PSet 4: Capacitors and RC circuits

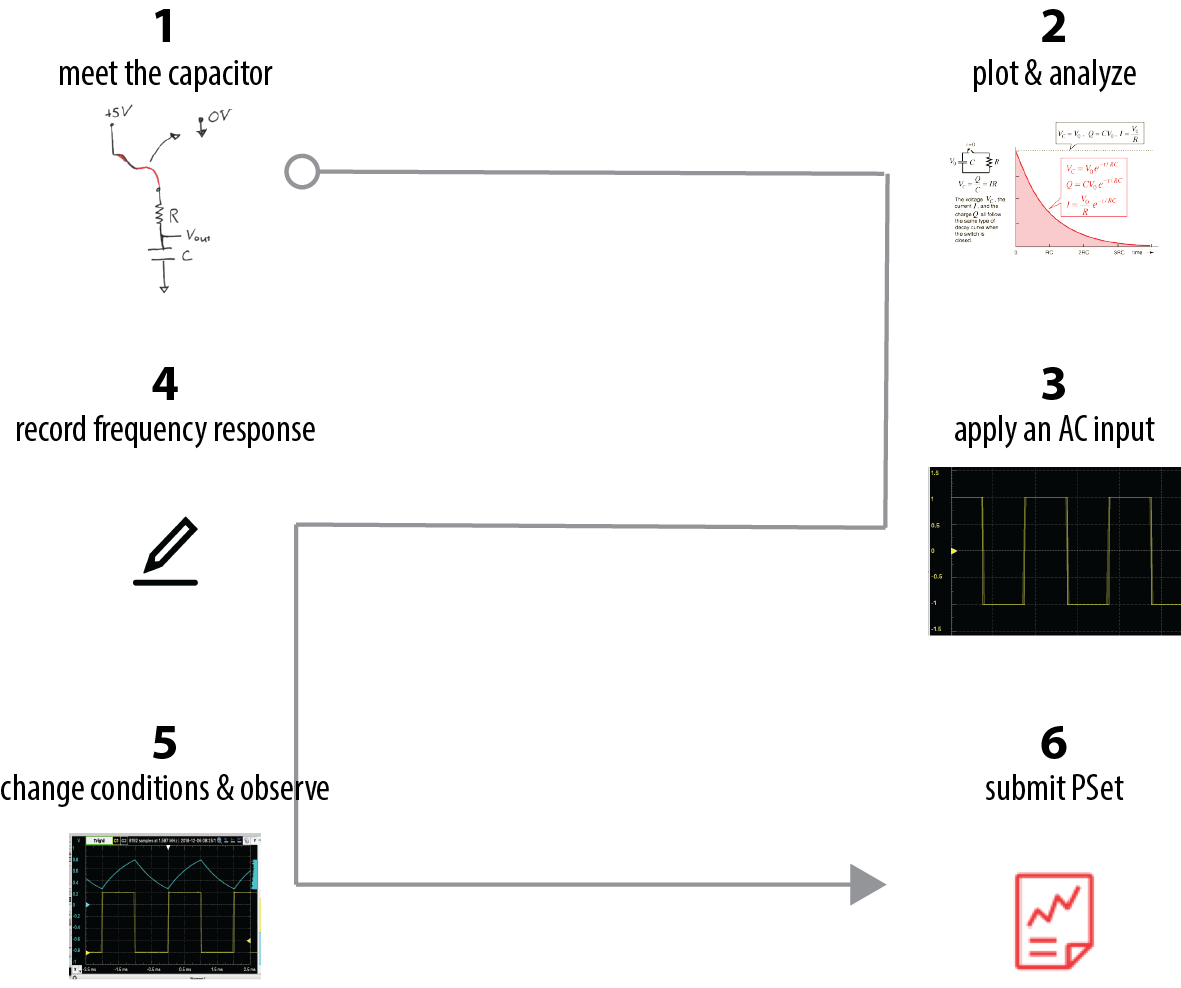
In this week’s lab, we will start to use capacitors and learn about their wonders.

