PRECISION ACOUSTICS

Differential membrane hydrophone

Precision Acoustics Ltd manufactures a wide range of hydrophones the ultrasonic frequency range. The Differential membrane hydrophone is a gold-standard hydrophone, ideally suited for measurements of broadband ultrasonic signals in the 500 kHz to 100 MHz range. The Differential membrane hydrophone is designed to be used in conjunction with a dedicated power supply that powers the fully differential internal preamplifier. The two items are supplied as a complete system by Precision Acoustics Ltd. Wherever the properties of the hydrophone are stated, they relate to the hydrophone/power-supply combination (a hydrophone system).

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INTRODUCTION

The Differential membrane hydrophone comprises a single layer of PVDF on which gold electrodes have been deposited such that, after polarisation only a small central circular area is piezo-electrically active. This gives a sensing device, which is acoustically transparent and can be used to plot the pressure distribution of ultrasonic fields. Incorporated within the membrane ring is an instrumentation amplifier. The power supply included with the membrane hydrophone provides power to the amplifier and transfers the signal to an oscilloscope through the 50 Ω termination.

PVDF hydrophones have an inherently wide bandwidth and Differential membrane hydrophones have been calibrated by NPL, London over the frequency range 300 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 Differential membrane hydrophone system contains several components. Carefully remove the packaging and identify the following:

- Differential membrane hydrophone

- Membrane hydrophone PSU

- Calibration certificate (printed)
- Mains inlet cable

PREPARING FOR MEASUREMENT

Mounting the hydrophone

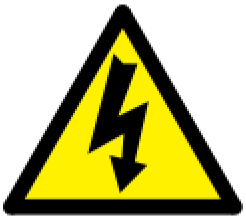
Hydrophones should be secured in a fixture that ensures the hydrophone can be moved around in a water tank to align it with the acoustic source. This could be a simple mount that secures the hydrophone via the two locating holes in the membrane ring or a more comprehensive mount capable of providing rotational adjustment.

An example of a Differential membrane hydrophone within a mount offering 3 independent rotation adjustments 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 NOTE

The membrane hydrophone PSU supplies an amplifier which is embedded in the hydrophone ring. 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 it on moving parts of the test tank system.

WARNING: If the membrane hydrophone PSU falls into the water tank, disconnect from mains BEFORE removal from the water.

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

WARNING: The membrane hydrophone must be handled with extreme care. The membrane is very delicate and must never be touched by hand or rubbed with any form of cloth or tissue.

