PRECISION ACOUSTICS

Needle hydrophones

Precision Acoustics Ltd manufactures a wide range of Needle hydrophones. The specific choice of hydrophone active element size is largely governed by the frequency of the ultrasonic signal being measured. A range of hydrophone diameters varying from 4.0 mm down to 40 µm permits the measurement of ultrasonic signals from 10 kHz up to 60 MHz. Needle hydrophones are designed to be used in conjunction with a preamplifier and a dedicated DC coupler/power supply. The three items are supplied as a complete system by Precision Acoustics Ltd. Wherever the properties of the hydrophone are stated, they relate to the hydrophone/preamplifier/power-supply combination (a hydrophone system).

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INTRODUCTION

Needle hydrophones have a small circular disc of PVDF mounted on the end of a narrow co-axial conductor. This gives a sensing device, which has a small scattering cross-section and can be used to plot the pressure distribution of ultrasonic fields. Needle hydrophones are commonly mounted directly onto a submersible preamplifier. However, for large amplitude acoustic fields in conjunction with high sensitivity hydrophones an optional attenuator can be inserted between the hydrophone and the preamplifier to prevent saturation of the input stage of the preamplifier.

The preamplifier then connects to a DC Coupler with power supply, which both provides it with power and also conditions the signal ready for acquisition on an oscilloscope with a 50 Ω termination. Very low amplitude signals may benefit from additional gain prior to the oscilloscope input stage and in this case an optional Hydrophone Booster Amplifier is available.

PVDF hydrophones have an inherently wide bandwidth and Needle hydrophones have been calibrated by NPL, London over the frequency range 10 kHz to 60 MHz.

Further information on making acoustic measurements with hydrophones can be found on our website (http://www.acoustics.co.uk). In addition, Precision Acoustics Ltd offers training courses covering many aspects of acoustic measurement techniques and practices.

Unpacking the hydrophone system

Each Needle hydrophones system contains several components. Carefully remove the packaging and identify the following:

- Needle hydrophones

- Preamplifier and DC Coupler

- Calibration certificate (printed)
- In line attenuator (OPTIONAL)
- Mains inlet cable
- Hydrophone booster amplifier (OPTIONAL)

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PREPARING FOR MEASUREMENT

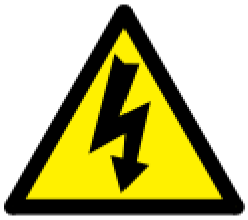
Mounting the hydrophone

Hydrophones should be secured in a fixture that ensure the hydrophone can be moved around in a water tank to align it with the acoustic source. The hydrophone mount should attach to the system via the preamplifier body and not attached directly to the shaft of the needle hydrophone.

An example of a Needle hydrophones within a simple L-shaped hydrophone mount is shown alongside. This mount is available from Precision Acoustics Ltd as an optional extra upon request.

It is recommended that all hydrophones receive 1h soaking before use. It is recommended that the hydrophone is placed in the water tank at this stage before completing the rest of the setup process.

IMPORTANT NOTES



The DC Coupler supplies voltage to the hydrophone preamplifier. It is mains operated and should be positioned away from water and connected to the mains supply via a Residual Current Device (RCD).

WARNING: DO NOT position DC Coupler on moving parts of the test tank system.

