ECE 321 - Quiz #2 - Name _____

Temperature, Strain, Instrumentation Amplifiers. April 11, 2019

1) Temperature Sensor: Assume a temperature sensor has the following characteristics:

$$R = 1000(1 + 0.0043 \cdot T)\ \Omega$$

where T is the temperature in degrees C. Design a circuit which outputs

- -10V at -40C and
- +10V at +40C

+40C (Vout = +10V)

$$R = 1172\Omega$$

$$X = \left(\frac{1172}{1172+1000}\right) 10V = 5.3959V$$

-40C (Vout = -10V)

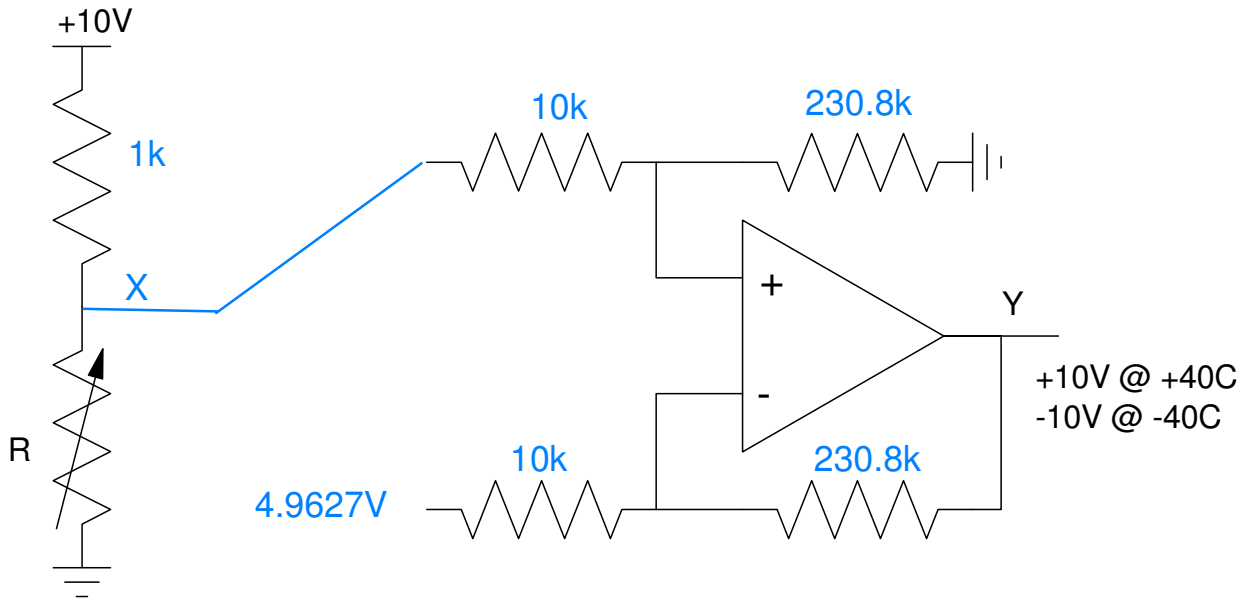
$$R = 828\Omega$$

$$X = \left(\frac{828}{828+1000}\right) 10V = 4.5295V$$

$$gain = \left(\frac{20V}{5.3959V - 4.5295V}\right) = 23.08$$

$$offset = \left(\frac{5.3959V + 4.5295V}{2}\right) = 4.9627V$$

the output should be 0V at the middle voltage



1b) For your circuit, what is the output votlage at 0C?

$$\left(\frac{X}{1k}\right) + \left(\frac{X-10}{1k}\right) + \left(\frac{X}{240.8k}\right) = 0$$

$$X = 4.9896V$$

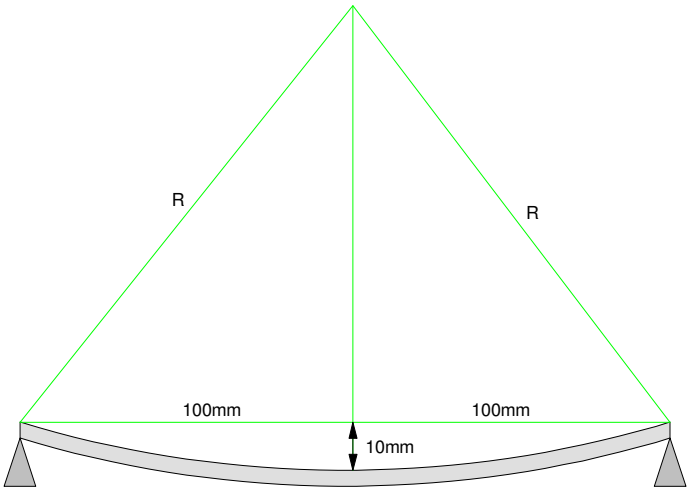
$$Y = 23.8(4.9896 - 4.9627) = 0.6412V$$

2) Strain Sensor (take 1). A pressure sensor uses a stain gage to measure the flex of a beam. Assume

