Lab 3a – Audio Amplifier Design and Prototyping

GOAL

The overall goal of Lab3 is to build a battery powered audio amplifier.

OBJECTIVES

Lab3a: (1) Design an audio amplifier using an op amp and Class AB stage.
(2) Build a prototype on a breadboard.
(3) Test your prototype to validate your design.

Lab3b: (1) Build a soldered version.
(2) Demonstrate a working amplifier.

GENERAL GUIDELINES

1) Each student builds his/her own circuits.
2) Test stations (e.g. oscilloscope, computer) must be shared.
3) You are allowed (even encouraged) to help each other. Of course, Prof. Hedrick will be around to provide assistance as well.
4) **Use neat wiring for your circuits! Starting in Lab 2, a messy circuit will cost you 1 pt (out of 10 for the demo).**
5) Keep your circuit components organized to make it easier to do the subsequent labs!
6) Each student must turn in his/her own lab report. See the course website for the template.

Honor Code Compliance: **You must turn in your own work**! Blatant duplication of circuit analysis, design, simulations, and/or lab reports will result in ZERO points and possible reporting to the Honor Council.

NOTE: There will be one lab exam near the end of the term. The lab exam will test each student's ability to use Multisim and prototype a circuit.

PARTS AND MATERIALS

- Power supply, scope, scope probes, function generator, BNC+alligator clips, banana cables
- Lab kit containing breadboard, wires, wire stripper, and other tools
- LF411 op amp
- Npn and pnp transistors (you decide)
- Resistors: You choose! (a whole bunch)
  16 ohm (brown/blue/black) (one)
- Capacitors: 0.1 uF ceramic (eight)
  ??? uF electrolytic (four)
- 16 ohm speaker (one)
- Audio cable (one)
- AA batteries (six)

- AA 3-pack battery holder (two)

INTRODUCTION

The overall goal of Lab3 (two weeks) is to build a battery-powered audio amplifier. You get to keep the soldered version of your amplifier (includes audio cable and speaker)! The overall specifications are the following:

1) +/- V_{CC} = +/- 4.5V
2) Overall voltage gain ≥ 10 from 400 Hz to 4 kHz
3) Input impedance $R_{IN} \geq 50$ kΩ
4) Drive a 16 Ω speaker with up to 125 mW.

PART 1: AMPLIFIER DESIGN

NOTE: If you have already finished PreLab3, then you can jump to Part 2 of the lab …

➢ **Show your calculations and simulations to Prof. Hedrick (2 out of 10 pts of lab demo grade).**

Your design calculations should include the following:

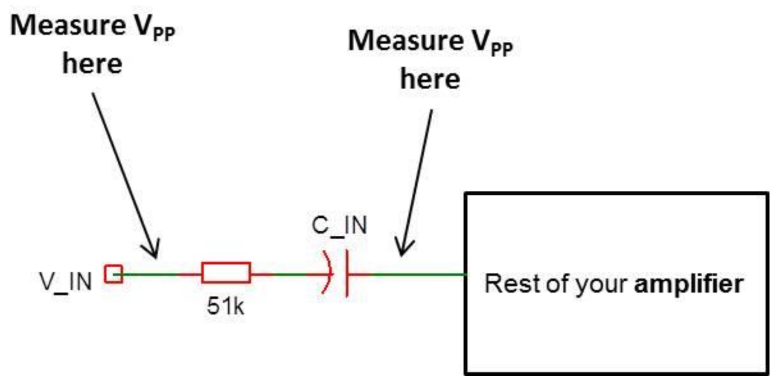
- Choice of Q1 (2N3904, 2N4401, or TIP31A). The TIP31A is a power transistor (datasheet on course website).
- The pnp version of the above transistors are (2N3906, 2N4403, or TIP32A).
- Adequate power rating of Q1 (assume Q2 is the same).
- Choice of RB1 and RB2 (choose standard value).
- Confirmation that the LF411 will provide the desired max output with +/- V_{CC} = +/- 4.5V.
- Choice of (R_{IN}, R1, R2) for non-inverting amplifier
- Choice of (R1, R2) for inverting amplifier.
- Choice of C_{IN} (choose standard value). Note that $f_C = 1/(2\pi R_{IN} C_{IN})$.
- Choice of C_{OUT} (choose standard value). Note that $f_C = 1/(2\pi R_{LOAD} C_{OUT})$.
- Simetrix simulation of the entire circuit.
    - Provide the schematic.
    - Perform transient simulations at 400 Hz, 1 kHz, and 4 kHz.
    - Provide waveforms of V_{IN} and V_{OUT} for all three cases.
    - Compute the voltage gain V_{OUT}/V_{IN} for all three cases.
    - Measure the input impedance Z_{IN} for all three cases. Remember that $Z_{IN} = V_{IN}/I_{IN}$.
    - Make sure your simulation results satisfy the design requirements!

PART 2: PROTOTYPE

This is where you validate your design.

- Circuit construction
  - Your breadboard circuit will be your template for soldering, so think carefully about where you place components and how they are wired!
  - Be NEAT!
  - Try to minimize the number of criss-crossing wires (OK to have a few).
  - Remember to include 0.1 uF bypass capacitors for the op amp and push-pull transistors!

- Circuit testing
  - Use a 16 ohm resistor as the test load.
  - Configure the Agilent function generator to "High Z" output.
  - Think about how to test your circuit's ability to produce the desired V_{OUT} ($4V_{PP}$ into 16 ohm). Your prelab simulations should help here.
  - Go ahead and configure the Agilent function generator and oscilloscope to measure V_{OUT} at 400 Hz, 1 kHz, and 4 kHz.
  - Determine the voltage gain at all three frequencies.
  - Does your gain satisfy the design requirement?
  - Record a snapshot of your circuit with a 1 kHz signal.
  - Measure R_{IN} using the following method:
    - Insert a 51 kohm resistor between the function generator and the input coupling capacitor.
    - Configure V_{IN} to be 4 kHz.
    - Measure the peak-to-peak voltage at the two locations in the figure.
    - Assuming C_{IN} is a perfect short, figure out R_{IN} by the voltage divider effect.
  - After you are done measuring R_{IN}, remove the 51 kohm resistor.



- **Demo scope traces of max V_{OUT} (400 Hz, 1 kHz, and 4 kHz sine wave) to Prof. Hedrick (4 out of 10 pts of lab demo grade).**
- **Present your measurements (gain and R_{IN}) to Prof. Hedrick (4 out of 10 pts of lab demo grade).**

(End of Lab 3a)