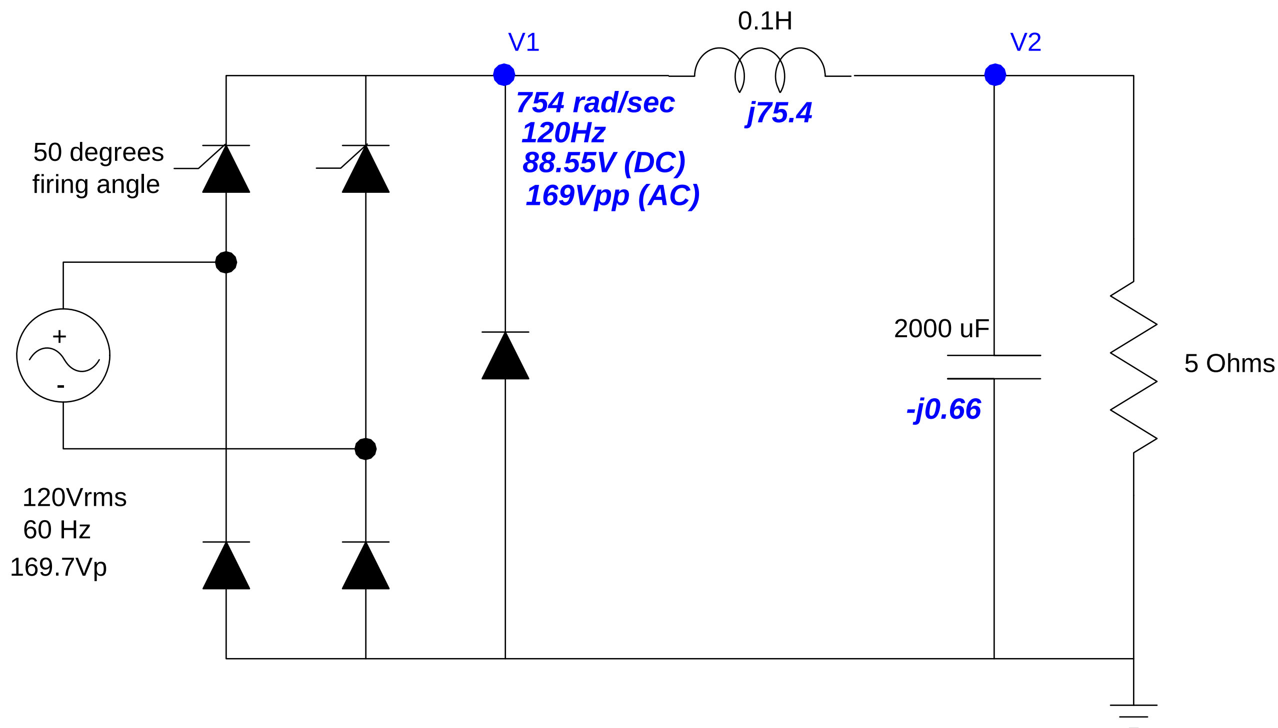
ECE 320 - Homework #7

SCR, Op-Amp Amplifiers. Due Monday, February 26th, 2018

SCR

1) Assume a firing angle of 50 degrees. Determine the voltages (DC and AC) at V1 and V2.



DC:

$$V_1 \approx \frac{1}{\pi}\left(\int_0^{0.8272}(-0.7)\cdot dt + \int_{0.8272}^{\pi} 169.7\sin(t)\cdot dt\right)$$

$$V_1 \approx \frac{1}{\pi}(-0.579 + 169.7(-\cos(t))_{0.8272}^{\pi})$$

$$V_1 \approx -0.1843 + 54.01(1 + \cos(50^0))$$

$$V_1 \approx 88.55V$$

note: The voltage is large enough that the 0.7V drop from the diode for 50 degrees doesn't have much effect on the output. You could also use

$$V_1 \approx \left(\frac{1+\cos\theta}{\pi}\right)V_p$$

$$V_1 \approx 88.74V$$

AC:

$$\max(V_1) = 169.7 - 1.4 = 168.3V$$

$$\min(V_1) = -0.7V$$

$$V_{1pp} = 169V_{pp}$$

AtV2:

$$\omega = 120Hz = 754\tfrac{rad}{\sec}$$

$$L \rightarrow j\omega L = j75.4\Omega$$

$$C \rightarrow \tfrac{1}{j\omega C} = -j0.66\Omega$$

R in parallel with C is

$$\left(\tfrac{1}{5} + \tfrac{1}{-j0.66}\right)^{-1} = 0.0864 - j0.6571\Omega$$

By voltage division

$$V_{2pp} = \left(\tfrac{(0.0864-j0.6571)}{(0.0864-j0.6571)+j75.4}\right)V_{1pp}$$

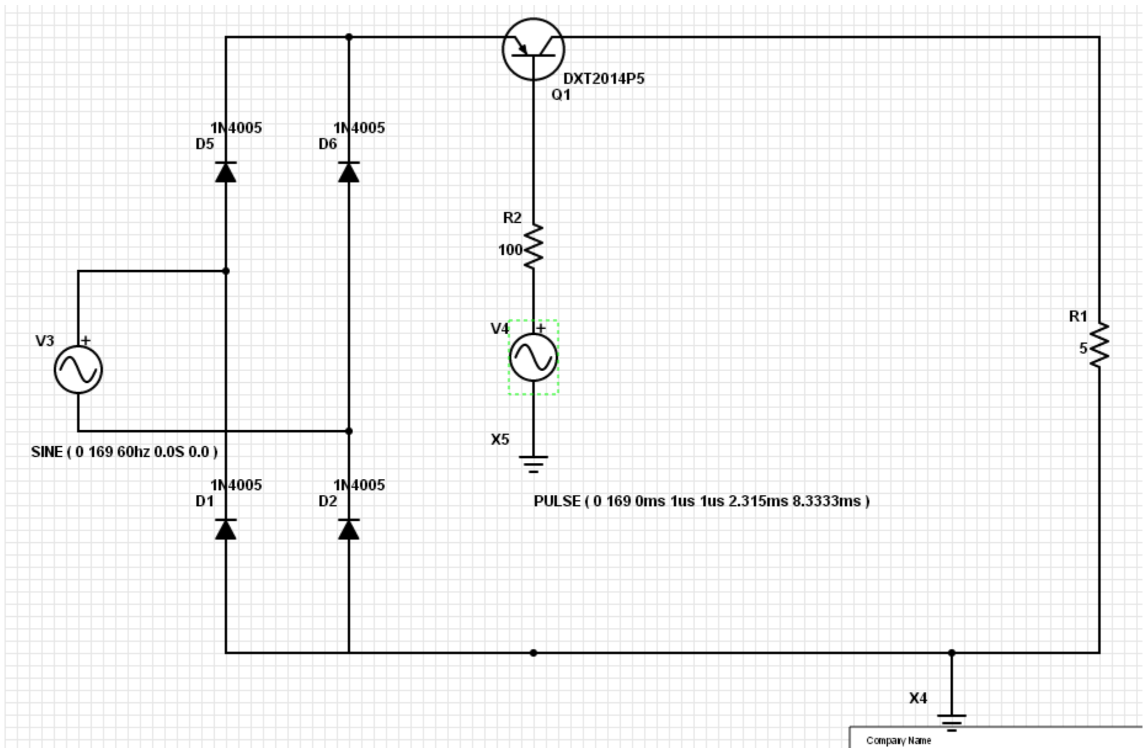
$$V_{2pp} = 1.486\angle -172^0$$

All we care about is the amplitude

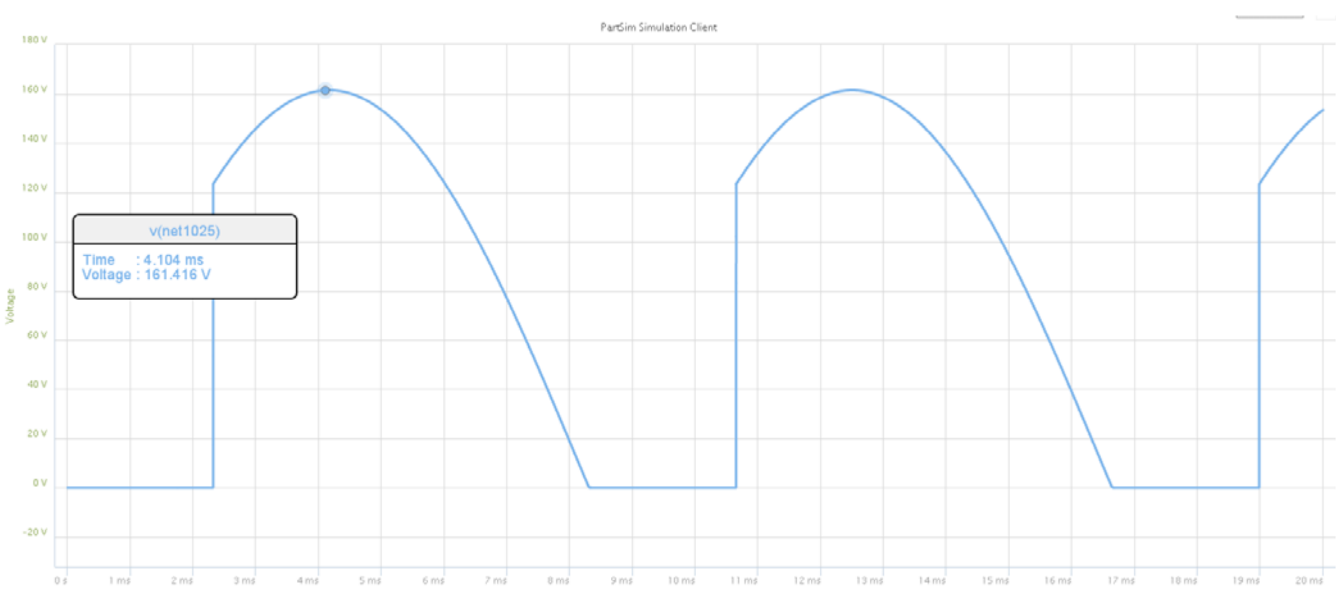
$$V_2 = 1.486V_{pp}$$

2) (Not Assigned). Use a transistor as a switch to turn on and off a full-wave rectified sine wave.