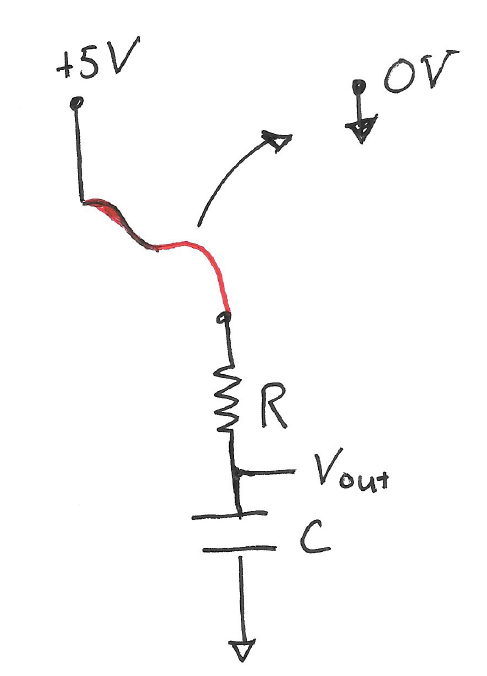
Goal: To observe how capacitors respond to direct current (DC) voltage inputs and an alternating current (AC) voltage square wave input.

Learning objectives

* Recognize that a capacitor stores charge;
* Graph the voltage change *across* and current *through* a capacitor as it charges;
* Use Wavegen to produce a square-wave AC signal of a specific frequency and amplitude;
* Compare the measured V(t) with the theoretical capacitor response;
* Calculate the approximate time constant, τ, of an RC circuit;
* Plot the voltage drop *across* a capacitor with changes in the square-wave input frequency

