Microelectronics ECSE 335

Laboratory No. 6

Design, Simulation and Validation of a General-Purpose Operational Amplifier

Purpose:

Design, simulate and validate the operation of a general-purpose operational amplifier using a discrete prototype involving commercially available BJT transistors. The student will draw much of their design from the work performed in the previous labs of this course.

Equipment Required:

a. Computer
b. SPICE Simulator (student choice)
c. Test Bench: DC Voltage supplies, Function Generator and Oscilloscope
d. Components:
   i. Student decision but must be available from the parts-master on the 4th floor service counter in the Trottier building.
   ii. It is suggested to assemble some of the circuit components prior to entering the laboratory to save time.

Write-Up Requirements:

A good laboratory report should contain a **brief** description of what the experiment was about, including circuit diagrams, and what you did, your data, your results, and anything else called for in the assignment, such as questions inserted in the laboratory description. Answers to these questions require observations that need to be made at the time you do the experiment.

While not always explicitly spelled out in any one laboratory, the use of SPICE should be used by the student to predict the experimental outcomes. SPICE results should be compared to that

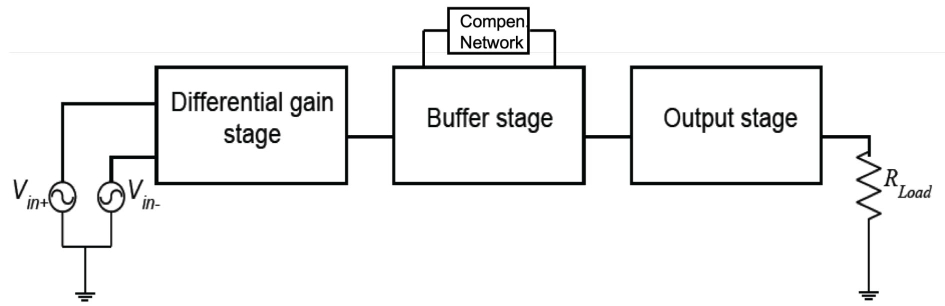

Figure 6.1: Block diagram of a multistage amplifier cascade with compensation that is used to realize a general-purpose operational amplifier.

obtained by measurement, and any differences explained or justified.

The laboratory report should be written using the IEEE paper style consisting of a **double-column single-space format**, and must adhere to the following when necessary:

1. Title page - Title of the assignment/project, authors' name, and course name.
2. Abstract - Abstract of the assignment/project report.
3. Introduction
4. Main body of the assignment/project report including figures.
6. Conclusions
7. References
8. Appendices

Operational Amplifier

In this section, the active load differential amplifier (Lab. 3), the buffer stage (Lab. 5) and the Class AB output stage (Lab. 4) will be combined as shown in Figure 6.1 in order to yield an operational amplifier with an open-loop gain of around 2500 V/V. Also, the amplifier's stability when configured in closed-loop will be investigated, compensation will be performed if needed and, finally, the circuit will be used in various closed-loop feedback configurations such as a noninverting amplifier.

Preparation

The student should make use of hand analysis and/or a circuit simulation tool such as SPICE to answer the following questions.

1. Get familiar with Chapter 11 in Sedra and Smith, 8th Ed.
2. Combine the active load differential amplifier, buffer stage, and Class AB output stage together and load them with a 330 Ω resistor. Ensure that the combination of the circuits yields the expected results from Spice simulations. Document the frequency response, gain, voltage transfer characteristic, and maximal input and output ranges. Make sure that the DC point at the

output is 0 V. Why is that critical in the context of feedback? Ensure that the parasitic capacitors are still accounted for.

3. Determine the phase margin of the circuit.
4. By examining the circuit diagram, determine where a compensating capacitor could be added to increase the phase margin of the circuit. You may use whichever compensating method you deem reasonable. Hint: Remember that, in its simplest form, compensating is equivalent to slowing down a circuit's frequency response to increase its phase margin.
5. If needed, compensate the circuit to yield a minimum phase margin of 25°.
6. Load the circuit with a 330 Ω resistor. Document the frequency response, voltage transfer characteristic, time response, and maximal input and output ranges. Hint: You may decouple the load with a series capacitor if you have problems.
7. Design a non-inverting feedback amplifier which provides a gain of 150 V/V. Do not assume the open-loop gain to be infinite in this case, but use your measured open loop gain value. Provide a schematic of the design. Plot the frequency response, time response, and voltage transfer characteristic of this design.
8. Comment on the effect of the feedback loop on the characteristics of the amplifier. Mainly, comment on the bandwidth, gain, and input resistance.
9. What are the advantages and disadvantages of feedback in this case?

Experiment

For the differential setup, perform the following in succession (make sure to use a 10X probe when required!):

1. Combine the circuits together and plot the frequency response using the 10X probe and find the 3-dB points.
2. Plot a time response of the input and output; keep your input signal very small so as not to saturate the output after amplification.
3. Plot the circuit's voltage transfer characteristic.
4. Measure the maximal input and output ranges of the circuit.
5. Measure the input resistance of the circuit.
6. Implement your non-inverting amplifier design and repeat steps 1. to 5.
7. Based on experimental results, comment on the performance of the circuit compared to the open-loop amplifier.

This concludes this lab.