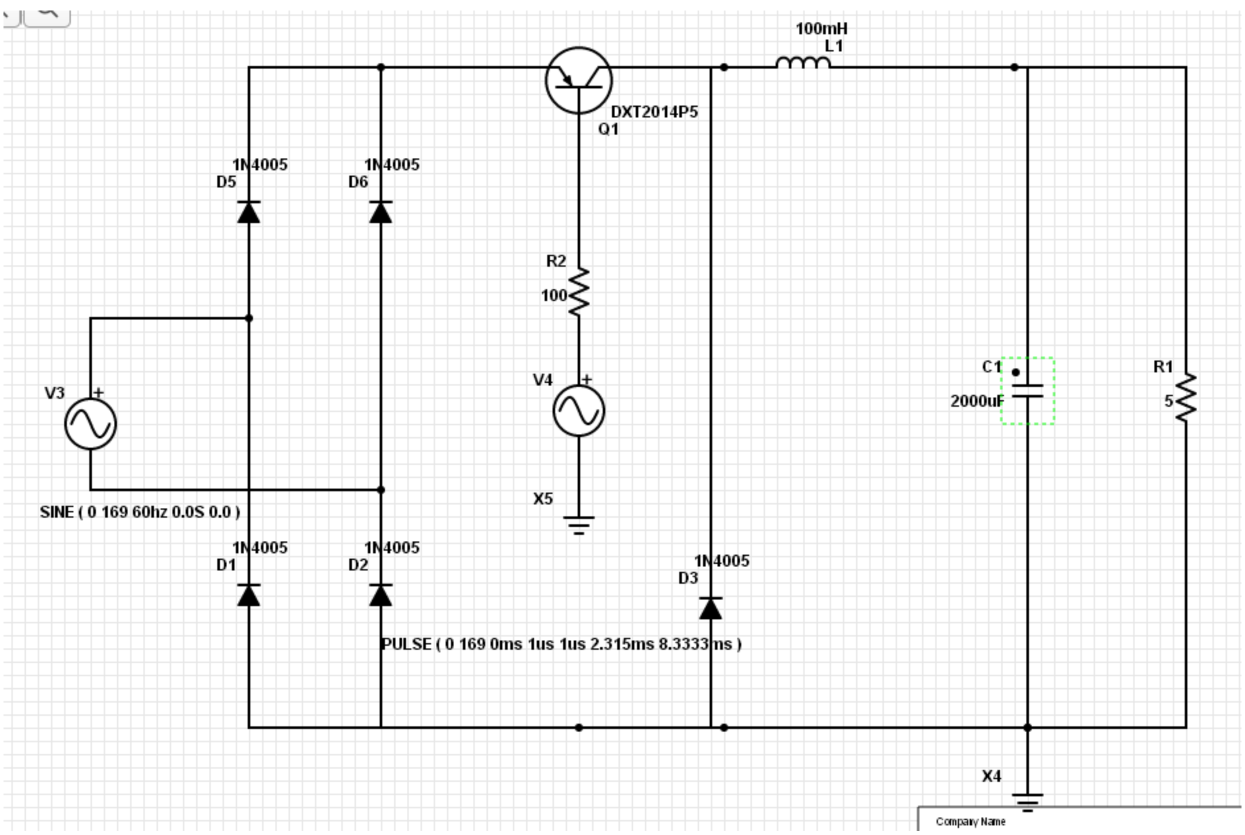
- NPN transistors act as switches to ground (+Vcc = on, 0V = off)
- PNP transistors act as switches to power: (+Vcc = off, 0V = on)

