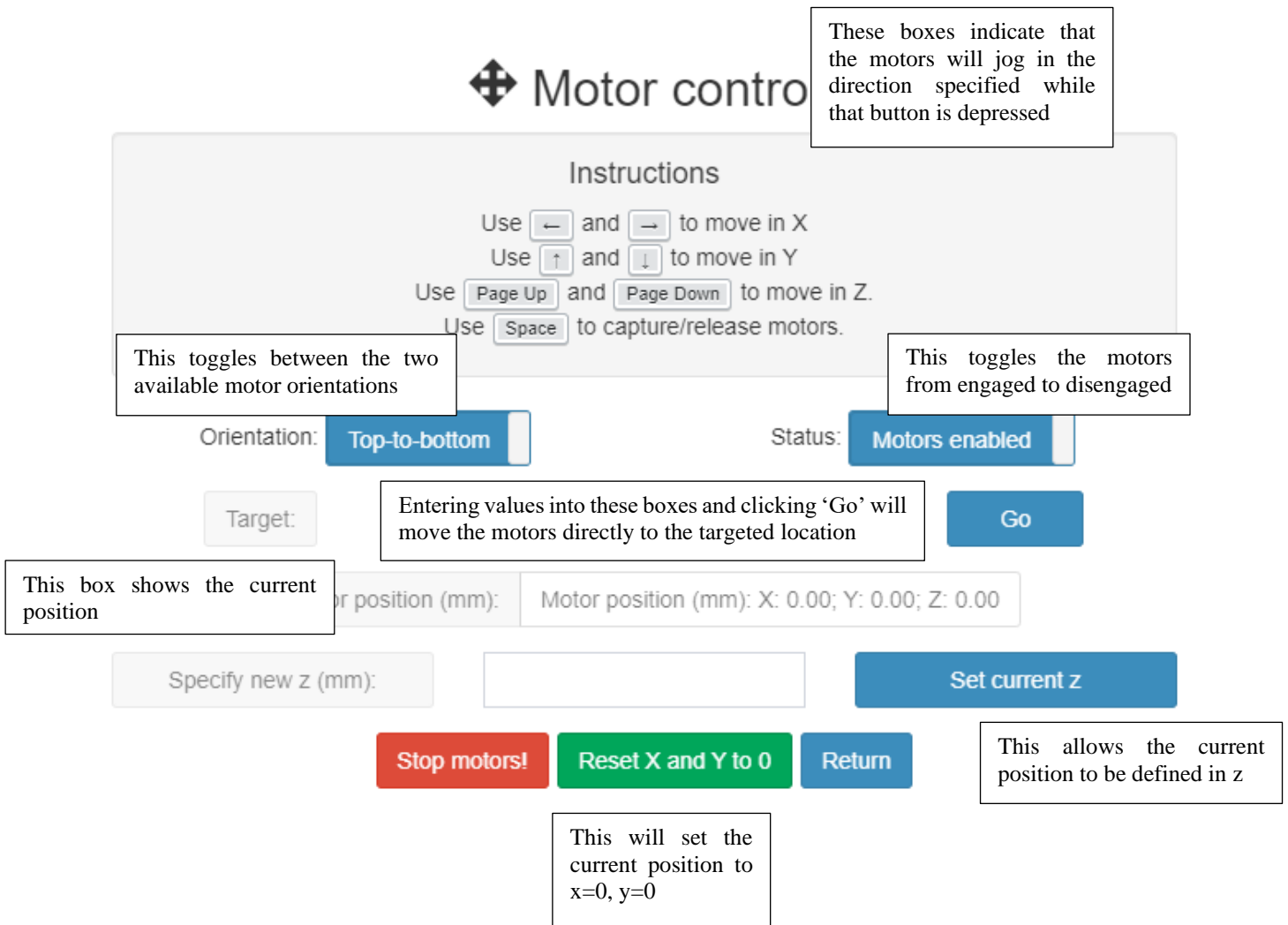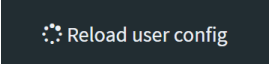config.py is run when the program is initialized. Changes to this file will not take effect until the next time the program is run.

user_config.py is also run when the program is initialized, but it will be re-initialized if the button

  is clicked in the GUI.

user_config.py contains most of the variables that can be expected to change on a regular basis.

