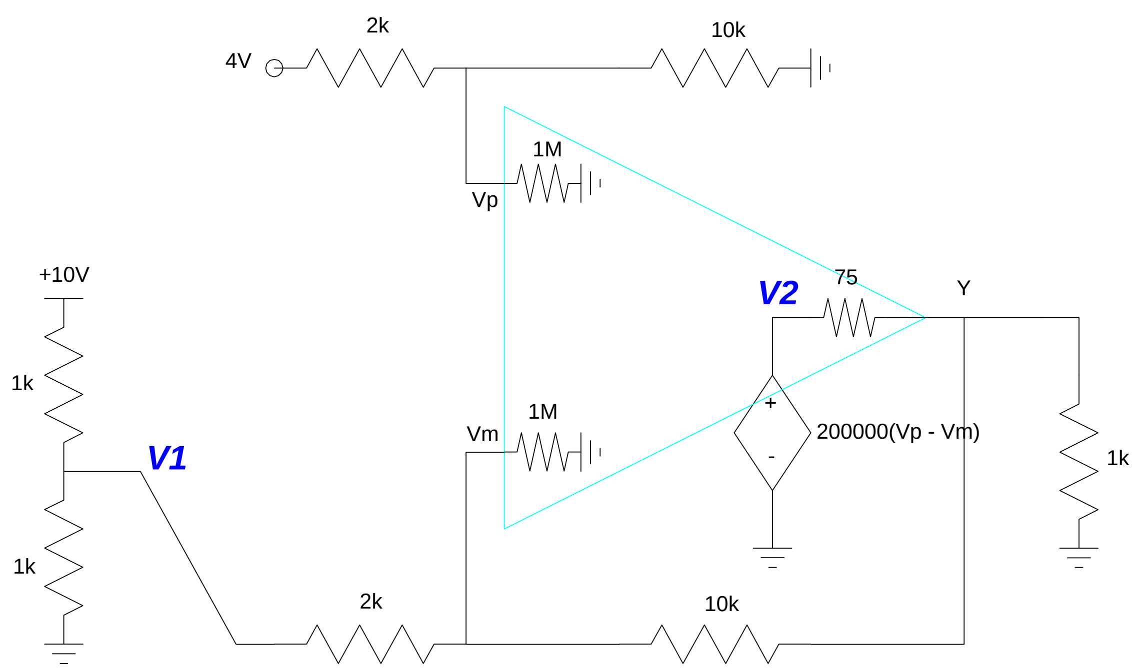
ECE 321 - Homework #1

Op-Amps, Instrumentation Amplifiers, Push-Pull Amplifiers. Due Monday, April 4th

1) Assume non-ideal op-amps. Write the voltage node equations for the following circuit.
2) Find the nodal voltages.



Problem 1 - 2

V1: $\left(\frac{V_1 - 10}{1k}\right) + \left(\frac{V_1}{1k}\right) + \left(\frac{V_1 - V_m}{2k}\right) = 0$

V2: $V_2 = 200000(V_p - V_m)$

Vp: $\left(\frac{V_p - 4}{2k}\right) + \left(\frac{V_p}{10k}\right) + \left(\frac{V_p}{1M}\right) = 0$

Vm: $\left(\frac{V_m - V_1}{2k}\right) + \left(\frac{V_m - Y}{10k}\right) + \left(\frac{V_m}{1M}\right) = 0$

Y: $\left(\frac{Y - V_2}{75}\right) + \left(\frac{Y - V_m}{10k}\right) + \left(\frac{Y}{1k}\right) = 0$

2) Solve. First rewrite, grouping terms:

$$2.5V_1 - 0.5V_m = 10$$

$$V_2 - 200000V_p + 200000V_m = 0$$

$$1.202V_p = 4$$

$$1.202V_m - V_1 - 0.2Y = 0$$

$$1.0825Y - V_2 - 0.0075V_m = 0$$

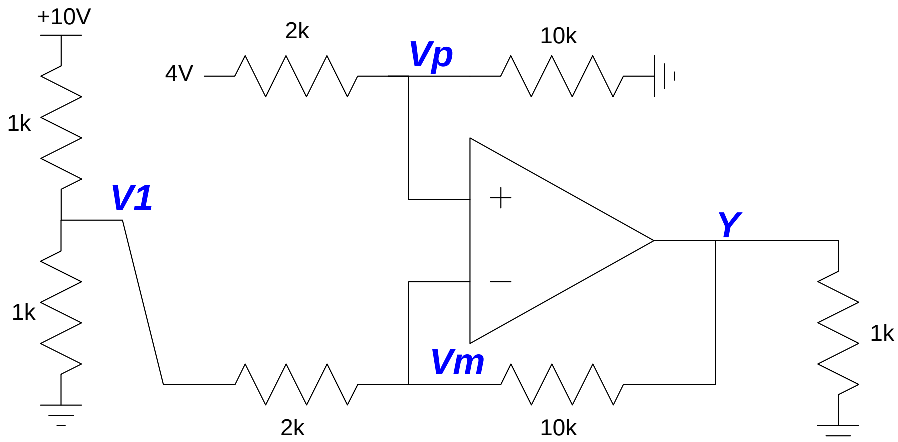
Put in matrix form:

$$\begin{bmatrix} 2.5 & 0 & 0 & -0.5 & 0 \\ 0 & 1 & -200k & 200k & 0 \\ 0 & 0 & 1.202 & 0 & 0 \\ -1 & 0 & 0 & 1.202 & -0.2 \\ 0 & -1 & 0 & -0.0075 & 1.0825 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_p \\ V_m \\ Y \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \\ 4 \\ 0 \\ 0 \end{bmatrix}$$

```
>> A=[  2.5,0,0,-0.5,0;
        0,1,-200000,200000,0;
        0,0,1.202,0,0;
        -1,0,0,1.202,-0.2;
        0,-1,0,-0.0075,1.0825]


  1.0e+005 *

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

>> B = [10;0;4;0;0]

    10
     0
     4
     0
     0

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

V1   4.6656
V2   -3.6272
Y   3.3278
Vp   3.3278
Vm   -3.3277

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



Problem 3 - 4

V1: $\left(\frac{V_1-10}{1k}\right)+\left(\frac{V_1}{1k}\right)+\left(\frac{V_1-V_m}{2k}\right)=0$

Y: $V_p=V_m$

Vp: $\left(\frac{V_p-4}{2k}\right)+\left(\frac{V_p}{10k}\right)=0$

Vm: $\left(\frac{V_m-V_1}{2k}\right)+\left(\frac{V_m-Y}{10k}\right)=0$

4) Find the nodal voltages.

Rewrite:

$$2.5V_1 - 0.5V_m = 10$$

$$V_p - V_m = 0$$

$$1.2V_p = 4$$

$$1.2V_m - V_1 - 0.2Y = 0$$

Put in matrix form:

$$\begin{bmatrix} 2.5 & 0 & -0.5 & 0 \\ 0 & 1 & -1 & 0 \\ 0 & 1.2 & 0 & 0 \\ -1 & 0 & 1.2 & -0.2 \end{bmatrix} \begin{bmatrix} V_1 \\ V_p \\ V_m \\ Y \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \\ 4 \\ 0 \end{bmatrix}$$

Solve in Matlab:

```
>> A = [2.5,0,-0.5,0;0,1,-1,0;0,1.2,0,0;-1,0,1.2,-0.2]

    2.5000         0   -0.5000         0
         0    1.0000   -1.0000         0
         0    1.2000         0         0
   -1.0000         0    1.2000   -0.2000

>> B = [10;0;4;0]

    10
     0
     4
     0

>> V = inv(A)*B

V1    4.6667
Vp    3.3333
Vm    3.3333
Y    -3.3333
```

Compare to the previous solution:

```
V1    4.6656
V2   -3.6272
Y     3.3278
Vp    3.3278
Vm   -3.3277
```

5) Assume a thermistor has the following resistance - temperature relationship.

$$R \approx 1000 \cdot \exp(-0.04(T-25))\ \Omega$$

Design a circuit which outputs

- -10V for T = -20C
- +10V for T = +20C
- Voltage proportional for -20V < T < +20C

Assume a 3k resistor for a voltage divider:

At -20C: (Vo = -10V)

R = 6049 Ohms

Va = 6.685V

At +20C: (Vo = +10V)

R = 1221 Ohms

Va = 2.8934V

The output voltage increases as Va decreases. COnnect the divider to the - input

The gain is

$$gain = \frac{\delta V_{out}}{\delta V_{in}} = \frac{20V}{6.685V - 2.8934V} = 5.2748$$

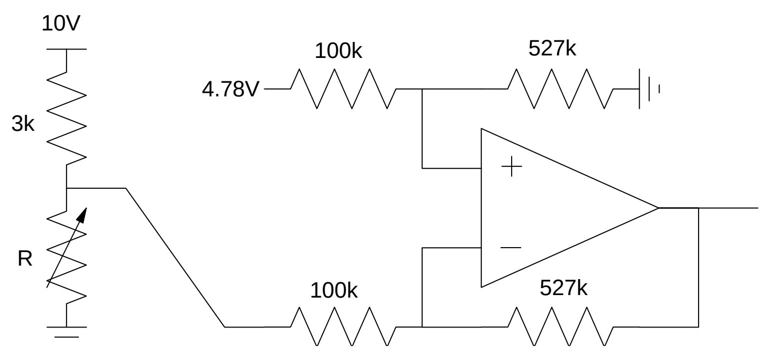
Let R1 = 100k, R2 = 527.48k

The offset fixes a point. At +20C, the output is +10V

$$V_o = gain(V_p - V_m)$$

$$10V = 5.2748(V_p - 2.9834V)$$

$$V_p = 4.7892V$$



6) Design a circuit with a push-pull amplifier

Input: -10V to +10V, capable of driving 10mA

Output: Red LED (I > 0) and Blue LED (I < 0)

Relationship:

I = -100mA to +100mA, proportional to V:

I = V/100