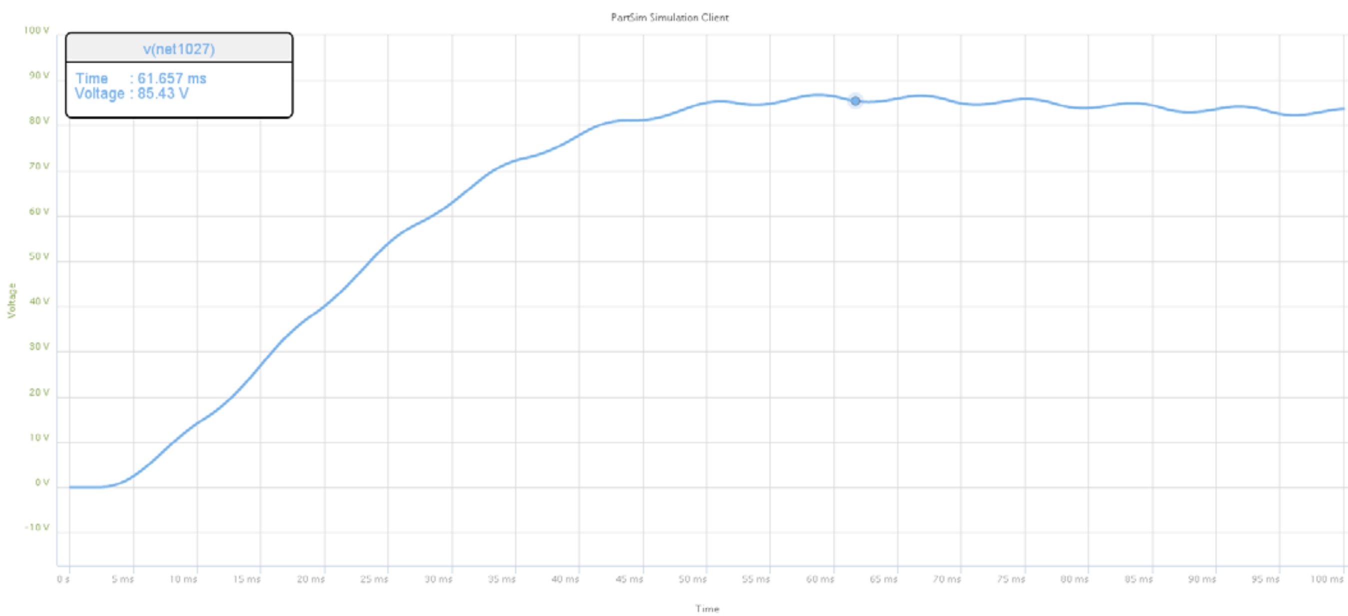


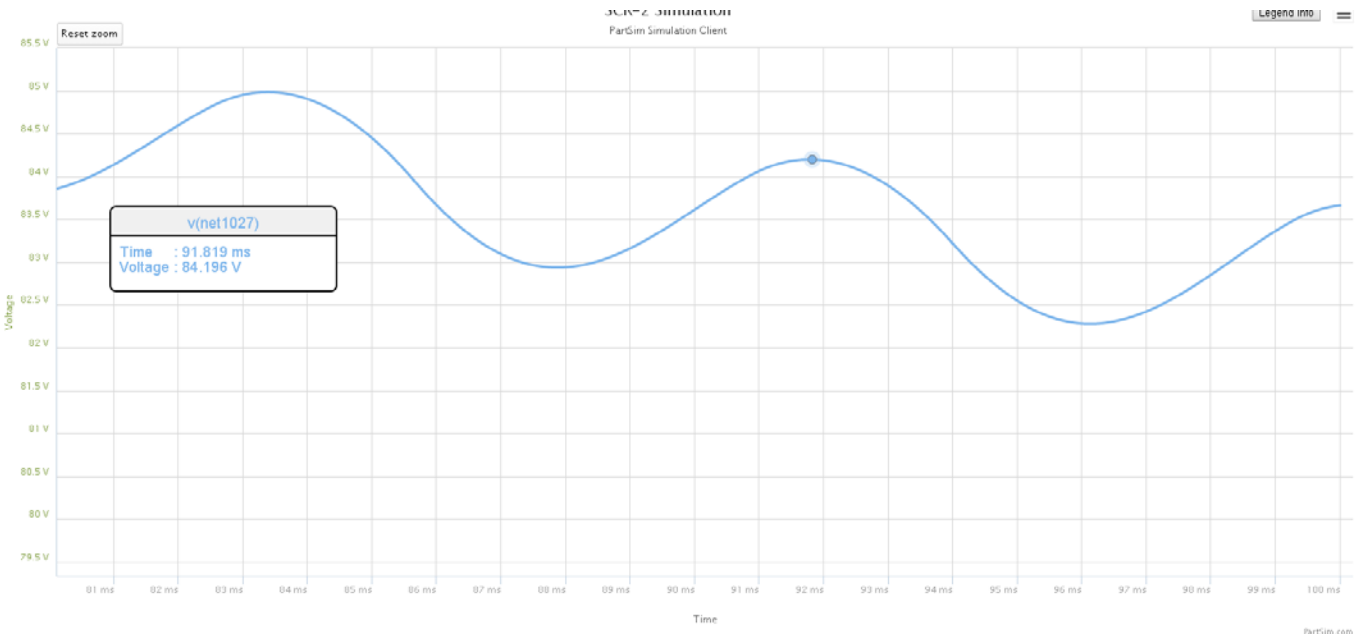
For a resistive load, this results in ...



Looks good: Adding in C and L


100mH
L1
DXT2014P5
Q1
1N4005
D5
1N4005
D6
R2
100
V3
V4
C1
2000uF
R1
5
X5
SINE (0 169 60hz 0.0S 0.0)
1N4005
D1
1N4005
D2
1N4005
D3
PULSE (0 169 0ms 1us 1us 2.315ms 8.3333ms)
X4
Company Name