- The length of the beam is 200mm
- The thickness of the beam is 2mm
- The beam deflects 10mm when the air pressure is 100 N/m2

Determine the strain on the inside edge and the outside edge. Assume the center line has no strain (free endpoints)

Radius (R)	Strain (inside edge)	Strain (outside edge)
505mm	**+0.00198**	**-0.00198**
	+0.0067	**+0.0106**



$$R^2 = (R-10)^2 + 100^2$$

$R = 505mm$ *inside surface*

$R = 506mm$ center line

assuming free endpoints (center line has no strain)

$$\varepsilon = \left(\frac{-1mm}{506mm}\right) = -0.00198 \quad \textit{inside}$$

$$\varepsilon = \left(\frac{+1mm}{506mm}\right) = +0.00198 \quad \textit{outside}$$

assuming fixed endpoints (beam stretches)

$$\theta = 2 \cdot \arctan\left(\frac{100mm}{495mm}\right) = 0.3987rad$$

$$L_{inside} = 505mm \cdot 0.3987rad = 201.33mm$$

$$\varepsilon_{inside} = \left(\frac{201.33-200}{200}\right) = +0.0067$$

$$L_{outside} = 507mm \cdot 0.3987rad = 202.128mm$$

$$\varepsilon_{outside} = \left(\frac{202.128-200}{200}\right) = +0.0106$$

3) Strain Sensor (take 2). Assume a strain sensor has a resistance of

$$R = 120(1 + 2.14\varepsilon)$$

where ε is the strain. Design a circuit which outputs

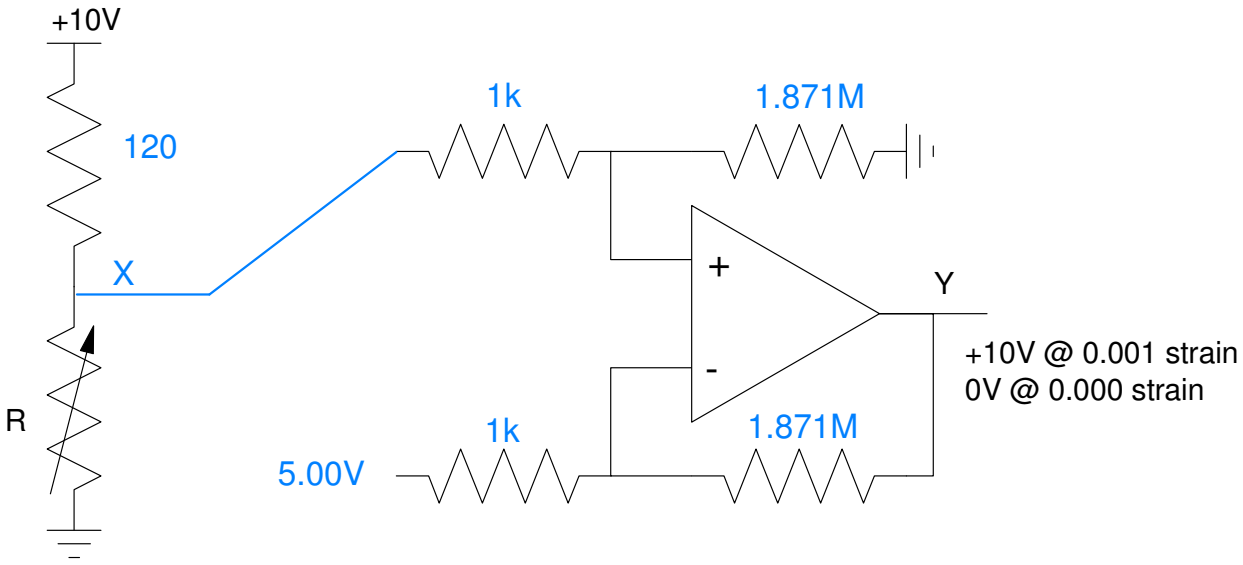
- 0V when the strain is 0 and
- +10V when the strain is +0.001

