ENSC 220 Lab #2: Op Amps
Vers 1.2 Oct. 20, 2005: Due Oct. 24, 2004

OBJECTIVE:
Using the circuits below you can study op amps and characterize their behavior.

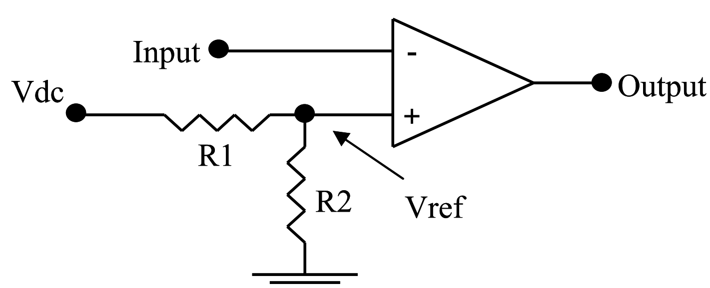
- Comparator
- Inverting Amplifier

PREPARATION:
- Read Lab Handbook 2.2.4 (Function Generator) and 2.2.5 (Oscilloscopes).
- Read Appendix X (pp. 268 - 272) on op-amp configurations.

EQUIPMENT:
- Basic lab tools and breadboard
- Dual DC power supply, set to TRACKING.
- Digital multimeter (DMM), Fluke 8010A or equivalent
- Function Generator, Wavetek 182A or equivalent
- Oscilloscope, Tektronix 2235 or similar
- Operational amplifier, TL072
- Resistors
- Connecting wire.

NOTES:
- Set current limit and connect the power after verifying the circuit & connections thoroughly.
- Check the multimeter setup before making any measurement. Improper setup can give incorrect readings and/or damage the meter.
- Connect your circuit neatly and logically on your breadboard to facilitate troubleshooting.
- When operating the op-amp from a single supply, the negative supply terminal (V-) of the op-amp should be grounded.
- Set the DC offset on the function generator to "0".
- Power supply voltages must not exceed ±12 volts.

METHOD:
- **COMPARATOR**:



Comparator

The comparator demonstrates the "open-loop" behavior of an op amp. You can design the reference voltage so that the output voltage will "switch" whenever the input voltage (at the inverting input *Vn*) reaches the reference voltage *Vref*.
Remember that the output voltage *Vo* for an ideal op amp is:

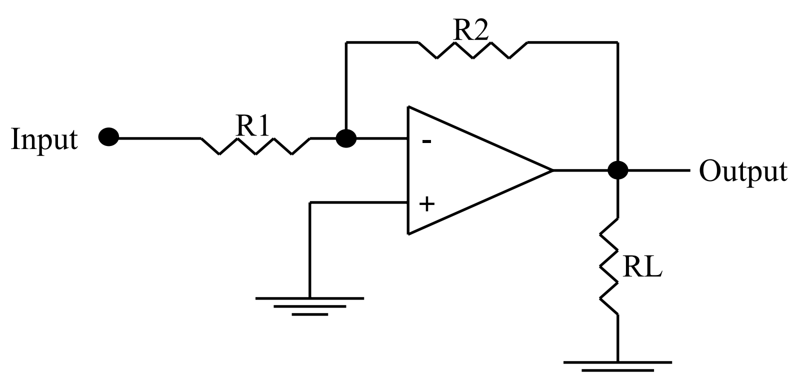
$$V_o = A(V_p - V_n)$$

where A = infinity.

Determine how nearly "ideal" your op amp is by the following method:

1. Choose appropriate R1, R2 and construct the circuit.
2. Choice of R1, R2 and Vdc will determine the value of Vref. Vdc can be your supply voltage.
3. Use the function generator to connect a 1 kHz triangular wave to the input.
4. Try adjusting the amplitude of the triangular signal. Observe and record the input and output using an oscilloscope. At very low input amplitude you will notice the output is fixed to one of the supply voltage levels. As the input signal approaches the Vref, the output will show a square wave.
5. Using the scope measurement determine the voltage of the input signal where the switching takes place. To do this you have to display the input and output simultaneously using the two channels of the oscilloscope.
6. Change the function generator setting to output sinusoidal signal.
7. Calculate and then measure the switching voltage level.
8. Introduce a resistor (say 2K7) in series with the inverting input. Does this affect the switching level?
9. Find the meaning of the term "slew rate" and measure it. (Slew rate is used to measure how fast an op-amp responds to the variation of the input signal.)
10. Adjust the input amplitude such that the output shows maximum possible amplitude. Measure the peak-to-peak value of the output voltage.
11. Compare this peak-to-peak swing to the magnitudes of the supply voltages used to power the op amp.
12. Try operating the op amp from a single supply and observe the output.

