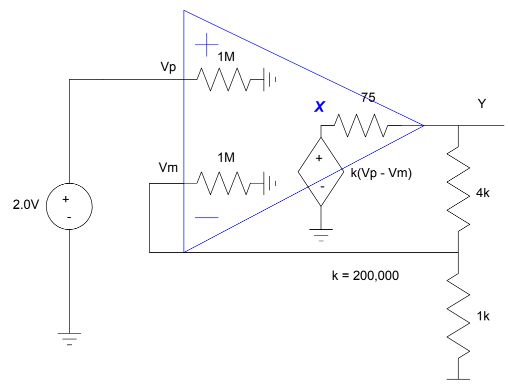
ECE 321 - Homework #1

Op-Amps - Due Wednesday April 8th

1) Write the voltage node equations for the following circuit using a non-ideal op-amp model:



You need four equations for four voltge nodes: Vp, Vm, Y, X,

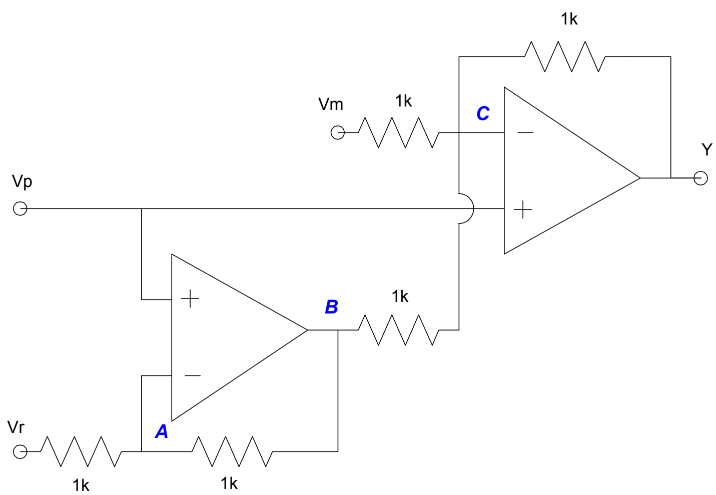
Y: Vp = Vm

X: X = 200,000(Vp - Vm)

Vp: Vp = 2

Vm: $\left(\frac{V_m}{2M}\right) + \left(\frac{V_m - Y}{4k}\right) + \left(\frac{V_m}{1k}\right) = 0$

2) Write the voltage node equations for the following circuit assuming ideal op-amps:



You need to write four equations for the four unknown voltage nodes (A, B, C, Y)

B: $V_A = V_p$

Y: $V_c = V_p$

A: $\left(\frac{V_A - V_r}{1k}\right) + \left(\frac{V_A - V_b}{1k}\right) = 0$

C: $\left(\frac{V_c - V_m}{1k}\right) + \left(\frac{V_c - V_b}{1k}\right) + \left(\frac{V_c - V_y}{1k}\right) = 0$

3) Mixer: Design an op-amp circuit which will add together two audio signals

Input:

- A: ±1V signal, capable of driving 10mA, 0-20kHz
- B: same

Output

- Y = ±10V signal, capable of driving 10mA, 0-20kHz

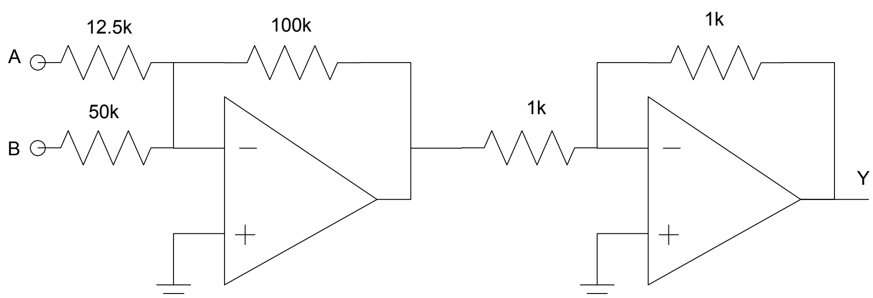
Relationship:

- Y = 8A + 2B

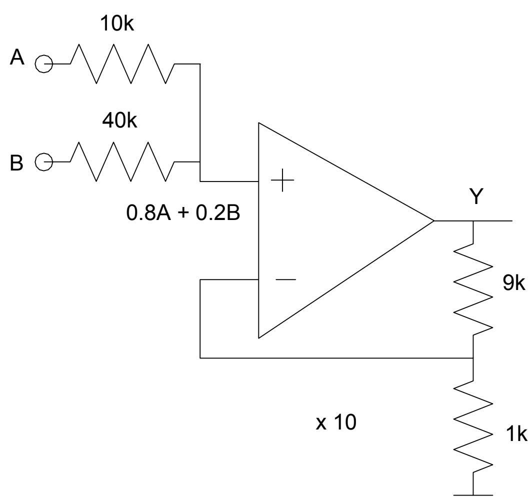
1V capable of driving 10mA means the input resistance is 100 Ohms (or more). Let the feedback resistor be 100k

For a gain of 8, use an 8:1 ratio for resistors

For a gain of 2, use a 2:1 ratio for resistors



Option 2:



4) Instrumentation Amplifier. Design a circuit to implement the following:

Input:

- X = 3..4V signal, capable of driving 10mA, 0-20kHz

Output:

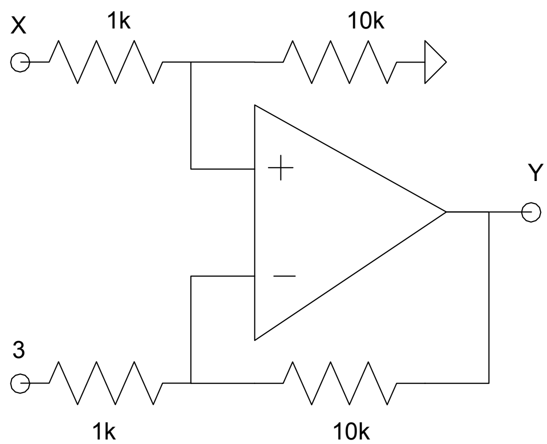
- Y = 0..10V signal, capable of driving 10mA, 0-20kHz

Relationship:

- Y = 10X - 30

Rewrite this as

$$Y = 10(X - 3)$$



5) Instrumentation Amplifier (take 2). Design a circuit to implement the following:

Input:

- Thermistor from 0 to 20C.
- $R = 1000 \cdot e^{-0.04(T-25)}\ \Omega$

Output:

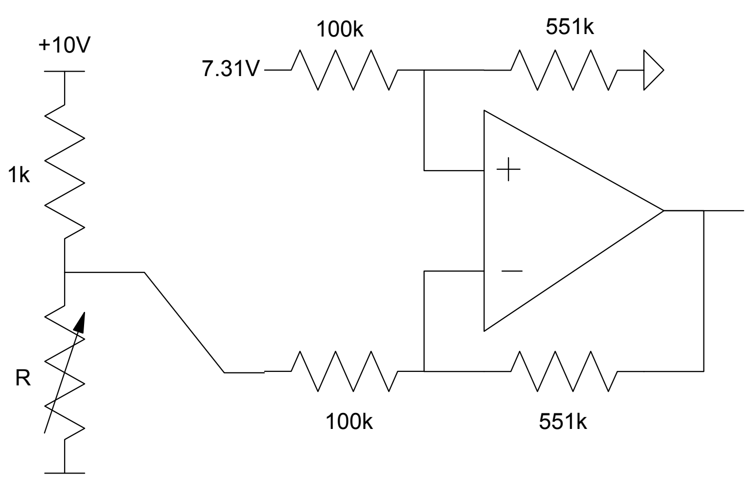
- Y = 0..10V signal, capable of driving 10mA, 0-20kHz

Relationship:

- 0C = 0V
- 20C = 10V
- Y = T/2

Assume a 1k resistor for a voltage divider. In MATLAB

```
-->T = [0,20]'

    0.
    20.

-->R = 1000*exp(-0.04*(T-25))

    2718.2818
    1221.4028

-->X = R ./ (1000+R) * 10

    7.3105858
    5.49834

-->gain = (10 - 0) / (X(2) - X(1))
 gain  =

  - 5.5180152

-->offset = X(1)

    7.3105858
```



6) Integrators and Differentiators: Design an op-amp circuit to implement the following function

Input:

- X = ±10V sinusoid, capable of driving 10mA, 0..100Hz

Output:

- Y = ±10V sinusoid, capable of driving 10mA, 0..100Hz

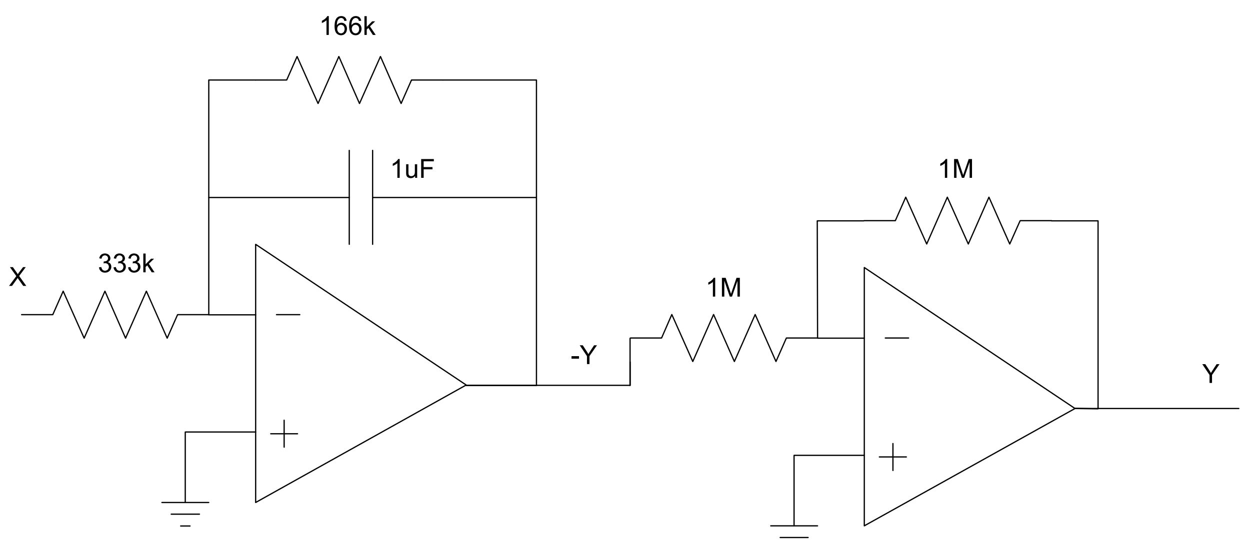
Relationship:

- $\frac{dY}{dt} + 6y = 3x$

Rewriting this...

$$sY + 6Y = 3X$$

$$Y = \left(\frac{3}{s+6}\right)X$$



7) Integrators and Differentiators (take 2): Design an op-amp circuit to implement the following function

Input:

- X = ±10V sinusoid, capable of driving 10mA, 0..100Hz

Output:

- Y = 10V sinusoid, capable of driving 10mA, 0..100Hz

Relationship:

- $\frac{d^2y}{dt^2} + 6\frac{dy}{dt} + 5y = 2x$
-

Rewrite as

$$s^2 Y + 6sY + 5Y = 2X$$

$$Y = \left(\frac{2}{s^2+6s+5}\right)X$$

$$Y = \left(\frac{2}{(s+1)(s+5)}\right)X$$

$$Y = \left(\frac{1}{s+1}\right)\left(\frac{2}{s+5}\right)X$$