ECE 321 - Homework #2

Light & Temperature Sensors, Audio & Strain Sensors. Due Wednesday, April 12th
Please email to jacob.glower@ndsu.edu, or submit as a hard copy, or submit on BlackBoard

Temperature Sensors

Assume you are using a thermistor where the temperature - resistance relationship is

$$R = 1000\ \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right)\ \Omega$$

where T is the temperature in degrees C.

1) Design a linearizing circuit so that the resistance is approximately linear from -20C to +20C. Plot the resulting resitance vs. temperature relationship.

First write a Matlab m-file to compute how liner the resistor is:

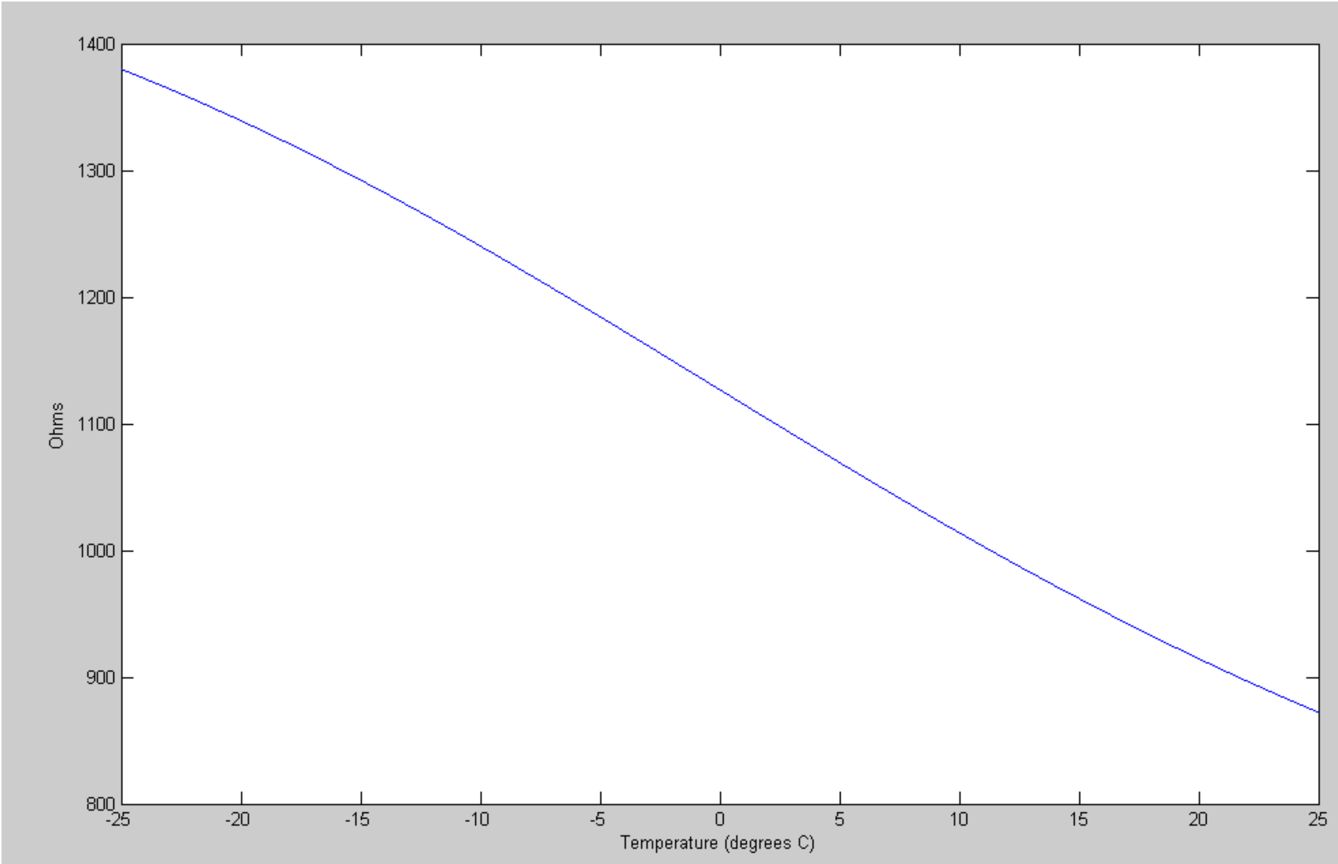
```
function [J] = Prob1(Z);

Ra = Z(1);
Rb = Z(2);

T1 = -20;
T2 = 0;
T3 = 20;

R1 = 1000*exp(3905/(T1+273) - 3905/298);
R2 = 1000*exp(3905/(T2+273) - 3905/298);
R3 = 1000*exp(3905/(T3+273) - 3905/298);

Z1 = (Ra+R1)*(Rb) / (Ra + R1 + Rb);
Z2 = (Ra+R2)*(Rb) / (Ra + R2 + Rb);
Z3 = (Ra+R3)*(Rb) / (Ra + R3 + Rb);

E = Z1 + Z3 - 2*Z2;

J = E^2;
end
```

