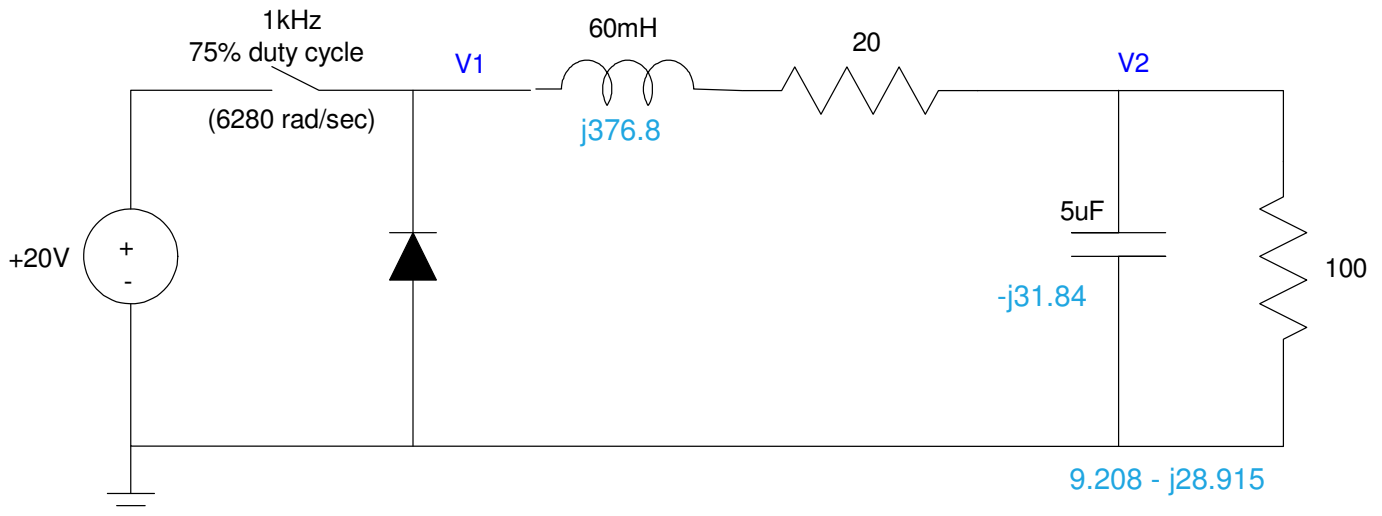


ECE 320 - Homework #5

DC to DC Converter, Fourier Transforms, AC to DC Converter, SCR

DC to DC Converters

1) Determine the voltages (both DC and AC) for V1 and V2.



DC:

$$V_1(DC) = (0.75)(20V) + (0.25)(-0.7V) = 14.825V$$

$$V_2(DC) = \left(\frac{100}{100+20} \right) V_1(DC) = 12.354V$$

AC:

$$V_1(AC) = 20.7V_{pp} \quad \text{max} = 20V, \text{ min} = -0.7V$$

$$V_2(AC) = \left(\frac{(9.208-j28.915)}{(9.208-j28.915)+(20+j376.8)} \right) \cdot 20.7V_{pp}$$

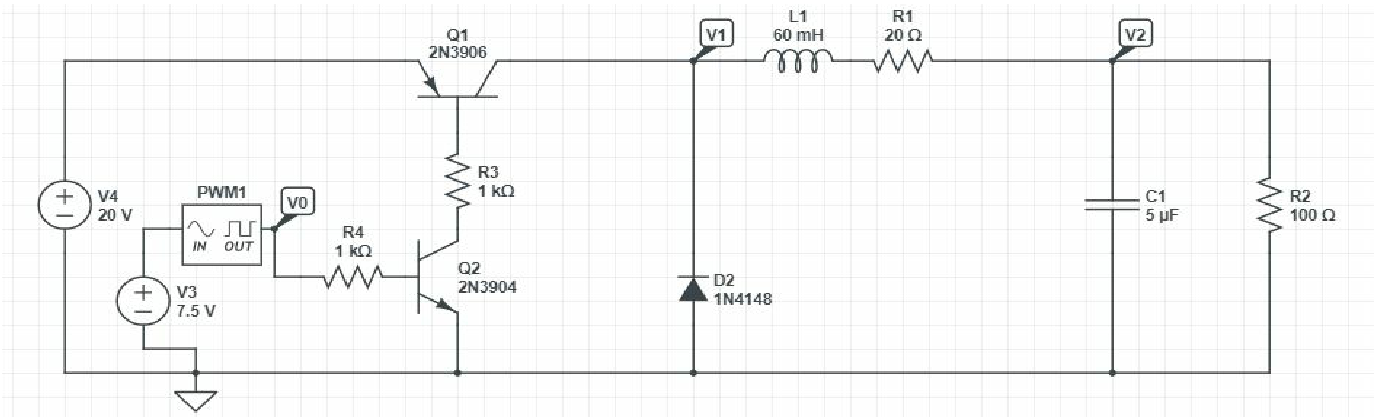
$$V_2(AC) = 1.799V_{pp} \quad \text{take the magnitude (phase doesn't matter)}$$

2) Simulate the circuit in CircuitLab and determine V2 (DC and AC)

- $\max(V2) = 13.05V$
- $\min(V2) = 11.41V$

DC = $(\max + \min) / 2 = 12.23V$ (vs. 12.35V computed)

AC = $(\max - \min) = 1.64V_{pp}$ (vs. 1.799V_{pp} computed)



