

Altoids Tin Headphone Amplifier Lab

Michigan State University - AEE/IEEE

Step 1: Required Parts

Table 1 shows a complete listing of the parts required to complete this project. Figure 1 shows a picture of what these parts look like. After receiving your parts bag check to make sure that you have everything. If you have trouble identifying any of the parts ask your lab TA for help.

Part Description	Value	Quantity
R1	4.75K	2
R2	100K	2
R3	1K	2
RLED/R4	10K	3
C1	470 uF	2
C2	0.1 uF	2
1/8 in Jack		2
1/8 in Plug		2
LED Holder		1
Battery Holder		1
IC Socket		1
Volume Knob		1
Potentiometer		1
Circuit Board		1
Solder		1
Op-Amp	OPA2132	1
9V Battery		1

Table 1: Listing of Parts

The last three components listed in table 1 are not shown in figure 1, and the last two components are not in the parts bag. You will receive these two once you complete the assembly and your circuit is checked.

The resistor values are not given directly on the part itself, instead there is a code. For the resistors that we are using 4.75K = 4751, 100K = 1003, 1K = 1001, and 10K = 1002. The code is simply three significant digits followed by a multiplier. For example, a resistor with the code 1001 has a value of 100×10^1 , or 1000Ω , which is the same as $1 \text{ k} \Omega$. Capacitor values are normally labeled directly on the part. C1 is labeled 470 uF, and C2 is labeled 0.1, where units are assumed.

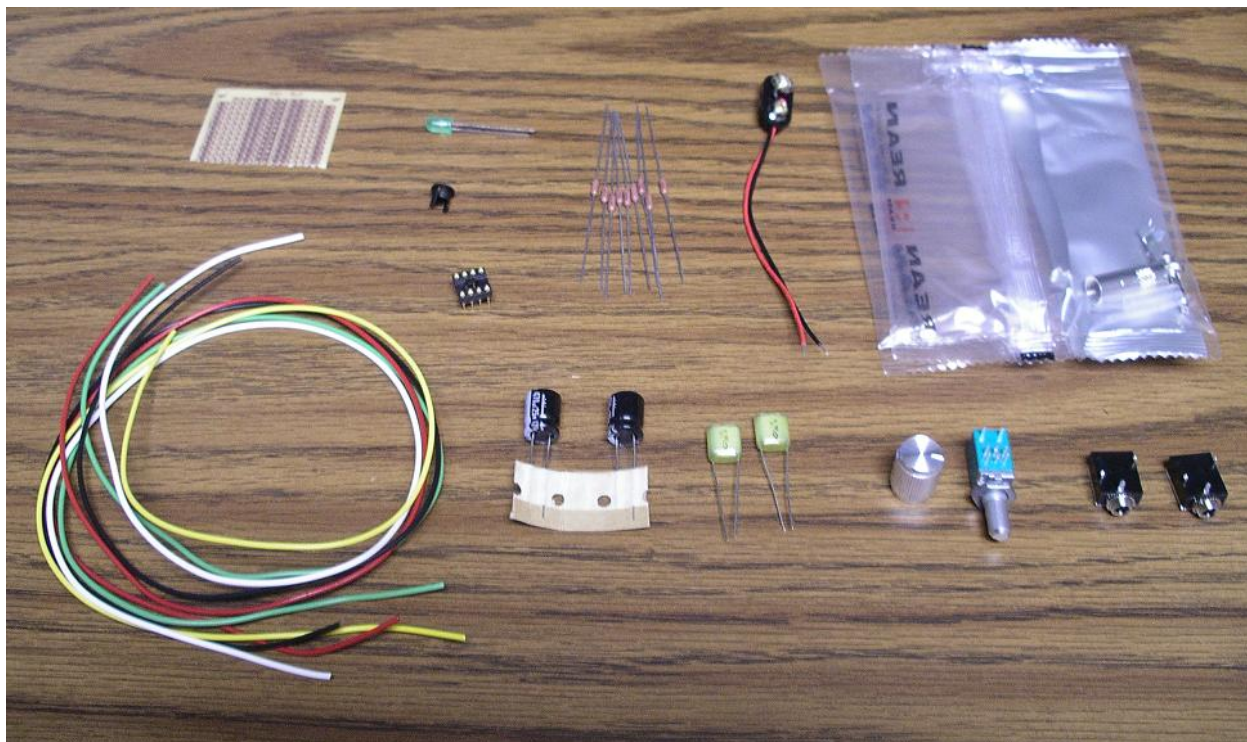


Figure 1: Picture of Parts



Figure 2: Polarity of Certain Parts

The first two components, the LED and the electrolytic capacitor have a polarity that must be followed. For both devices the longer lead is the positive lead. Also, the negative side of the LED is the flat side, and the negative side of the capacitor is the side with the white stripe. The third component is the op-amp socket. The side with the notch will line up with another notch on the op-amp itself. Next is the potentiometer/switch. The two leads on the far right side are for the switch. Here polarity does not matter. The other 6 leads are for the potentiometer. The bottom two are ground, the middle two are the output (of the potentiometer), and the top two are the input (to the potentiometer). Left and Right can be either side, but to make the wiring easier we are going to make the right pin the left channel, and the left pin the right channel. It is also very important that the bottom two pins are grounded, and not the top two. If this is reversed it will

still work, but the amplifier will turn on at full volume. Next is the input/output jack. The middle pin is ground, the right pin is the right channel, and the left pin is the left channel. Finally there is the 1/8 inch jack connector. Here the longest lead is ground, the second longest lead is the right channel, and the shortest lead is the left channel.

Step 2: Schematic and Layout

The next thing to consider is the schematic, which is a diagram showing the electrical connections of all the individual components. For this project there is also a layout, which shows you where each individual component is placed. This makes assembly a lot easier, but most times you will only be given a schematic. The schematic is shown in figure 3 and the layout is shown in figure 4.