PartSim Simulation Client
v(net1027)
Time : 61.657 ms
Voltage : 85.43 V
100 V
90 V
80 V
70 V
60 V
50 V
40 V
30 V
20 V
10 V
0 V
-10 V
Voltage
0 s
5 ms
10 ms
15 ms
20 ms
25 ms
30 ms
35 ms
40 ms
45 ms
50 ms
55 ms
60 ms
65 ms
70 ms
75 ms
80 ms
85 ms
90 ms
95 ms
100 ms
Time



V2(DC) = 83V (approx)

V2(AC) = 1.22Vpp (approx)

3) Determine the firing angle, C, and L so that

The DC voltage at the load is 50V

$$V_1 \approx \left(\frac{1+\cos\theta}{\pi}\right) V_p$$

$$50 \approx \left(\frac{1+\cos\theta}{\pi}\right) 169$$

$$\theta = 94.04^0$$

The ripple at the load is 1Vpp

$$\max(V_1) = 169.7 \cdot \sin(94.04^0) - 1.4V$$

$$\max(V_1) = 167.9V$$

$$\min(V_1) = -0.7V$$

$$V_{1pp} = 168.6V_{pp}$$

Pick L to make the ripple 20x smaller (somewhat arbitrary)

$$|j\omega L| = 20R$$

$$\omega L = 100$$

$$L = \frac{100}{754} = 132.6mH$$

This should result in a ripple at V2 that is 20x smaller

$$V_2 = \frac{168.6}{20} = 8.42V_{pp}$$

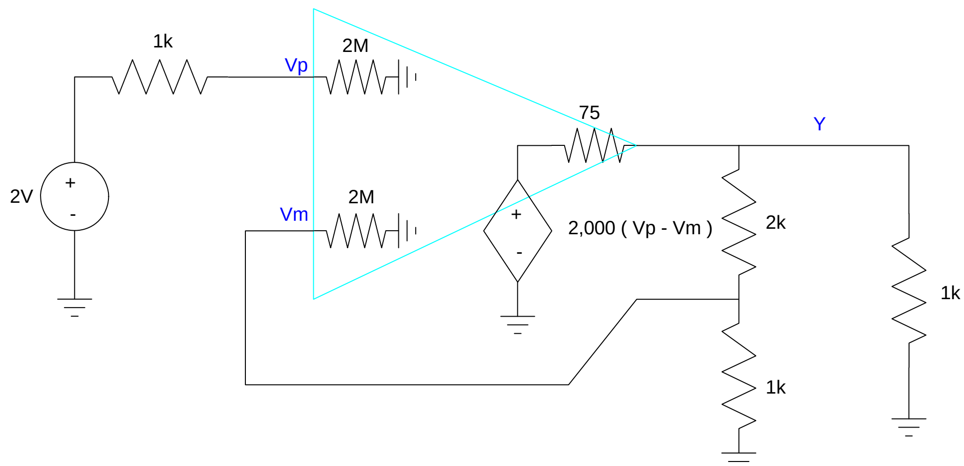
To bring the ripple down to 1Vpp, add a capacitor which is 8.42 times smaller than R

$$\frac{1}{\omega C} = \frac{1}{8.42} \cdot 5\Omega$$

$$\frac{1}{\omega C} = 0.5932$$

$$C = 2235\mu F$$

4) For the following op-amp circuit with a gain of 'only' 2000:



a) Write the voltage node equations

$$\left(\frac{V_p - 2}{1k}\right) + \left(\frac{V_p}{2M}\right) = 0$$

$$\left(\frac{V_m}{2M}\right) + \left(\frac{V_m}{1k}\right) + \left(\frac{V_m - Y}{2k}\right) = 0$$

$$\left(\frac{Y - V_3}{75}\right) + \left(\frac{Y - V_m}{2k}\right) + \left(\frac{Y}{1k}\right) = 0$$

$$V_3 = 2000(V_p - V_m)$$

b) Solve for the voltages at Vp, Vm, and Y

Multiply each equation by 1000 and separate terms

$$1.0005 V_p = 2$$

$$1.5005 V_m - 0.5 Y = 0$$

$$14.8333 Y - 13.333 V_3 - 0.5 V_m = 0$$

$$V_3 - 2000 V_p + 2000 V_m = 0$$

Place in matrix form

$$\begin{bmatrix} 1.005 & 0 & 0 & 0 \\ 0 & 1.5005 & 0 & -0.5 \\ 0 & -0.5 & -13.333 & 14.8333 \\ -2000 & 2000 & 1 & 0 \end{bmatrix} \begin{bmatrix} V_p \\ V_m \\ V_3 \\ Y \end{bmatrix} = \begin{bmatrix} 2 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Solve

