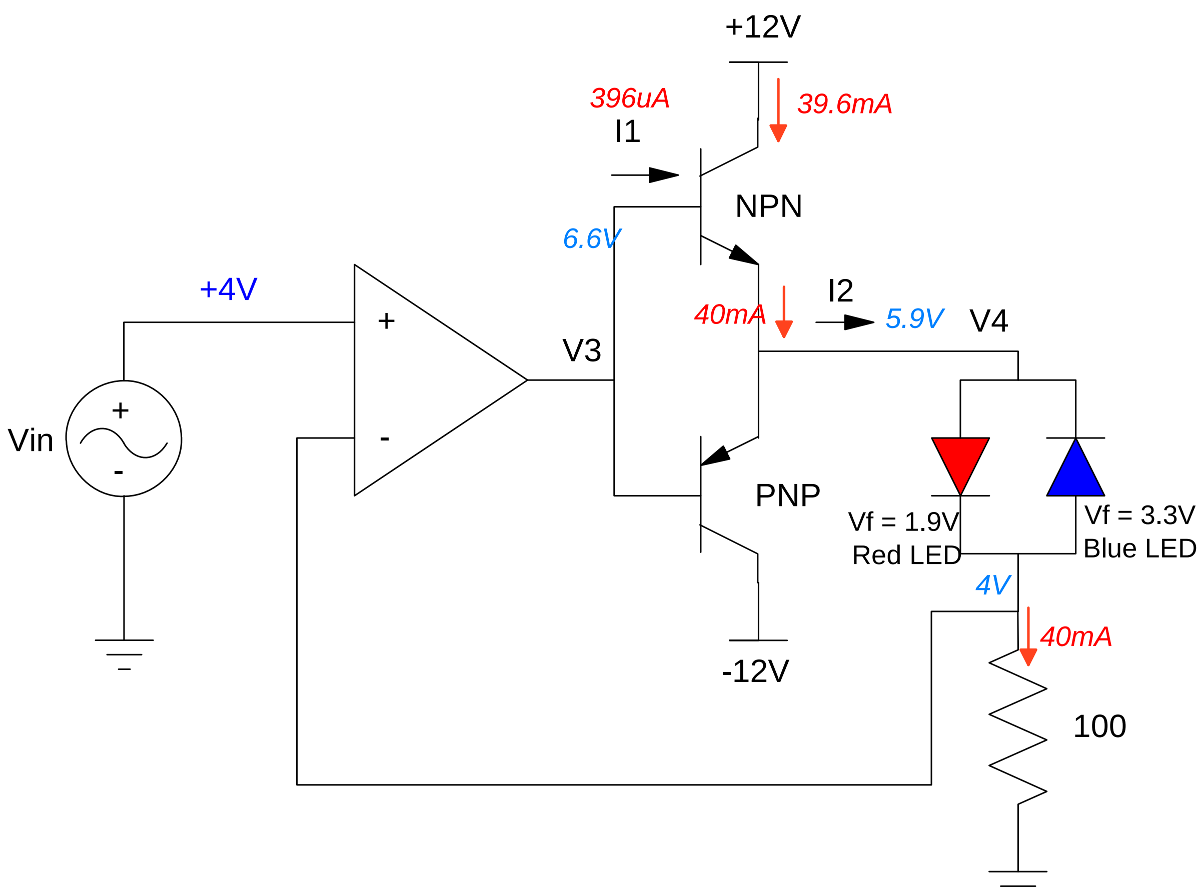
ECE 321: Final Name ____________________

Tuesday May 9, 1PM, room 125

1) Quiz 1 - Push Pull. Determine the voltages and currents for the following circuit. Assume transistors with