3) Change the duty cycle and C so that

- The DC voltage at V2 = 5.00V
- The ripple at V2 is 1Vpp

For 5V

$$V_2 = \left(\frac{100}{100+20} \right) V_1 = 5.00V$$

$$V_1 = 6.00V$$

$$6V = 20V \cdot \alpha + (-0.7V) \cdot (1 - \alpha)$$

$$\alpha = \left(\frac{6.7}{20.7} \right) = 32.4\%$$

For C:

- 5uF resulted in 1.64Vpp ripple
- Larger C results in less ripple

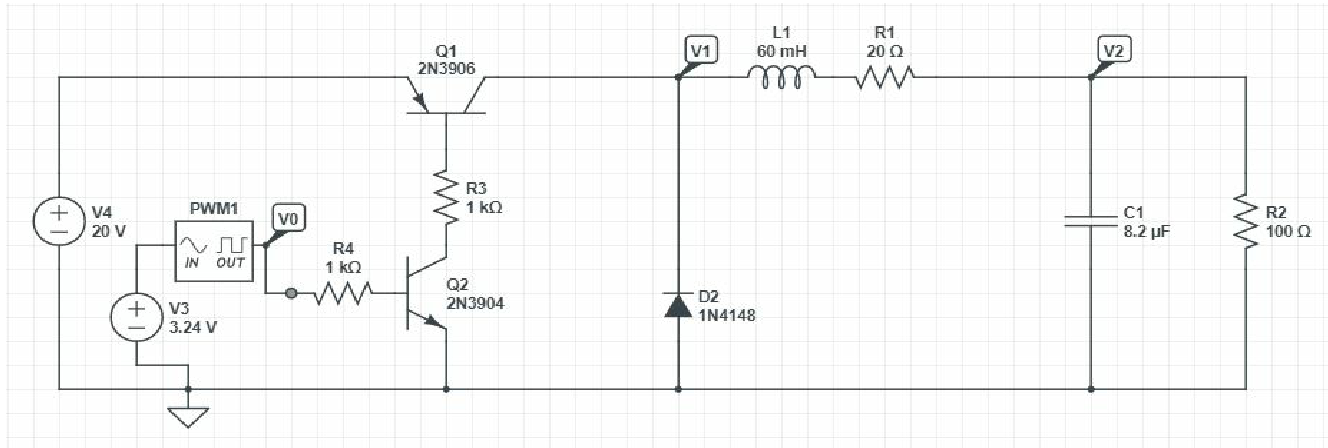
$$C \approx \left(\frac{1.64V_{pp}}{1V_{pp}} \right) 5\mu F = 8.2\mu F$$

4) Check your results for problem #6 in CircuitLab

- $\max(V2) = 5.476V$
- $\min(V2) = 4.289V$

$$DC = (\max + \min) / 2 = 4.883V$$

$$AC = \max - \min = 1.187V_{pp}$$



DC to DC Converter (problems 4 - 6)

Fourier Transforms

5) Going back to problem #1, determine the Fourier Transform for V1 out to the 3rd harmonic (3kHz)

```
>> t = [0:0.0001:1]';  
>> V1 = 20*(t<0.75) - 0.7*(t>0.75);  
>> DC = mean(V1)
```

DC =

14.8235

```
>> c1 = 2*mean(V1 .* exp(-j*2*pi*t))
```

c1 =

-6.5864 - 6.5903i

```
>> c2 = 2*mean(V1 .* exp(-j*2*pi*t * 2))
```

c2 =

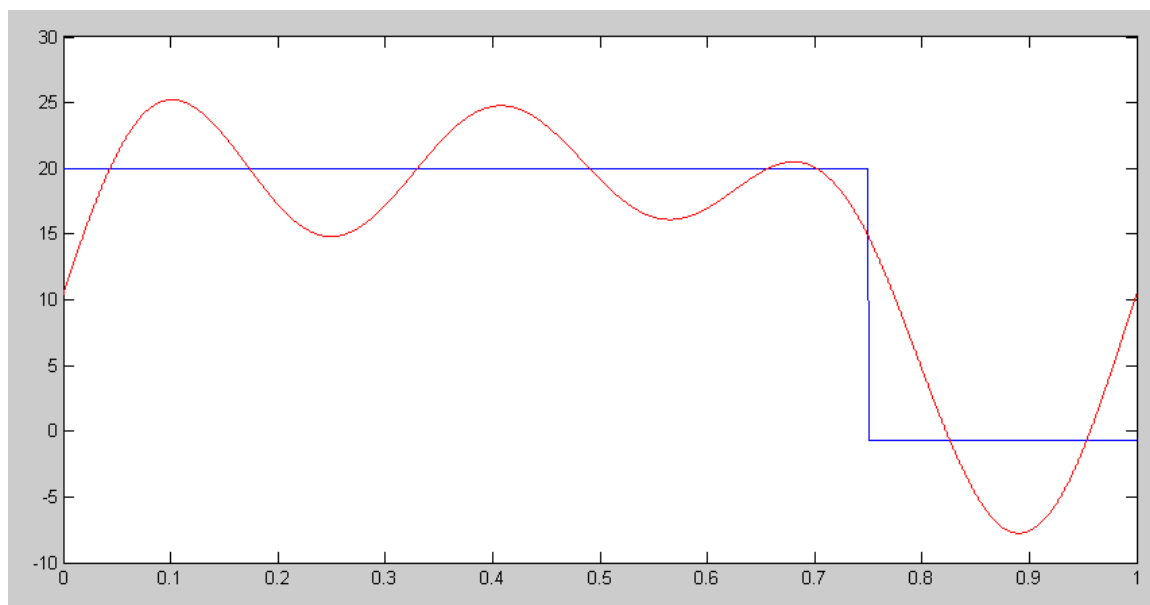
0.0039 - 6.5884i

```
>> c3 = 2*mean(V1 .* exp(-j*2*pi*t * 3))
```

c3 =

2.1980 - 2.1942i

```
>> Yf = DC + real(c1)*cos(2*pi*t) - imag(c1)*sin(2*pi*t);  
>> Yf = Yf + real(c2)*cos(2*pi*t*2) - imag(c2)*sin(2*pi*t*2);  
>> Yf = Yf + real(c3)*cos(2*pi*t*3) - imag(c2)*sin(2*pi*t*3);  
>> plot(t,V1,'b',t,Yf,'r');  
>>
```