**Specific variables of note:**

| | |
|---|---|
| dut_override | If the values of these keys are not '-1', the value they represent in the program will be overwritten by the new value entered here. For instance, if 'f_c' is changed from '-1' to '5.5', the center frequency will be treated as 5.5 MHz, even if the waveform returns a different value for center frequency. |
| calc_pars | Default values put into the analysis tool. |
| alignmentmethod | See alignment section of this document |
| plot_pars | Changes the appearance of various plots both during operation and in the output phase. For instance, 'raster_colormap' will take any matplotlib colormap to color the real-time raster plot. 'wfm_plot_f2' will change the upper limit of the *x*-axis of frequency spectra plots. |
| autosearch | Whenever autosearch is checked, and during fine z-scans and during alignment, the program undergoes a search routine to find the peak at that depth and location. <br><br> 'method' changes how it does this: **'CenterOfMass'** performs a small cross axis scan (with search limit 'CoMsearchLim' in steps of 'CoMstepinlambda') and return to the center of mass of the points evaluated. This is the slowest search method, but is useful when evaluating unfocused devices (eg. physiotherapy), or highly focused sources when away from the focal depth (eg. HIFU). <br><br> **'PeakPII'** searches the *x* and *y*-directions for 3 successive drops to identify a local maximum to which it will return. <br><br> **'PeakRMS'** follows the same algorithm as 'PeakPII' but it bases the search on the RMS of the scope, rather than transferring the waveform at each location. 'PeakRMS' is the fastest method but can get lost. |

# Remote control (rc) interface

From version 3.2.5 onwards, an optional remote control interface is available. Contact Acertara if your system is not so-equipped. The rc interface allows access to functions after some of the error checking. Care should be taken while setting up an rc routine. It is recommended that an rc routine be developed in parallel to using the system from the GUI, though the `run_headless` option allows an established rc routine to execute with no visual feedback on the host machine.

0. Enabling/setting up rc connection:
- In config.txt, the following rc parameters are available:

```
###############RC TOOLS#########################
HOST = '127.0.0.1'  # Standard loopback interface address (localhost)
PORT = 50005        # Port to listen on (non-privileged ports are > 1023)
client_rec_buffer = 4096  # bytes
run_headless = False
```

- HOST can be any ip address to which clients should attempt to make a connection
- PORT can be nearly any number > 1023
- client_rec_buffer is the maximum number of bytes sent in either direction. Most commands are much shorter, but the interface allows the client to obtain some metadata from the host that may be longer. 4096 bytes is recommended for normal operation
- run_headless, if True, will start AMSPy without attempting to launch the normal web-based GUI
- Two files are provided in rcTools. Neither file is required to interface with AMSPy though, together, they provide an example of the available functionality.
- The TCP_IP and TCP_PORT must match the values assigned by config.txt for HOST and PORT, respectively
- A valid license code must be found in the licenses.txt file to enable the rc interface

1. The example program can be run through the standalone python distribution in rcTools. For example, from a command prompt, run `python_rc.bat rcAMSpy_menu.py` while AMSpy is running. If the configuration is correct, the following should appear:

The choices are as follows:
0. CONNECTSCOPE. Accepts three parameters: scope type, scope IP, acquisition channel.
    a. Eg. `tektronix mdo, 10.1.0.22, 1`. This will attempt to connect to a tektronix mdo scope on ip address 10.1.0.22 with channel 1 being the active channel.
    b. If no arguments are provided, an attempt will be made with default values from config.txt
    c. Returns 'REVERTED_TO_DEFAULT' if the system opted to use default configurations (no parameters or invalid parameters supplied), or a success message if the values supplied were used appropriately.
1. CONNECTMOTORS. Accepts four parameters: motor controller type, orientation, motor ip, minimum safe z distance.
    a. Eg. `galil, right-to-left, 10.1.0.23, 3`. This will attempt to connect to galil motors on ip address 10.1.0.23, configured so that the positive z-axis runs from right-to-left. A minimum z depth of 3 mm is assigned creating a soft limit for subsequently-assigned movement targets (cannot be less than 3 mm, though job motors commands and the ability to reset the current z depth are known workarounds for this soft limit.)
    b. If no arguments are provided, an attempt will be made with the default values from config.txt
    c. Returns 'REVERTED_TO_DEFAULT' if the system opted to use default configurations (no parameters or invalid parameters supplied), or a success message if the values supplied were used appropriately.
2. CONFIRMINIT. Requests the status of the scope and motor connections.
    a. Returns TRUE if both connections are made; otherwise returns a string describing what connections have been made successfully
3. SPECIFYJOB. Accepts a single parameter: a path to where the data will be stored
    a. If no arguments are provided, a date/time stamped default directory will be made in the output directory as specified in config.txt
    b. Returns TRUE if a directory was created successfully
4. SPECIFYPROBE. Accepts 1) a comma separated list in `key,value,key,value…` format or, 2) the absolute path to a csv file containing probe parameters. The available keys are as reported in any of the output files under `DUT`. For example,
    a. probe_sn: "asdf",
    b. nom_fdepth: 50,
    c. nom_fdepthelev: 50,
    d. nom_fc: 3.5,
    e. tag: "",
    f. probe_name: "test",
    g. operator: "",
    h. CWflag: false,
    i. aperturetype: "circle",
    j. aperturecircleOD: 12.5,
    k. aperturecircleID: 0,
    l. aperturerectLen: 6,
    m. aperturerectHei: 4,
    n. apertureother: 3.14159,
    o. z_bp: 18.75
    Would be sent as
    `probe_sn,asdf,nom_fdepth,50,nom_fdepthelev,50,nom_fc,3.5,tag,"",probe_name,test,operator,""
    ,CWflag,false,aperturetype,circle,aperturecircleOD,12.5,aperturecircleID,0,aperturerectLen,6,aper
    turerectHei,4,apertureotehr,3.14159`. Note: it is possible to send only a subset of these key/value pairs (eg. k through n in this example would not be used as the aperturetype is circle)

    The csv file would bear some resemblance to the probe templates as saved by the GUI, though probe templates do not include the probe_sn and operator info
5. GETPROBE. Returns information about the current DUT. If a specific key is provided, only that value will be returned; otherwise, the entire set of key/value pairs is returned

6. SPECIFYHYD. Accepts the absolute path to a properly-formatted hydrophone data file. Returns HYDROPHONE_INITIALIZED if this hydrophone is parsed appropriately. If no path is supplied, the code will use the default hydrophone per config.txt.
7. SET_FC. Sets the functional center frequency (used to determine step sizes; an alternative to 'first waveform' collection.
8. GET_META. Returns the metadata of the most recent acquisition sequence (commands 9-12)
9. ACQ_ZSCAN. Accepts four parameters: z_start, z_stop, z_step, do_searches at each location.
   a. Eg. 5,55,5,false would perform a non-search z-scan from 5 mm to 55 mm in 5 mm steps
   b. This command triggers a holding pattern that checks for completion regularly. When the z scan is finished, 'Long task completed' is returned.
   c. After the sequence is complete, information about it can be obtained using command 8 'GET_META'
10. ACQ_XCN. Accepts four parameters: depth, search limit, step size, do initial search.
   a. Eg. pii3,-26,0.5,false performs a set of cross-axis scans at the pii.3 depth (defined by z-scan) to a drop-off of -26 dB from the peak in 0.5 $\lambda$ steps. No initial autosearch is performed. If the first parameter (depth) is a number, this will be treated as a depth in mm
   b. This command triggers a holding pattern that checks for completion regularly. When the z scan is finished, 'Long task completed' is returned.
   c. After the sequence is complete, information about it can be obtained using command 8 'GET_META'
11. ACQ_RST. Accepts four parameters: depth, x-span, y-span, and step size.
   a. Eg. pii3,10,12,1 performs a raster scan at the pii3 depth with an x-span of 10 mm, a y-span of 12 mm, and a step size of $\lambda$
   b. This command triggers a holding pattern that checks for completion regularly. When the z scan is finished, 'Long task completed' is returned.
   c. After the sequence is complete, information about it can be obtained using command 8 'GET_META'
12. ACQ_WFM. Accepts five parameters: depth, time resolution, acquisition channel, if an autosearch should be performed, if spatial averaging should be estimated
   a. Eg. pii0,high,1,true,false performs a waveform capture at the pii0 depth with the 'high' number of points on the oscilloscope using data from channel 1. A search is performed beforehand, but not a spatial averaging measurement routine
   b. This command triggers a holding pattern that checks for completion regularly. When the z scan is finished, 'Long task completed' is returned.
   c. After the sequence is complete, information about it can be obtained using command 8 'GET_META'
13. GET_LOC. Returns the current location
14. SET_LOC. Accepts a comma-separated list of coordinates to assign to the current motor position
15. GO_LOC. Accepts a comma-separated list of coordinates defining a location to which the motors should move
16. CLOSE. Attempts to close the rc connection gracefully (AMSPy will continue to run)
17. x. Tells AMSPy to stop running (will not close web tab, though). Then severs rc connection.