Optimize with fminsearch()

```
>> [Z,e] = fminsearch('Prob1',[1000,2000])

Z = 1049.6    1518.9

e =     0
```

Plot the resulting resistance vs. temperature:

```
>> Ra = Z(1);
>> Rb = Z(2);
>> T = [-20:0.01:20]';
>> T = [-25:0.01:25]';
>> R = 1000 * exp( 3905 ./ (T+273) - 3905/298);
>> Z = (Ra+R)*Rb ./ (Ra+R+Rb);
>> plot(T,Z)
>> xlabel('Temperature (degrees C)');
>> ylabel('Ohms');
```



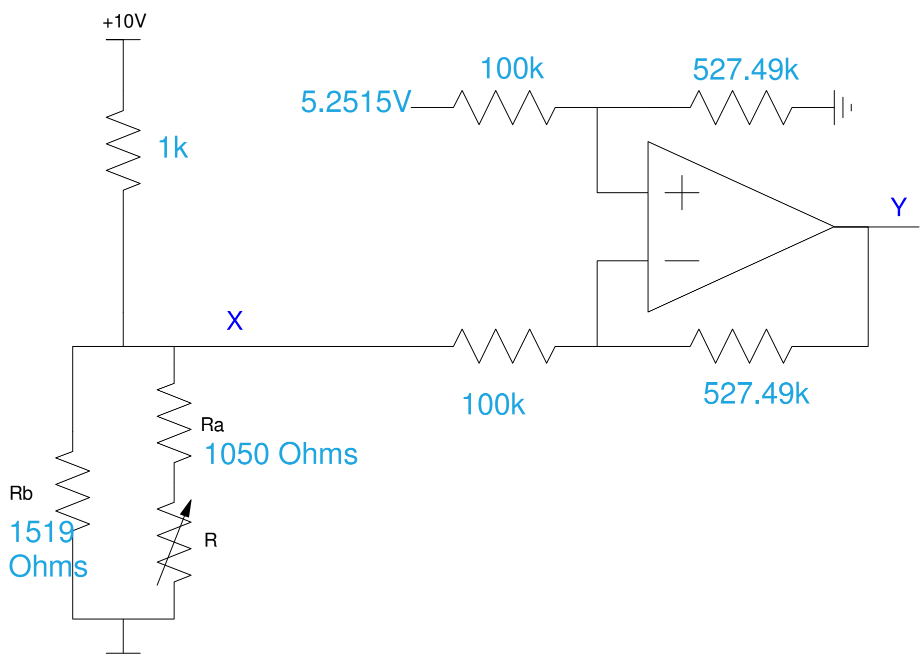
1400
1300
1200
1100
1000
900
800
Ohms
-25
-20
-15
-10
-5
0
5
10
15
20
25
Temperature (degrees C)

2) Using the linearizing circuit from problem 4, design a circuit which outputs

- 0V at -20C
- +5V at +20C
- Proportional in between.