6) Using the Fourier Transform approximation for V1, determine V2 out to the 3rd harmonic (3kHz)

```
>> % DC
>> w = 0;
>> V2_0 = 100 / (100+20) * DC

V2_0 =

    12.3529

>> % 1st harmonic
>> w = 2*pi*1000;
>> C = 1/(j*w*5e-6);
>> L = j*0.06*w;
>> R1 = 1 / (1/100 + 1/C);
>> R2 = 20 + L;
>> V2_1 = (R1 / (R1 + R2))*c1

V2_1 =

    0.3100 + 0.7473i

>> % 2nd harmonic
>> w = 2*pi*1000 * 2;
>> C = 1/(j*w*5e-6);
>> L = j*0.06*w;
>> R1 = 1 / (1/100 + 1/C);
>> R2 = 20 + L;
>> V2_2 = (R1 / (R1 + R2))*c2

V2_2 =

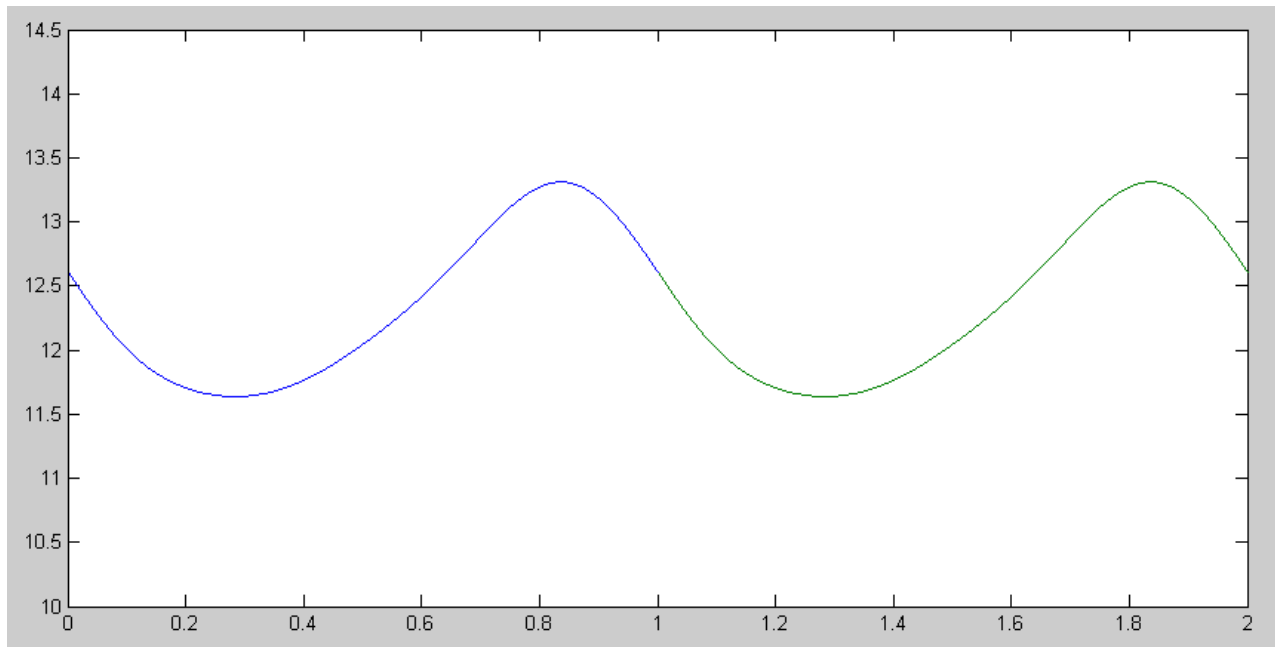
   -0.0263 + 0.1377i

>> % 3rd harmonic
>> w = 2*pi*1000 * 3;
>> C = 1/(j*w*5e-6);
>> L = j*0.06*w;
>> R1 = 1 / (1/100 + 1/C);
>> R2 = 20 + L;
>> V2_3 = (R1 / (R1 + R2))*c3

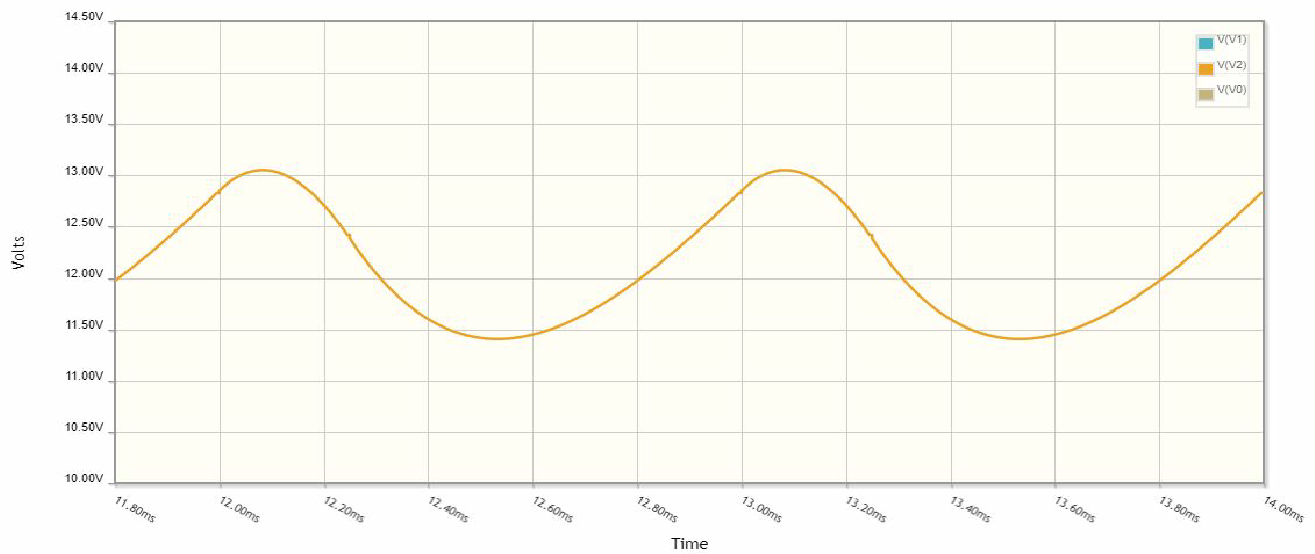
V2_3 =

   -0.0231 + 0.0179i

>>
>> V2 = 0*t + V2_0;
>> w0 = 2*pi;
>> V2 = V2 + real(V2_1)*cos(w0*t) - imag(V2_1)*sin(w0*t);
>> V2 = V2 + real(V2_2)*cos(2*w0*t) - imag(V2_2)*sin(2*w0*t);
>> V2 = V2 + real(V2_3)*cos(3*w0*t) - imag(V2_3)*sin(3*w0*t);
>> plot(t,V2)
>> xlabel('Time (ms)');
```



