Let's Build Some World Class Hydrophones

by DJJules

Updated September 2022: SEE STEP FIVE FOR ADDITIONAL INFO

New Audio Demo Too!

Thomas Rex Beverly, a professional sound recordist, took a pair of these to Greenland in July. He released a commercial sound library using them. I put a link to the demo of the library at the end of this Instructable.

https://www.youtube.com/embed/xTosPVaVVog?enablejsapi=1&origin=https://www.instructables.com

I spent 20 years in the Navy as a Submariner. Although I wasn't a Sonar Tech, I spent a lot of time in the Sonar Shack listening. You could hear all sorts of things; whales, crustaceans, pile drivers building north atlantic oil rigs, and of course, the occasional Russian Submarine. Being the Audio Guy I am, I found this fascinating and always wanted my own set of hydrophones to continue the journey. Which leads us to today's Instructable: Build your own professional grade hydrophones. These may not match the durability of what the Navy and commercial ones do, but they certainly meet or exceed the acoustic properties they do. Best of all, they are inexpensive to build.

We need three critical things for the acoustics:

1. The right transducer
2. A high impedance, low noise buffer amplifier PCB Here: https://www.jlielectronics.com/diy-accessories/p4...
3. Resin to embed items one and two in

Other items for the build:

1. Male XLR jack
2. Microphone cable (that can be submerged)
3. A mold to put the parts in - I have a couple ways to do this.

Supplies:

Fully populated PCB available from JLI Electronics: https://www.jlielectronics.com/diy-accessories/p48...

Male XLR: https://www.redco.com/Neutrik-NC3MX-B.html

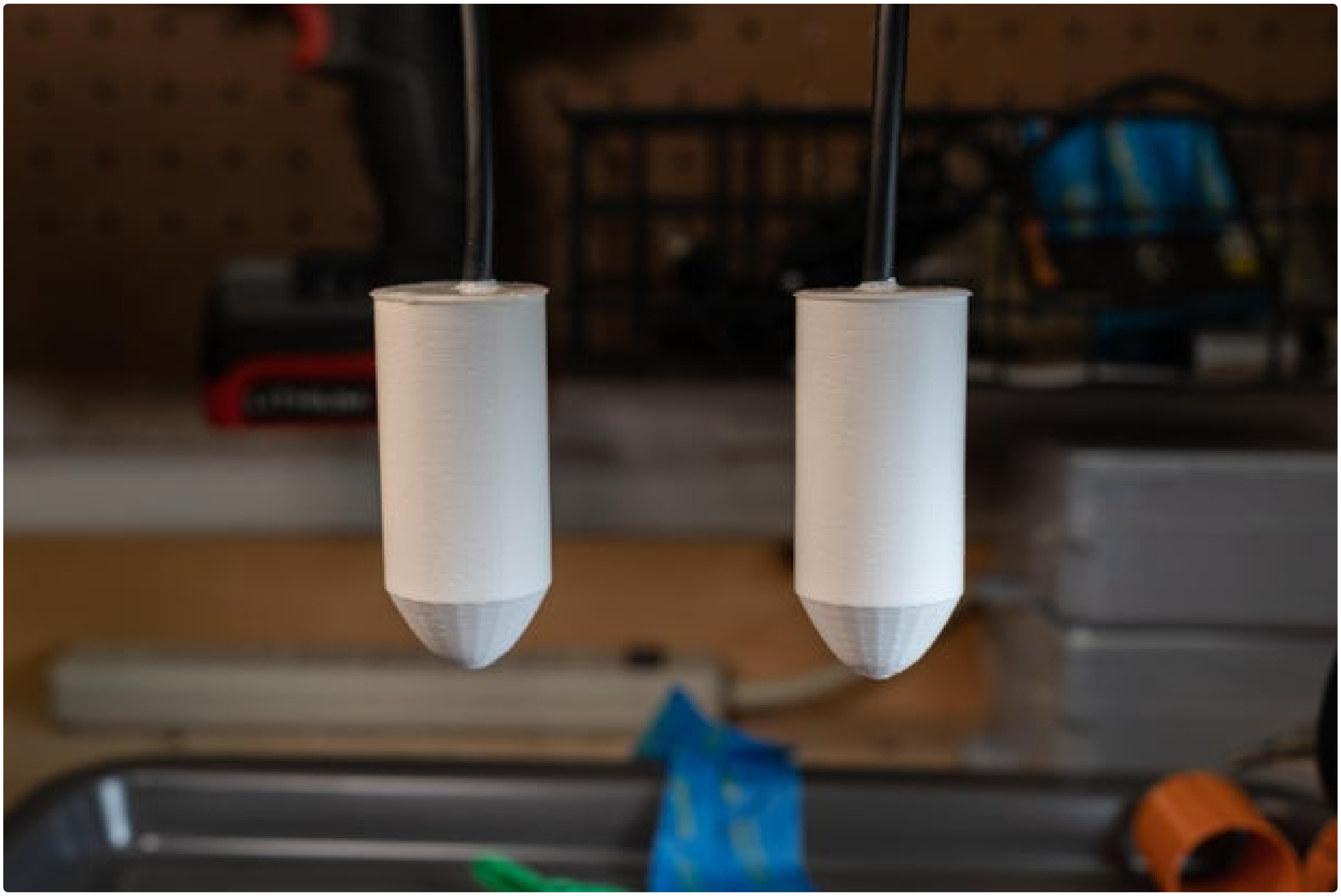
Microphone cable: https://www.redco.com/Mogami-W2549.html

SIngle Edge Razor Blade

Soldering Iron

Hand Tools


DIY
Hydrophones
SOUND SLEUTH



Step 1: Background

What is a Piezoelectric material anyway? The phenomenon was discovered by two french physicists (Yea, Go Physics!) Pierre and Jacques Curie in 1880. In essence, applying a force to some crystal structures, causes a voltage to be generated. The converse is also true, if you apply a voltage to the crystal it will deform. Like most discoveries back then, it was hard to turn the concept into useful things. Then in World War I, the need to find submarines became important, leading to the invention of Sonar in 1917. Of course we kept improving that over the years, leading to the modern submarine sonar systems on my three boats. Interestingly, the basic transducer designs didn't really change. The most common material today for the transducers is PZT or Lead Zirconium Titanate. It is used for ultrasound, sonars, fish finders and all sorts of other fun things.

It was so important to the Navy they wrote a standard for it: https://quicksearch.dla.mil/qsDocDetails.aspx?ide...

The cool thing for us is that you can buy single quantities of already prepared PZT material in various shapes, already silver plated on two sides, just waiting to be turned into a hydrophone. All we have to do is solder on some leads! The shape that ended up using and sounded the best to me was the cylinder, same as the NOAA article. There is far more to this and for a lot more theory read this for background.

https://www.americanpiezo.com/knowledge-center/pie...

Then there is this amazing paper from the Naval Postgraduate school

https://apps.dtic.mil/sti/pdfs/AD1068326.pdf

Before we talk about the embedding of the transducer into urethane, a review of underwater acoustics is in order. Sound behaves differently in water than in air. Water is a liquid and non compressible. We tend to think of sound being 20-

20,000Hz in air. That is because that is what we can hear. Bats and other nocturnal critters can extend that into the 100Khz plus range, which they mostly use for echolocation. In the water, sound waves go from about 10Hz to 1Mhz. Yup, one megahertz. That is mainly for imaging and advanced sonar applications. Above that, sound gets absorbed quickly. It also travels much further in water. And when you are in the open ocean, lower frequency sounds can travel really far. The other thing about bodies of water is reflections at the surface and the bottom. Lakes and the ocean are like gigantic caverns with lots of echo and reverberant properties.

The other difference between air and water is "speed of sound". In water, it is totally dependent on density. Which for the Navy and sonar, makes salinity, depth, and temperature really important. For example it is 1450 Meters per second in freshwater and 1500 Meters per second in salt water. In air it is about 345 Meters per second. Pay attention -- there is a quiz… For us we can ball park it 4.25 times faster. The reason I point this out is well, if we are going to record underwater sounds, we might as well do it in Stereo. So we should multiply the standard spacings for microphones by that amount to get a decent sound. Our ears are about 20cm apart or 7-8 inches, we should space the hydrophones at least 3 feet apart. For those of you with the calculators out… I am winging it. :-)

The last thing to take into account is how sound transfers from water to other things. This one can get complex. Sound is traveling in water as a wave. Changes in density cause a change in the speed and reflect or refract it. So, if we keep the resin we are molding the piezo element in as close to the density of water as we can, we will get maximum sound transfer without worrying about how the shape of the mold modifies the sound. That eases mold design.

Step 2: The Transducer

The most critical component to these is the actual piezo element we are using. I found one that works really well and is less than $20 each. What I found doing my research was that there are two types of transducers used, which also matches my Navy experience. The first is the Active transmitter. Think underwater speaker. The second kind, and what we are doing, is called Passive. Think underwater microphone. In my search I found a great article from NOAA This one showed the basics. I could not find the specific transducer they were using, but I found a company called Steminc, which has a plethora of them! I tried several which all worked, but this one, which is cylindrical, is the one I settled on.

Step 3: The Electronics for the Buffer:

After building many microphones with an Op Amp as the impedance converter, I smiled when I saw what they were doing in the NOAA article. They used a great one, but it was at EOL or "End Of Life". It only made sense for me to adapt my circuit for use in a hydrophone. Piezo elements need a high impedance circuit to pick up the voltage they produce. This is similar to a condenser microphone. One of the problems with piezo elements, and this applies to pickups on musical instruments, is that they need a high impedance preamp on them. We need about a 1Meg input impedance vs the 1Gig that a condenser needs. This has to do with the inherent capacitance of the transducer. The piezo element is 6600pf. So with a 1 meg resistor we have a low cutoff frequency of 24hz. This works really well. If it goes into a preamp with an input impedance of say 10K Ohm, (typical of line level inputs) it has a cutoff of about 2.2Khz. Which will sound really tiny and bad. Thus piezo pickups have a bad reputation. For those thinking ahead already, this circuit makes a fantastic pick up interface that runs off of phantom power.

This uses the same Opamp as in my Condenser Microphone instructables.

https://www.instructables.com/OPA-Based-Alice-Mic...

https://www.instructables.com/True-Condenser-OPA-M...

In fact we are using almost the exact same circuit. The board is smaller 26mmX29MM to allow embedding into resin. And a couple components (the capacitors) are smaller in value but provide excellent results.

Here is how it works:

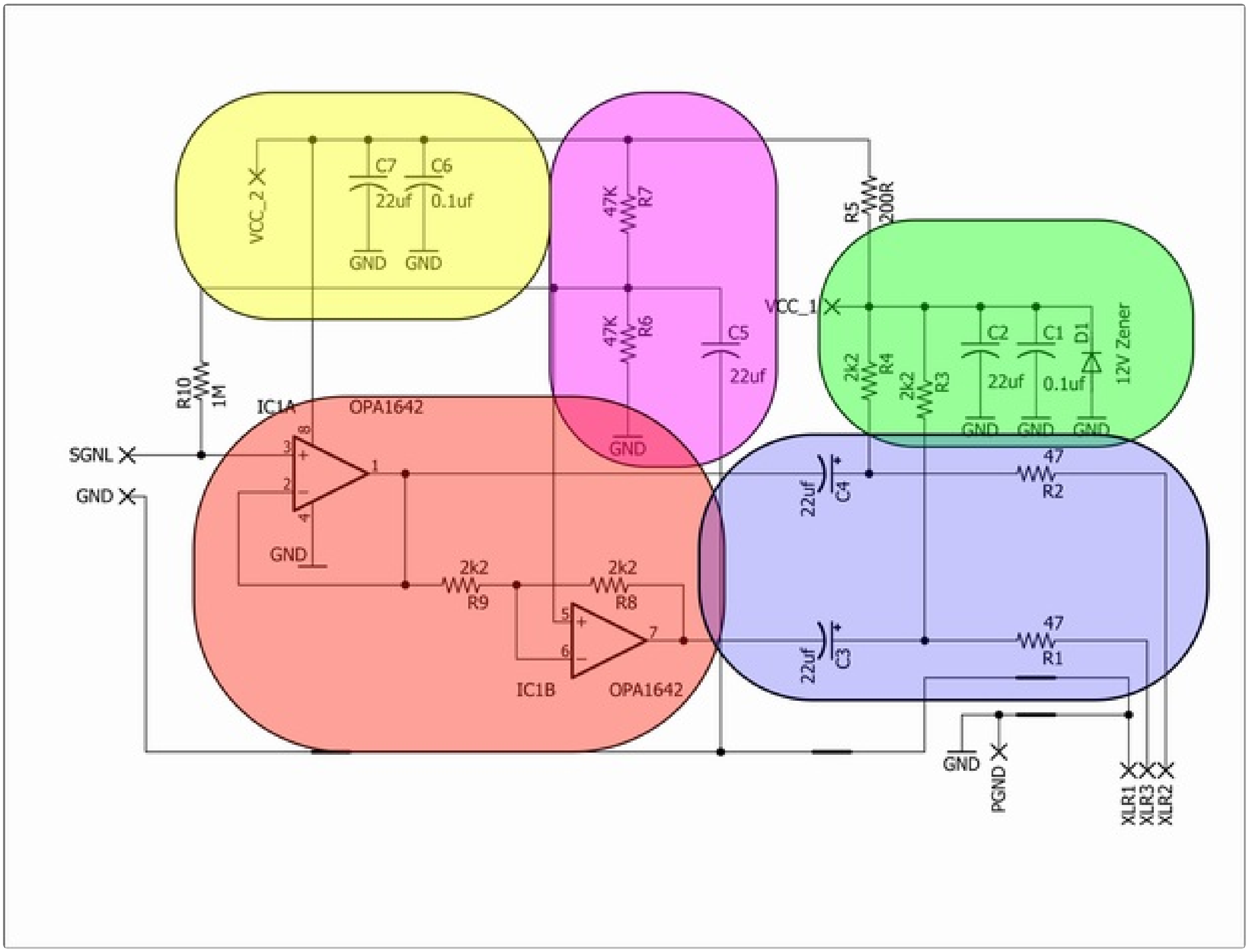
The Blue section has our two incoming 47Ohm resistors coupled into two 22uF capacitors. This passes the signal out to the XLR connector and the mic preamp. Tapping off of this are two 2.2K resistors. These feed the incoming phantom power to the Green section. The Green section has a 12V zener and associated resistors and capacitors which generate filtered 12VDC. Then in the Pink section, we have a resistor divider with two 47K resistors and a filter capacitor. This generates a stable voltage that is roughly half the 12 volts. We are using this as a "virtual ground" for the operational amplifier in the Red section. There are two op amp stages. One is a non-inverting buffer connected directly to the Piezo element with a 1M resistor connected to the virtual ground from the Pink section. The Yellow section are filter caps for the op amp. The .1uF should be as close to the supply pins as possible.