# Visual Summary



1. **Meet the capacitor**

Build the circuit below, using a wire





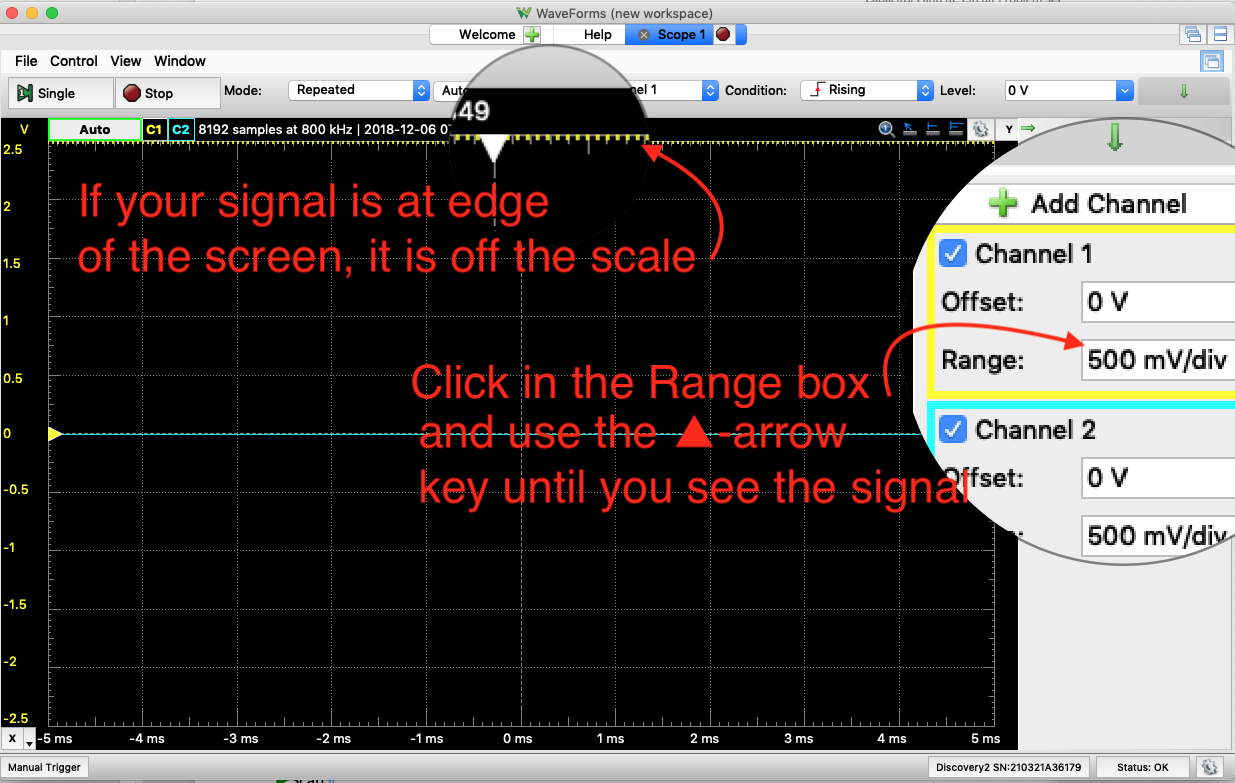


Set up the AD so that it uses Chanel 1 to measure the ΔV *across* the capacitor.



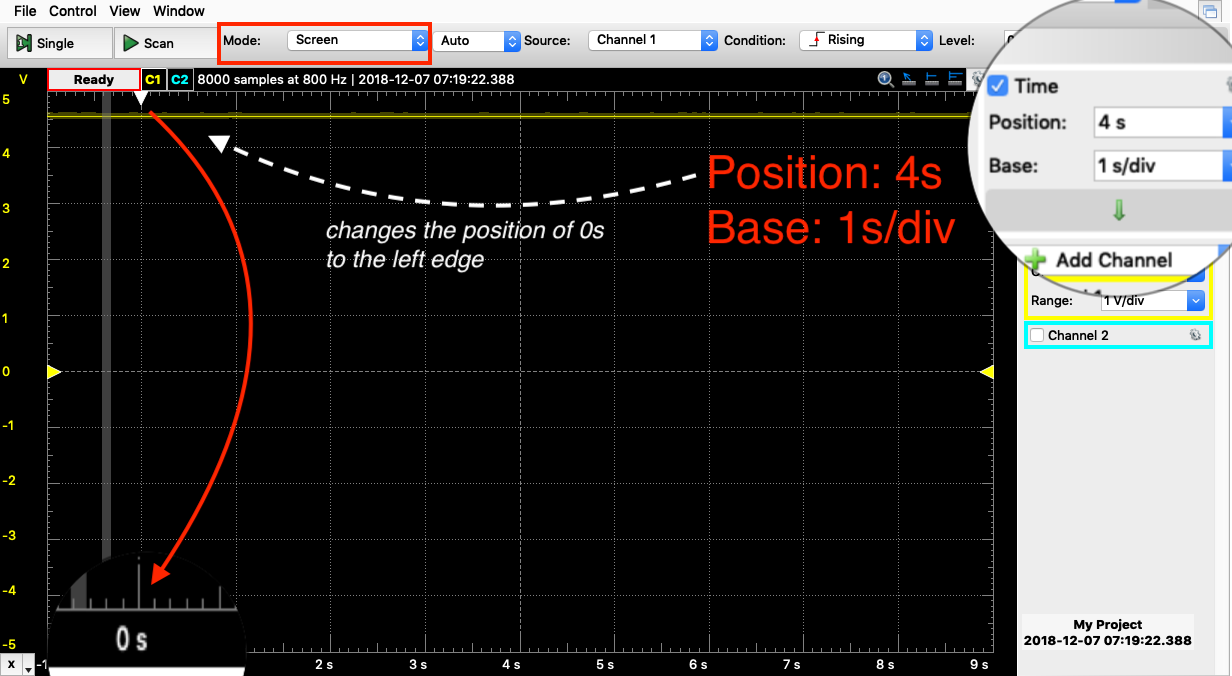


Add , ►Run. Use the tips in the graph below to find your signal.



Prepare to monitor what happens over time when you switch from 5V to 0V input:

Set **Mode:** Screen, Change the Time>**Base:** 1 s/div, Time>Position: 4s



By hand, quickly move the wire at +5V to ground. Watch the voltage *across* the capacitor change with time. We call this behavior “discharging.” Record your observations on the PSet worksheet (page 8)



Now, you will record the change in ΔVcap during charging. If your capacitor has fully discharged, Ch1+ should indicate Vout=0.

