ECE 320 - Homework #7

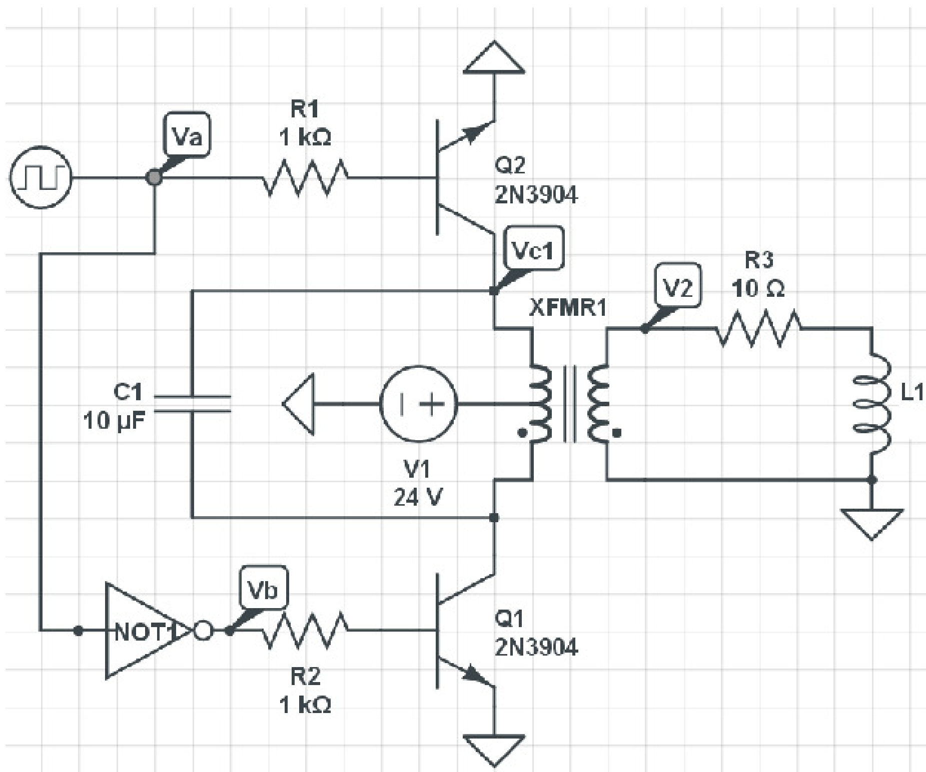
DC to AC, SCR. Due Monday, February 28th