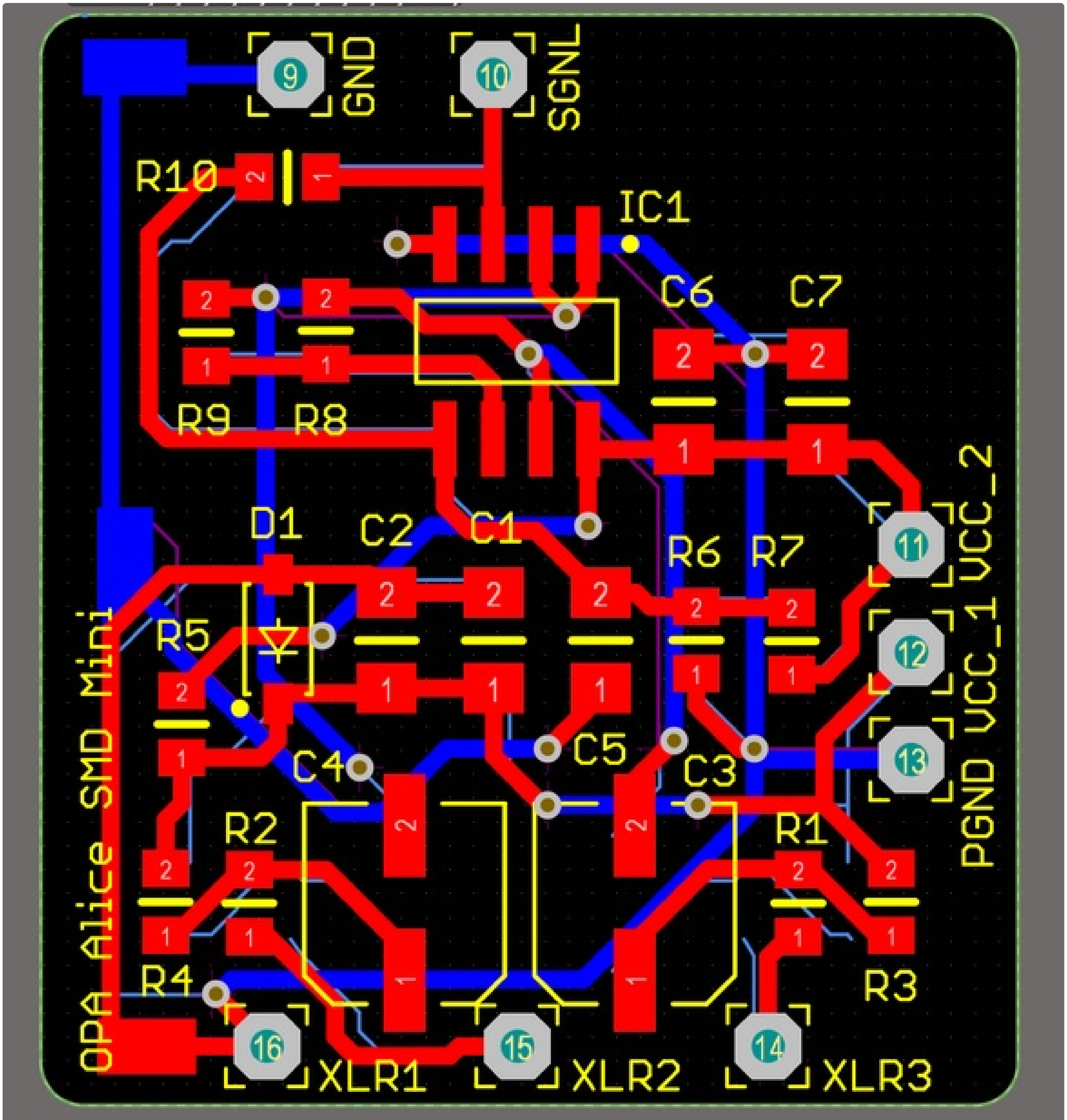
The op amp is the heart of the circuit. The OPA1642 has really low noise, low distortion, and high bandwidth. That gives us a flat buffer amplifier, probably good to a megahertz. Then we have an inverting buffer from the second op amp stage and its two 2.2K resistors. This lets us drive a differential signal into the mic preamp. All in a little 26mm X 29mm PCB.

You can order the board from PCBWay if you want to assemble it using Surface Mount Components, or you can order one premade and populated from JLI Electronics. I recommend that.

PCBWay: https://www.pcbway.com/project/shareproject/OPAAli...

JLI Electronics: https://www.jlielectronics.com/diy-accessories/p48...





Download

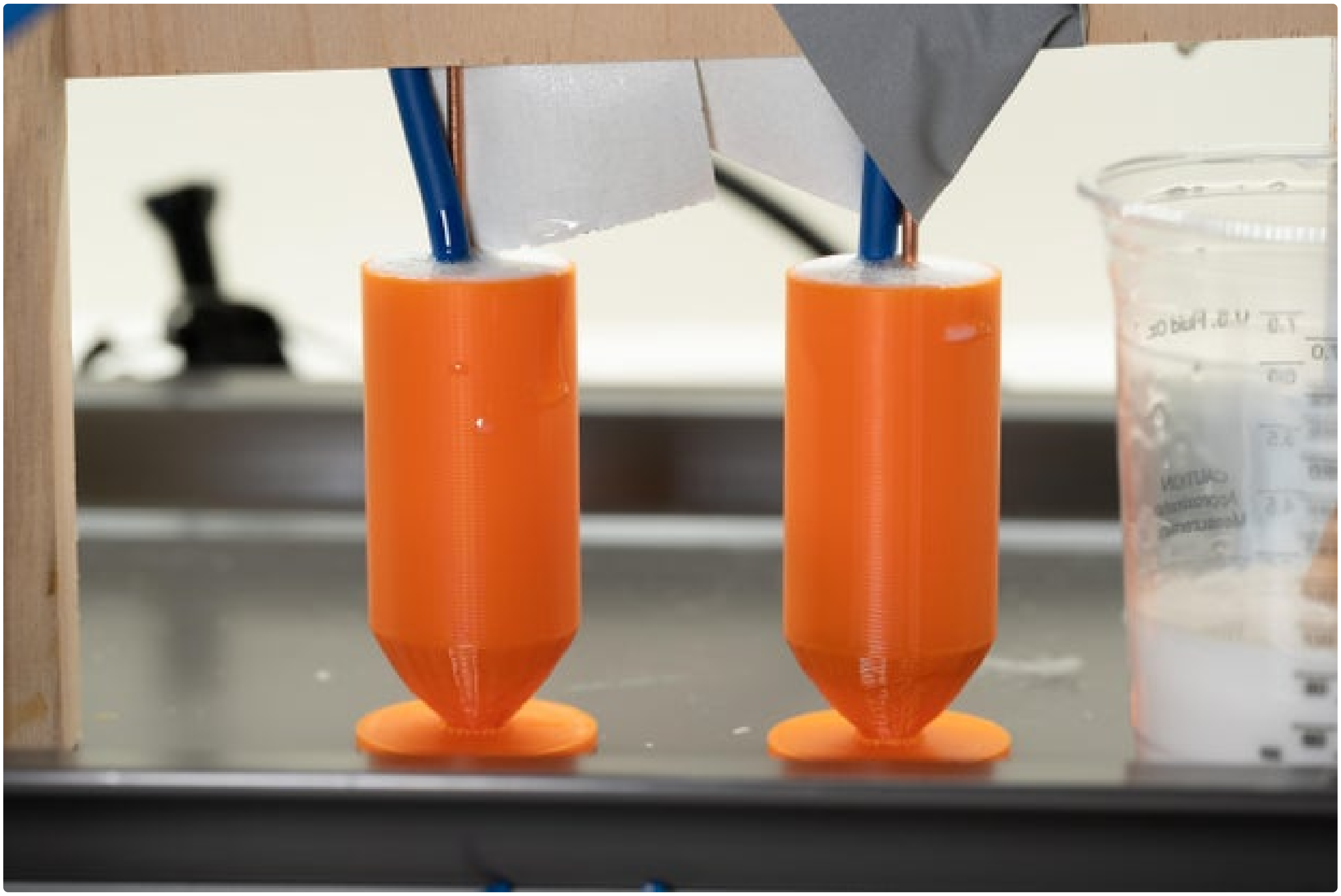
https://www.instructables.com/F14/BU3B/KZY53QFF/F14BU3BKZY53QFF.csv

