



# SoundTrap ST300 and ST4300

## series user guide

September 2021



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## ***1 About this guide***

This guide begins with a 'Quick start' section to help you get going with your new SoundTrap, including software installation and basic deployment instructions. This is followed by several sections containing more detailed information around operation, deployment, maintenance and troubleshooting. It is highly recommended you read the entire guide to ensure you have a good understanding of the instrument and how to get the most from its capabilities.

## ***2 Quick start guide***

To start using your SoundTrap you'll need to install the SoundTrap Host software.

### ***2.1 Install the SoundTrap host on your PC***

- Pre-installation Notes:
  - The SoundTrap host software supports Windows 7 and 8 (32 or 64 bit versions).
  - Do not connect the SoundTrap to your computer until you have completed the SoundTrap host software installation.
  - The installation will be smoother if you're logged into windows as an administrator.
- Visit [www.OceanInstruments.co.nz/downloads/](http://www.OceanInstruments.co.nz/downloads/) to download the software.
- Download and run the installer.
- Once the install completes, run the SoundTrap Host application.

### ***2.2 Connect SoundTrap to your PC***

- Connect the SoundTrap using the USB cable provided.
- The drivers will take a couple of minutes to install. Once complete you should see your SoundTrap appear in the 'Device List' on the left, as shown in figure 1.
- Select your SoundTrap by clicking its label on the left.

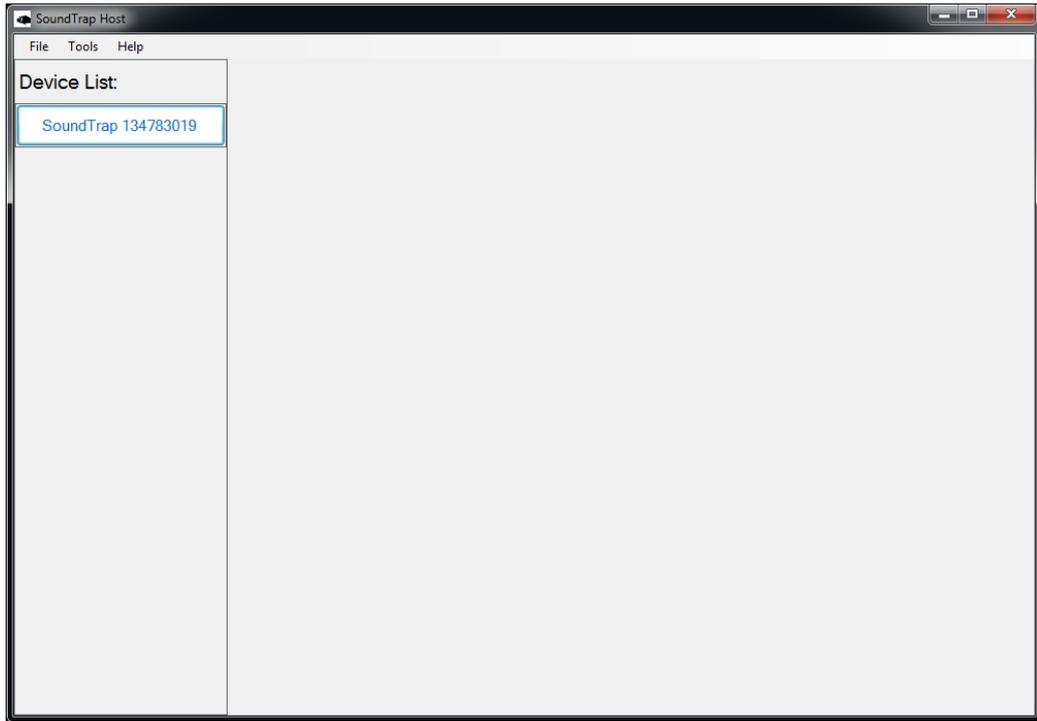


Figure 1 - The Device List

### ***2.3 Check SoundTrap Status***

Note the 'Status' panel on the right (Figure 3). Verify that the battery has sufficient charge and the memory is not full.

