

ENEE 307
Electronic Circuit Design Laboratory
Spring 2012

A. Iliadis
Electrical Engineering Department
University of Maryland
College Park
MD 20742

Audio Amplifiers

2.1. Audio Amplifiers

Before coming to this lab you should have your PSPICE design ready to show to your TA and have studied Chapter 6, 7, and 9 on BJT Amps in Sedra and Smith 6th Edition. Use PSPICE to design all your circuits and determine the resistor values. Include your PSPICE design in your report.

2.1.1. Audio Amps.

Audio Amps are amplifiers working in the audio frequency range between 15 to 20 Hz and 15 to 20 kHz, and they are capable of delivering enough power to drive the speakers of a system. Although one can make a very sophisticated Audio Amp with several stages of pre-amplification and power, the most simple designs are usually more than adequate and consist mainly of an input single (or double) stage differential amplifier for the voltage gain necessary and an output stage power amp (current) for driving the speakers. Speaker input resistances are usually 8 Ω , although 4 and 16 Ω speakers are common in the market too. Therefore, your output stage should be designed for an 8 Ω speaker.

The input stage will accept the voltage output of the sensor element, which could be a CD player, a tape recorder, a microphone, or any other element producing a small voltage output, usually of the order of a few hundred μ V to several mV, provide the linear amplification of the signal and input it to the power stage for the speakers. Volume control is usually set at the input stage controlling the gain.

In the first part of this Lab you can use the double stage Dif. Amp from project #1, and design a final output power stage to deliver the necessary current to drive the speakers, or you can redesign the pre-amp stage if its performance was far below specs. Linear amplification is important as it decides the total harmonic distortion (THD) of your audio amp and hence its HiFi quality. THD must usually be below 1% for HiFi results. The 3904-6 npn-pnp complimentary BJT pair will be your active transistor elements and you may choose any passive component values given by SPICE (resistors, capacitors etc) and that you deem appropriate to make your circuit work under the given specifications.

The specs for the audio amp are: 3-6W power to 8 Ω load at 20Hz to >15 KHz response.

2.1.2. Power Amp Classes.

There are different classes of power amps but the one most useful for audio applications is the class AB amp push-pull type of arrangement. In the AB class an npn and a pnp transistor are connected in the way shown in Fig. 2.1 and biased just above their cut-off region so that they are just on when there is no signal in the input to amplify. When a sinusoidal input signal comes to the input the npn Q1 transistor amplifies the positive part of the signal cycle, while the pnp Q2 transistor is just on at quiescent point, and when the positive cycle ends Q1 is just on while Q2 turns fully on and amplifies the negative part of the signal. Thus during the positive cycle only Q1 is in fully on state while Q2 is just on at the quiescent point chosen by the designer (ie you), and during the negative cycle Q2 is fully on while Q1 is just on at quiescent point. This way power consumption is dramatically reduced and the amplification efficiency:

$$\eta = P_o(ac) / [P_{in}(dc) + P_{is}(ac)]$$

is increased. Where $P_{is}(ac)$ is the input signal power, which is much smaller than $P_{in}(dc)$ from the power supply and hence can be neglected. Depending on the chosen quiescent point of the two transistors η can be between 50 and 70% an efficiency 2-3 times better than a class A amplifier (25%). The class AB amp is also better than the class B amps which are basically the same as AB only the quiescent point is at zero, because they have no cross-over distortion around zero. The trade-off however of the AB class is a reduction in efficiency. Class B amps have an efficiency of 78%.

Biasing of the two Q1, Q2 transistors can be done with either diodes or diode connected transistors as shown in Fig. 2.1.

The amp power dissipation is defined as:

$$P_d = P_{in}(dc) - P_o(ac) = P_o [1/\eta - 1]$$

2.1.3. Power Output Stages: Darlington Pair, Compound Pair.

The two output AB class push-pull transistors will provide some current gain for the output current but this may not be enough for the requirements of driving the speakers. To increase the current gain significantly we can use two npn transistors connected as in Fig. 2.2, which constitutes a Darlington pair with an overall $\beta = \beta_1 \beta_2$. This will provide a substantial current gain for the positive part of the signal cycle. However npn transistors have betas much lower than pnp transistors, and a darlington pair with pnp transistors will not have comparable gain to the npn Darlington pair. In this case we connect a pnp transistor with two npn transistors as shown in Fig. 2.3, which constitutes Compound Darlington transistor with an overall gain $\beta = \beta_1 \beta_2 \beta_3$.

2.1.4. Design approach.

For your audio amp you may use the double stage differential pair from project #1, or you may cut one stage out if your single stage gives you enough voltage gain to go to the output power stage, or you may design it from the start.

Fig. 2.4 suggests an audio amp schematic.

Once you have your amp working, use your signal generator to input a sinusoidal signal and measure the gain and power of your amp on an $8\ \Omega$ load. You may also input a mic or other input and listen to the speaker.