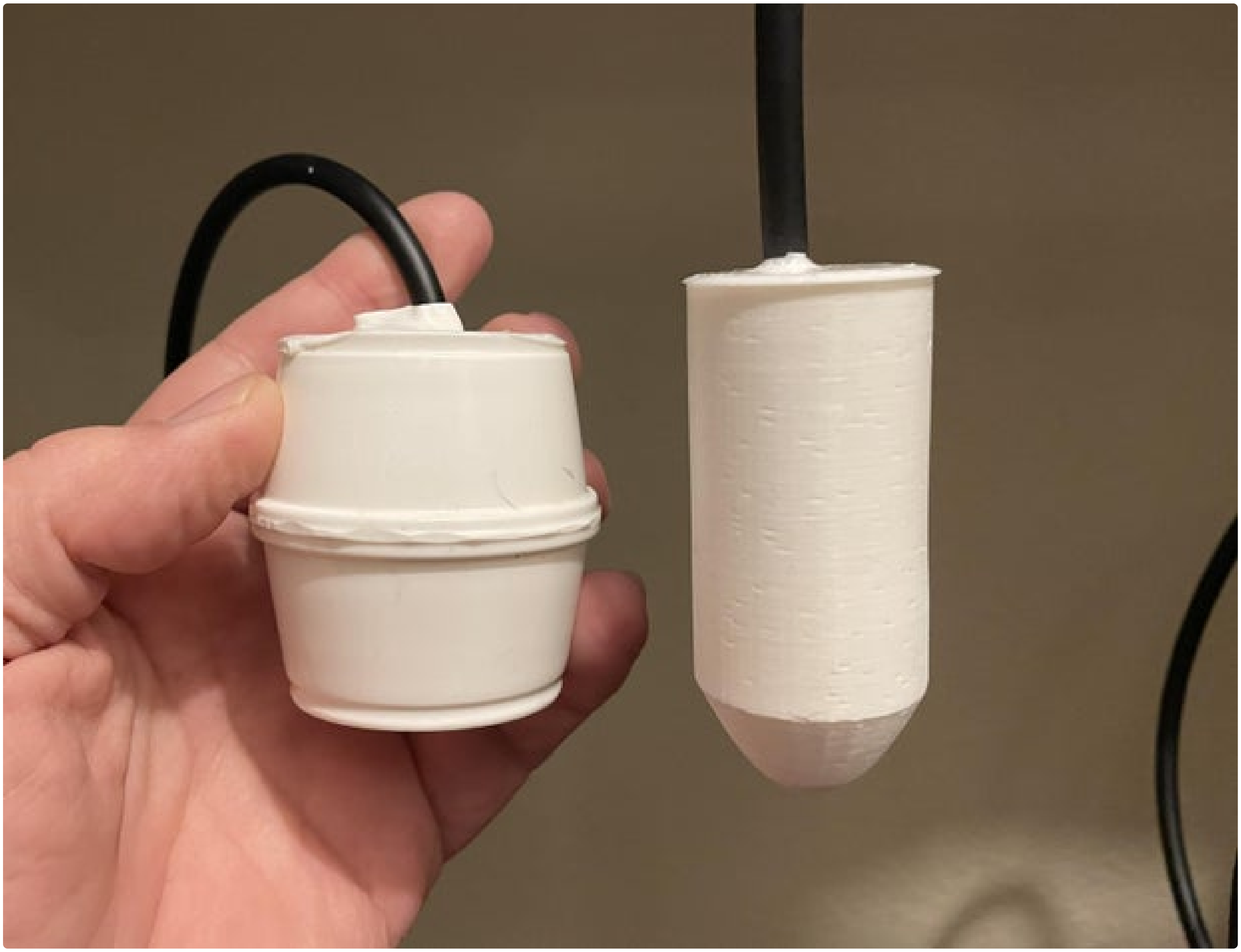
Step 4: The Resin and the Mold

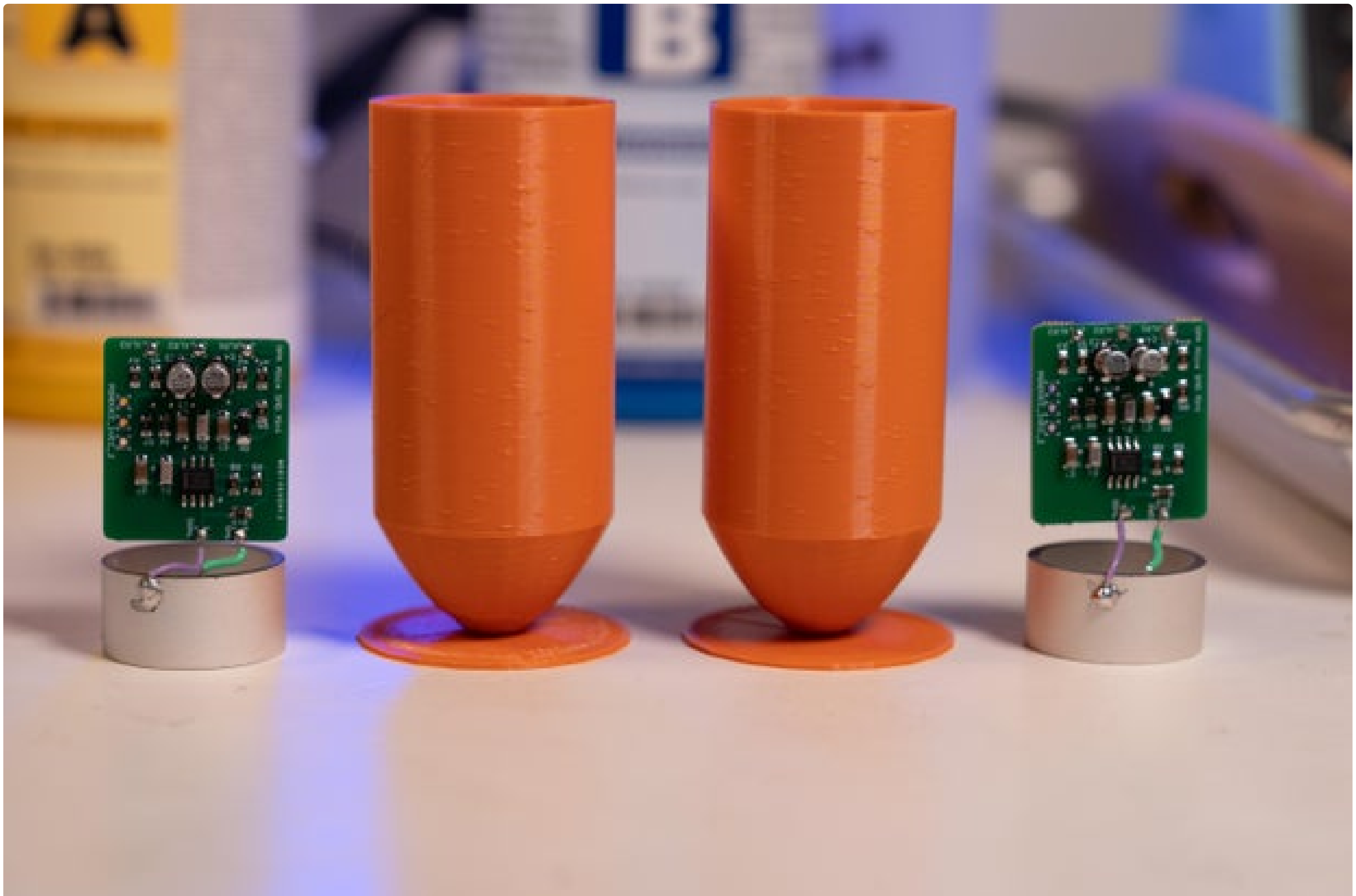
I tried to find the exact urethane resin that the NOAA paper used but couldn't. What I did find was perfect as it has a specific gravity, (which is related to water density pure water = 1) of 1.05 which is really close. And, the specific gravity of seawater is 1.03 so it is even closer to the seawater.

We are using this: https://www.amazon.com/gp/product/B00E3ZJ9XW/

It is easy to work with and most importantly, it has a Specific Gravity of 1.05 g/cc or almost identical of water. This is really important for sound transfer. Just like glass in water. The closer to the index of refraction for water that the glass is, the harder it is to see when it is submerged. For comparison, Water is 1.33 and glass about 1.5 so that is about a 10-12% difference. Acoustically this resin has a 3-4% difference making it quite transparent to underwater sound.







View in 3D Download

https://www.instructables.com/FHE/BOKV/KZ5KALX1/FHEBOKVKZ5KALX1.stl

Step 5: Connecting It All Up

NOTE: For 60hz Hum I am adding a Ground Wire to be in contact with the water!

See the photos with the solid copper wire connected to the shield. This was added September 2022 due to feedback from several builders who experienced this. Doing some more research there are commercial ones that have a metal portion that is grounded and I found another NOAA guide from 2013 that recommends this as well.

The ground wire does not have to be long. Just that is is contact with the water the hydrophone is used with.

Wiring the Piezo Elements

These are made from ceramic piezo material. It has silver plating on the inside and outside surfaces which can be soldered with some caution. PZT material has something called a "Curie Temperature" Normally that is associated with magnets. As in if you heat it above the curie temperature, it is no longer a magnet… For piezoelectric material, it means that above that temperature, it affects the piezoelectric properties. Which we want to avoid. Also, it is ceramic so heating it unevenly will cause stress and potential breakage. With that said, just be careful and watch the video. It is easy but be careful.

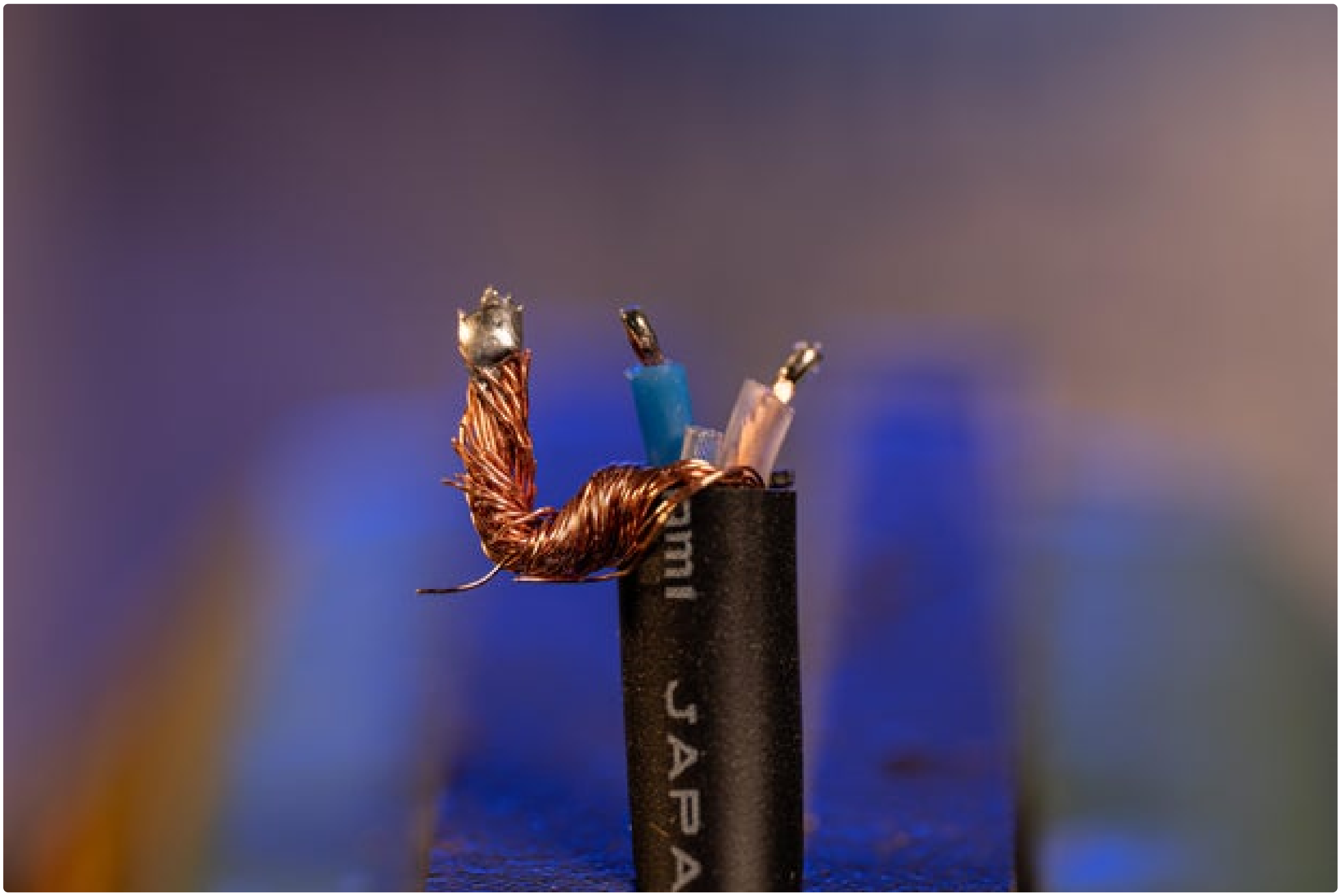
To maintain the polarity the same for the two transducers, we need to wire them the same. I chose to wire the Signal lead to the outside and shield or ground to the middle.

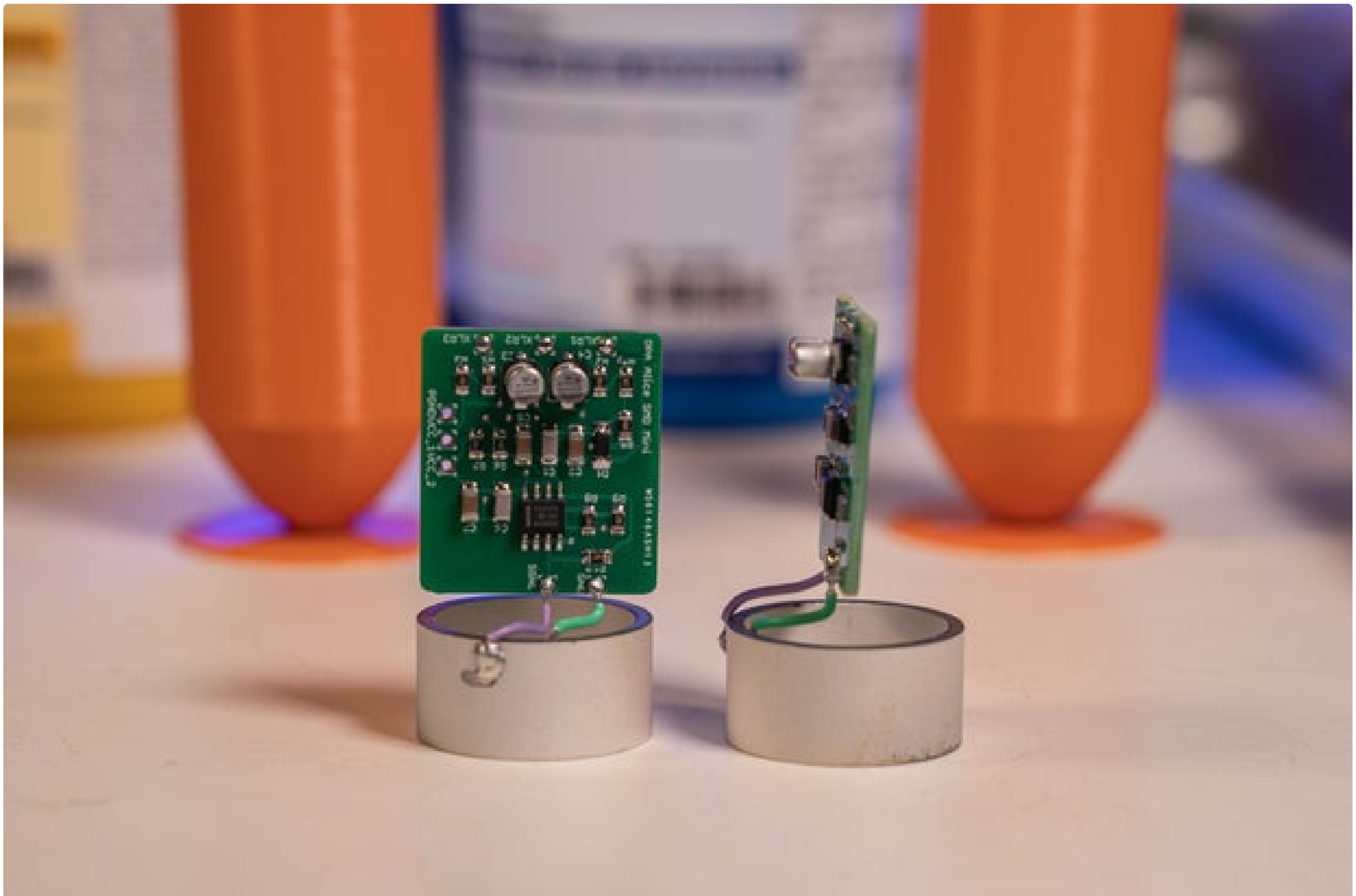
I chose this particular microphone cable for its durability, strength and ease of working with it. Note, there is "Waterproof" microphone cabling available. That is really for permanent installations where the cable is submerged for years. And it is priced accordingly. I have tested the fully built hydrophones for 24hours in my swimming pool with no issues.

