Problem set: Op-amps

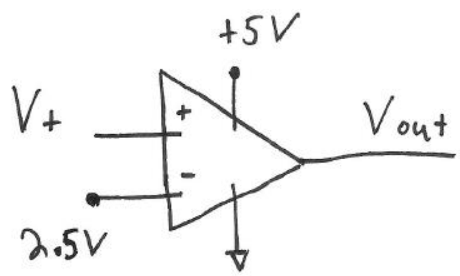
Goal: Experience how the operational amplifier ("Op-amp") functions and how it can be used to get more accurate voltage measurements. *Why? The reason is in the puzzle, page 2.*

Use the last sheet of these instructions to record your responses for this Problem Set.

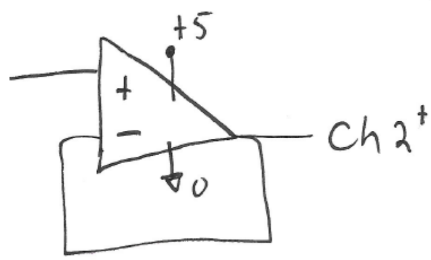
Overview

In this problem set, you're going to use an op-amp in two configurations that are schematically represented below, OPEN LOOP and with negative feedback, as a VOLTAGE FOLLOWER:

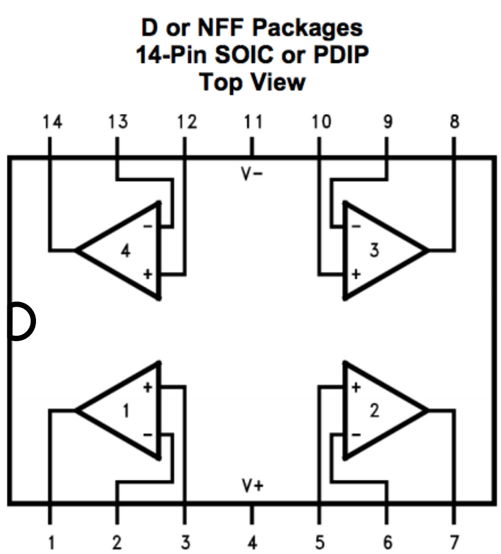
OPEN LOOP



VOLTAGE FOLLOWER



You'll be using the LMC6484 chip which has the pin configuration pictured below.



V^- and V^+ are source or "rail" voltages that supply all the op-amps.

$$V^- = V_s^-, V^+ = V_s^+$$

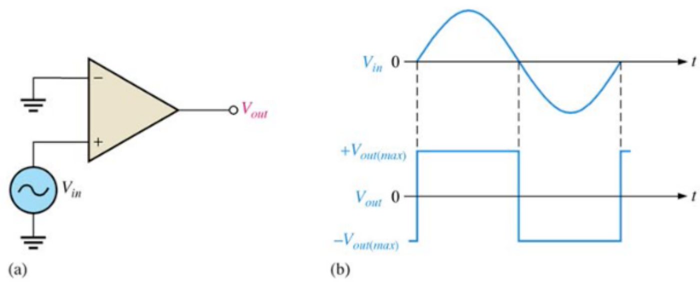
To use this chip as indicated in the above schematic,

$$V_s^- =$$

$$V_s^+ =$$

As you work through this problem set, you'll need to recall the **behavior of op-amps**:

1. $I_+ = I_- = 0$
2. For $V_s^- < V_{out} < V_s^+$, $V_{in}^+ = V_{in}^-$, also:



Source: Anastasia Armstrong, https://slideplayer.com/slide/11113908/

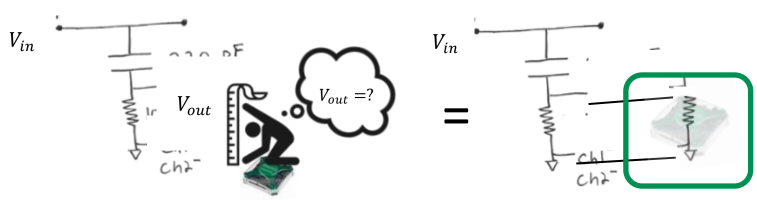
3. It takes time for V_{out} to switch states from $V_s^- \to V_s^+$

First, a puzzle…

In general, we want our decisions to be based on objective facts. But sometimes, the act of *observing* distorts what's being *observed*.