Matlab Result for V2 (problem #4) using 3 terms from the Fourier Transform



CircuitLab Simulation for V2 (problem #4)

```
>> mean(V2)
ans = 12.3530

>> max(V2) - min(V2)
ans = 1.6727
```

These match the CircuitLab simulations

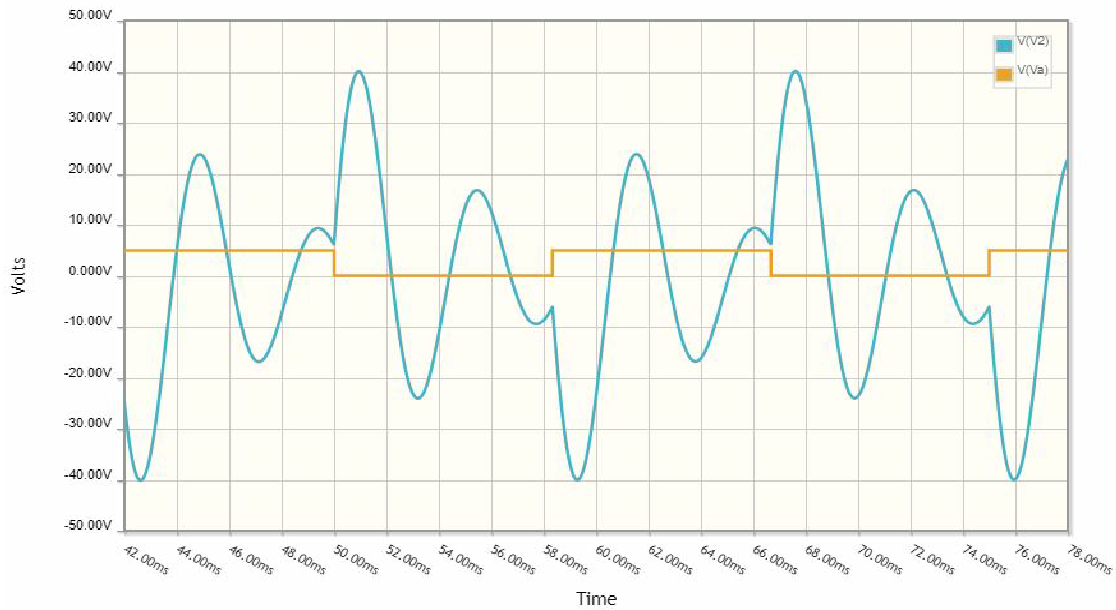
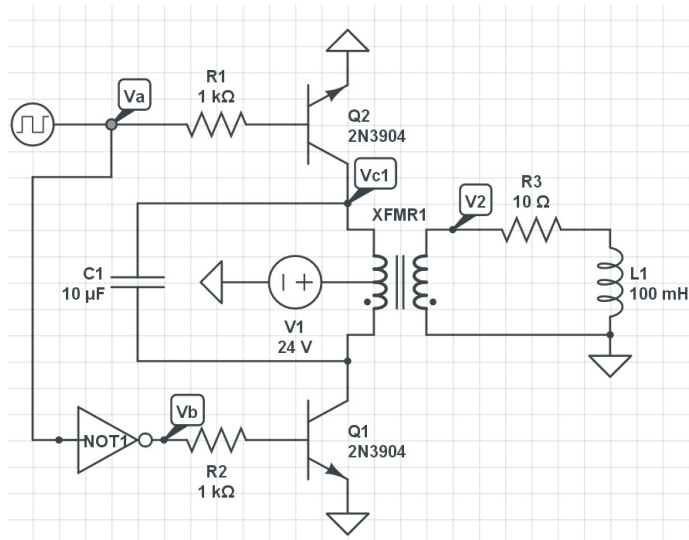
- $DC = (max + min) / 2 = 12.23V$
- $AC = (max - min) = 1.64V_{pp}$

