

ECE 320 - Homework #7

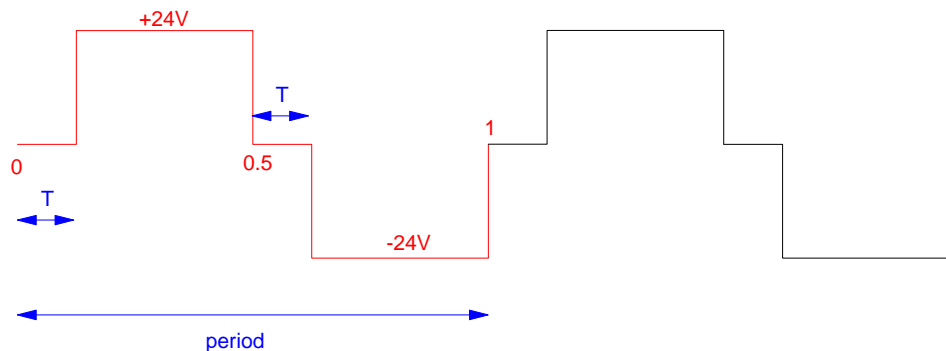
DC to AC Converters, SCR, Differential Amplifier. Due Monday, October 8st, 2018

DC to AC Converters.

1) Using an H-bridge with a 24.4V source, you can generate the waveform shown below. From the lecture notes,

- If $T = 0$, the efficiency is 81% (81% of the energy in this waveform is in its 1st harmonic)
- If $T = 1/6$, the efficiency is 91.1%

What is the optimal value of T ? (i.e. what value maximizes the energy in the 1st harmonic?)



Start with something we know: if $T = 1/6$, the efficiency is 91%

```
t = [0:0.001:1]';
T = 1/6;
x = 24*(t<0.5-T) - 24*(t>0.5).*(t<1-T);
X1 = 2*mean(x .* exp(-j*2*pi*t));
eff = 0.5*abs(X1)^2 / mean(x.^2)
```

eff = 0.9111

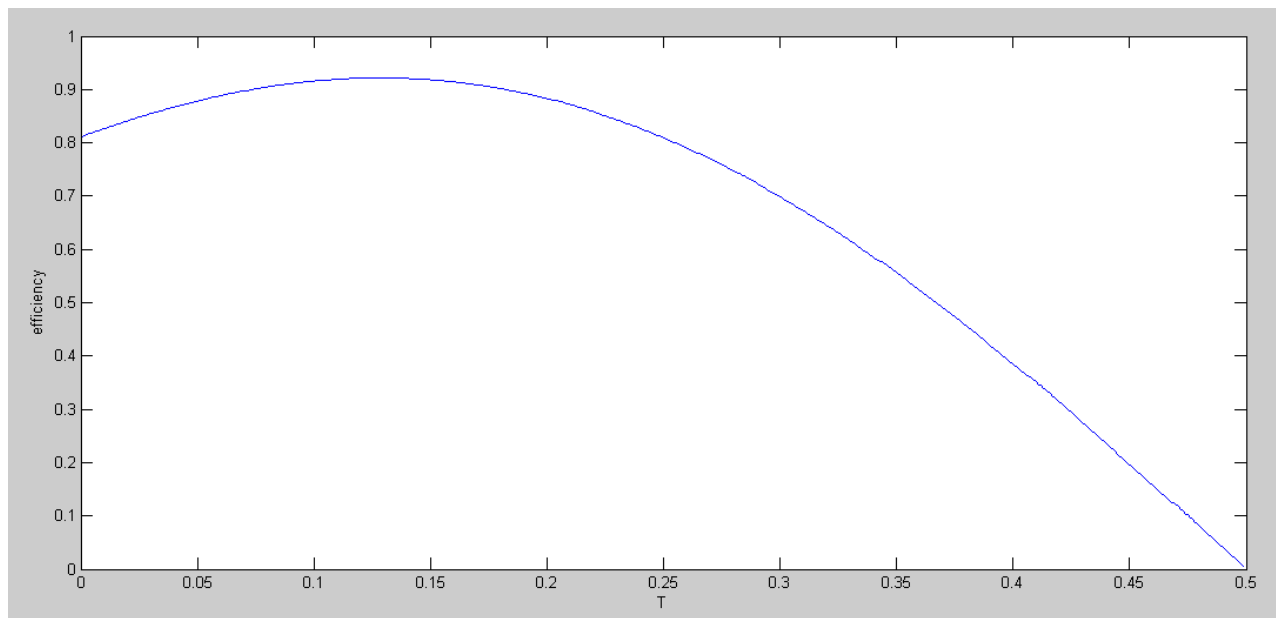
That checks. Now put this in a loop where we sweep T from 0 to 0.5

```
t = [0:0.001:1]';
X = [];
Y = [];

for i=1:499
    T = i/1000;
    x = 24*(t<0.5-T) - 24*(t>0.5).*(t<1-T);
    X1 = 2*mean(x .* exp(-j*2*pi*t));
    eff = 0.5*abs(X1)^2 / mean(x.^2)

    X = [X ; T];
    Y = [Y ; eff];
end

plot(X, Y)
```