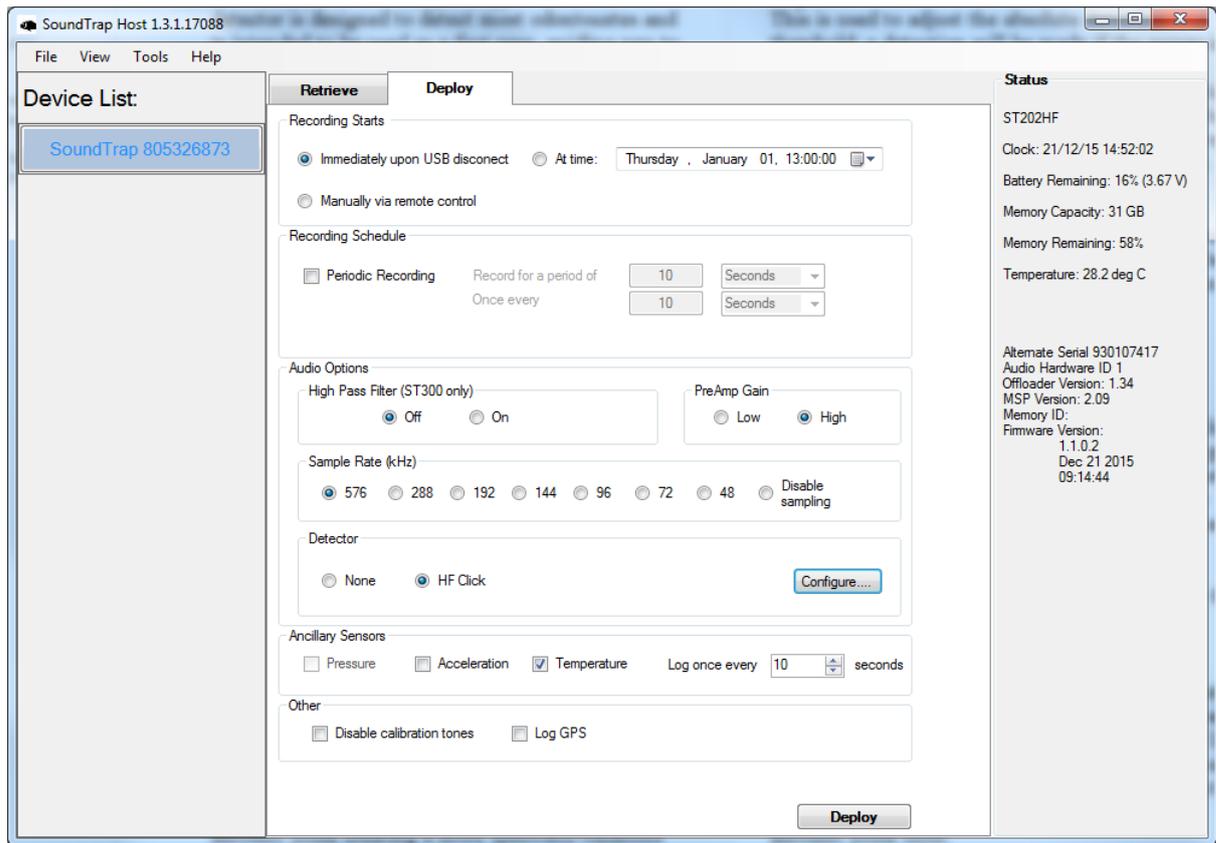


Figure 2 – Deploy Control

## 2.4 Configure the deployment

- Select the 'Deploy' tab as shown in figure 2.
- Configure the deployment parameters as follows:
  - The '**Recording Starts**' section determines when recording will begin. Recording can begin immediately on disconnection of the USB cable, at a pre-determined date and time, or manually using the IR remote control. Note that the remote can always be used to override the other options.
  - The '**Recording Schedule**' section provides selection of continuous or periodic recording. For continuous recording simply leave the 'Periodic Recording' option unchecked.
  - Options available in the '**Audio Options**' will vary according to your device's capabilities. Options include the following:
    - **Channel Selection** selects which channels to record on.

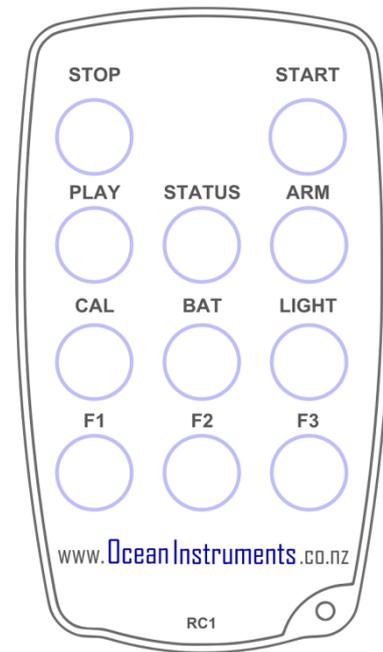
- **Sample Rate** should be set based on the frequency band of interest and data rate considerations. A 96 kHz sampling rate is often a good choice for general environmental noise measurements. Contact OI support if unsure.
  - **Preamp Gain** should usually be set to 'High'. This will result in a maximum SPL before clipping of approximately 172 dB re 1 uPa. The 'Low' setting should be used for very noisy environments such as in the vicinity of pile driving. The low setting increases the maximum SPL to around 184 dB, but comes at the cost of lower sensitivity.
  - **High pass filter**. This should usually be turned off. Generally only used in high energy sites or when towing a SoundTrap behind a boat. Turning this on reduces sensitivity in the band 0 to 600 Hz, while leaving higher frequencies unaffected.
- Detector – see HF Click Detector section below.
  - Ancillary sensors – select those you want to log and at what interval. See following section for details.
- Once you've made your selections click the deploy button which will save the settings and you're ready to go!
  - The instruments internal clock is synchronised to your PC when you click the deploy button.
  - If you change your mind about something, just re-select the instrument from the 'Device List'.
  - Unplug the USB cable and replace it with the dummy plug. If the connector becomes dry, lubricate with silicon grease or spray to ensure a water tight fit.

**Your SoundTrap is supplied with a dummy plug for the wet connector. Please ensure that you remember to use it when deploying the SoundTrap in order to prevent damage.**

## 2.5 Begin recording using the IR Remote Control

You may use the remote control to start recording.

- Press 'START' to start recording.
  - Press 'STOP' to stop recording.
  - If you have set a recording to start recording at a later time, the recorder will blink red to indicate it is 'armed' and waiting.
  - The 'armed' state is cancelled by pressing Stop key.
  - Re-enable the armed state by pressing the ARM button.
- 
- You can verify recording has started by checking for slow blinking of the status (green) indicator.
  - Note that the remote is splash proof and designed to tolerate wet hands. Don't attempt to use it underwater – you'll be disappointed.



## 2.6 Data Offload

Once you're done recording, reconnect your SoundTrap to your PC and select the Retrieve Tab, as shown in figure 4.