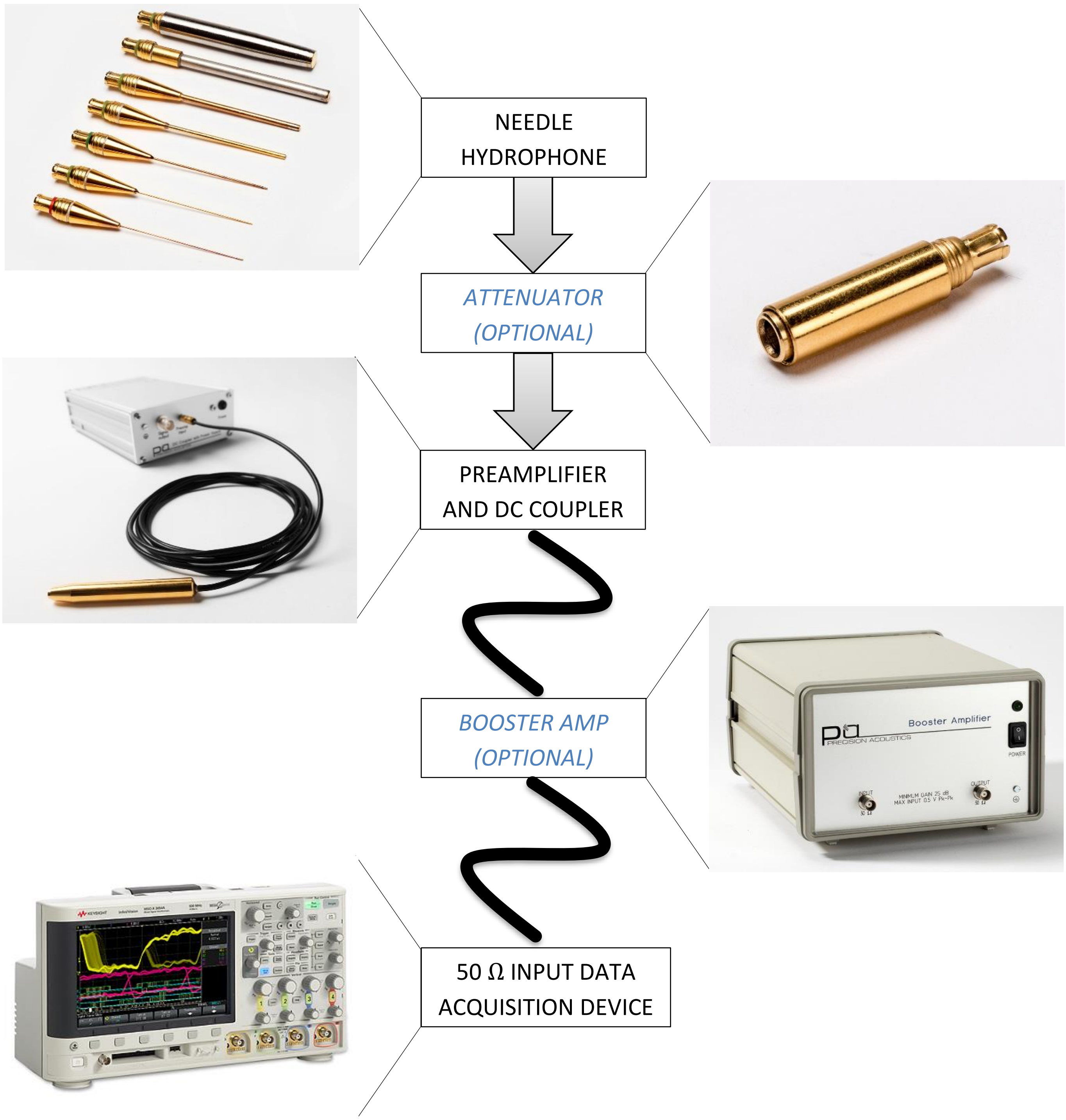
WARNING: If the DC Coupler falls into the water tank, disconnect from mains BEFORE removal from the water.

WARNING: The interchangeable needle probes must be handled with extreme care. The sensor on the tip of each probe is very delicate and must never be touched by hand.

If the equipment is used in a manner not specified in this document, the protection provided by the equipment may be impaired