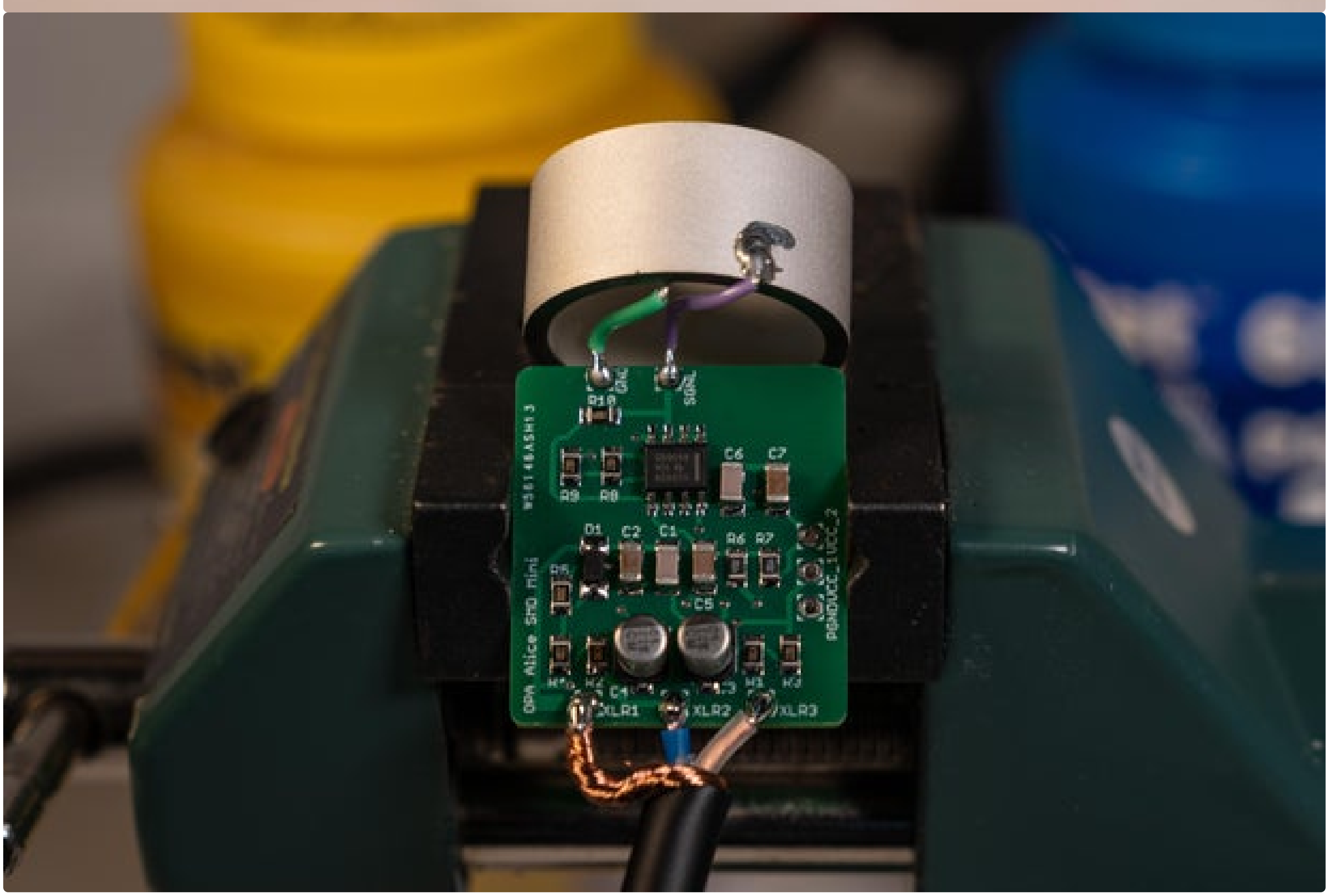
Wire the PCB end mic cable per the picture and the video

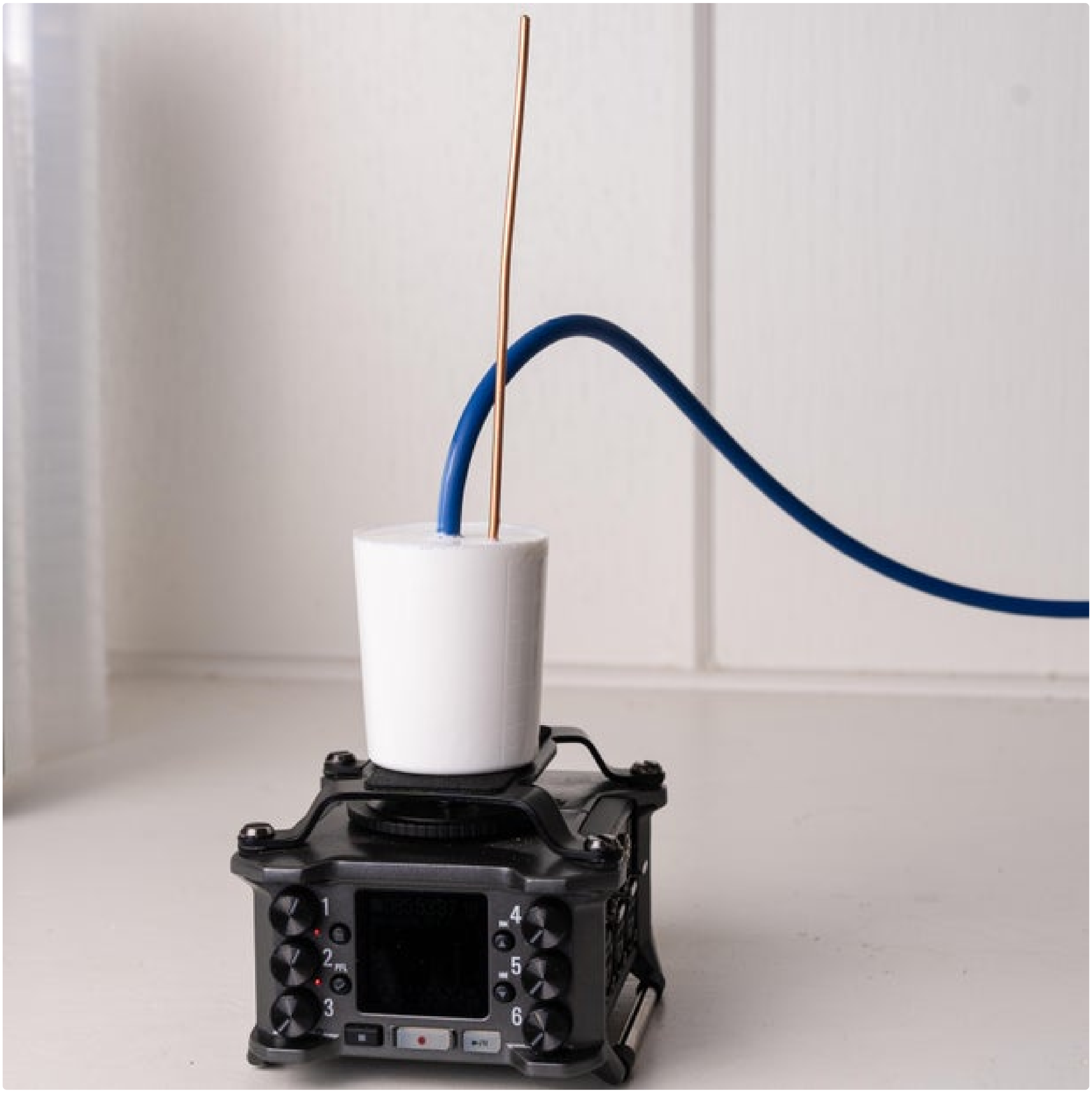
The XLR connector end is standard Pin one shield, Pin two (hot) to blue and Pin three (cold) to clear.

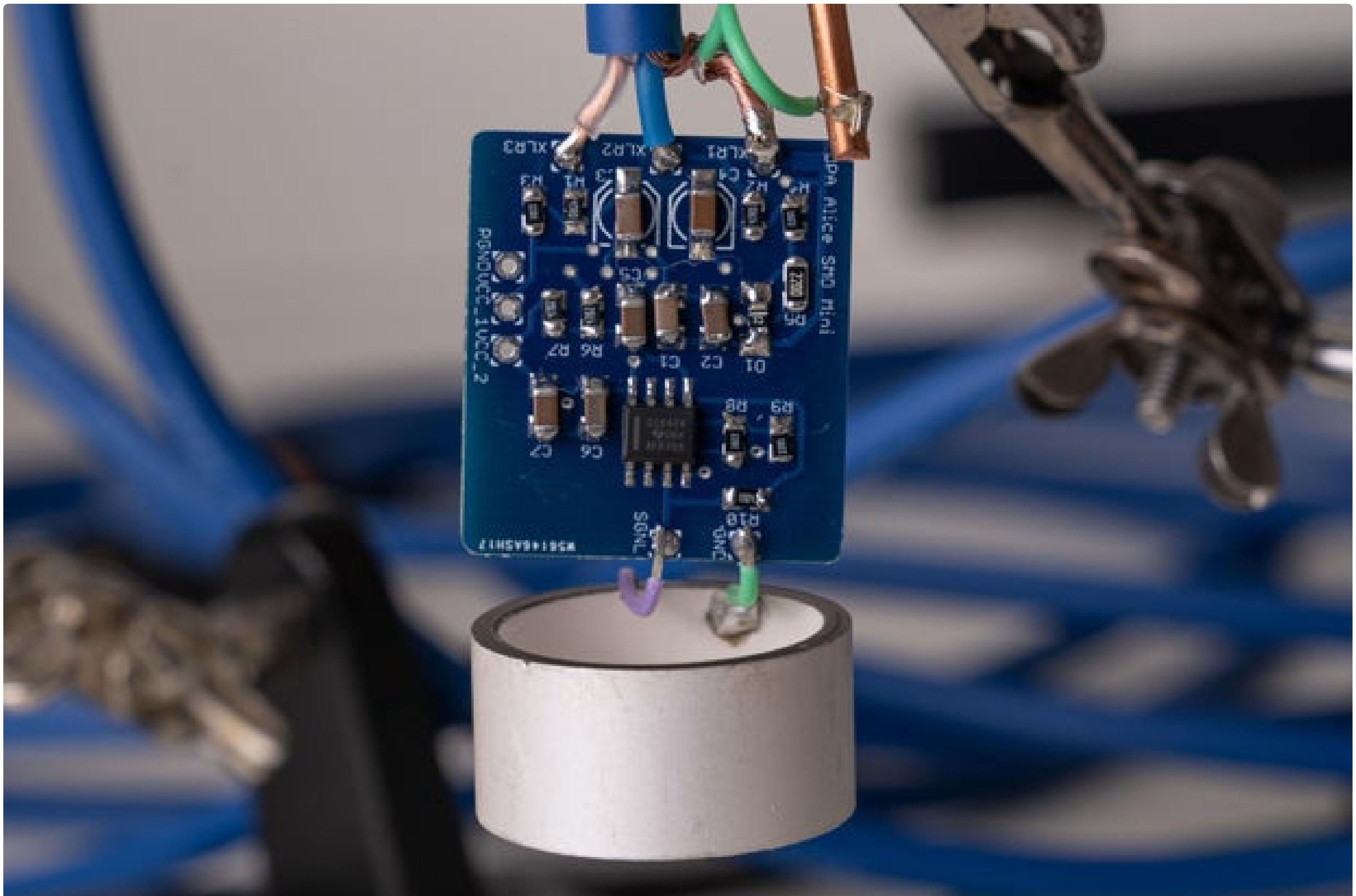
IMPORTANT! After you solder the cable to the PCB and XLR connector, TEST IT BEFORE MOLDING!!!!