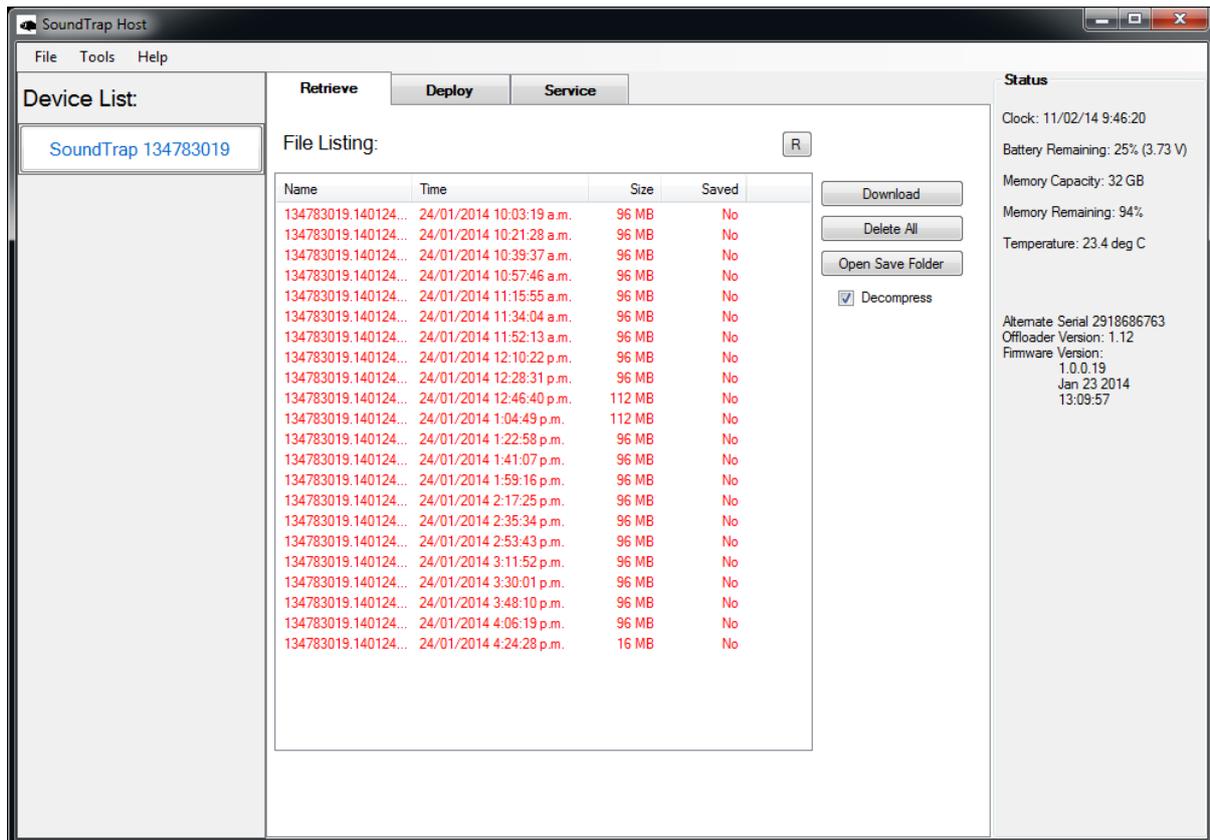


Figure 3 – Retrieve Tab

- You will see a list of files in the SoundTrap's memory, including the file name (made from the device serial number plus local date and time), date recorded, approximate size and whether it has yet been downloaded to your computer's hard drive.
- Download individual files by right clicking the file and selecting 'download'.
- By default all files will be downloaded to a 'SoundTrap' folder under My Documents. This default location can be changed under the 'Tools' menu.
- Click the 'Open Save Folder' button to open the download folder location.
- To download all files, select all files using the shift key, then click the 'Download' button.
- To delete, click the 'Delete All' button. Files cannot be deleted individually.

- For faster download in the field, or to save disk space, un-check the 'Decompress' checkbox. This will disable the decompression step of the offload process, meaning you will end up with 'sud' files only. These can be decompressed into wav files at a later time using the 'File Extraction' option under the tools menu.

## **3 More details**

### **3.1 Data Files**

Downloads produce several types of files:

- 'sud' files which are the raw downloaded file. This is a compressed file and therefore ideal for storing or sending of complete recordings. It can then be decompressed at a later time into the following constituent file formats.
- 'wav' files containing the audio. This is a Microsoft WAV format file that can be opened by any media player, matlab, raven etc.
- 'xml' files which contain metadata such as date recorded, gain setting, etc.
- 'csv' files containing ancillary sensor data (e.g. temperature)

All file types follow the same naming convention consisting of the device serial number followed by the date and time of the start of the recording in the format YYMMDDHHMMSS.

For duty cycled recording there will usually be one file per recording period. For continuous recording a maximum file length of 1036800000 samples (2GB of wav) will determine the length of the files. This equates to 1 hour recordings for a 288khz sample rate.

Where smaller than 2G files are desired for continuous recording it is recommended to set a duty cycle with 'zero off time'. For example, a duty cycle of 30 minutes every 30 minutes will result in continuous 30 minutes files with no missing samples between files.

### **3.2 Battery charging**

SoundTrap uses an internal rechargeable Lithium ion battery. The battery is recharged by plugging the SoundTrap into a computer's USB port, or other USB power supply. Look for the blue LED indicator to confirm that the battery is charging. Once the charging cycle completes the blue indicator will extinguish. Charging time for ST202 (STD or HF) is approximately 8 hours for a completely discharged battery. Some additional notes about battery charging:

- The battery will charge while data is being offloaded over the USB.
- The charge level reported by the SoundTrap Host software (in percentage and voltage terms) is only accurate to within approximately 10%. Determination of whether the battery is fully charged should be by observation of the blue LED indicator, NOT the approximation given by the Host software.

- Once the battery reaches full charge (blue indicator extinguished) the charge indicator in the Host software will start to fall. The charging process will restart once the charge indicator drops to around 90%. Do not be concerned that the battery is not fully charged. Provided the blue LED is not lit, the battery should be considered fully charged.
- Battery charging will be quicker when the SoundTrap is not connected to the host software. If the green LED is NOT flashing (indicating USB communication mode) battery recharging will be quicker. As such, for quickest recharge time do not start the Host software, or alternatively charge the SoundTrap from a USB power supply rather than a computer.
- The battery should not be left for long periods in a discharged state. When storing a SoundTrap for the off-season, ensure the battery is fully recharged before placing in storage. To ensure battery longevity, give the battery a top up once every 3 months.
- If the SoundTrap has been left unused for several months the battery may be in a severely discharged condition. In order to recover from this state the SoundTrap will begin trickle charging the battery until it reaches a normal state. This process can be very slow if the SoundTrap is connected to the Host software. See the trouble shooting guide if your SoundTrap has trouble recovering from this condition.

