ECE 321 - Final - Name ____________________

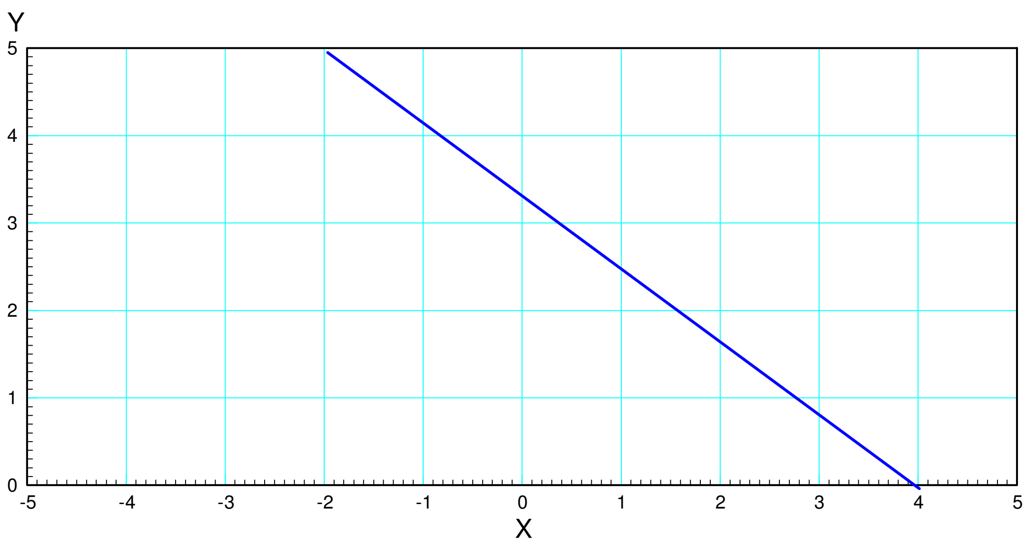
R = 2140 (Your Birth Month)*1000 + (Your Birthdate)*10

- For example, Feb 14th would be R = 2140 Ohms.

1) Amplifiers

1a) Determine the equation for the line, Y = AX + B

1b) Design an op-amp circuit to implement Y = f(X). Include R in your answer somewhere (birth month & date)