Note: if the rc connection is closed (Eg. by ctrl + c in the command prompt), the program will interrupt any long task (commands 9-12) as a safety measure.

**Note: the rc commands can be customized. Please contact Acertara for more information. The version described here might not be generalizable or what is found on your system.**

# AMSPy: sending emails

AMSPy can be configured to send emails to report certain things (advanced reporting for report review; as an option if an acceptance criterion fails).

AMSPy is currently configured to support two email protocols: smtp and gmail (using the google api client). File `config.txt` contains the following:

```
email_from = 'sender@gmail.com'
email_alias = 'Joe Exotic'   # smtp only
email_password = '<include password>'   # smtp only
email_smtp = 'smtp.somewhere.com'   # smtp only
email_to_business = 'businessside@somewhere.com'   # report review
email_to_handson = 'handson@somewhere.com'   # report review
email_to_technical = 'technicalreader@somewhere.com'   # report review
email_to_operator = 'operator@somewhere.com'   # in case of acceptance
criterion failure
```

If the email_from is a gmail address, follow the directions from google to create a local token that will allow AMSPy to send emails through the gmail address: https://developers.google.com/sheets/api/quickstart/python. Once this process is complete, a file called `token.pickle` will be stored in the local (usually C:/AMS) directory. This token should allow emails to be sent.

If the email address provided (email_from) is not a gmail address, an attempt will be made to send an email using email_from, email_password, and email_smtp. A simplified program that follows the same path is as follows:

```python
import smtplib
from email.message import EmailMessage

config = dict()
config["email_from"] = "joe@exotic.com"
config["email_alias"] = "Joe Exotic"
config["email_smtp"] = "smtp.exotic.com"
config["email_password"] = "Tigers123"

msg = EmailMessage()
msg.set_content("Please support my candidacy")
msg["Subject"] = "I am running for president"
msg["From"] = config["email_alias"]
msg["To"] = "testrecipient@america.com"
server = smtplib.SMTP_SSL(config["email_smtp"], 465)
server.login(config["email_from"], config["email_password"])
server.send_message(msg)
server.close()
```

It is recommended that one test the various methods of sending email using the suggested smtp program or the quickstart.py file provided by google prior to trying to use AMSPy to send emails.

# Appendix A. Hydrophone Data Files

In order to provide properly calibrated measurement data, the AMS system needs information on the sensitivity of the hydrophone being used. In addition, the measurement accuracy is affected by the effective size of the hydrophone's sensitive element. For membrane-type hydrophones, this effective diameter is different than the nominal spot size (because of poling field considerations) and is frequency dependent (because of Lamb waves within the membrane structure). The software uses the effective diameter information to compensate for any spatial averaging that may occur during the measurement of the ultrasonic beam characteristics.

The manufacturer of the hydrophone should supply both the sensitivity and effective diameter data.

