

Lab 3: Properties of Transistors

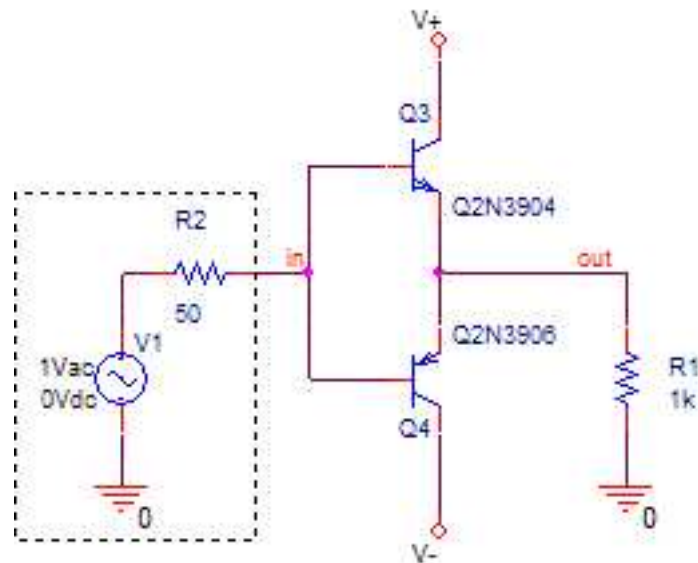
Due Tuesday, March 2, midnight

You may work in pairs for this lab. Turn in one lab for your pair by email to jrising@olin.edu.

Note: **Do not take apart your circuits after completing this lab; we will use them again!**

3.1 Push-Pull (Class B) Amplifier

The complementary symmetric power amplifier, or push-pull amplifier, shown below, has some powerful advantages and one notable disadvantage. For example, the push-pull amplifier dissipates no power when the input signal is 0. The disadvantage that we will try to overcome in this lab is the cross-over distortion for signals near 0 V.



3.1.1 Cross-over Effect

1. Describe conceptually the behavior of the various components in this circuit for different ranges of input voltage. When are the transistors on? How will the output be related to the input for different input voltages, positive and negative?

2. In lab, setup the signal generator to supply a 440 Hz sinusoid. Hook a speaker from the supply room to the signal and listen to the sound.
3. On your breadboard, create the push-pull amplifier above. Drive it with the sinusoid and listen to the results using the speaker. Can you tell a difference? Now look at the input and output on the scope.
4. Create the circuit in PSPICE and simulate its effects for a few periods. Explain what you see. Include the plots in your lab report, with both the input and the output shown.

3.1.2 Calculating the THD

One measure of distortion is the “Total Harmonic Distortion” (THD) of your output signal. Since you input a pure sine wave, you expect to get a pure sine wave back out, or, put another way, you expect there to be only one component in the spectrum of your signal, represented by one Fourier coefficient. If there are other coefficients, these are distorting your original signal.

THD is calculated as $THD = 100\% \times \sqrt{\frac{F_1^2 + F_2^2 + F_3^2 + \dots}{F_0^2}}$, where F_0 is the fundamental frequency, F_1 is the first harmonic, and so on.

PSPICE can output the Fourier coefficients. In your Simulation Profile, click on Output File Options and select Perform Fourier Analysis. Center Frequency is the fundamental frequency you are driving your circuit at; Number of Harmonics should be at least 5; and Output Variables should be of the form V(out), where out is your output node. After you run your simulation, the data will be included in the .out file corresponding to your simulation profile.

1. Using PSPICE, calculate the THD of your distorted signal for a 440 Hz input wave.

How might you fix this circuit? Feel free to experiment and try out your own ideas; worth through the following sections when you are ready. You may choose to go beyond the sections below to try to minimize the THD as much as possible.

3.2 Low Pass Filter

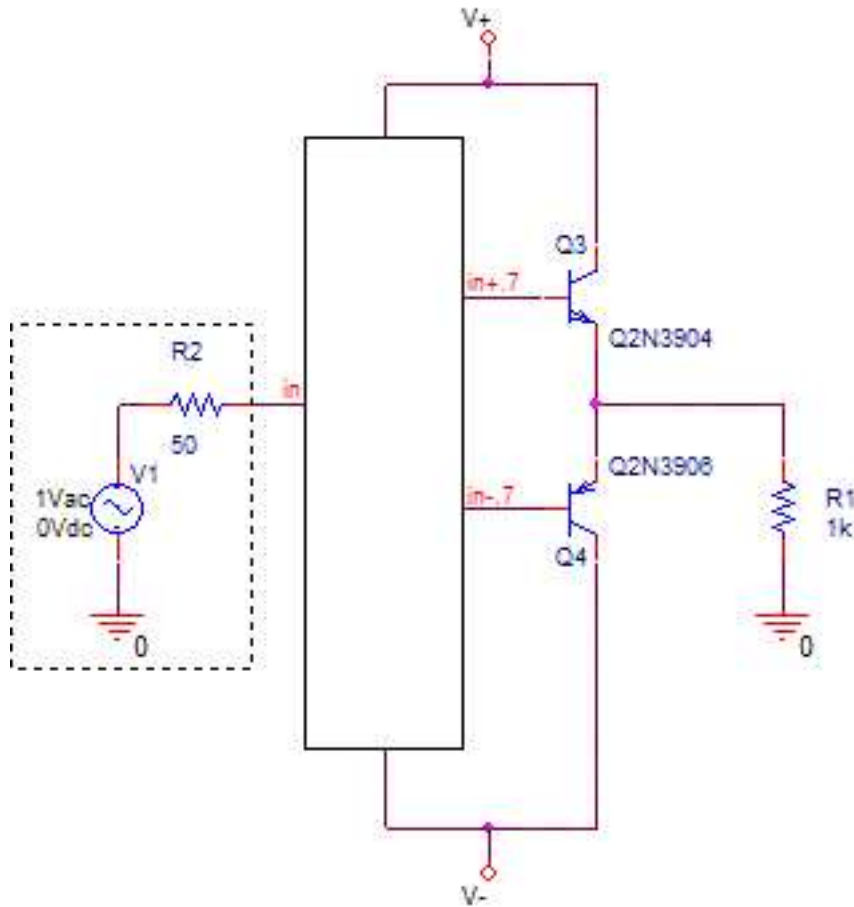
The first thing to try is to filter out the unwanted harmonics.

