ShanghaiTech University
School of Information Science and Technology
EE112 Lab Experiments

Lab 5: Multi-Stage Amplifiers Lab

Contents

1. Introduction

Often, a single transistor amplifier cannot satisfy all of the specifications for a given application and an amplifier circuit is designed with multiple cascaded single-transistor amplifiers. In this lab, you will implement a three-stage amplifier, which will amplify an audio signal from a headphone jack and drive a low-impedance speaker.

Make sure to download and print out the Pre-Lab Worksheet and the Lab Worksheet. You may also find the datasheets for the transistors used in this lab to be useful: 2N4401, 2N4403, BS170.

Make sure to complete the Pre-Lab Worksheet before coming to lab. Your lab TA will check that you have completed the Pre-Lab Worksheet at the beginning of your lab section. Fill out the Pre-Lab and Lab Worksheet while doing the lab and turn them in with supporting traces and plots at the beginning of the first lab section for Lab 6.

2. Materials

Please don’t forget to set a current limit on your power supply! 150 mA is a reasonable value to set for the current limit. The components that you will need in Lab 5 are listed in Table 1.

Component	Quantity
BS170 (NMOS)	1
2N4403 (PNP)	1
2N4401 (NPN)	3
100 μF capacitor	1
8 Ω	1
10 μF capacitor	1

100 kΩ pot	1
10 kΩ pot	1
1 kΩ pot	1
Resistors	Various Values

Table 1: Lab5 Components

3. Lab

3.1 First stage

While you are not obligated to build the input stage exactly as shown in Figure 7, with the two potentiometers, the author thinks that it is a good idea to do so. Adjusting the two potentiometers gives you two almost totally independent knobs to tune I_d and R_D to achieve your desired gain and drain voltage bias.

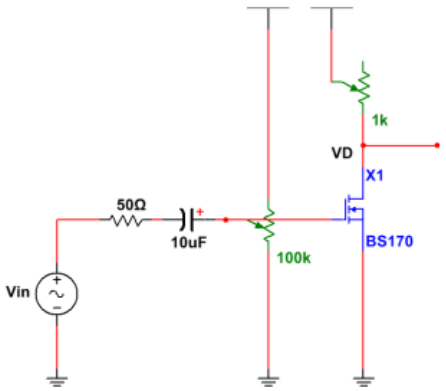

Figure 1: Input stage circuit

Measure the gain, DC output voltage, and output swing of this circuit, and write these values in your lab worksheet. Also write the component values of your designed circuit in your worksheet.

Also measure the output resistance of the circuit by loading the drain of the circuit shown in Figure 1 with a shunt resistor to ground approximately equal to the output resistance that you calculated in the prelab. The output AC voltage amplitude should drop by about one half. Calculate the output resistance from the AC output voltage measurement of the loaded circuit.

You may want to place a 100 μF capacitor in series with the loading resistor to prevent DC current from flowing into the loading resistor and altering your drain voltage bias point, if you think that that will alter the output resistance measurement by a lot. If you decide to do this, make sure that you measure the AC output voltage at a frequency where the coupling capacitor looks like a short circuit. Ask your lab TA if you are confused by this discussion regarding output resistance measurement.

Make sure to capture a single oscilloscope trace with both input voltage and output voltage waveforms demonstrating the circuit's gain, output voltage, and swing and include it with your lab worksheet. This means that in addition to measuring the AC amplitudes of the input and output waveforms, you must also measure the DC offset of the output waveform. Ask your lab TA if you do not know how to do this. Also capture an oscilloscope trace with both input and output voltage waveforms showing the output resistance measurement.

3.2 Output stage

Build the circuit shown in Figure 2. Since we are pushing the transistors sort of close to their power dissipation limits, they will heat up, and so their I-V characteristics will drift a little bit. Because no special effort was taken by the author to ensure that the circuit design of the output stage has perfect temperature stability, the bias current will drift a little bit as the transistors heat up. You may need to adjust the 10 kΩ potentiometer a little bit to compensate for the bias current fluctuating as the transistors heat up.