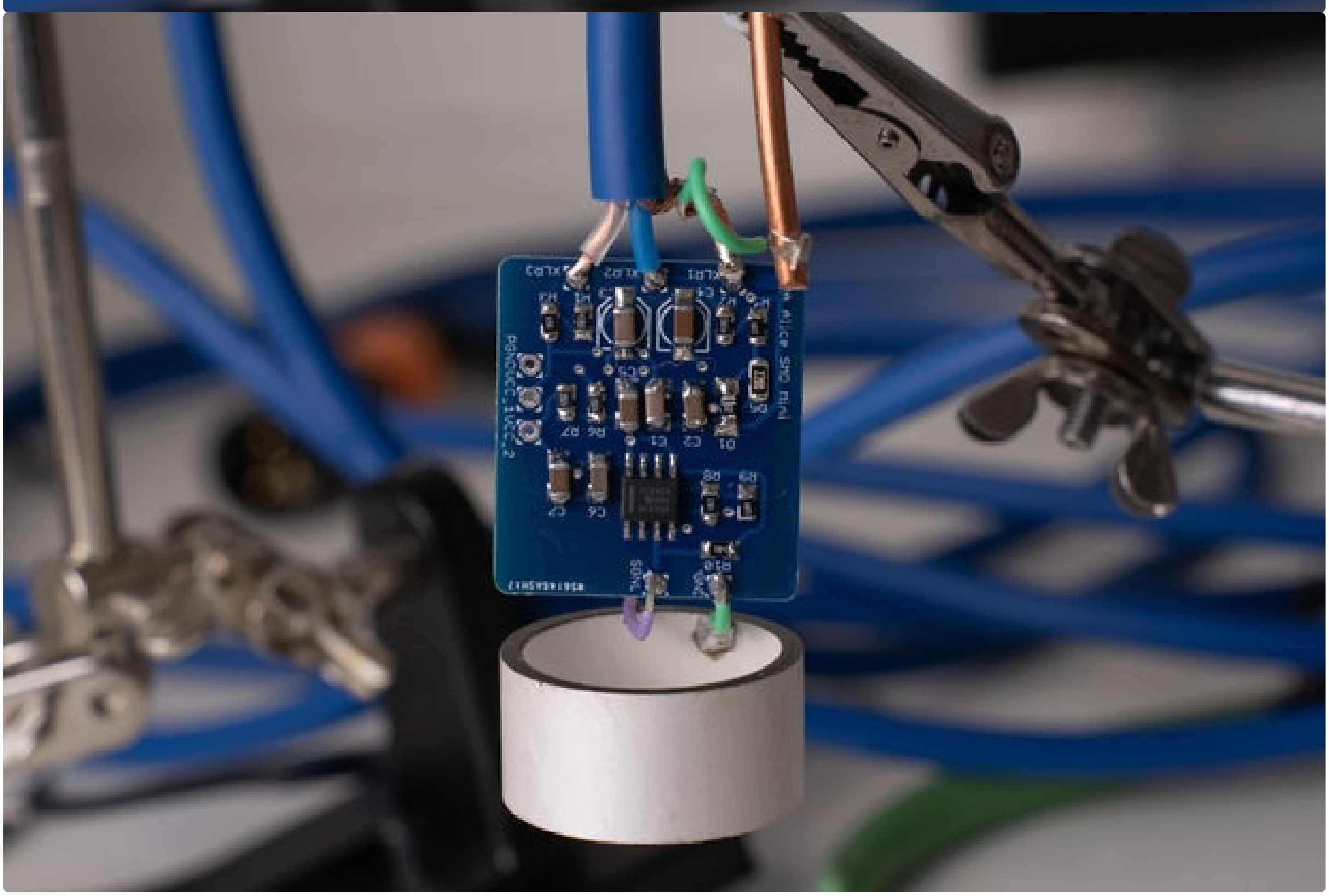


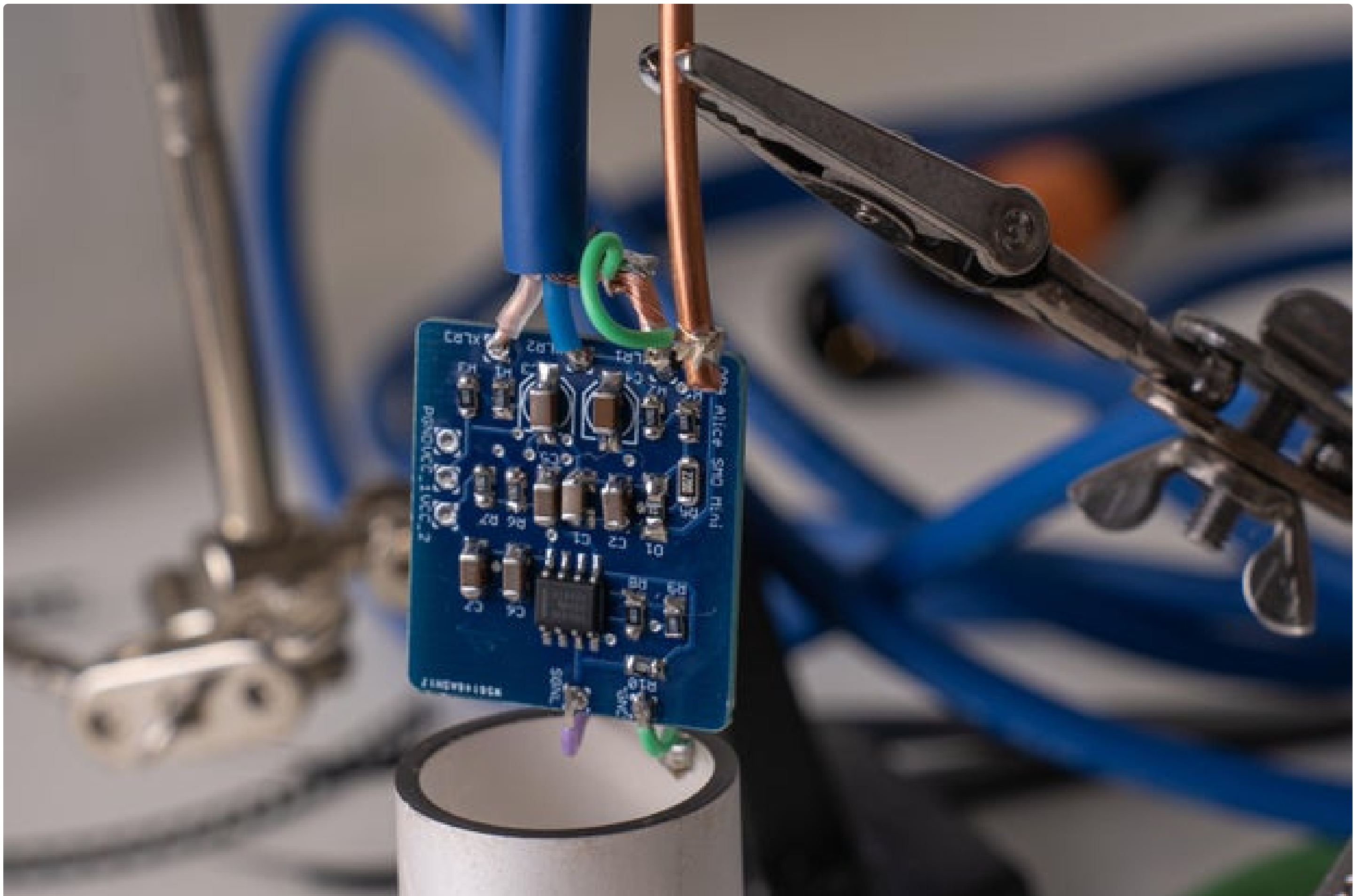


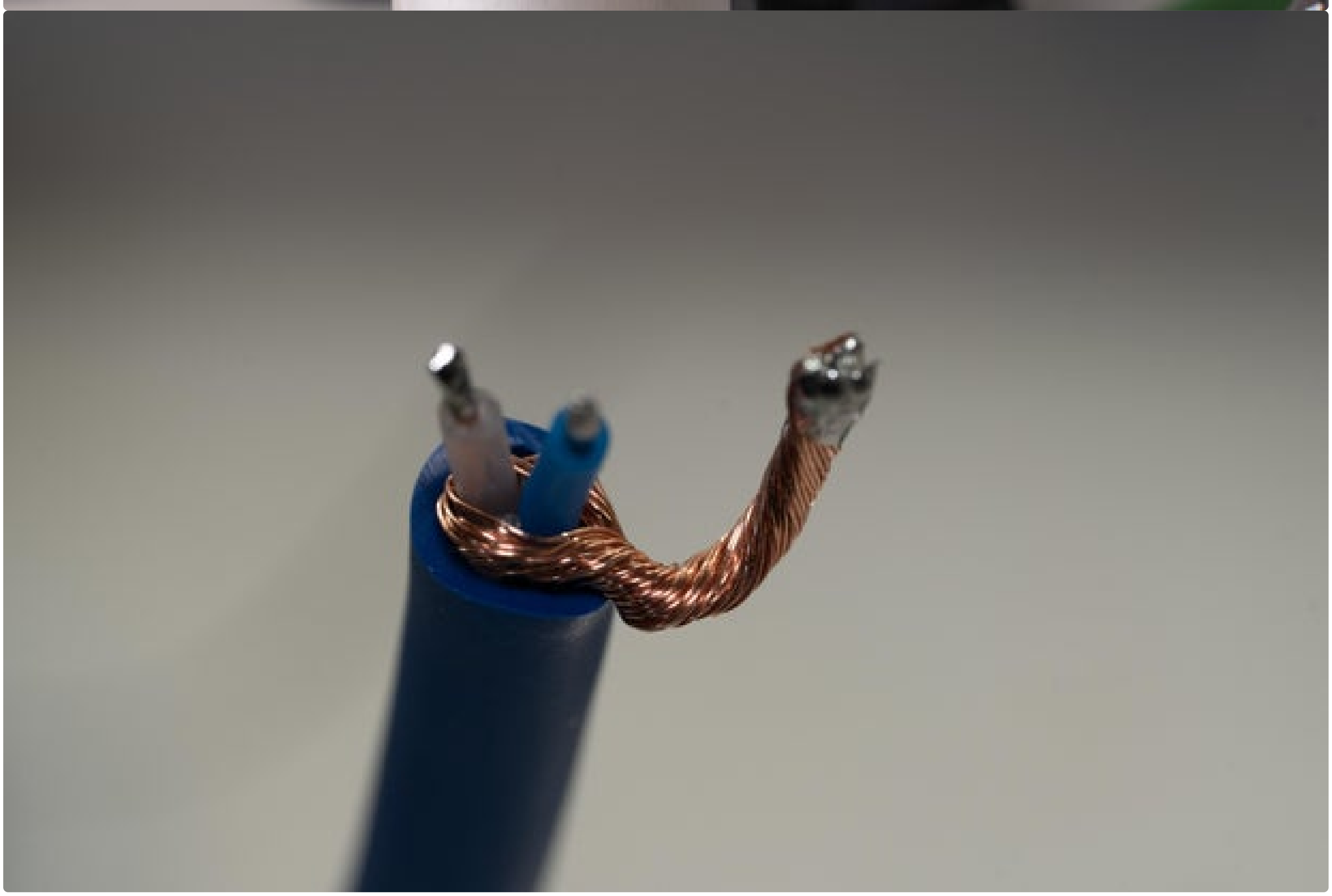

GND
SIGNAL
R10
C6
C7
R9
R8
D1
C2
C1
R6
R7
R5
C5
OPA Alice SMD mini
XLR1
XLR2
XLR3

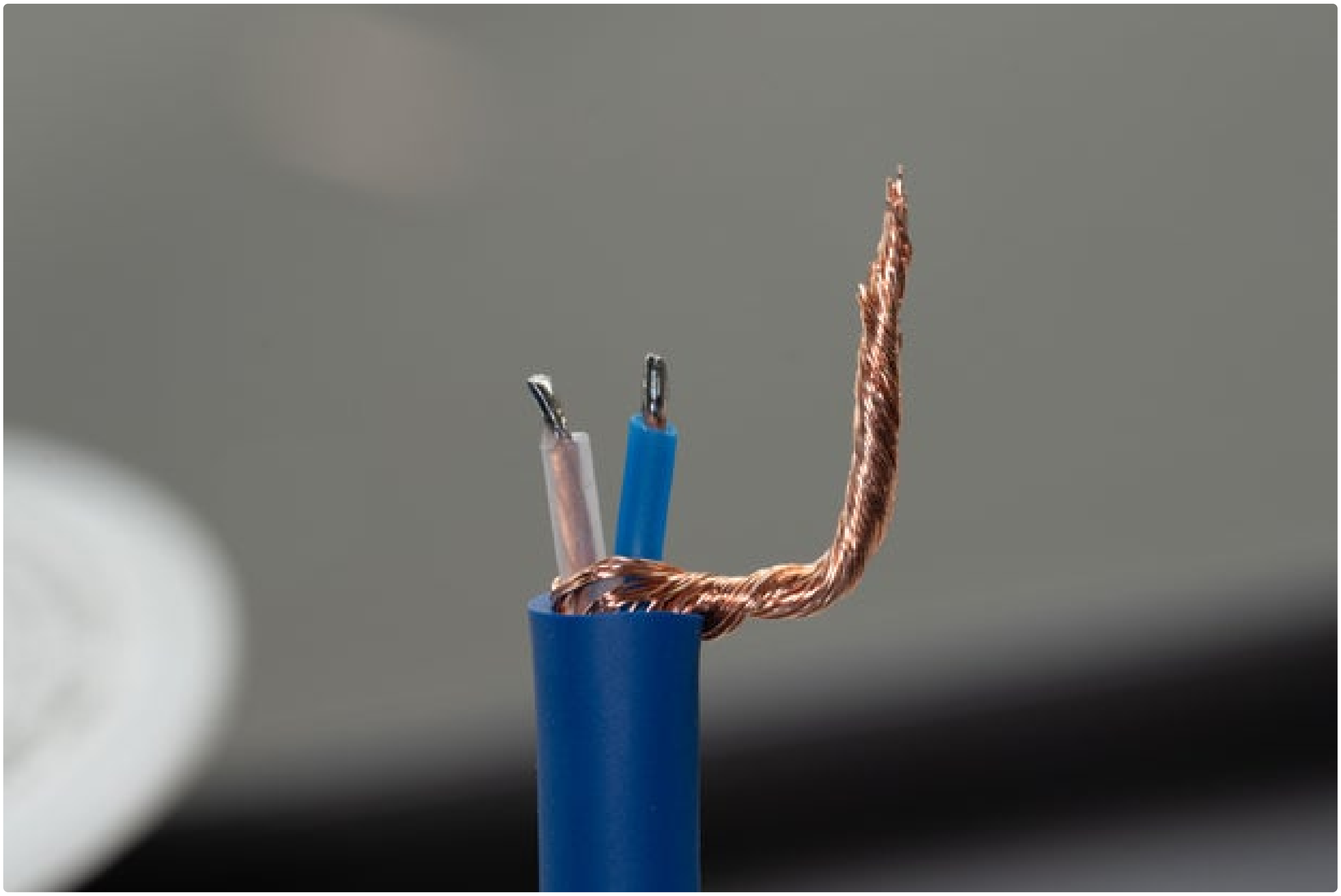












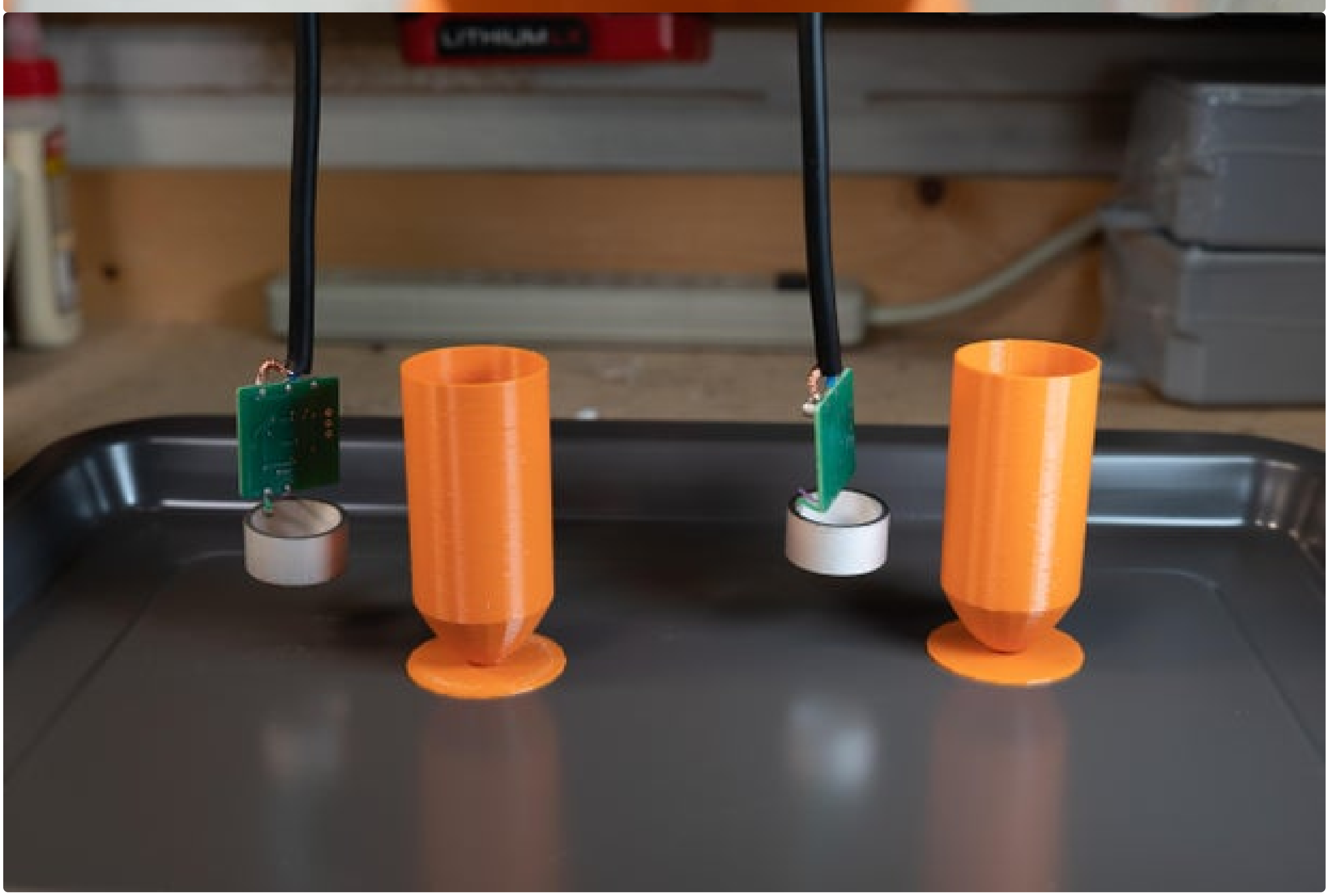
Step 6: Embedding the Assembly

My initial prototype was with two 50Ml measuring cups. I cut the bottom off of one and then glued it with hot glue upside down to the other one. Use enough hot glue to seal them together. A small bead the whole way around is recommended. There is no acoustic difference in the final build. We are using a two part resin. You mix equal parts "A" and "B" then stir it up. Couple things to note. The resin gets just a bit thinner (less viscous) as it mixes and blends. It gets a little clearer at that point too, That is about a minute of mixing. This is when it is ready to pour. Over the next few minutes it starts to set and gets thicker. About five minutes later, it turns white as it sets and hardens. In another 15-20 minutes, it is set hard enough to break the mold away. I used a single edge razor blade to score the mold on one side and then break it free. I did not use a release agent on the mold. This resin is pretty forgiving that way. One final note on the resin. You will see bubbles as it mixes and you pour. They do not affect the sound quality at all.

