SANTA CLARA UNIVERSITY	ELEN 115 Spring 2023	S. Krishnan

Laboratory #3: Operational Amplifier Applications

I. OBJECTIVES

- To analyze various operational amplifier circuits
- To learn how to build amplifier topologies and study their performance

III. LAB PROCEDURE

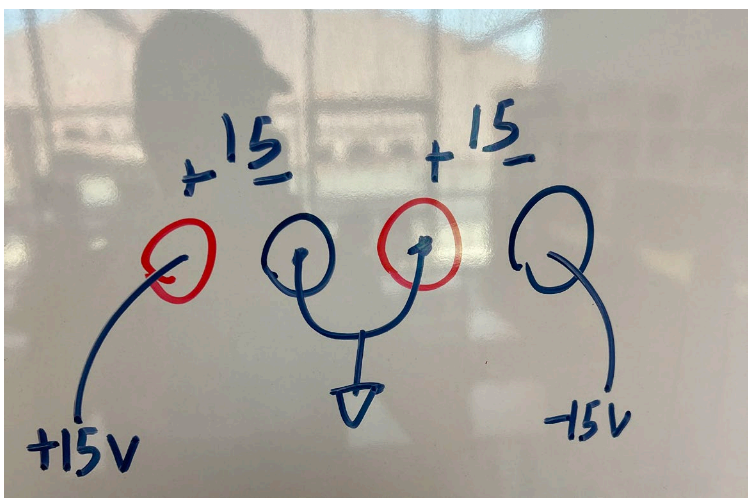
For the Lab experiment, use ±15V as the DC power supplies to the opamp.
The impedance of the input channel of the Oscilloscope is set to 50 Ohms.
The impedance of the output channel of the Oscilloscope is set to 1Mohms.

1. Amplifier Configurations

(a) Using the resistor and capacitor values from the prelab, construct the active low pass filter on your breadboard.

- Remember to provide dc power supplies for the opamp.
  Use ±15V as the DC power supplies to the opamp.

  Connect as shown below.



(b) Remove the capacitor from the filter on your breadboard for the initial part of the lab.

(c) Provide an input that is a 1KHz, 200mV peak to peak sinusoidal voltage from the signal generator to the input.

- Connect the input and output voltages on the Oscilloscope.
  The impedance of the input channel of the Oscilloscope is set to 50 Ohms.
  The impedance of the output channel of the Oscilloscope is set to 1Mohms.
- Observe the input and output voltages on the Oscilloscope.

TA Check Point: Complete b and demo your setup to your TA

(d) Transient plots:

Observe the input and output voltages on the Oscilloscope.

Calculate the exact gain by measuring the peak to peak voltages of the input and output waveforms on the oscilloscope.

Make sure you use the cursors to accurately measure the peak to peak values.

Do you observe any discrepancies with what you calculated in prelab. Explain why?

TA Check Point: Complete (c) and demo the results to your TA

2. Amplifier imperfections

(Remove the capacitor from the filter on your breadboard for this part of the lab)

Observe the output for the below cases of input:

(i) 1KHz, 200mV peak to peak sine wave

Do the results look as expected? Explain why or why not?

Make sure to take a screen capture of the simulation waveforms.

What behaviour do you observe?

Normal, slew rate limiting, bandwidth limitation, output saturation

Look at the datasheet of the opamp and find the specification/limits of this charecteristic. Note the parameter and the value for your lab report.

(ii) Change the frequency of the input signal from 1KHz to 10KHz, 20KHz, 50KHz and amplitude 200mV peak to peak sine wave.

For each frequency measure the peak to peak output voltage.

Do the results look as expected? Explain why or why not?

Make sure to take a screen capture of the simulation waveforms.

What behaviour do you observe?

Normal, slew rate limiting, bandwidth limitation, output saturation

Look at the datasheet of the opamp and find the specification/limits of this charecteristic. Note the parameter and the value for your lab report.

1 KHz, sine wave with peak to peak values 0.5V, 1V, 1,5V, 2V and 2.5V.

Do the results look as expected? Explain why or why not?