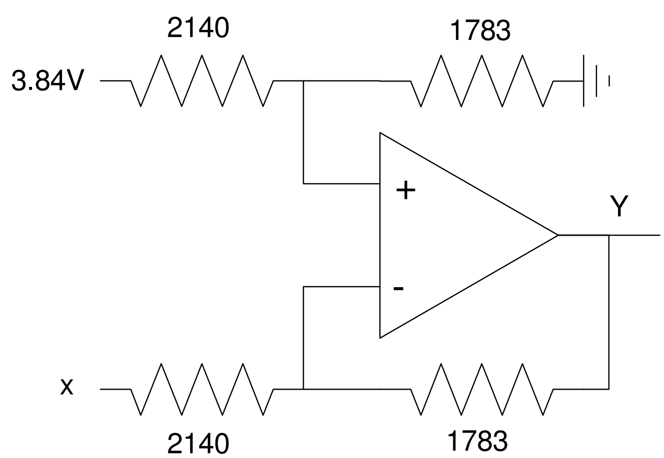


$$slope = \left(\frac{-5}{6}\right)$$

$$y = \frac{-5}{6}x + 3.2$$

Rewrite as

$$Y = \frac{5}{6}(3.84 - x)$$



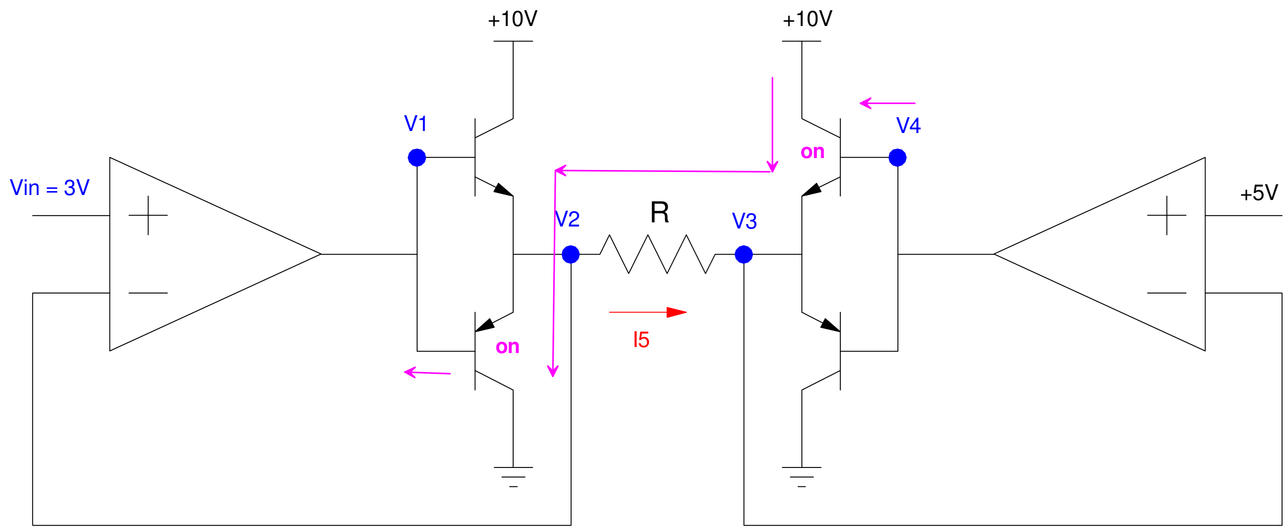
2) Push-Pull Amplifier

The following circuit can output -5V to +5V using only a single 10V power supply. Determine the votlges and currents when Vin = 3V. Assume 3904/3906 transistors

- $\beta = 200$
- $| V_{be} | = 0.7V$

R	V1	V2	V3	V4	I5
2140	**2.30V**	**3.00V**	**5.00V**	**5.70V**	**-934uA** 2V / 2140 Ohms

R = birth month * 1000 + birth day * 10. Feb 14th = 2140 Ohms



3) Instrumentation Amplifier

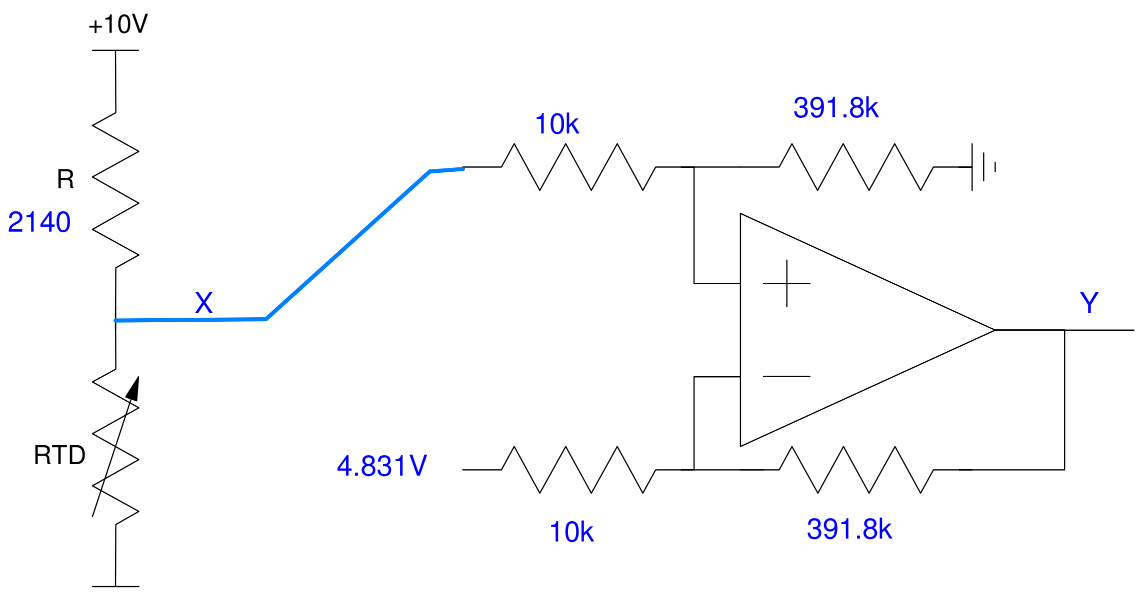
An RTD (type of temperature sensor) has a resistance - temperature relationship of

