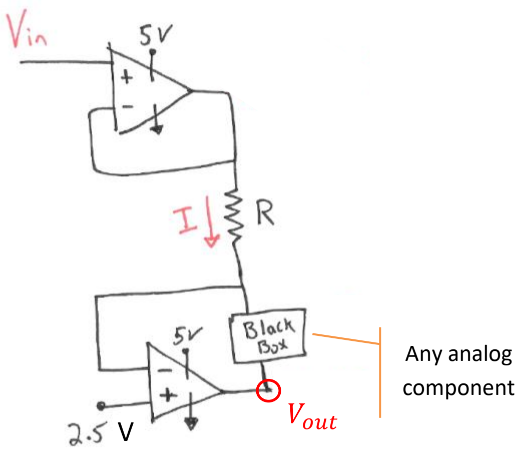
Lab: Controlling Current with Op-Amps

Goals: 1. Use negative feedback of an op-amp to control current; 2. Verify the theoretical $V - I$ characteristics of a capacitor and a light-emitting diode using a controlled current.

Warm up: Op-Amps in negative feedback

A useful circuit for exploring the relationship between voltage and current is shown in Figure 1.

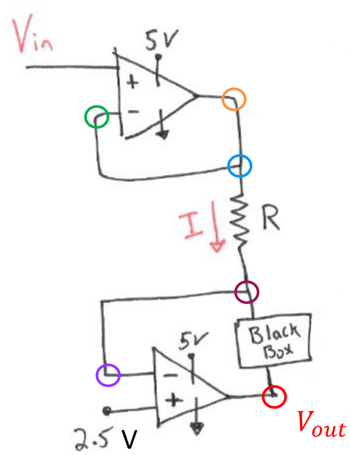


Draw a boundary around any op-amp to the left that is wired in "negative feedback."

Figure 1: Generic source current, measure voltage circuit.

First, let' try to understand this general circuit using our rules when op-amps are wired in **negative feedback**:

- $I_{in}^{+} = I_{in}^{-} \approx 0$
- $V_{in}^{+} = V_{in}^{-}$



Applying $V_{in}^{+} = V_{in}^{-}$, determine the voltages at the following colored nodes?

Write the values on the circuit schematic.

Applying $I_{in}^{+} = I_{in}^{-} \approx 0$, write an equation for I and for $I_{BlackBox}$

By controlling V_{in}^{+} and selecting an appropriate value of **R**, I can control $I_{BlackBox}$.

*How can you determine the voltage dropped **across** the Black Box?*

Part I: Verifying the *I-V* behavior of a capacitor

1. Build the circuit shown Figure 2a) using the LMC6484A chip which has the pin configuration pictured in Figure 2b) . (You might want to redraw 2a) using 2b) before you build it.)

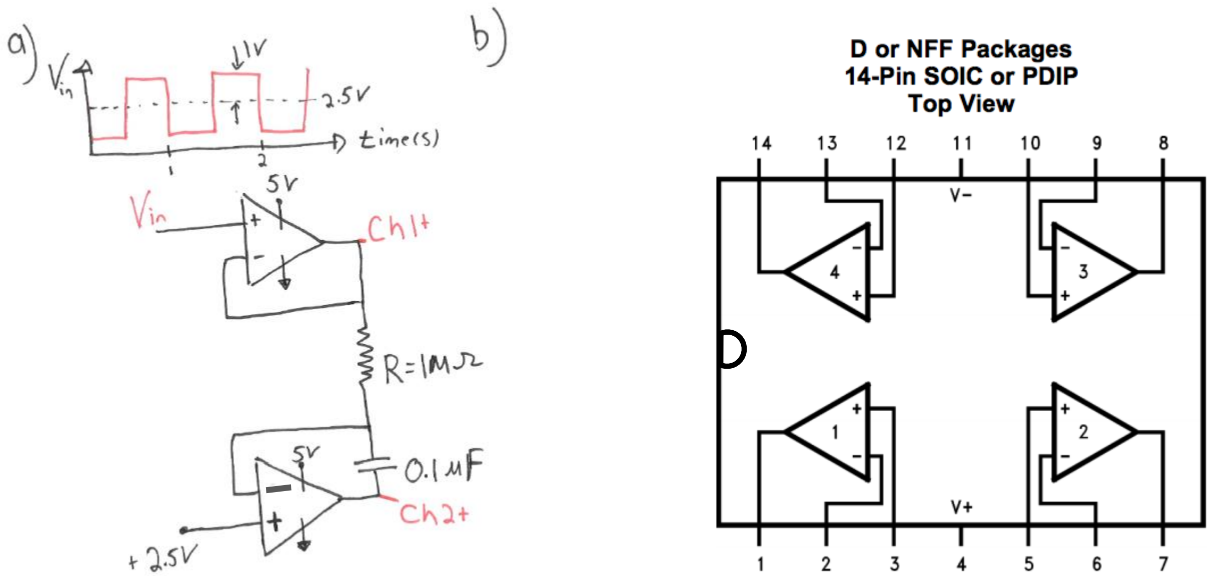


Figure 2. a) Circuit to test the capacitor performance, b) Pin configuration of LMC6484A chip.

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

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

$$V_s^- =$$

$$V_s^+ =$$

2. Connect the Analog Discovery to the circuit; Set Wavegen using the V_{in} signal of Figure 2a).

Ensure the Discovery GROUND and the op-amp GROUND (V_s^-) are equal.