Make sure to take a screen capture of the simulation waveforms.

What behaviour do you observe?

Normal, slew rate limiting, bandwidth limitation, output saturation

(iii) Change the frequency of the input signal to 20KHz. Set the amplitude 200mV peak to peak and then increase the peak to peak amplitude form 200mV, 400mV, 600mV, 800mV to 1V.

Do the results look as expected? Explain why or why not?

Make sure to take a screen capture of the simulation waveforms.

What behaviour do you observe?

Normal, slew rate limiting, bandwidth limitation, output saturation

Look at the datasheet of the opamp and find the specification/limits of this charecteristic. Note the parameter and the value for your lab report.

(iv) Set the input for the values that showed slew rate limiting.

Change the time setting on the scope and see the rising edge of the input and output. Measure the slope of the output.

Look at the data sheet of the 741 opamp and record its slew rate. Compare with your slope calculations. Comment on what you find. Explain any discrepancies.

TA Check Point: Complete 2 and demo the results to your TA

3. **Amplifier Voltage Transfer Characteristics**

Set the input source (from function generator) to a 1 kHz, 10mV peak to peak triangle wave with symmetry of 50%.
Set the horizontal axis mode of the oscilloscope to XY where the input signal is represented by the x-axis and the output signal is represented by the y-axis.
Click the "Horiz" button, Select "Time Mode" on the screen and select "XY".
Capture a screenshot of the plot.
How could you determine the gain of the circuit from the plot collected?
Do you notice any non-idealities from this plot? Explain why these happen.

TA Check Point: Complete 3 and demo the results to your TA

4. **Low Pass Filter**

(a) Modify the circuit to make it the low pass filter with a 3dB frequency of **5KHz** that you designed in the prelab.

(b) Transient Behavior

For the below steps, get a screen shot of the input on CH1 and output voltage on CH2.

- Set the input to a 1KHz, 200mV peak to peak sine wave and observe the output.
- Set the input to a 1KHz, 200mV peak to peak triangular wave and observe the output.
- Set the input to a 1KHz, 200mV peak to peak square wave and observe the output.
- Comment on the output waveforms.

TA Check Point: Complete Part 4(b) and demo the results to your TA

(c) Frequency Behavior

(1) Set the input to a sinusoidal input with 200mV amplitude and 1Hz frequency. Connect an oscilloscope at the output to monitor the voltage.
(2) Observe v_{IN} and v_{OUT} on the oscilloscope. Zoom in to see two to three time periods.
Do the results look as expected? Why or why not?
Make sure to take a screen capture of the measured waveforms.
(5) Change the input to 10Hz frequency. Repeat step 2.
(6) Change the input to 100Hz frequency. Repeat step 2.
(7) Change the input to 1KHz frequency. Repeat step 2.
(8) Change the input to 10KHz frequency. Repeat step 2.
(9) Change the input to 50KHz frequency. Repeat step 2.
(10) What have you observed while doing steps (2) through (9)? What behavior does this circuit show?
(11) Take a few more frequency points so as to collect enough data to do a Bode Plot.

- Obtain a Bode plot.
- Measure the gain and 3 dB cut-off point for the design using the measured values.
- Compare it with the theoretical design value.

TA Check Point: Complete Part 4(c) and demo the results to your TA

Extra Credit: Operating with a single power supply

If the dc power supplies for the opamp are +15V and GND (No negative supply):

(a) What would the output be for an input that is a 1KHz, 200mV peak to peak sinusoidal voltage from the signal generator.

(b) What changes would you make in the circuit to make it function as a low pass filter?

(c) Draw a schematic showing this.

(d) Connect the active filter on a single supply and show that your solution works.

TA Check Point: Complete the extra credit and demo the results to your TA

IV. REPORT

Additional beyond what is stated in the report format include the following:

a) The steps for the design and analysis of the circuit.

b) Schematic diagram of the opamp circuits and sketch of the circuit arrangement on the board.

d) Measurement results.

e) Explanation for the outputs observed.

f) Discussion of any discrepancies and suggestions for improvements in the design.