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

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

- 0V at 0C and
- 10V at +25C

Let R be your birth month * 1000 + birth day * 10. Feb 14th = 2140 Ohms



At 0C

- RTD = 2000
- X = 4.831V
- Y = 0V

At +25C

- RTD = 2215 Ohms
- X = 5.086V
- Y = 10V

$$gain = \left(\frac{10V - 0V}{5.086V - 4.831V}\right) = 39.18$$

4) Filter: Analysis

Assume X and Y are related by the following transfer function

$$Y = \left(\frac{500(s+2)}{(s+10)(s+30)}\right)X$$

a) What is the differential equation relating X and Y?

b) Determine y(t) assuming

$$x(t) = 5 + 2\cos(\omega t) + 4\sin(\omega t)$$

where ω is your birth date (1..31)

DC:

$$s = 0$$

$$X = 5$$

$$Y = \left(\frac{500(s+2)}{(s+10)(s+30)}\right)_{s=0} \cdot (5 + j0)$$

$$Y = 16.67$$

$$y(t) = 16.67$$

AC: Feb 14th:

$$s = j14$$

$$X = 2 - j4$$

$$Y = \left(\frac{500(s+2)}{(s+10)(s+30)}\right)_{s=j14} \cdot (2 - j4)$$

$$Y = 26.879 - j48.580$$

$$y(t) = 26.879\cos(14t) + 48.580\sin(14t)$$

Total answer: DC + AC

$$y(t) = 16.67 + 26.879\cos(14t) + 48.580\sin(14t)$$

5) Filter: Design

Design a circuit so that the gain is

- 0.9 < gain < 1.1 for frequencies below 10 rad/sec
- gain < 0.3 for frequencies above 15 rad/sec

Determine the gain of your final design at 10 and 15 rad/sec

Number of poles needed:

$$\left(\frac{10}{15}\right)^n < 0.3$$

$$n > 2.969$$

Let N = 4

Assume a corner at 10 rad/sec

Assume a Chebychev filter

$$G(s) = \left(\frac{6387}{(s+7.2\angle\pm 38.5^0)(s+11.1\angle\pm 77.8^0)} \right.$$

In Matlab

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p1 = 7.2*exp(j*38.5*pi/180);
p2 = conj(p1);
p3 = 11.1*exp(j*77.8*pi/180);
p4 = conj(p3);

G = zpk([],[-p1,-p2,-p3,-p4],abs(p1*p2*p3*p4))

                   6387.2064
----------------------------------------------
(s^2 + 11.27s + 51.84) (s^2 + 4.691s + 123.2)

abs(evalfr(G, j*10))

ans =   0.995712822369479

abs(evalfr(G, j*15))