Connecting the hydrophone system

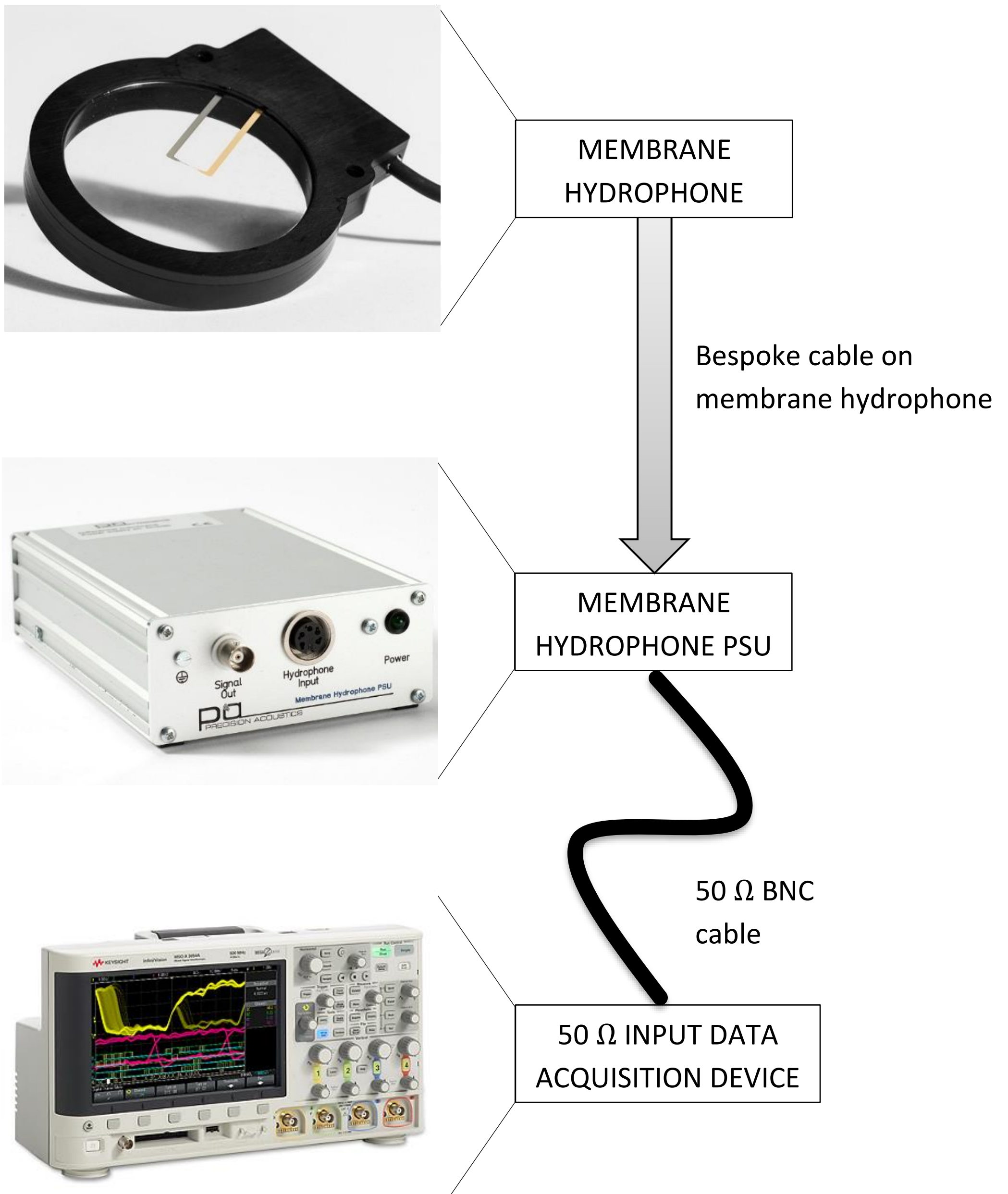


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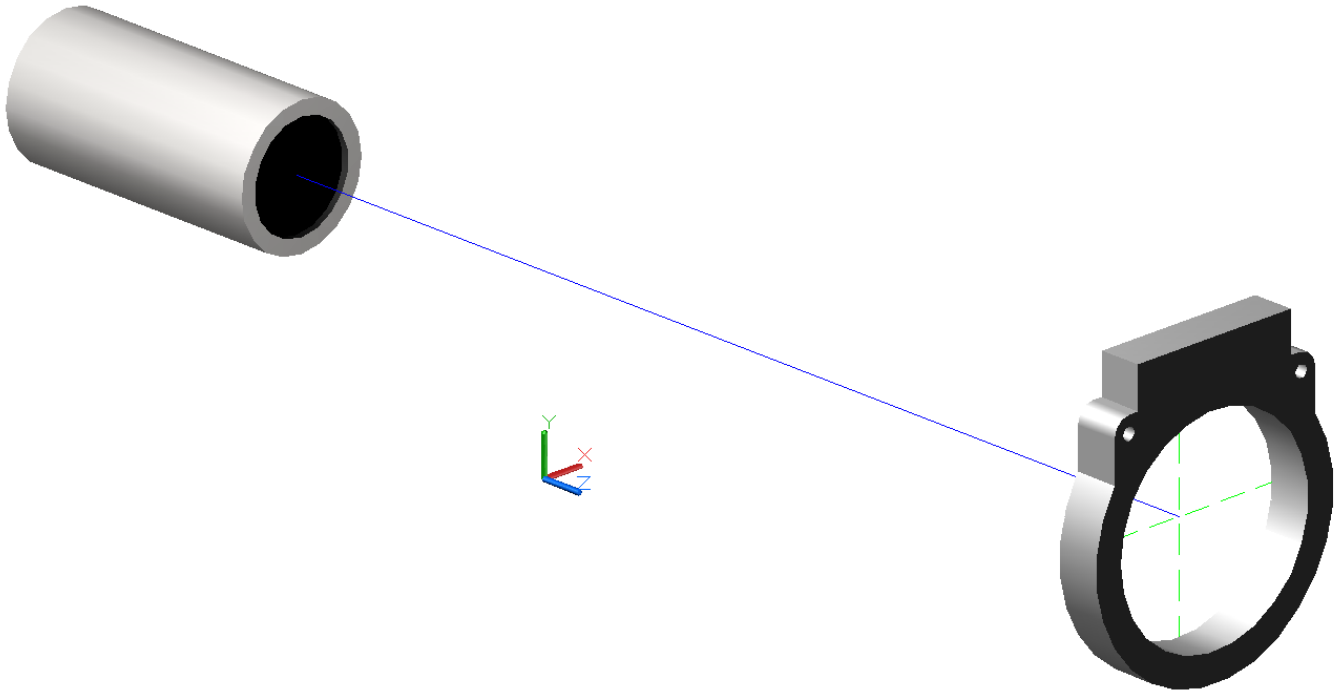
Image shown for illustrative purposes only

Once the connections above are made, mains power should then be applied to the membrane hydrophone PSU 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 plane of the hydrophone active element is orthogonal to the acoustic axis of the transducer (as shown in the image below). If the membrane 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. This can be a particular problem with differential membrane hydrophones where the active area is not clearly visible.
- 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 membrane hydrophone PSU from the main supply
- Remove the Differential membrane hydrophone from the water.
    - Rinse the membrane with de-ionised water. Do not attempt rub the membrane 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 Membrane hydrophone PSU has a green LED power indicator on the front panel. If this is not illuminated then the most likely fault is a blown fuse on the membrane hydrophone PSU. If this needs replacing then a 0.2 A, Quick blow, 20 mm fuse should be used.

Provided the membrane is not physically damaged, there are no electrical or mechanical checks which will determine whether the differential membrane hydrophone is working correctly. It can only be checked acoustically. Ensure that the power supply is working and connected to the membrane cable. 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 membrane hydrophone system should be returned to Precision Acoustics for inspection. It is unlikely that the membrane can be repaired but a generous discount will be offered against a new membrane.

Frequency asked questions (FAQ)

- What liquids can I used my hydrophone in?
    - *The Differential membrane hydrophone is designed for use in 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 membrane surface.*

- 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 membrane*
- 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*

POWER SUPPLY SPECIFICATION

Model number	DPSU
AC supply voltage	Wide range input: 100/120V, 0.2A at 60Hz or 230/240V, 0.2A at 50Hz AC. (switchable)
Input impedance	50 Ω
Output impedance	50 Ω
Power consumption	2.4 W
Operating temperature range	0 °C to 50 °C
Relative humidity (recommended)	50%
Terminations	Custom 5-way connector (input) BNC (output)
Maximum dimensions	185 mm (length) 109 mm (width) 45 mm (height)
Weight	925 g

Note: Connection to a power supply must be made via the mains cord supplied by Precision Acoustics Ltd. If another cord is to be used it must conform to IEC60320-1 or BS1363-1: 2016 (UK only).

PRODUCT SUPPORT

Disclaimer

Use of either the hydrophone or its power supply in a way not in accordance with information provided in these product instructions may be hazardous. Precision Acoustics does not accept liability for incidents occurring as a result of improper use and recommends these instructions MUST be followed.

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.