ECE 321 - Homework #5

DC Analsis of Transtor Amplfiers, 2-Ports, CE Amplifiers. Due Monday, May 3rd

Please make the subject "ECE 321 HW#4" if submitting homework electronically to Jacob_Glower@yahoo.com (or on blackboard)

1) Determine the Q-point for the following transistor circuit. Assume C's are large and assume 3904 transistors:

- Vbe = 0.7V
- β=200

First, replace R1 and R2 with their Thevenin equivalent

$$R_b = 400k||800k = 266.7k$$

$$V_b = \left(\frac{R_2}{R_1+R_2}\right) 12V = 4.00V$$

Compute Ib

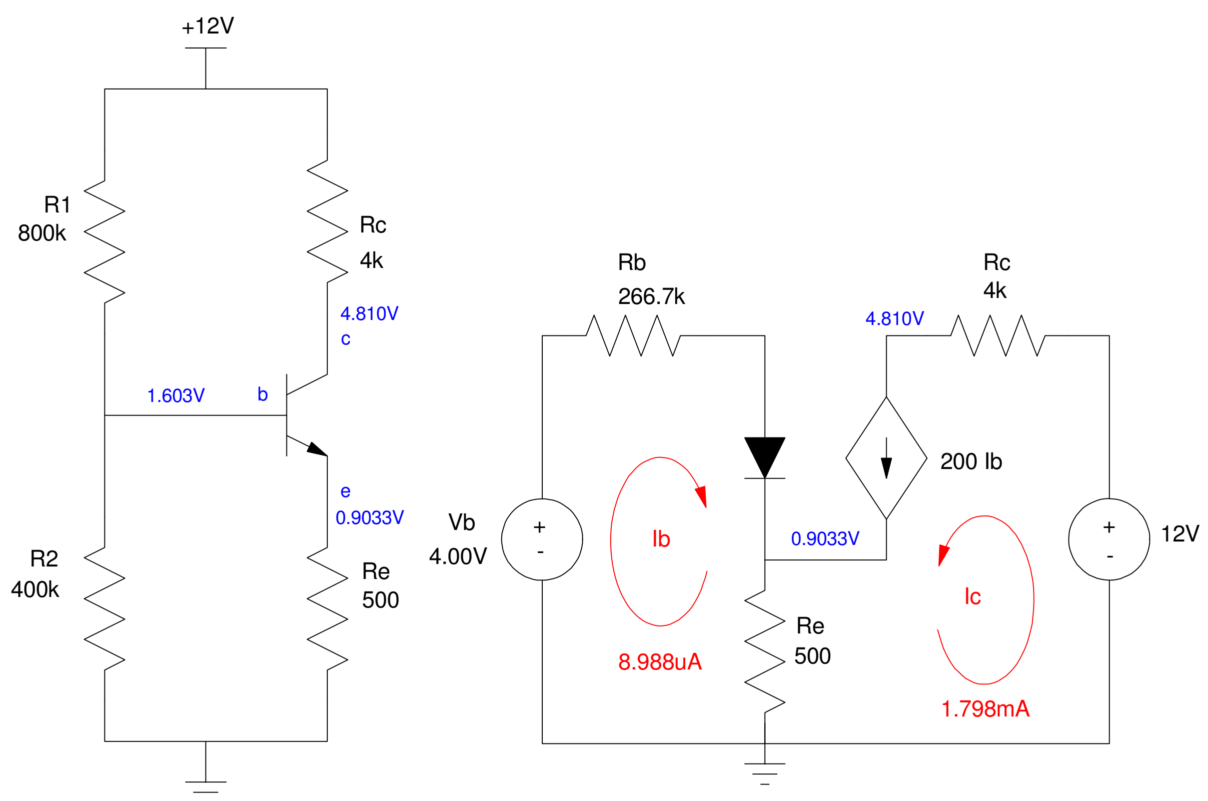
$$-4 + 266.7k \cdot I_b + 0.7 + 500(I_b + I_c) = 0$$

$$I_b = \left(\frac{4.00-0.7}{266.7k+(1+\beta)\cdot 500}\right) = 8.988\mu A$$

$$I_c = \beta I_b = 1.798mA$$

Compute the Q-point

$$V_{ce} = 12 - I_c R_c - (I_c + I_b) R_e = 3.907V \qquad \textit{active mode}$$



2) Modify this circuit so that

- The Q-point is stabilized for variations in β, and
- The Q-point is Vce = 6.0V

This is similar to problem #1, just go backwards (right to left)

