Project Overview

There are three circuits that need to be built for the headphone amplifier project.

1) A power circuit
2) Two amplifier circuits

You will build each of these circuits on a breadboard and test it before assembling the circuit on the printed circuit board. Since the two amplifier circuits are identical, you will only need to put one of these on the breadboard.

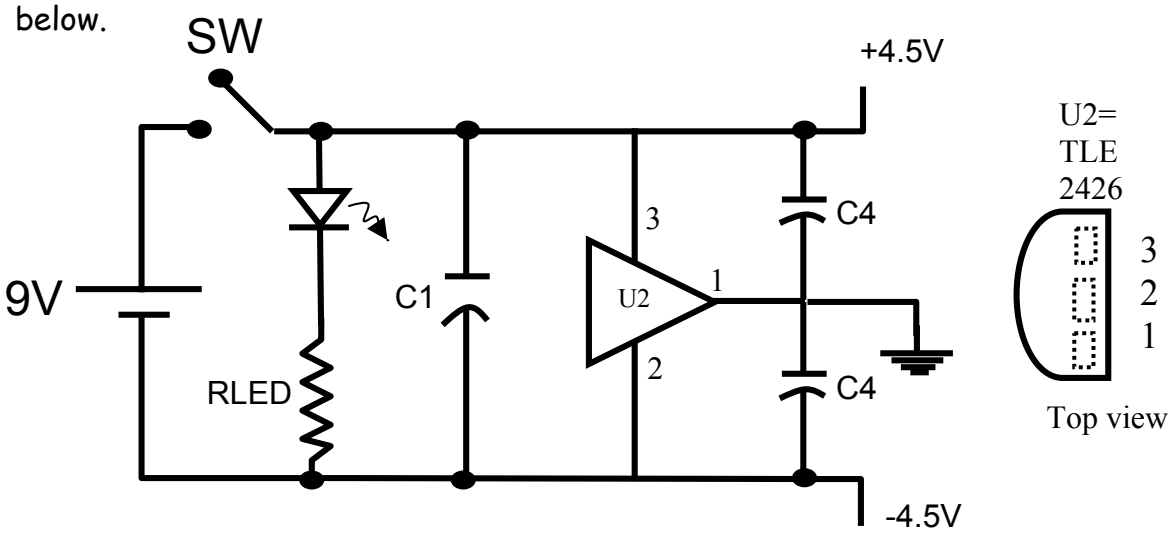
Project Schedule

Week	Activity
Wednesday April 7	Breadboard and test the power circuit. Derive an equation for the amplifier circuit. Breadboard and begin testing the amplifier circuit
Wednesday April 14	Finish testing the amplifier circuit Practice soldering
Wednesday April 21	Assemble the circuit on the circuit board and put it in its box. Assembly Instructions at: http://www.jdslabs.com/assembly_cmoy.php
Wednesday April 28	Lab Practical
Friday April 39, 4:30 PM	Turn in Draft of report
Thursday May 6, 4:30 PM	Turn in Final Draft of report

I will return your draft on Monday with feedback. Late drafts will not be accepted. If your first draft is not turned in on time, you will not get any feedback and you will loose one half letter grade on your final report. If your final report is late you will loose one half letter grade per day it is late.

The power circuit

Most operational amplifiers work off of +/- power supplies relative to a ground. The amplifier that we have chosen will run off of a wide range of voltages: anywhere from +/- 2.5 to +/-18V. We are going to use a single 9 Volt battery and turn it into a +/- 4.5 V power supply using the circuit shown below.



•SW is a switch.

•RLED is a 24.3kΩ resistor to limit the current through the LED.

•The diode is a blue LED that turns on when you close the switch, so you know the circuit is on. The direction of the LED matters! Be careful when you wire it.

•There is one capacitors labeled C1. It is 470μF, and it is an electrolytic capacitor. This means that it is polarized and it matters which way you put it in the circuit. If you put it in backwards, **it will explode**. Capacitors C4 are the very small yellow ones. These are 0.1μF ceramic caps. Capacitors on the power supply are there to filter unwanted noise. (Think back to the diode lab 5.)

