Lab assignment: Using Capacitors to Measure Humidity

<u>Goal:</u> Sense and compute relative humidity by measuring capacitance.

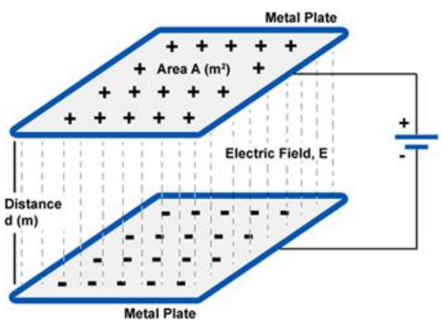
How can we sense humidity with a capacitor?

Now that you've been in Needham, Massachusetts for a few weeks, you've experienced humidity!

%RH

Relative humidity is the percent of water vapor in the air *relative* to how much water vapor the air can hold before the water condenses—that is, before it rains or snows, depending on the temperature.

A capacitor is something that has the "capacity" to store charge. Often the charge is stored across parallel plates of metal, like so:



Source: https://sites.google.com/site/nithinjoseph2066/electromagnetics/parallel-plate-capacitor

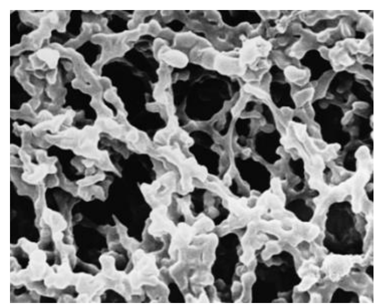
We normally refer to separated + and - charges as "electric potential differences" or "Voltage differences."

$$\text{Capacitance} = \frac{charge\ stored}{\Delta V}$$

It turns out that we can increase the charge stored in a parallel-plate capacitor by placing a non-conducting material between the plates.

In the case of this lab, for the humidity sensor, the material between the capacitor plates is a water-sensitive polymeric (i.e., plastic) material, likely cellulose ester.

It's made from sugar molecules and looks like this in an electron microscope: The cellulose ester scaffolding is about 10,000 times smaller than the thickness of a human hair.

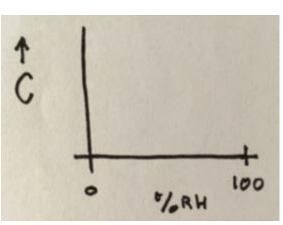


Source: https://www.labsupply.co.nz/

Water vapor from the air attaches to the surface of the cellulose ester fibers, enabling more charge to be stored in the capacitor:

Capacitance ⇡ with ⇡ %RH

You are going to create a circuit that uses this humidity sensor as the *transducer.* <u>Roughly</u>, what does the *transfer* or *reference* curve for your sensor look like?



Hint: Manufacturers publish performance data on the sensors they sell. They want you to know exactly how it will perform in a circuit and under what *circuit conditions* it will perform this way.

transducer: a device that converts one physical quantity to another e.g.

Under what *circuit conditions* (Hz, voltage input) was this *reference* curve generated?

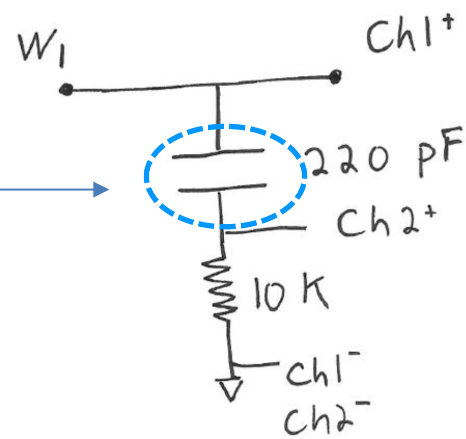
Part 1. Calibrating a circuit for your %RH sensor

Goal: Create a circuit that you can use to measure %RH with this humidity sensor transducer.

You'll *calibrate* this circuit by simulating the circuit test conditions of the manufacturer. You'll use capacitors of known values in the range of the transducer's response: 160 to 190 pF. You will record the circuit's response in Root Mean Square (RMS) Voltage. Look up the difference between different types of amplitude---dialogue with a neighbor, ninja or instructor about this question:

How is the V-RMS different from the V-peak and V-peak-peak? (Can you sketch a graph that illustrates?)

1. Build the circuit shown



After you develop your calibration curve, you'll substitute the humidity sensor for the *capacitor* in the circuit (Part 2).

2. Connect the Discovery to your circuit.

Ensure the Discovery and circuit share a ground.

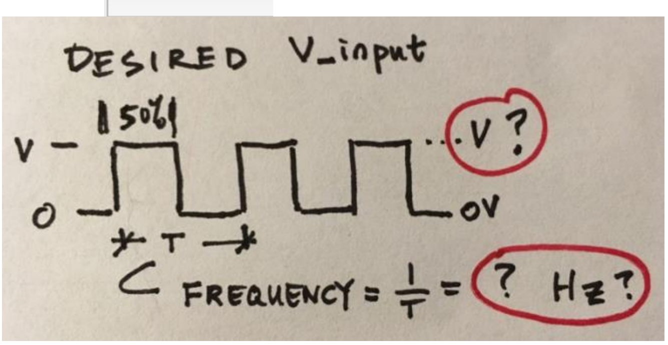
Use Wavegen 1 as the V_input

Use Scope Channel 1 to monitor V_input;

Use Scope Channel 2 to monitor the V dropped *across* the resistor.

3. Set 

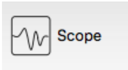
, then ► Run



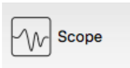
We want to set the V_input so that the humidity sensor will respond with the manufacturer's *reference* curve.

What *circuit conditions* (signal Hz, V_input) should we use?