DC to AC

7) Let

- A = 0V / 5V square wave, 60Hz, 0 degree time delay
- B = 0V / 5V square wave, 60Hz, 180 degree time delay
- C1 = 10uF

Determine using CircuitLab the voltage V2 (i.e. the voltage across a DC motor, modeled as a 10 Ohm & 100mH load)

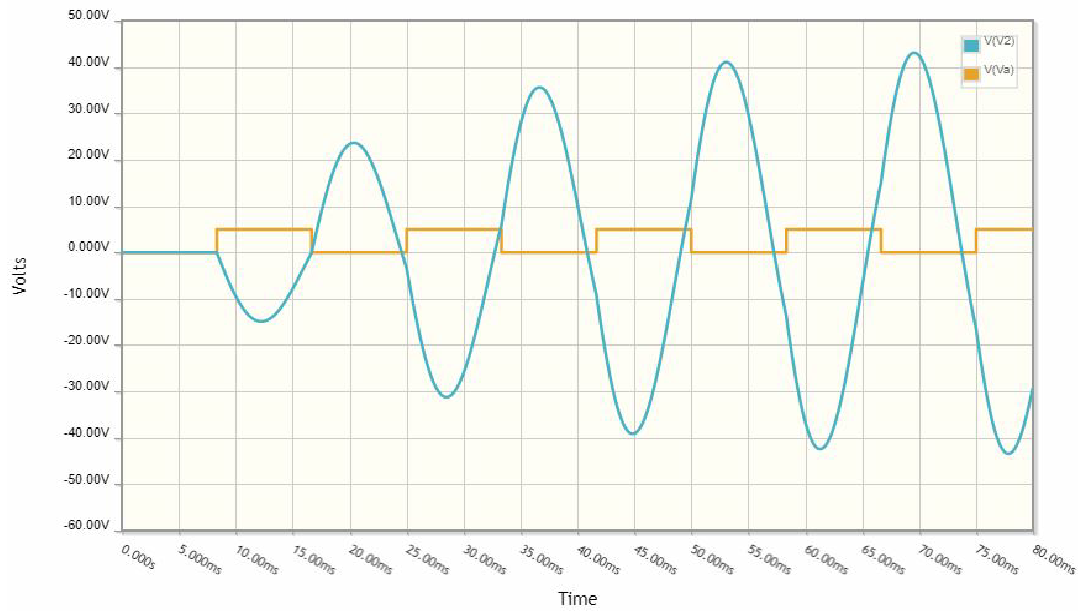


8) Adjust C1 so that the voltage across the motor is as close to a sine wave as possible (trial and error)

In theory, resonance is

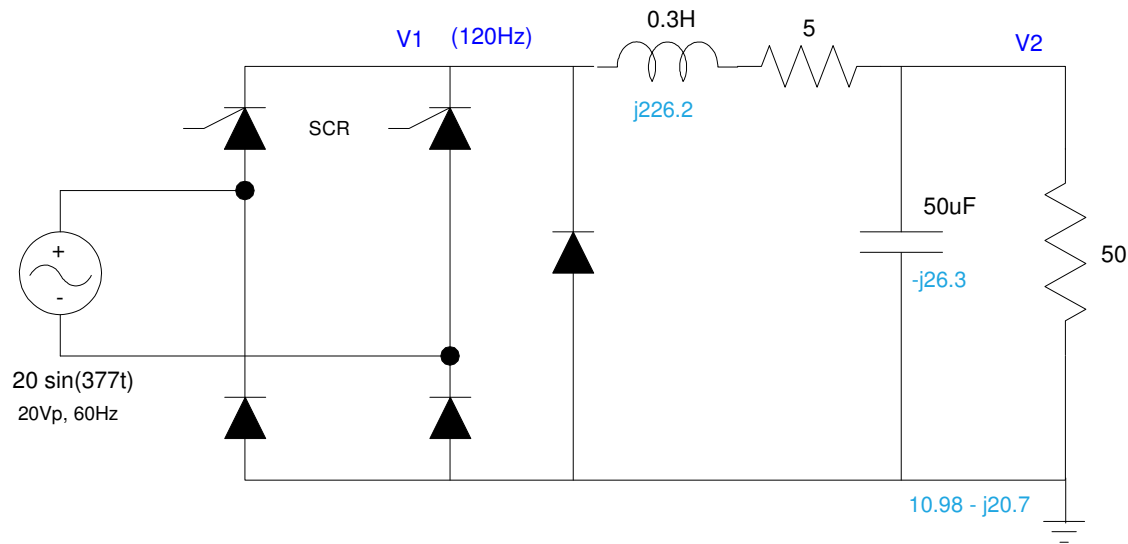
$$\omega = \frac{1}{\sqrt{LC}}$$

For 377 rad/sec (60Hz), L = 0.1H, C = 70uF. Adjusting to get a sine wave, C = 120uF



SCR

9) Assume a firing angle of 45 degrees. Determine the voltage at V1 and V2 (both DC and AC).