0 Strain	0.001 strain
$R = 120\Omega$	$R = 120.2568\Omega$
$X = 5.00V$	$X = \left(\frac{R}{R+120}\right)10V = 5.0053V$

Gain

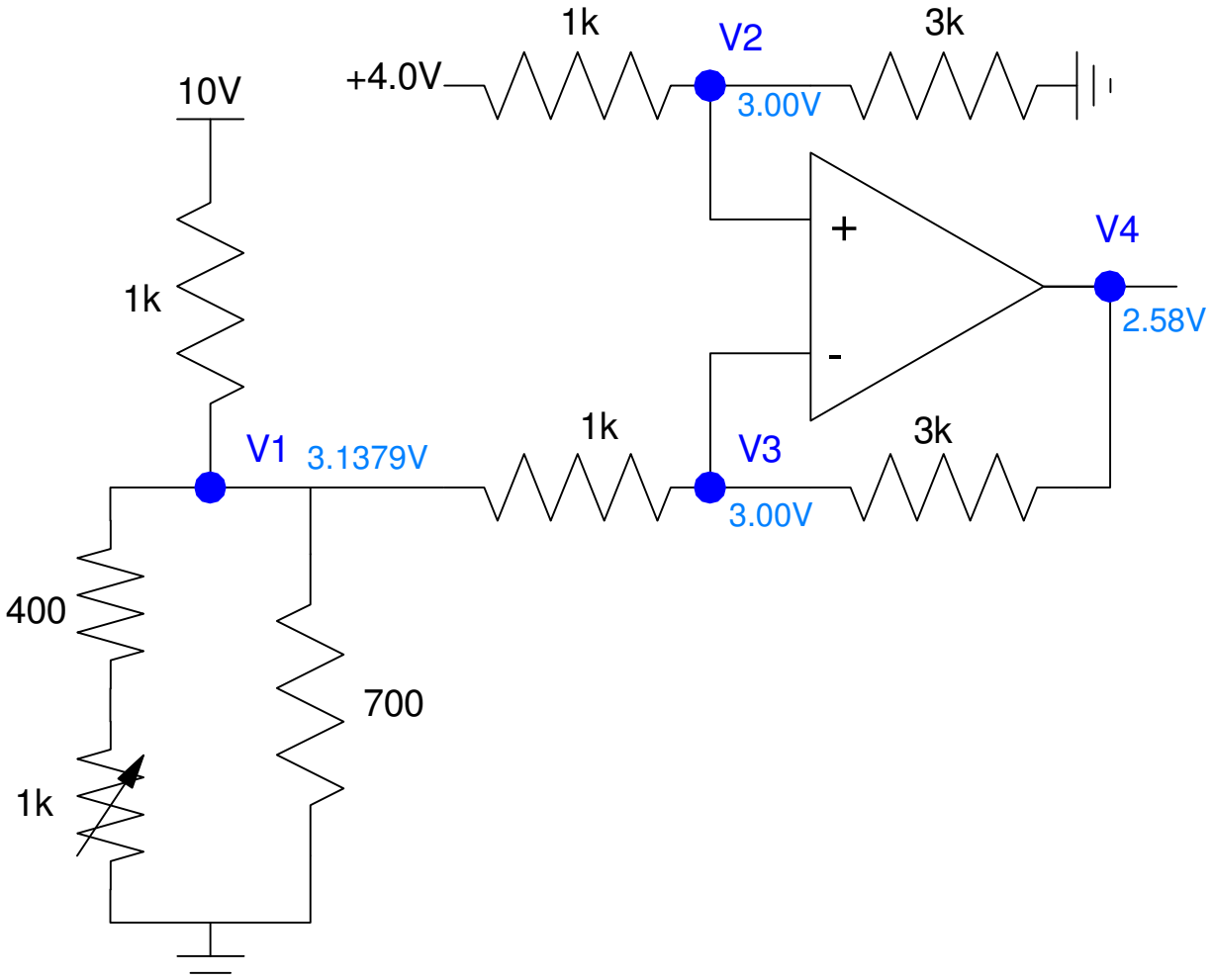
$$gain = \left(\frac{10V}{5.0053-5.000}\right) = 1871$$