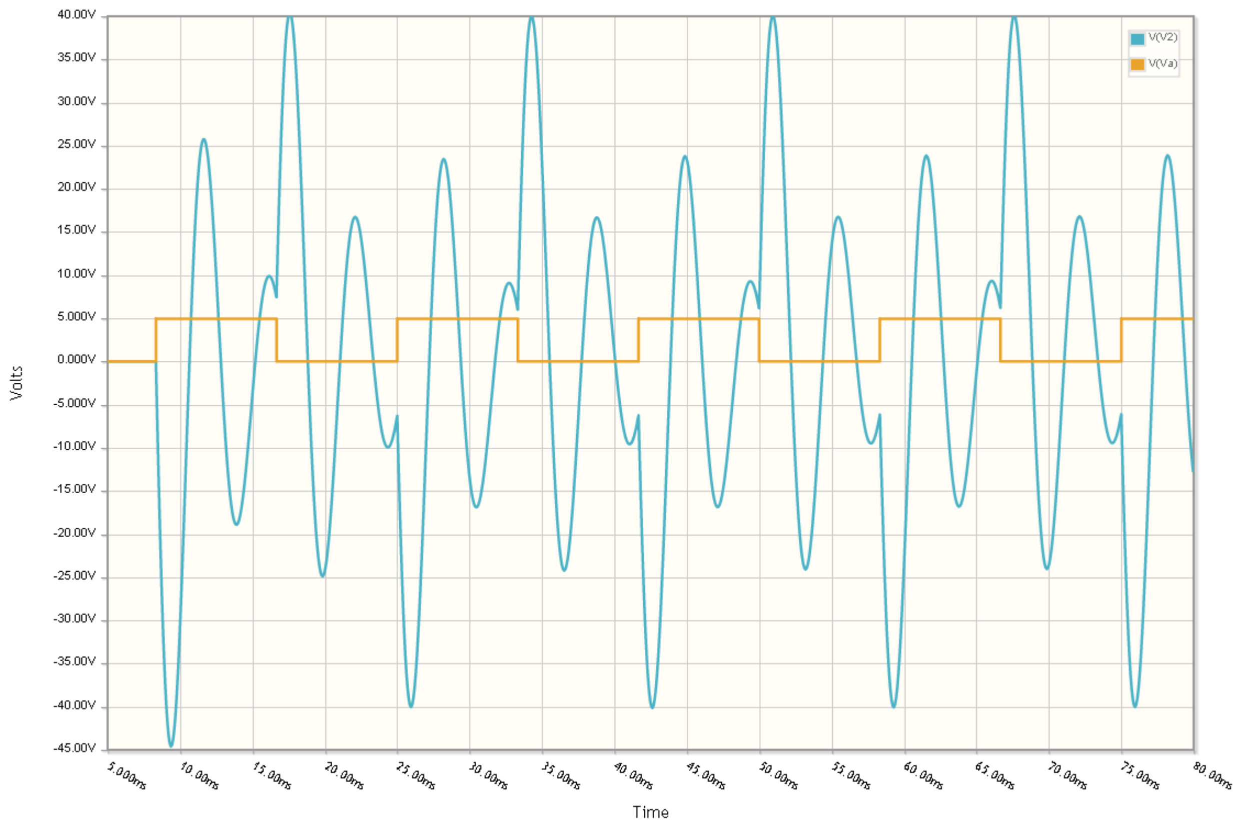
DC to AC

1) Let L1 = 200mH

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

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




V(V2)
V(Va)
40.00V
35.00V
30.00V
25.00V
20.00V
15.00V
10.00V
5.000V
0.000V
-5.000V
-10.00V
-15.00V
-20.00V
-25.00V
-30.00V
-35.00V
-40.00V
-45.00V
Volts
5.000ms
10.00ms
15.00ms
20.00ms
25.00ms
30.00ms
35.00ms
40.00ms
45.00ms
50.00ms
55.00ms
60.00ms
65.00ms
70.00ms
75.00ms
80.00ms
Time

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

For resonance, ideally

$$\left(\frac{1}{LC}\right) = \omega_0^2$$

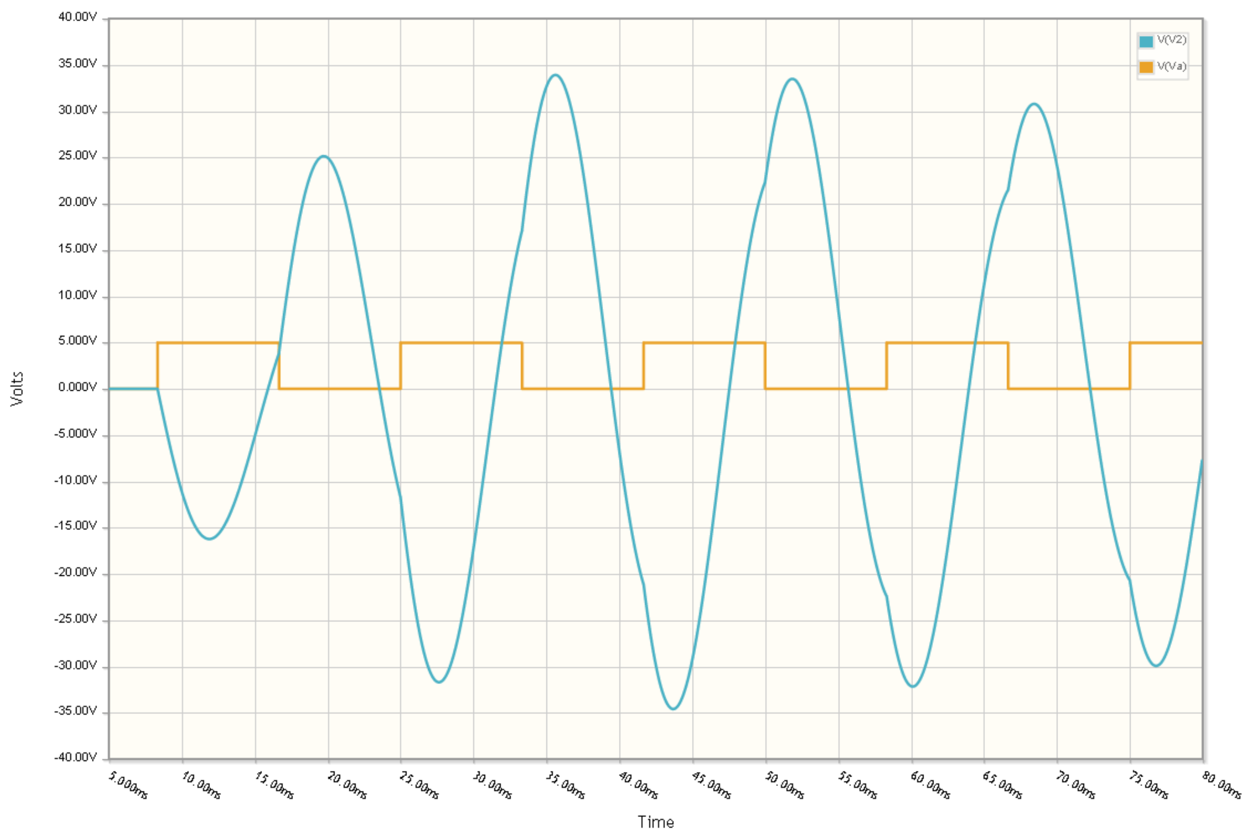
$$\left(\frac{1}{(0.1H)(C)}\right) = (2\pi \cdot 60Hz)^2$$

