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Introduction to Sensors, Instrumentation, and Measurement

02/22/2024

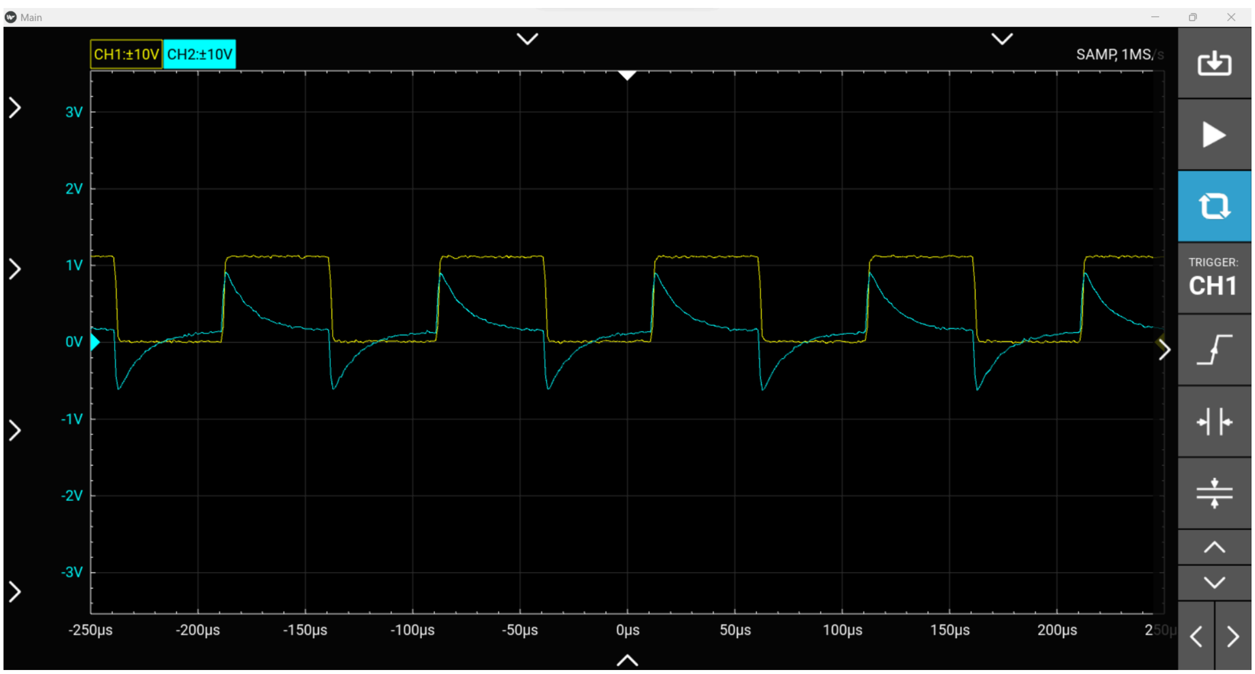
Lab Four: Using Capacitors to Measure Humidity

Purpose:

Build a circuit to measure relative humidity by sensing capacitance of the sensor.