Before pouring the resin in, make sure the PCB and piezo element are not touching the wall or bottom. That ensures everything is sealed.

Note:

The resin I am using worked for me without a Release Agent. You SHOULD use a release agent with any other kind of resin.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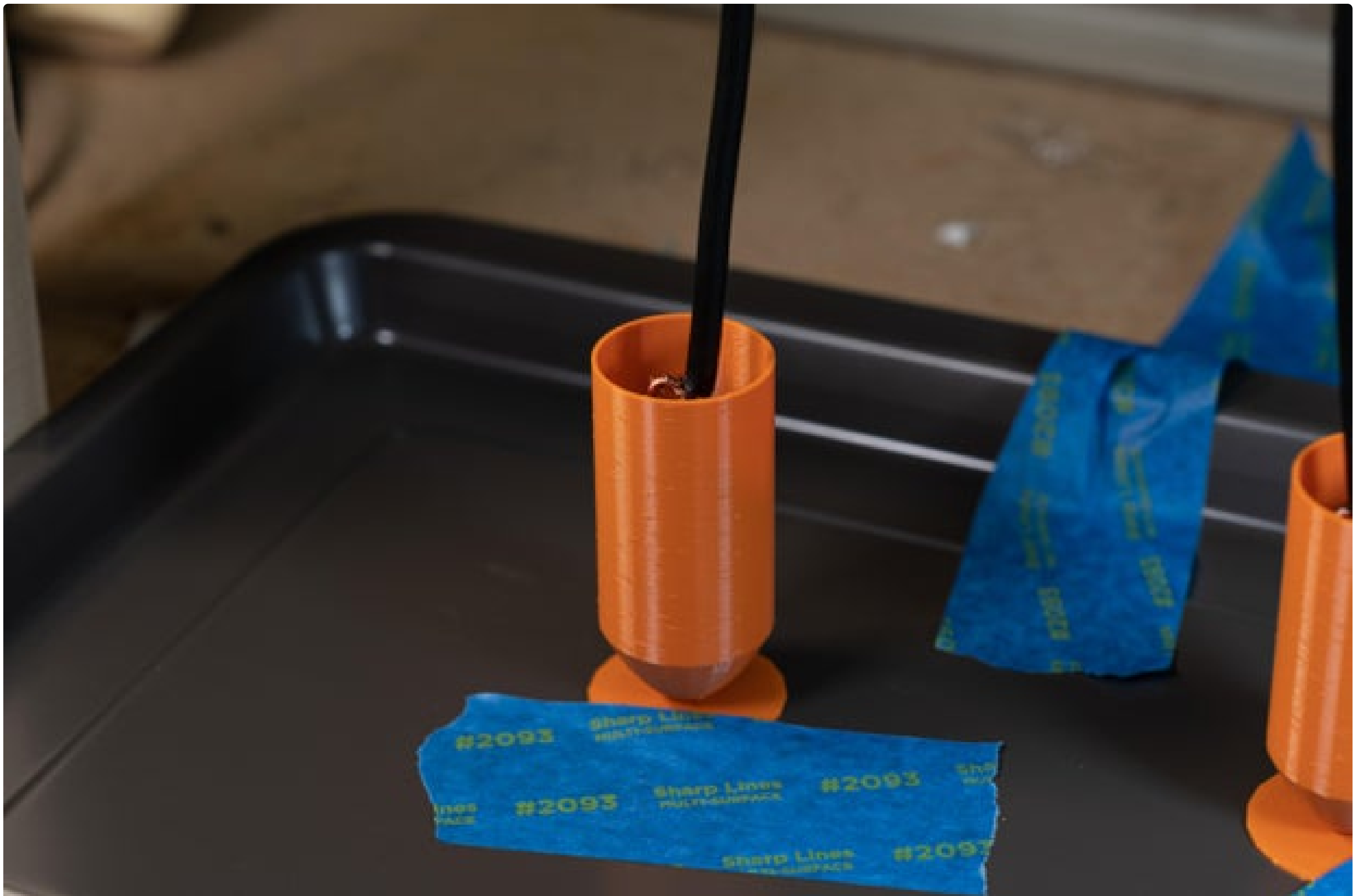
#2093
Sharp Lines
#2093
Sharp Lines
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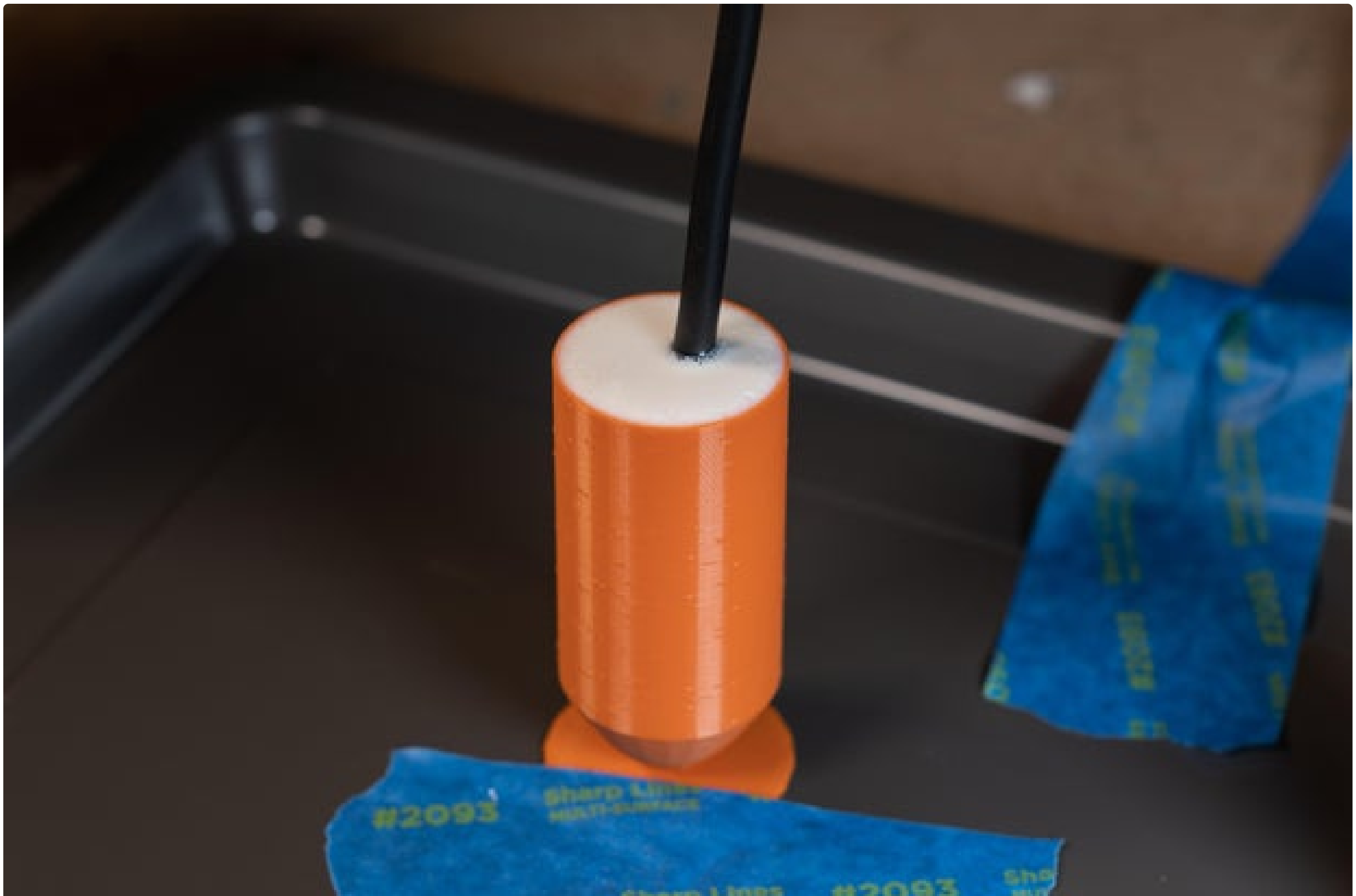
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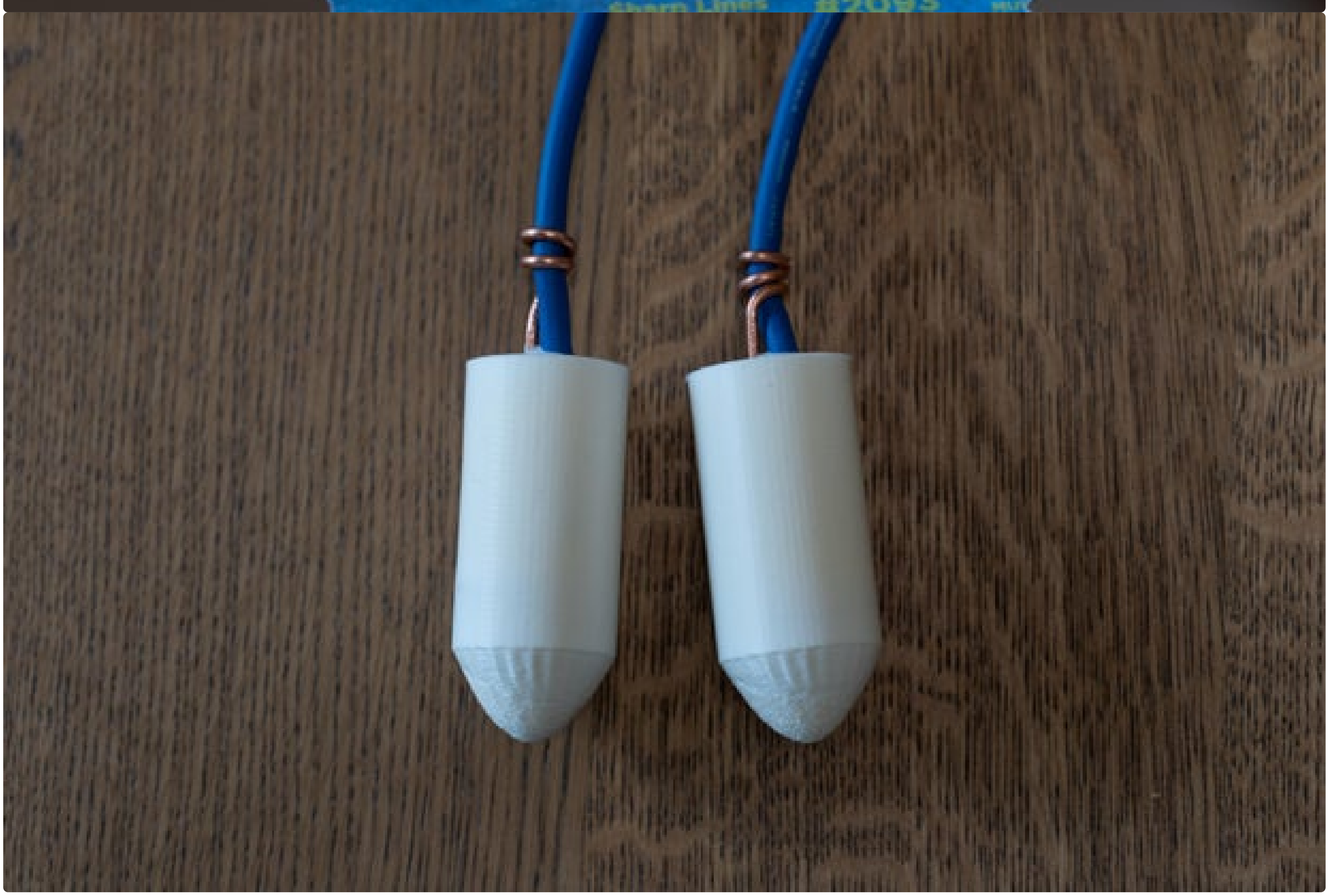
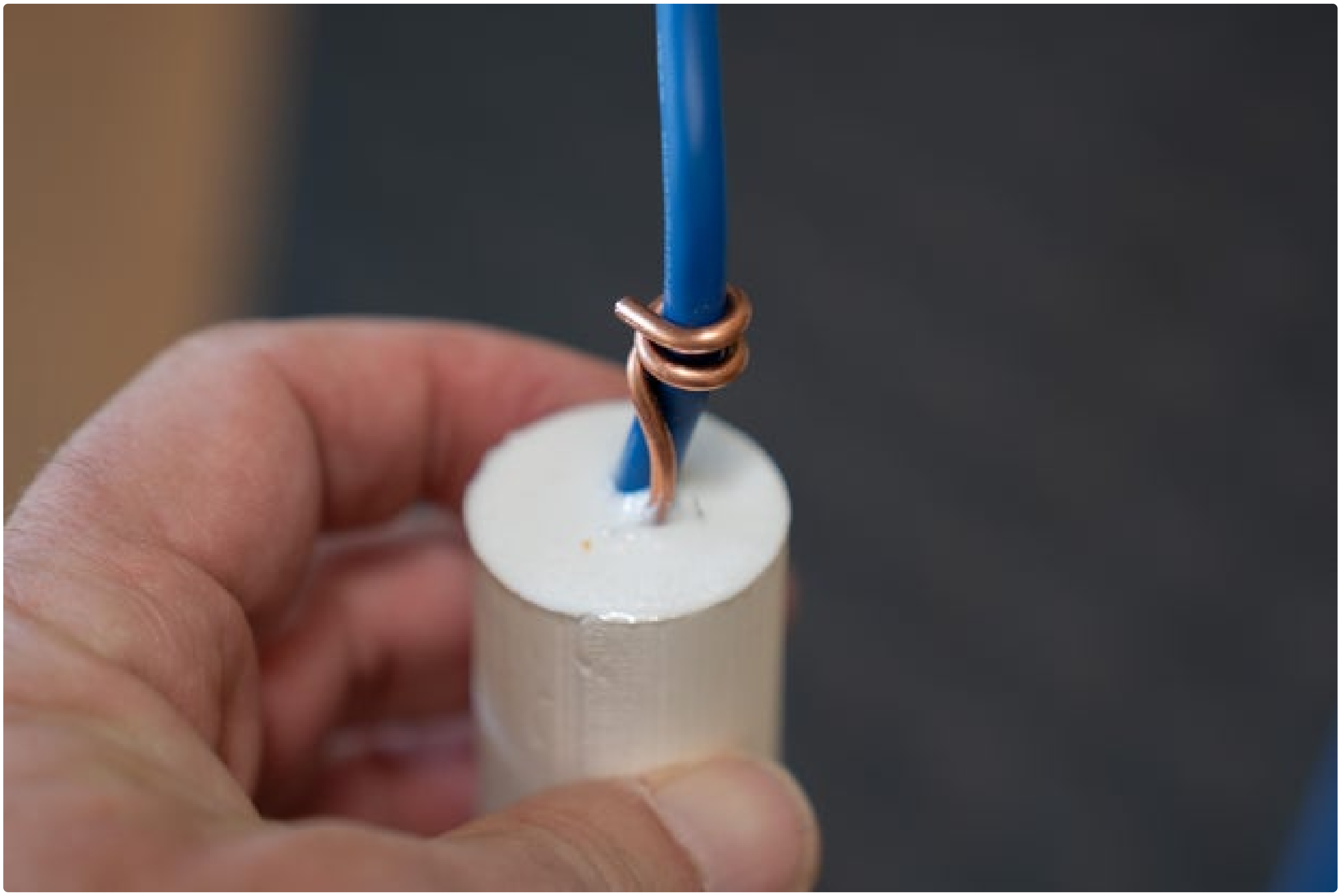




