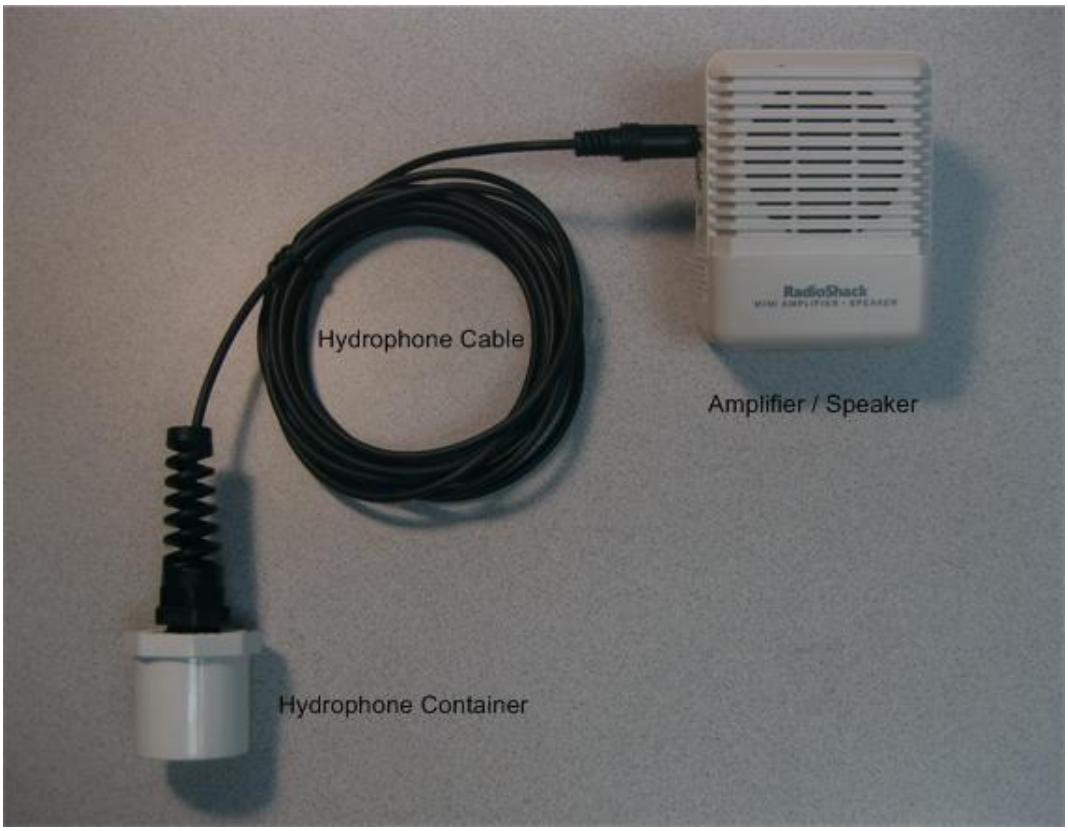
COSEE TEK ~ University of Connecticut
Simple Hydrophone Design

Material List and Fabrication Instructions
Version 4.0 Modified for MaTTS (6/25/2014)
by Kevin Joy, John Hamilton, Matthew Jewell & Ivar Babb