Disconnect the input wire from Ground.

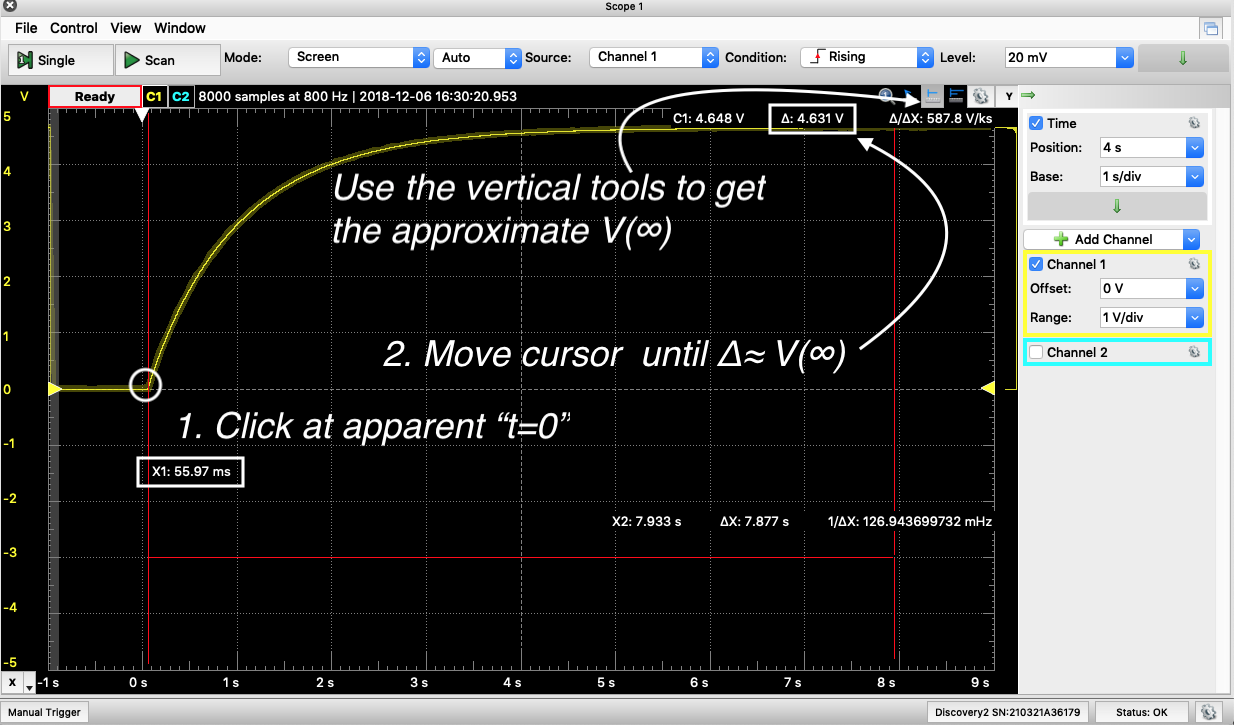
When the cursor scope gets to 0 s, plug the Vin wire to the +5 V rail of your breadboard. Stop it when it gets to 9 s and save this plot. 

1. **Plot & analyze**

The plot of V(t) is theorized to adhere to (p. 35, text\*). In this section, you will use the Scope tools to determine the value of and τ. Then you’ll plot the measured V(t) with the analytical (i.e., theoretical) V(t).

\*in the text, V(∞)=1 and τ=1.

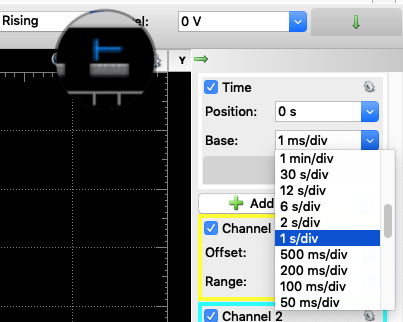
We don’t have t=∞, but we have a large enough t that *Vout ≈ V(∞)*



Now we need to use the same tool to find the value of τ. In this case, the t=0 starts at X1~59 ms, V(∞)≈4.63 V. We can determine τ from .