$$C = 70.3\mu F$$

Trial and error adjustment results in

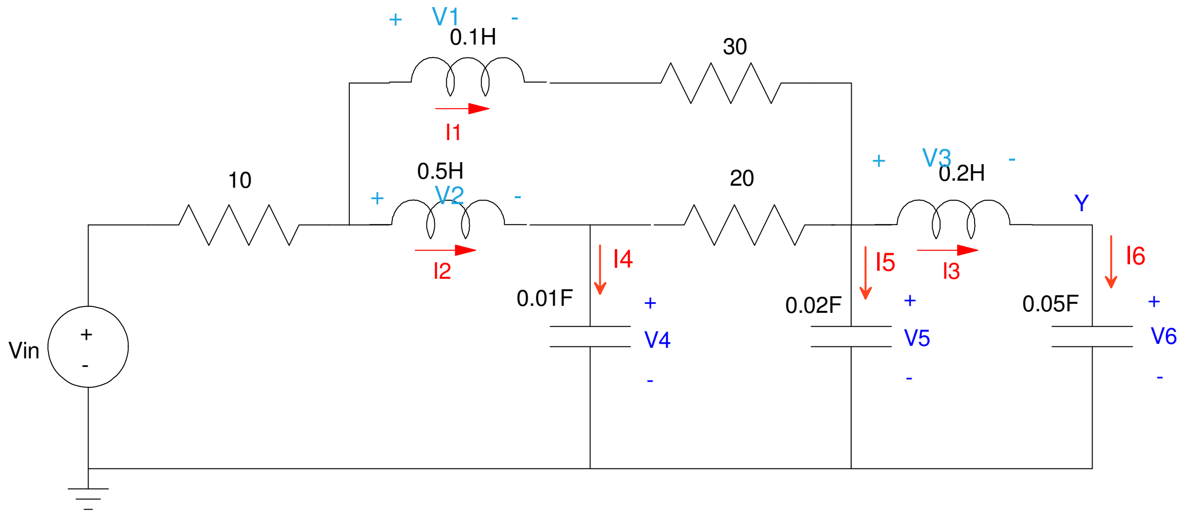
C = 100uF

This isn't a prefect sine wave at V2, but it's pretty close (meaning the harmonics are fairly small)