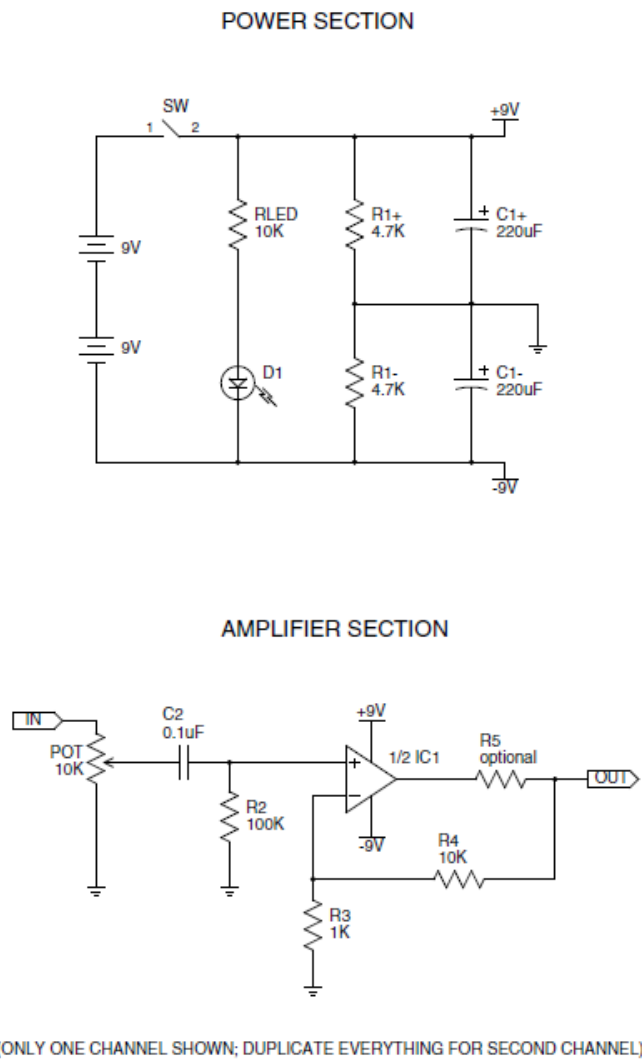


Figure 3: Aloiods Tin Headphone Amplifier Schematic

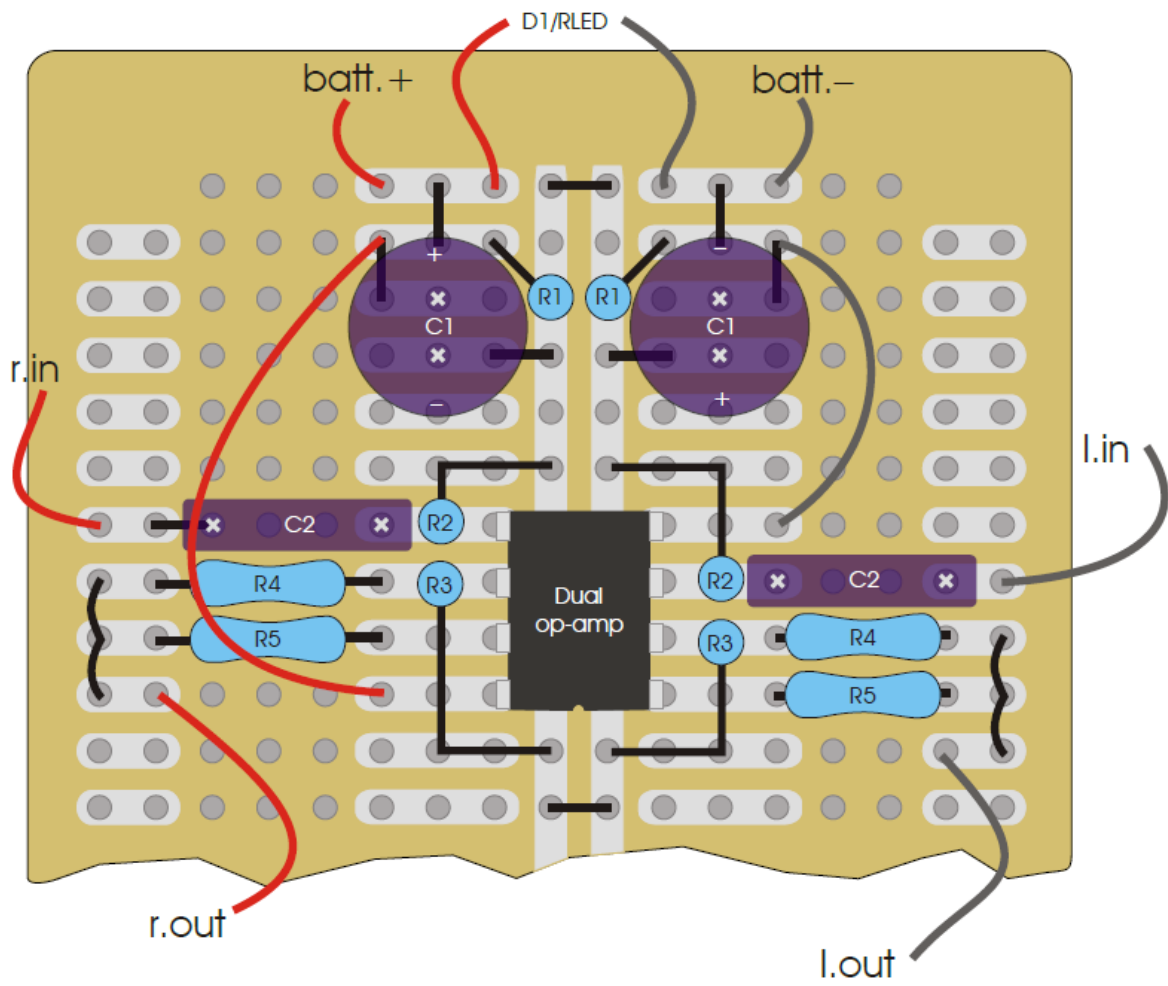


Figure 4: Aloids Tin Headphone Amplifier Layout

Step 3: Basic Soldering Technique

Soldering is the process of electrically connecting a component to the circuit board through a metallurgical bond. This requires very high temperatures (provided by a soldering iron), and a special blend of metal (solder). Solder is normally a combination of lead and tin, but for this project we are using a special solder that is lead and tin, but also has a small amount of copper and silver. This makes the process of soldering much easier.

The first thing to consider is which side to place the components on, and which side to solder on. Figure 5 shows both sides. You want to place your components on the side pictured on the left, and do your soldering on the side pictured on the right.

