This homework assignment is required if your grade on the midterm exam was below 70. The point value is 0.5x[80 - (your midterm grade)]. Points will be added to your midterm grade. For example, if your midterm grade is 68, the assignment is worth 12/2 = 6 points, which may bring your midterm score up to 74. If your midterm grade was above 80, do not submit this assignment.

Fill in the last four digits of your student number in the blanks ____  ____  ____  ____ These digits are variables a b c and d. Now calculate the following and write the number in the blank:

- \( Vcc = a + 5 \text{ volts} \) = ____. In for any reason you consider one of those values inconvenient you may substitute variable d for a, b, or c. Note: Vdd is used on the next page.
- \( Vdd = a + 3 \text{ volts} \) = ____
- \( i_{ref} = \frac{(b + 2)}{10} \text{ mA} \) = ____
- \( i_{out} = c + 2 \text{ mA} \) = ____

Figure 1 is a simple op-amp. Fill in your value for Vcc and set R1 for i_{ref}. Now set R2 so that the voltage at node 3 is Vcc/2. Set R3 for your value of i_{out}.

\[ \text{Vcc} = _____ \]
\[ \text{R1} = _____ \]
\[ \text{R2} = _____ \]
\[ \text{R3} = _____ \]

Calculate the open loop gain from the inverting and noninverting inputs to output at node 3.

- \( g^+ = ______ \)
- \( g^- = ______ \)

Using LTspice and 2N3904 NPN transistors, simulate the behavior of the circuit in Figure 1, using your values calculated from variables a, b, c, and d. Use the AC simulator to determine the inverting and non-inverting open-loop gain as a function of frequency, and then repeat the gain study using transient simulation at a frequency of 1 kHz.

Modify the circuit for a reference current of 500 microamps and an output stage current of 2 mA with a power supply voltage of 9v, and repeat your simulations.
The simplest op-amp application is a voltage follower. Figure 2 shows the inverting input connected to the output.

Explore the circuit in LTspice AC and transient simulations. Determine the frequency response and maximum and minimum voltages at the non-inverting input that the circuit will follow. Use 1 kHz sine wave with DC offset input.

\[ \text{Vin max} = \underline{\text{_______}} \]
\[ \text{Vin min} = \underline{\text{_______}} \]

Explore the circuit in LTSpice driving a 32 ohm headphone load through a DC blocking capacitor. What modifications are needed to obtain satisfactory headphone volume without distortion?

Suggested Project:

Build the 5 transistor discrete op-amp circuit in the lab, using discrete components and construction method of your choice, not a solderless breadboard. Connect it as a follower, gain of -10 amplifier, and as a summing amplifier with variable gain driven by two equal signals. Measure the performance and record the results in your design notebook.

Project demonstration: Demonstrate the summing amplifier project driven by the stereo output of a personal device and driving a mono 32 ohm headphone load.