Plot the resulting output voltage vs. temperature.

```
>> % -20C
>> T = -20;
>> R = 1000 * exp( 3905 ./ (T+273) - 3905/298);
>> Z1 = (Ra+R)*Rb ./ (Ra+R+Rb);
>> V1 = Z1 / (Z1+1000)*10

V1 =    5.7254

>> % +20C
>> T = 20;
>> R = 1000 * exp( 3905 ./ (T+273) - 3905/298);
>> Z2 = (Ra+R)*Rb ./ (Ra+R+Rb);
>> V2 = Z2 / (Z2+1000)*10

V2 =    4.7776

>> gain = (5-0) / (V2-V1)

gain =   -5.2749

>> offset = (V1+V2)/2

offset =    5.2515
```

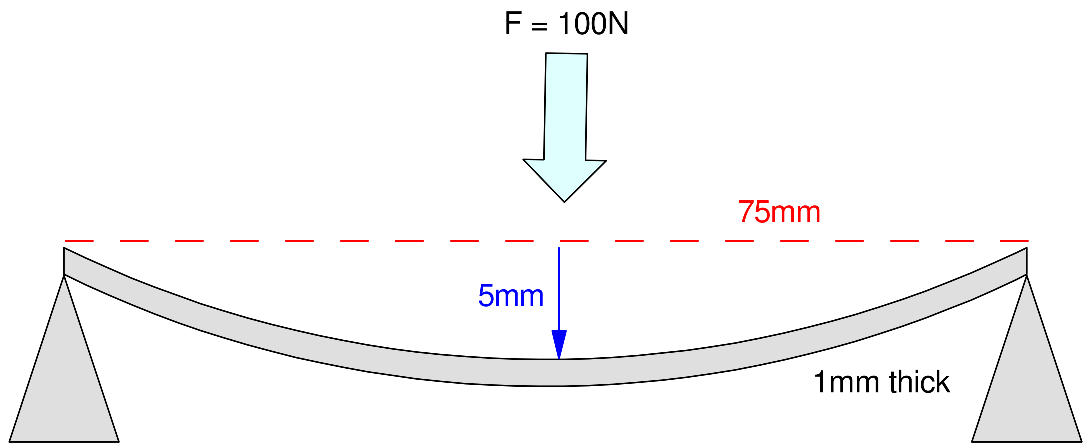


Audio / Strain Sensors

3) A strain sensor is connected to a metal rod to measure the force applied to the center of the beam. Assume

- The beam's thickness is 1mm,
- The beam's lenfgth is 75mm,
- The beam deflects 5mm when a force of 100N is applied to it, and
- The strain - resistance relationship of the strain sensor is

$$R = 120(1 + 2.14\varepsilon)\Omega$$



a) Determine the strain on the outside edge and the resistance when the beam deflects by 5mm