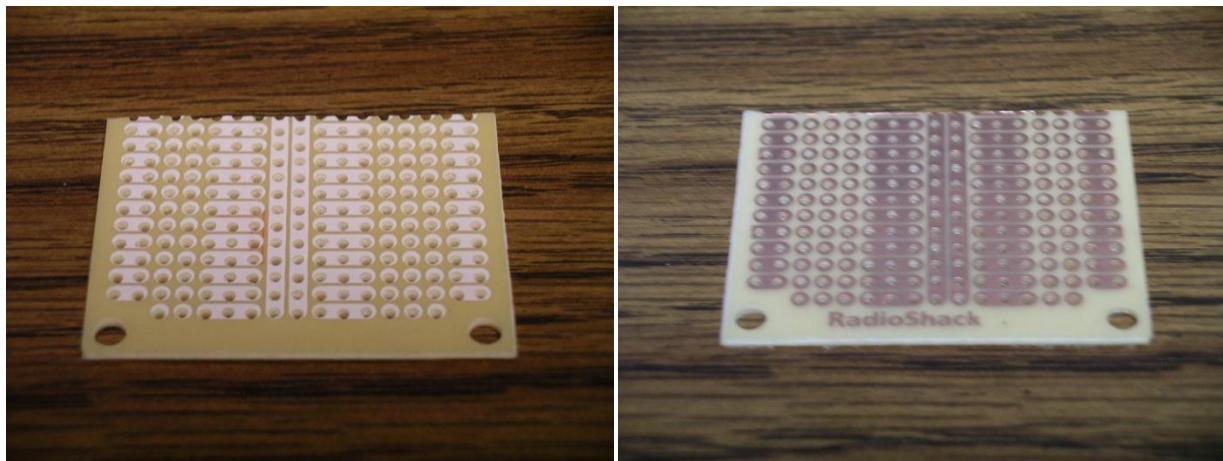


Figure 5: Different sides of the circuit board.

Next is the process of placing the component on the circuit board. Always double check the schematic and the layout to make sure that you have the right component in the correct location. First, bend the leads of the component so they will fit in the board. This is best done with a pair of pliers. Next, place the component through the holes, and bend each lead slightly outward to hold the component in place. All of this is shown in figure 6.

Next is the actual process of soldering. Ideally this should take around 5 seconds to complete from the time the tip touches the connection to the time the tip is removed. Any longer and you risk damaging the component, and any shorter you risk creating a bad solder joint. If it is taking a different amount of time then you need to adjust the temperature of your soldering iron.

The general process for soldering it to touch the iron to both the component lead and the circuit board on one side, let it heat up for a few seconds, and then apply the solder from the opposite side. This process is detailed in figure 7.

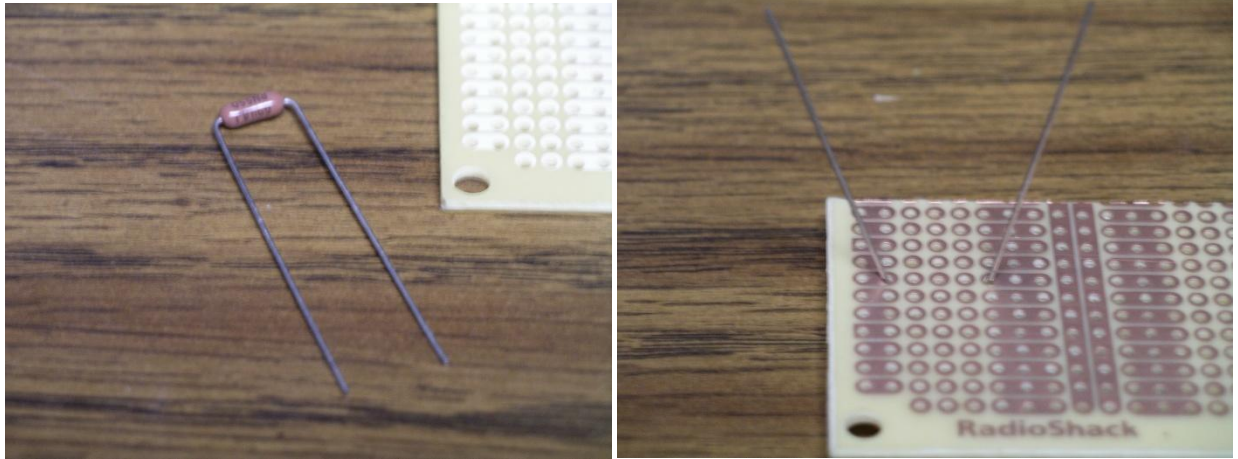


Figure 6: Placing the component on the board

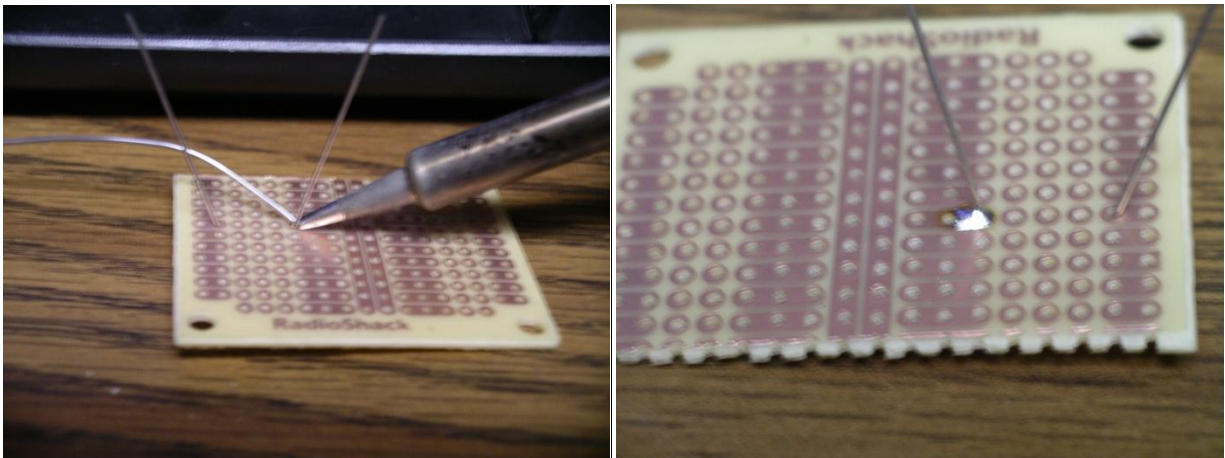


Figure 7: How to Solder

There must be a small amount of solder on the tip in order for it to conduct heat. Don't apply too much though, since this could get solder on the adjacent pads. Also, make sure that solder is covering both the lead and the component before you remove the iron. If solder isn't sticking then you aren't transferring enough heat to the connection. Finally, always remember to leave a little bit of solder on the tip of the iron when you put it back in the holder. This prevents the tip from oxidizing, and makes it last longer.

A completed solder joint is also shown in figure 7. Notice that it is shiny, and covers both the component lead and the circuit board. A bad solder joint would be one that doesn't completely cover both surfaces, or has too much or too little solder.

The next step is to trim the excess lead length using a pair of flush cutters. You want to trim the lead of just at the point where the solder stops, no shorter, and no longer. A picture of this is given in figure 8.