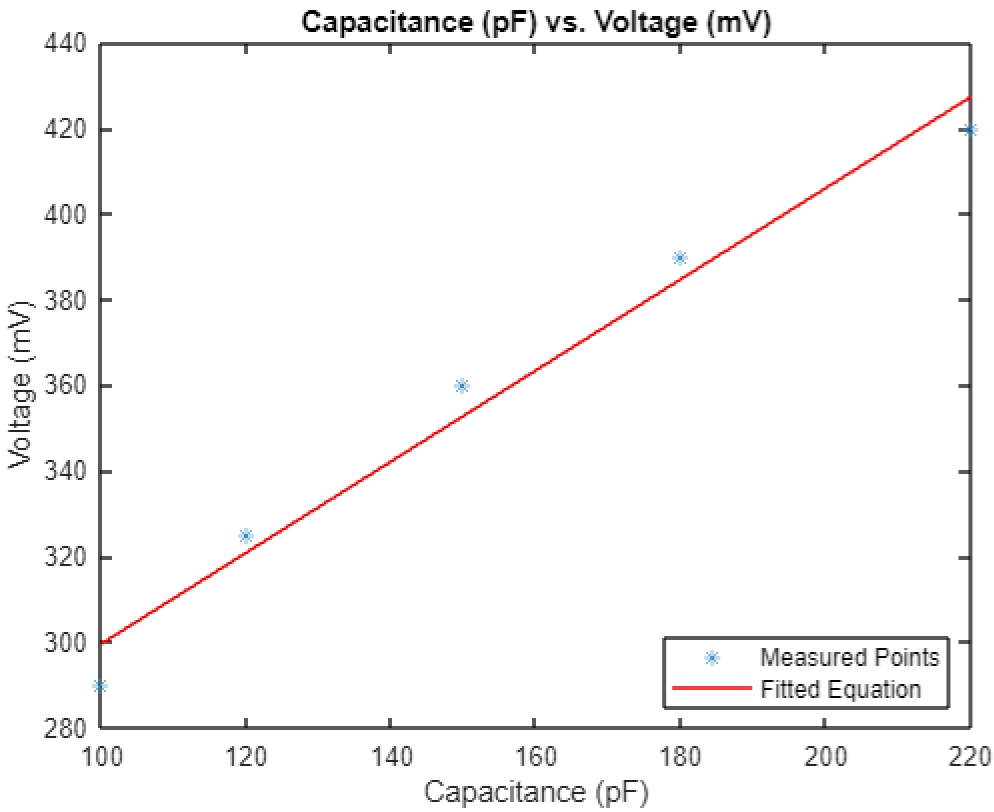
Results:

1.) Screenshot of circuit output for a couple of cycles with a caption



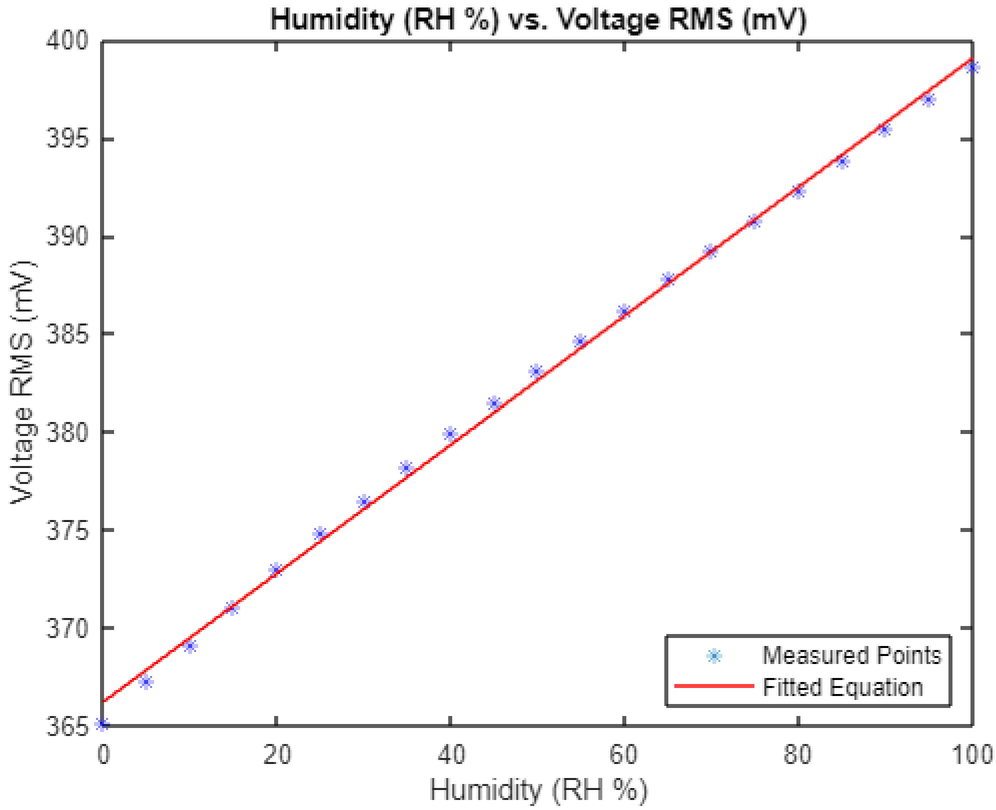
Graph of Time (microseconds) vs. Voltage (V) of a CR circuit (120 picofarads and 100kΩs). The input is a square wave from 0 volts to 1 volt with a frequency of 10k Hz. Channel one (yellow) is taken over the entire circuit, while channel two (blue) is taken over just the second resistor.