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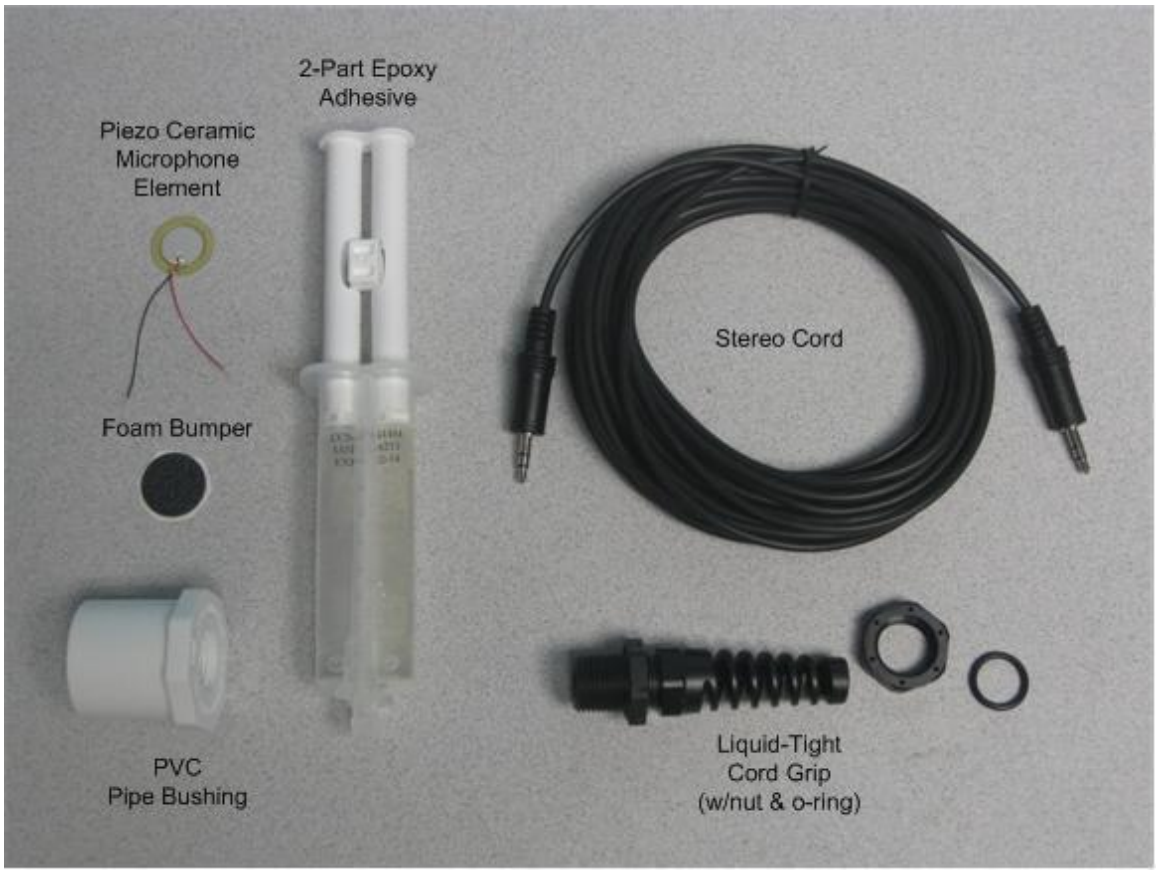
COSEE TEK ~ University of Connecticut

Simple Hydrophone Design - Basic Material List



Hydrophone Components		
Description	Vendor	Part Number
Piezo Ceramic Microphone Element	SparkFun	SEN-10293
Stereo Cord with 3.5mm Connectors (25')	McMaster-Carr	8317T15
2-Part Epoxy Adhesive in a Syringe	McMaster-Carr	7670A22
Adhesive-Backed Round Foam Bumper (100pk)	McMaster-Carr	8213K2
PVC Pipe Hex Reducing Bushing	McMaster-Carr	4880K826
Nylon Liquid-Tight Cord Grip (.08"- .24")	McMaster-Carr	69915K62
Amplifier Components (not shown above)		
Mini Audio Amplifier (not shown)	Radio Shack	277-1008
9Volt Battery for Audio Amplifier	Miscellaneous	

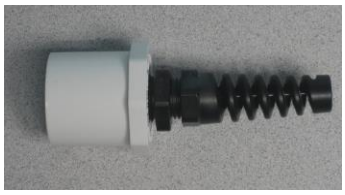
Note:
SparkFun is an online reseller of electronics & electrical supplies (see www.sparkfun.com).
McMaster-Carr is an online reseller of industrial supplies (see www.mcmaster.com).
See Appendix 4 for the complete material list and alternative options.

The COSEE-TEK Simple Hydrophone Design, Version 4.0 project has been developed to offer a simple, functional, and affordable hydrophone that minimizes the need for electrical and/or mechanical expertise while providing a hands-on approach to introduce the science of underwater sound to students of all ages. This document and activity provides a complete material list (Appendix 4), fabrication instructions, and detailed schematics (Appendix 3) to enable the construction of a turnkey hydrophone system for completion within a single laboratory or classroom session. A connection schematic (Appendix 5) is also included to outline the recommended approach to connecting the completed hydrophone system to a personal computer or mobile device for subsequent testing, and/or visual display, capture and analysis of underwater sounds.

This project owes credit to numerous hydrophone designs and DIY (do-it-yourself) projects that were used to form the basis for this activity and considerations for the design provided herein. See Appendix 1 for a complete list of references used in the consideration of this document as well as useful links to other acoustic resources, activities and additional information.

Hydrophone Components:

The hydrophone design presented through this activity demonstrates the use of simple and affordable components for the construction of a useful and functional scientific tool for acoustic research and education. The complete hydrophone system has been designed to offer a turnkey solution through the inclusion of three major system components; 1) hydrophone container; 2) hydrophone cable; and 3) amplifier/speaker.



The hydrophone container is the underwater component of the system designed to provide a termination enclosure in which to house the piezoelectric microphone element as well as all associated electrical connections. This container is fabricated from a simple PVC pipe fitting and Nylon liquid tight cord grip. The PVC fitting provides a suitable enclosure for the piezoelectric microphone element and electrical components, while the cord grip with strain-relief secures the hydrophone cable as it enters the hydrophone container and provides strain relief for the cable at this point of entry. 2-part epoxy adhesive is used to secure, insolate, and seal all electrical components and connections within this hydrophone container.