Efficiency of DC to AC converter vs. off time (T)

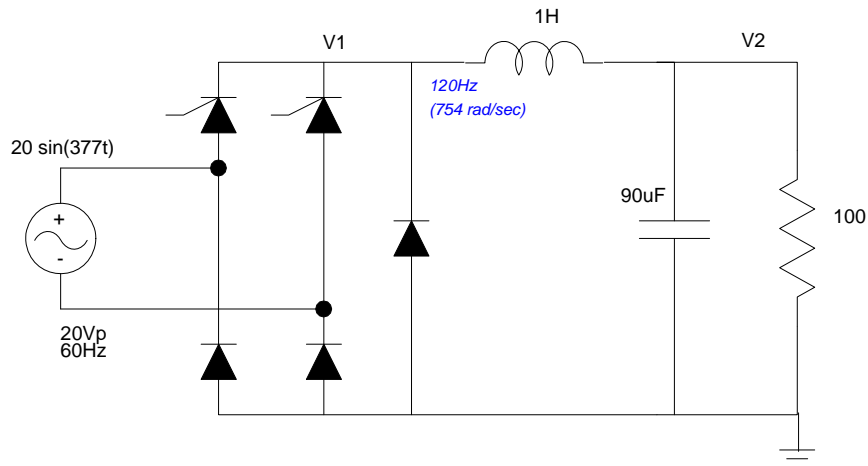
The peak is at

T = 0.128

efficiency = 0.9217

SCR:

2) Assume the following circuit has a firing angle of 47 degrees. Determine the voltages at V1 and V2 (DC and AC)