To stabilize the Q-point, let

$$R_b << (1+\beta)R_e = 100.5k$$

Let Rb = 10k. To set the Q-point to 6.00V

$$V_{ce} = 6.00V = 12 - I_c R_c - (I_c + I_b)R_e$$

$$I_c = \left(\frac{12V - 6V}{R_c + \left(1 + \frac{1}{200}\right) R_e}\right) = 1.333mA$$

$$I_b = \frac{I_c}{\beta} = 6.663\mu A$$

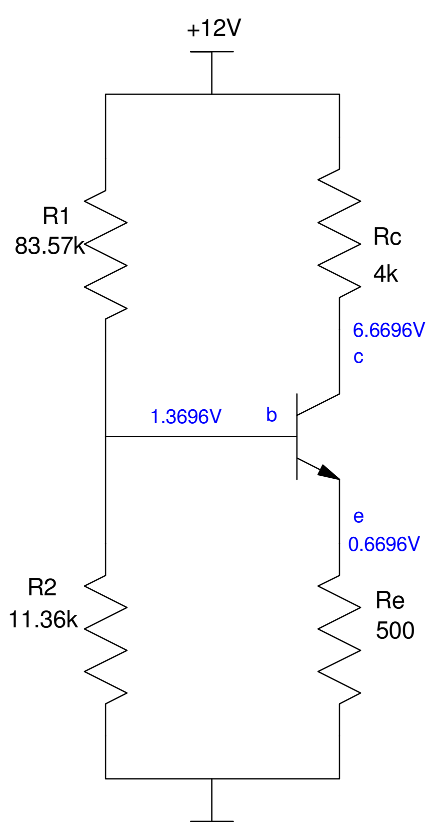
$$V_b = R_b I_b + 0.7 + R_e(I_b + I_c) = 1.436V$$

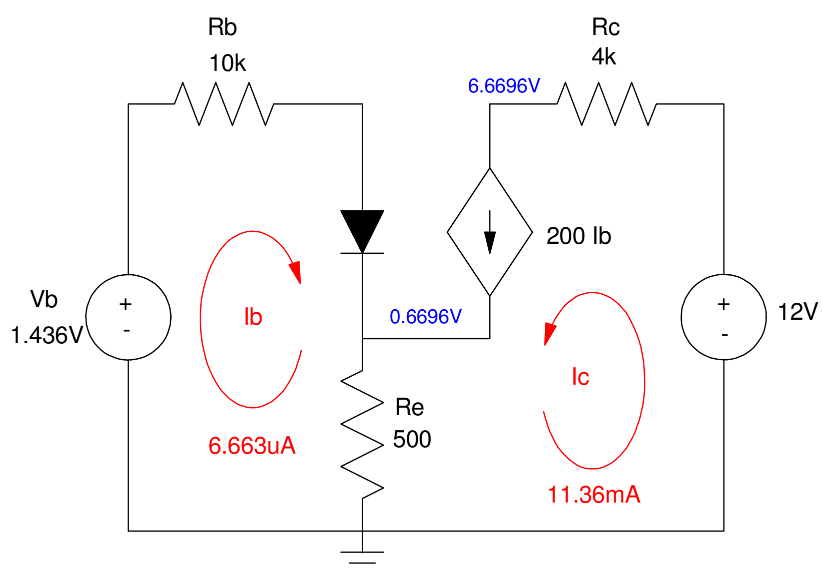
Now find R1 and R2

$$R_1 || R_2 = R_b = 10k \qquad \left(\frac{R_2}{R_1 + R_2}\right) 12V = V_b = 1.436V$$

Solving

$$R_1 = \left(\frac{12V}{1.436V}\right) 10k = 83.57k\Omega \qquad R_2 = 11.36k\Omega$$