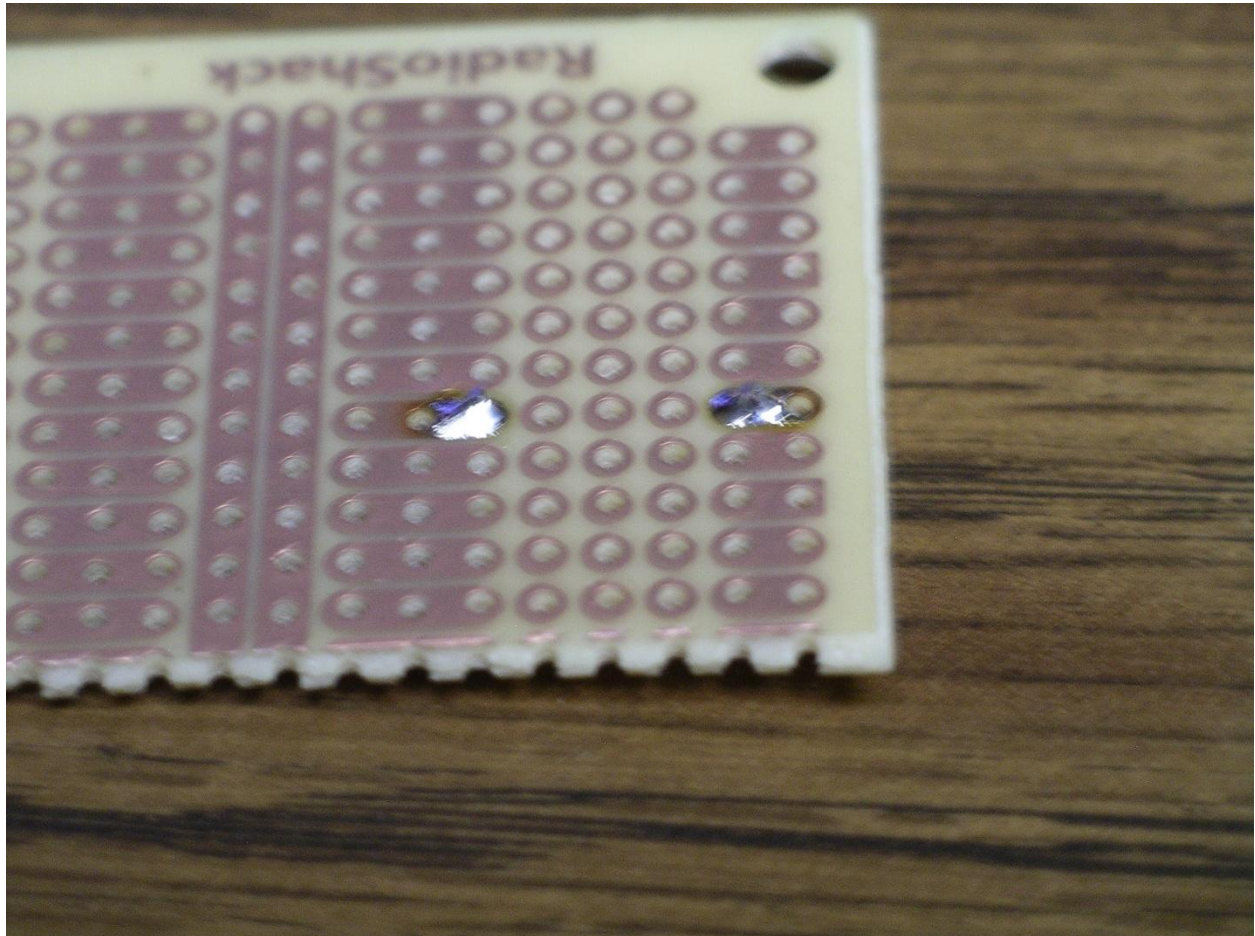


Figure 8: Completed and Trimmed Solder Joint

Step 4: Circuit Board Assembly

Now we are to the fun part, assembling the circuit. The general process for doing this is to find a component on the schematic, see where it goes on the layout, and then solder it into place. We are going to start with the shortest components (resistors, sockets, and jumpers), and work our way up to the tallest components (capacitors). The reason for doing this is that it makes assembly a lot easier. It makes placing the components easier, and they stay put when you flip the board over for soldering. You can also bend the leads outward to keep the components in place as shown in figure 6.

Place R4, and RLED first, followed by the IC socket (pay attention to polarity), and finish off with resistors R1-R3. **Save all of your excess resistor leads; you will need these to form jumpers in the next step.** The positioning on RLED is not shown in the layout; we are going to place it on the circuit board. Also the bending of R2/R3 can be tricky. Both of these issues are shown in figure 9. A picture of what your board should look like after completing this step is shown in figure 10.