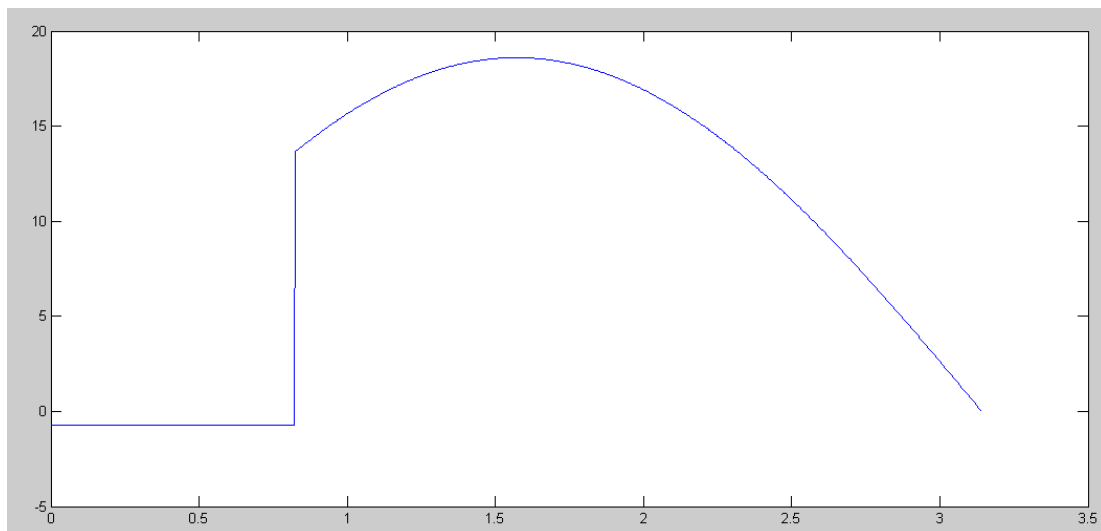


$V_1(t)$: This is

- A sine wave from 47 degrees to 180 degrees,
- -0.7V from 0 to 47 degrees

In Matlab:

```
>> V1 = 18.6 * sin(t) .* (t > 47/180*pi) - 0.7*(t < 47/180*pi);  
>> plot(t,V1)
```



```
>> DC = mean(V1)

DC =      9.7599

>> AC = max(V1) - min(V1)

AC =      19.3000  Vpp
```

V2(DC)

$$V2(DC) = 9.7599V \quad (\text{same as } V1)$$

V2(AC)

$$\omega = 754 \frac{\text{rad}}{\text{sec}} = 120\text{Hz}$$

$$L \rightarrow j754\Omega$$

$$C \rightarrow \frac{1}{j\omega C} = -j14.7\Omega$$

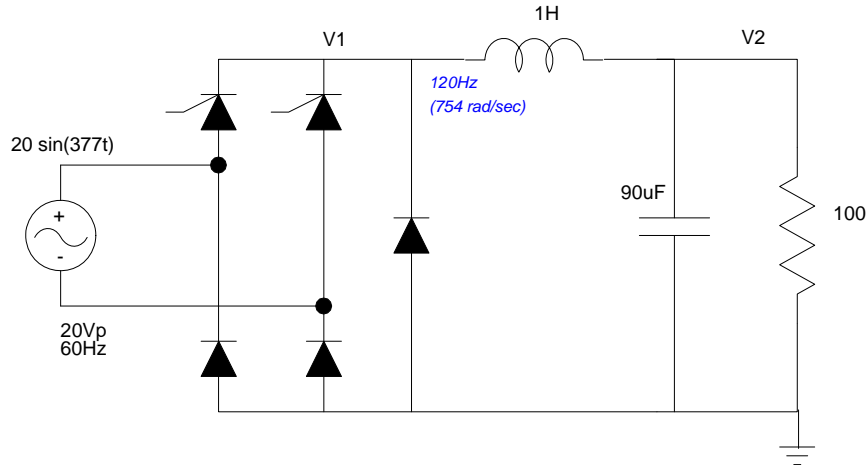
$$100\Omega || -j14.7\Omega = 2.125 - j14.423$$

$$V_2 = \left(\frac{(2.125 - j14.423)}{(2.125 - j14.423) + (j754)} \right) \cdot 19.3V_{pp}$$

$$V_2 = 0.380V_{pp}$$

3) Determine R, L, and C, and firing angle so that the following SCR has

- A DC voltage of 5.00V at V2
- A peak-to-peak ripple of 200mVpp at V2, and
- Draws 100mA at V2.