Find the radius of curvature

$$r^2 = (r-5)^2 + (37.5)^2$$

$$r = 143.125mm$$

the strain on the outside edge is

$$\varepsilon = \left(\frac{0.5mm}{143.125mm}\right) = 0.003493$$

$$R = 120.89711\Omega$$

b) Design a circuit which outputs

- 0V at 0lb force and
- +10V at 100N force

Assume a voltage divider with a 120 Ohm resistor

$$R(\varepsilon = 0) = 120\Omega$$

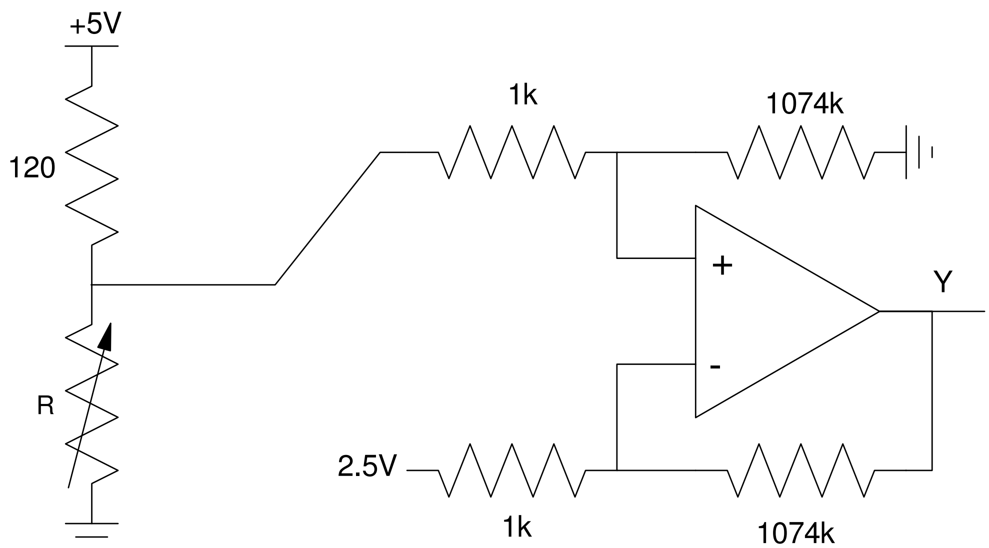
$$V_a = 2.5V$$

$$R(\varepsilon = 0.003493) = 120.89711\Omega$$

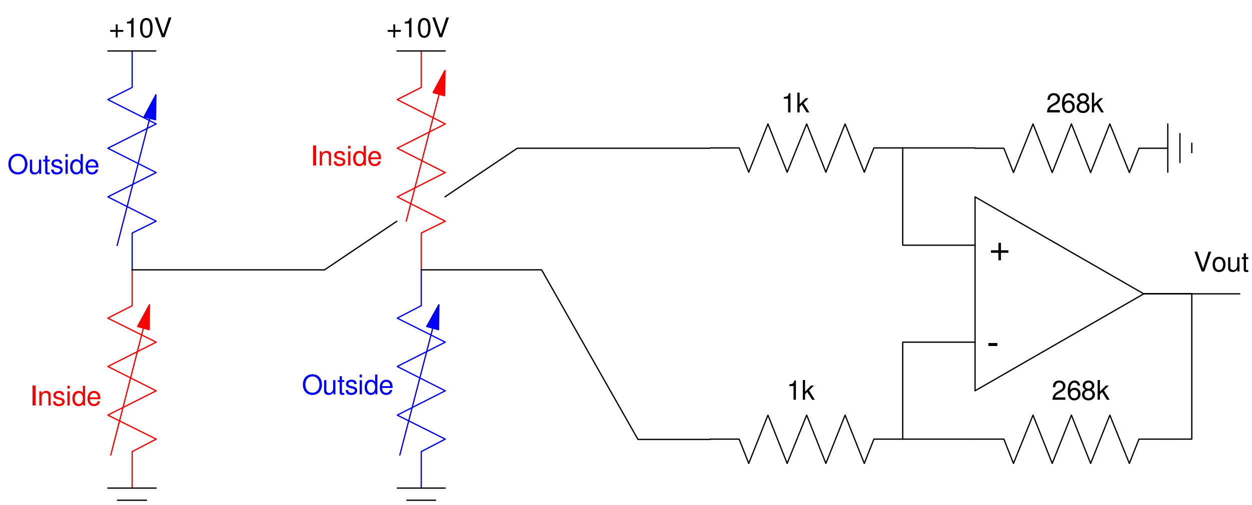
$$V_a = \left(\frac{R}{120+R}\right) 5V = 2.503910V$$

$$gain = \left(\frac{10V-0V}{2.503910V-2.50000V}\right) = 1074.09$$

$$offset = 2.500V$$



A better option is to use four strain gages. This reduces the required gain by 4x (268.52)



Theramin

The light sensor in your lab kit (also available in ECE 201) has a resistance varying from 2k (room light) to >200k (dark). The following circuit outputs a triangle wave with the frequency varying with light level (with R)

4) Frequency Control (R1): Determing the frequency of the output for

- R1 = 2000 Ohms (light), and
- R1 = 200k Ohms (dark)

What range of frequency do you expect with this circuit if R1 is a CdS light sensor which varies from 2k to 200k Ohms?

