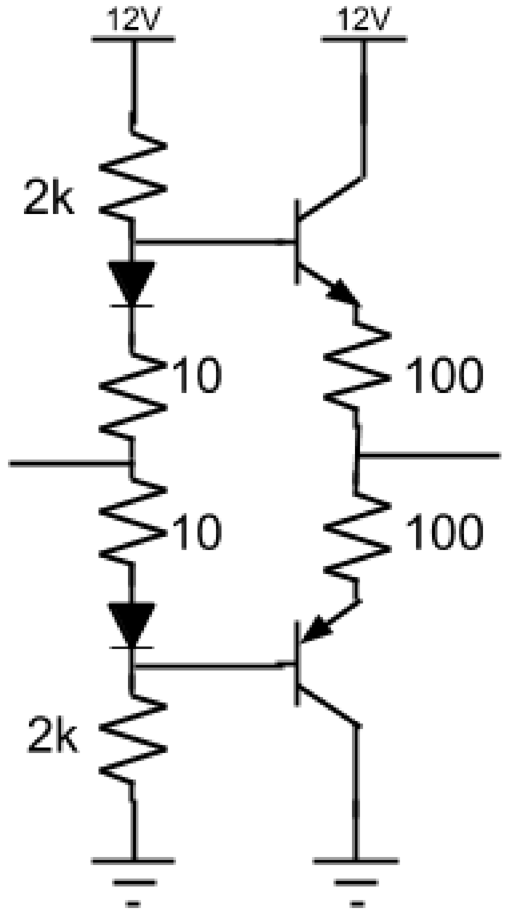

Figure 1: Schematic of a Class AB push-pull amplifier.

1 Warmup Problem

Find the r_{in} and r_{out} of the class AB amplifier in Figure 1 and the approximate bias current running in each branch. Assume the beta of all transistors is 100 and the V_{BEON} of all transistors is 0.7V. I recommend making liberal use of symmetry arguments.

2 Lab Introduction

In this lab you will simulate and characterize several output stages. You will also connect one of your output stages to last week's differential stage to make an open-loop op-amp. The learning goals are listed below:

- Implement class A, B and AB amplifiers, which requires considering their biasing.
- Observe differences in distortion, power output and efficiency between the amplifiers.

IMPORTANT NOTE: The class AB circuit you build here is the output stage of your operational amplifier. Please keep it available for future simulations.

3 Compare Output Stages

In this section you will simulate and compare class A, class B, and class AB power amplifiers.

Please do the following for each amplifier for two or three different input amplitudes that demonstrate different linearity behaviors:

1. Measure the output impedance. Note that it's easy to measure this incorrectly in a class B amplifier: you need to add 0.7V to your output signal to account for the deadzone.
2. Save a trace containing the input and output waveforms overlaid at the maximum input amplitude you test.
3. Use your output voltage measurements to calculate the power driven into the load.
4. Measure the power pulled from the supply and calculate the efficiency of your amplifier. What is the maximum efficiency you can achieve?
5. Record the values of input amplitude at which there are significant changes in the shape of your output wave. Qualitatively compare the swing and non-linearity of these stages.
6. Compare your output waveform to major sources of non-linearity in theory. Explain any significant distortion in your output waveform. You don't need to fix this distortion, just explain where it comes from.
7. Comment on the sound the amplifier would make when driving into a speaker(an 8Ω load). You can hear this sound by taking your simulation data into Matlab's `play()` command or similar software.
8. Calculate or simulate the power dissipated in all resistors and transistors and comment if you would need to do something special with our standard lab resistors (0.1W rated) or transistors (0.3W rated depended on heat sinking) to handle the power. Bear in mind that capacitive coupling the output can have a significant effect on dissipation in your load resistor.

Some design details of the amplifiers appear below:

- All amplifiers may have capacitively coupled inputs.
- All amplifiers must have capacitively coupled outputs. Don't overdo it on your output coupling cap because large capacitors at the output of an emitter follower can make the stage unstable.
- All amplifier measurements (except output impedance) should be carried out with a speaker (8Ω) load attached. All measurements should be taken at 1kHz.
- These amplifiers may require practical biasing circuits that were not pictured in lecture. These circuits will probably just be resistor dividers, but feel free to build current mirrors.

- The class A amplifier should be an emitter follower which is biased with 10mA of current. It should operate on a 12V supply.
- The class B amplifier should be a push-pull operating off of a 12V supply.
- The class AB amplifier should be built to the design in Figure 1.

Required Data: r_{out}, P_S, P_L, and η for each amplifier for several different amplitudes of v_{IN}. Overlaid input and output oscilloscope traces over 1-4 periods for each amplifier at max amplitude, discussion of non-linearity and comparisons between amplifiers.

4 Create an Open Loop Op-Amp

Connect your differential stage from lab 8 to the class AB output stage in this lab by creating a third gain stage. This stage must level shift voltages such that the output of all of the stages may be DC coupled to one-another. The stage must also provide gain such that the open-loop op-amp has a DC gain of 50 or more. You may alter the design of any of the three stages in order to accomplish these design goals of DC coupling and an open loop gain of 50.