# *Final Project—Audio Amplifier*

*Physics 251*

*Fall 2022*

The remaining lab periods will be devoted to an audio amplifier project. You are to design and build an amplifier that will amplify the output at the headphone jack of your phone (or similar device) to a level that can drive a speaker. For design purposes, make an amplifier that can deliver at least 3 watts to a $4\,\Omega$ or and $8\,\Omega$ load.

## *References*

For ideas, look at figures 4.26, 2.69, 2.71, 2.72, 2.78 and 2.91 in the book. My advice: read the text before reading online sources.

## ***Timeline***

- 28 Nov
  Hand in a preliminary design of your amplifier. Keep a copy in your lab notebook.
- 30 Nov
  Make and do initial testing of your design. (See more about testing below.) You want to get your desired gain into a $100\,\Omega$ resistor. Refine your design as needed to get to this point.
- 5 Dec
  Finish testing with the $100\,\Omega$ load and switch to a $5\,\Omega$ or so load. When testing with the $5\,\Omega$ load, be especially cognizant of the temperature of the output transistors.
- 7 Dec
  After all testing is done, connect your phone and a speaker and see how it works. Show me the working circuit in action at this point.
- 12 Dec
  Hand in your final project report to me on **12 Dec by 3pm**.

## ***Things to consider during design***

1. More complicated is not necessarily better. Trying to get a simple amplifier working and then improving it is better than starting with an exotic design. Keep it simple.
2. The headphone jack on your phone expects to be connected to $30\,\Omega$ headphones.
3. To protect your phone from DC voltages in your amplifier, use a capacitor for coupling.
4. Keep it simple.

5. Include a volume control (don't plan to use the volume adjustment in your phone). Make sure you can adjust the volume all the way down to zero.

6. During the design phase, work out DC and AC voltages at key places in the circuit.

7. Keep it simple.

8. Power dissipated as heat will definitely be an issue. You will be using TO220 package transistors in the output stage. These have a metal tab that can be connected to a heat sink, and you will want to make use of that feature.

   - You will have calculated the rms output voltage for 3 W (or more, if you're shooting for more than 3 W) into $4\,\Omega$ or $8\,\Omega$. You can also calculate rms current through the load.
   - From the needed peak to peak output voltage you can decide on a power supply voltage (we are limited to either 15 or 30 volts, 0.5A on your protoboard, or, with 12 or 24 volts, 1.5 A using the older power supplies.)
   - From the above you can estimate the power dissipated in the transistors. Without a heat sink, they will get HOT at a couple of watts.

## *Construction Considerations*

1. On a protoboard, unintended feedback causing oscillations can be a problem. Keep the input and output separated. Provide bypassing. Especially, bypass the power to the output transistors right at the transistor with large (say $1000\,\mu F$) capacitors.

2. The TO220 transistors will go into the holes on the protoboard. Be gentle and push straight down.

3. The tabs on the transistors and, therefore, the heat sinks are connected to the collector and will be at the collector voltage.

4. (From the protoboard manual:) By-Pass Capacitors: Even though the PB-203A's power supplies are tightly regulated, even a short length of power bus can cause a linear IC (i.e. op amp) to break into oscillation at high frequencies due to increased inductance. This increased inductance can be offset by adding simple by-pass capacitors. By-pass capacitors ($0.1\,pF$ ceramic disk type will be sufficient) should by-pass the power buses as close to the ICs power supply pins as possible. Utilize this technique for each IC. Do not use electrolytic or paper capacitors as power bus by-pass capacitors. They have high inductances, and become unreliable as by-passes above 1 MHz.

## Testing

### *Preliminary testing*

Before applying power, connect a 100 Ω load and the scope to the output. Short the input to ground and then apply power. Immediately check to see if anything is getting hot. If so turn the power off. If not, there should be no output signal. Check DC voltages and compare with any calculations you made. If all this seems okay, set your function generator to the output level expected from your phone and to about 1kHz and connect it to the input. Check the gain and the action of the volume control. Roughly check the frequency response (the ear is said to respond to frequencies from about 20 to about 20,000 Hz).

### *Dummy Load Testing*

To approximate the load that will be presented by a speaker, parallel two 10 Ω, 2 W resistors. The leads on these will probably not fit into the holes on your protoboard, so you will have to use clip leads. Run the same tests as above. Check the temperature of the output transistors. Can you really get the voltage across the load you need for design power? If not, what is the maximum? Take data so you can plot power out vs $\log(f)$ over the audio frequency range.

## Report

This is your final report, the culmination of everything we've learned all combined into one project. It should be an example of your best writing, with clearly labeled plots and excellent discussion of your design. The objective of the project was to make an amplifier that would amplify the output of your phone to the level needed to deliver at least 3 W to a 4 Ω or 8 Ω speaker.

- Did your circuit do this? If not, how close did it come?
- Did your best effort work at all?

You will need at least one and probably two neat and complete circuit diagrams in your report. First, include the preliminary design you handed on 28 Nov. If your final circuit is different, include a diagram for that also. If you made a bare bones and then a Cadillac version, you should include both diagrams.

Also, include (1) a gain (dB) vs $\log f$ plot, and (2) an output power vs $\log f$ plot.

These should be for the 5 Ω resistive load. You must provide a circuit description of your most successful amplifier. A circuit description tells what each major part of the circuit is for. There are examples in the book – see section 2.62 or 4.81 among many other places.