ans =   0.213292607621345
```

6) Filter Design

Design a circuit to imlement the following filter:

$$Y = \left(\frac{10.000}{(s^2+10s+R)\left(s^2+20s+2R\right)} \right) X$$

where R is your birth month * 1000 + birth date * 10. For example, Feb 14 = 2140

$$Y = \left(\frac{10.000}{(s^2+10s+2140)\left(s^2+20s+4280\right)} \right) X$$

$$Y = \left(\frac{10,000}{\left(s+46.260\angle\pm83.79^0\right)\left(s+65.42\angle\pm81.21^0\right)} \right.$$

For the first stage

$$\frac{1}{RC} = 46.260$$

R = 100k, C = 216nF

$$3 - k = 2\cos\left(83.79^0\right)$$

$$k = 2.784$$

For the second stage

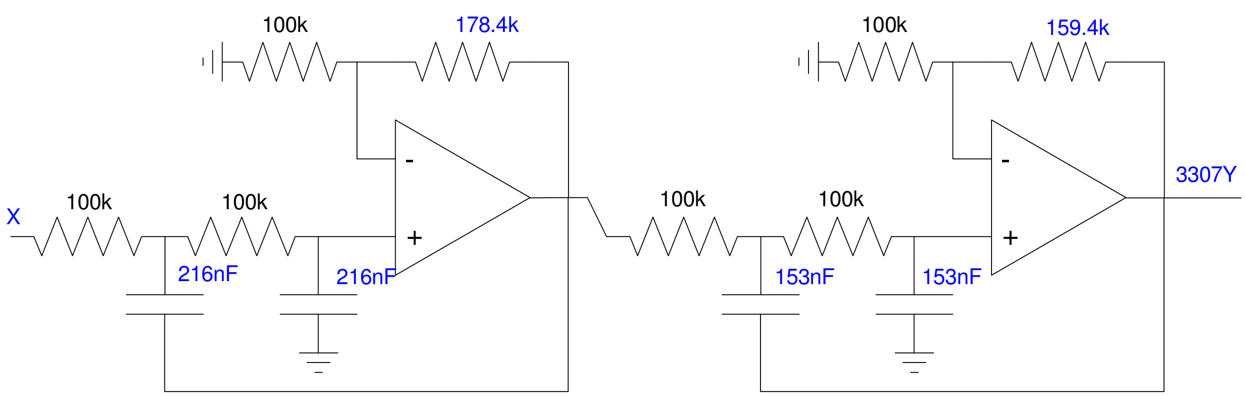
$$\frac{1}{RC} = 65.42$$

R = 100k, C = 153nF

$$3 - k = 2\cos\left(81.21^0\right)$$

$$k = 2.594$$

- The DC gain should be 0.002184.
- It's actually k1*k2 = 7.222
- The output is 3307*y



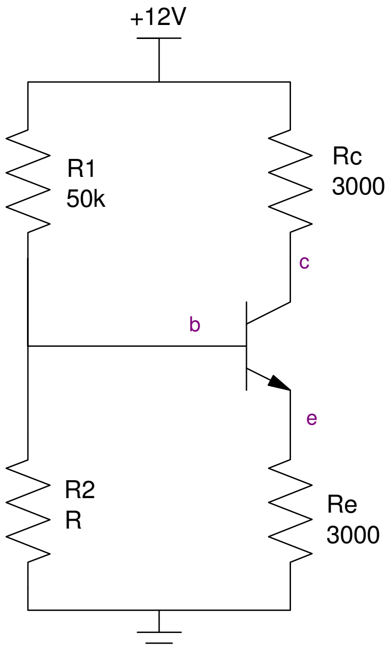
7) CE Amplifier (DC)

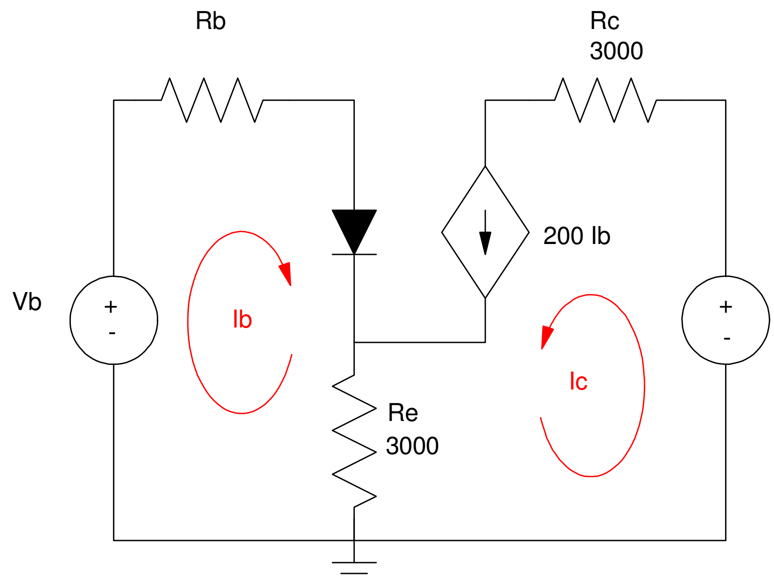
Determine the Q-point (Vc, Rc) for the following transistor circuit. Assume a 3904 transistor