The hydrophone cable is the component of the system designed to carry the electrical signal, originating from the hydrophone container, to the audio amplifier or other surface equipment. The black PVC jacket of the hydrophone cable provides a watertight layer surrounding the individual conductors of the hydrophone cable, while the 3.5mm male stereo plug provides an ideal means of connecting the hydrophone to the surface-mounted audio amplifier.

Cable Selection and Length Considerations:

A 25' stereo audio cable, with 3.5mm (1/8") male stereo connectors, has been specified within the material list for this activity in order to provide one option of suitable length and design to enable hydrophone deployment to depths of up to 20', while providing direct compatibility with the audio amplifier identified for surface connections. Alternative cables of this design are also available in lengths from 1-1/2' to 50' from the designated supplier, while longer cables are available from alternative material suppliers.

As only one 3.5mm male connector is required for the construction of a single hydrophone, any similar audio cable, having 3.5mm male connectors at each end, can provide for one or two hydrophone builds. Therefore, in selecting the source cable for this activity, consider the length necessary to meet the needs of the application as well as the potential for dividing the cable into two segments, should multiple hydrophones be required. Ultimately, in determining the required length for any hydrophone cable, be sure to consider both the depth to which the hydrophone is to be deployed as well as the length of cable required to reach the audio amplifier and/or other surface equipment.

Note, if you purchase one of the six cable options from the material list, your cable may arrive in one of two different configurations; Type 1 has white, red and yellow wires. This is known as a three conductor cable and was the cable used in documenting/illustrating these instructions. Type 2 has white and red wires and an un-insulated shield wire. This is known as a twisted shielded pair (TSP) cable. **If using the Type 2 cable, the un-insulated shield wire should be used in place of the yellow wire described within this document.**

The Audio Amplifier/Speaker offers an off-the-shelf solution to providing much needed amplification to the source audio signal, while offering a simple means to produce an audible signal of the underwater sounds via a built-in speaker. Additionally, this component of the hydrophone system offers a 3.5mm output jack, enabling simple connection of the amplified audio signal to a personal computer and mobile device for visual display and/or recording.

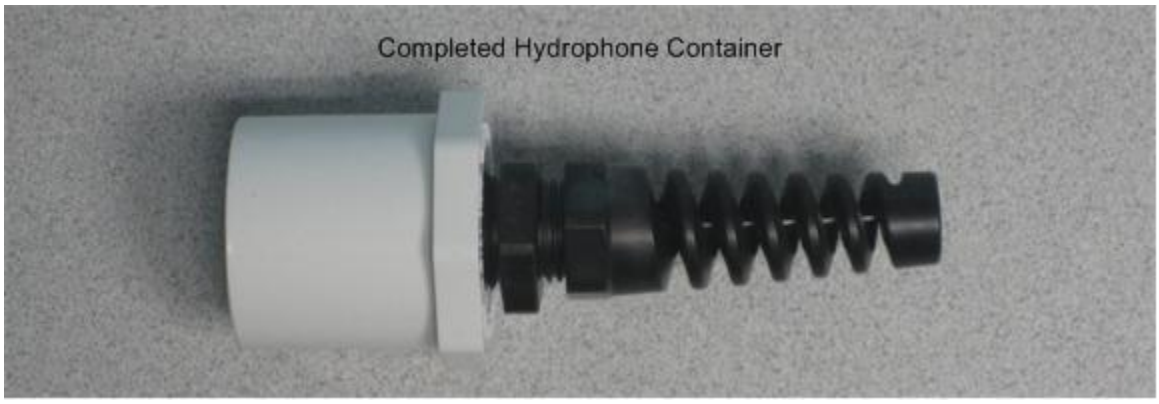
Recommended Tools:

1. Ruler or tape measure
2. Wire strippers (#26AWG to #14AWG)
3. Adjustable or open-ended wrenches
4. Small Philips head screwdriver
5. Scissors
6. Tape (electrical or masking)
7. Rubber gloves