Only replace the mains cord with one of sufficient current rating

CONNECTING THE HYDROPHONE SYSTEM



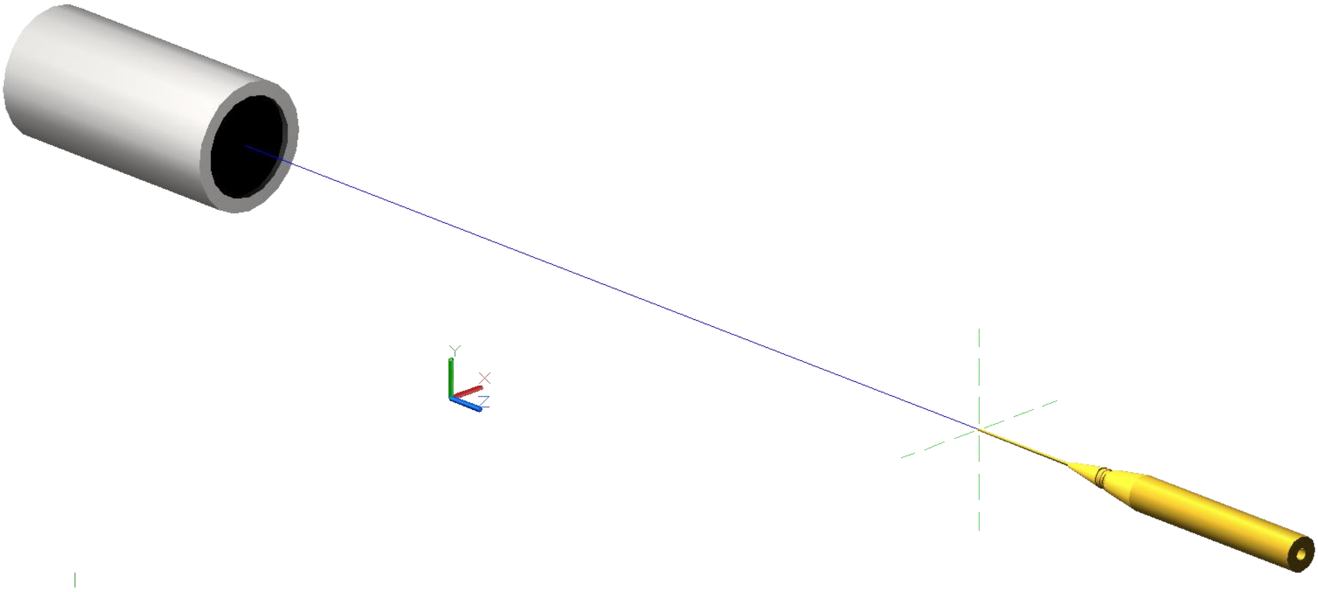
© Keysight Technologies
Image shown for illustrative purposes only

Once the connections above are made, mains power should then be applied to the DC Coupler, the Booster amplifier (if present) and the data acquisition device. The hydrophone system is now ready for operation.

Please see the section “After measurements are complete” for information about care of your hydrophone system after use.

ORIENTATION AND ALIGNMENT

All hydrophones exhibit a directional response, and the maximum hydrophone signal will be received when the shaft of the needle hydrophone is co-axial with the acoustic axis of the transducer (as shown in the image below). If the hydrophone is rotated about the X or Y axes, there may be a reduction in the amplitude of received signal, even if the active element remains on the acoustic axis of the source. This directionality effect will be more noticeable at higher frequencies and with larger hydrophone active elements.



FINDING A HYDROPHONE SIGNAL

- For large amplitude low frequency signals generated by single element transducers, this is not generally a problem. However, for high frequency, narrow beam transducers this can take a significant time, even if you do follow the steps suggested below.
- Set DAQ for a higher sensitivity (e.g. 5-10 mV/div), which can always be changed later.
- Visually align hydrophone and transducer. (Assuming the optical axis is close to acoustic axis)
- Triggering. Check that your DAQ system is triggering properly. Particularly if you are triggering from the acoustic signal, check that you set the trigger level is to a low level since the acoustic signal may be small.
- Assess the transducer–hydrophone distance and use $x = ct$ to calculate approximate propagation delay and set the timebase delay on your DAQ accordingly. Consider using a deliberately reduced timebase delay in conjunction with a larger time per div setting to acquire a longer time trace thereby ensuring that the required signal will be "in there, somewhere". Once found refine settings accordingly.
- Although the signal in the far field of a transducer should be more smoothly varying, a highly directional beam can be difficult to find. Instead, try moving hydrophone close to surface of transducer and locating signal there. Once signal is found, move gradually further away from transducer (aligning hydrophone as necessary on the way) until desired field position is achieved.

