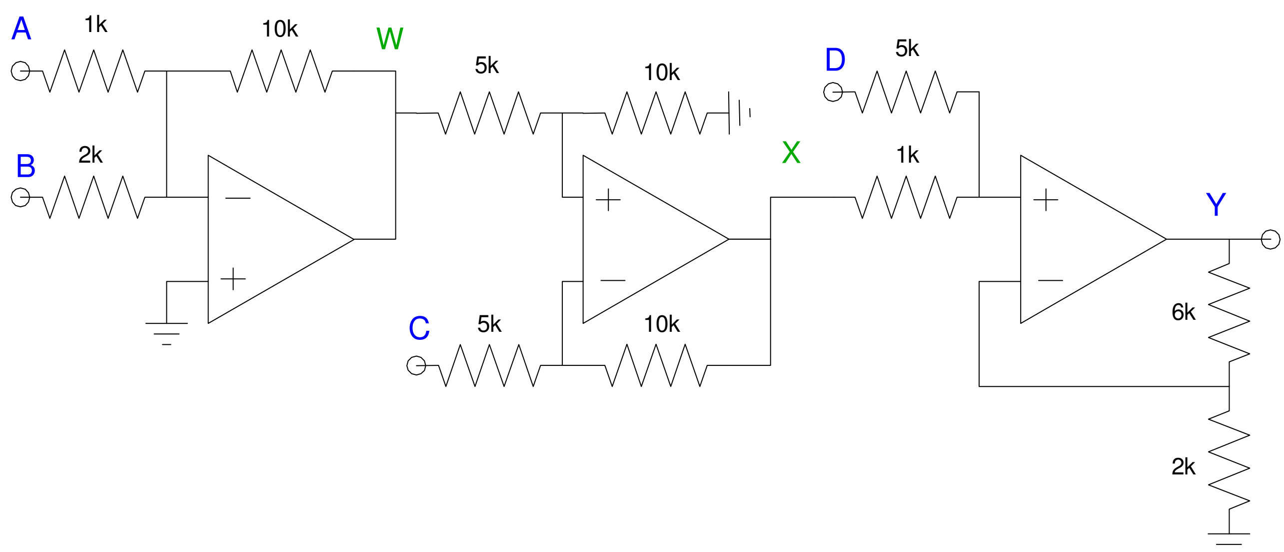
ECE 321 - Final Exam - Name ____________________

Spring 2022

1. OpAmp Circuits: Determine y as a function of A, B, C, and D. Assume

- Ideal op-amps
- R 900 + 100*(your birth month) + (your birth day).