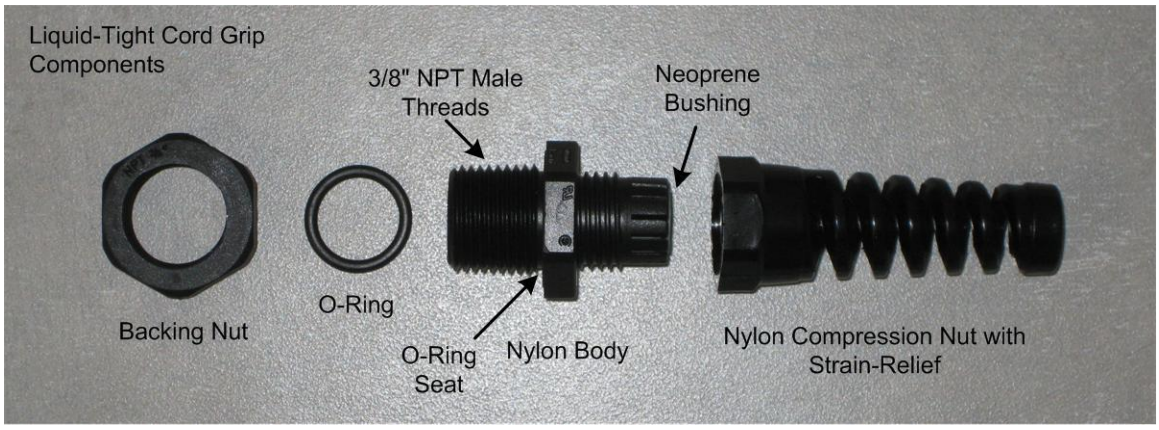
Preparations of Primary Components:

See Appendix 3 for a complete assembly schematic
The following steps outline the preparation of the three primary hydrophone components described in the previous section of this document (Hydrophone Container; Hydrophone Cable; Audio Amplifier/Speaker). The initial preparation of these components is necessary to complete the final steps involving electrical connections and potting of the hydrophone container. The order in which these primary components are completed is not important as long as all three are completed before moving on with the rest of the hydrophone build.

Preparation of the Hydrophone Container:



The hydrophone container incorporates simple nylon and PVC components that utilize threaded compression fittings to connect to one another. Although compression fittings are often used to form a watertight seal between two surfaces, it should be noted that for this activity, the hydrophone unit will be filled with 2-part epoxy adhesive as a means of potting all electrical components and thus sealing out water incursion.



The nylon liquid-tight cord grip provides a flexible means of terminating and securing the hydrophone cable into the body of the hydrophone container and sealing the container for inclusion of the 2-part liquid epoxy adhesive.

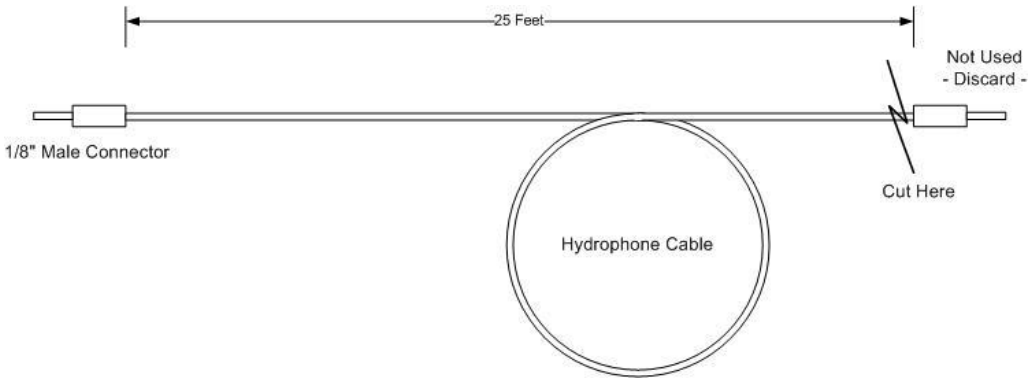
1) If the liquid-tight cord grip came assembled with the backing nut threaded to the nylon body, remove the backing nut and set it aside. The backing nut and O-ring are not required for this activity and may be discarded or repurposed.

2) Thread the 3/8” NPT male threads of the nylon liquid-tight cord grip body into the PVC pipe bushing until the two units are properly secured. When installing an NPT fitting of this nature, thread the two components together by hand until they are “hand tight”. (**Note: Do not tighten the compression nut at this time**) Next, using a suitable wrench, tighten the fittings another 1-1/2 to 3 turns past finger tight to complete the installation.

Preparation of the Hydrophone Cable:

This phase of the construction process involves the preparation of one or two hydrophone cables from the source audio cable. The ultimate goal of this procedure is to end up with a cable of sufficient length for the required application, having one end terminated with 3.5mm male connector and the other end cut to expose the individual wire leads. This cable will be referred to as the hydrophone cable throughout the following instructions.

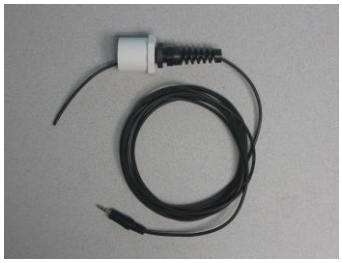
3) Cut off one of the 3.5mm male connectors as close to one end of the cable as possible. This will provide you with a single hydrophone cable of the maximum length having one 3.5mm male connector at one end and flying leads at the other.