1. Design a low-pass filter of the appropriate characteristics to pass input signals in the likely-to-be audible range, but reject signals which are likely to be unwanted harmonics of these desired signals.
2. Calculate the THD of the new signal.
3. Comment on the effectiveness of your filter. What is its effective range? Does it have any other advantages or disadvantages?

3.3 Diode Biasing

It is possible to “bias” the inputs to the transistors by the amount needed to turn them on, thereby eliminating most of the deadzone.

1. Try to design a way to offset the voltage at the transistor’s base terminals by .7 V, to account for the “turn-on” voltage of the transistors. You may be able to do this with resistors and a capacitor, or resistors and diodes (which also have a .7 V drop when active). Your resulting circuit should look like this:



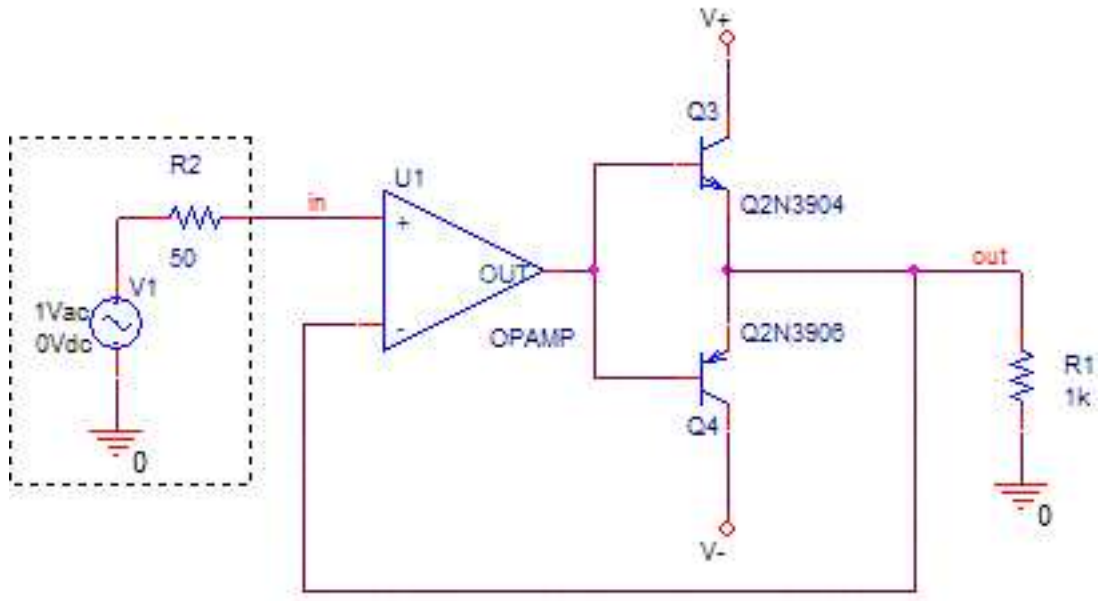
Make sure that the resistance of the box between $V+$ and $V-$ is at least $10k\Omega$.

- Again, look at your result on the scope and model your circuit in PSPICE. Does your solution have any problems? Explain any curious features on the graph. Include your plots in your lab report.
- Using PSPICE, calculate the new THD of this circuit. Can you get it below 2%?

3.4 Op-Amp Feedback

Another solution is to use feedback to adjust the input to meet the output. Remember that the op-amp will do whatever it takes to zero the difference between its inputs.

- Build the following circuit, in PSPICE and on your breadboard.



2. Look at this new circuit's behavior. Include plots in your lab report.
3. Calculate the new THD.

3.5 Feedback and Biasing

1. Finally, combine the biasing design with the feedback design by biasing the output from the op-amp.
2. Model your circuit in PSPICE and test it in the lab to make sure that it works.
3. Calculate the final THD.