R 900 + 100*mo + day	Y = aA + bB + cC + dD
1414	



$$W = -10A - 5B$$

$$X = 2(W - C)$$

$$Y = 5\left(\frac{5X+D}{6}\right)$$

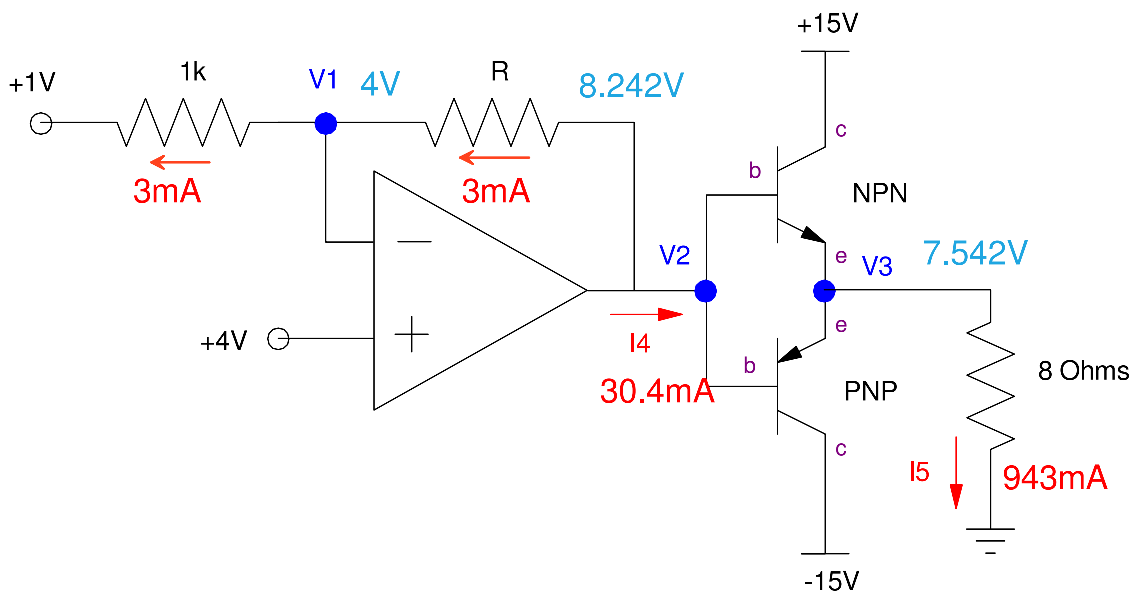
net

$$Y = \left(\frac{5}{6}\right)D - \left(\frac{50}{6}\right)C - \left(\frac{100}{6}\right)A - \left(\frac{50}{6}\right)B$$

2. Push-Pull: Determine the voltages and currents for the following push-pull amplifier. Assume

- R = 1100 + 100*(birth month) + (birth day).
- | Vce | = 0.7V (ideal silicon diodes)
- $\beta = 30$

R 900 + 100*mo + day	V1	V2	V3	I4	I5
1414	**4V**	**8.242V**	**7.542V**	**30.4mA**	**943mA**



3. Instrumentation Amplifier: Assume an RTD has the temperature - resistance relationship of

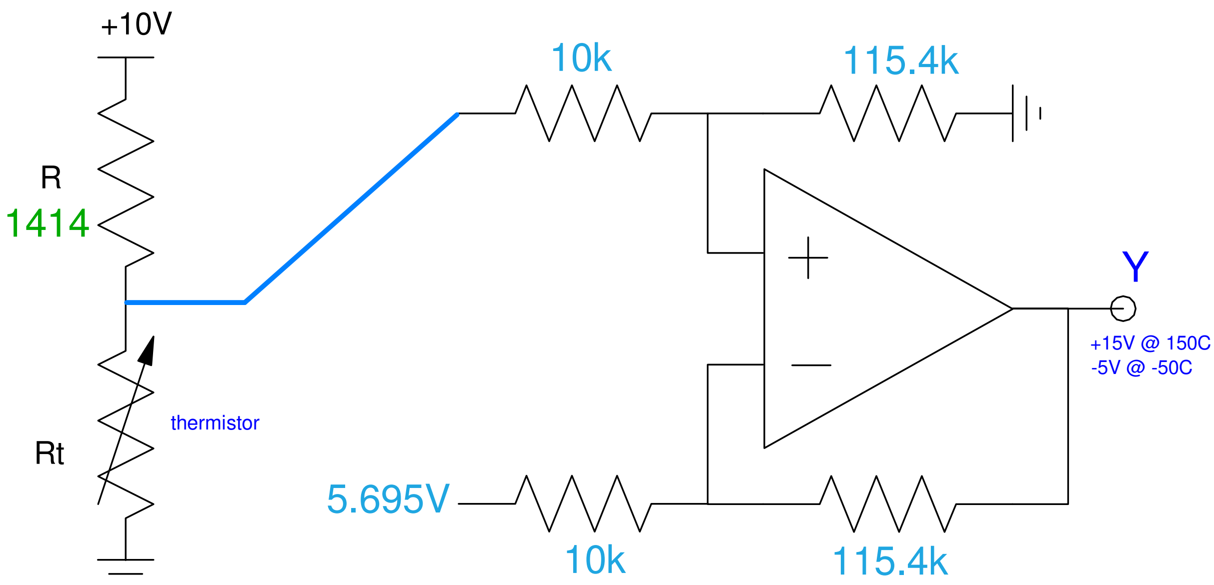
$$R_t = 2000 \cdot (1 + 0.0043T)\Omega$$