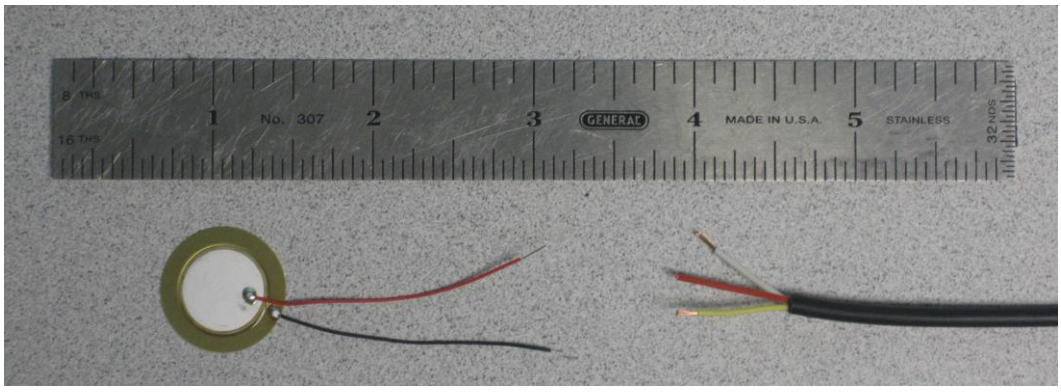


Single hydrophone cable from 25' stereo audio cable with 3.5mm male to 3.5mm male connectors.

Termination and Electrical Connections of the Hydrophone Cable:

4) Working with the components prepared in the previous steps, feed the cut end of the hydrophone cable through the cord grip end of the hydrophone container, and out the opening of the PVC pipe bushing. Be sure to feed a sufficient length (about 3 inches) of cable through the opening to provide plenty of slack to work with.





5) Working from the cut end of the hydrophone cable, strip back and remove approximately 3/4" of the outer cable jacket, exposing the individual wire leads within. Note, the #12 or #14 AWG wire stripper works well for this task. **Be careful not to penetrate the insulation of the wires inside**.

6) Using the #26 AWG wire stripper, strip approximately 1/8" of insulation from the ends of the white and yellow (uninsulated shield) wires, leaving the entire length of the red wire intact. The red wire of the hydrophone

cable is not required for this exercise as only those wires associated with the tip and shield of the 3.5mm connector are required for this mono microphone signal (see Construction Schematic Appendix 3).

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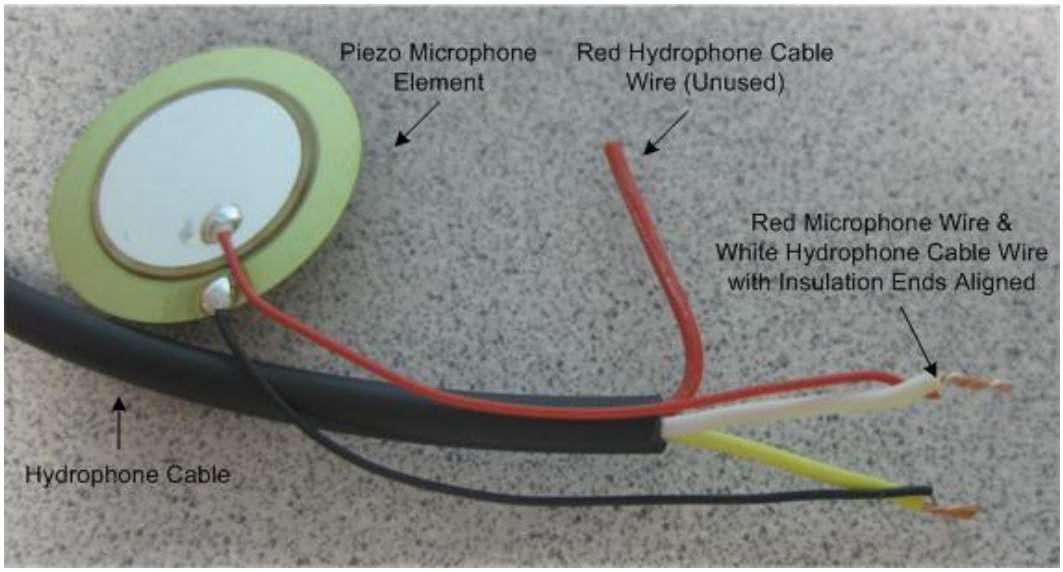
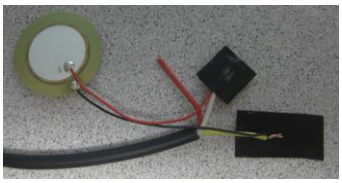


7) Working with the piezoelectric microphone element and hydrophone cable, match the **red microphone wire to the white wire from the hydrophone cable** and twist the exposed leads securely together. You will find that by holding both wires parallel to one another, with their insulation ends aligned, you can twist the smaller wire of the microphone element tightly around the wire from the hydrophone cable forming a strong electrical and mechanical bond. Once complete, test the integrity of the connection by gently pulling on the wires. If they separate from one another, repeat the process to ensure that a suitable mechanical connection is made.