### ***3.3 Using the optional external battery pack***

The ST300 series products support the connection of an external battery pack. Connection of the battery pack is straightforward. First fit the battery pack with 3 x fresh D cell alkaline batteries, carefully ensuring correct polarity.

**We strongly recommend using Energizer brand batteries.** Advertised dururances are based on this brand, and performance of other brands is unknown. Most importantly, Energizers are guaranteed not to leak electrolyte when left in a discharged state. Other battery brands may leak, possibly causing damage.

Before opening the housing always check for flooding by shaking the recorder and listening for water sloshing around inside. If flooding is suspected, then be aware that the housing may be pressurised and therefore potentially dangerous. Carefully relieve any pressure by opening the small seal screw at the base of the housing.

Before closing the battery housing ensure that the o’ring seal is perfectly clean, free from nicks or other damage, well lubricated and properly seated. Generously apply silicon o’ring grease on both the o’ring and the tubes sealing surface. Close the housing by screwing closed by hand until the shoulder snugs up against the titanium tube. You may choose to use a lever arm (e.g. screwdriver) through the holes provided top and bottom. However difficulty in screwing home the cap may indicate insufficient o’ring lubrication; do not apply excessive force – instead correct by applying o’ring lubricant.

Fit the supplied cable between the battery pack and SoundTrap, using the supplied plastic collars to lock the two connectors. The cable should plug in without effort. Where it is difficult to insert it is important to lubricate the connector with silicon grease or spray.

Verify the supply of power from the external battery to the SoundTrap. Do this by pressing the ‘BAT’ button on the IR remote and observing the SoundTrap’s red status LED. If all is well you should see two long red flashes. Note that there is a 10 second delay between connecting the battery and the software determining that the supply is stable. Observation of the two long flashes is confirmation that the external battery is available, has viable batteries, and is ready to go.

A single short red flash indicates a problem. In this event, disconnect the external battery and inspect for correct battery insertion and adequate battery condition.

When deploying with the battery pack it is important to avoid any strain on the cable. Tight bends close to the connector are particularly problematic as they can cause the connector rubber to deform and allow water to reach the contacts. This will destroy the connector. **It is therefore very important to avoid tight bends in the cable.**

### ***3.4 Calculation of deployment endurance***

An excel spreadsheet is provided on the web site to help with the calculation of deployment times for differing deployment parameters. The spreadsheet provides deployment estimates, as well as identifying one of three possible deployment constraints: battery capacity, memory capacity, or file count. While the first two are obvious, the file count constraint requires explanation.

The file system used by SoundTrap currently has a minimum file size of 4 MB. When using periodic recording, if the programmed 'record for a period of' period is very short, the resultant file may be smaller than the minimum file size. This will result in inefficient usage of memory, and the deployment may be artificially memory limited. For example, a SoundTrap 202 has 64 GB of memory; dividing this by the minimum file size of 4 MB gives a maximum of 16000 files.

This limitation becomes an issue when using low sample rates in combination with X3 compression. By experimenting with the periodic recording parameters in the deployment spreadsheet it will become clear how to best avoid this limitation.

### ***3.5 Clock details***

SoundTrap's clock is synchronised to your PC whenever you click on the 'deploy' button, with an accuracy of +/- 0.5s.

Internally the clock is maintained in UTC time. When files are offloaded to the PC file times are converted to local time (using the PC's location settings) for population of the filenames. This means that the dates and times in the filenames are always in the time zone of the PC that was used to offload the files. This can be important where files are offloaded in a region other than that in which they were recorded. Alternatively, filenames can be assigned UTC times by selecting the 'Use UTC time' option under the tools menu.

Like most electronic devices, SoundTrap relies on a crystal oscillator for time keeping. The oscillator used in the ST300/ST4300 has an accuracy of +/- 20PPM, or +/- 1.77 seconds per day. The audio sample rate is derived from the same oscillator, meaning the sample rate is subject to the same

accuracy. The oscillator will drift with temperature with this range. For more information on the clock accuracy please see documentation for the oscillator – part OV-7604-C7-STD-020.

Sampling rate accuracy is also subject to occasional sampling gaps. The nature of SD flash memory cards is such that occasional the memory card will fail to keep up with sampling, thereby resulting in dropped samples. When this occurs, an entry will be written to the log (xml) files in the format “sampling gap X us at sample Y”. There is an experimental option under the Tools menu ‘Zero Fill Dropouts’. This function will attempt to fill any sampling gaps with a series of zeros. This may be useful where more precise sampling timing is required.

### 3.6 Ancillary Sensors

All SoundTraps include temperature and accelerometer sensors. Logging of these is enabled by selecting the corresponding checkbox in the deployment screen of the SoundTrap Host software. Note that logging can only take place while the recorder is awake, meaning that sensor logging is subject to the same duty cycle as that configured for audio recording.

Sensor data is offloaded alongside audio data, and is decompressed into CSV format files, one file per sensor, per audio recording.

Temperature data is recorded in degrees Celsius. Note that these measurements are only valid when the instrument is fully submerged, and that measurements made in air will be incorrect due to internal heat build-up, particularly when connected to USB and recharging the battery.

Accelerometer data is recorded as unscaled 16 bit values ranging +/- 32768. The full scale sensitivity of the accelerometer is +/- 2 g, meaning each count represents 61 ug. The orientation of the accelerometers axis for the ST300 is shown in the adjacent diagram. Older ST200 models have the X and Y axis transposed. Note that the X & Y axis are not easily discerned as the rotation of the sensor within the housing varies. This is generally of little consequence for inclination and cable strum applications, but where required can be measured by placing the recorder in a known static orientation, observing the resultant measurements and solving for gravitational acceleration. For those wanting more detailed information on the accelerometer sensor characteristics, please refer to the datasheet for the Kionix KXTI9.