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

- +15V at +150C, and
- -5V at -50C

Assume

- R = 900 + 100*(your birth month) + (your birth date)



-50C

- Rt = 1570 Ohms
- Vx = 5.261V
- Vy = -5V

+150C

- Rt = 3290 Ohms
- Vx = 6.994V
- Vy = +10V

Y goes up as X goes up. Connect to the + input

The gain needed is

$$gain = \left(\frac{+15V - (-5V)}{6.994V - 5.261V} \right) = 11.54$$

The offset needed comes from

$$Y = +15V = 11.543(6.994V - B)$$

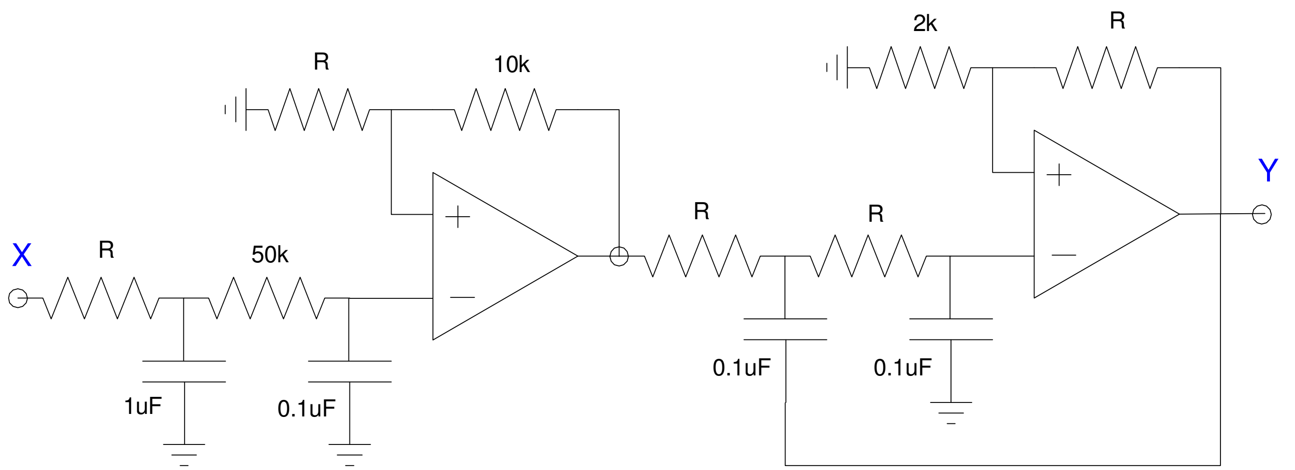
$$B = 5.695V$$

4. Filters: Let

- R 900 + 100*(your birth month) + (your birth day). May 14th would give R = 1614 Ohms

Find the transfer function from X to Y

R 900 + 100*mo + day	Transfer Function Y = G(s) * X
1414	



Stage 1: Low-pass filter with real poles

$$p_1 = \left(\frac{1}{R \cdot 1\mu F}\right) = 707.2$$

$$p_2 = \left(\frac{1}{50k \cdot 0.1\mu F}\right) = 200$$

$$k = 1 + \left(\frac{10k}{R}\right) = 8.072$$

$$G_1 = \left(\frac{707.2}{s+707.2}\right)\left(\frac{200}{s+200}\right)(8.072)$$