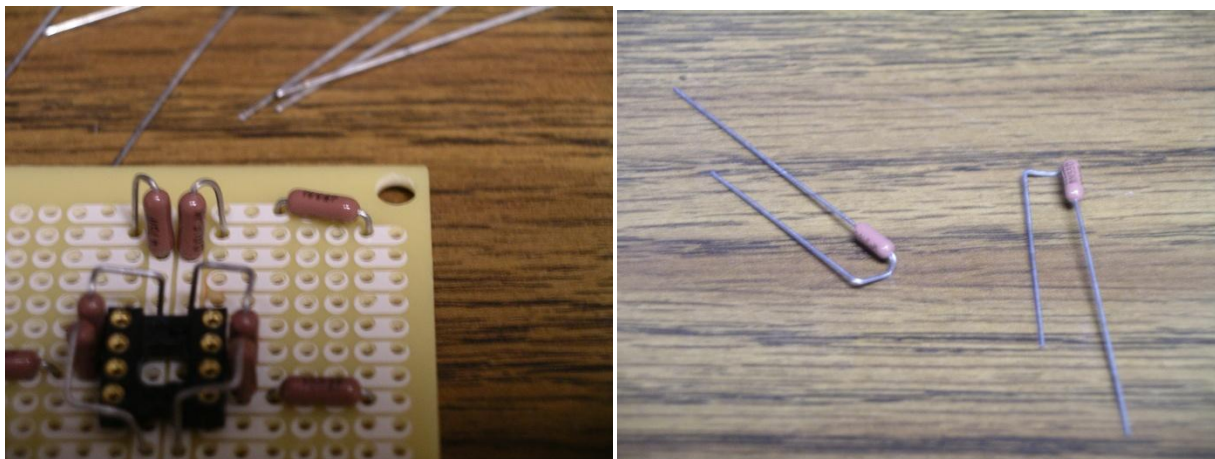


Figure 9: Positioning of RLED and Bending of R2/R3

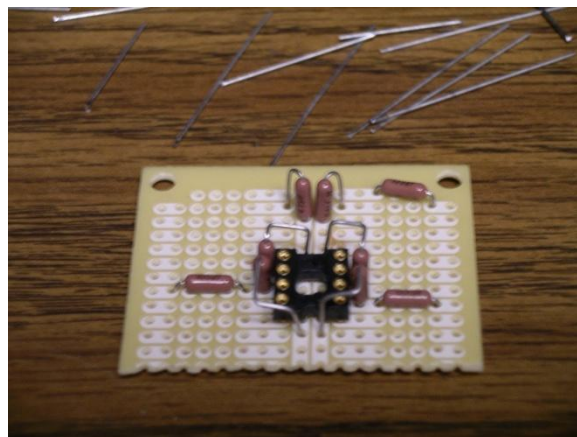


Figure 10: Progress So Far

The next step is to create the jumpers required to tie adjacent pads together. These are shown in the layout as a black wire connecting two pads that is not connected to any component. We will form these using our excess resistor leads from the previous step. There are two types of jumpers, and m-jumper which connects three pads, and a regular jumper which connects two pads. It is easiest to use pliers to form the jumpers. Finally, these jumpers tend to fall out when you are soldering them, so make sure to bend the leads to hold them in place. Figure 11 shows the process of creating jumpers, along with a board that has all of the jumpers installed.

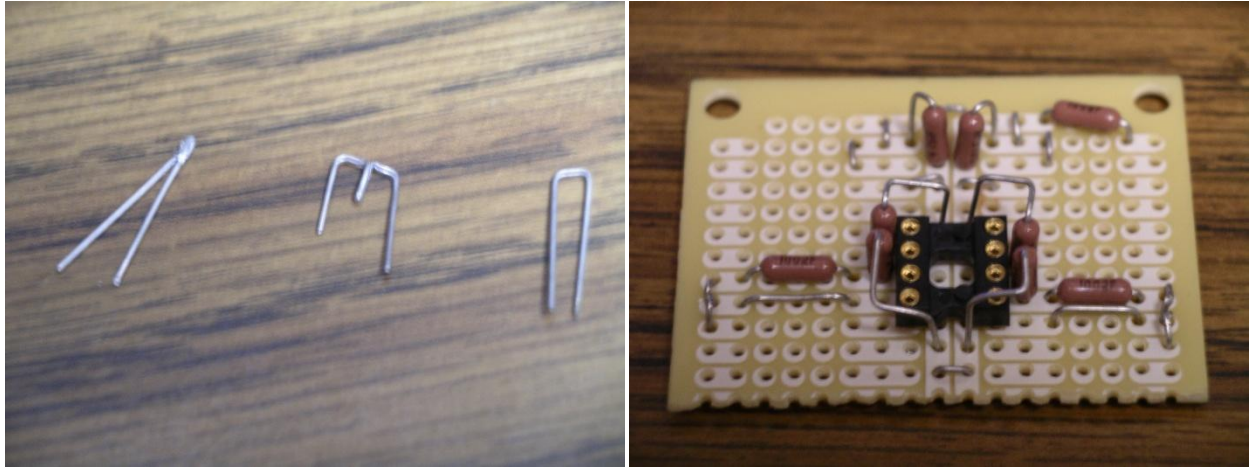


Figure 11: Jumpers and a board with them installed

The final step is to install the capacitors (remember polarity), and two power wires: one for the positive supply, and one for the negative supply. These power wires must be run underneath the board since we ran out of holes on top. Start by soldering a 2 inch length of each wire to the connection nearest the op-amp socket. Then cut the wire to length, strip it, and solder it to the remaining pin. A picture of a 100 percent completed circuit board is shown in figure 12.

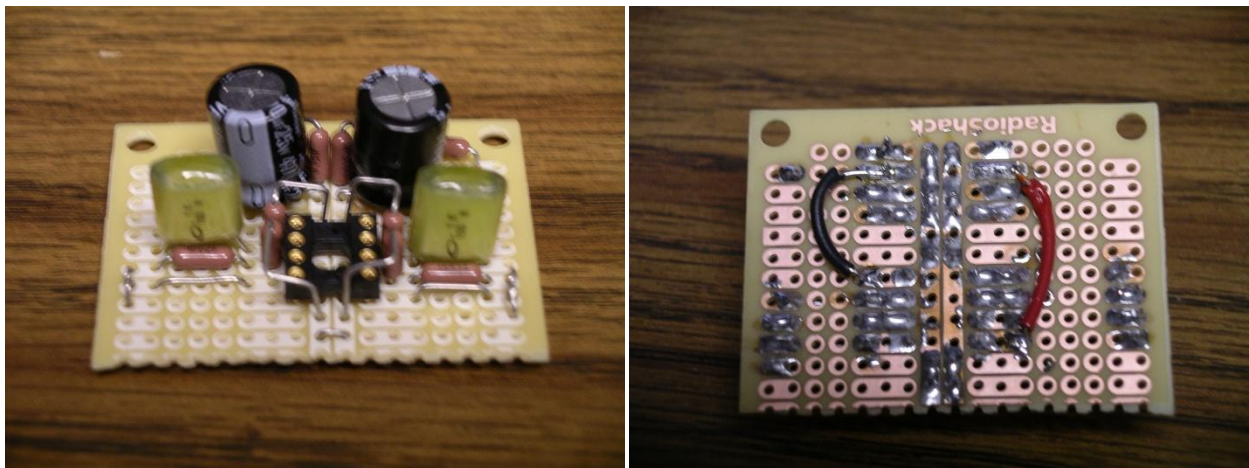


Figure 12: Completed circuit board, both top and bottom.

Step 5: Altoids Tin Preparation

Now we need to prepare the Altoids tin to hold the circuit board that we just built. This involves two steps: putting a layer of electrical tape on the bottom of the Altoids tin, and punching holes for the input/output jack, potentiometer, and LED. The reason we need to put electrical tape on the bottom of the tin is to prevent the connections on the solder side of the board from shorting to the case. This can be done with 3-4 strips of $\frac{3}{4}$ inch wide tape, or a single piece of 2 inch wide tape. Just make sure that you cover the entire bottom. Figure 13 shows what this look like.



Figure 13: Electrical tape used to prevent shorting.

The next step is to punch a total of four holes in the side of the Altoids tin. These four holes will be for the potentiometer/switch, input jack, output jack, and LED. To do this we will be using an industrial hole punch; of which we only have one, so make sure to share. A picture of this hole punch is shown in figure 14. The potentiometer hole has a diameter of $\frac{9}{32}$, and every other hole has a diameter of $\frac{1}{4}$ inch. To make things easier we will have everyone punch their $\frac{1}{4}$ inch holes first, the die will be changed, and finally everyone will punch their last $\frac{9}{32}$ diameter hole.