- Noise. Where there is poor signal to noise ratio (SNR), it can sometimes be difficult to locate signal.
  - If you believe hydrophone position is correct, use time domain averaging to improve SNR. If signal is buried in noise, it should reveal itself.
  - If averaging is not available on oscilloscope, try moving hydrophone slightly backwards and forwards along the acoustic axis of the transducer. This should cause the signal to move on the screen of the DAQ and the human eye can sometimes recognise a moving pattern easier than a stationary one.

CONVERTING HYDROPHONE VOLTAGE TO ULTRASONIC PRESSURE

A hydrophone produces an electrical output signal in response to the surface integral of the acoustic pressure received over its active element. There may not be a linear relationship between the acoustic pressure stimulus and the voltage response. In fact, the relationship is almost always frequency dependent, and a conversion process will be required to obtain the acoustic pressure signal from the hydrophone output voltage. A detailed description of this process can be found within references [1] [2] and [3]. When the source of ultrasound is only operating at one frequency (e.g. continuous wave) or with very narrow bandwidth (e.g. sinusoidal tone burst) the relevant IEC standard [4] states that the pressure signal, $p(t)$, can be calculated from the measured hydrophone voltage, $v(t)$, according to the relationship

$$p(t) = \frac{v(t)}{M(f_{awf})}$$

where $M(f_{awf})$ = sensitivity of a hydrophone at the acoustic working frequency of the source. More generally however, and especially if the acoustic signal is broadband, the pressure signal should be calculated according to the relationship

$$p(t) = \mathcal{F}^{-1}\left\{\frac{\mathcal{F}(v(t))}{M(f)}\right\}$$

where $\mathcal{F}$ and $\mathcal{F}^{-1}$are the Fourier and inverse Fourier transforms and $M(f)$ = sensitivity of a hydrophone

FINDING THE BEAM MAXIMUM

Many acoustic measurements require the maximum value of the acoustic pressure field to be located. The following two steps are required to maximise the hydrophone signal.

- Correct for directional response of hydrophone – consider the hydrophone active element as lying in the X-Y plane (Z direction coming normally out of active element). There will be a directivity pattern associated with both the X and the Y axes (although hopefully the patterns are the same). First rotate about the X-axis to obtain maximum signal, and then repeat around the Y Axis.
- Find the pressure field maximum – centred on your current position, move the hydrophone along a line parallel with the X-axis. Move the hydrophone to the location of the field maximum along that line. Repeat this type of line scan alignment in the orthogonal direction of the Y-axis. The hydrophone should now be at the position of a maximum. Ensure that your line scans

are long enough to capture the global maximum rather than a local maximum. Repeat with finer scans if required
- If your hydrophone mount does not have truly independent degrees of freedom there may be some translation of the hydrophone tip during rotation, so you may have to iterate through the above two steps.

ALIGNING THE TRANSDUCER BEAM

To align the acoustic axis of the transducer with one of the axes of your hydrophone positioning system.

- Place hydrophone close to the near field /far field separation distance $\frac{a^2}{\lambda}$ of the transducer and conduct a line scan in the X direction, centred on your current position. Note the position of the maximum.
- Move the hydrophone a known distance further into the far field of the transducer and conduct a second, centred line scan. Once again note the position of the maximum.
- Use trigonometry to ascertain the angular misalignment of the acoustic axis of the transducer and rotate the transducer to correct accordingly.
- Repeat this process for the Y direction.
- The transducer may not have well behaved field symmetry and the positions of the maxima may appear to vary as a function of angle, so it is best to repeat the above process for a second iteration, to fine tune the alignment.

AFTER MEASUREMENTS ARE COMPLETE

Once measurements are complete please observe the following steps

- Disconnect the DC Coupler from the main supply
- Remove the Needle hydrophones from the water.
    - Rinse the needle probe with de-ionised water. Do not attempt rub the tip with a cloth/tissue to “clean” it.
- Leave the hydrophone to air dry in a secure location where it cannot get damaged.

TROUBLESHOOTING AND FAQ

Troubleshooting

The DC Coupler has a green LED power indicator on the front panel. If this is not illuminated, then the most likely fault is a blown fuse. If this needs replacing then a 0.2 A, Quick blow, 20 mm fuse should be used.