2.) Circuit calibration curve with labeled axes and units, fitted equation to the data, and caption.



Calibration curve for Voltage (mV) vs Capacitance (pF) in a CR circuit. The input was a square wave from 0 volts to 1 volt with a frequency of 10k Hz. The voltage was a V-RMS reading taken over a 100kΩ resistor. The fitted equation is: Capacitance = (Voltage - 193.0373)/1.0647.

3.) Measurement curve with labeled axes, units, and caption.



Measurement curve for Voltage (mV) vs Humidity (RH %) in a circuit with a humidity sensor and a 100kΩ ohm resistor. The humidity vs capacitance data is sourced from this [humidity data source](). The capacitance is then converted to voltage based on the voltage equation *Capacitance = (Voltage - 193.0373)/1.0647 from the graph above. The fitted equation for this graph is: Voltage = 0.3286 * Humidity + 366.2027*.

4.) Measurement of % relative humidity and reflections on whether it is a reasonable result.

The humidity sensor, when plugged into my circuit under the same conditions as the capacitors, had a reading of ~385 mV. When plugged into the transfer equation:

$$Voltage = 0.3286 * Humidity + 366.2027.$$

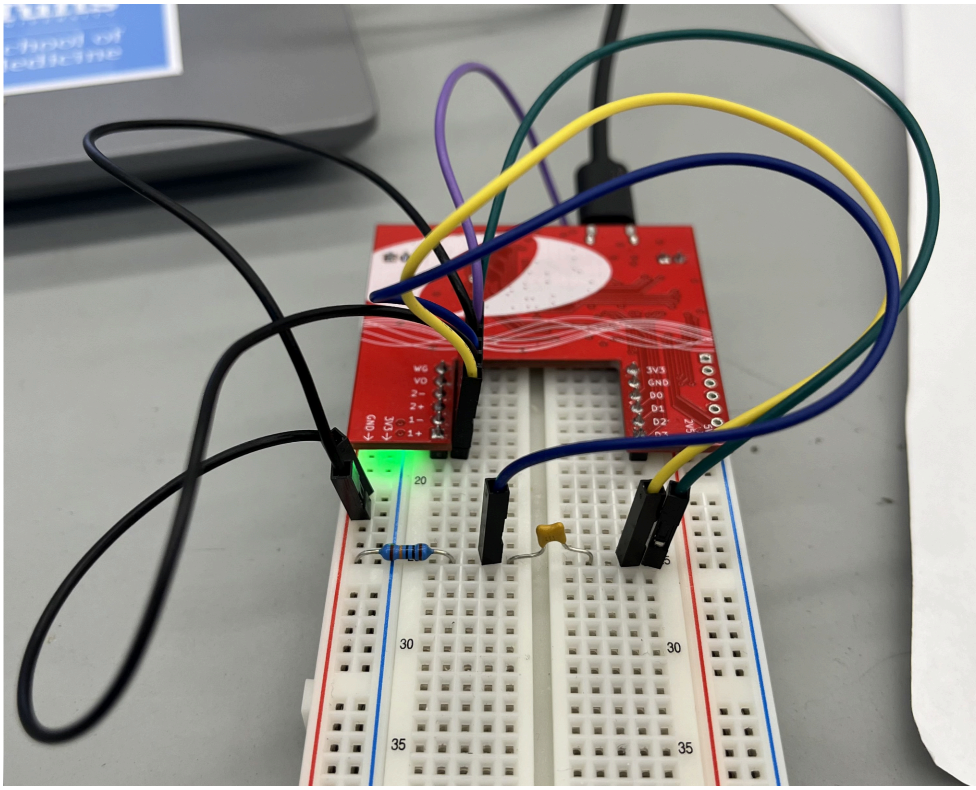
$$Humidity = (Voltage - 366.2027)/0.3286$$