Output is 0V when strain = 0 when X = 5.000V



4) The following circuit uses a linearizing circuit with an instrumentation amplifier. Determine the voltages at V1..V4

V1	V2	V3	V4
3.1379 V	**3.00 V**	**3.00 V**	**2.5862 V**



$$\left(\frac{V_1-10}{1k}\right)+\left(\frac{V_1}{1400}\right)+\left(\frac{V_1}{700}\right)+\left(\frac{V_1}{4000}\right)=0$$

$$V_1 = 3.1379V$$

$$V_2 = \left(\frac{3k}{3k+1k}\right)4V = 3V$$

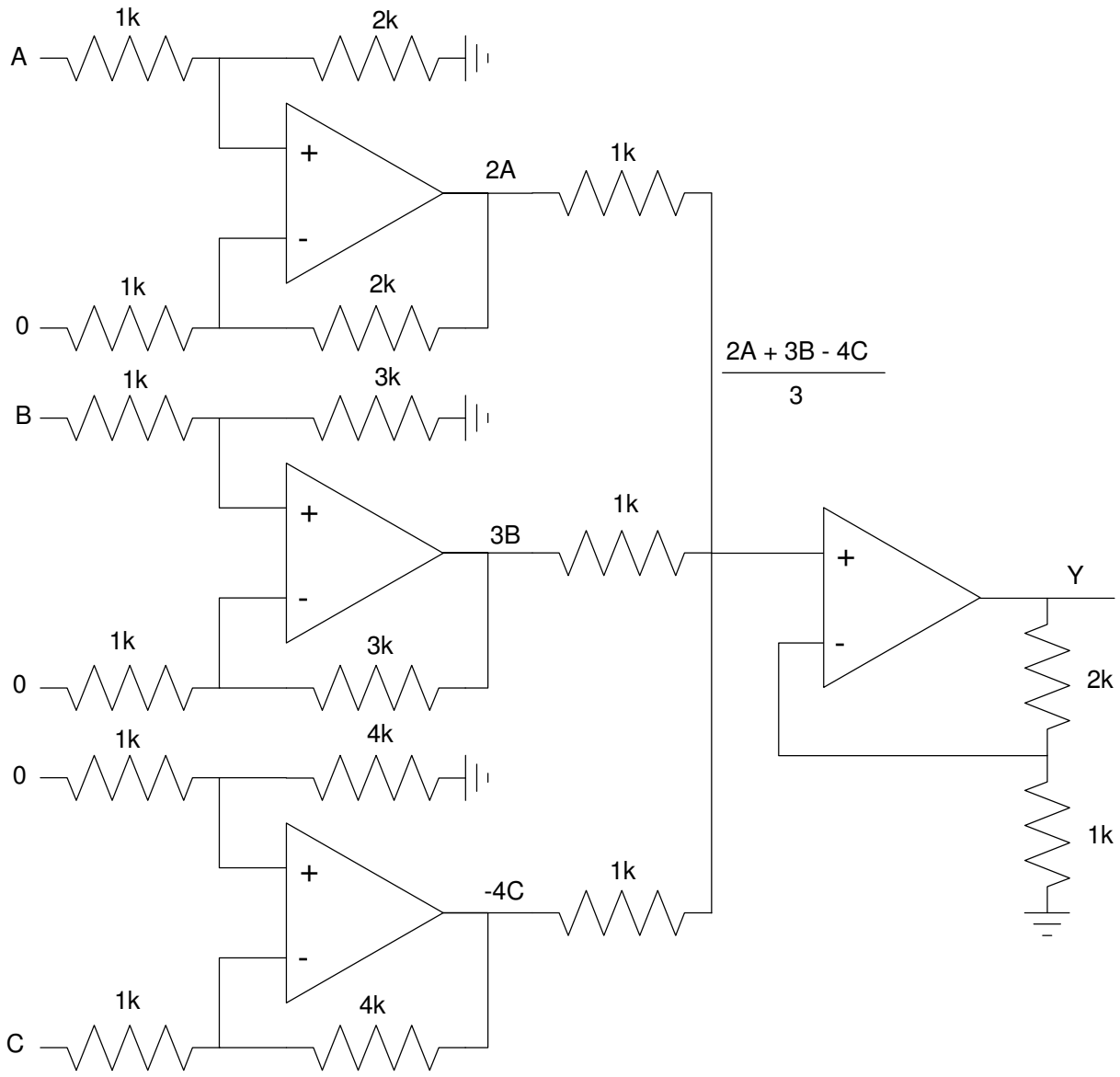
$$V_3 = V_2 = 3V$$

$$V_4 = \left(\frac{3k}{1k}\right)(4V - V_1) = 2.5862V$$