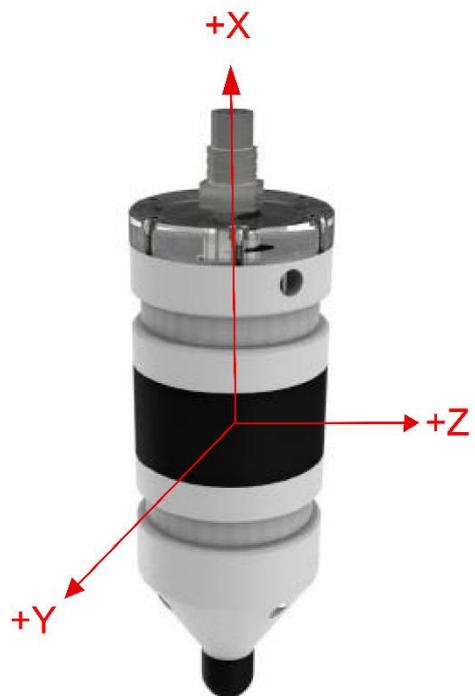


Figure 4 - Accelerometer axis for ST300

### ***3.7 ST4300 multi channel recording***

The ST4300 supports connection of up to four external hydrophones. These are connected via four wetplugs at the base of the recorder. Each wetplug has a number adjacent to it relating it to the channel selection in the deployment settings.

ST4300 output files are multichannel wav files where the channel numbering is from lowest to highest physical channel number. For example - recording on channels 2 and 4 only would result in a two channel wav file with the 1<sup>st</sup> wav channel pertaining to the 2<sup>nd</sup> physical channel.

Recording endurance will be reduced by increased channel count due to both increased power consumption and data rate. We recommend using our online endurance calculator to make these calculations. Note that the calculator assumes use of HTI-96-MIN hydrophones which consume approximately 3.6 mW. Use of other hydrophones may give different results.

Compatible hydrophones can be obtained from High Tech Inc USA with model code:

*HTI-96-MIN/3V/Low Noise/SoundTrap/-165dB.*

This model has bandwidth of 30 kHz. For higher frequency models we recommend discussing your requirements with HTI.

While use of other manufacturers hydrophones is possible we advise a cautious approach. To be compatible hydrophones must operate on a 3V supply with a max power draw of 10 mW. Contact OI for more information including connector pin-out.

**Is is critical that unused channel connectors are protected with dummy wet plugs. Failure to do so will result in damage.**

### 3.8 Deployment scheme

The anchoring scheme used is very dependent on the goals of the data collection in combination with the deployment environment. Thankfully SoundTraps are more easily deployed than traditional acoustic recorders due to their small size. A SoundTrap's weight in water is approximately 0.5 kg.

Most often the hydrophone is located near the sea floor, using an anchored line. This involves running a line between a heavy anchor weight and either a surface or sub-surface float. A sub-surface float is often best, as it is less affected by weather/swell and is less likely to be tampered with. The SoundTrap should be attached to the line a couple of meters off the bottom. Two grooves in the housing circumference provide attachment points for cable ties for this purpose. Do not use hose clamps or any other fastener that will place clamping stress on the housing as this may cause damage. There are also two lanyard attachment points which can be used to provide additional security/redundancy.

Ensure there are no metal objects in close proximity (3cm) to the SoundTrap wet connector eg using metal brackets or wire rope. Doing so may lead to galvanic corrosion (and eventual failure) of the stainless steel wet-socket body.

Don't mount your SoundTrap so close to the sea floor that it may become covered in sand or mud. This will also lead to corrosion and eventual failure of the wet connector.

Be mindful that a taut line combined with strong currents may result in 'cable strum' which may disrupt your recordings. In this case a rigid frame may be more appropriate.

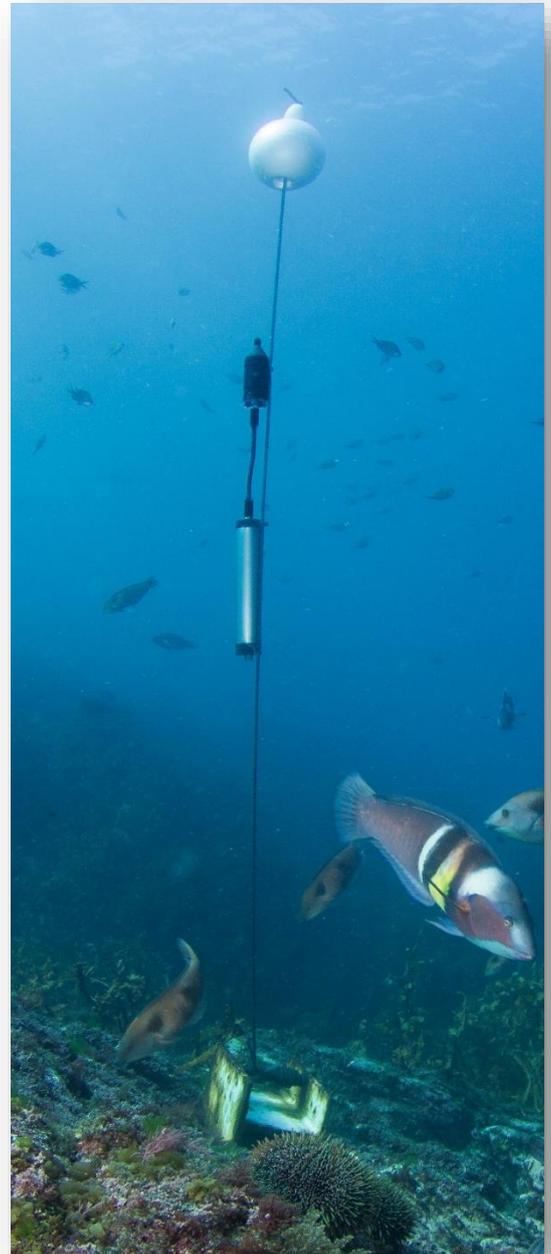


Figure 5 - Typical deployment including external battery

## **Deploying with the external battery housing**

The external battery housing has two cable tie slots, bottom and top. Cable ties should be threaded through the associated holes so they cannot slip off. When using an external battery housing the weight of the complete system in water is approximately 1.5 kg. It is important to ensure that the battery and recorder are secured to the line such that there is minimal stress on the power cable. See the image alongside as an example.