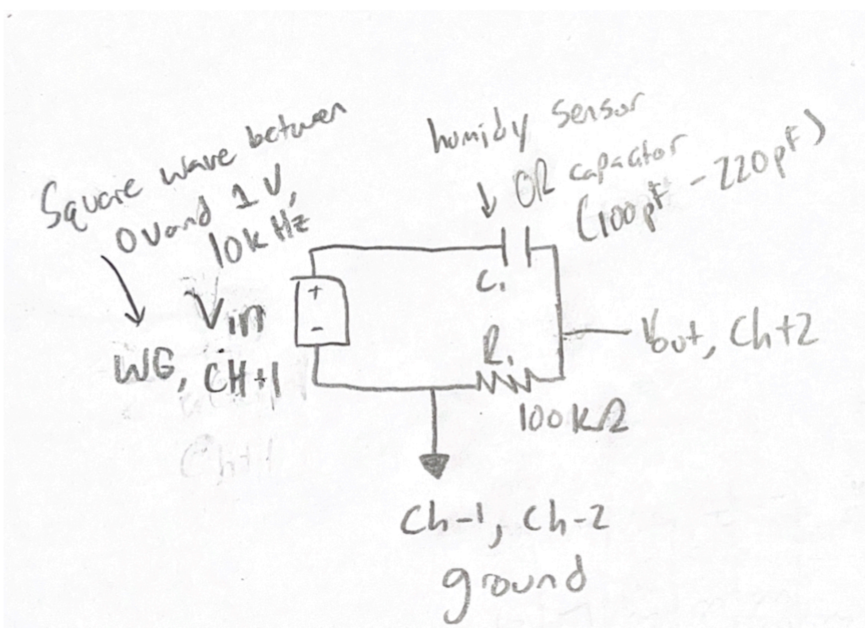
$$Humidity = (385 - 366.2027)/0.3286$$

$$Humidity = 57.2041996\%$$

This is a reasonable result when compared to the humidity reading for the Needham area at the same time: 49% (as measured by www.weather.com).

5.) A sketch of circuit with labeled components and O-scope connections with a photo.





6.) Your code or screenshot of equations used for Excel.

```
clear;  % clear the memory
clf;    % clear the figure to start new

Capacitance = [100; 120; 150; 180; 220];
Voltage = [290; 325; 360; 390; 420];

plot(Capacitance,Voltage,'*');  % plot data as * points
hold on;                % hold the plot so that the next one will overlay

p = polyfit(Capacitance,Voltage,1);   % p returns 2 coefficients fitting r = a_1 * x + a_2
r = p(1) .* Capacitance + p(2); % compute a new vector r that has matching datapoints in x
% line of best fit:  Voltage = 1.0647 * Capacitance + 193.0373
% to convert voltage to capacitance: Capacitance = (Voltage - 193.0373)/1.0647

plot(Capacitance, r,'r')

title("Capacitance (pF) vs. Voltage (mV)")
xlabel('Capacitance (pF)')
ylabel('Voltage (mV)')
legend("Measured Points", "Fitted Equation", "Location", "southeast")
hold off

Humidity = [0; 5; 10; 15; 20; 25; 30; 35; 40; 45; 50; 55; 60; 65; 70; 75; 80; 85; 90; 95; 100];
Capacitance = [161.6; 163.6; 165.4; 167.2; 169.0; 170.7; 172.3; 173.9; 175.5; 177.0; 178.5; 180;
181.4; 182.9; 184.3; 185.7; 187.2; 188.6; 190.1; 191.6; 193.1];
%Voltage = 1.0647 * Capacitance + 193.0373
Cap_to_Voltage = 1.0647 .* Capacitance + 193.0373;

plot(Humidity,Cap_to_Voltage,'*', 'Color',"blue");  % plot data as * points
hold on;                % hold the plot so that the next one will overlay

p_new = polyfit(Humidity,Cap_to_Voltage,1);   % p_new returns 2 coefficients fitting r = a_1 *
x + a_2
r_new = p_new(1) .* Humidity + p_new(2); % compute a new vector r_new that has matching
datapoints in x
% line of best fit:  Voltage = 0.3286 * Humidity + 366.2027
% to convert voltage to capacitance: Humidity = (Voltage - 366.2027)/0.3286

plot(Humidity, r_new,'r')
title("Humidity (RH %) vs. Voltage RMS (mV)")
xlabel('Humidity (RH %)')
ylabel('Voltage RMS (mV)')
legend("Measured Points", "Fitted Equation", "Location", "southeast")
```