Lab 5: Audio Power Amplifier with Feedback

Introduction

The linearity requirement of audio power amplifiers is usually very high because our ear is very sensitive to distortion of sound. Despite the glitch-les class-AB operation, the power amplifier in Lab 3 is not linear enough for audio applications.

The nonlinearity of the power amplifier can be significantly improved by employing a negative feedback around the power amplifier as shown in Figure 1. The opamp acts as an error amplifier which detects and amplify the difference between the input (V_i) and output (V_o).

In this lab, you will simulate and test the audio power amplifier with feedback. Circuits from all of the previous labs, a common-source amplifier, current mirror, operational amplifier, and power amplifier will be used in this lab. A full schematic of the audio power amplifier is shown in Figure 2. As in Lab 3, the supply voltage is 12 V due to the large V_{TH} of the power transistors, and both the input and output bias points are 6 V for maximum signal swing. An 8-Ω speaker is connected to the output via a DC block capacitor as speakers cannot accept any DC current in general.

Preparation

1. Determine the type of feedback in Figure 2.
2. Determine the value of C_s for the cutoff frequency of 50 Hz or less.
3. Determine the value of R_1 so M1 and M2 are barely ON when $V_o = 6$V by simulation.

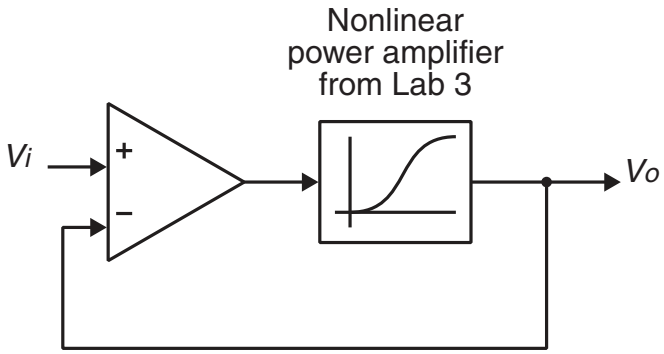

Figure 1: Feedback around the nonlinear amplifier from Lab 3.

