P3 Hi-Z Scope Probe

In this project, you will build a hi-impedance scope probe for connecting to the hi-z input on your audio adapter. This will be the ¼" input type (and not XLR). On some adapters this is called the "instrument input" jack. My adapter has a switch that chooses balanced line in, or an unbalanced hi-z input. Most adapters today are designed to have a guitar or bass plugged directly into them.

******************** WARNING ********************

If your audio adapter does NOT have an unbalanced instrument input jack, you can still design a probe for it, but use at your own risk. In this case, you should definitely add the optional protection circuitry at the end of the document.

I would strongly advise finding a cheap audio adapter with the unbalanced instrument input connector rather than potentially harming a more expensive piece of gear.

******************** WARNING ********************

You will need to fabricate two ends of the probe; the first has the ¼" plug and the other has the probe itself. Be sure to use a standard unbalanced ¼" plug and NOT a TRS plug. You will need to use shielded guitar cable or microphone cable to connect the probe to the jack.

The basic probe will work for debugging battery powered projects and other low-voltage, low-current devices. If you want to work on higher voltage gear, you should add the protection components in the last section of this paper.

3.1 Schematic

The schematic for the basic probe is shown in Figure 3.1. The T-S plug is a standard component. The probe itself is a finishing nail, with a resistance of about 3 ohms. You will need a plastic tube (Bic Pen) for the probe handle.

The 10k resistor is a current limiting resistor to try to protect the input of the audio adapter.

The two back-to-back electrolytic caps need to be rated higher than the input voltage range of the audio adapter which is usually $5V_{P-P}$ to $10V_{P-P}$ these days but will depend on the adapter itself. Since capacitances add in parallel and split in series, the overall capacitance here will be 50μF.

The ground wire connects directly to the shield of the cable and then out to an alligator clip that you can easily clip to the ground node of a circuit or clip it to another lead.

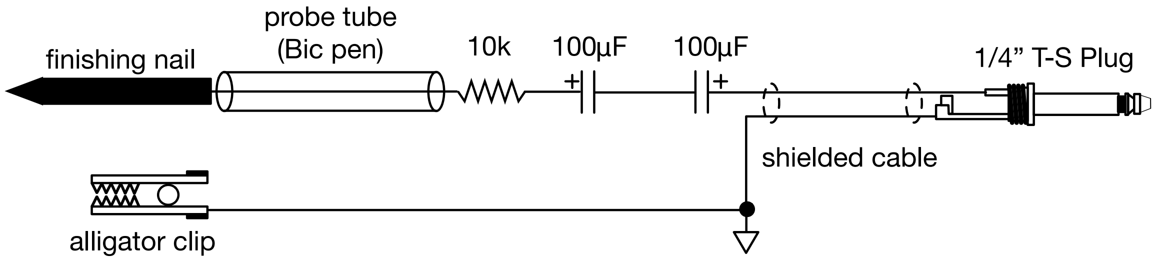

Figure 3.1: schematic for the scope probe

3.2 Bill of Materials (B.O.M.)

The Scope Probe project has the following BOM.

Project 1: Bench/Test Speaker				
P/N	**Ref**	**Description**	**Vendor**	**Vendor P/N**
WCP-R100	R1	1k resistor 1/8 or ¼ W(*)		
WCP-100u	C1, C2	100μF Electrolytic Cap		
WCP-CLIP	-	Alligator clip		
WCP-TRS	-	¼” TRS Cable		
WCP-MISC	-	Finishing nail Bic Pen		

(*) for the best current protection, choose the 1/8W resistor; see Section 3.5 for more information

3.3 ¼” Mono Plug End

The end that will connect to the audio adapter is a ¼” mono plug. Follow the instructions on the website for wiring this end, which is very standard routine. Test the connections to make sure the tip and sleeve do not short together.

3.4 Scope Probe End Assembly

First, pull the pen apart and pull out the ink and tip. Separate the tip from the ink cartridge and discard the ink part. Pull the tip out of the pen leaving only the brown plastic insert; this will hold the probe end when you are done.

3.4.1 Probe Tip Attachment

The probe tip is made from a finishing nail. You need to place it in a vise or helping-hands then heat with the soldering iron until you can melt solder on to it. This will take some time, but not more than 30 seconds of heating the nail. Prepare a piece of ***stranded hookup wire*** about as long as the pen sleeve. Prep one end by stripping 1/8” and soldering the lead. Go back to the nail, re-heat it and then solder the wire to the nail. It will stick, but do not be tempted to blow on the connection to cool it down or you risk making a cold solder joint.

3.4.2 Back to Back Caps

Assemble the back-to-back electrolytic caps with the negative electrodes soldered together. Then, heat-shrink the assembly as shown in Figure 3.2.

