

Lab #5 {100 pts. Total} Op Amp Circuits

OBJECTIVES:

- Become familiar with operational amplifier circuits.
- Design circuits containing operational amplifier(s) to meet given requirements.
- Construct, test, and debug operational amplifier circuits.

PARTS LIST:

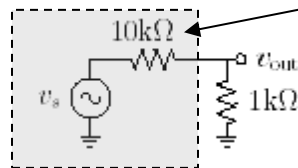
IMPORTANT: Some parts below are determined by your PRE-LAB.

- 10kΩ, 1kΩ, and other R's determined by your design
- some operational amplifier(s): LM741, TL084, LF353, or similar {LF353 has better performance than 741)

EXPERIMENT 1: (50 points)

Procedure:

1. (20 points) Assume the following circuit:



This circuit cannot be altered. It represents a “large circuit” lumped into a Thevenin equivalent. The 1k load cannot be changed.

Fig. 1

The v_s and 10k resistance are the Thevenin equivalent of a larger circuit. This circuit is needed to drive another circuit with an input resistance of 1k. This 1k resistance is considered the “load” resistance for the larger circuit. By analyzing this circuit, this circuit will produce an output:

$$v_{out} = \frac{R_L}{R_s + R_L} v_s = 0.09v_s$$

The situation depicted in **Fig. 1** is not a good situation. Think of the signal v_s as a voice signal connected to a microphone that has an equivalent resistance of 10k and the 1k resistance as a speaker. By reducing the amplitude by one-tenth, v_s would not be heard at all through the speaker. Therefore, try to keep the signal approximately the same.

(1a) (5 points) Design a circuit that will keep the signal approximately equal at the output - $v_{out} \sim v_s$. You cannot alter the input v_s , the 10kΩ or the 1kΩ resistors. They all have to be in the circuit.

(1b) (5 points) Build your designed circuit. Fix $v_s = 5\text{V DC}$. Measure v_{out} .

- If it is not close ($0.8 v_s < v_{out} < 1.2 v_s$) modify your design until it is.

(1c) (5 points) By hand, calculate the current through the 1k “load” resistor shown in Fig. 1 without the added amplifier. Measure the actual current through the 1k “load” resistor on your design and compare that to the hand calculation.

(1d) (5 points) Describe in detail where the additional current comes from. Describe what situation you would want to use this circuit.

2. (15 points)

(2a) (5 points) Apply a sinusoidal signal as v_s . Select amplitude that is easy to observe on the scope. Vary the input frequency and take measurements to create the magnitude Bode plot for this circuit similar to how you did it in Lab 1.

(2b) (10 points) Make a rough sketch of the magnitude Bode plot with all relevant points marked. These points should include but are not limited to:

- low-frequency value in the flat section
- "corner" frequency (f_C)
- downward slope

IMPORTANT: *A circuit such as the voltage follower does not treat all input waveforms equally. In particular, the circuit will not have a gain of 1 for all input frequencies. The op-amp cannot act like an ideal op-amp at all frequencies—it has limitations.*

The frequency response of a circuit is a measurement of how some characteristic of the circuit varies as a function of the input frequency, in our case, we'll see how the gain changes.

3. (10 points) How does your measured f_C (the corner frequency or -3dB point) compare to your expected f_C ?

IMPORTANT: *For unity gain, $f_C = f_T$.*

Look up f_T in the data sheet for your op-amp (shown Bandwidth or as BW @ AV=1, read: bandwidth at gain = 1) on a data sheet. Notice that the data sheet shows minimum and typical values for the bandwidth. Your f_C may well be higher. There is nothing wrong with a part exceeding specifications.

4. (5 points) From the Bode plot created in 2a, pick an AC input signal v_s with reasonable frequency and amplitude to verify $v_{out} \sim v_s$.

IMPORTANT: *Remember...*

- *The voltage you actually get out of the HP/Agilent function generator is twice the voltage it shows. So, if you want 100 mVpp, set the HP/Agilent to 50 mVpp. Be careful, this little flaw could be a big headache someday.*
- *That gain is V_{out}/V_{in} , and refers to how much bigger the output is than the input-- in this case it's no bigger at all. Incidentally, if you want the scope voltage measurements to make sense, be sure to let it*

know that your probes are both 1x (Hit A1 and use the right-most button under the screen, repeat for A2). It won't detect the probe automatically.

- Be on the lookout for bad probes—I found several, but not before wasting quite a bit of time wondering why all I could get on the scope was noise.

EXPERIMENT 2: (50 points)

Procedure:

1. (35 points)

(1a) (5 points) Design a non-inverting amplifier with a gain of 101V/V. Build your designed amplifier.

(1b) (5 points) Start testing by applying a 100 mVpp sine wave at 1kHz (shown as 50 mVpp on the HP/Agilent). Note that the input signal looks awfully noisy, but most of that is actually scope noise. To prove that, simply hook the scope probe to its own ground and notice how much of the noise is still there.

(1c) (5 points) Verify the gain at a relatively low frequency. If not, make modifications to your circuit to get a gain of 101V/V for the non-inverting amplifier.

IMPORTANT: You may also see “distortion” for the non-inverting amplifier because the gain is very high. If you do, turn down the amplitude and/or frequency so there is no distortion.

(1d) (5 points) Find the -3dB point.

(1e) (5 points) How does this compare to your expected f_c ?

IMPORTANT: The expected -3dB point can be calculated from the bandwidth value given on the datasheet for your operational amplifier using **Formula 1.0**

Formula 1.0 $GBP = \text{gain} * \text{bandwidth}$ where GBP is the Gain Bandwidth Product on the datasheet

Rearranging **Formula 1.0** and using the -3dB point from **(1c)**, the bandwidth of your circuit can be found by **Formula 1.1**

Formula 1.1 $\text{bandwidth} = GBP/\text{gain}$ where GBP is the Gain Bandwidth Product on the datasheet

IMPORTANT: If the datasheet does not have a GBP, it will have either a f_T or bandwidth listed. This will be the bandwidth at unity gain and can be treated as the GBP. Again, watch for any distortion of the output waveform and turn down the input amplitude if you see any.

(1f) (5 points) Take two measurements beyond f_c and determine the slope at this part of the frequency response curve.

- Sketch a simple frequency response curve showing what you've measured.

(1g) (5 points) Measure the gain again at $5f_c$ and again at $10f_c$.

- Did the gain decrease by a factor of 2 between $5f_c$ and $10f_c$ (-20dB per decade roll-off)?

2. Measuring the Clipping Levels (saturation)

(15 points) Change the input coupling of both analog channels (A1 and A2) back to DC. Turn down the input frequency to about 1 kHz.

- **(5 points)** Turn up the input voltage until the output clips both top and bottom (tops and bottoms of the output waveform are cut off)
- **(5 points)** Sketch this waveform in your notebook, and indicate the clipping on the drawing.
- **(5 points)** Measure both clipping levels and compare to the values stated in the data sheet.