Circuits and Differential Equations

3) Write the differential equations that describe the following circuit



$$V_1 = 0.1\dot{I}_1 = V_{in} - 10(I_1 + I_2) - 30I_1 - V_5$$

$$V_2 = 0.5\dot{I}_2 = V_{in} - 10(I_1 + I_2) - V_4$$

$$V_3 = 0.2\dot{I}_3 = V_5 - V_6$$

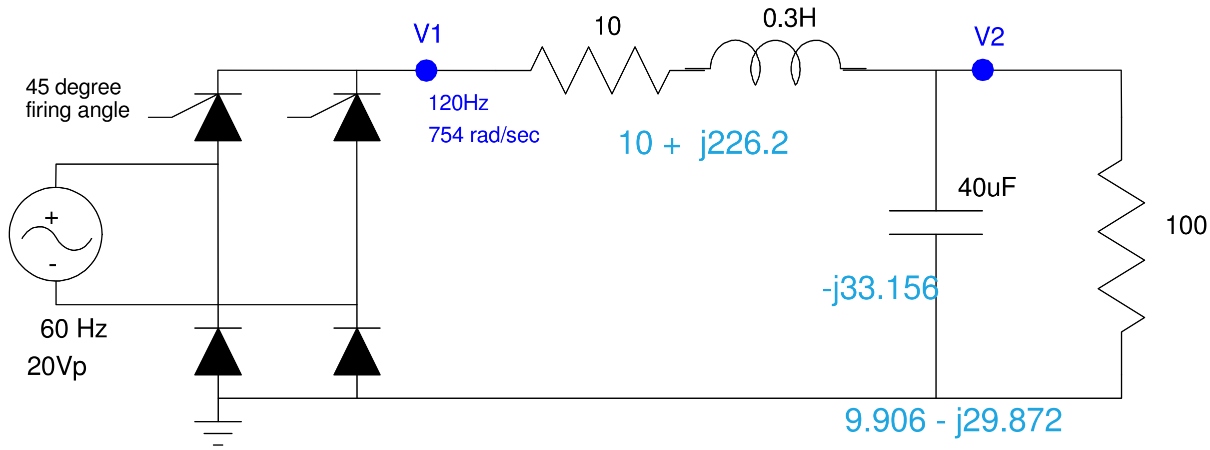
$$I_4 = 0.01\dot{V}_4 = I_2 - \left(\frac{V_4 - V_5}{20}\right)$$

$$I_5 = 0.02\dot{V}_5 = \left(\frac{V_4 - V_5}{20}\right) + I_1 - I_3$$

$$I_6 = 0.05\dot{V}_6 = I_3$$

SCR

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



SCR: Problem 4 - 6

DC Analysis

$$V_1(DC) = \left(\frac{2V_p\cos\theta}{\pi}\right) - 1.4 \qquad \textit{correct equation}$$

$$V_1(DC) = \left(\frac{2\cdot 20\cdot\cos\left(45^0\right)}{\pi}\right) - 1.4$$

$$V_1(DC) = 7.603V$$

$$V_2(DC) = \left(\frac{100}{100+10}\right)\cdot 7.603V$$

$$V_2(DC) = 6.911V$$

AC Analysis

$$V_1(AC) = 20V\cdot(1+\sin(45^0))$$

$$V_1(AC) = 34.142V_{pp}$$

$$V_2(AC) = \left(\frac{(9.906-j29.872)}{(9.906-j29.872)+(10+j226.2)}\right)\cdot 34.142V_{pp}$$