### ***3.9 Housing maintenance***

SoundTrap ST200 & ST300 series recorders come in two housing types – standard and deep with 500 and 1000m depth rating respectively. Both types of housing are filled with mineral oil in order to achieve their depth rating. You will notice an air bubble visible through the transparent window, which over time will tend to grow in size.

#### ***Standard housing (500m rated)***

Most ST300 recorders are of this type. For this housing topping up is only necessary when deploying deeper than 200m. If the air bubble becomes larger than approximately 12 mm diameter and you intend to deploy beyond 100m then you should top it up.

#### ***Deep Housing (1000m rated)***

This housing is recognisable by the soft rubber diaphragm around it's middle section. Most ST200 series recorders are of this type. When using these housings at **any depth** it is important to check that the mineral oil is topped up. If the air bubble is larger than approximately 12 mm diameter, the oil must be topped up.

#### **Topping up procedure**

Topping up is done via the filler port screw, located next to the wet plug socket. This is best achieved using a syringe and large gauge needle (16 gauge works well). The oil should be a good quality mineral oil, as commonly available from drug stores. Feel free to send us an email if you are unsure.

### ***3.10 Software updates***

New software releases will be made available via the Ocean Instruments website. You may wish to subscribe to our email list in order to receive notification of these updates. The update procedure is generally straightforward – simply install the new software over top of the existing by running the msi file and following the usual Windows software install prompts.

The software updates will typically include updates to both the windows software as well as the device firmware. The updating of the device firmware is an automatic process that occurs when pressing the ‘deploy’ button.

### ***3.11 MSP firmware updates***

From time to time a software release may include an update to the ‘MSP’ firmware. This is a special section of the device firmware that changes infrequently. In the rare event that an MSP update is required, the user will be advised during the deploy procedure and will be asked to connect the ‘reset battery’. This is a security feature that ensures the MSP firmware cannot be unintentionally modified. In order to proceed you will need a 9V battery. When asked to ‘connect the reset battery’ you should connect the 9V battery to the battery connector provided on the USB cable. **Note that you must make this connection in one smooth motion, being careful not to ‘bounce’ the connections between the battery and the contacts.** Once the connection is made you can click the OK button as per the software instructions. You will then be asked to remove the reset battery. This done, the MSP firmware update will proceed and complete within a few seconds. If presented with the error message “MSP Erase failed”, it is likely that the connection of the battery was not smooth – please try again, this time ensuring that the contacts come together in a smooth motion, without bouncing.

### ***3.12 Calibration***

Each SoundTrap is factory calibrated from new. The standard factory calibration consists of a piston phone calibration at 250 Hz, performed for both low and high gain settings. The calibration data is not shipped with the hydrophone, but instead made available online from the calibration page of the Ocean Instruments website <http://www.oceaninstruments.co.nz/>

The calibration data is provided as an end-to-end value. This measure is provided for both high and low gain settings, and represents the SPL that will result in a normalised ( $\pm 1.0$ ) wav file with a full-scale signal ie 2.0 units peak to peak.

Note that in contrast to traditional hydrophone systems, with SoundTraps there is no need to be concerned with sensitivity in voltage terms. Because SoundTraps integrate the recorder and hydrophone in a single package, there is a fixed relationship between sound pressure and the resultant wav file data, thereby simplifying calibration and eliminating the need for voltage calculations.

Application of the calibration data varies depending on the software used. Descriptions follow for some of the most commonly used software.

### **MATLAB**

To convert wav data to units of uPa, simply scale by the end-to-end calibration value. Example code:

```
[y, Fs] = wavread(filename);           % read wav data from file
cal = 173.3;                           % value from calibration sheet
cal = power(10, cal / 20);              % convert calibration from dB into ratio
y = y * cal;                            % multiply wav data by calibration to convert to units of uPa
```

### **PAMGUARD**

PAMGAURD expects calibration data in terms of gain and ADC range. To work around this, specify a preamplifier gain of the calibration value \* -1.0 (eg -176.0) and specify the Peak-Peak voltage range as 2.0 V.

### **PAMGuide**

PAMGuide provides several convenient calibration schemes. For SoundTrap data select the end-to-end calibration type and enter a system sensitivity of the calibration value \* -1.0 (eg -176.0).

### **Audacity**

Audacity reports SPL in units of dB re full scale. To scale SoundTrap data use the following:

Value in dB re 1 uPa = audacity value + end-to-end calibration – 3dB;

For example, if the end-to-end value from the calibration sheet is 176.0 dB, and audacity reports a level of -70 dB, the calibrated SPL is 103.0 dB re 1 uPa.

### ***Calibration Tones***

By default, a series of calibration tones will be audible at the beginning of each recording. These can be used to check the calibration of the recording. After applying the calibration to a recording, the SPL of the 1 kHz tone should be equal to the calibration tone level stated on the calibration sheet.

If the calibration tones are an annoyance, they can be disabled on the deploy tab. However, we recommend keeping them enabled where possible as they provide a useful check of system calibration and performance.

### ***ST4300 Calibration***

ST4300 recorders have a fixed gain of -4dB. Overall system calibration is determined by the hydrophone used. This is calculated by adding recorder gain to the hydrophone calibration. For example, using a hydrophone with a sensitivity of 177 dB re 1uPa will result in an overall system calibration of 173 dB. This is the SPL that will result in a normalised ( $\pm 1.0$ ) wav file with a full-scale signal ie 2.0 units peak to peak. This can be applied to data using the application examples above.

