MAE 3340 *INSTRUMENTATION SYSTEMS*

Laboratory Exercise 7: Operational Amplifiers

Student NAME: ______________________________________

Team Name / SECTION ______________________________________

Hand in This Completed Document as the Laboratory Report

(Complete) Executive Summary:

Once you have completed the Lab..... Explain the objectives of this exercise and what you learned about operational amplifiers.

Introduction:

In this lab you will learn about operational amplifiers by building the circuit shown in Figure 1. This multiple purpose circuit has the capability of acting as a voltage polarity inverter, a high-impedance voltage follower, a voltage amplifier, and a voltage divider. All in 1 circuit! This circuit features both continuously-variable potentiometer resistor and an OpAmp. The potentiometer allows this circuit to server multiple purposes. A potentiometer informally called a "pot," is a three-terminal resistor with a sliding contact that forms an adjustable voltage divider. Potentiometers are commonly used to control electrical devices such as volume controls on audio equipment.

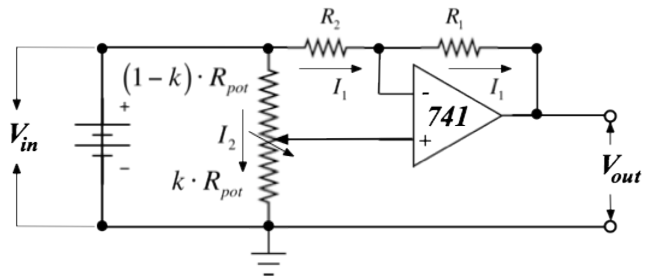

Figure 1. Lab 7 Amplifier Circuit.

An operational amplifier (op-amp) is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output. In this configuration, an op-amp produces an output potential (relative to circuit ground) that is typically hundreds of thousands of times larger than the potential difference between its input terminals. Op-amps are among the most widely used electronic devices today, being used in a vast array of consumer, industrial, and scientific devices. *The potentiometer you will be using is built by Honeywell, has a nominal resistance of 2500 W, and a tolerance of 5%. The spec sheets are included in the lab 7 lecture notes.* The *pot* resistor is rated for 2 Watts. Full rotation is 312^{o}.

For this lab you will be using the Natiotional Semiconductor 741 OpAmp. Although many other designs beat the NS-741 for speed, low noise, etc, this OpAmp works well as a general-purpose device. One of its advantages is that it is *compensated* to ensure that under most circumstances it won't produce unwanted spurious oscillations. This property makes 741 easy to use, but the down-side is the poor speed/gain performance compared to more modern op-amps.

For typical amplifier design negative feedback is used, by applying a portion of the output voltage to the inverting input. The *closed loop* feedback greatly reduces the gain of the amplifier. When negative feedback is used, the circuit's overall gain and response becomes determined mostly by the feedback network rather than by the op-amp itself. You can observe this negative feedback loop in Figure 1.

Equipment:

1.My DAQ Chassis and USB Cable

2. MyDAQ Red and Black Voltage Probes

3.MyDAQ BreadBoard

4.Honeywell 2.5 kW, 2 Watt Potentiometer

5.Breadboard Jumper Wires

6.10 Assorted Resistors from *1000 W to 5000 kW*

7.National Semiconductor 741 OpAmp

8. "Sharpie" Felt Tip Marker

Pre-Lab Preparations:

Go through the Lab 7 lecture notes and make sure you understand the circuit analysis. Then using you MyDAQ in OhmMeter Mode ...

a) Verify that All Resistances lie Between *1 kΩ and 5kΩ*

b) Ensure that Two Resistors ~ *1000 Ω*

c) Power Dissipated by Potentiometer @$5Vdc\ V_{in:}$ ________________

d) Maximum Power Dissipated in R_1 R_2 @$5Vdc\ V_{in:}$ ________________

e) Expected Range of Output Voltages:_________________________

f) *Based on R_1 Resistor Range from 1KΩ to 5 KΩ*

g) Actual Potentiometer Resistance ($k=1$):________%Deviation___________

h) Actual Potentiometer Resistance ($k=0$): _______%Deviation ___________

i) Find Rotation Point on Potentiometer where $k=0.5$, Mark with "Sharpie" Felt Tip Pen

j) Perform the calculation to ensure that the ¼ Watt Limit is not exceeded for any Resistor with any Potentiometer setting at @5Vdc V_{in}.