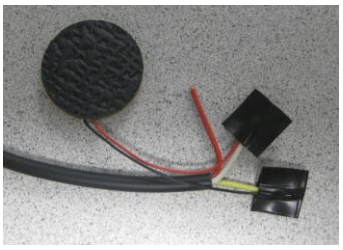
8) Following the technique utilized in the previous step, **match the black microphone wire to the yellow (uninsulated shield) wire from the hydrophone cable** and twist the exposed leads securely together. Test this connection in a similar fashion and repair if necessary.

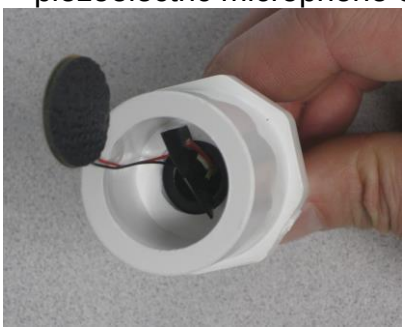
PLEASE HAVE INSTRUCTOR CHECK WORK

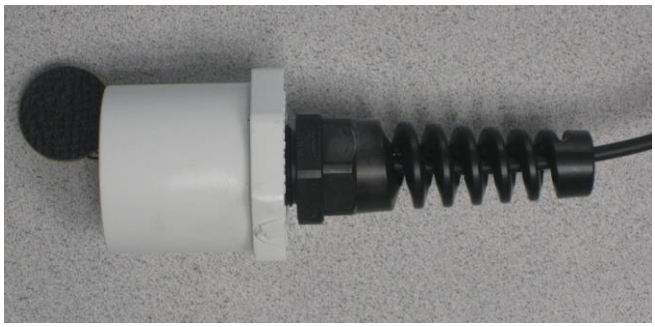
9) Cut two strips of tape to approximately 3/8” in length and fold over the ends of each wire pair to insulate the exposed wires from making contact with one another. As most generic tape is approximately ¾” in width, the end product will resemble two flat 3/8” squares covering the exposed wire leads.



10) Peel the foam bumper from its backing paper and stick the bumper over the **ceramic (white) side** of the piezoelectric microphone element ensuring that the bumper is centered on the disc. This bumper ultimately provides an air space in the final potted assembly in which the piezoelectric microphone element can vibrate.







11) With all connections made, and with the foam bumper in place, gently pull the hydrophone cable back through the nylon cord grip until the taped connections touch the bottom of the PVC bushing.

12) Holding the PVC bushing in one hand, tighten the compression nut with strain relief fully against the nylon body of the liquid tight cord grip. When fully tightened, no space should be visible between the two components of the cord grip and the hydrophone cable should be held securely in place.

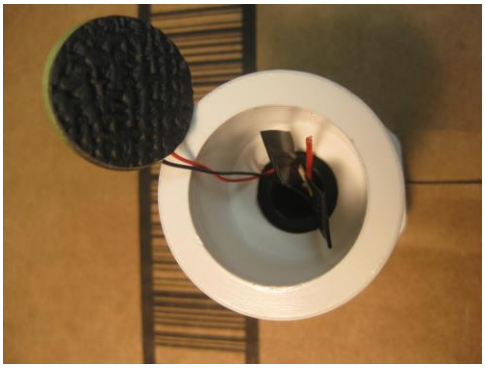
Testing Prior to Epoxy Fill:

13) Plug the 3.5mm” male connector of the hydrophone cable into the input jack of the audio amplifier and turn the amplifier on to full power. If the electrical connections have been made appropriately, tapping the piezoelectric microphone element will emit an audible sound from the audio amplifier. This simple test will ensure that the microphone element is wired properly and is operational prior to potting the components within the 2-part epoxy adhesive.