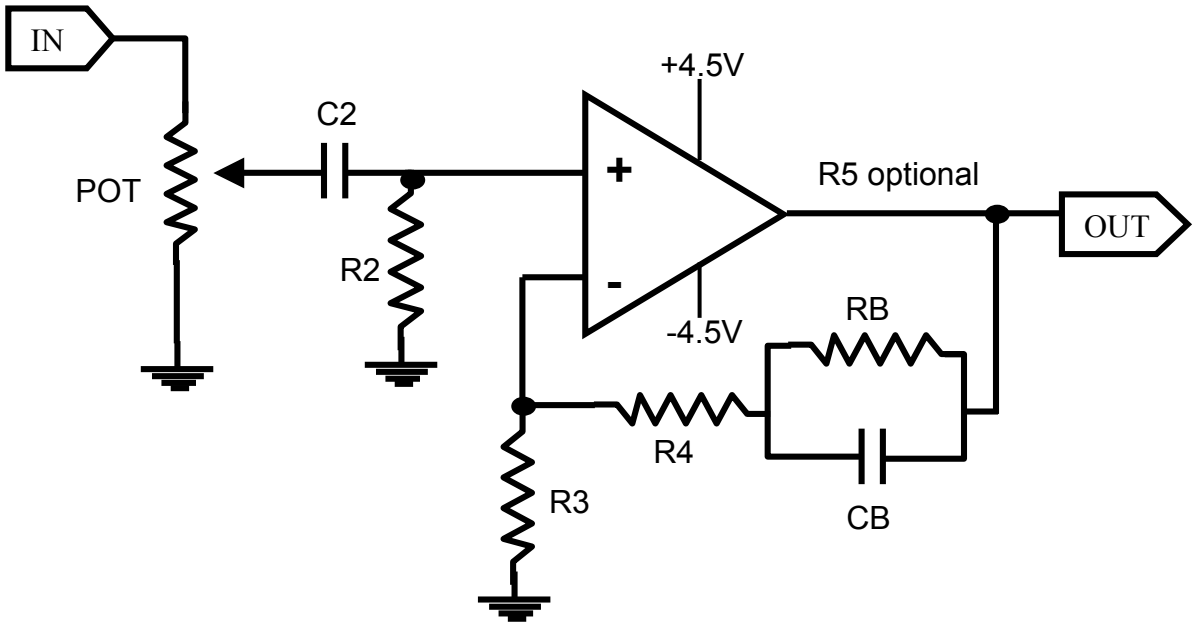
•Notice the input to this circuit is a 9V battery. There are two outputs relative to the ground, +4.5 V and -4.5V.

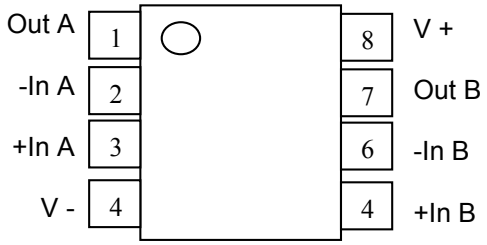
•U2 is a virtual ground (or rail splitter) chip TLE 2426. Don't wire it backwards.

1) Build the power circuit on a breadboard.
2) Measure the input and the two outputs of the circuit. Make sure you measure the outputs as precisely as possible. Perhaps use the 4 digit multimeter.
3) In your report talk about the role of each component in this circuit. Why was it important to match the R1 resistors?

The Amplifier Circuit

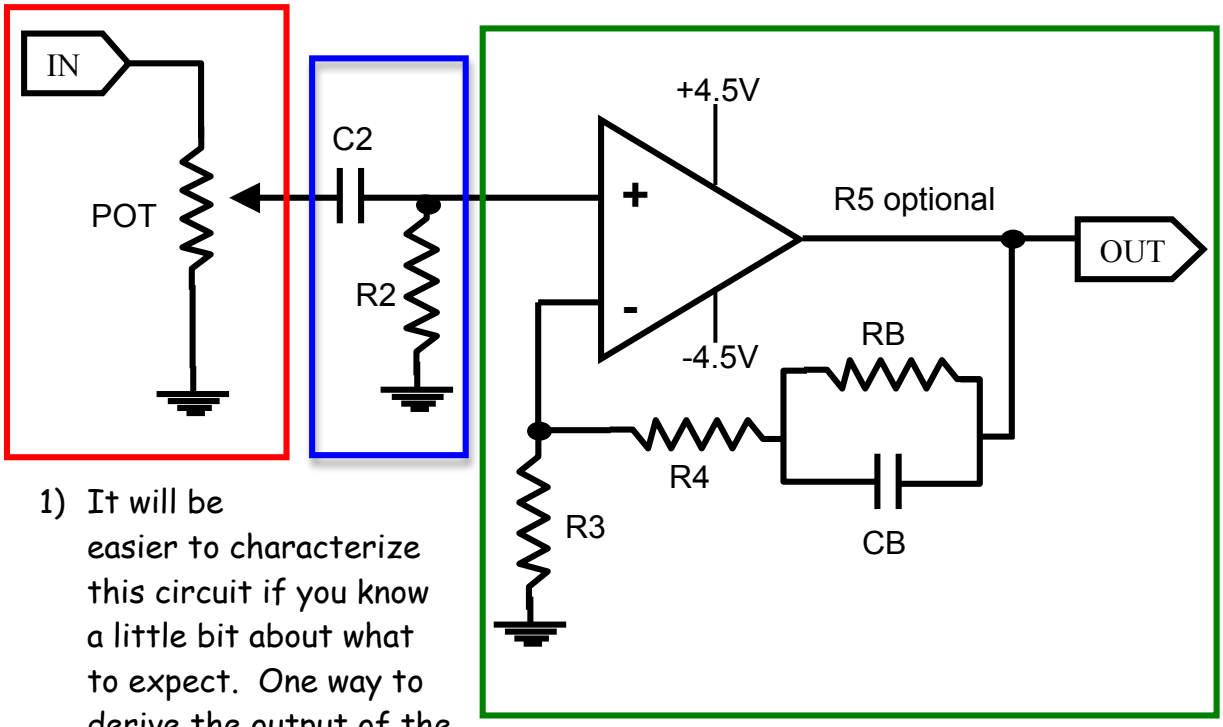
Each headphone speaker gets its own amplifier as shown in the circuit diagram below. So for your actual amplifier you will need two of these. For testing purposes we will only build one on the breadboard.