The period should be

$$T = (R_a + 2R_b) \cdot C \cdot \ln(2)$$

For R1 = 2k

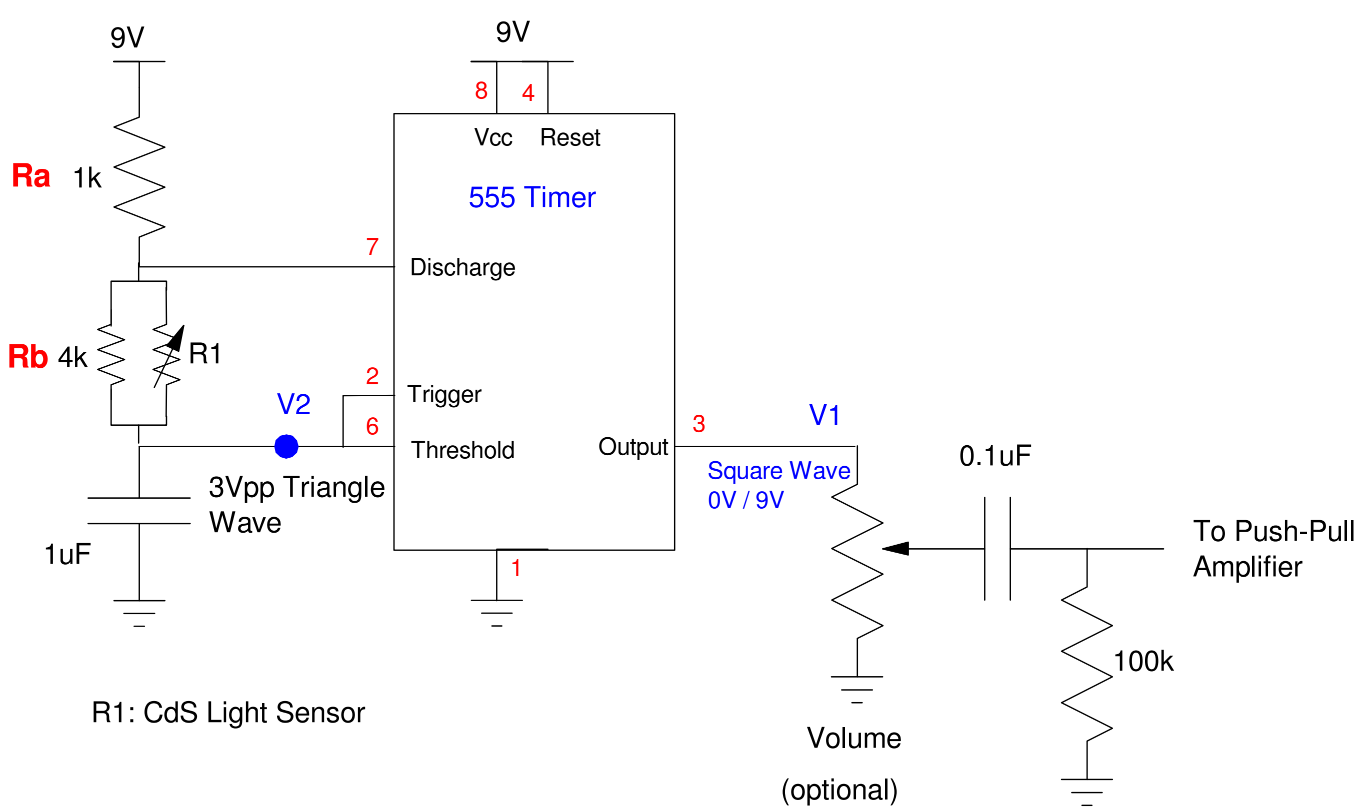
$$T = (1000 + 1333) \cdot 1\mu F \cdot \ln(2) = 1.617ms$$