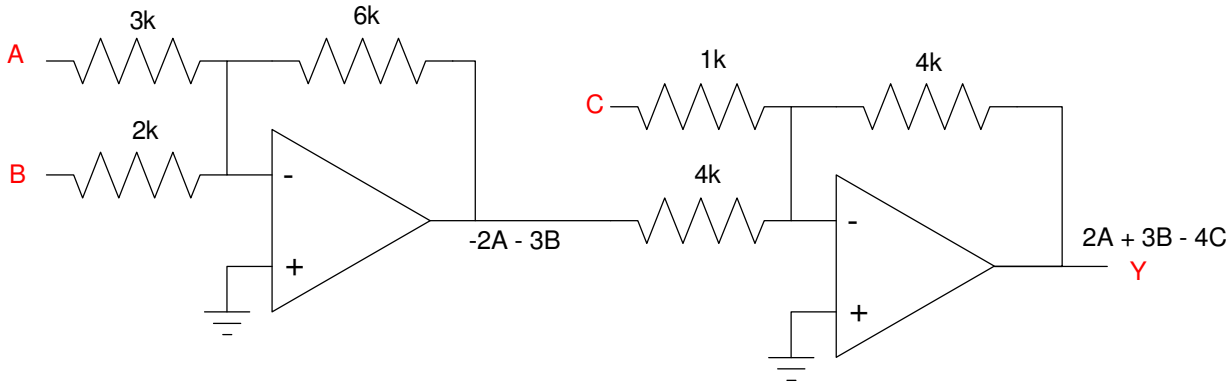
5) Let {A, B, C} be -10V to +10V analog voltages capable of driving 20mA (or less). Design a circuit to implement

$$Y = 2A + 3B - 4C$$

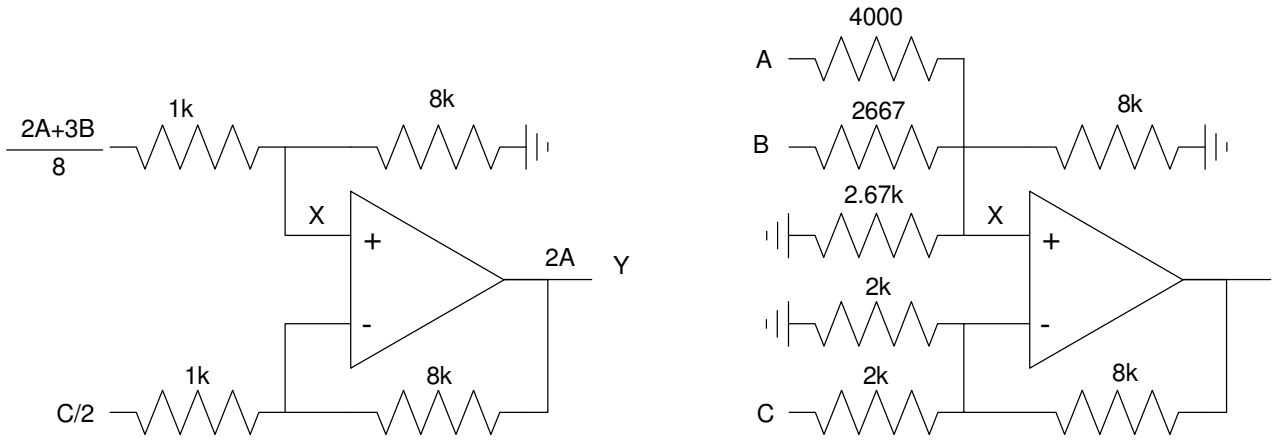
4 Op-Amp Design:



2 Op-Amp Design



1 Op-Amp Design



Bonus: All but three of the following countries have tuition-free college. Which three?

Brazil - **Canada** - Germany - Finland - **France** - Norway - Slovenia - Sweden - **United States**

United States:

- $9,700/y (public)
- $37,000/y (private)

Canada:

- $1,288 / y

France:

- $200 / y