Figure 15 shows the layout and placement of each of the holes. Start by using a ruler to mark out the horizontal location of each of the holes. The vertical position does not need to be marked, as you will have to punch the holes as far down as the punch will let you. Basically the three holes on the front of the case are spaced $\frac{1}{2}$ inch apart (center to center), with the outer holes being $\frac{5}{8}$ inch from the outside of the case. Looking at the case straight on the input jack goes in the middle, the potentiometer on the left, and the output jack on the right. Finally there is the LED hole, which is on the side of the case, and spaced $\frac{5}{8}$ inch from the front on the case.



Figure 14: Heavy duty hole punch.



Figure 15: Location of punched holes.

The next step is the wiring of the amplifier. This is where we will make all of the connections from the potentiometer/switch, input/output jacks, and LED to the circuit board. To make things easier we will be assembling all of the wiring outside of the case (into a wiring harness), attaching it to the amplifier, and finally putting the whole assembly inside the case. Each specific wire will have to be a certain length, and we will also be color coding all of our wires to make troubleshooting easier. Figure 17 shows a schematic layout of all the wiring interconnections.



Potentiometer Switch	Switch to Board Power	3 in
	Ground	3.5 in
Input Jack to Potentiometer	Right	1.75 in
	Left	2.25 in
	Ground	3.75 in
Potentiometer to Board Input	Right	5 in
	Left	3 in
Output Jack to Board Output	Right	2.5 in
	Left	2 in
	Ground	3.75 in
LED	Positive	3 in
	Negative	2 in

Connection	Color Code
Positive Power	Red
Negative Power	Black
Ground	Green
Right Channel	White
Left Channel	Yellow

Table 2: Wire lengths and color coding.

Table 2 shows the wire lengths and color code for each connection that we will be making. If you have any questions about where a certain wire should be connected or what length it should be ask your instructor. Start by cutting wires to the exact lengths given in table 2; use the five colors of wire that were provided in your kit, and make sure each connection type is the right color by using the color code, also given in table 2. After all of the wires are cut to the correct length strip off a little less that a $\frac{1}{4}$ inch from both sides of all the wire. Do this using the blue wire strippers located in the tool bin at your bench. This is 22 gauge wire, so make sure to use the correct cutter. If it is very difficult to strip the wire you can go down a size on the stripper to 20 gauge. Remember that the wire lengths given are the total length; you do not need to add or subtract a $\frac{1}{4}$ inch to account for the stripped ends.

Now that you have all of the wires cut to the right length and stripped you will start soldering the potentiometer/switch, input/output jacks, and the LED. Remember that each of these parts has a certain polarity, or pinout, which was described in step 1. Refer back to this to make sure that you are hooking everything up correctly. Start by making one end of the wire into a loop, and then placing it onto the component that you want to solder. The input/output jacks have holes in the contact that make it very easy to slide a wire in place, For the potentiometer and LED you will have

to just place the wire loop around the contact. For the potentiometer connections it is a good idea to bend the outside leads outward to make sure that nothing shorts together. As an example the ground connection to the potentiometer is shown. Note that in this case the loop will cover two leads. For every other connection you will only want to cover one lead. Once you have the loop in place the only thing left to do is solder it in place. This entire process is shown in figure 18.

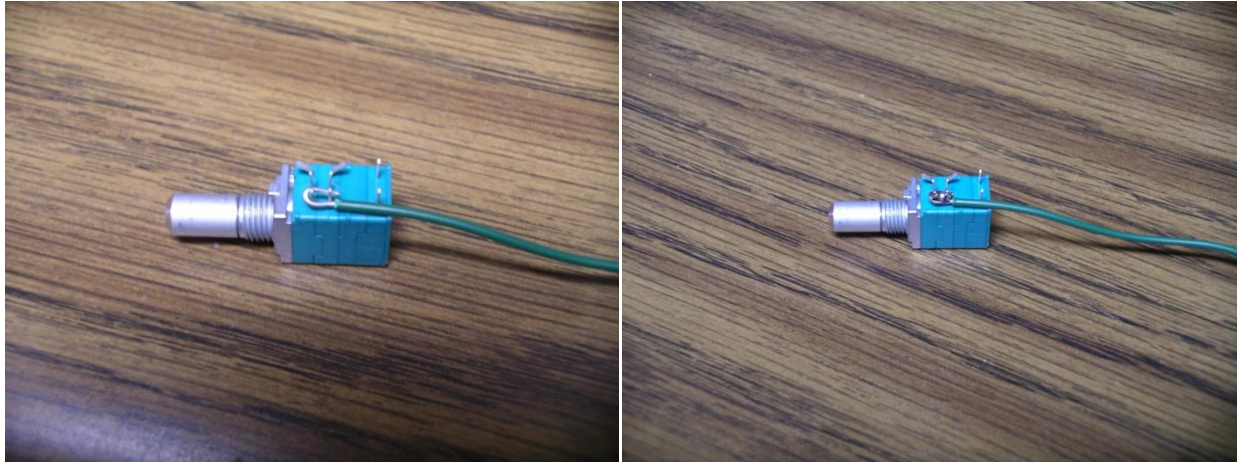


Figure 18: Soldering a wire to the potentiometer ground.

Follow this same process for the remaining connections. A completed wiring harness is pictured in figure 19. Note that the second connection to the switch is the negative battery lead. You do not need to cut any wire off of the battery leads; the 4 inches of wire that is comes with will work fine.