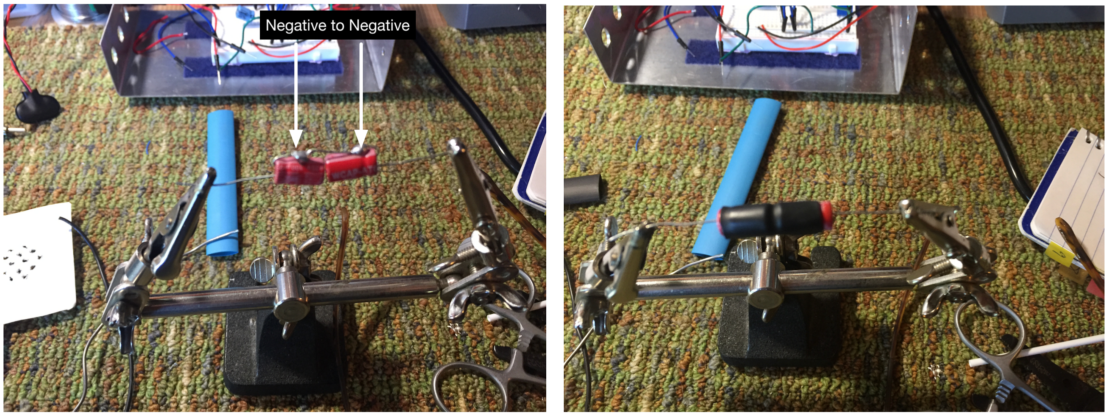

Figure 3.2: Back-to-back cap wiring, then covering with heat-shrink tubing

3.4.3 Current Limiting Resistor

Bend one lead backwards and solder the current limiting resistor to it. Here I am using a 10k resistor. Solder the other end of the resistor to a piece of **stranded wire** that is cut to about the length of the pen. Add another layer of heat shrink to cover the resistor-capacitor connection. Heat shrinking the connection to the stranded wire is optional but I do it anyway on this one. This is shown in Figure 3.3 (top). After that, test fit the assembly by pushing the nail/wire into the pen; the nail should be poking out of the end with a bit of wire to spare – a little too much wire here is OK; not enough will cause a re-do. This is in Figure 3.3 (bottom).

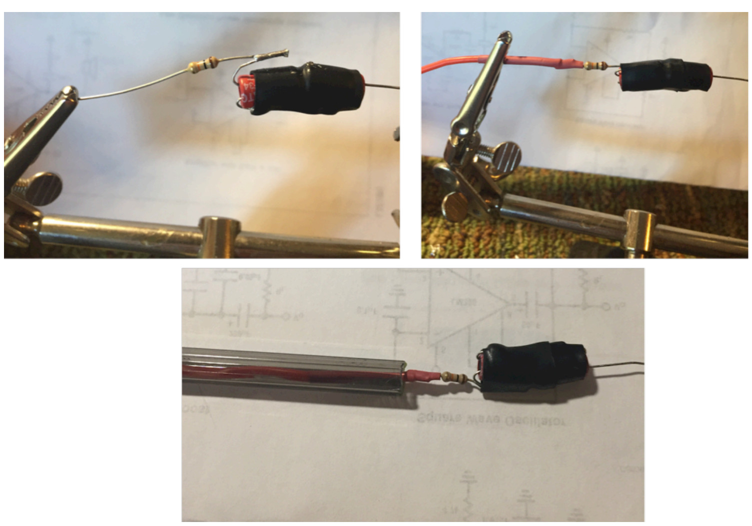

Figure 3.3: (top) solder the current protection resistor in place, then connect to the stranded wire and heat-shrink the connection (bottom) test fit the probe; push the wire and nail combination into the pen sleeve and then up to the capacitors

3.4.4 Ground Wire

Prepare the ground wire by stripping back part of the ¼" shielded cable and exposing the copper shield wires – be careful not to cut into the inner (hot) wire. Prepare the connection with solder and then connect it to a piece of ***black stranded hookup wire*** that is about as long as the pen (or longer). Heat-shrink the connection as shown in Figure 3.4. Prepare and solder the other end to an alligator clip as shown in Figure 3.4 and heat-shrink the connection.