Use the vertical tool to determine τ from your data.

Left click on the tool,

With the cursor, point to and left click (and release) on the apparent V(t=0)=0 position. This is the point at which Vin=+5V.

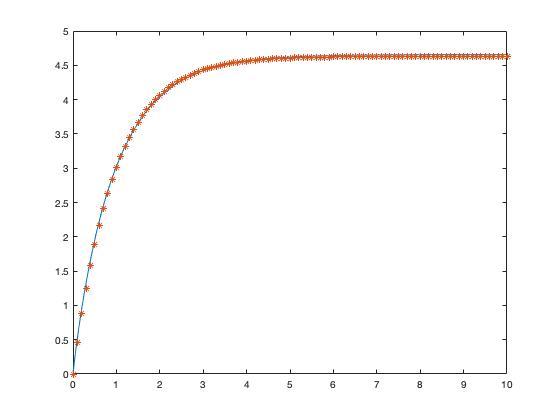
Move the cursor to the right until the Channel 1+ value (C1), Δ = V(t=τ). At this point, ΔX = τ.

Record your measured values of V(∞) and τ on the PSet worksheet (p. 8). 

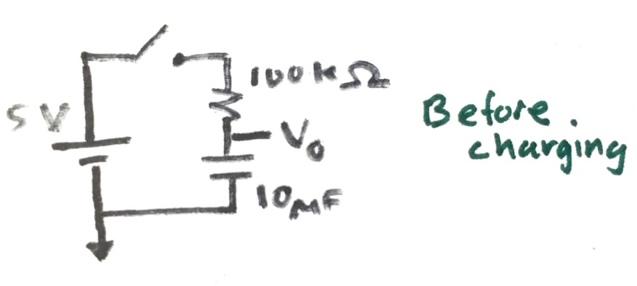
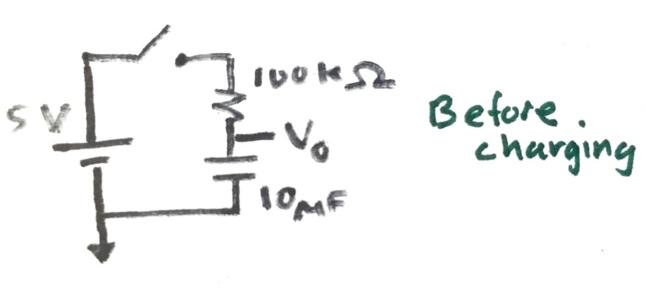
Plot and compare the measured and theoreticalV(t)for the charging capacitor.

*For a quick guide on using MatLab for these plots, see* [*isim.olin.edu*](http://isim.olin.edu/)*, Class 6.*

Your theoretical charging curve is likely to fit well to the experimental data.



As a reminder, here is the circuit before you began charging the capacitor:



From our text, we know that the equation for the current *through* the capacitor is , where is the voltage drop *across* the capacitor. In our case, .