To account for the -0.7V when the diodes are off, shift the output by +0.7V (so V1 goes 0V to 19.3). To make the output 5V (plus a 0.7V offset), the firing angle should be:

$$5.7V = \frac{19.3}{\pi}(1 + \cos \theta)$$

$$\theta = 94.13^\circ$$

To draw 100mA at 5V, the output resistance should be

$$R = \frac{5V}{100mA} = 50\Omega$$

To reduce the ripple (19.3Vpp at V1) to 200mVpp at V2, let L reduce the ripple 10x (somewhat arbitrary)

$$\omega L = 10R = 500$$

$$L = \frac{500}{754} = 0.663H$$

This reduces the ripple at V2 to 1.93Vpp. To reduce it to 100mVpp, add a capacitor

$$\frac{1}{\omega C} = \left(\frac{100mV}{1.93V} \right) 50\Omega$$

$$\frac{1}{\omega C} = 2.59\Omega$$

$$C = 512\mu F$$

Answer:

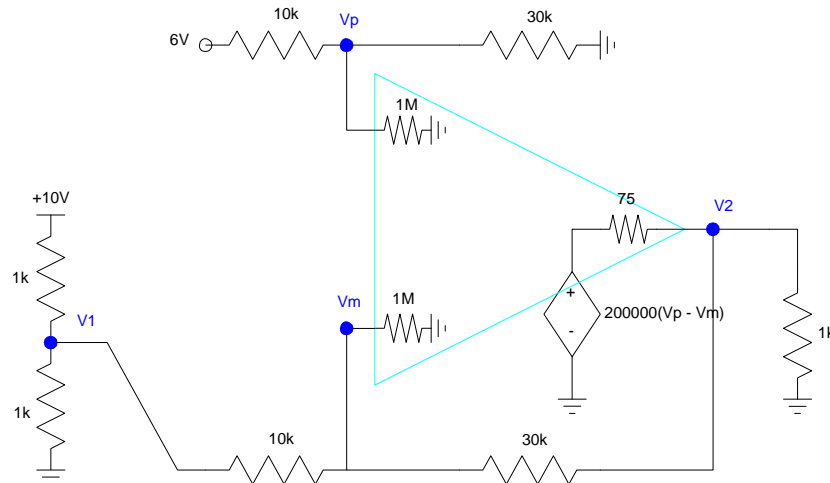
94 degree firing angle

R = 50 Ohms, L = 0.633H, C = 512uF

Differential Amplifier

4) For the following circuit

- Write the voltage node equations
- Solve for the voltages using Matlab (or similar program)



$$\left(\frac{V_1-10}{1k}\right) + \left(\frac{V_1}{1k}\right) + \left(\frac{V_1-V_m}{10k}\right) = 0$$

$$\left(\frac{V_m-V_1}{10k}\right) + \left(\frac{V_m}{1M}\right) + \left(\frac{V_m-V_2}{30k}\right) = 0$$

$$\left(\frac{V_2-V_3}{75}\right) + \left(\frac{V_2-V_m}{30k}\right) + \left(\frac{V_2}{1k}\right) = 0$$

$$\left(\frac{V_p-6}{10k}\right) + \left(\frac{V_p}{1M}\right) + \left(\frac{V_p}{30k}\right) = 0$$

$$V_3 = 200,000(V_p - V_m)$$

Solve: Place in matrix form

$$\begin{bmatrix} \left(\frac{1}{1k} + \frac{1}{1k} + \frac{1}{10k}\right) & 0 & 0 & 0 & \left(\frac{-1}{10k}\right) \\ \left(\frac{-1}{10k}\right) & \left(\frac{-1}{30k}\right) & 0 & 0 & \left(\frac{1}{10k} + \frac{1}{1M} + \frac{1}{1k}\right) \\ 0 & \left(\frac{1}{75} + \frac{1}{30k} + \frac{1}{1k}\right) & \left(\frac{-1}{75}\right) & 0 & \left(\frac{-1}{30k}\right) \\ 0 & 0 & 0 & \left(\frac{1}{10k} + \frac{1}{1M} + \frac{1}{30k}\right) & 0 \\ 0 & 0 & 1 & -200000 & 200000 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_p \\ V_m \end{bmatrix} = \begin{bmatrix} \left(\frac{10}{1k}\right) \\ 0 \\ 0 \\ \left(\frac{6}{10k}\right) \\ 0 \end{bmatrix}$$