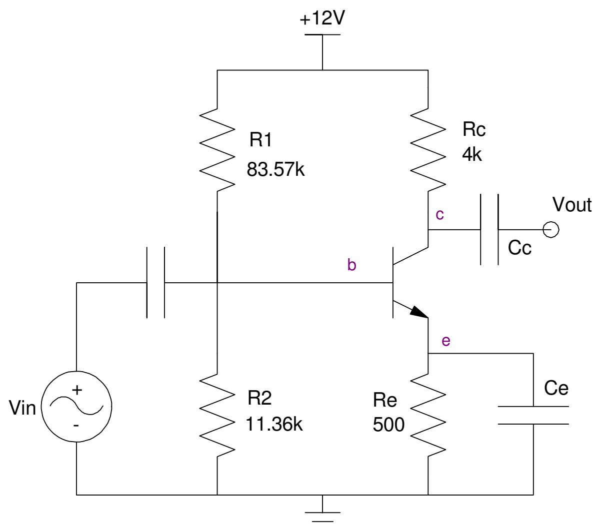


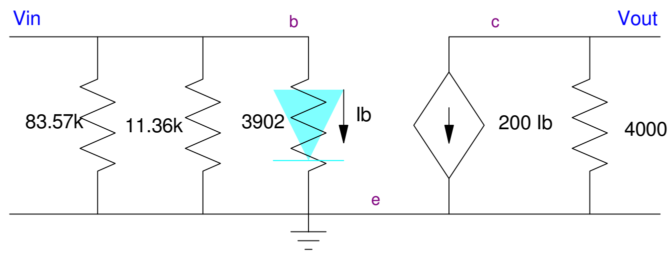


From this point on, use the circuit you designed for problem #2

3) Draw the small-signal model for the circuit of problem #2. From this, determine the 2-port model for the Common Emitter amplifier

$$r_f = \left(\frac{0.026V}{I_b}\right) = \left(\frac{0.026V}{6.663\mu A}\right) = 3902\Omega$$