### **3.13 Troubleshooting**

First port of call when experiencing problems is to check that you are using the most up to date software. Oftentimes small issues are most easily resolved by updating the software – please try this first. The latest software can be downloaded from here:

[www.OceanInstruments.co.nz/downloads/](http://www.OceanInstruments.co.nz/downloads/)

**Problem:** SoundTrap doesn't appear in device list when plugged into computer

**Solution:** This is usually due to the batteries being dead flat. When deploying for long periods the battery may become discharged to the point the device is incapable of communicating over the USB. Quickest solution is to:

1. Disconnect the SoundTrap from the USB
2. Close the SoundTrap Host software
3. Reconnect the SoundTrap to the USB
4. If the blue LED indicator does not light, press the STOP button on the remote
5. The blue LED indicator should now light to indicate battery is charging.
6. Leave for at least 30 minutes to allow the battery to recover.
7. Start the host software and confirm device connects.

**Problem:** Offload process reports errors and produces smaller than expected files.

**Solution:** This indicates errors with USB communication. Common causes include:

1. Offloading when the recorder battery is very low - recharge overnight and try again
2. Using a external hard drive on the same set of ports - this can overload the USB controller.
3. Using a USB hub - try connecting directly to the computer
4. Using a low-quality laptop - try a better computer
5. The recorder wetsocket is in poor condition - carefully clean internal contacts.

**Problem:** SoundTrap still won't connect despite having recharged the batteries.

**Solution:** In cases of extreme battery discharge (e.g. a SoundTrap that has been in storage for several months), it may be necessary to reset the device hardware. Before doing the reset, first

ensure you have recharged the battery as above, preferably leaving to charge overnight in order to recondition the battery. Then perform a hardware reset (this won't result in any loss of data):

1. Disconnect the SoundTrap from the computer USB port, leaving the offload cable attached to the SoundTrap.
2. Momentarily touch a 9V battery to the battery clip on the offload cable.
3. You should see the green LED blink to indicate a successful reset.
4. Point the IR remote at the clear window and press 'STOP', press a couple of times to be sure it is received.
5. Connect the SoundTrap to the USB.
8. Start the host software and confirm device connects.

**Problem:** SoundTrap battery won't recharge, or reports wildly fluctuating battery charge.

**Solution:** This most often occurs in cases of complete battery discharge followed by a long period of disuse. For future avoidance of this problem ensure that you store SoundTraps with the battery in a charged state. The battery can often be recovered using the following method:

1. Connect the SoundTrap to a USB wall charger, such as that used for a mobile smart phone.
2. Leave on charge for a minimum of 48 hours.
3. Reconnect to a PC and check that battery reports full charge (i.e. > 85 %).
4. If the problem persists contact Ocean Instruments to arrange for the battery to be replaced.

**Problem:** IR Remote is not working.

**Solution:**

1. Check that it has a battery. These are not supplied due to shipping restrictions. Correct battery type is the commonly available CR2032. Be sure to remove the plastic insulator sheet before inserting the battery.
2. Ensure that you are pointing the remote directly at the clear window at the top.

## **4 Appendices**

### **4.1 SoundTrap HF Click Detector**

The SoundTrap 'HF Click' Detector is a general purpose high frequency click detector followed by a snippet extractor. The detector is designed to detect most odontocetes and is intended to be used as a first pass, guiding you to times in your recordings with lots of transients. You would typically use the detector with a low detection threshold so that it makes a lot of false detects but also detects most genuine clicks (i.e., high sensitivity, low specificity). You then evaluate the reported detections in Pamguard to reduce obvious false detects, to classify clicks into species groups, and to identify bouts, as you would with a continuous wideband recording. The benefits of doing on-board click detection are that you get much longer recording times from your SoundTrap and you can identify times of interest more quickly when you get the data back. The downside of course is that you do not have the full wideband recording on the SoundTrap. This is mitigated in SoundTrap's detector by recording a short snippet of wideband sound around each detection. A few 100's of  $\mu\text{s}$  is often all that is needed to classify odontocete clicks into general classes. The detector can be configured to also make a continuous recording at lower bandwidth that allows you to quantify the general ambient noise conditions, an important factor affecting detector performance, as well as the presence of low frequency whistles that can help with species identification.

#### **4.1.1 Click detector**

The click detector comprises an approximate pre-whitening filter followed by a power-in-band Constant False Alarm Rate (CFAR) detector. The whitening filter (a 35kHz high-pass filter) corrects the typical low-frequency emphasis of underwater ambient noise creating a more spectrally-balanced signal for the detector. The power-in-band detector consists of a highpass Finite Impulse Response (FIR) filter (approximate 3 dB bandwidth 115 - 160 kHz) followed by a moving average power estimator. The duration of the moving average window is a user parameter (see below). In parallel, the power of the full bandwidth whitened signal is measured using a much longer exponential window to give an estimate of the ambient noise power. This is used to adjust the absolute detection threshold: a detection will be made if the power-in-band is greater than the ambient power by more than the Relative Detection Threshold (RDT) which is a user parameter. When a detection is made, the time of the detection and the ambient noise power at the time are passed to the snippet extractor. A user-selectable blanking time must then elapse before another

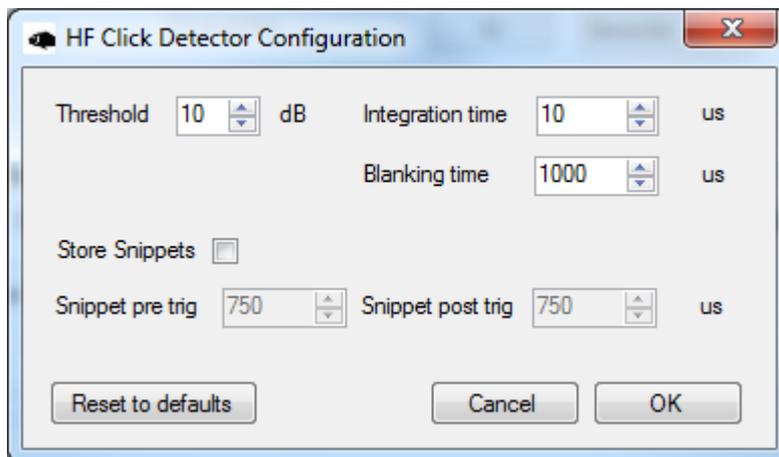
detection can be made. This blanking-time is useful to avoid detecting echoes from a click or to prevent detecting a large number of clicks if an animal is buzzing near the recorder.