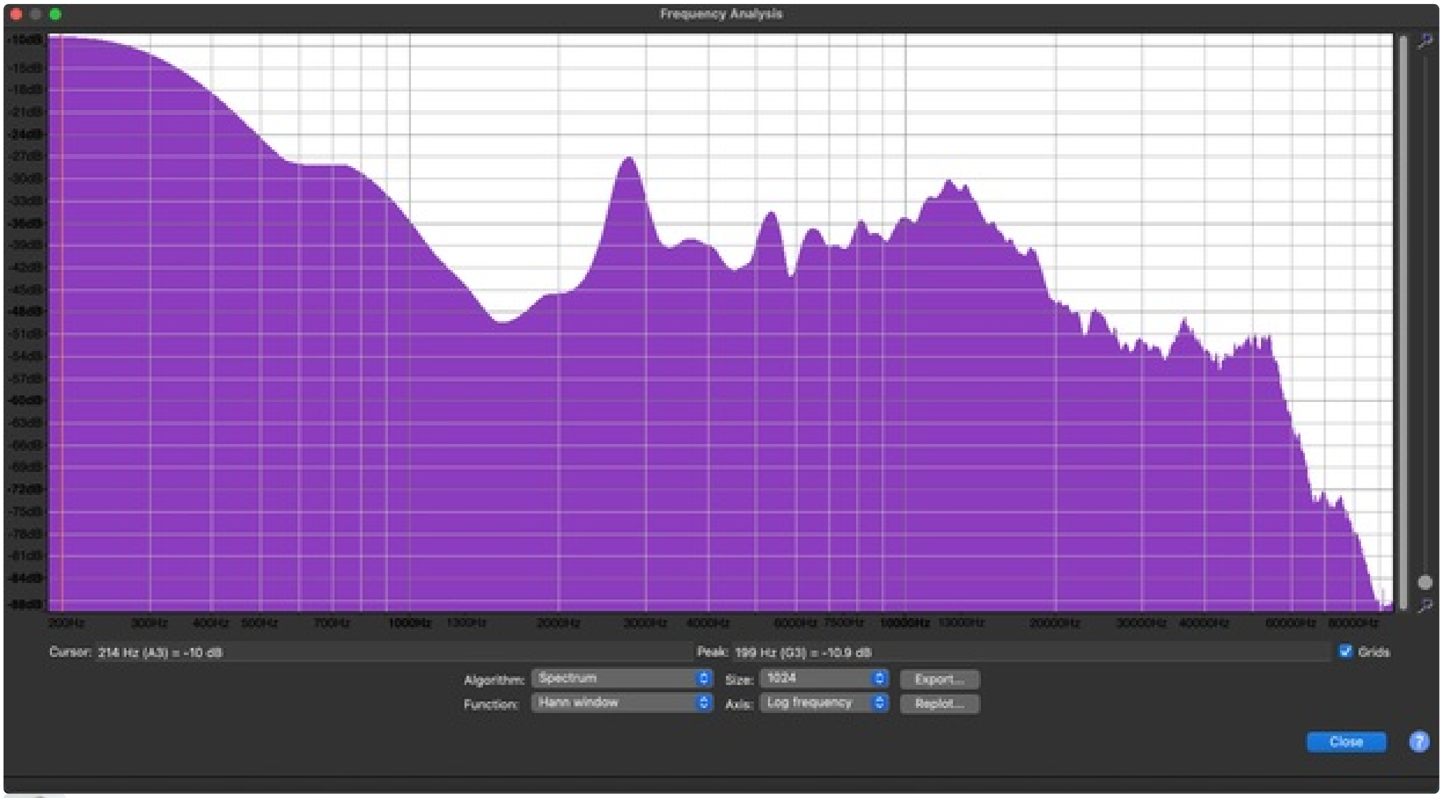
Step 7: Testing and Use

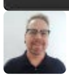
These are quite amazing! The circuit I am using gives about 100dB of dynamic range and between the cylinder and the circuit the frequency response extends to several hundred kilohertz. Along with capturing biologics, which I plan on when I can travel again, you can use them to record sounds that can be slowed down significantly to produce really amazing surreal soundscapes. These are a sound designer's dream. To do so, record with them at a high sample rate like 192Khz. I'm using a Zoom F6. Bring the file into any editor (Audacity is a great one for this) then slow it down 4-8 times. The above graph shows the sonic profile of the hot metal into water. Recorded at 192Khz into the Zoom the I plotted a 2-3 second snippet. See my demo at the end of the build video for this.

Here is the Demo of them used off the coast of Greenland July 2022 Soundcloud Demo:

Here they are in Dry Ice and Red Hot Metal

They are a great addition to your sonic arsenal. Enjoy! Please comment, ask questions and let us know if you build a set.





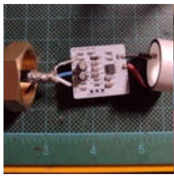
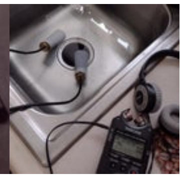
Thank you, Jules, for the great work you did on this Instructable. Your writing and documentation made this not only thorough but also easy to understand.

My build:
I purchased a few completed boards from PCBway, I knew I wanted at least 2 and that seemed like the most economical way to go. Next, I opted for using Canare cable; with each hydrophone at 50ft in length, I think the cotton strands inside will add some extra strength for long underwater runs. The specs are also otherwise similar to Mogami. Then, I opted to use a 1.5" brass cap for my water ground, drilled to fit the cable snugly. Assembly of the board to the cable was a breeze. I had never worked with a cylinder piezo and was worried I would damage it but it took the solder like a champ. When it came to make a mold, I opted for a couple of plastic shot glasses with the cup end cut off. I also added 4 drops of EpoxyColor black dye to the polyurethane cause I did not want white.
A couple of notes of caution:
1. It was windy the first day I put everything together and I had some issues with ESD (electrostatic discharge) and managed to zap 2 of my OPA1642s. In 15 years of working with electronics I have never had that happen, so be careful and be sure to ground yourself.
2. The piezo cylinder may shift in the mold and become exposed. So be sure to carefully examine your piece once you de-mold it. I had to make a small batch of the polyurethane and patch one up.

In use:
I took the hydrophones out this morning and am amazed at how great they sound. The first location I went to was a boat launch near a small beach and marina. The shellfish under the dock and on the pilings were alive and popping. It sounded like a campfire.
My next stop was the mouth of the San Gabriel River (between Seal Beach and Long Beach, Ca). It was here that I really started to appreciate how great these hydrophones are. I could still hear some shellfish sizzle, but I could also hear clicking (dolphins?) both near and far as well as cool creaky and bubbling sounds. Here is a link to some of the sounds I recorded.
https://soundcloud.com/potar-usa/hydrophones-under-the-bridge-to-seal-beach

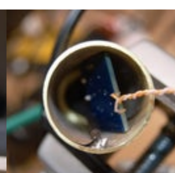
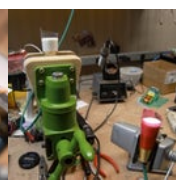
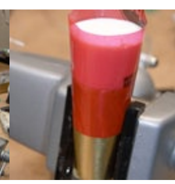
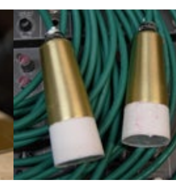
I am already scouring Google Maps for more locations to go dunk these.

Thank you again, Jules for the great work you did on this. I plan on trying one of your microphone builds next.

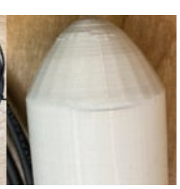


Thank you so much for the help!!!

I just completed my second set with grounding. My first set hummed so bad they are unusable. I discussed this with Jules and he updated this Instructable to include a ground connection with the water.
I decided to use brass chair leg ends to make this water ground as well as to provide a mold for the resin pour, and hopefully some additional durability. I tested both before pouring the resin by tapping on the piezos. Both worked and were quiet.
Preliminary test in my aquarium results show no hum although I am hearing some weird "electronic noise" in one of them. I'll know more when I take them out into the field and drop them in a river.
I also built these from the raw PCBs this time rather than buying the pre-made ones from JLI. Soldering surface-mount components is a challenge but they both seem to work.



Completed! - 2 of the four I intend to make. SMD components soldered under a 25x magnification binocular microscope. OPA1642s came separately from China via ebay, but they seem to work fine. Now to throw them in the river and see what I get. Looking forward to seeing the dolphins again at Rosemarkie to try them out properly. Note the dark line in the 2nd pic where the piezo element was too close to the side of the mould (mold) when the resin was added. I'll cover this with a bit more resin when I pour the second set. I used the resin specified, 60 grams of Part 1 (yellow) to 56 grams of Part 2 (blue) just filled the two moulds (molds) with a little spillage. Brilliant instructable - thanks, Jules!



Hi NicAndy - out of curiosity, where did you get such thin-gauge XLR cable?

I found it on ebay, from "designacable" - Van Damme XKE Starquad 4 Core Cable. Balanced XLR Mic. Screened Bulk Reel Tour. The only problem with it was that it has two blue and two white-covered wires, so you have to keep track of which is which when connecting up. I'm sure they have other miniature xlr cable as well.

I've only just seen Jules's addition re earthing, although I haven't had any problems with hum so far. Mods in progress!

More on the cable. The one I mentioned above is 6mm diameter, whereas I actually used a 3mm diameter “Professional low-noise microphone cable” (also from ebay in the UK).
I found I did need earthing, so I got hold of some 32mm brass tube and cut short (25-30mm) lengths off it. I used a belt sander to reduce the diameter of the hydrophones, and then took a saw and a Dremel/rasp to reveal the top right-hand corner of the pcb where the pin 1 connection was. I soldered a short piece of wire to the inside of the brass tube using a hot-air gun (normally used for heat-shrinking) to melt the cored solder, and soldered the other end to the pin 1 connection on the pcb. Checked continuity with the xlr plug. Then reformed the mould (mold) around the unit and added more resin. I’m very pleased with the results! Hopefully the brass will withstand even salt water, and it can easily be cleaned if it tarnishes.

Hello there, I purchased one of your buffer pcbs from JLI for my first hydrophone. However, now Id like to modify and incorporate your design with some work of my own.
Is it possible for you to share the gerber files and/or the pcb design files, as far as I can tell, I can only find the board information on PCBway, and it seems like they will not let me download gerbers/design files...
Have you already done this and I am missing it?

Hi Jules, I am about to build a couple of your hydrophones. First I like to mention that I have read several of those Naval Postgraduate school papers over the years too but couldn't figure out the piezo electronics and I also realize how difficult it is to actually choose and source equivalent piezos. When you posted the instructable this spring it was like a dream come true. I´m very happy and thankful about that. Molto grazie.

Right now all parts are available at mouser, except those two22uF caps from input-section. And those should have a 35V rating anyway as you mention over at pcbway. The only available 35V 22uF capacitor is not from UCM series but UWD series and all the difference might be:UWD1V220MCQ1GS takes more soldering heat and has 5mm instead of 4mm diameter. Do you think this is a valid replacement and will it physically fit on the pcb?
https://www.mouser.at/ProductDetail/Nichicon/UWD1V220MCQ1GS?
qs=4aNf6TG8tj%2FF9rjNC25EMg%3D%3D

Thanks for your kind words. Those capacitors should work and I have had PCBWay make these. Yea, once I found a source of the Piezo Cylinders used for these I was super excited. They turned out great and I am already working on a follow up project using them. I am building a set for whales in late Jan off of Hawaii.