The sensitivity and effective diameter data are stored as values as a function of frequency, for as many frequency points as are available. The AMS program will interpolate between these frequency data points if the measured center frequency of the ultrasound signal is within the range of stored data. If the measured center frequency is outside of the range of supplied data, the program will use the value supplied at the nearest calibration point. This is illustrated in the figures below, where data was available from 1.0 to 20.0 MHz. In the example below, the program will use 0.026 mV/Pa for frequencies below 1.0 MHz and 0.053 mV/Pa above 20.0MHz.
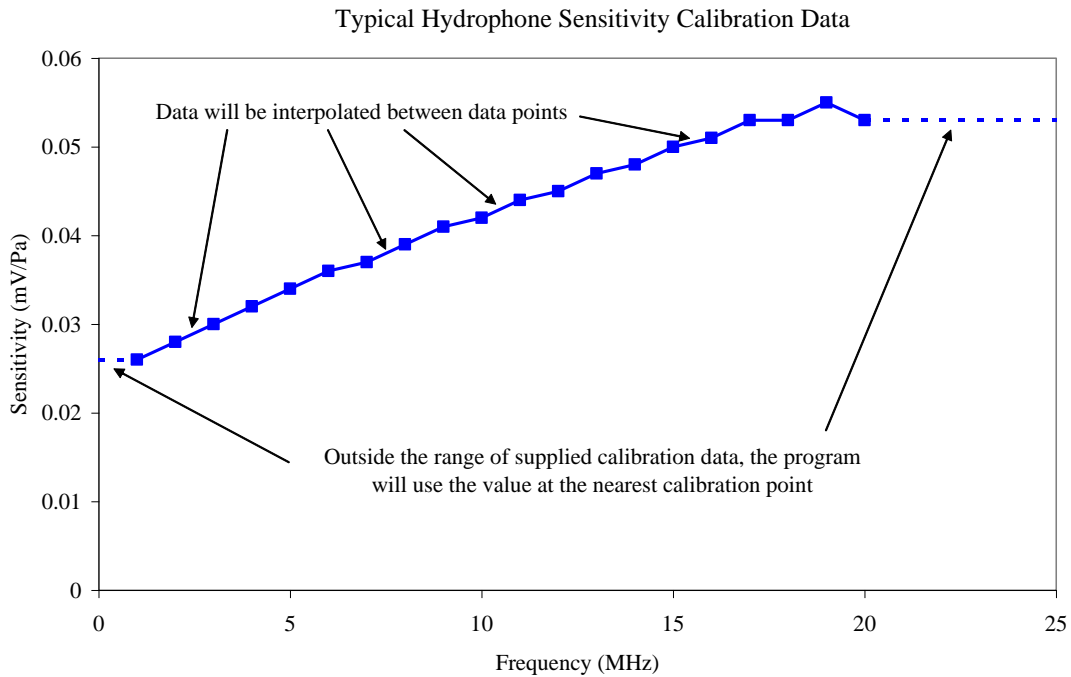


**Figure 1. Example Hydrophone Sensitivity Data**

# Hydrophone data file format

Here is an example hydrophone data file, with column labels (A, B, C) and line numbers added for clarity. **These should not be present in the final file.**