*As always, the units of measure are important. 1 Amp = 1 Farad Volt/second*

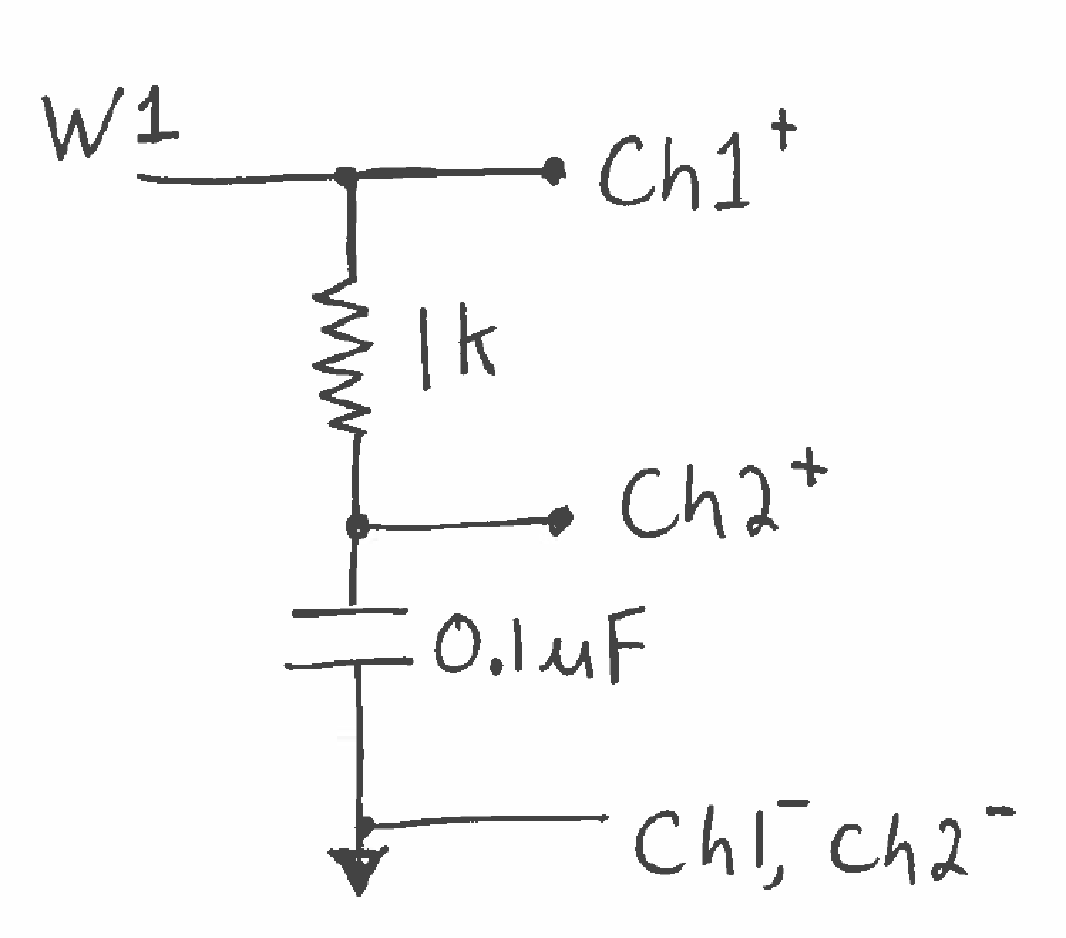


On the same graph, plot the currents through the resistor and capacitor. Use for the resistor and for the capacitor. 

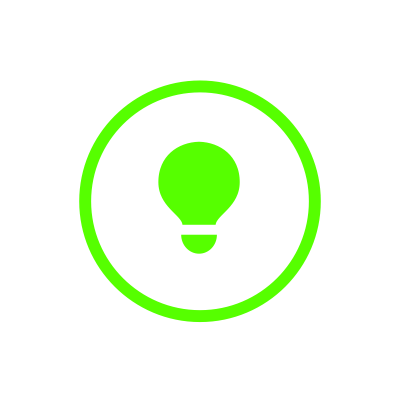


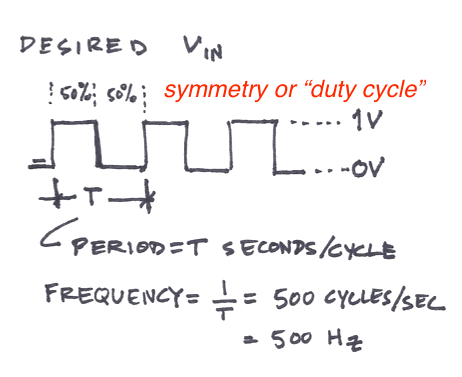
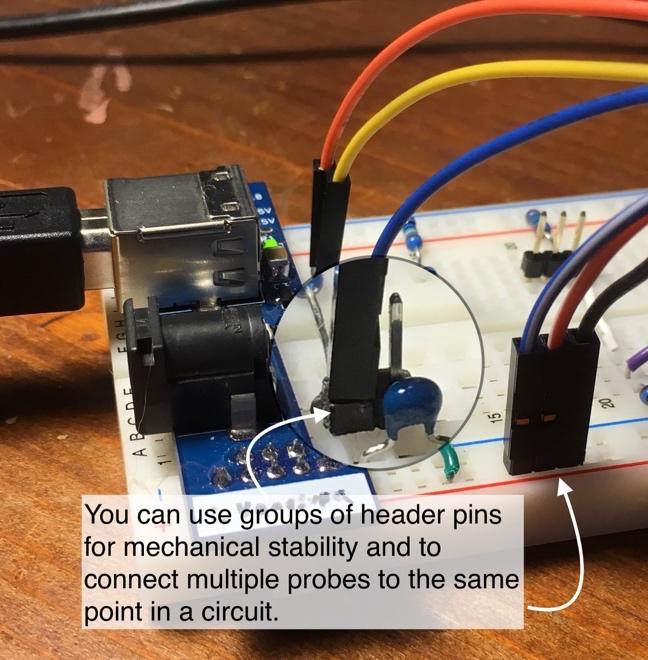
1. **Apply an AC input**