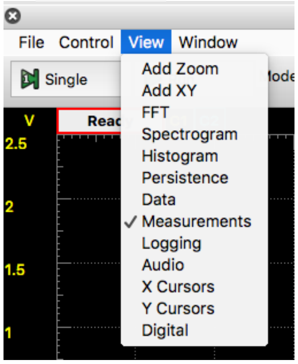
Once you have determined the conditions for the waveform, ► Run

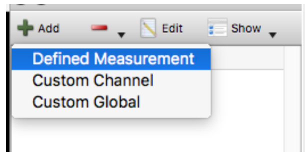
4. Set up 

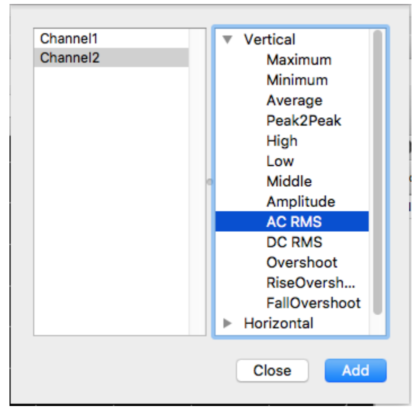
, then ▶ Scan

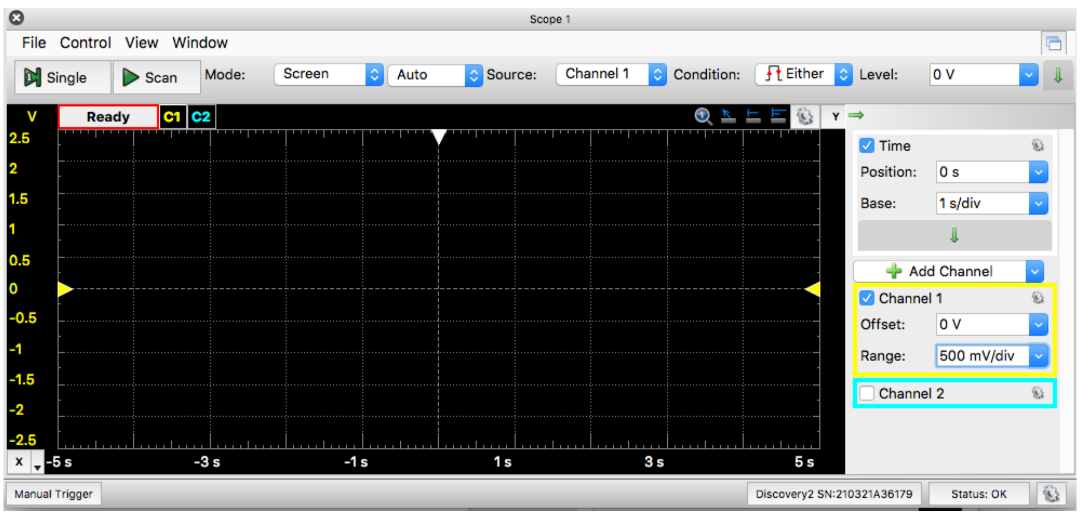
In 

, add a measurement of Channel 2 Amplitude.









How can you adjust the time base to see 3-4 cycles?

Use Channel 2: What V range will allow you to see your input signal?

▶ Scan and complete the table below for your calibration curve

Capacitance value (R=10K)	Measured RMS Voltage amplitude
100 pF	
120 pF	
150 pF	
180 pF	
220 pF	

Once you have recorded the measurements (V-RMS), replace the 220 pF capacitor with a 100 pF capacitor. Note that the signal decays faster and the RMS voltage has decreased significantly. *How does this circuit feature help you with the goal of measuring humidity?*

Generate the plot of the C v. V-RMS relationship for your lab report from your measured data.

Part 2. Measuring the ambient %RH using your circuit

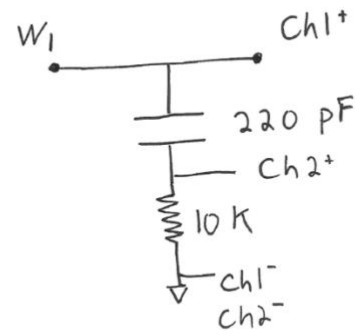
Replace the capacitor in your circuit with the humidity sensor. **Take the measurement of the RMS amplitude**. From your calibration data from Part 1, and the data sheet for the humidity sensor, determine the relative humidity of the room.

Check your result to the relative humidity of the day (which you can check at www.weather.com).

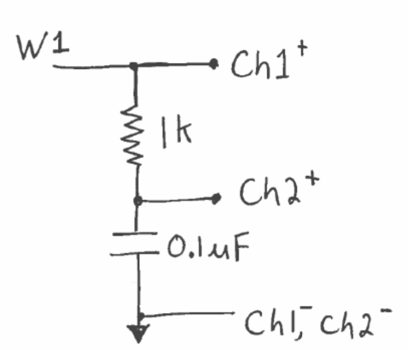
Deliverables:

The results you need to save are highlighted in **RED** in the lab above, just to help remind you as you go along what to save. The summary is listed below.

- Plot the measured voltage versus time data from the 1 volt square wave at 10 kHz into the CR circuit.



- Comment on the difference with the RC circuit from last class.



- Compare your measurement to the *analytical solution*. Note that the analytical solution will be the same for the CR circuit as the RC circuit in the book, just with a minor adjustment.
- Plot your calibration data for the capacitance meter that you created (i.e. a plot of the table data). Plot a reasonable linear fit, overlaid on the data points and report what your calibration equation is.
- Report on your results of using the capacitance meter you built in Part 2 to measure the relative humidity. Check the humidity for the day and see if the result makes sense.

**analytical solution* = The value that you would get if you used the equations for an idealized RC or CR circuit.