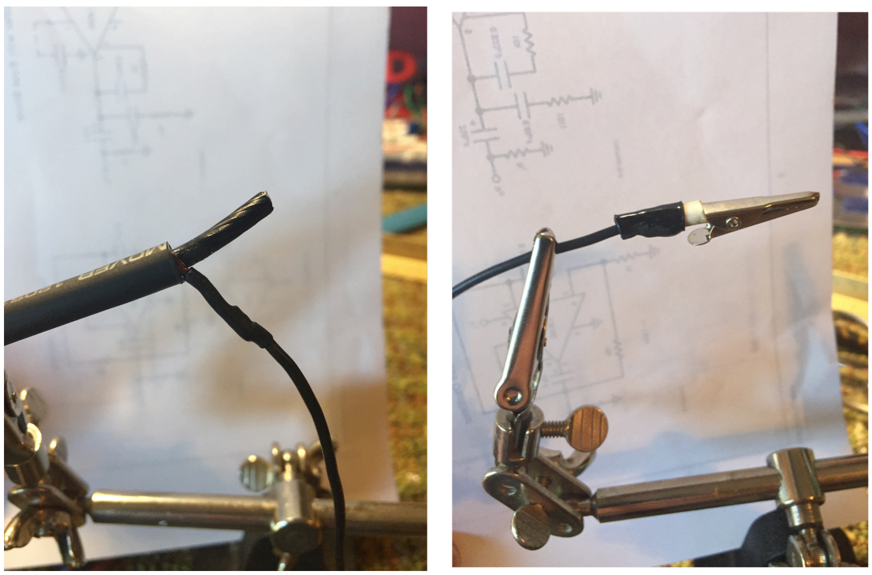

Figure 3.4: (left) solder the black stranded hookup wire to the exposed copper shield and heat-shrink the connection then (right) add the alligator clip to the other end and heat-shrink that connection too

3.4.5 Connect Cable to Probe

In the last step place the probe end and the ¼" cable end next to each other and prepare the connectors. Run a large heat shrink tubing around the probe (pen) and thread the ground wire through it. Cut the capacitor lead to about 1/8" and solder to the hot wire of the ¼" connector. This is shown in Figure 3.5. Once the connections are made, heat-shrink the entire connection so that there are no exposed wires from the cable to the probe sleeve (pen).

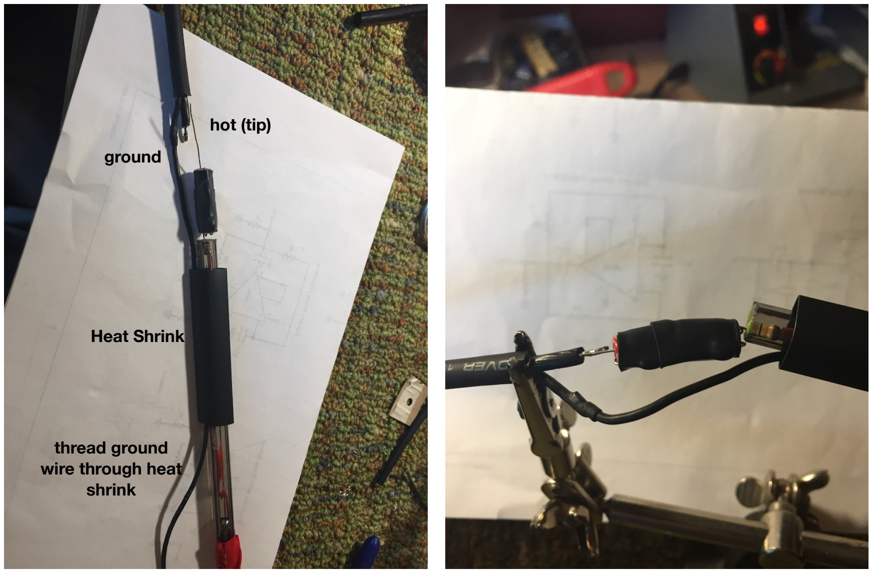

Figure 3.5: (left) test fit everything and cut the wires and electrodes to length as required; add the heat-shrink tubing to enclose everything (right) make the final solder connection to the hot wire of the cable

3.4.6 Finish the Probe Tip

The finishing nail is the same diameter as the original ink tip so you can re-use the tip holder as shown in Figure 3.6. Thread the nail into the tip holder and then place that into the pen sleeve. Although this will be a tight fit, you need to make sure that the wire and probe tip do not move when you bare down on the probe end while working with it. I used hot melt glue to form a little plug inside of the sleeve tip.

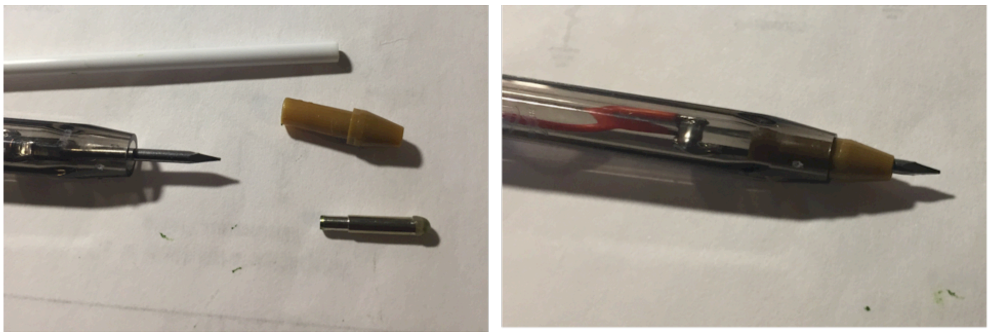

Figure 3.6: re-use the pen tip (brown portion) and insert the nail through it, then feed this into the pen sleeve; make sure there is a plug of material (glue) to prevent the probe from moving when you bear down on it