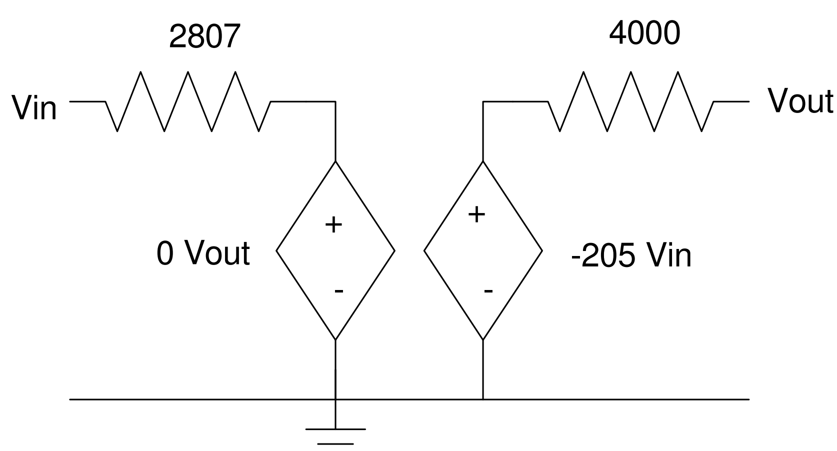
From this

Rin = 83.57k || 11.36k || 3902 = 2807

Ain = 0

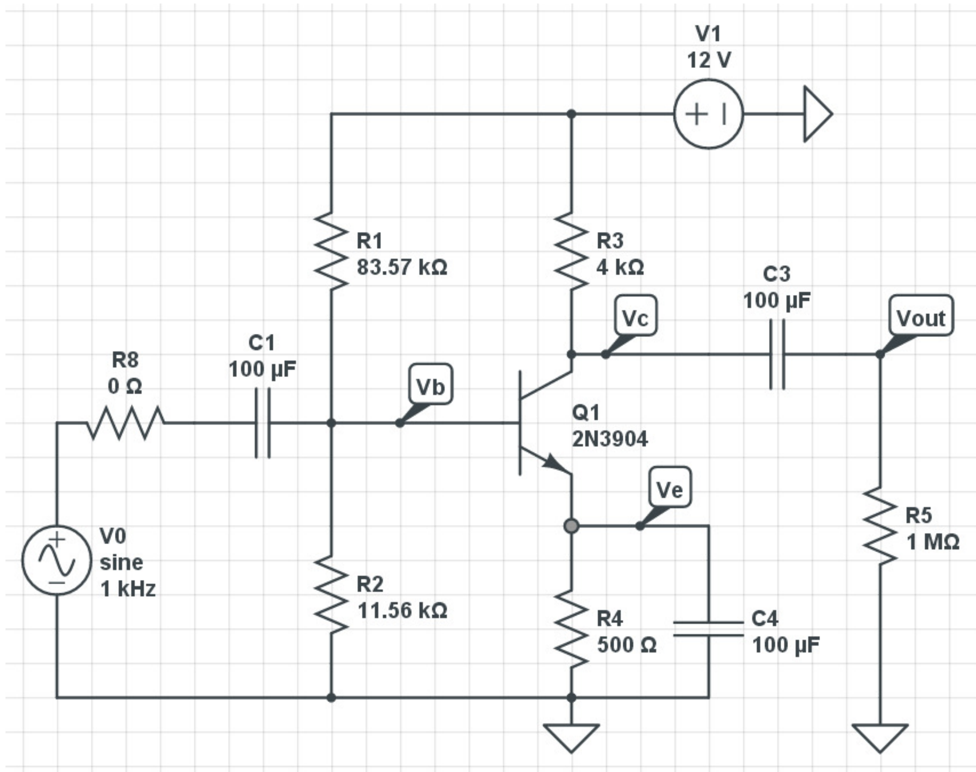
Rout = 4k

$$A_o = -\left(\frac{\beta R_c}{r_f}\right) = -\left(\frac{200 \cdot 4000}{3902}\right) = -205$$



4) Simulate this circuit in CircuitLab. Verify each of the 2-port parameters at 1kHz