2.1.5. IC Audio Amp.

Use the IC audio amp (LM380) to drive the speaker and measure its performance. Then compare with the performance of your audio amp.

2.1.6. High Power Audio Amp. Extra Credit.

When your audio amp is working well, you may use the power output transistors MJL3281A (npn) and MJL1302A (pnp), which are rated at 100W to build a high power amp. Please use cooling for the output transistors and a volume control (pot) in the preamp stage to control output power to the speaker.

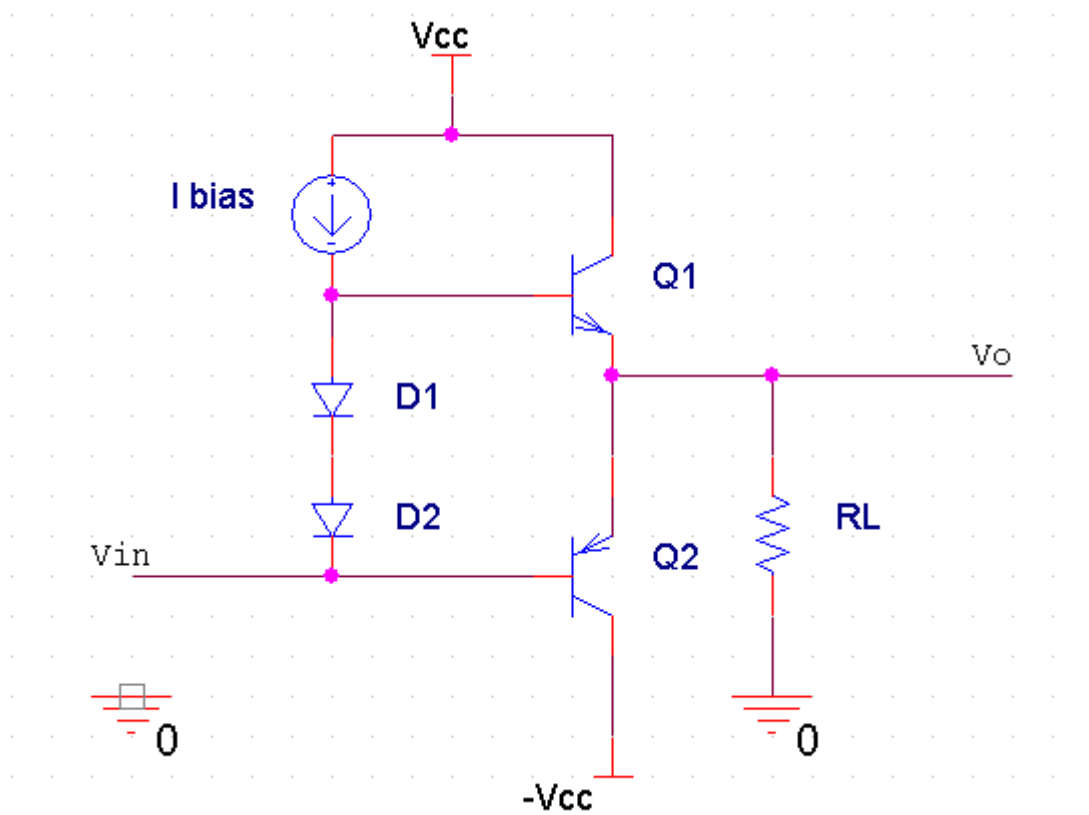


Figure 2.1. Class AB output stage amp.