Stage 2: Low-pass filter with complex poles

$$p = \left(\frac{1}{R \cdot 0.1iF}\right) = 7072$$

$$k = 1 + \frac{R}{2k} = 1.707$$

$$3 - k = 2\cos\theta$$

$$\theta = 49.7^0$$

$$G_2 = \left(\frac{1.707 \cdot 7072^2}{s+7072\angle\pm 49.7^0}\right)$$

The total transfer function is then G1 * G2

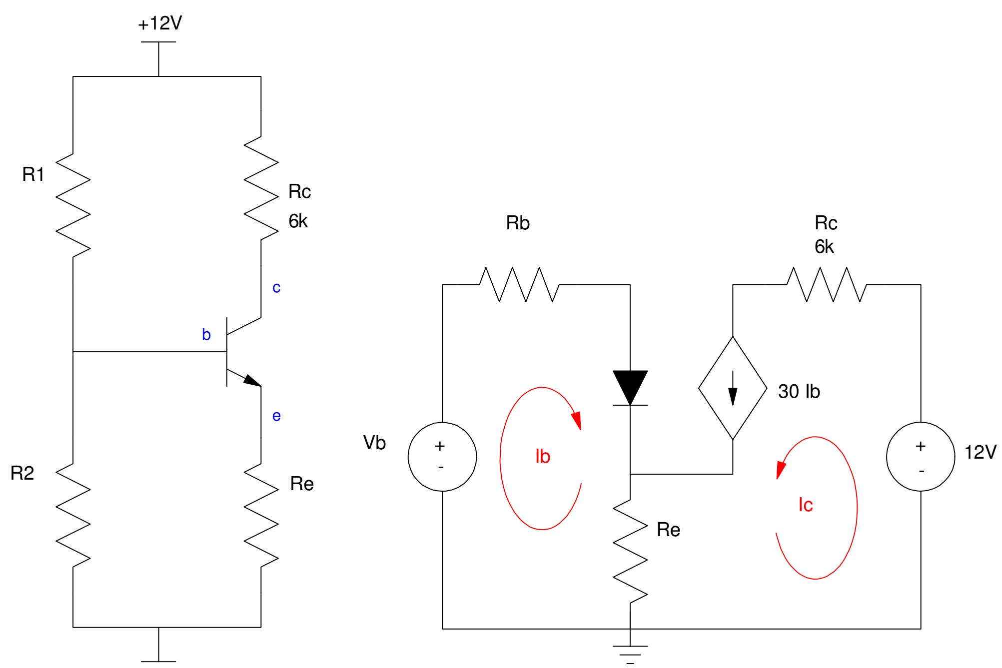
5. CE Amplifiers (DC design): Determine R1 and R2 so that

- The Q-point is stabilized fpr variations in β, and
- Vce = 3.0V

Assume

- Re = 900 + 100*(your birth month) + (your birth date)
- $\beta = 30$
- | Vbe | = 0.7V (ideal silicon diode)

Re 900 + 100*mo + day	R1	R2	Vb	Ic
1414	**5119**	**18.30k**	**2.623V**	**1.206mA**



$$I_c = \left(\frac{9V}{6000+R_e+\frac{1}{30}R_e}\right) = 1.206mA$$

$$I_b = \left(\frac{1}{30}\right)I_c = 40.21\mu A$$

To stabilize the Q-point

$$R_b << (1+\beta)R_e = 43.83k$$

Let Rb = 4k

$$V_b = R_e(I_b + I_c) + 0.7 + R_b I_b = 2.623V$$

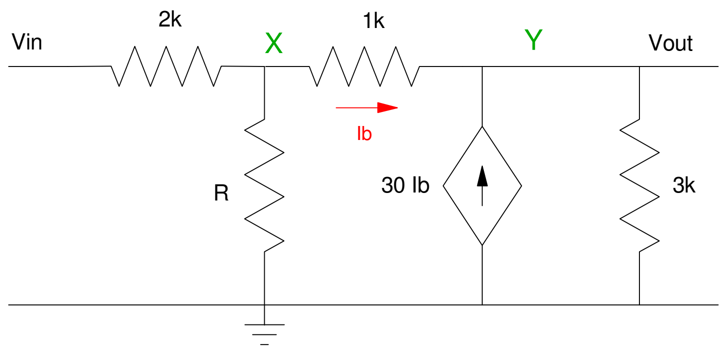
$$R_1 = \left(\frac{12V}{2.623V}\right)4k = 18.30k$$

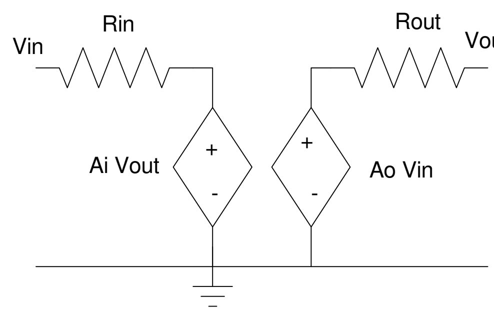
$$R_2 = 5119\Omega$$

6. 2-Port model: Determine the 2-port parameters for the following circuit. Assume

