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Lab 6 and 7: Operational Amplifiers

EEE 117 Lab – Section 04: Tuesday, 4:30pm – 7:10pm

Abstract:

The purpose of this lab is to provide introduction to practical Operational Amplifiers (Op Amps). While also allowing acquaintance with the oscilloscope, power supply, function generator, and digital multimeter. Operational Amplifiers can be broken down to a device that amplifies voltage and can be used with external feedback components such as resistors and capacitors. The feedback components determine the resulting function or operation of the amplifier. Only one type of Op Amp will be used (µA741), however it will be placed in four different circuit models; Inverting Amplifier, Saturation in Inverting Amplifier, Strain Gauge Amplifier, Weighted Summer.

Introduction:

When investigating the four types of it is very important to double check the power supply wiring because when improper voltages are applied to the Op Amp it can lead to burning a hole in the breadboard or destroying the Op Amp. The Op Amp requires two 9V supplies and the only ground is the junction between the two power supplies. A pin configuration of the µA741 Op Amp can be seen in Figure 1. Adjust the function generator to have an input voltage (V_1) at a 500Hz sinusoid with a peak-to-peak voltage of 3V and 0 DC offset, before signal is applied to the circuit. Make sure the oscilloscope is set to DC coupling as well. Measure the input and output voltages with both the oscilloscope and Digital Multimeter (DMM). Compare the two sets of measurements with each other, and to the theoretical gain. For this lab the theoretical value for the oscilloscope is 3V and for the DMM 1.06V. Also describe the phase relationship between the input and output. View figure 2 to see the circuit layout, and use figure 5 to get the theoretical voltage output.

The second part is a continuation of investigating the inverting amplifier, so the circuit layout will be that same. However this time an increase in the applied peak-to-peak will be used, until a distortion is observed. Change the power supply voltage from 9V to 5V because a lower voltage will allow for a more visible distortion; record the maximum and minimum voltages. Afterwards reduce the applied input voltage back to a 3V peak-to-peak, and apply a DC offset voltage while also increasing it until distortion is observed. Record the maximum and minimum voltages.

The strain gauge amplifier uses the same single input configuration as the inverting amplifier, and input signal should also be the same. Measurements should be made like in the previous part. The circuit layout can be found on figure 3, the different resistances being used are (ΔR); 0.2kΩ, 1kΩ, 4.2kΩ. To figure out the theoretical values for each ΔR can be calculated using the equation in figure 6. The theoretical values for voltage output are as follows; 0.2kΩ oscilloscope = 0.2V, DMM = 0.071V; 1kΩ oscilloscope = 1V, DMM = 0.354V; 4.2kΩ oscilloscope = 4.2V, DMM = 1.485V. Compare the measured and theoretical gains for each value of ΔR, and observe the phase relationship between input and output.

Weighted summer amplifier uses the two inverting configuration, and the circuit layout for it can be seen in figure 4. Use a 2V peak-to-peak, 500 Hz sinusoidal signal input for channel one, and a 2V DC input for channel two. Make sure to measure the output voltage with the DMM on the DC setting and the DMM on the AC setting. Use the oscilloscope to measure the average DC and the RMS value of the output voltage. Measure for both AC and DC coupling. Use figure 7 to find out the theoretical value for this amplifier.

Simulations and Data Collection:

When creating the circuit on the breadboard there was the possibility of connecting the wrong wires. As a precaution the following colors were used to represent the type of connections being made; red = input voltage, black = ground, orange/yellow = V_{cc}[in], blue/white = V_{cc}[out]. The following table 1 shows the measurements of voltage input and output for the inverting amplifier. While figure 8 shows the phase relationship between both voltages.

Part 1. Inverting Amplifier				
V(in)/V(out) Measurements	Oscilloscope	DMM	% Error Oscilloscope	% Error DMM
V(in):	2.97	1.013	1%	4%
V(out):	2.95	1.023	2%	3%

Table 1. Voltage Input and Output for Inverting Amplifier with Percent Error

When measuring the distortion of the inverting amplifier the maximum voltages can be found on table 2. Whereas the phase relationship can be seen on figures 9 and 10, the figures also contain the maximum and minimum voltages the oscilloscope recorded. When there was no DC offset the waveform was more distorted than with DC offset.

Part 2. Saturation in the Inverting Amplifier		
Voltage (max./min.)	W/ Distortion	W/ DC Offset Distortion
Maximum Voltage	4.18	-2.64
Minimum Voltage	-3.06	-2.84

Table 2. Maximum and Minimum Voltages from Distortion of the Inverting Amplifier

The strain gauge amplifier had multiple measurements of voltage input and outputs because of the change resistance. Overall the recorded values were close to the theoretical values, except for the 0.2kΩ which had a high percent error. The remaining values can be seen on table 3. An example waveform showing the phase relationship between the voltage input and output can be seen on figure 11.

Part 3. Strain Gauge Amplifier				
ΔR 0.2k(ohms)	Oscilloscope	DMM	% Error Oscilloscope	% Error DMM
V(in):	3.14	1.09	4.67%	2.73%
V(out):	0.25	0.061	25%	14.08%
ΔR 1k(ohms)				
V(in):	3.14	1.09	4.67%	2.73%
V(out):	1.01	0.342	1%	3.39%
ΔR 4.2k(ohms)				
V(in):	3.14	1.09	4.67%	2.73%
V(out):	4.3	1.45	2.33%	2.36%

Table 3. Voltage Input and Output from Stain Gauge Amplifier with Percent Error

Lastly the weight summer amplifier used the two input configuration allowing there two pass in two different types of voltage sources. The values collected from the oscilloscope and DMM can be viewed in table 4, while the waveform from AC and DC coupling can be seen on figures 12 and 13.

Part 4a. Weighted Summer		
	DMM (DC) Setting	DMM (AC) Setting
V(out)	-1.98 V	0.348 V
Part 4b. Weighted Summer		
	DC Coupling	AC Coupling
Average	-1.98 V	0 V
RMS	2.02 V	352 mV

Table 4. Voltage Output, Average Output, and RMS from Weighted Summer

Results and Calculations:

When assessing the inverting amplifier the voltage inputs and outputs the percent error was relatively low for both the oscilloscope and DMM. To get the voltage output the equation on figure 5 was used but with the recorded values instead. Looking over the stain gauge amplifier results the first ΔR of 0.2kΩ the percent error was high for both the voltage input and output. The calculations for this part was done using the equation on figure 6. After the first set of ΔR the remaining measurements had low percent errors meaning the values recorded were close to the theoretical values. For the weighted summer amplifier the theoretical value was found using the equation in figure 7.

Conclusion:

In the end the recorded values in the inverting amplifier section were consistent with the theoretical values of an ideal Op Amp. The measurements made by the oscilloscope were significantly different than those by the DMM. When the signals were being distorted the cutoff or the horizontal line is called the clipping. This is because the input voltage is being set to a larger value than what is going into the Op-Amp. It would clip when the input voltage exceeds this set voltage. The maximum and minimum voltages were close to the 5V power supply going into the Op-Amp. In the strain gauge amplifier the values were attempted to be kept at a peak-to-peak, even though the voltage output was kept within its' theoretical value. The high percent error we experienced was probably because of misplacing the probes in our circuit. The various voltage measurements in the weighted summer amplifier, is because the DMM records the value in respects to RMS, meaning the it is being multiplied by the square-root of two.