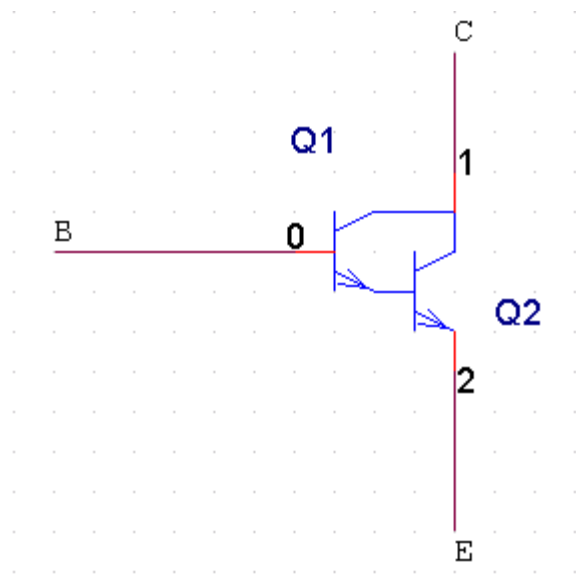


Figure 2.2. A Darlington pair output stage element (npn)
 $b=b1.b2$

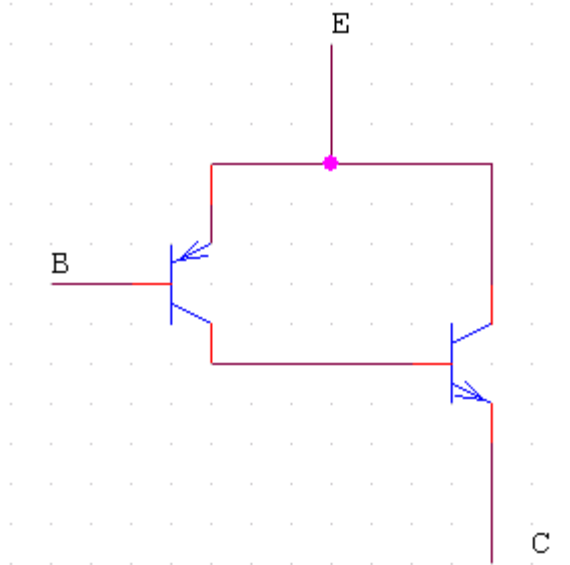


Figure 2.3. A compound pair output element (pnp)

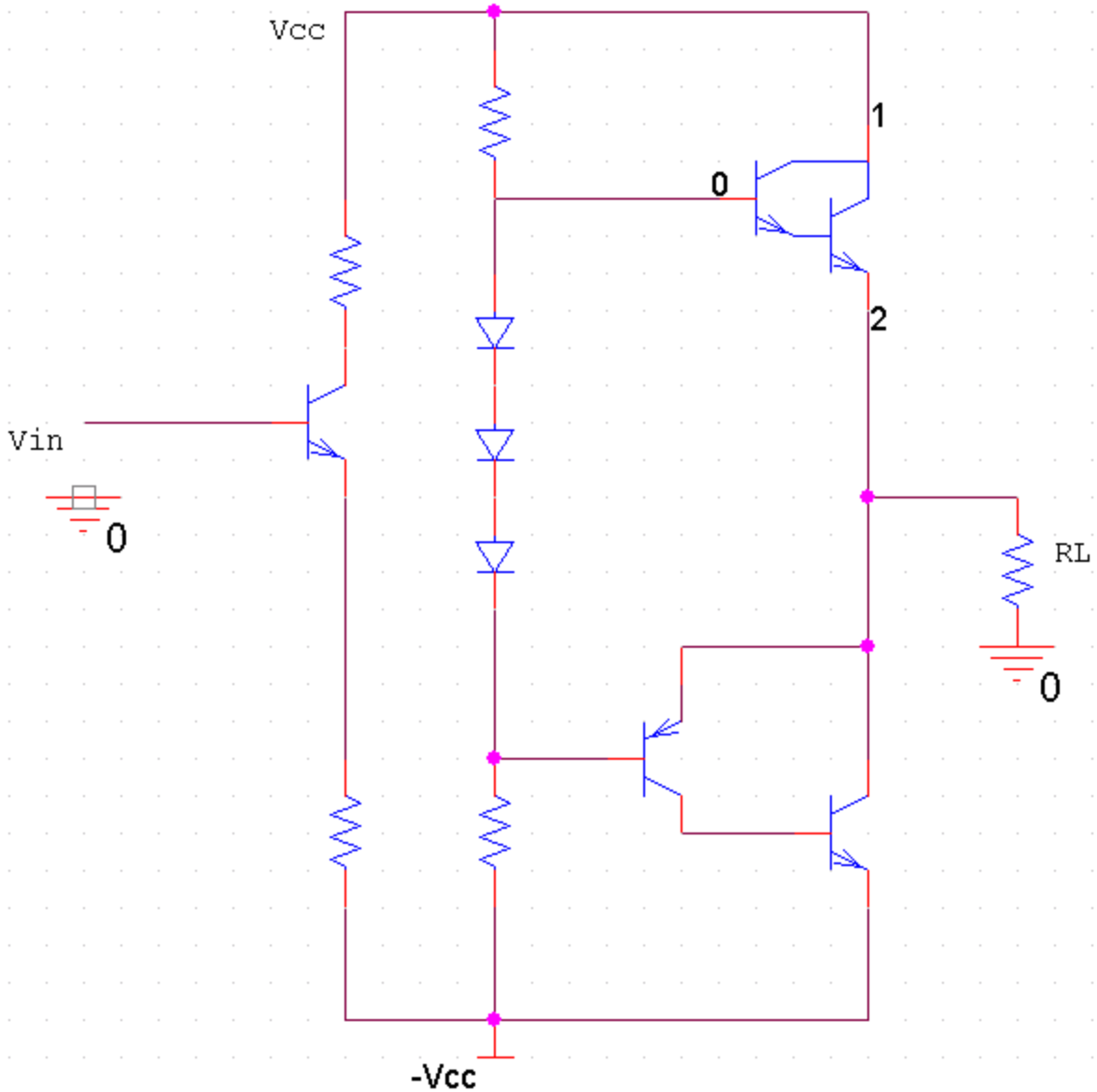


Figure 2.4 Output stage for power amp.

1. Introduce feedback for stability
2. Suggest protection for “thermal runaway”
3. Suggest protection for “short circuit” of output
4. Define all currents and voltages
5. Use capacitors to isolate if needed