- $V_{be} = 0.7V$
- $\beta = 100$
- $\max(Ic) = 200mA$

I1	I2	V3	V4
396uA	**40mA**	**6.6V**	**5.9V**

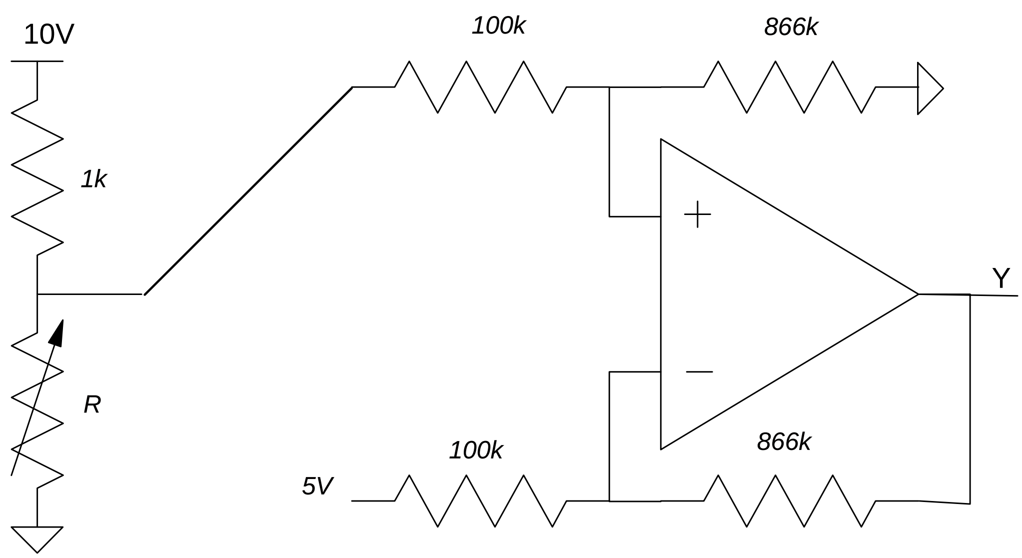


2) Quiz 1 - Inst Amplifier. An RTD (temperature-dependent resistor) has a temperature - resistance relationship of

$$R = 1000 \cdot (1 + 0.006T)\ \Omega$$

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

- 0V at 0C and
- 10V at 100C



First select the top resistor in the voltage divider. A middle values works usually, so let it be 1k

At 0C

- R = 1000 Ohms
- Vin = 5V
- Vout = 0V

At 100C

- R = 1600 Ohms
- Vin = 6.15V
- Vout = 10V

As the input goes up, the output goes up. Connet to the + input.

To get the output to have a 10V swing, add a gain of

$$gain = \frac{6.15V - 5V}{10V - 0V} = 8.6666$$

The output is 0V when the input is 5V. Make the offset 5V

3) Quiz 2 - Filter Analysis: Determine the differential equation relating X and Y.

$$Y = \left(\frac{3s+2}{(s+4)(s+20)}\right) X = \left(\frac{3s+2}{s^2+24s+80}\right) X$$

Cross multiply

$$(s^2 + 24s + 80)Y = (3s + 2)X$$

'sY' means 'the derivative of y'

$$\boxed{\frac{d^2y}{dt^2} + 24\frac{dy}{dt} + 80y = 3\frac{dx}{dt} + 2x}$$

Determine y(t) given x(t)

$$x(t) = 4 + 5\sin(6t)$$

x(t) = 4

s = 0

$$\left(\frac{3s+2}{s^2+24s+80}\right)_{s=0} = 0.025$$

$$y = (0.025) \cdot 4$$

$$y = 0.1$$

x(t) = 5 sin(6t)