Now we are going to see how capacitors respond to AC inputs. Build the circuit below and connect the AD.

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**Figure 1: Simple RC circuit for part 2 of the lab.**

***You should have nothing from the Analog Discovery connected to the 5 Volt power rail on your breadboard.*** 



Use 

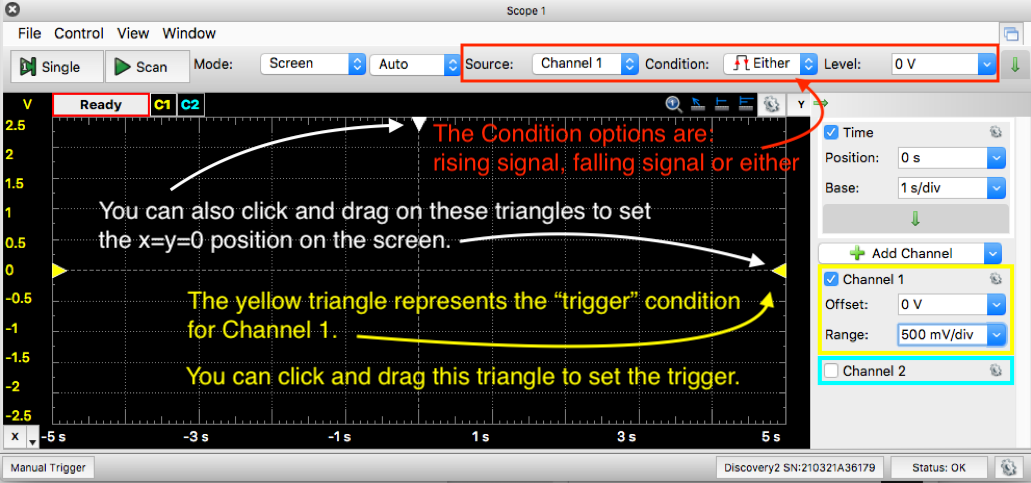
to create the desired Vin and then ►Run



Setup ►Run. You should see the voltage response of several cycles. If not, let’s troubleshoot:

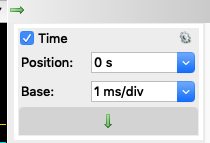
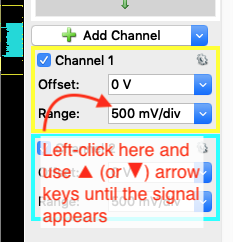
*If the signal is scrolling by on the screen, you can fix the data to the t=0 point by specifying* 

Trigger conditions: *What data source?* *What condition of the data? What voltage level of the condition?*









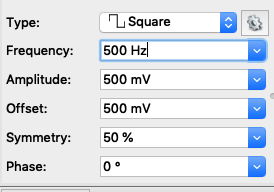


Comment in the worksheet on the ways the capacitor response to frequency changes is similar to or different from the response you got from Part I.