$$V_2(AC) = 5.445V_{pp}$$

5) Change this circuit so that

- The voltge at V2 is 9.00V (DC)
- With a ripple of 1.00Vpp

$$V_2(DC) = \left(\frac{100}{100+10}\right) V_1(DC)$$

$$V_1(DC) = \left(\frac{110}{100}\right) 9.00V$$

$$V_1(DC) = 9.9V$$

For the firing angle

$$V_1(DC) = 9.9V = \left(\frac{2 \cdot 20 \cdot \cos\theta}{\pi}\right) - 1.4$$

$$\theta = 27.439^0$$

For the ripple

$$V_1(AC) = 20V \cdot (1 + \sin(27.439^0))$$

$$V_1(AC) = 29.216V_{pp}$$

If C = 0, the ripple is

$$V_2(AC) = \left(\frac{100}{(100)+(10+j226.2)}\right) \cdot 29.216V_{pp}$$

$$V_2(AC) = 11.615V_{pp}$$

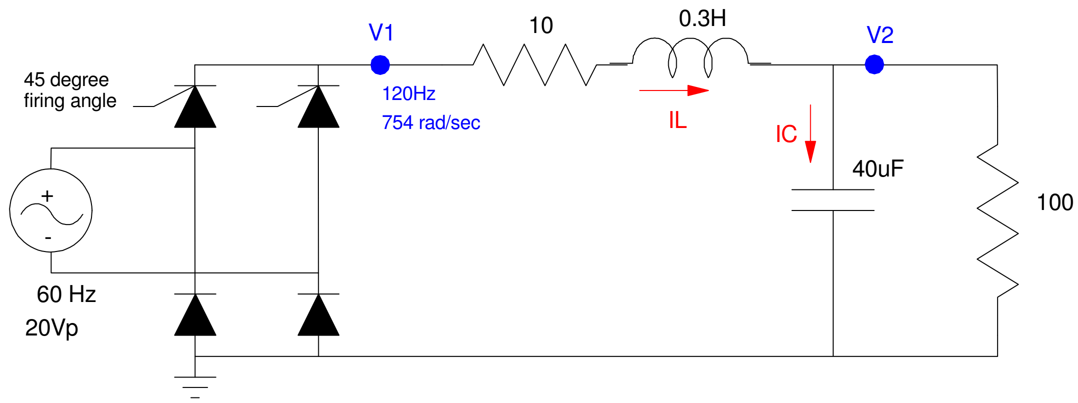
For a ripple of 1.00Vpp

$$\left|\frac{1}{j\omega C}\right| = \left(\frac{1V_{pp}}{11.615V_{pp}}\right) 100\Omega = 8.61\Omega$$

$$C = 154\mu F$$

6) Simulate this circuit in Matlab by

- Writing the differential eqautions which describe this circuit (state variables: IL and Vc)
- Specify V1(t) as a full-wave rectified sine wave, clipped at 45 degrees (from problem #4)
- Use numerical integration to find V2(t)



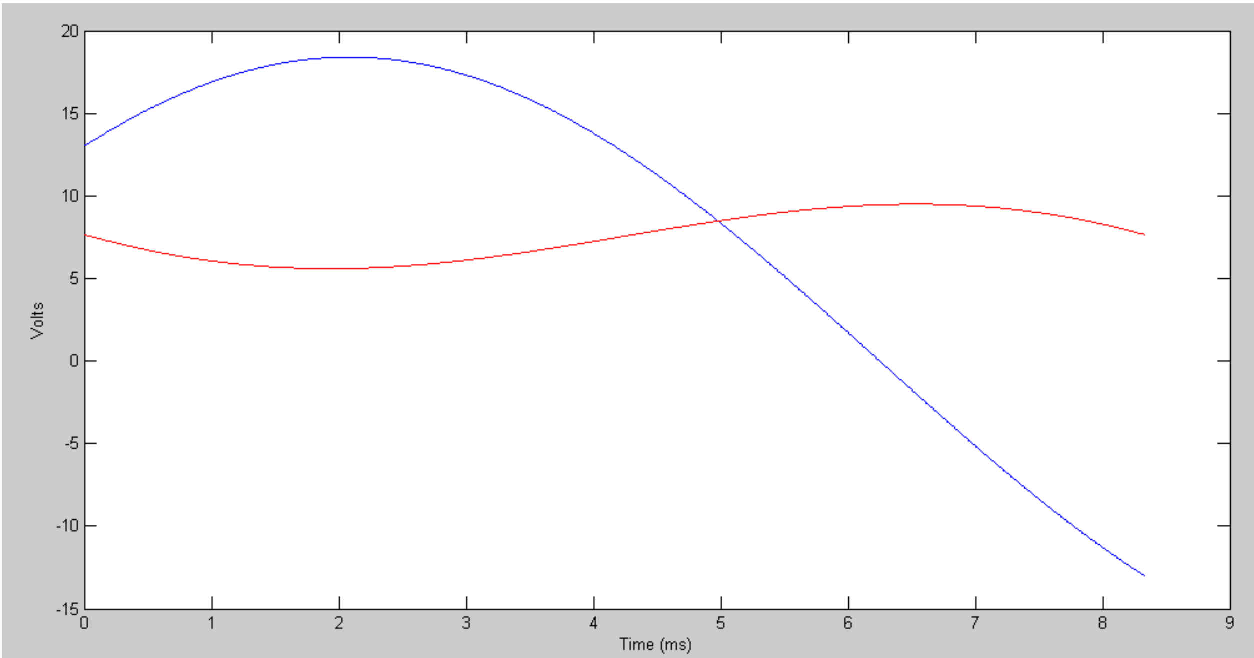
$$V_L = L\dot{I}_L = V_1 - 10I_L - V_c$$