- $\beta = 200$
- $| Vbe | = 0.7$

R	Vb	Rb	Vce	Ic
7140	**1.4811V**	**6171**	**10.4575V**	**256.4mA**

R = birth month * 1000 +   birth day * 10.   For example, Feb 14th = 2140 Ohms





$$R_b = R_1 || R = 6171\Omega$$

$$V_b = \left(\frac{R}{R+50k}\right) 12V = 1.4811V$$

$$I_b = \left(\frac{1.4811V - 0.7V}{6171 + 201(3000)}\right) = 1.2822\mu A$$

$$I_c = 200 I_b = 256.4mA$$

$$V_{ce} = 12 - 6000 I_c - 3000 I_b = 10.4575V$$

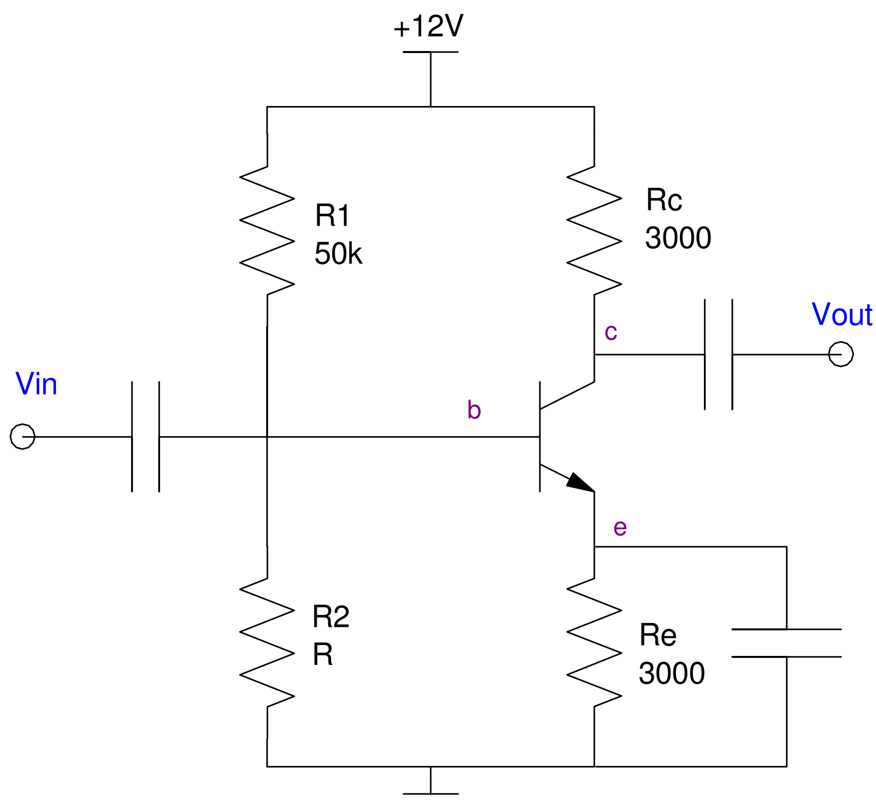
8) CE Amplifier (AC)

Draw the small signal model for this amplifier and the resulting 2-port model. Assume 3904 transistors

- $\beta = 200$
- Vbe = 0.7V

R	Rin	Ai	Rout	Ao
7140	**5356**	**0**	**3000**	**-14.79**

R = birth month * 1000 + birth day * 10. For example, Feb 14th = 2140 Ohms



$$r_f = \frac{0.052}{I_b} = \frac{0.052}{1.2822\mu A} = 40.55k\Omega$$

$$R_{in} = 7140||50k||40.55k = 5356\Omega$$

$$R_{out} = R_c = 3000$$

$$A_0 = -\frac{\beta R_c}{r_f} = -14.79$$