1. **Record the frequency response**

You’ll need to work with both Scope and Wavegen:

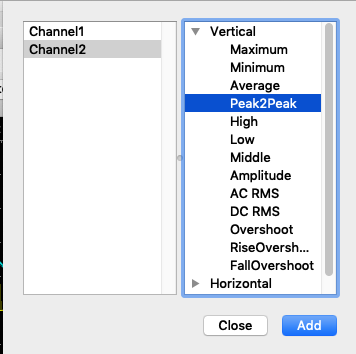


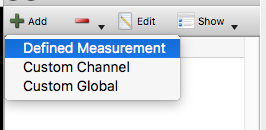
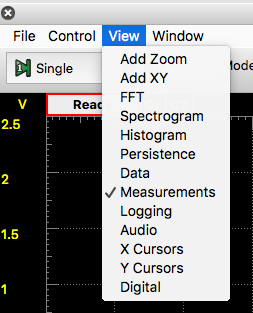
In the Wavegen, left-click in the Frequency: box. 

Use ▲ arrow key to step up to 1.5 kHz (“Arrow-stepping”) and notice what happens.

Now, try adjusting the frequency up and down using “Arrow-stepping” to observe what happens to the output signal as frequency increases.

The behavior you observe should be the similar as in Figure 3.9 of the book.

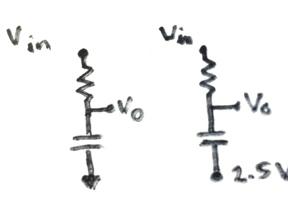
In , View>Measurements, Add Defined Measurement, Channel 2>Vertical> Peak2Peak.





Now adjust the V\_in frequency using “Arrow-stepping”, from 100 Hz to 200 kHz. Notice and record the voltage drop over the capacitor in the PSet worksheet (Column 1, table, p. 11).

1. **Change the conditions & observe**

Now change the input signal to be a square wave with 1 V amplitude, centered at 0V (PSet Worksheet table, Column 2, p. 11). Record the voltage drop over the capacitor at the different frequencies. 

Now change the reference for the capacitor from Ground to 2.5 V.

Repeat the sweep of frequencies and record the values in the PSet Worksheet table, Column 3.

1. **Submit PSet**

**Deliverables:**

For this assignment, you turn in the worksheet and the plots you were requested to make. Create plots with clear axis labels with units. The plot should be well labeled. This is not a lab report, so just the plots.

**PSet 3 Worksheet**

1. Meet the capacitor

Sketch what you observed of Vout(t) upon moving the Vin = +5V➝ 0V. In this rough sketch, label the axes, and the V(t=0s) and V(t=9s) second values.

The theoretical discharging curve for an RC circuit is . How did your observed V(t) deviate from this idealized exponential decay and why?

1. Plot and Analyze

V(∞)measured = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Volts approximate τmeasured = \_\_\_\_\_\_\_\_\_\_\_sec

Compute RC for your circuit, RC = \_\_\_\_\_\_\_\_\_\_\_\_\_\_sec.

Theoretically, RC=τ. Compare the RC for your circuit to the experimental τ

Include the following plots for the charging capacitor:

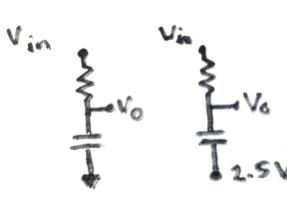
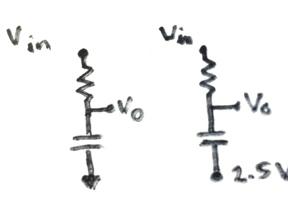
1. V(t) for the charging capacitor with V(t)theory,
2. I(t) for the resistor with I(t) for the capacitor

Comment on plot 2:

1. Apply an AC Signal

Comment in the worksheet on the ways this response is similar to or different from the response you got from Part I. *Sketching and labeling a single cycle can help explain.*

1. Change frequency & 5. Response



|  |  |  |  |
| --- | --- | --- | --- |
| Conditions: | Vin=  0 – 1 V | Vin=  -1 to 1V | Vin =  -1 to 1V |
| Vin freq  (Hz) | ΔV over capacitor  (volts) | | |
| 100 |  |  |  |
| 200 |  |  |  |
| 500 |  |  |  |
| 1 k |  |  |  |
| 2 k |  |  |  |
| 5 k |  |  |  |
| 10 k |  |  |  |
| 20 k |  |  |  |
| 50 k |  |  |  |
| 100 k |  |  |  |
| 200 k |  |  |  |