DC Analysis:

$$V_1(DC) \approx \left(\frac{18.6+0.7}{\pi} \right) \cdot (1 + \cos(45^\circ)) - 0.7$$

$$V_1(DC) \approx 9.787V$$

$$V_2(DC) = \left(\frac{50}{50+5} \right) V_1(DC) = 8.799V$$

AC Analysis (120Hz = 754 rad/sec)

$$V_1(AC) \approx 18.4V - (-0.7V) = 19.3V_{pp}$$

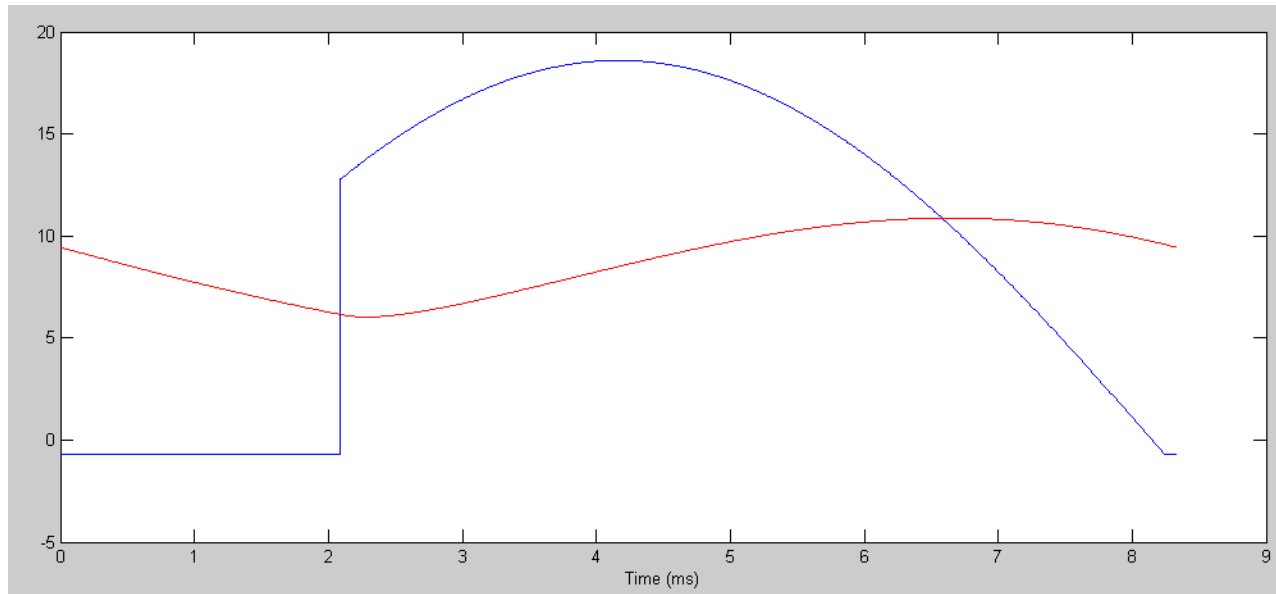
$$V_2(AC) = \left(\frac{(10.98-j20.7)}{(10.98-j20.7)+(5+j226.2)} \right) 19.3V_{pp}$$

$$V_2(AC) = 2.194V_{pp}$$

Simulation Results

```
>> DC = mean(V2)  
8.7647
```

```
>> Vpp = max(V2) - min(V2)  
2.3669
```



10) Change this circuit so that

- The voltage at V2 is 10.00V (DC)
- With a ripple of 500mVpp

$$V_2(DC) = 10V$$

$$V_1(DC) = \left(\frac{50+5}{50} \right) V_2 = 11.00V$$

$$11.00V = \left(\frac{18.6+0.7}{\pi} \right) \cdot (1 + \cos(\theta)) - 0.7$$

$$\theta = 25.25^\circ$$

Without C2, the ripple is

$$V_2(AC) = \left(\frac{50}{50+(5+j226)} \right) 19.3V_{pp}$$

$$V_2(AC) = 4.14V_{pp}$$

To make the ripple 15x smaller, make the impedance of the capacitor 15x smaller than R

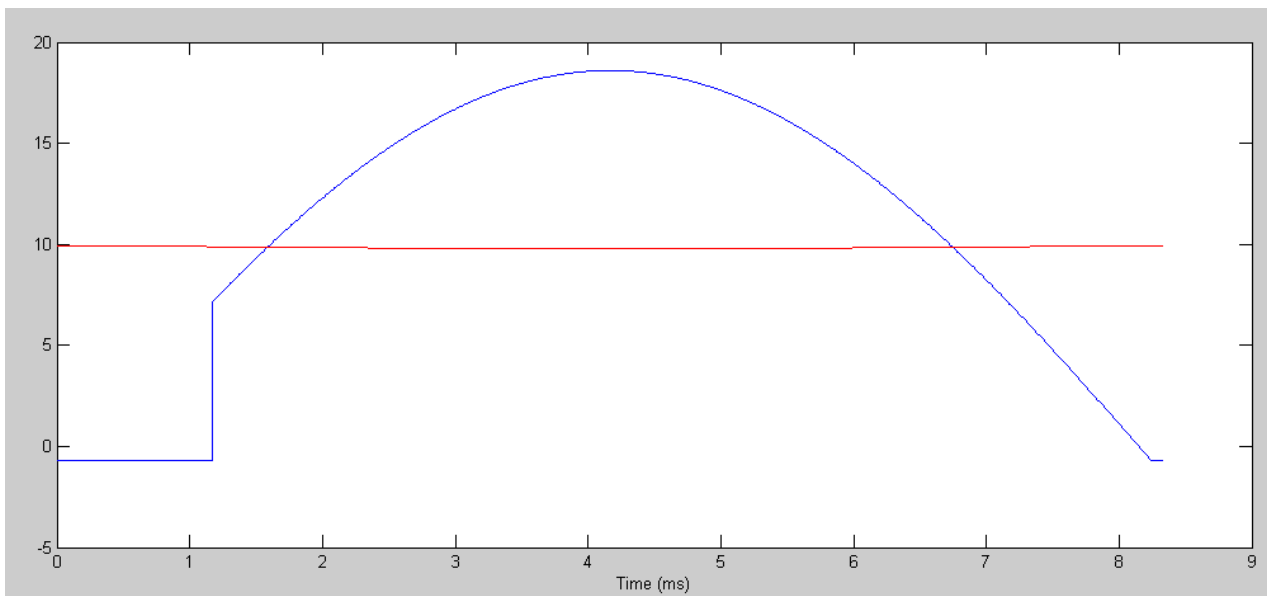
$$\left| \frac{1}{j\omega C} \right| = \left(\frac{0.5V_{pp}}{4.14V_{pp}} \right) 50\Omega = 6.02\Omega$$