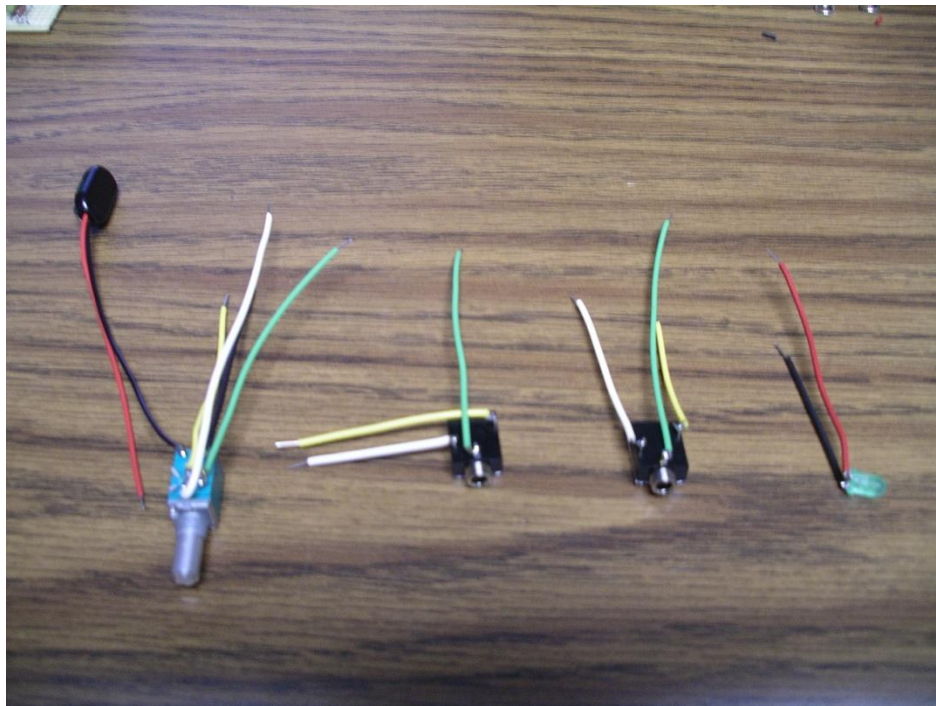


Figure 19: Completed wiring harness.

The next step will be to connect the input jack to the potentiometer input. The signal flow here is into the input jack, to the potentiometer (volume control), and finally to the input of the amplifier board. We are working with very little space here, so we have to run the wires from the input jack, underneath the potentiometer, and to the other side. A picture of this connection is given in figure 20.

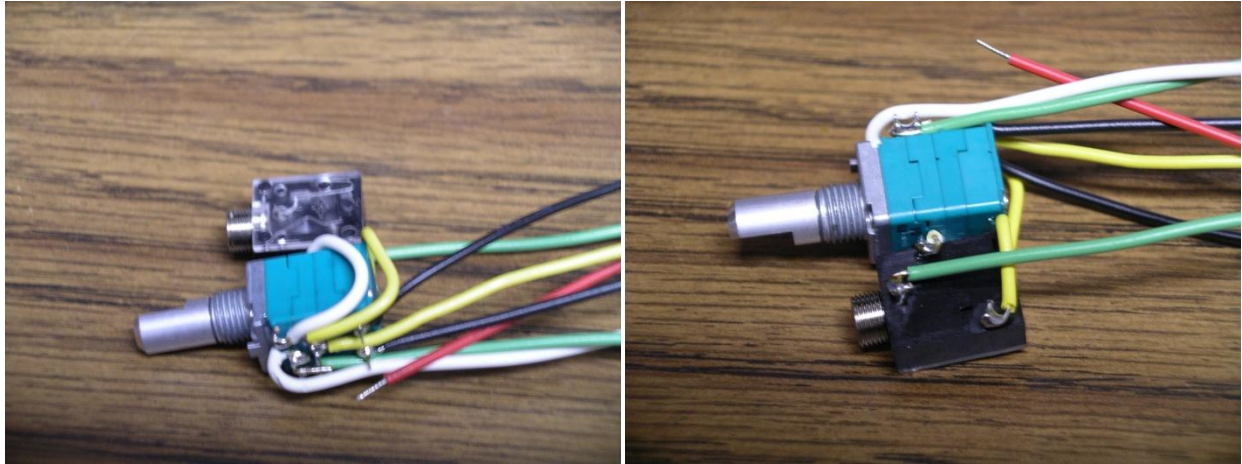


Figure 20: Wiring the input jack to the potentiometer.

The final step in the wiring process will be to connect each component to the amplifier board. All of these connections are detailed in figure 17. The only difference is the connection of the LED. Since we placed the LED resistor on the circuit board we need to modify the wiring a little bit. This change is shown in figure 21. If you have any questions ask your instructor.

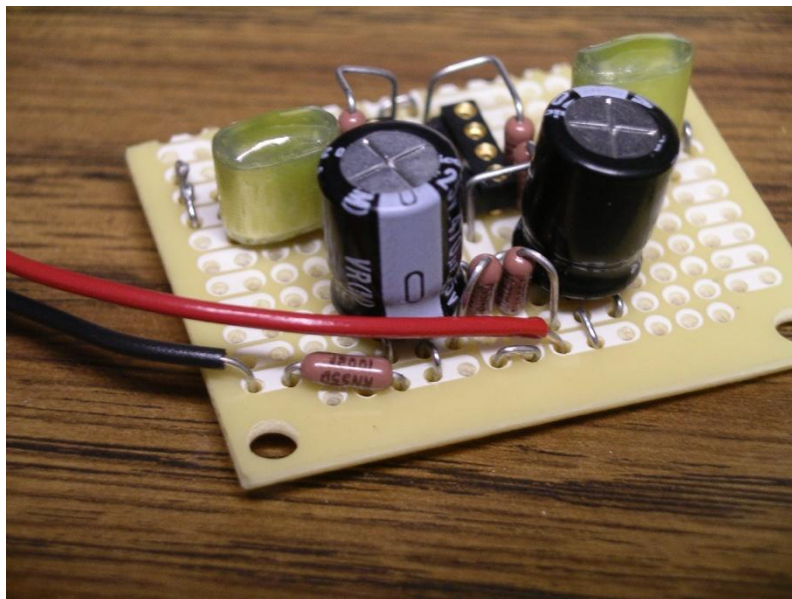


Figure 21: Change in the LED wire placement.

Once all the wires are attached to the amplifier board we can place the entire assembly into the Altoids tin. Pop the black LED holder in the side hole that you punched first, and after everything is placed attach the nuts on the potentiometer and input/output jack and tighten. Congratulations, you have finished the assembly of the amplifier.



Figure 22: Completed Altoids Tin Headphone Amplifier.

Step 7: Cable Making

For this step we will be making a short 1/8 inch to 1/8 inch cable that you can use to connect your mp3 player to your amplifier. Use the two 1/8 inch plugs that were included with your kit, and any remaining wire. Your cable can be any length that you like, but a length of 3 inches is good if you want to place your mp3 player directly on top of your amplifier. Also remember to color code your wires (right = white, left = yellow, and ground = green). Start by cutting each wire to the same length and stripping off about a quarter inch of insulation from the ends. Refer to the polarity given in part one to make sure you are making the right connections. It doesn't really matter though; as long as you connect the same point on each 1/8 inch jack together you will be fine. Solder each wire to the connector, and cut off any excess. Finally use pliers to crimp the strain relief onto the cable. A cable up to this point is shown in figure 23.