| | A | B | C |
|---|---|---|---|
| | | A | B | C |
| 1 | Hydrophone: | S5-394 | |
| 2 | Last Calibrated: | 11/15/2017 | |
| 3 | Data Entered by: | Person A | |
| 4 | On: | Monday, November 27, 2017  10:00 AM | |
| 5 | Using Global Rev: | 3 | |
| 6 | Preamp: | Y | |
| 7 | Preamp: | Internal | |
| 8 | Num of Points: | 30 | |
| 9 | Freq (MHz) | Sens | |
| 10 | 2 | 0.037 | -268.6359655 |
| 11 | 4 | 0.04 | -267.9588002 |
| 12 | 6 | 0.043 | -267.3306309 |
| 13 | 8 | 0.045 | -266.9357497 |
| 14 | 10 | 0.046 | -266.7448434 |
| 15 | 12 | 0.047 | -266.5580428 |
| 16 | 14 | 0.046 | -266.7448434 |
| 17 | 16 | 0.046 | -266.7448434 |
| 18 | 18 | 0.045 | -266.9357497 |
| 19 | 20 | 0.044 | -267.1309465 |
| 20 | 22 | 0.043 | -267.3306309 |
| 21 | 24 | 0.042 | -267.5350142 |
| 22 | 26 | 0.041 | -267.7443229 |
| 23 | 28 | 0.041 | -267.7443229 |
| 24 | 30 | 0.04 | -267.9588002 |
| 25 | 32 | 0.04 | -267.9588002 |
| 26 | 34 | 0.04 | -267.9588002 |
| 27 | 36 | 0.039 | -268.1787079 |
| 28 | 38 | 0.039 | -268.1787079 |
| 29 | 40 | 0.038 | -268.4043281 |
| 30 | 42 | 0.036 | -268.87395 |
| 31 | 44 | 0.033 | -269.6297212 |
| 32 | 46 | 0.03 | -270.4575749 |
| 33 | 48 | 0.026 | -271.700533 |
| 34 | 50 | 0.021 | -273.5556141 |
| 35 | 52 | 0.018 | -274.8945499 |
| 36 | 54 | 0.015 | -276.4781748 |
| 37 | 56 | 0.012 | -278.4163751 |
| 38 | 58 | 0.01 | -280 |
| 39 | 60 | 0.009 | -280.9151498 |
| 40 | Num of Diam Points: | 3 | |
| 41 | Freq (MHz) | Diam | |
| 42 | 5 | 0.524169 | |
| 43 | 7.5 | 0.497531 | |
| 44 | 10 | 0.490657 | |

Essential components:
1. File name must end in ".hyd" in order for the software to recognize that it is a hydrophone data file.
2. Data must be tab-delimited.
3. The name in B1 will be attached to all files captured with it.
4. If entered correctly, the 'last calibrated' date in combination with config parameters 'validate_calibration = True' and 'val_cal_years = xx.' and 'val_cal_warning_years = xx.' will warn the user if the time since calibration exceeds val_cal_warning_years, or give a

caution if the time since calibration exceeds 'val_cal_years'.

5. If B6 is 'Y' or 'yes', the oscilloscope will be set to have an input impedance of 50Ωwhile if B6 is 'N' or 'no', the oscilloscope will be set to have an input impedance of 1 kΩ.

6. A line needs to begin with 'Num of Points', as in A8, followed by an integer giving the number of lines of frequency/sensitivity pairs (B8).

7. After the frequency/sensitivity pairs, a line needs to begin with 'Num of Diam Points', as in A40, followed by an integer giving the number of frequency/diameter pairs (B40).

8. Frequency must be given in MHz (column A), sensitivity must be in linear units of µV/Pa (column B). Column C shown here in log units is optional and is not used by the software.

Note:
The number of frequency/sensitivity pairs and frequency/diameter pairs need not be the number shown in the example

# Appendix B. Maintenance

**Mechanical components**
Acertara recommends lubricating rails and ball screws with petroleum jelly or a light coat of machine oil on a quarterly basis, or whenever these components appear dry.

**Paratus water conditioning unit**
For system fitted with the Paratus water conditioning unit, Acertara recommends the following:
1. **Daily Inspection**
    a. Verify Blue Light on U.V. Filter body is lit while Paratus is in operation.
        i. No Light = Replace U.V. Filter Bulb.

    b. Verify Vacuum Gauge reads > 2.25 in/Hg
        i. Vacuum Gauge reads < 2.25 in/Hg contact Acertara.

    c. Verify Flow is > 1 GPM
        i. Replace U.V. Filter and Sediment Filter.
            1. 10 µm filter used in U.V. Filter.
            2. 5 µm  filter used in Sediment Filter.

2. **Weekly Inspection**
        i. Inspect Paratus return tube and AMS Tank walls for algae or other contaminants.  Wipe contaminated areas with cloth and mix with AMS tank water. Run Paratus to filter and kill contaminants.

Program Timer to treat water daily at these time intervals: 45 minutes for small AMS tank and 90 minutes for large AMS tank.

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