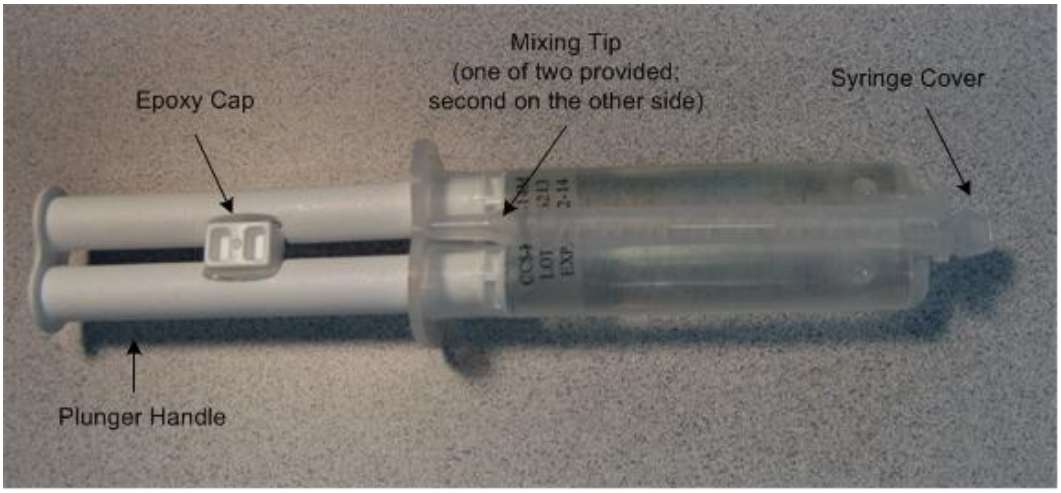
PLEASE HAVE INSTRUCTOR CHECK WORK

Potting the Hydrophone Components:

It is necessary to support the hydrophone container upright and level when filling this component with the 2-part epoxy adhesive as outlined in the following steps. It is recommended to use a bench vise or other suitable tool, if available, to support the hydrophone container. If no such tool is available, a simple alternative utilizing a cardboard box is provided in the following step (#14).



14) Using scissors, cut a slit inwards from one side of a cardboard box, followed by a small hole about the diameter of the nylon cord grip used in constructing the hydrophone assembly. This will provide the means to securely hold the hydrophone container in an upright position, allowing for the epoxy adhesive to be injected directly into the PVC bushing and nylon cord grip of this container.



15) Put on the rubber gloves to protect your hands prior to working with the 2-part epoxy adhesive.

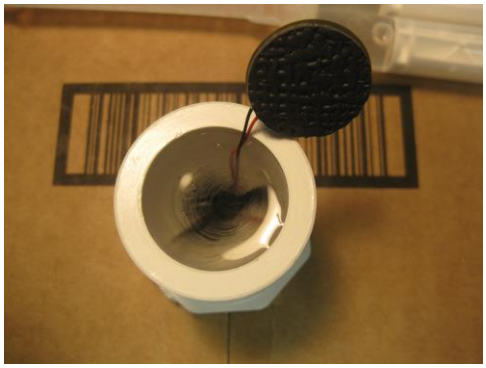
16) Using scissors, cut away the tape securing the two mixing tips to the syringe body and set the tips aside for future use.

17) Pry the epoxy cap from between the plunger handles and set it aside for future use.

18) Holding the epoxy syringe in one hand, twist and break off the syringe cover to expose the opening of the two-chambers containing the epoxy resin and epoxy hardener. Avoid applying pressure to the plunger handle as this will cause the epoxy to be ejected from the syringe chambers.

19) Install one of the mixing tips onto the open end of the syringe body by pushing the rectangular end of the syringe tip inwards until it bottoms out against the syringe body, twisting it to lock it securely in place.

20) Start a timer to monitor your progress as you will have **approximately five minutes** from the initial injection of epoxy until the resin begins to harden.

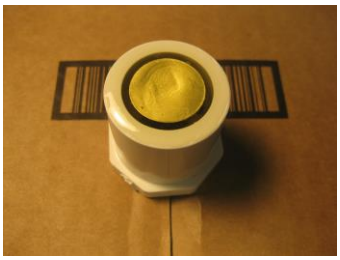


21) Point the syringe into the bottom of the hydrophone container, centering it over the opening to the liquid-tight cord grip. Apply even pressure to the plunger handle to begin injecting the two-part epoxy into the bottom of the hydrophone container, filling all voids as you continue upwards. Maintaining consistent pressure with a slight rotational motion will ensure that minimal air bubbles are formed as the epoxy is injected into your hydrophone container. Fill the hydrophone container to approximately 1/16” from the top of the PVC bushing.

22) Gently bend the wires of the microphone element over and position the element bumper side down against the surface of the epoxy until it is parallel with the top of the PVC bushing. Depending on the speed with which you injected the epoxy, you should have a few minutes to

maneuver and position the element with the paper clip to ensure it is centered and level with the surface of the PVC bushing.

23) Once you feel the epoxy beginning to set up, and can no longer move the microphone element with ease, continue adding a second layer of epoxy over the surface of the element, working in a circular motion from center to the outer edge of the hydrophone container. Working with care, you should be able to add a thin layer extending slightly above, and across the entire surface of the hydrophone container. Remove and discard the mixing tip from the epoxy syringe and seal the epoxy with the cap provided.



24) Allow the epoxy to cure for an additional 15 minutes before deploying in water for further testing.