If we have enough transistors in the lab, you can try putting 2x 2N4401 transistors in parallel in place of Q3 and Q4 to halve the power dissipation in each device. You may have to readjust R_C to ensure that the correct I_{bias} is flowing through both transistors. This may help with the temperature stability somewhat.

Since the input at the base of Q3 is not being biased by virtue of being connected to the rest of the three stage circuit, you will need to add a DC bias to the input for the circuit manually. You can decide to design a resistor bias network with coupling capacitor to DC bias the base and to couple in the AC input voltage, but honestly, it is easier to directly connect the function generator to the base and add a DC offset to the AC voltage. If you are using the function generator in its default 50 Ω output impedance mode, make sure to remember that both the AC and DC voltage generated by the function generator are a factor of 2 greater than what is displayed on the front panel! Also remember to account for the 50 Ω output impedance of the function generator, if you think that it will matter.

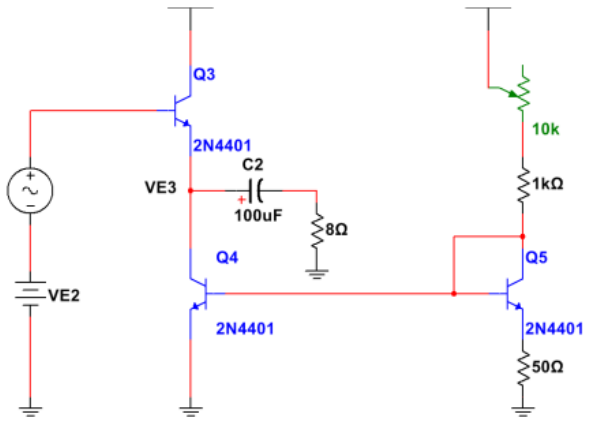

Figure 2: Output stage circuit

Measure the gain and output swing of the stage, and write these values in the table in your lab worksheet. Also write the component values of your designed circuit in your worksheet.

Also measure the input resistance of the circuit shown in Figure 2 by placing a resistor in series with the function generator and the output stage with a magnitude equal to the input resistance of the stage that you calculated in the prelab. The amplitude of the AC voltage at the output of the stage should be approximately halved. Infer the input resistance from this reduced amplitude of the AC output voltage.

Make sure to increase the input bias voltage so that the base of Q3 is biased to V_{E2}! About one half of the input DC voltage will be dropped across the resistor that you added to the circuit. It is probably smart to measure the DC offset of the base of Q3 on the oscilloscope so you know how much DC voltage to set in the function generator. Ask your lab TA if you are confused by this procedure for input resistance measurement.

Make sure to capture a single oscilloscope trace with both input voltage and output voltage waveforms demonstrating the circuit's gain and swing and add it to your worksheet. Also capture an oscilloscope trace with both input and output voltage waveforms showing the input resistance measurement.

3.3 Middle stage

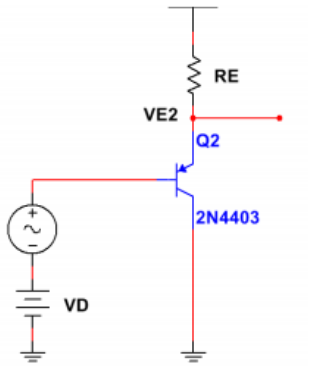

Figure 3: Middle stage circuit

Measure the unloaded gain and swing of the stage. You will have to bias the input just like in the measurements of the output stage. Also measure the input and output resistance in the same manner as the measurements of the previous stages. Write these values in your lab worksheet.

Capture an oscilloscope trace demonstrating gain and swing and include it with your lab worksheet. Also capture oscilloscope traces for the input and output impedance measurements and attach them to your lab worksheet.

3.4 Putting it all together

Cascade the three stages together as shown in Figure 1 (Prelab) and measure the DC voltages at V_D, V_{E2}, and V_{E3}. Write the values in your lab worksheet. Measure the gain and output swing of the circuit and write the values in your worksheet. Capture an oscilloscope trace demonstrating that the entire circuit meets the gain and swing specifications.

Reference

[1] UNIVERSITY OF CALIFORNIA AT BERKELEY, College of Engineering Department of Electrical Engineering and Computer Sciences, EE105 Lab Experiments