CH332 Lab 1: OPERATIONAL AMPLIFIERS

In this experiment you will work through a couple of handouts from Forest M. Mims III on 741 op amp circuits. You will build a) voltage follower, b) the inverting circuit, c) the non-inverting circuit, d) the difference amplifier circuit, and e) the summing amplifier circuit. You will calculate the CMRR of your op amp. You will propagate the error in a circuit and discuss absolute vs. relative error.

For each circuit you should generate a table of five input voltages and the corresponding output voltage. From the table calculate the gain of each circuit. Compare the theoretical gain to the actual gain.

REFERENCES:

- F.M. Mims III, "Engineer's Mini-Notebook: Op Amp IC Circuits", Radio Shack, 1985.
- National Semiconductor Corporation, "An Applications Guide for Op Amps", Application Note 20, 1969.
- Skoog et al, "Principals of Instrumental Analysis", 6th edition, Chapter 2 and 3.
  - Fig 3-5: Voltage Follower
  - Fig 3-7: Inverting Voltage Amplifier
  - Fig 3-6: Noninverting Amplifier
  - Fig 3-13: Difference Op Amp
  - Fig 3-16b: Summing Op Amp
  - See pp 69-03 for CMRR

WEEK 1 PRELAB: What is a voltage follower? Include a detailed circuit diagram and information about the gain for this circuit. What is the CMRR of a 741 op amp (define and explain CMRR)? How is CMRR measured? How will you measure the CMRR of your 741 op amp in lab?

HELPFUL HINTS AND PRECAUTIONS:
1. Please note the pin assignments from the top view of the 741 OP-AMPs that you will be using. (Incorrect pin assignments can cause the Op-AMP to explode.) 741 Pinouts
2. Leave the power off until all of your connections have been checked. Have another student check your set-up before turning the power on.
3. Note that it is common practice to omit the connections to the positive and negative power supply voltages in the circuit diagrams. However, they must be properly connected. The pin that should be connected to the positive power supply (approx. +10V) is commonly marked +Vcc or +Vs. The pin for the negative supply (approx. -10V) is commonly marked -Vcc or -Vs. See figures 1 and 2 on the linear op amp circuits handout. A good operating procedure is to number the pin connections on the circuit diagram before making the connections on the board.
5. A resistor color code is provided in the handout for your convenience. You may also reference many good resister charts on the web.

LABORATORY INSTRUCTIONS WEEK 1:
Working from the selected portions of Mim's notebook, Skoog, and the applications note, build the following circuits using any resistors you choose (but choose them wisely!) and the 741 Op Amp provided:

a) the voltage follower

a) the inverting op amp circuit

b) the non-inverting circuit

c) the summing amplifier circuit

d) the difference amplifier circuit

For each circuit that you build, include the following in your notebook: (1) a detailed circuit diagram, (2) a clear legend to identify the resistances of all resistors chosen (record the manufacturers code and the actual resistance measured by the multimeter), and (3) an equation to describe the circuit function. For each circuit, set the input voltage to several (at least 5) separate values and measure the corresponding output voltage. Record your observations, including limits to the voltages you can generate. The input (Vin) and output voltage (Vout) will be measured using the (Vernier) voltmeter. The **experimental** gain will use the input and output voltages. Use the gain equation of the circuit with the manufacturer values of the resistors (Ohms) to calculate the **theoretical** gain. Use LINEST to further evaluate the **experimental** gain.

Comparing the manufacturer value of the resistors (and tolerance) to the actual resistance of the resistors measured by the multimeter, propagate the error in the gain in **the non-inverting and inverting** circuit due to resistance and discuss absolute and relative error.

Measure the CMRR of your 741 Op Amp at **two** different paired input voltages.

TO HAND IN WEEK 1: (Only diagrams, spreadsheets etc. are needed this week...no lab report.)

1. Please include detailed circuit diagrams for each circuit that you built and a description of the circuit function including the equation used to calculate the gain.

2. For each circuit generate a table of input voltages and the corresponding output voltage measured by the multimeter. Determine the **experimental** gain from these values. Use the gain equation and the manufacturers resistor code to determine the **theoretical** gain for each circuit. **Using the t value**, calculate the 95% confidence interval for the **experimental** gain corresponding to each circuit. Does the **theoretical** gain lie inside the confidence interval? This data should be in a *well documented* Excel spreadsheet. Please remember to include the resistor values that were used in each circuit. Please include sample calculations. Are you “confident” in the data for each circuit? Discuss.

3. Use **LINEST** to further evaluate the gain and the R^2 value for each circuit. Explain your confidence in the data in terms of accuracy and the precision.

4. Discuss the limitation of the output of your 741 op amp.

5. Use the measured and the manufacturer’s resistance value of each resistor used in the non-inverting and inverting circuit to propagate the error in the gain. What can you say about gain resistor error in a circuit? <u>Discuss</u> the absolute error vs. the relative error in the gain.

5. Explain two other sources of error (besides resistor error) that could contribute to the difference between the predicted and actual voltage outputs.

6. What is the experimental CMRR of your 741 op amp? What is the manufacturer's value for the CMRR of the 741 Op Amp? If the relationship between decibel and voltage is (dB=10 log (Vin^2/Vout^2), would this op amp be successful at filtering out noise from the fluorescent lights in the lab (suggested to be about 36 db at peak usage)? Briefly discuss. What disadvantage inherent in the difference circuit has a large affect on the measurement of CMRR? Explain.

<u>NOTE</u>: A copy of F.M. Mims III, "Engineer's Mini-Notebook: Op Amp IC Circuits" and other valuable information can be located next to each one of the breadboard setups in the lab. Please use the reference materials, but please keep them in the lab. Thanks

<u>WEEK 2 PRELAB</u>: Design an op amp circuit to measure the temperature of a solution using a pair of thermocouples. Use figure 3-13 in Skoog as a starting point, but add the following capabilities to the circuit:

a) Add a circuit to null the instrument response (set the response to zero for samples with identical temperatures).

b) Add a circuit to linearly shift the instrument response in a positive or negative direction.

c) Add a circuit to change the output gain of the instrument.

d) Add a circuit to integrate the output signal over a time period of 30 seconds. (approx. value of capacitor needed?)

******30% of your lab grade will be based on you preliminary design. Be as specific as possible: label and explain the drawing so that it clearly states what you are trying to do!!!!*****

LABORATORY INSTRUCTIONS FOR WEEK 2:

Test and modify your thermocouple design. To begin, build the thermocouple without integration the circuit. Consider using both fixed resistors and potentiometers for both the gain control and the null circuits. Calibrate your circuit at two gain levels by measuring circuit output as a function of water temperature. Add the integration circuit and test the effect of different resistor and capacitor combinations (RC constant) on time.

TO HAND IN WEEK 2: (This will be in lab report form.)

- Include a complete drawing of your final circuitry. Build a *well documented* Excel spreadsheet for your circuit as a function of output vs. temperature (at two different gains). Use **DeLevie macros** to find the 95% confidence interval for your thermocouple (both gains). Include a confidence interval graph for each circuit. Discuss the quality of your thermocouple.

- What is the uncertainty in the temperature measurements (mV) using the thermocouple and circuitry (both gains)?

- Why would the integration circuit be useful for temperature measurements?

- Find the maximum predicted gain for your circuitry. Find the actual gain in each trial. Include stats.

- Discuss two sources of error. Improvements?

- Propose another (alternative) circuit that could have been used for amplifying a thermocouple signal. Draw and explain the details of this circuit and how your changes could improve our instrument.