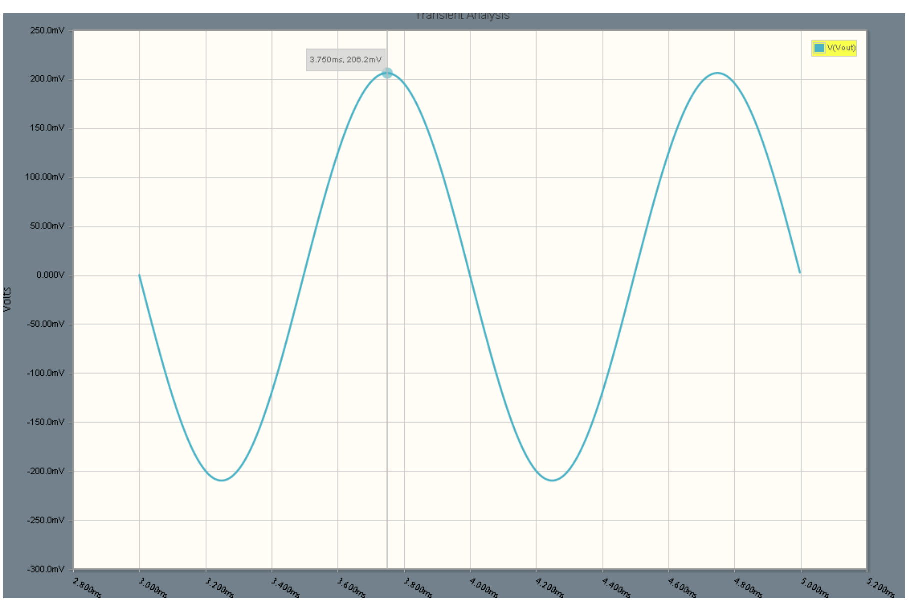
- Rin
- Rout
- Ao



CircuitLab circuit. hfe changed to 200 on the 3904

Ao: R8 = 0, R5 = 1M, V0 = 1mV 1kHz

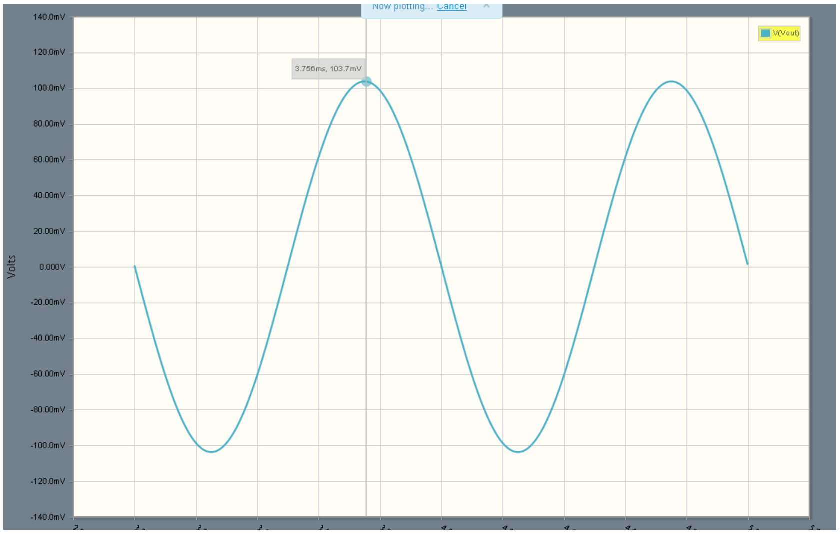
- Vc = 206.6mV
- V1 = 206.5mV (peak)
- Ao = V1/V0 = 206.5 (vs. -205 calculated)



V0 = 1mV results in V1 = 206.5mV. Note: V0 needs to be small enough that V1 is still a sine wave (i.e. no clipping)

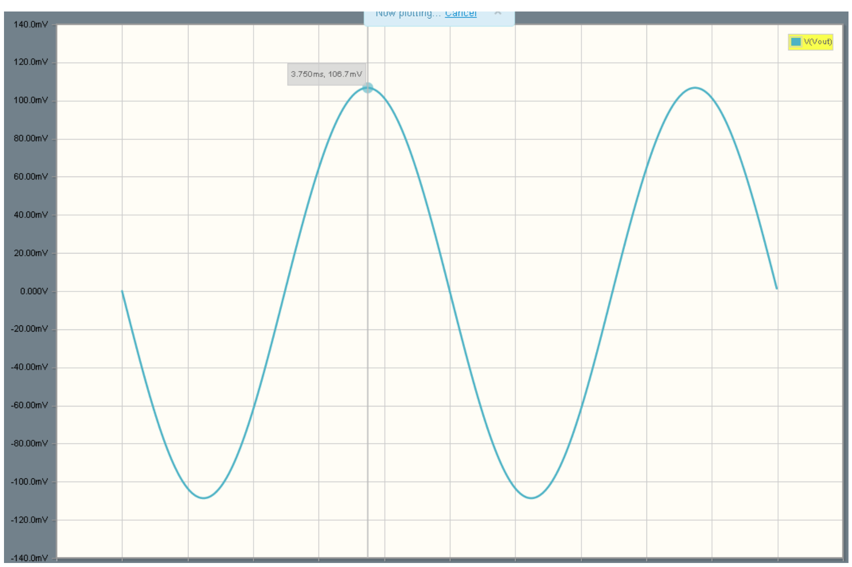
Rin: R8 = 2806, R5 = 1M, V0 = 1mV @ 1kHz

- Vo = 108.1mV
- $\left(\frac{R_{in}}{R_{in}+R_8}\right)206.6mV = 108.1mV$
- $R_{in} = \left(\frac{108.1mV}{206.6mV-108.1mV}\right)R_8 = 3079\Omega$