k) Also verify that the potentiometer will not reach its 2-Watt limit when the +5 Volt excitation is used.

l) *Show these calculations as an attachment to your lab report.*

m) Populate the Resistor Table Below

Table 1: Resistor Data

Resistor Number	**Nominal Value, kΩ**	**Tolerance, %**	**Measured Value, kΩ**	**% Deviation**
	Example: Use Student-Built Spreadsheet			

Pre-Lab Uncertainty Analysis:

a. Following the Procedure Laid Out in the lab Notes , Calculate the Expected Uncertainty in the Amplifier Gain

$$Gain = V_{out}/V_{in}$$

b. Based on the Manufacturer's Specs for R_{pot}, R_1, and R_2. *For k ={0, ½, 1} Potentiometer Settings*

c. Use Chain Rule for Error Propagation

d. Assume σ_k/k ~ linearity tolerance (See Slide 18 of Lab Notes)

e. Plot Expected Gain Error as a function of R_1/R_2

f. *Assume V_{in} is exact*

g. *Show these calculations as an attachment to your lab repor along with your gain-error plot.*

Lab Procedure:

a) Build and Test Circuit per Instructions in Lab 7 Lecture Notes
b) Start with $R_1 = R_2 \sim 1000\ \Omega$.
c) Power Up Circuit
d) Populate Voltage Tables for all R_1 Resistors, Keep $R_2 \sim 1000\ \Omega$ ϕor all tests.
e) Measure Voltages across nodes *{a,c}* and *{b,c}* Using MyDAQ Voltage Probes. See Figure on Slide 17 of Lab 7 Notes
f) Be sure to power down circuit when swapping out R_1
g) Repeat Part 3 for Potentiometer *k={0, ½, 1}*

Table 2: Voltage data for *k=0, R_2~1000 kΩ*

R_1 Number	Measured Value, *kΩ*	V_{in}	"V_{out}"	V_{out}/V_{in}, Gain	$V_{\{a,c\}}$
		Example: Use Student-Built Spreadsheet			

Table 3: Voltage data for *k=1/2, R_2~1000 kΩ*

R_1 Number	Measured Value, *kΩ*	V_{in}	"V_{out}"	V_{out}/V_{in}, Gain	$V_{\{a,c\}}$
		Example: Use Student Built Spreadsheet			

Table 2: Voltage data for *k=1, R_2~1000 kΩ*

R_1 Number	Measured Value, *kΩ*	V_{in}	"V_{out}"	V_{out}/V_{in}, *Gain*	$V_{\{a,c\}}$
		Example: Use Student Built Spreadsheet			

Post-Lab Error Analysis:

a) For each Potentiometer setting → k={1, ½, 0} Calculate your mean Gain Value {V_{out}/V_{in}} and the corresponding Sample Standard Deviation for the 9 samples, from tables 2, 3, 4. *Each table will have its own sample mean and standard deviation.*

b) Assess the 95% confidence interval for the mean values generated for each table.

  a. Based on the Normal (Gaussian) Distribution

  b. Based on the Student-T Distribution with the appropriate degrees of freedom

c) Compare this confidence interval to the expected gain uncertainty calculated from the pre-lab error analysis.

d) Turn in you error analysis as an attachment to this report.

Post-Lab Assessment:

a) See ~~Figure 32~~ **Slide 36** in Lab 7 Lecture Notes. This figure shows the expected results. How does your data agree?

b) Give a +5Vdc excitation voltage, what happens to the output voltage once the ratio R_1/R_2 exceeds 3? Why?

c) At the k = 0 potentiometer setting, what voltage reading did you get across {*a,c*}? (See Figure of slide 2 Lab Lecture Notes) Why? What feature of the OpAmp gives this property?