s = j6

$$\left(\frac{3s+2}{s^2+24s+80}\right)_{s=j6} = 0.12\angle 10^0$$

$$y = (0.12\angle 10^0) \cdot 5\sin(6t)$$

$$y(t) = 0.6\sin(6t + 10^0)$$

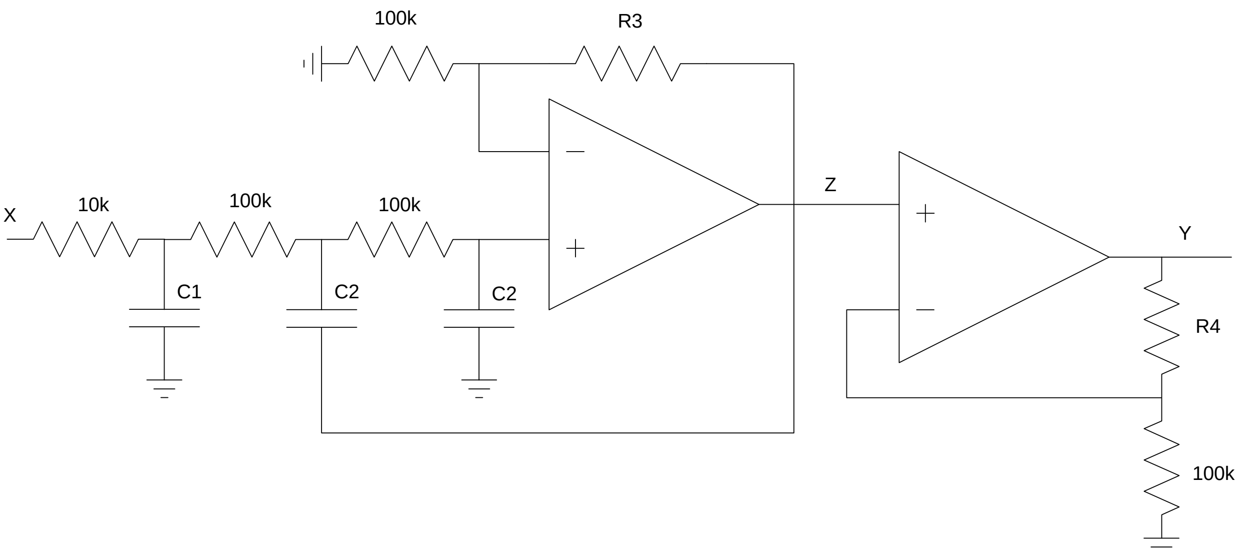
Total Answer:

$$\boxed{y(t) = 0.1 + 0.6\sin(6t + 10^0)}$$

4) Quiz 2 - Find R and C to implement the following Chebychev filter

$$Y = \left(\frac{4000}{(s+8)(s+12\angle 70^0)(s+12\angle -70^0)}\right)X = \left(\frac{4000}{(s+8)(s+8.2s+12^2)}\right)X$$

C1	C2	R3	R4
12.5uF	**0.833uF**	**131k**	**50k**



$$Z = \left(\frac{a\left(\frac{1}{100k\cdot C_2}\right)^2}{s^2+\left(\frac{3-a}{100k\cdot C_2}\right)s+\left(\frac{1}{100k\cdot C_2}\right)^2}\right)\left(\frac{1}{10k\cdot C_1 s+1}\right)X \qquad Y = \left(1+\frac{R_4}{100k}\right)Z$$

$$a = 1+\frac{R_3}{100k}$$

(s+8)

$$\frac{1}{10k\cdot C} = 8$$

$$C_1 = 12.5\mu F$$

overall gain = 3.47 = 2.316 * 1.5

R4 = 50k

12:

$$\left(\frac{1}{100k\cdot C_2}\right) = 12$$

$$C_2 = 0.833\mu F$$

3-a

$$12(3-a) = 8.2$$

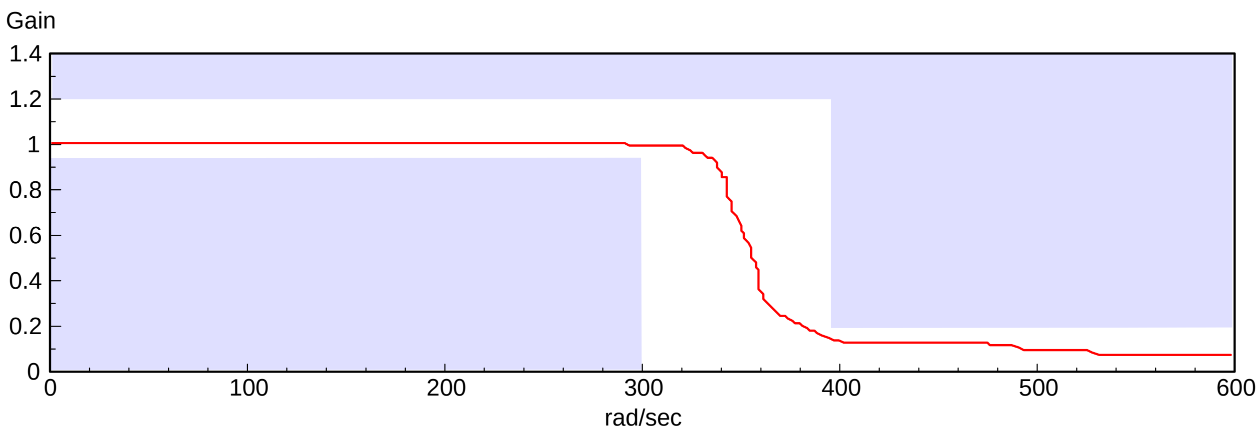
$$a = 2.316 = 1+\frac{R_3}{100k}$$

5) Quiz 3 - A low-pass filter is to have a gain of

- $0.9 < \text{gain} < 1.2$ for frequencies below 300 rad/sec (48 Hz)
- $\text{gain} < 0.2$ for frequencies above 400 rad/sec 64 Hz)

Determine the number of poles required (N) and give the transfer function for an Nth order Butterworth filter with a corner at 300 rad/sec

N # of poles	G(s) transfer function for an N-order Butterworth low pass filter
6	$\left(\frac{300^6}{(s+300\angle\pm 15^0)(s+300\angle\pm 45^0)(s+300\angle\pm 75^0)}\right)$



$$\left(\frac{300}{400}\right)^N = 0.2$$

$$N = 5.59$$

round up to N = 6. The angle between poles is

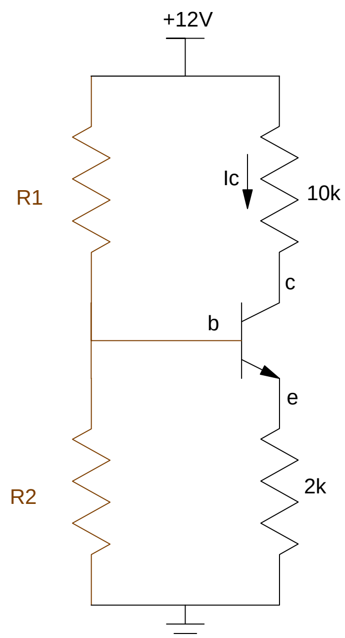
$$\frac{180}{N} = 30^0$$

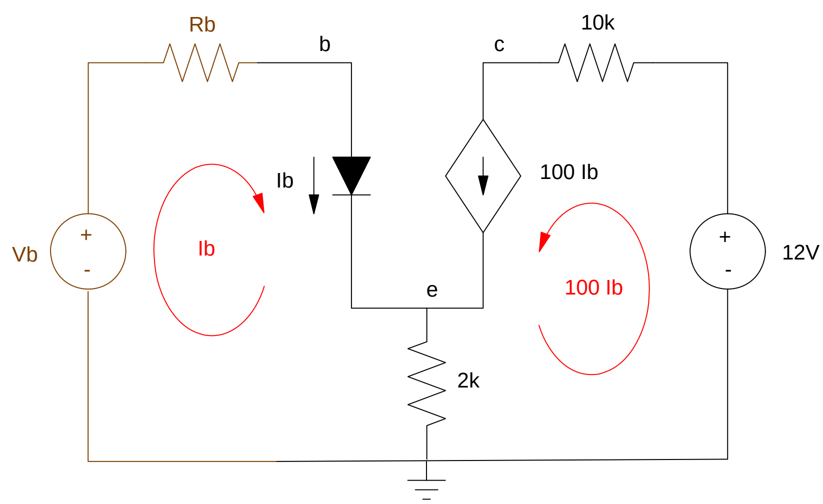
6) Quiz 3 - BJT: DC Analysis. Find R1 and R2 so that