Solve using Matlab

```
>> a1 = [1/1000+1/1000+1/10000, 0, 0, 0, -1/10000];
>> a2 = [-1/10000, -1/30000, 0, 0, 1/10000+1/1e6+1/1e3];
>> a3 = [0, 1/75+1/30000+1/1000, -1/75, 0, -1/30000];
>> a4 = [0, 0, 0, 1/10000+1/1e6+1/30e3, 0];
>> a5 = [0, 0, 1, -200000, 200000];
```

```
>> A = [a1;a2;a3;a4;a5]
```

```
A =
```

```
1.0e+005 *
```

0.0000	0	0	0	-0.0000
-0.0000	-0.0000	0	0	0.0000
0	0.0000	-0.0000	0	-0.0000
0	0	0	0.0000	0
0	0	0.0000	-2.0000	2.0000

```
>> B = [10/1000;0;0;6/10000;0];
```

```
>> V = inv(A)*B
```

```
V1 4.9746
```

```
V2 3.0761
```

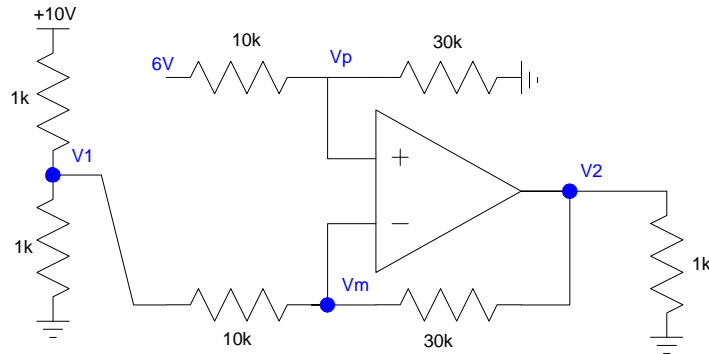
```
V3 3.3034
```

```
Vp 4.4665
```

```
Vm 4.4665
```

5) For the following circuit

- Write the voltage node equations
- Solve for the voltages



For an op-amp with negative feedback:

$$V_p = V_m$$

$$\left(\frac{V_1 - 10}{1k} \right) + \left(\frac{V_1}{1k} \right) + \left(\frac{V_1 - V_m}{10k} \right) = 0$$

$$\left(\frac{V_p - 6}{10k} \right) + \left(\frac{V_p}{30k} \right) = 0$$

$$\left(\frac{V_m - V_1}{10k} \right) + \left(\frac{V_m - V_2}{30k} \right) = 0$$

Solving in Matlab:

$$\begin{bmatrix} 0 & 0 & 1 & -1 \\ \left(\frac{1}{1k} + \frac{1}{1k} + \frac{1}{10k} \right) & 0 & 0 & \left(\frac{-1}{10k} \right) \\ 0 & 0 & \left(\frac{1}{10k} + \frac{1}{30k} \right) & 0 \\ \left(\frac{-1}{10k} \right) & \left(\frac{-1}{30k} \right) & 0 & \left(\frac{1}{10k} + \frac{1}{30k} \right) \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_p \\ V_m \end{bmatrix} = \begin{bmatrix} 0 \\ \left(\frac{10}{1k} \right) \\ \left(\frac{6}{10k} \right) \\ 0 \end{bmatrix}$$

```
>> a1 = [0,0,1,-1];
>> a2 = [1/1e3+1/1e3+1/1e4,0,0,-1/1e4];
>> a3 = [0,0,1/10e3+1/30e3,0];
>> a4 = [-1/10e3,-1/30e3,0,1/10e3+1/30e3];
>> A = [a1;a2;a3;a4];
>> B = [0;10/1e3;6/10e3;0];
>> V = inv(A)*B
```

	problem 5	problem 4
V1	4.9762	4.9746
V2	3.0714	3.0761
Vp	4.5000	4.4665
Vm	4.5000	4.4665