$$C_2 = 220\mu F$$

```
> DC = mean(V2)
    9.8405
```

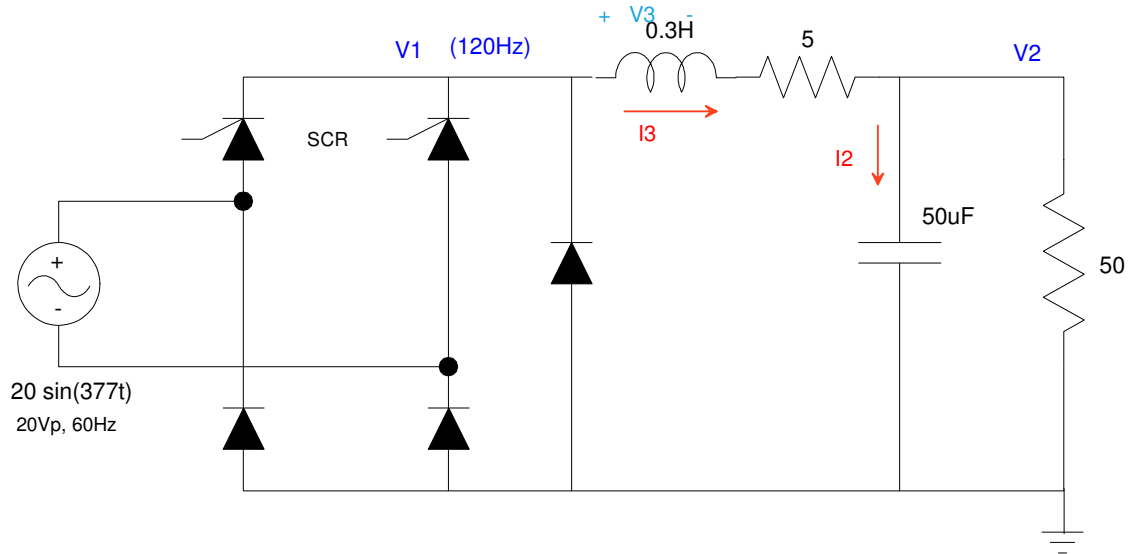
```
>> Vpp = max(V2) - min(V2)
```

0.732



11) Simulate this circuit in Matlab by

- Writing the differential equations which describe this circuit (state variables: I_L and V_C)
- Specify $V_1(t)$ as a full-wave rectified sine wave, clipped at X degrees (from problem #4)
- Use numerical integration to find $V_2(t)$



The differential equations that describe this circuit are than:

$$I_2 = CsV_2 = I_3 - \frac{V_2}{50}$$

$$V_3 = LsI_3 = V_1 - 5I_3 - V_2$$

Matlab Code:

```
t0 = [0:0.001:1]';
angle = t0*180;
% firing angle
Fire = 45;

V0 = abs(20*sin(t0*pi));
V0 = V0 - 1.4;
V0 = max(-0.7, V0);

V0 = V0.*(angle > Fire) - 0.7*(angle <= Fire);
t = t0 / 120;
dt = t(2) - t(1);

plot(t,V0);

V2 = 0;
I3 = 0;
V2 = 0*t;
I3 = 0*t;
L = 0.3;
C = 5e-6;

npt = length(t);

% itterate for 100 cycles to reach steady state
for n=1:100
    I3(1) = I3(npt);
    V2(1) = V2(npt);

    for i=1:length(t)-1
        dI3 = (V0(i) - 5*I3(i) - V2(i))/L;
        dV2 = (I3(i) - V2(i)/50) / C;

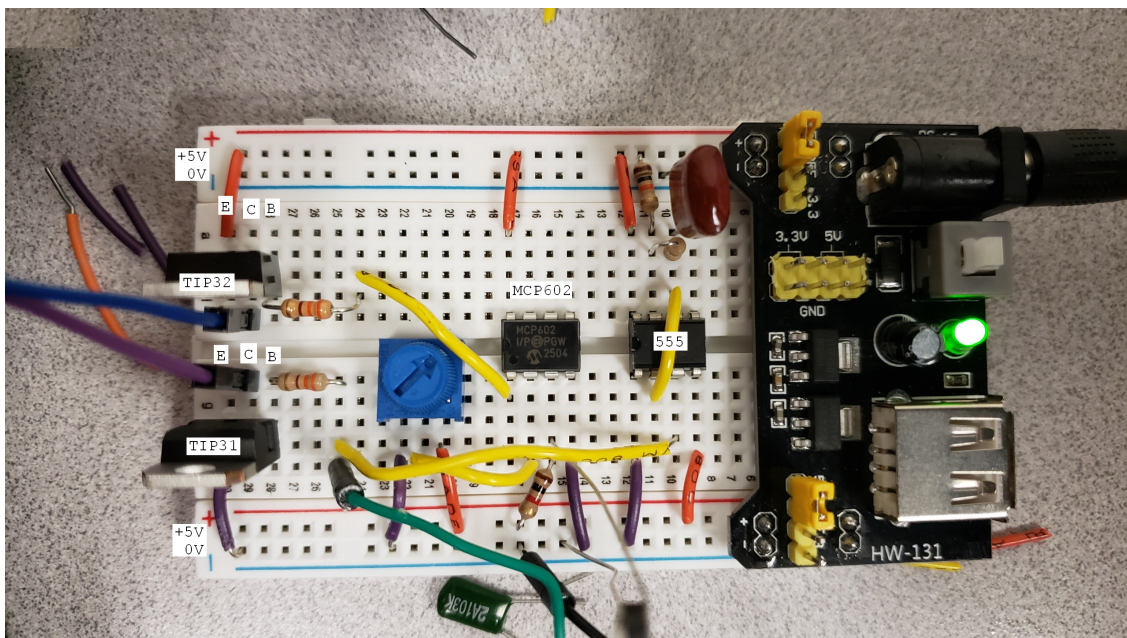
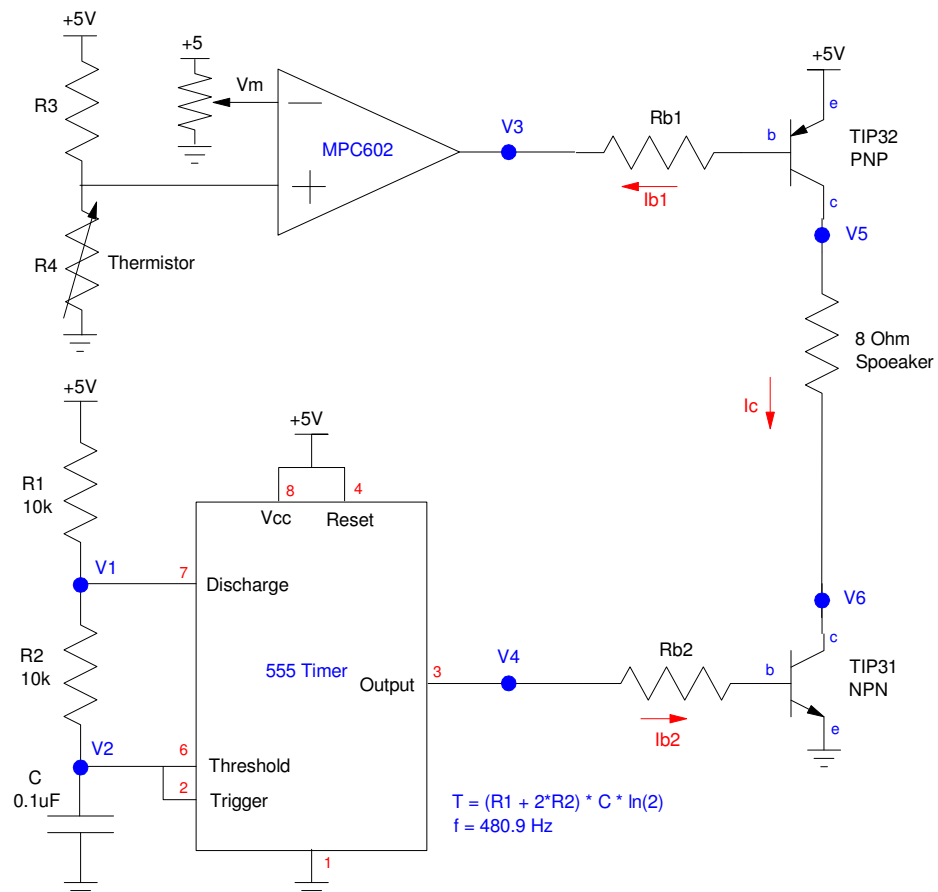
        I3(i+1) = I3(i) + dI3*dt;
        V2(i+1) = V2(i) + dV2*dt;
    end

    plot(t*1000,V0,'b',t*1000,V2,'r');
    xlabel('Time (ms)')
    pause(0.1);
end
```

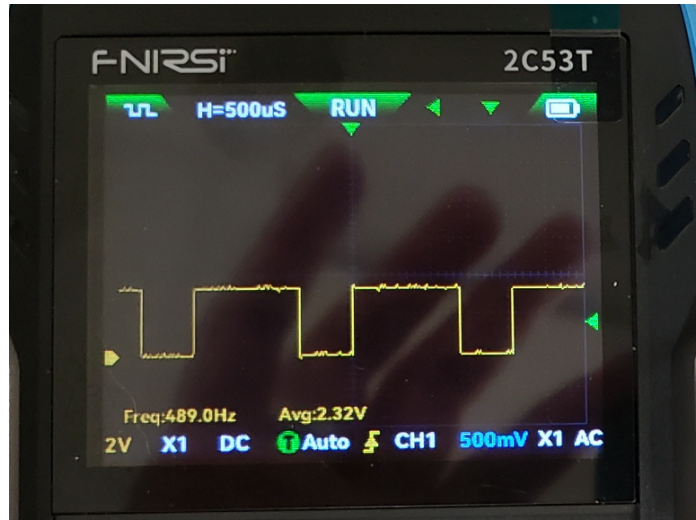
Lab

13) Build the following circuit

- Include a photo of your breadboard circuit for full credit



555 Timer outputs a square wave



Comparator switches as the temperature goes up and down

- R = 1k (hot) V3 = 473mV
- R = 10k (cold) V3 = 5V

NPN switch works

- When hot, the speaker turns on and off

PNP switch works

- When cold, the PNP remains off (no sound)