- **INVERTING AMPLIFIER**



Inverting Amplifier

The inverting amplifier demonstrates the "closed-loop" operation of an op amp because a portion of the output is "fed back" to the input. Design the amplifier with a gain of -10 [V/V], connect a 1 kHz sine wave and use RL = 1K at the output:

1. Find the maximum amplitude of the input for which the output is not distorted.
2. For a non distorting level of input signal determine the gain of your amplifier (Vout/Vin). Compare this measured gain to your calculated gain. Can you explain the discrepancies within the measurement errors?
3. Decrease the load RL to 100Ω, and note the effect on the output signal and gain.
4. See what happens when you operate this circuit from a single negative supply.
5. Return to dual supply.
6. Disengage the tracking. Vary each side from 12 volts to zero volts, observing the effect on the output. Engage tracking and restore to ±12 volt operation.

LAB REPORT

Overall:

Put names, student numbers and group number on the provided title page (see last page of this decription) You will lose a mark if any of the information is missing.

Do not reproduce the lab handout in your write-up. Reproductions of the schematics would be very useful, (either drawn by hand and scanned or computer drawn).

Structure your lab report in sections such that it is clear what you are discussing. Make sure to provide a conclusion summarizing your observations.

Include a introduction, but it is not necessary to provide a procedure section. If you change part of the procedure simply say so in your discussion and state why. For example, if there were no 1kΩ resistors in the bins you could use a 1.2kΩ and note the change in your write-up.

This is a formal lab report. (Imagine that you are submitting this to your boss at work.) There will be marks for the readability and presentation of your lab. It should NOT be in point form however effective use of tables and lists will be very useful. Also, label all figures and tables appropriately as well as placing them in the appropriate sections.

Section 1 Comparator:

- State the nominal and measured values for all resistor and supply voltage values used.
- Record all frequencies used measuring the value with the oscilloscope.
- Provide screen captures of inputs and outputs as well as sentence descriptions sufficient to show and explain your observations.
- Give the values for V_{dc} and V_{ref} and describe how you got V_{ref}.
- In step 4, provide screen captures of the input and output for an input signal lower than V_{ref} and for an input signal greater than V_{ref}.
- State the value of the switching voltage and show the measurement on a screen capture for both the triangular input and sinusoidal input. In a few sentences justify why the switching level did or did not change.
- Provide the definition of slew rate, describe how you measured it (include a screen capture) and state your measured slew rate.

- For step 11, in a few sentences explain why the measured peak-to-peak output does or does not match the magnitude of the supply voltages.

Section 2 Inverting Amplifier:

- Show your calculated gain and state your supply voltages. Measure and state the input frequency and peak-to-peak amplitude (maximum) you used (screen capture) and the resistance of R_L.
- Calculate the both the expected and measured gain of your amplifier using equations and screen captures. Compare the two gains and in a few sentences explain the results.
- State the measured value of R_L and your gain and provide a screen capture of the measurement. In a few sentences justify why the gain did or did not change.
- Make that when you are doing step 6 that your V_{in} and thus V_{out} is at the maximum non-distorting level. Provide two screen captures of V_{in} and V_{out}: one where $0V < V_{supplypos} < 12V$ and one where $-12V < V_{supplyneg} < 0V$. State what V_{supply} is for each screen capture.

Conclusion:

You need to write up a conclusion to your lab that discusses your observations. Summarize your results and talk about whether or not they were what you expected and provide explanations for any discrepancies.

Additional Lab Notes:

Instead of a screen capture you can substitute a graph or drawing, however make sure to include relevant information such as frequency, peak-to-peak values and the scale of both axes. The substitute must be accurate enough for me to easily extract values of interest like points where curves cross, slopes, DC offsets, etc.

If you have a value within a sentence **bold** the value so we can easily pick out your numbers.

Make sure that all of your values have units.

For your numbers please use engineering notation rather than scientific notation.

Use the provided title page which you can enter your group number and member names and student numbers either in Acrobat or after printing.
Number your pages!

Additional Discussion:
All of these "non-ideal" effects can be explained and analyzed using a more sophisticated circuit model for the op amp. Try to come up with a model to explain some of your observations.

ENSC 220
Fall 2005

Lab 2:
Operational Amplifiers

Group #

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Dr. Glenn Chapman
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