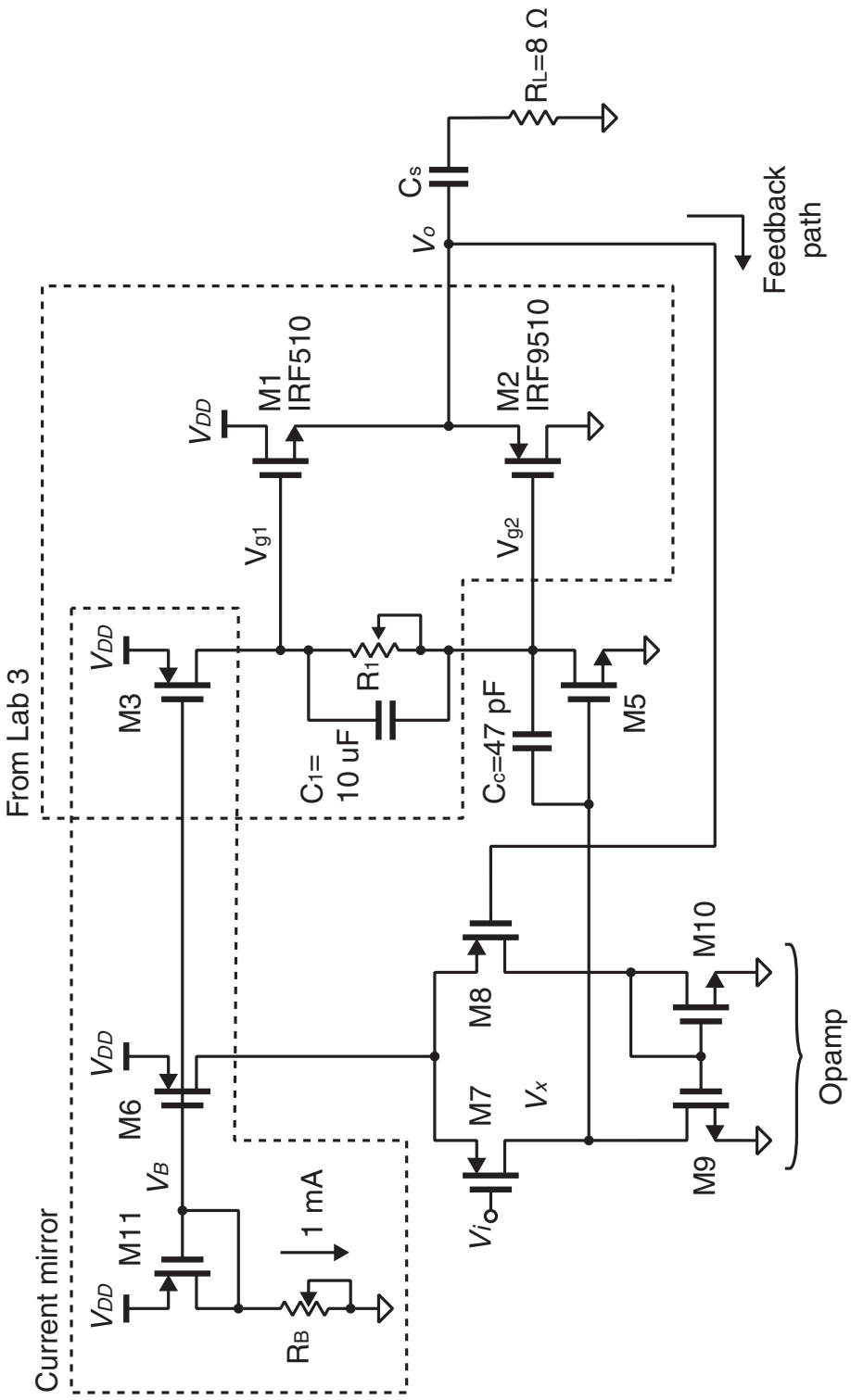

Figure 2: A full schematic of the audio power amplifier.

Table 1: Minimum parts list

Part	Description	Quantity
ALD1101	NMOS transistor pair	2
ALD1102	PMOS transistor pair	3
IRF510	NMOS power transistor	1
IRF9510	PMOS power transistor	1
-	C_s in Figure 2	1
-	47-pF capacitor	1
-	8-Ω speaker	1
-	8-Ω resistor (1 W or more)	1
-	10-kΩ multi-turn potentiometer	3

4. Run a 50-ms transient simulation for the power amplifier with class-AB biasing from Lab 3 with 1-kHz 2-V_{pp} output biased at 6 V. Set the maximum time step of the transient simulation to 1 μs. Plot the output spectrum using the FFT function of the simulator. Find the power efficiency of the amplifier.

5. Repeat step 4. with feedback. Both the input (V_i) and output (V_o) bias point should be 6 V.

6. Repeat step 5. without class-AB biasing (thus class-B) in the power amplifier. The class-AB biasing can be disabled by shorting R_1.

7. Modify the circuit in step 5. for the gain of 4. This can be done by changing β of the feedback. Remember that the input and output bias point should remain 6 V. This requires a clever feedback network because a simple two-resistor voltage divider divides the output signal as well as its bias point. *Hint: Both V_{DD} and GND are small signal grounds.*

8. Organize the results for presentation to your TA.

Lab

The audio power amplifier simulated in the preparation is experimentally tested in lab. The minimum parts list is for this lab is shown in Table 1. The 8-Ω resistor will be used as a dummy load of the speaker to avoid unpleasant sound during circuit debugging.

1. Setup the power supply to limit the output current to 250 mA. **This step is very important for your safety** because improper biasing of the power transistors (IRF510 and IRF9510) can cause them to sink amperes of current. In such a condition, **the power transistors get extremely hot and they may even burn and/or pop.** Set the maximum power supply current as follows:

(a) Disconnect everything from the output port of the power supply except the connection between the '-' and GND terminals.

(b) Turn the current limit to an arbitrary high value.

(c) Set the output voltage to 12 V.

(d) Turn the current limit to zero.

(e) Short the '+' and '-' terminals.

(f) Slowly crank up the current limit until the ammeter reading of the power supply reaches 250 mA.

(g) Turn off the power supply and remove the short.

(h) Turn on the power supply. Do not touch the current limit knob from this point.

If the current limiter trips during your experiment, do not crank up the current limit but fix your circuit. The power amplifier in this lab should not need more than 250 mA if wired and biased properly. **If you are not sure about this step, ask your TA for assistance before turning on the power supply.**

2. Implement the audio power amplifier with class-B biasing in the power stage. Apply a 2-V_{pp} sinusoid biased at 6 V and observe the output. Measure the power efficiency. Keep the circuit as compact as possible as parasitic inductance of long wires can turn the feedback unstable.

3. Repeat step 2. with class-AB biasing. Adjust the R_1 in the same way as Lab 3.

4. Modify the audio power amplifier in step 3. for a gain of 4.

5. Connect a speaker to the output and observe the difference in sound quality with and without class-AB biasing. The class-AB biasing can be simply disabled by shorting R_1.

6. Organize the results for presentation to your TA.