- The Q-point is stabilized for variations in β and
- The Q point is Vce = 6V

Assume $\beta = 100$

R1	R2	Vb	Rb
132k	**23.5k**	**1.808**	**20k**





To get a Q point of 6V

$$I_c = \frac{12V - 6V}{10k + 1.01 \cdot 2k} = 499\mu A$$

$$I_b = \frac{I_c}{100} = 4.99\mu A$$

To stabilize the Q point

$$(1+\beta)R_e >> R_b$$

$$R_b << 202k$$

Let Rb = 20k

$$V_b = 20k \cdot I_b + 0.7 + 2k \cdot (I_b + I_c) = 1.808V$$

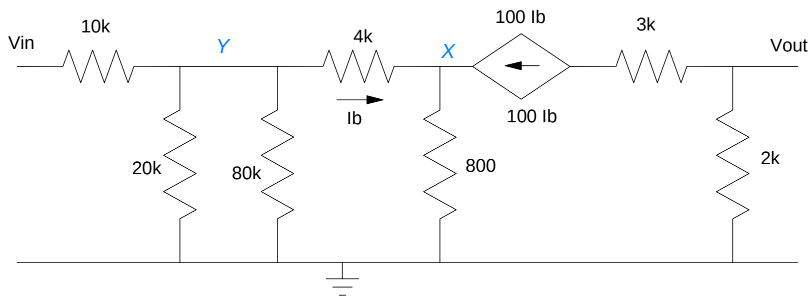
$$\left(\frac{R_1 R_2}{R_1 + R_2}\right) = 20k$$

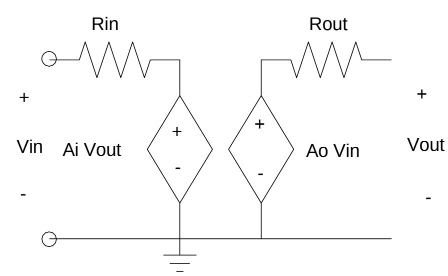
$$\left(\frac{R_2}{R_1 + R_2}\right) 12V = 1.808V$$

solve 2 equations for 2 unknowns to get R1 and R2

7 - Quiz 4) Determine the 2-port model for the following amplifier:

Rin	Ai	Rout	Ao
23.46k	**0**	**2k**	**-1.354**





Rin: Short Vout, apply 1V to Vin. Find I

The 800 Ohm resistor looks like a 80.8k resistor looking left. This gives

$$R_{in} = 10k + 20k || 80k || (4k + 80.8k)$$

$$R_{in} = 10k + 13.46k$$

Ai: Apply 1V to Vout. Measure teh voltage at Vin. Turns out 0V works - the currents balance

$$\left(\frac{X}{4k+16k}\right) + \left(\frac{X}{800}\right) + 100\left(\frac{X}{4k+16k}\right) = 0$$

$$X = 0$$

Rout: Short Vin. Apply 1V to Vout. Measure the current. Like Ai, the voltage at X will be

X = 0,   Ib = 0,   Rout = 2k

Ao: Apply 1V to Vin. Measure the voltage at Vout

The 800 Ohm resistor looks like an 80.8k resistor. By voltage division then

$$X = \left(\frac{80.8k}{80.8k+4k}\right) Y = 0.9528Y$$

$$\left(\frac{Y-1}{10k}\right) + \left(\frac{Y}{20k}\right) + \left(\frac{Y}{80k}\right) + \left(\frac{Y-0.9528Y}{4k}\right) = 0$$

$$Y = 0.5737V$$

$$I_b = 6.77\mu A$$

$$V_o = -100 I_b \cdot 2k - 1.354$$

ACHA Bonus!! What is the idea behind health insurance?

Insurance is a zero-sum game.

Take an expense where the average cost for a population is small but the individual cost may be high. Everyone chips in, paying the average cost. This pays the high cost for the individuals who need it.

For example, take auto insurance. Suppose the probability of an accident is small (1/1000) but the cost of that accident is large ($100,000). The average cost for a population is $100

If a group of 1000 people all pitch in $100 into a pool, that pool will have enough money to cover the cost of the person who gets into an accident. That's what insruance is.

- The people who don't get into an accident are subsidizing the person who gets into an accident
- The person who gets into the accident could be anyone. That $100 premium covers the cost in the event that you are the one who gets into an accident.

That's what health insurance is as well:

- Everyone pays into a pool the average cost of health care.
- This creates a pool of money that will cover the cost of health care for those individuals who wind up needing it.
- We don't know the future: anyone could be in need of health coverage.

Paul Ryan is correct when he says that the healthy people are subsidizing the people who get sick. That's pretty much the definition of health insurance.