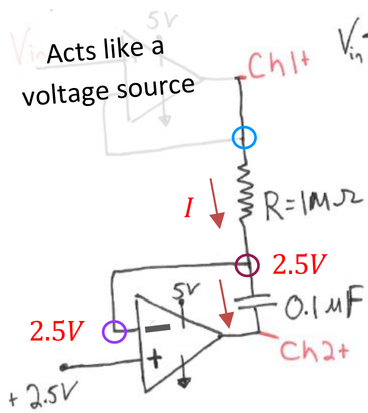
Use Wavegen 1 as the V_{in}^{+}

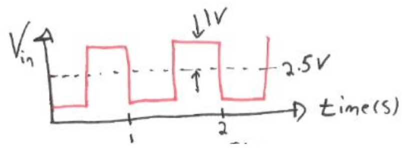
Use Scope Channels 1 & 2 as shown;

Your reference voltage is +2.5V.

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

3. Assess the expected voltage across the capacitor:





The top op-amp forces a current through the capacitor:

$I_R = I_{cap} = \ ?$

You can think of current as charged particles flowing in time, in fact, 1 Amp = 1 Coulomb of charge /second.

What does the capacitor do with the charge flow?

To see if you're getting the output that you expect, we'll have to recall that

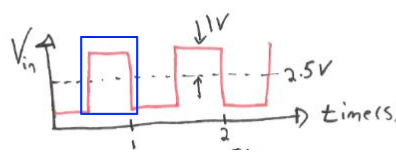
$$I_{capacitor} = c \cdot \frac{dV}{dt},$$

where *c* is the capacitance of the capacitor and $\frac{dV}{dt}$ is the change in voltage across the capacitor with time.

Let's rearrange this equation and integrate:

$$\frac{1}{c}\int I_{capacitor}\, dt = \int dV$$

We're only looking at ½ a cycle



And since the voltage is constant during the ½ cycle that we are integrating over,

$$\frac{1}{c}\int \frac{V_{in} - 2.5}{R} dt = V(t)$$

$$\frac{1}{cR} t = V(t)$$

What should V(t) v. t look like over the whole period?

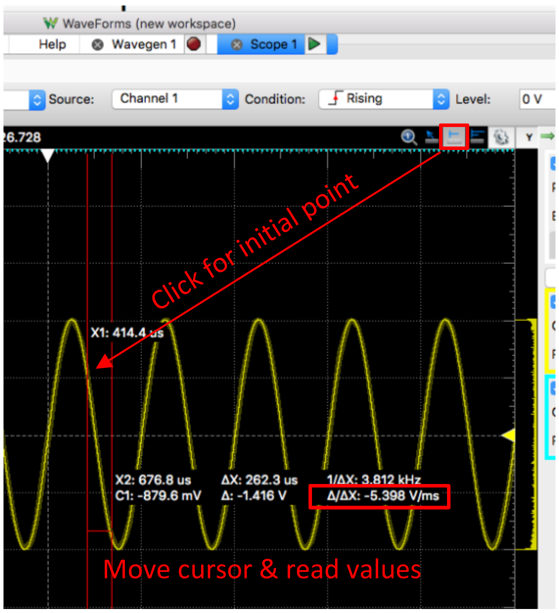
Is your capacitor functioning as expected?

4. Let's verify the theoretical behavior of a capacitor, $\frac{dV}{dt} = \frac{1}{c} \cdot I_{capacitor}$

Using Wavegen, change V_{in} (therefore changing $I_{capacitor}$). Use 5 different V_{in} $(all > 0\ V)$ and measure $\frac{dV}{dt}$ across the capacitor. Fill in the table below.

In choosing my range of V_{in} values, what is my V_{max}?

To measure $\frac{dV}{dt}$, use the **vertical** cursor tool on your dataset (*data shown is fake)*:



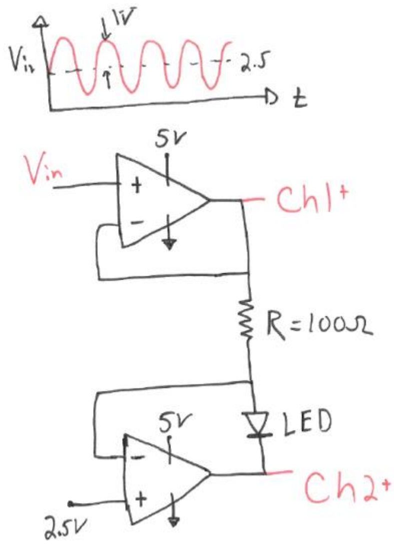
$V_{in}(Volts)$	$\frac{dV}{dt}$ (measured) Volts/second

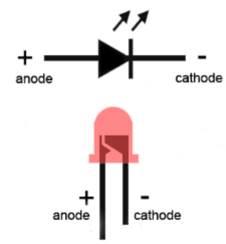
Did you verify our basic capacitor law, $\frac{dV}{dt} = \frac{1}{c} I$?

Save to turn in.

Part I: Verifying the *I*-*V* behavior of a light-emitting diode

5. The second Black Box to test is a light emitting diode, LED. Build the circuit shown Figure 3.





https://www.allaboutcircuits.com/tools/led-resistor-calculator/

Figure 3. Circuit using LED as Black Box.

6. Connect the Analog Discovery and adjust the settings on Wavegen to V_{in} in Figure 3.

Ensure the Discovery GROUND and the op-amp GROUND (V_s^-) are equal.

Use Wavegen 1 as the V_{in}^+

Use Scope Channels 1 & 2 as shown;

Your reference voltage is +2.5V.

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

7. On the scope, add an x-y plot. An idealized V-I curve for an LED looks something like [this](#).

Which of Ch1 or Ch2 represents I (y-axis)?

Check to see that your x-y plot makes sense.

Save the data for Channel 1 and Channel 2. In your lab report you will want to make a plot where voltage across the LED is on the x-axis and current through the LED is on the y-axis. Note that you are measuring only voltage, but you can infer the current since you know that the circuit has a 100 ohm resistor.