- R = 900 + 100*(your birth month) + (your birth date) Ohms

R 900 + 100*mo + day	Rin	Ai	Rout	Ao
1414	**2586**	**0.5857**	**57.84**	**0.4062**





Rin: Short Vout

$$R_{in} = 2k + R||1k = 2586\Omega$$

Ai: Apply 1V to Vout, find Vin

$$A_i = \left(\frac{1414}{1414+1000}\right) = 0.5857$$

Rout: Short Vin, Apply 1V to Vout and find the current

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

$$X = 0.4531V$$

$$I = \left(\frac{1V}{3k\Omega}\right) + \left(\frac{1V-0.4531V}{1k}\right) + 30\left(\frac{1-0.4531}{1k}\right) = 17.29mA$$

$$R_{out} = \frac{1V}{17.29mA} = 57.84\Omega$$

Ao: Apply 1V to Vin, find Vout

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

$$\left(\frac{Y-X}{1k}\right) + 30\left(\frac{Y-X}{1k}\right) + \left(\frac{Y}{3k}\right) = 0$$

Solving 2 equations for 2 unknowns

X = 0.4106

Y = 0.4062 = Ao

7. 2-Port model (experimental): Determine the 2-port parameters for an unknown ciruit (shown in blue) given the following experimental data:

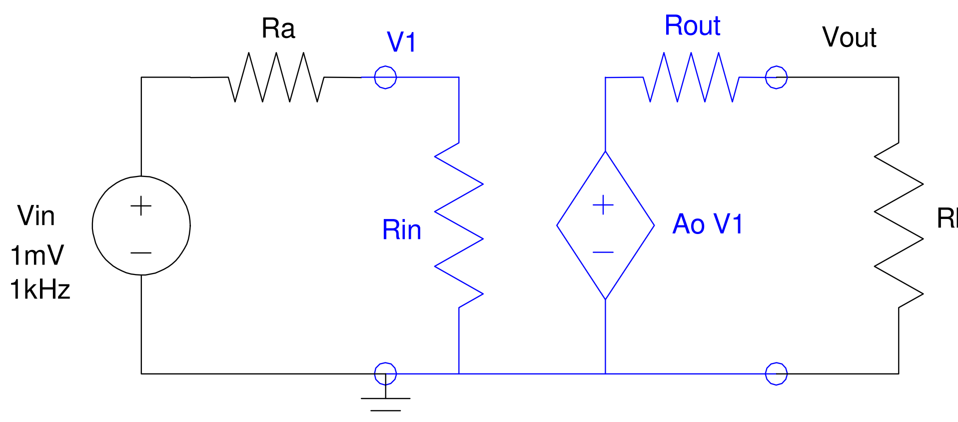
Case 1:
- Vin = 1mV @ 1kHz
- Ra = 0 Ohms
- Rb = infinity (open)
- Vout = 96mV @ 1kHz

Case 2:
- Vin = 1mV @ 1kHz
- Ra = R Ohms
- Rb = infinity (open)
- Vout = 63mV @ 1kHz

Case 3:
- Vin = 1mV @ 1kHz
- Ra = 0 Ohms
- Rb = R Ohms
- Vout = 28mV @ 1kHz

Assume
- R = 900 + 100*(your birth month) + (your birth date) Ohms
- Ai = 0

R 900 + 100*mo + day	Rin	Ai	Rout	Ao
1414	**2699**	**0**	**3434**	**96**



Ao: Case 1:

$$A_o = \left(\frac{96mV}{1mV}\right) = 96$$

Rin: Case 2

$$R_{in} = \left(\frac{63mV}{96mV-63mV}\right)1414\Omega = 2699\Omega$$

Rout: Case 3

$$R_{out} = \left(\frac{96mV-28mV}{28mV}\right)1414\Omega = 3434\Omega$$