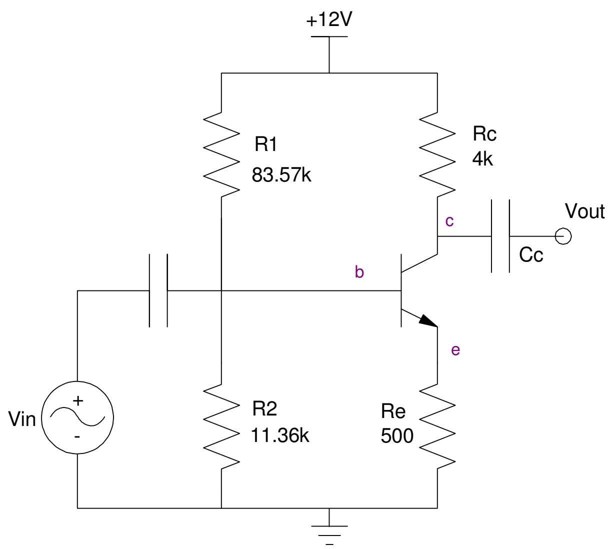
Rout: R8 = 0, R5 = 4k, V0 = 1mV @ 1kHz

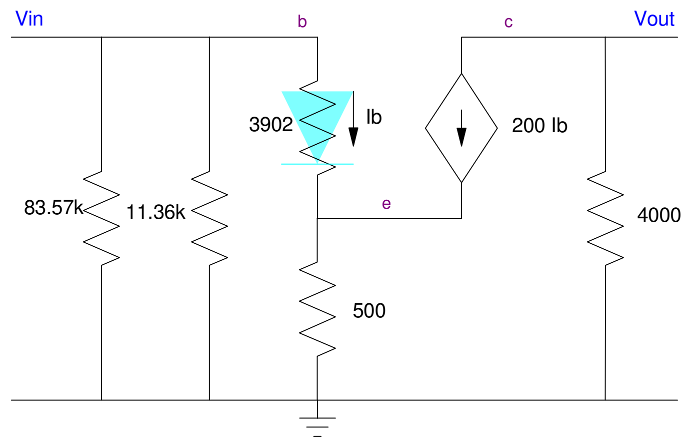
- Vo = 107.1mV
- $\left(\frac{4k}{4k+R_{out}}\right)206.6mV = 107.1mV$
- $R_{out} = \left(\frac{107.1mV}{206.6mV-107.1mV}\right)4k = 4305\Omega$



	Rin	Ao	Rout
Calculated	2807 Ohms	-205	4000 Ohms
CircuitLab	3079 Ohms	-206.5	4305 Ohms

5) Remove Ce. Now draw the small-signal model for the circuit of problem #2. From this, determine the 2-port model for the Common Emitter amplifier





Rin:

- Short Vout
- Apply 1V at Vin
- Compute the current at Iin

$$I_{in} = \frac{1V}{83.57k} + \frac{1V}{11.36k} + \frac{1V}{3902+(1+\beta)500} = 109.6\mu A$$

$$R_{in} = \frac{1V}{109.6\mu A} = 9126\Omega$$

Rout:

- Short Vin
- This sets Ib = 0
- Rout = 4000

Ao:

- Apply 1V at Vin

$$I_b = \frac{1V}{3902+(1+\beta)500} = 9.578\mu A$$

$$200 I_b = 1.916 mA$$

$$V_o = A_o = -4000 \cdot 200 I_b = -7.663$$

6) Simulate this circuit in CircuitLab. Verify each of the 2-port parameters at 1kHz

Ao:

- Change Ce to 1nF (essentially remove it)
- Apply 1mV @ 1kHz to Vin
- Vout = 7.662mV
- Ao = -7.662

Rin:

- Add 9126 Ohms at Vin
- Apply 1mV @ 1kHz at Vin
- Vout = 3.856mV

$$R_{in} = \left(\frac{3.856mV}{7.662mV - 3.856mV}\right) 9126\Omega = 9246\Omega$$

Rout:

- Change the load from 10M to 4k
- Apply 1mV @ 1kHz at Vin
- Vout = 3.836mV

$$R_{out} = \left(\frac{3.836mV}{7.662mV - 3.836mV}\right) 4000\Omega = 4010\Omega$$

	Rin	Ao	Rout
Calculated	9126 Ohms	-7.663	4000 Ohms
CircuitLab	9246 Ohms	-7.662	4010 Ohms