$$I_c = C\dot{V}_c = I_L - \left(\frac{V_c}{100}\right)$$

Matlab Code

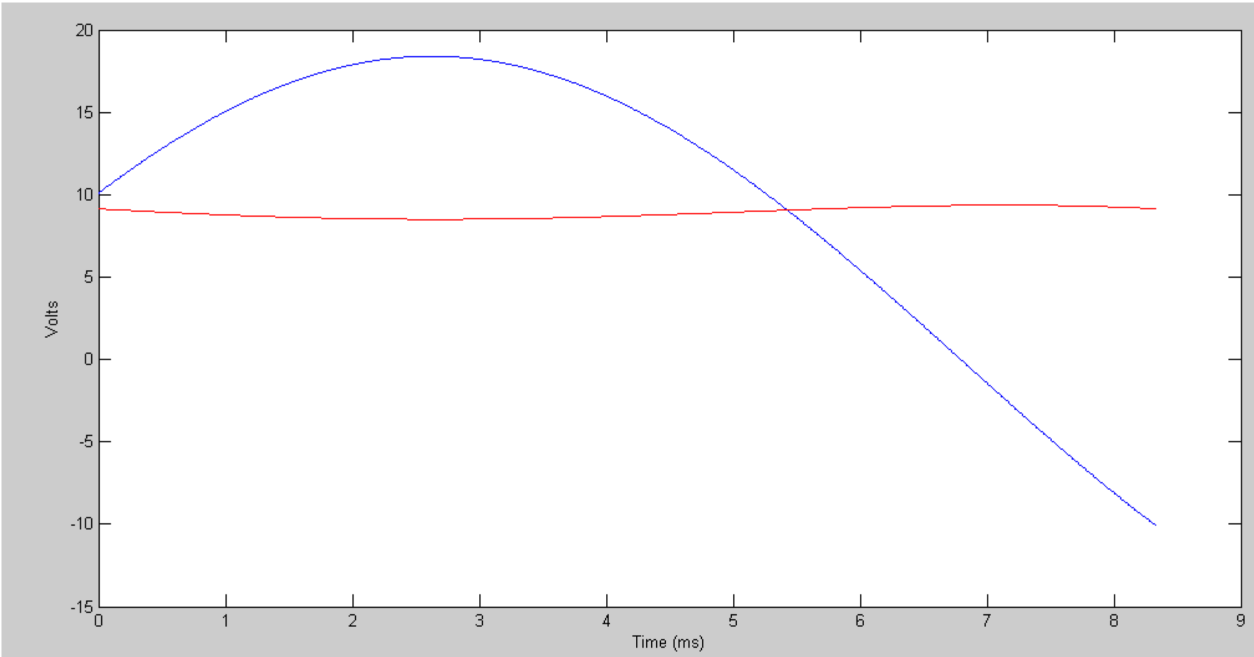
```
t = [0:0.001:1]';
V1 = 20*sin(t*pi + 45*pi/180) - 1.4;
VC = 0*t;
IL = 0*t;
npt = length(t);

t = t/120;
dt = t(2) - t(1);

C = 40e-6;
R = 100;
L = 0.3;

for n=1:40

    VC(1) = VC(npt);
    IL(1) = IL(npt);

    for i=1:npt-1
        dVC = ( IL(i) - VC(i)/R ) / C;
        dIL = ( V1(i) - 10*IL(i) - VC(i) ) / L;

        VC(i+1) = VC(i) + dVC * dt;
        IL(i+1) = IL(i) + dIL * dt;
    end

    plot(t, V1, t, VC);
    pause(0.1);
end

plot(t*1000, V1, 'b', t*1000, VC, 'r');
xlabel('Time (ms)');
ylabel('Volts');
```

Simulation Results: Problem #4




```
>> DC = mean(VC)

DC =     6.9249 V            vs 6.911V calculated

>> AC = max(VC) - min(VC)

AC =     4.2487 Vpp          vs. 5.445Vpp calculated
```

Simulation Results (problem #5)



Simulation Results for Vc:

```
>> mean(VC)

ans =     9.0087            vs. 9.00V calculated

>> max(VC) - min(VC)

ans =     0.8589 Vpp        vs. 1.00Vpp calculated
```