The follow up project sounds exciting. Can you tell me - when experimenting with alternative piezo-elements (from Europe or more likely China) do I need to adjust anything other than the output resistor of 1M - to maintain a low cutoff around 24hz. Or is there more to it and the answer will be too comprehensive? Thank you.

If you do find an alternative supplier for the piezos, it would be really cool if you could share here. The current supplier has great prices, but the shipping price is pretty punitive if you're ordering in low quantities.

Incredible work!
We are working on some projects in Palau and Seychelles, and Id love to incorporate your

design. I just had a couple questions for you, firstly, do you think its reasonable to expect a good signal in the ultrasonic range - maybe even up 150khz? Im not seeing a low-pass filter in the circuit, but I suppose the sensing element itself might only work within a certain range...
Secondly, (more a matter of interest) how hard do you think this would be to adapt for use in an embedded system? Would the design have to be single sided? Are you aware of any pre-amp/amp setup that would be relatively small and suitable for digital recording and transmission?
Cheers, and fine job!
Brett

This has a response easily into the low megahertz range. With that said, you would need a recorder that supports that. I've used at 192Khz sample rate. By embedded system, do you mean where it tied directly into a complete recording system? If so yes. The board can be powered from 12VDC if needed.

Sorry, Im not sure how I missed the frequency response graph in your instructions - more great work!
By "embedded system" I just mean make it work with some sort raspberry pi or arduino thingy.
We are working on some marine remote monitoring equipment for conservation work. We are using something similar to a very slow raspberry pi (Onion Omega 2) and some cellular modules to transmit environmental data (ph, temp, dissolved, oxygen, etc).
We would love to be able to handle audio and transmit live, or close to it.
I do not have experience with custom/analog audio devices (although I did make some custom EMG circuits back in school), so I dont really know a lot of standard or off the shelf ways to amplify and digitize the signal your device creates.
Theres a lot of affordable-ish ADC ICs available, but Ive never tried to capture an analog signal this fast, and it seems like there might be a lot of pitfalls along the way.
Another option would be to transmit the signal using some sort of audio fm transmitter, and capture the data with a software defined radio, but I think a lot of signal quality might be lost along the way?

I was just wondering if you could point me in the right direction?

That's what I thought you were talking about. It is possible but there is a large difference in transmitting temp/pressure and environmental data and updating the data periodically. vs "live streaming" the audio. It can be done but It is beyond my paygrade. I do know of commercial units that record locally then get retrieved periodically for things like this. That is actually one of my next projects. "underwater drop rig"

If there is a budget friendly recorder that is compatible with this I would love to know the entire setup.

Yes, I expect that since we need a higher sampel frequency than normal audio formats we might run into some issues.
If you get a git repository or some such thing going during your next project Id love to check it out.
If I get anything working I will be sure to contact you.

How long can the cable coming from the transducer be? Also, is it the conductor length or the water depth that limits the cable length?

Thanks,
John

I've built ones with 100ft cables on them. No problem

Thanks. Just what I need as I move from the bay to offshore (Gulf of Mexico). Just need to buy some more cable:)

I just made these and I have a hum issue. I tested them before casting in resin and they sounded exactly like in your video as I tapped on the Piezo transducers. To test them I put them in my aquarium over a couple airstones but was met with loud 60HZ (I guessing) hum. As soon as I take them out of the water, the hum stops. I shut off the aquarium lights, pump, etc and though the hum diminishes slightly, it is still there. In fact I dropped one into a tall glass of water and it hums. When I stick my finger in the water the hum gets louder. Pull them out of the water and the hum goes away and they appear to work normally, as in tapping on them produces sound.

I think I have this resolved with a ground connection. Please see Step 5 for more information.

what are you using for a recorder? I have a couple thoughts. Please email me @ ryckebusch@gmail.com

Wonderful post, very well written.

I am looking at making two of these, one to take out on the boat and another to anchor just off shore with a solar powered PI or Arduino to transmit back (3G) to a website (and possibly open this up to others to enjoy). I am a computer and electronic nerd at heart, so buidling is part of the fun!

My question is around direction, I am presuming that there are probably two ways to tackle this?
1) Use a directional receiver something like http://whaledolphintrust.org.nz/wp-content/uploads...
2) Use two hydrophones and use software to determine distance based on time deltas, something like https://groups.csail.mit.edu/drl/wiki/images/b/ba/...

Admittedly I need to do some research on this, but was wondering if you had some quick pointers?

Hi...I made a pair of these with the components that were recommended. When testing with my recorder and 48V phantom power I only get a motor boat sound and nothing sounds like your test on the video. I've checked my connections several times and they appear to be correct. Any suggestions?

What are you using for the recorder/source of P48? and I hate to ask this, did you test before embedding in resin?

HI..thanks for responding. I'm using a Microtrack II recorder by M-Audio. It has a switch for P48. It doesn't have XLR connections but, has two 1/4 inch TRS connectors. I use an XLR to TRS adapter. The unit is not encased. I just humms and only faintly seems to respond to touch.
Thanks for your help.
Bruce

Do you have a Multi Meter that can measure voltage? With P48 connected, we should have 22-25VDC on the input XLR_2 and XLR_3 when referenced to XLR_1 (ground) then @ the VCC_1 or VCC_2 somewhere around 11.8VDC.

reach out to me via email ryckebusch@gmail.com we will sort this out.

Yes...I'll try it out. Thank you.
Bruce

Good morning!
Thank you so much for all of your work, and for this resource!

I'm having a bit of a repeatable issue with this build, and wondered if you may have a sense of what could be causing my problem.
I am using all of the components that you recommend above (aside from the brand of mic cable

*I'm AM still using quality cable -Canare Star-Quad), but each of my assemblies is exhibiting grounding/shielding problems.

When I test the assembly prior to encasing in resin, I get a good amount of low hum. This happens regardless of preamp I'm powering from. If I touch something metal with my other hand, the hum is reduced, but never goes away completely.
With one build, thinking this could go away once potted, I completed a unit, finding only that once the hydrophone touched the water, I get a VERY loud buzz on the output (as If I had a straight short).

JLI has been kind enough to send me replacement boards, in the event there was an issue on that end, but I'm still getting the same problem.

Again, I'm using everything listed in the above instructable, connected to aprox 40ft of Canare star-quad cable. (I have tried both tying the ground pin to the shell and floating it)

Thoughts?

Thank you in advance for your time!
Wyatt

Interesting. Thank you both, and please keep us posted, Jules!
The ground lead is something I had seen in one of your previous posts, rmmoore, but I was unsure whether it would apply in my case, as I'm running everything balanced and shielded.
I would certainly love to find a solution that worked without doing this, the only problem is, one can't know whether the solution works prior to completing the build. If I had to go this route, I wonder if intentionally causing a bit of the shield braid to protrude from the mould would serve the same function without compromising the integrity of the circuit/watertightness. I could then tie the shield to the case at the XLR end, effectively doing the same thing you have done, but within a single cable.
I have two weeks or so before I need these, so I'll hold off a bit before attempting this as a solution.

Thanks again,
Wyatt

Wyatt,
I've encountered the same hum with the hydrophones I made picking up EMI.

A solution I've found that eliminates the hum was attaching a single conductor wire on the outside of the hydrophone assembly and running that to the audio ground of my unit (in my case I wired this to a 3.5mm plug to go into the "Aux. / Mic In" input on my recorder). The attached photo shows a nut attached to the end of the wire which I used during testing so the wire would sink while I was testing hum reduction at various distances from the hydrophone. I found that having the wire any distance more than ~1-ft or so from the hydrophone would not help with hum reduction, so attaching it directly made the most sense. Hope this helps and let me know if i can expand on anything!

I am looking into this, a couple other people reported similar things. I am looking at some copper screen for shielding. I have not had issues using mine, even when near welding equipment. I will keep you informed on this.

Jules

What a great instructable! Thank you for the detailed explanations.
Do you have any recommendation for audio amplifier to go with your hydrophone?
Thanks

You can use any microphone preamp or USB interface that supplies Phantom Power. I use the ZoomF6 for field recording. Plus it records at 196Khz, which lets you down pitch ultrasonic sounds.

Great. I will check it out.
Thank you!

Hello. I just found out that half of the parts from the BOM is out of stock on mouser. I am pretty novice in ordering parts and I just want to ask kindly if someone can help me if there are alternatives for these parts, which are in n stock, or could be ordered from other sites... I just got the PCBs from PCBWAY and I want to order the parts to build them :)

These are the missing parts :
Aluminum Electrolytic Capacitors - SMD 25V 22uF TOL 20% AEC-Q200Thin Film Resistors - SMD 0805 2200ohms 25ppm 0.5% AEC-Q200Thin Film Resistors - SMD 1M OHM .5% 25PPM 1/8WAudio Amplifiers Sound-Plus Hi-Perf JFET-Inp Aud Op AmpZener Diodes 12 Volt 0.5W 2% AUTO
Thanks so much !!!

I ordered some of the cylindrical piezo elements to do some testing with. I don't have your amplifier PCB or XLR recorder though, so I was doing some tests with a USB guitar interface, which are designed for piezo pickups. I soldered some shielded wire to the piezo, and potted it using the 65D that you used. I then ran a short wire into the USB guitar amplifier for testing. The cylindrical piezo is nice because it picks up the audio from all directions instead of just one axis like a flat piezo disk.

However, I'm running into a problem that I can hear a hum on the wires just as I'm about to lower it into the bucket of water. On my desk, the piezo is quiet. But the hum gets louder as it approaches the water, and then more loud in the water. If I touch the ground wire near the amplifier input plug, the hum is lower. I tried many different amplifiers, including a Behringer UMC404HD which has 1M input impedance, and the hum is the same. Interestingly, if I run a wire from the ground of my amplifier and touch it into the water, the hum goes away. I also did a test with a regular piezo wrapped in kapton tape into the amplifier, and still get the hum.

Is this problem caused by me trying to separate the amplifier and the piezo and not potting them together? Have I built some kind of capacitor with the epoxy as the dielectric, or is my bucket of water somehow holding an electrical charge? I didn't want to pot a USB amplifier and piezo just to find the hum is still there and waste a bunch of money. Do you have any ideas? Thanks!

You may want to add some shielding around the cylinder and ground it. I haven't tried these unbalanced into your setup but going off of experience with Piezo pickups and contact mics, you will need some shielding doing it that way. My design and the NOAA one doesn't as the high impedance parts and transducer are submerged in water. Then the signal coming out is low impedance and balanced. If I hold the hydrophones in my hand not submerged, I will get a little hum. Especially if I am indoors. Outdoors and in water, never had an issue.

Thank you both for the comments. This makes a lot of sense and explains what I was experiencing. I found it unbelievable that a bucket of water could hold a voltage potential like this, and surprised the ground wire to the water fixed it. And the link to the dolphin recording information is exactly what I needed to read, which confirms that doing grounding like this is the right solution for me. Now I need to try recording the sidewalk chalk in a bucket again to see what it sounds like with no hum in the background. Thanks again!

Hey we have occasionally solved "ground loop hum" by adding a "saltwater ground." See e.g. http://www.speakdolphin.com/ground.cfm

That said, an ideal DIY hydrophone won't have the hum issue! (So thanks for pointing us in the right electronic direction @DJJules)

Very interesting project! I've built a couple of hydrophones with piezo mikes, and using a PCV as sleave filled with epoxy. They work okay. This looks like it will work better. Our summer cottage is in the Pacific Northwest on the water and the Orcas go by regularly. I'm hoping to see if I can hear them. One thing I'm trying to do is connect the mike to a short range radio transmitter (FM or 915MHZ) to transmit the signal to the cottage. Have you tried anything like that? The other thing I have is a cutoff filter to try and isolate the frequency the Orcas chat on...

Thanks! I haven't gone to remote transmission but I'm planning a version with a a waterproof case that can hold a recorder. Kind of an aquatic "Drop Rig" that nature recordists use.

I'm looking for the live option so it can hopefully alert us that Orcas are in the vacinity.

Check out our open source solution for that @bundolo via http://github.com/orcasound or just listen to live feeds via https://live.orcasound.net

Yea that need a more permanent install. Would be great to have!

Thank you for the wonderfully detailed write up! I built the COSEETEK device linked below and was disappointed with the performance - I seem to hear not much except when water splashes against the sensor or cable. I was hoping to learn more about this, and eventually build your implementation and see if things are better.

Are disk shaped piezo buzzer elements a drop-in replacement for the cylindrical piezo that you used? The COSEETEK device uses a small foam bumper behind the piezo element to form a small air pocket, and a thin epoxy layer on top. Why do they use an air pocket while your design avoids this? Does the air pocket give better audio performance? Having the air in there limits the depth rating, so was curious to understand the tradeoffs here. I've noticed most underwater hydrophones all have very shallow depth due to air pockets, while yours is basically full ocean depth since its entirely potted with no air.

If you were to encase your piezo cylinder into a huge cube of resin, won't that reduce the volume of the sound? Or do you need to keep the resin as thin as possible to capture the most sound?

For testing, can you connect one of those cylindrical piezo elements up to something like a guitar amplifier to see how it performs? Or are these cylindrical piezos different and won't work like this?

Thanks!


Mine are literally based on the design that the Navy and National Oceanographic Institute uses. See the link to the NOAA Paper in the Instructable. The cylinder, in direct contact with the resin (which is close to the density of water) directly feels the vibrations of the sound waves in water. Works great. Could it be a larger mold, yes. I wouldn't go square foot or anything. The challenge with an airspace is that it compresses as you get deeper. The COSEE TEK one would alter its response the deeper it got.


Thanks for the reply. At some point, the COSEETEK device would just implode, since the layer of epoxy is very thin and designed to keep water out and not intense water pressure. I will have to read the NOAA paper in more detail, since I'm fascinated by designing hydrophones with no air gaps for full ocean depth usage. Thanks.