- C2 is a 1μF capacitor (gray).
- R2 is a 100 kΩ resistor.
- R3 is a 2.05 kΩ resistor.
- R4 is a 10 kΩ resistor.
- R5 is a short-- 0 Ω. You do not need it.
- POT is a 10 kΩ potentiometer. Use the one supplied.
- RB = 24 kΩ and CB = 0.068 μF are a bass boost
- The operational amplifier you will be using is the OPA2134. It is a dual amplifier with two sets of inputs and two outputs. The pinout for the OPA 2134 is shown above.

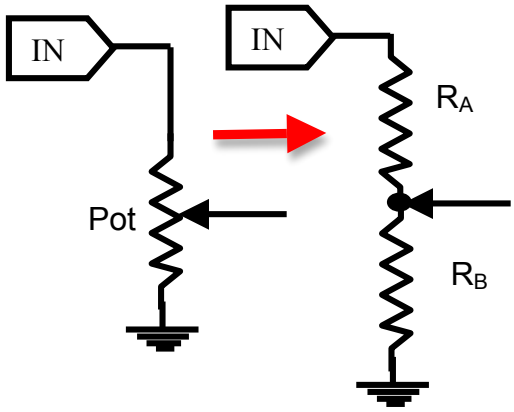
Theory of the circuit



1) It will be easier to characterize this circuit if you know a little bit about what to expect. One way to derive the output of the circuit is to think of the circuit as three different modules hooked together in series. Remember the rule of impedances. In your report you should convince me that this is a legitimate way to procedue.
2) What does the red circuit do? Calculate Voutred/Vin for this circuit.
3) What does the blue circuit do? Calculate Voutblue/Vinblue.
4) What does the green circuit do without RB and CB? What functionality do RB and CB add? Use the golden rules of op-amps and Ohm's law to derive an equation for Vout/Vingreen for this circuit. HINT: You can use treat all of the stuff in the feedback branch of this circuit as Z and calculate the impedance of this separately to make the derivation less cumbersome.
5) Recognizing that Vinblue=Voutred and Vingreen=Voutblue, find Vout/Vin for the entire circuit.
6) It is useful to plot the behavior of each of the three parts of the circuit separately to see how they behave. Put the equation for each circuit into a program like excel, and plot Vout/Vin as a function of frequency for the audio range (1 Hz to 20 kHz). Next plot the product of the three circuits as a function of frequency. I suggest you link to the circuit values separately so that you can vary them. For example, what happens when RB and Z_{CB} go to zero?

Characterizing the circuit

1) Build this circuit. Instead of using the potentiometer on the breadboard, I suggest you build this circuit with two fixed resistors that total 10,000 Ω. Try the following three combinations (R_A, R_B) → (1000 Ω, 9000 Ω), (5000 Ω, 5000 Ω) and (9000 Ω, 9000 Ω).



2) Characterize the circuit using a sine wave from your function generator as an input to the circuit. You should make sure that the amplitude of the input sine wave is relatively small so that your amplifier isn't causing the signal to clip. Measure the output and the input over a range of frequencies from 1 Hz up through 20 kHz. Remember your ear is only sensitive to 20kHz. This is your primary data, so make sure that you are careful, and that you collect enough data to make a very nice graph.
3) Repeat the characterization of the circuit using the (5000 Ω, 5000 Ω) with CB=0.01μF.
4) What is the purpose of R2 C2?
5) How does the gain work?

MATCHing resistors

For this circuit you will want to MATCH the resistors between the two amplifier circuits. So you will want two R2, two R3, two R4 and two RB that are matched. If the resistors aren't matched, the headphone speakers will sound different, so it is critical that the resistors have the same value. We are starting with 1% metal film resistors, but we can do better. You will use a 4 digit multimeter to choose resistors that have the same value as measured by the meter. You may need to measure 20 or more resistors before you find two that match. I suggest you take out a blank sheet of paper, and each time you measure a resistor, write down the resistance, and put the resistor on top of it.

Report

Introduction: give a context for audio amplifiers in general and headphone amplifiers specifically

Theory: Show the circuit diagrams, and explain what each circuit is supposed to do. Be specific. Try to explain the function of each resistor and capacitor. Derive the equation for Vout/Vin for the amplifier circuit

Procedure: Explain what values are chosen for the circuit elements, and how you characterized the circuit.

Analysis: Explain the choice of R2 in combination with C2 and its purpose. Where does the gain come from for the amplifier. Show your data and explain what each part of the circuit actually does. It would be useful to plot the data and the theory together.

If you can explain the choices for particular values of circuit elements you should do that here. There is lots of information on the internet about this particular amplifier that you may find helpful.

Conclusions: Does the amplifier behave as expected? Justify your answer with your theory and data. What are some modifications that you might be able to make to improve the performance?