In ISIM,  has been our *observer.*

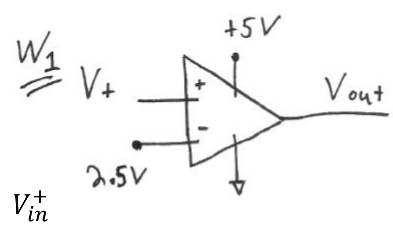
Under what conditions are the observations distorted by the observer?



I. Open loop behavior

1. Create the circuit below using any op-amp within the LMC6484 chip.

You'll use the output of Wavegen as the V_{in}^+ signal.



2. Connect the Analog Discovery to your circuit

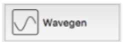
Ensure the Discovery and the op-amp share a GROUND.

Use Wavegen 1 as the V_{in}^+

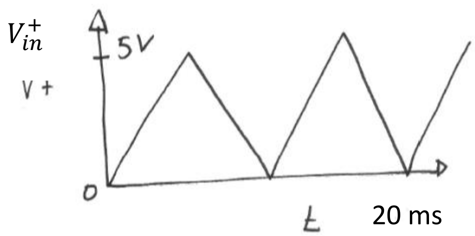
Use Scope Channel 1 to monitor V_{in}^+;

Use Scope Channel 2 to monitor V_{out}.

Where do you connect $Ch1^-$ and $Ch2^-$?

3. Set the 

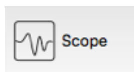
conditions, ▶ Run.



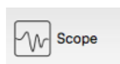
Given the input, what are you expecting for V_{out}?

*[**Hint**: See **behavior of op-amps**, page 1]*

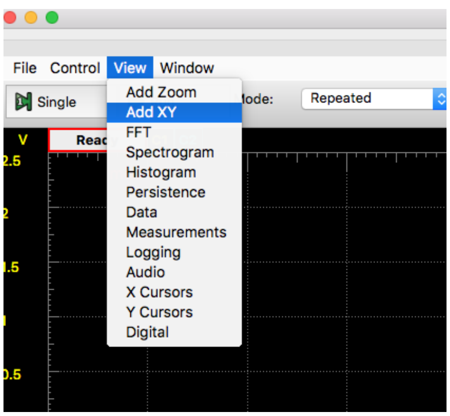
Sketch the expected $V_{out}(t)$ on the V_{in} v. time graph, left.

4. Observe $V_{out}(t)$ with 

Confirm that you get Figure 5.3 in book (**note**: $V_{-} = 3.5$ V in Fig. 5.3, *not* 2.5V). **Save to turn in**.

5. Monitor $V_{in}(t)$ v. $V_{out}(t)$ with 

Add an x-y plot and set the X and Y values.



*Of $V_{in}^{+}(t)$ and $V_{out}(t)$, which is the **independent** variable that you would assign to the x-axis?*

That is, which of the two can you vary, independently of the other?

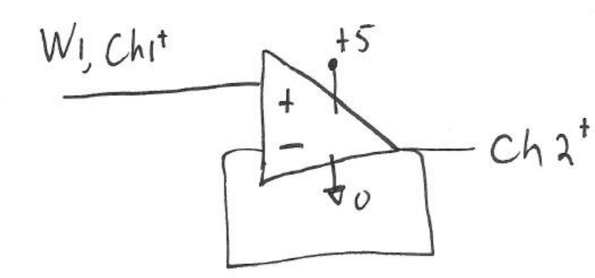
See for yourself that you get Figure 5.4 (p. 65).

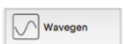
Save this x-y plot to turn in.

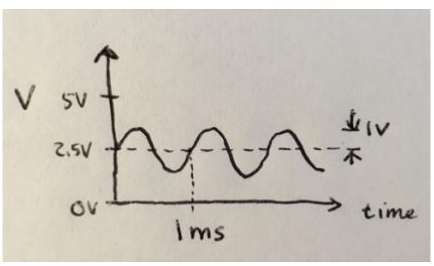
II. Op-amp voltage follower

One of the simplest and most useful op-amp circuits is called a voltage follower, described in section 5.3 of the book. The circuit consists of simply wiring the op-amp's output to the negative input.