$$f = \frac{1}{T} = 618.29Hz$$

For R1 = 200k

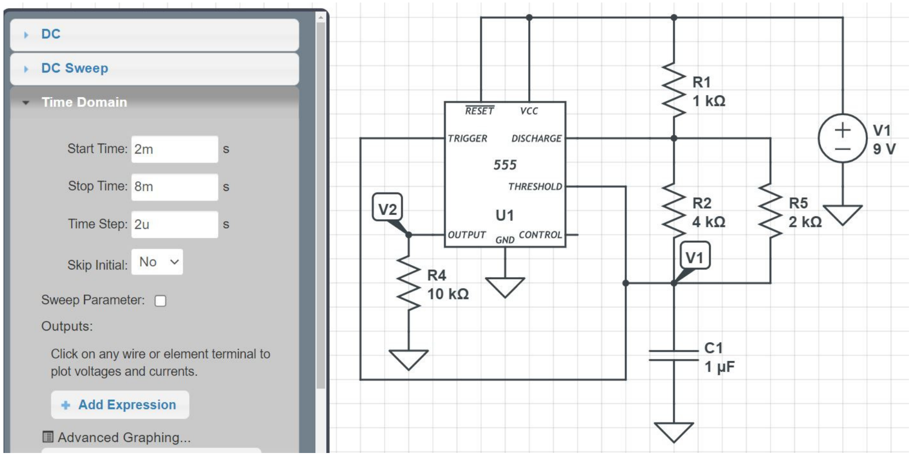
$$T = (1000 + 3921) \cdot 1\mu F \cdot \ln(2) = 3.411ms$$

$$f = \frac{1}{T} = 293.13Hz$$

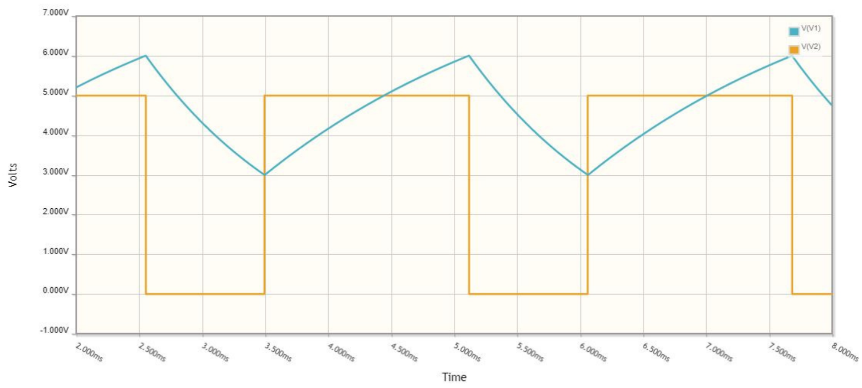


5) Determine the voltages at V1 and V2 using CircuitLab for

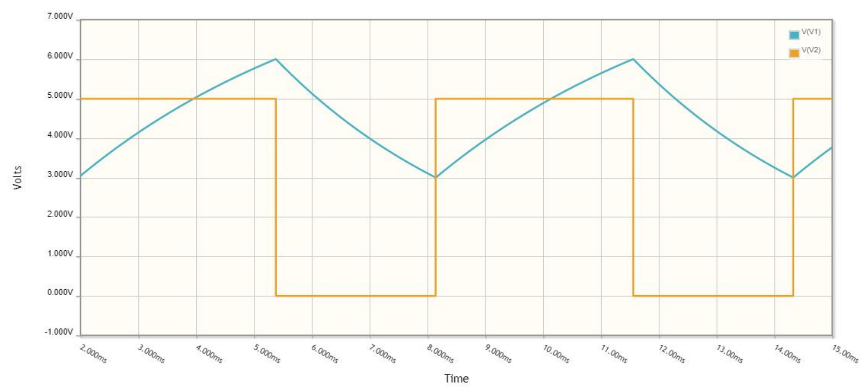
- R1 = 2000 Ohms (light), and
- R1 = 200k Ohms (dark)