Provided the MCX connector is intact, there are no electrical or mechanical checks which will determine whether the needle probe is working correctly. It can only be checked acoustically. Connect the needle probe to a DC Coupler / Preamplifier combination that is known to be working. Then follow the instructions above for finding a signal. If no signal can be found and you are certain that your transducer is working correctly, there may be a fault with the needle probe and the system should be returned to Precision Acoustics for a free inspection. Most needle faults can be repaired and, following inspection a quotation will be sent for the repair.

Frequency asked questions (FAQ)

- What liquids can I used my hydrophone in?
    - *The Needle hydrophones is designed for use in de-ionised water with a conductivity of < 5 µS/cm. Degassing so that dissolved gas content is < 5 ppm is also recommended.*
    - *For high amplitude fields the dissolved gas limit changes from recommended to required and the level drops to < 2.5 ppm. Failure to do so may result in cavitation damage to the hydrophone which is NOT covered by our warranty.*
    - *Hydrophones can be used in castor oil or mineral oil. The hydrophone is constructed from PVDF which although resilient can be damaged by some organic solvents. If any medium other than water is used, the calibration figure will not be valid since the medium will have changed the electrical and acoustical loading conditions on the hydrophone*
- Do I have to soak the hydrophone?
    - *All hydrophones should be soaked before use. Our recommendation is to soak for 1 hour so that the output stabilises before measurements are taken, although most hydrophones stabilise after about 20 minutes.*
- How long can I leave the hydrophone in water?
    - *Hydrophones should be removed from the water whenever they are not in use and we advise that if they are left immersed longer than 24 hours they are removed as soon as possible and dried out.*
- How do I dry the hydrophone?
    - *Rinse the hydrophone in distilled water after use and leave to air dry or place in a warm oven at no more than 50 °C. Do not touch the hydrophone tip.*
- How do I clean the calcium carbonate deposits from the hydrophone?
    - *Immerse the hydrophone in lemon juice and then rinse in distilled or running water. Never use a cloth/towel/abrasive cleaner on the tip.*
- Do I have to terminate the hydrophone output in 50 Ω?
    - *The input and output from your measurement equipment should be terminated with 50 Ω. Cables connecting to/from the hydrophone system must have a characteristic impedance of 50 Ω. If your data acquisition equipment has only a high impedance termination then you much use an inline through 50 Ω terminator to achieve the correct impedance*

PRODUCT SUPPORT

Disclaimer

All information is based on results gained from experience and tests, and is believed to be accurate but is given without acceptance of liability for loss or damage attributable to reliance thereon as conditions of use lie outside the control of Precision Acoustics Ltd.

Warranty

Warranty will be for 12 months against defect of hardware component or manufacture only.

If a warranty claim is made on devices that have been calibrated at NPL London, the charge for calibration of the replacement device is pro-rata against the used part of the original device's 12-month calibration.

Warranty replacement after	Calibration period remaining	Discount on recalibration charge
3 months	9 months	75%
8 months	4 months	33%

Contact

Further advice and technical assistance can be obtained from our Applications Engineers

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Terms and conditions

PA terms & conditions are available at https://www.acoustics.co.uk/company/terms-and-conditions/

REFERENCES

[1] A. Hurrell, "Voltage to Pressure Conversion: Are You Getting "Phased" by the Problem?," *J. Phys: Conf. Ser.,* vol. 1, pp. 57-62, 2004.

[2] V. Wilkens and C. Koch, "Improvement of hydrophone measurements on diagnostic ultrasound machines using broadband complex-valued calibration data," *J. Phys: Conf. Ser.,* vol. 1, 2004.

[3] A. M. Hurrell and S. Rajagopal, "The practicalities of obtaining and using hydrophone calibration data to derive pressure waveforms," *IEEE Trans UFFC.,* vol. 64, pp. 126-140, 2017.

[4] IEC, *62127 Ultrasonics - Hydrophones - Part 1: Measurement and characterisation of medical ultrasonic fields up to 40 MHz,* 2013.