### 4.1.2 Snippet extractor

For each detection, an entry is added to the detection log and a snippet of wideband sound surrounding the detection time is saved. The snippet starts and ends a user-selectable time before and after the detection (user parameters: *pre-trigger* and *post-trigger*). Evidently, saving longer snippets per detection means that the memory is used up more rapidly so this feature allows the user to trade-off the amount of context that is saved for each detection against the total recording time. It is important to note that the snippet is taken from the whitened sound and so is high-pass filtered.

### 4.1.3 User parameters

The user parameters can be set by clicking the 'Configure' button in the Detector section.



**Threshold:** The level in dB that the power-in-band must exceed the ambient noise level by for a detection to take place. A value of 12 dB will have a high detection rate but will produce many false positives. A value of 20 dB will detect only strong transients that are well above the ambient noise floor.

**Integration Time:** Set this to the approximate duration of the clicks of interest. For most delphinids you would use a short averaging time, e.g., 70  $\mu$ s, while for beaked whales, porpoises and NBHF delphinids, an averaging time of 150-300  $\mu$ s would be appropriate. If you are interested in detecting any toothed whale click, you can either go with a long averaging time (which will reduce the SNR of

short transients and so give poorer detection of delphinids) or an intermediate value which will tend to reduce sensitivity to both short and long transients but not by much.

*Blanking time:* Time that must then elapse after a detection before another detection can be made. Useful to avoid detecting echoes from a click or to prevent detecting a large number of clicks if an animal is buzzing near the recorder.

*Store Snippets:* Select to enable storage of detection snippets.

*Snippet pre- and post-trigger durations:* The time with respect to the detection at which the snippet will be taken. The snippet starts *pre-trigger* seconds before the detection and ends *post-trigger* seconds after the detection. These are both limited to 1.5 ms maximum which is more than long enough to cover odontocete clicks. The number of samples saved per snippet is determined by the sum of the pre- and post-trigger times. With the maximum settings, 1728 samples will be saved per snippet.

#### **4.1.4 Output File formats**

The ST click detector produces two additional output files per recording with suffixes 'bcl' and 'dvw'. These are in addition to the .wav and .xml files generated normally. The Pamguard interface automatically interprets these files when displaying detection and continuous recording results. For users interested in accessing the data using other interfaces, the details of the file formats are given below:

- **xml** This is the metadata file produced by SoundTrap to document each recording. The ST detector adds metadata about the detector and the user settings to this file.
- **wav** This is a Microsoft WAV format file containing the decimated continuous sound recording produced in parallel with the detector. The sampling rate is selected by the user but would typically be 48kHz or 96kHz to maximize recording time. By default, sound data is compressed in the SoundTrap using the lossless X3 compressor but this is transparent to the user: the .wav file contains the reconstituted uncompressed data.
- **dvw** This is a Microsoft WAV format file containing the wideband sound snippets for each detection. The sampling rate is 576 kHz and the snippets are arranged contiguously with a constant number of samples per snippet. The size of each snippet is set the by the pre- and post-trigger user parameters. The snippet size in samples will be close to  $\text{round}((\text{pre}+\text{post})\cdot 576e3)$  but the precise sample count can be found in the .xml file (see the Matlab tools for an example of how to extract this information automatically). By default,

snippet sound data is compressed using the lossless X3 compressor but this is transparent to the user: the .dwv file contains the reconstituted uncompressed data. Up to 100000 snippets will be saved per recording (i.e., per output file). If more detections are made over this interval, they will be reported in the BCL file (see below) but no snippet will be saved. This puts an upper limit on the memory usage rate making it easier to calculate for how long the SoundTrap will be able to record.

- **bcl** This is a comma-separated-variable (CSV) text file containing information about detections. Each line has 7 columns with the following format:

*Seconds (in Unix seconds), Microseconds, Report type, Info1,Info2,Info3,Info4,*

To obtain high enough resolution, timing information is spread over two fields (Seconds and Microseconds). The time of each entry is then Seconds+Microseconds/1e6. The four Info fields are determined by the report type of which there are two. Detections have a report type of 'D'. The next two fields (Info1 and Info2) indicate whether a snippet was saved (1 or 0) and the noise level at the time of the detection. Fields Info3 and Info4 are not used in detection reports. The second report type is an effort report which has a type of 'E'. The effort report indicates the times over which the detector was operating. There will usually be an on-effort report at the start of each recording (i.e., with a detector state of 1) and an off-effort report at the end of each recording. The on-effort report has no other data and so appears as: *seconds,microseconds,E,1,,*

The off-effort report appears as: *seconds,microseconds,E,0,noise level,ndets,nsaved,*

where ndets is the total number of detections made since going on effort and nsaved is the number of these for which snippets were saved. In both report types, the noise level is given in Centibels, i.e.,  $100 \log_{10}(p)$  where p is the noise power referenced to the recorder calibration. The absolute threshold used for each detection is then  $p+10^{(RDT/10)}$ . If no detections were made throughout a recording, the BCL file will contain two lines:

*start\_time,microseconds,E,1,,*

*end\_time,microseconds,E,0,noise level,0,0*

If there are detections, they will be bracketed between these lines and the appropriate detections counts will be changed in the off-effort report. The BCL file can be read and

displayed by Excel, Libre Office, Open Office etc. See also the Matlab tools for a function to read this file format.

#### ***4.1.5 Click Detector Caveats and Cautions***

While every care has been taken in producing the SoundTrap Click Detector, this is free software offered as is in the hope that it will be useful: there is no warranty, implied or otherwise, nor implication of fitness for any particular purpose. Please use responsibly! Test that the code functions correctly on your SoundTrap before deploying it, e.g., by setting the RDT to 12 dB and then tapping lightly on the hydrophone with a finger nail. Even if the code is functioning, it may not detect clicks because of poor signal-to-noise ratio, because of inappropriate user settings, or because of a poor mooring design (the same problems that would give you a bad continuous recording).