Congratulations! You have just completed the fabrication and wiring of your hydrophone assembly and are now ready to experience underwater sounds.

Refer to the connection diagram in Appendix 5 for visual instructions on cabling and connecting the hydrophone assembly to a personal computer or other mobile device. This diagram also depicts the connection of a simple speaker (i.e. computer speaker) to a source computer for the creation of underwater sounds in a laboratory or classroom environment.

History of the "How to Build A Hydrophone" Activity:

Kevin Hardy of the Scripps Institute of Oceanography, UCSD introduced a "Build A Hydrophone" project in 2000 within which he provided a material list, assembly schematics, glossary of terms and other valuable resources forming the foundation of this activity. This work has appeared as the basis for many subsequent hydrophone build activities and offered one of, if not the first activity of this nature.

In 2002, the Discovery of Sound in the Sea (DOSITS) team, at the University of Rhode Island, added significant value to this project by utilizing the Hardy design as the basis for developing their own comprehensive step-by-step guide on "How to Build a Hydrophone".

Nearly ten years later, this activity was picked up and reevaluated by a team from the Center for Ocean Sciences Education for Excellence, Technology and Engineering for Knowledge (COSEE-TEK), at the University of Connecticut, and a new design was introduced offering a new and improved hydrophone housing and simplified wiring plan. This activity is still valid and offers a simple, functional, and affordable design for a DIY hydrophone, utilizing an electret microphone element. See http://www.coseetek.net/resources/

The activity offered in this document builds upon this previous work and design concepts gained through alternative sources (see references below) to provide a vastly simplified hydrophone design based upon the use of a piezoelectric microphone element. The primary advantage to utilizing this element over an electret microphone element is that the piezoelectric element requires no power to operate, thereby reducing the number of components and fabrication effort required to complete the activity.

References:

Web References:

- Discovery of Sound in the Sea, University of Rhode Island, Office of Marine Programs, http://www.dosits.org/
- Raven: Interactive Sound Analysis Software, The Cornell Lab of Ornithology, Bioacoustics Research Program http://www.birds.cornell.edu/brp/raven/RavenOverview.html

References:

- Hardy, K. 2000. Build A Hydrophone. Scripps Institute of Oceanography/UCSD

- E. R. Vivas and B. L. Lopez (2011, March 12). Construction, calibration, and field test of a home-made, low-cost hydrophone system for cetacean acoustic research. Acoustical Society of America; Proceedings of Meetings on Acoustics, Cancun Mexico, 15-19 November 2010

Personal Communication Reference:

- Peter Stephanishen, personal communication; University of Rhode Island, OCE 311 "Coastal Measurements and Applications", Laboratory exercise, 2006.

See Appendix 3 for a complete assembly schematic

Simplified Instructions for Hydrophone Fabrication:

1. Assemble the hydrophone container by attaching the body of the liquid-tight cord grip to the outside of the PVC Pipe bushing.
2. Cut the stereo cord in half or at one end depending on the number of hydrophones required for assembly.
3. Insert the 9V battery into the audio amplifier/speaker.
4. Insert the cut end of the hydrophone cable through the cord-grip end of the hydrophone container.
5. Strip and remove ¾" of outer jacket from the end of the hydrophone cable.
6. Strip and remove 1/8" of insulation from the ends of the white and yellow wires of the hydrophone cable.
7. Twist and connect the exposed leads of the red microphone wire to the white wire from the hydrophone cable.
8. Repeat step 7 to connect the black microphone wire to the yellow cable wire.
9. Cover and insulate the exposed wire connections with two small pieces of electrical tape (approximately 3/8" square).
10. Install the self-adhesive foam bumper centered over the ceramic side of the piezoelectric microphone element.
11. Pull the hydrophone cable back through the liquid-tight cord grip until the taped connections touch the bottom of the PVC bushing.
12. Fully tighten the compression nut to the body of the liquid-tight cord grip.
13. Plug the hydrophone cable into the amplifier/speaker and test the system to ensure proper wiring.
14. Secure the hydrophone container upright and level with a bench vise or other suitable tool. See detailed step 14 for a simple alternative option.
15. Wearing rubber gloves, remove all detachable components (i.e. mixing tips & epoxy cap) from the packaging of the 2-part epoxy syringe.
16. Break off the syringe cover and install one of the mixing tips over the exposed end of the syringe.
17. Fill the hydrophone container with epoxy to approximately 1/16" of the top of the PVC bushing, ensuring minimal air bubbles are formed in the process.
18. Position the microphone element, centered within the PVC bushing, and bumper-side down, parallel with, against the surface of the epoxy adhesive.
19. Inject the remaining epoxy adhesive, covering the microphone element to the outer edge of the PVC bushing.
20. Allow epoxy to cure fully for an additional 15 minutes before use.