1. Alter your circuit from the **open loop** observations to create a voltage follower.



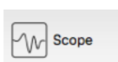
2. Change the input signal , ▶ Run.



Given the input, what are you expecting for V_{out}?

*[**Hint**: See **behavior of op-amps**, page 1]*

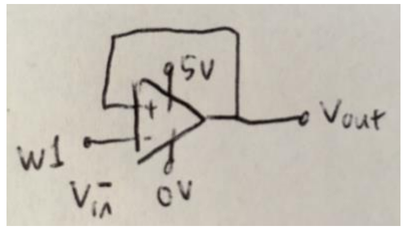
Sketch the expected $V_{out}(t)$ on the V_{in} v. time graph, left.

3. Using , monitor V_{out} (t).

Does the follower work as expected? Record your response on the last page.

You don't need a figure to turn in.

4. Increase the frequency. At some point the follower will not operate fast enough to keep up with the input. At what frequency (approximately) do you notice a significant different between output and input?
5. Set the input frequency back to 1 kHz. Amplitude = 1 V, centered about 0 V. Why doesn't this circuit work as expected?
6. Return the Wavegen signal to that of step 2 above. Change the input to be a square wave. How long does it take (approximately) for the output to catch up to the change in the input? You will need to zoom in the time scale.

7. Just for fun, reconfigure the circuit as shown: 

Confirm that this circuit does not work as a follower. No need to turn anything in, just confirm that it doesn't work.

III. Follower as a buffer

This follower circuit is useful since the input to the op amp draws no current, the follower can be added between components of a system in order to isolate the components from each other. A simple example is found in the difference between the two circuits shown in Figures 1a and 1b.

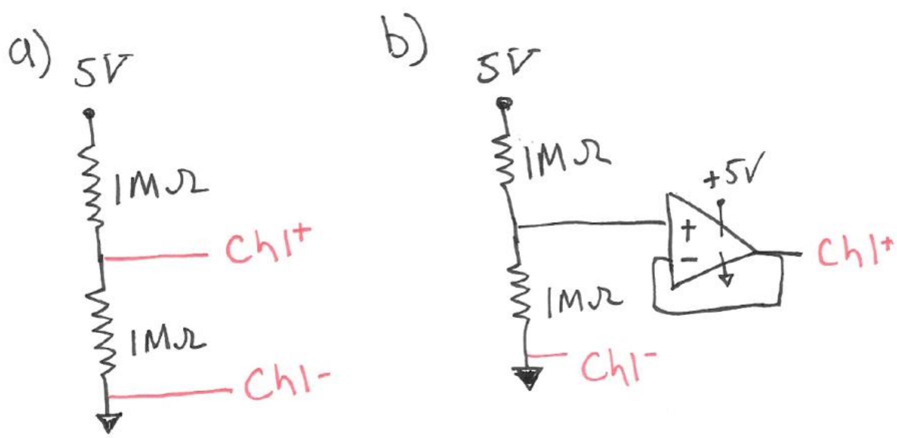


Figure 1. a) Voltage divider; b) Voltage divider with voltage follower.

Test the measurement of a simple voltage divider as shown in Figure 1 and see the difference between the circuit Figure 1a and 1b.

How do you expect the results to be different?

Why?

*[**Hint**: Consider your answer to **the puzzle**]*

Report the value of V_{out} for circuits a and b.

Problem set response sheet

Use this sheet to record your responses and turn in.

Open loop behavior:

Turn in your version of Figures 5.3 and 5.4.

Op-amp voltage follower:

3. Does the follower work as advertised? You don't need a figure to turn in. How is it similar or different?
4. At some point the follower will not operate fast enough to keep up with the input. At what frequency (approximately) do you notice a significant difference between output and input?
5. Change the input to be a square wave. How long does it take (approximately) for the output to catch up to the change in the input?
6. Set the input frequency back to 1 kHz. Amplitude = 1 V, centered about 0 V. Why doesn't this circuit not work?
7. For the positive feedback circuit, confirm that this circuit does not work as a follower. No need to turn anything in, just confirm that it doesn't work.

Follower as a buffer:

Report the value of V_{out} for circuits a and b