Circuitlab Simulation



Voltages when R5 = 2k (period = 2.6ms, f = 384Hz)

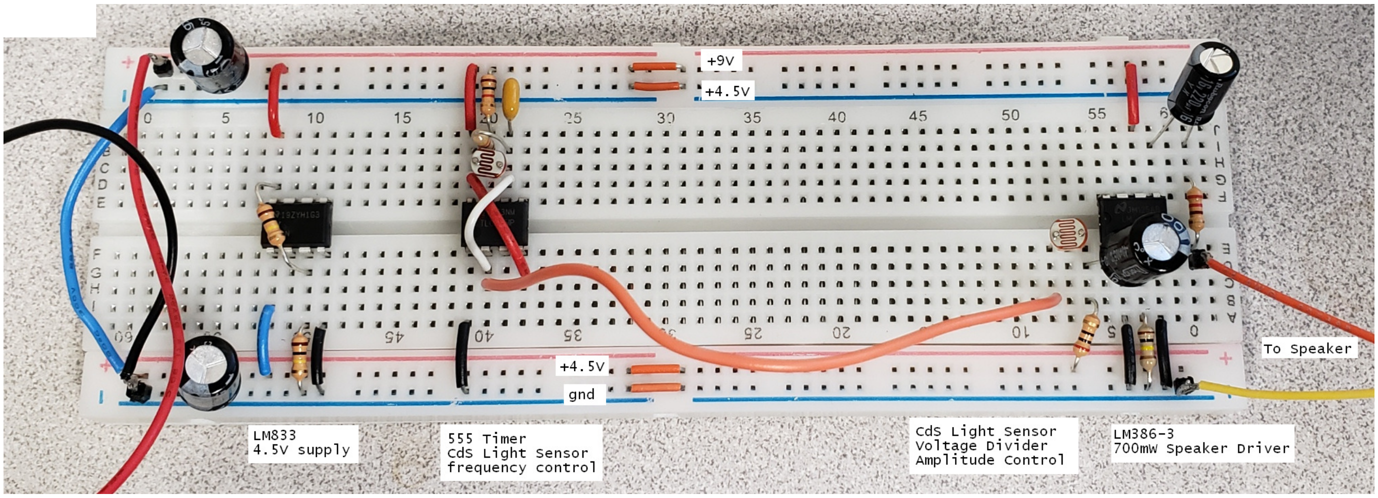


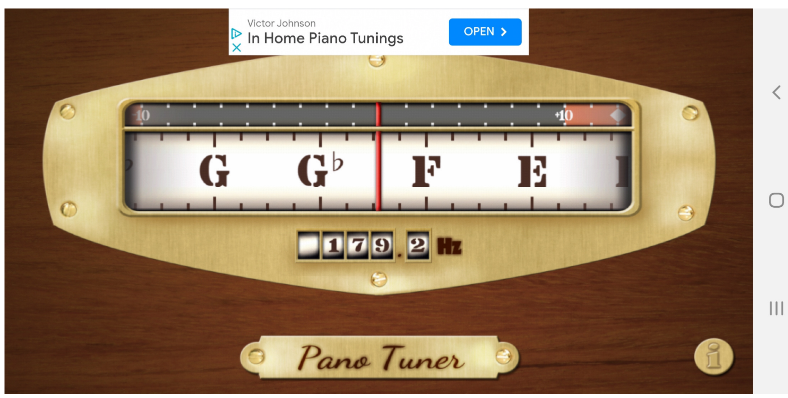
Voltages when R5 = 200k (period = 6.3ms, f = 158Hz)

Lab

6) Build this circuit on your breadboard. Measure

- The frequency of V1 when R1 = light
- The frequency of V1 when R1 = dark





Output when Light

Output when Dark

7) Demo: Demonstrate this Theramin