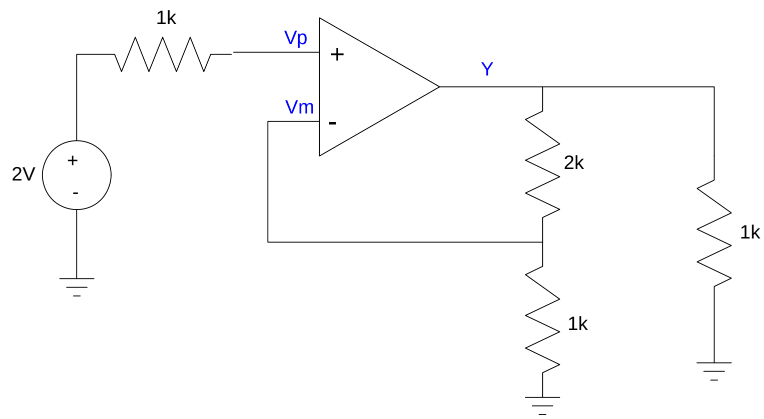
```
-->A = [1.005,0,0,0 ; 0,1.5005,0,-0.5 ; 0,-0.5,-13.3333,14.83333 ; -2000,2000,1,0]
 A  =

    1.005    0.         0.          0.
    0.       1.5005     0.        - 0.5
```

```
    0.     - 0.5     - 13.3333    14.83333
  - 2000.    2000.     1.         0.

-->B = [2;0;0;0]
 B  =

    2.
    0.
    0.
    0.

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

    1.9900498  Vp
    1.9867705  Vm
    6.5585677  V3
    5.9622982  Y
```

5) For the following op-amp circuit

- a) Write the voltage node equations
- b) Solve for the voltages at Vp, Vm, and Y

Assume an ideal op-amp.



$$V_p = 2V$$

$$V_p = V_m$$

$$\left(\frac{V_m}{1k}\right) + \left(\frac{V_m - Y}{2k}\right) = 0$$

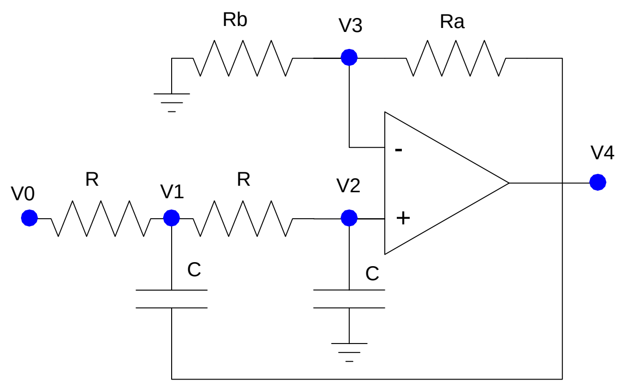
Solving

$$Y = \left(1 + \frac{2k}{1k}\right) 2V$$

$$Y = 6V$$

The previous answer was 5.9622V. About the same

6) Assume ideal op-amps. Write the voltage node equations for the following circuit



The impedance of a capacitor is $\frac{1}{Cs}$

$$V_3 = V_2$$

$$\left(\frac{V_1 - V_0}{R}\right) + \left(\frac{V_1 - V_2}{R}\right) + \left(\frac{V_1 - V_4}{1/Cs}\right) = 0$$

$$\left(\frac{V_2 - V_1}{R}\right) + \left(\frac{V_2}{1/Cs}\right) = 0$$

$$\left(\frac{V_3}{R_b}\right) + \left(\frac{V_3 - V_4}{R_a}\right) = 0$$