3.5 Protection Circuitry

If you are going to work on equipment with high voltages or currents that could potentially damage your audio adapter's ¼" input, then you can add one or both of the protection mechanisms to the circuit. Many of today's audio adapters already have the over-voltage protection circuit installed in their input block but it won't hurt to add another layer.

3.5.1 Overvoltage Protection

To protect against overvoltage scenarios, you need to add a pair of back to back Zener diodes. You will first need to find out the maximum peak-to-peak voltage that your adapter can handle. This can be a bit tricky, so if you are unsure about calculating peak-to-peak and RMS voltages, get some assistance. Here are the specs for my Presonus 1824c adapter's line-in port:

Instrument Inputs	
Maximum Level	+15 dBu (unbalanced, min gain)
Gain Range	80 dB
Frequency Response	20 Hz - 20 kHz (min gain)
Dynamic Range	112 dB (A-wtd, min gain)
THD + N	0.020% (1 kHz, +10 dBu, min gain)
Input Impedance	1M Ω

Figure 3.7: electrical specs for my audio adapter's unbalanced instrument input

Figure 3.7 lists the maximum input as +15dBu unbalanced which is 4.36 V_{RMS} or about 12.5V_{P-P}. This means that the signal would have a maximum positive voltage of +6.25 V and maximum negative value of -6.25V. To be conservative, let's limit our maximum input value to about +/- 5V or 10V_{P-P}. We need to find a Zener diode with a Zener voltage close to 5V and the standard value closest is 5.1V. We can use a pair of Zener diodes in a back-to-back topology to protect the adapter's input.

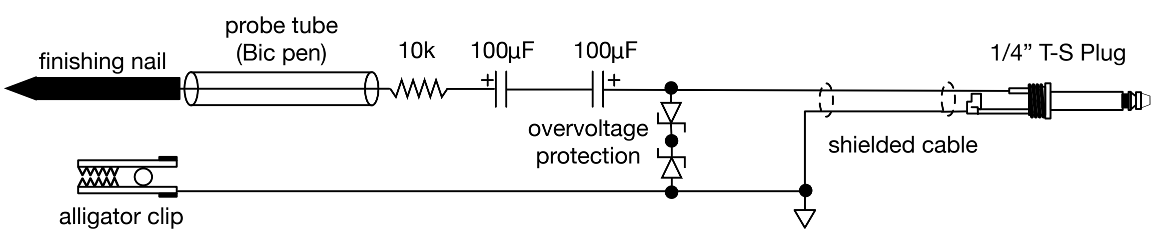

Figure 3.8: the pair of Zener diodes adds overvoltage protection right at the adapter's input jack

3.5.2 Overcurrent Protection

The probe has a series 10k resistor at the input from the circuit input. This will limit the current into the adapter. In my adapter's case, with a maximum 10V_{P-P} input signal, the current would be 1mA_{P-P}. The power dissipated would be 10mW which is below both the the 0.125mW limit (1/8W resistor) and the 0.25mW limit (1/4 W resistor). So, in theory we would be protected.

However, if you want more protection against excess current – which might happen with audio power amplifiers - you can install a simple fast-blow fuse in series with the hot input connection. This may not be necessary if the audio adapter's input circuit has a large series resistor, which will combine with the 10k resistor in our probe. It will be up to you to pick the fuse value depending on your choice for the resistor's power limit. I would simply match the resistor's current limit value to add a second layer of protection.

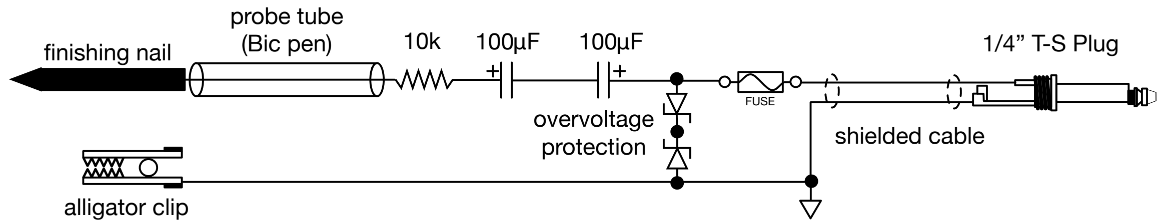

Figure 3.9: the added series fuse will give another layer of over-current protection should you decide that you need it