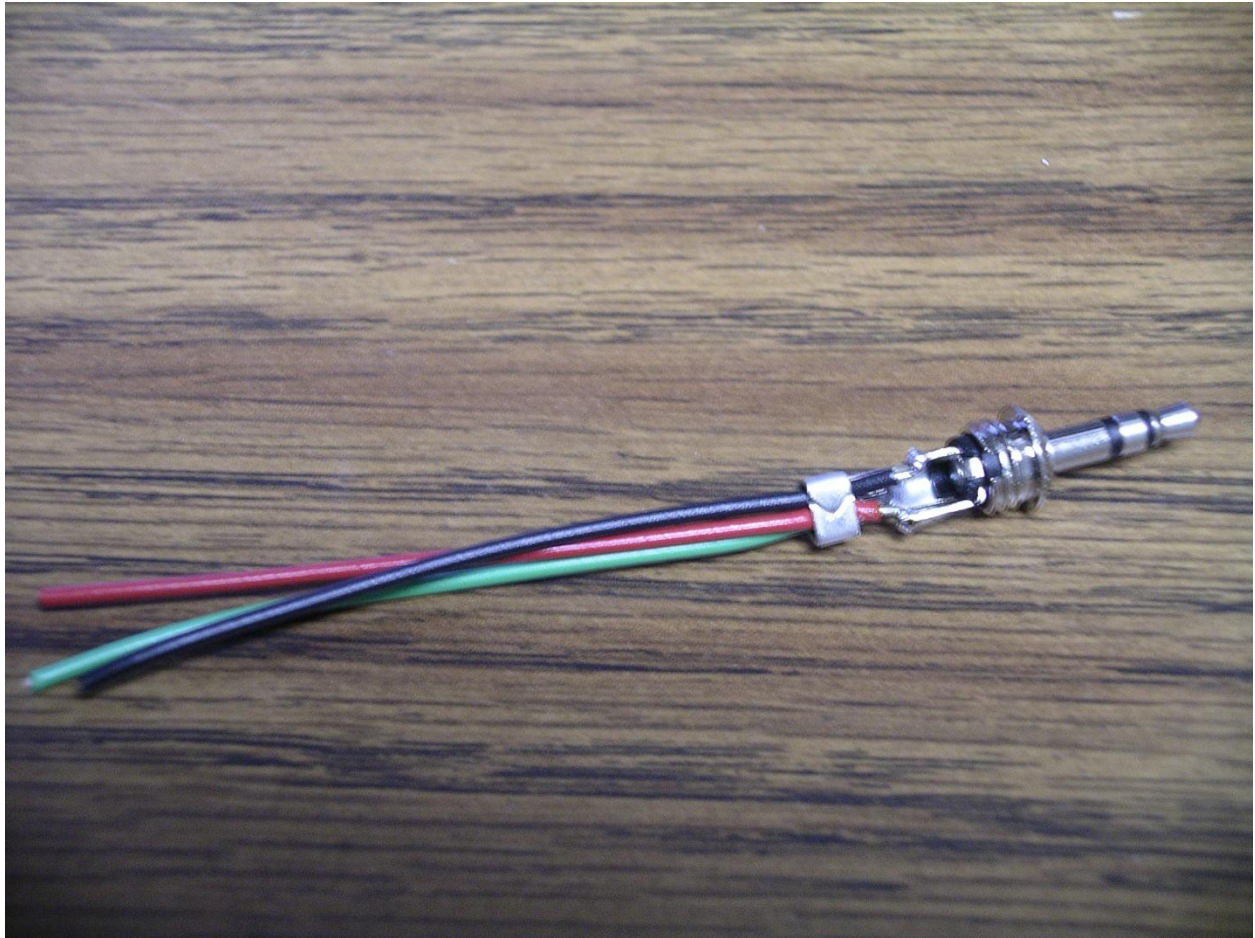


Figure 23: One side of an 1/8 inch cable.

The next step is very important. Start by sliding the clear insulator over the connections that you just soldered. This will prevent the left/right connections from shorting to ground. Then slide the outside of the connector over the wire and tighten it into place. Also very important: make sure that you slide the second connector outside and insulator over the cable in the opposite direction before soldering the other end on. A picture of this is given in figure 24. Once you have soldered the other end into place you can then slide the insulator over the connection, and screw the other end into place. Your cable is now finished.



Figure 24: Connector insulator and outside cover.

Step 8: Testing

The final step will be to test the amplifier before hooking up anything that could possibly be damaged. Start by getting a 9 volt battery from your instructor and hooking this up to the battery lead. Turn the potentiometer just until you hear a click, which means that the power has been turned on. Check to see that the LED is lit up. If it is not then you have made a wiring mistake. Next get two grabber leads (red/black) and hook them up to the DMM (digital multimeter). Set the meter to read volts DC, and hook up the black wire to any ground point on the amplifier (green wire, or the entire two middle strips of the board). Use the red lead to measure the voltages at pins 4 and 8. These voltages should be -4.5 V and $+4.5\text{ V}$ respectively. The exact value of the voltage is not important, as long as they are matched. To locate pins 4 and 8, remember that pin 1 is the bottom right pin of the op-amp when looking at figure 4, and the pins are numbered 1-8 in a counter clockwise direction. Also check the voltages on all other pins to make sure that they are zero or very small. If your amplifier passes this step then proceed to the next section. If not see your instructor for help.

The next step will be to place the op-amp in the socket. See your instructor to get an op-amp, and make sure that the amplifier power is off before inserting the op-amp into the socket. Also pay attention to polarity: the notch on the op-amp socket will line up with the notch on the op-amp itself. Next plug your mp3 player into the input jack, start some music playing, and turn on the amplifier. Again using the DMM measure the DC voltage at right and left wires of the output jack. If these voltages are more than a couple mV there is a big problem; see your instruction for help. If not then you can move on.

Finally we will test to see that the amplifier is actually amplifying signals. Turn on the oscilloscope at your lab bench and wait for it to power up. When it does press the preset button to initialize the factory defaults of the instrument. Adjust the vertical scale of around 500 mV/div and the horizontal scale to around $1\text{-}10\text{ ms/div}$. Hook up the channel one probe to the right input, and the channel two probe to the right output. You should see two waveforms on the screen: Adjust the vertical scale if necessary to fit the entire waveform on the screen. Adjust the potentiometer and watch the output signal. It should change but the input should remain the same, unless you change the volume on your mp3 player. Turn the potentiometer volume all the way up and measure the peak-to-peak voltage of the input and output. Take the ratio of these two to get the gain of the amplifier: it should be around 11. If this is the case then your amplifier is working exactly as it should.

Step 9: Enjoyment

Thanks for participating in the Altoids tin headphone amplifier lab.

