ECE 321 - Homework #4

2-Port Models, DC Analysis of Transistor Amplifiers. Due Monday, November 27th, 2017

1) Determine the 2-port model for the following circuit.

Rin: Short Vout. Measure the resistance at the input.

$$R_{in} = 400 + 500 || 1000 = 733\Omega$$

Ai: Apply 1V at the output. Measure the voltage at the input

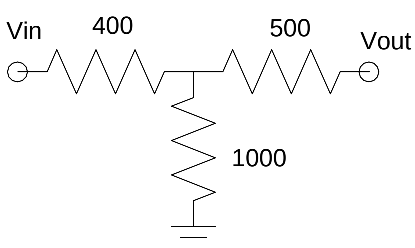
$$A_i = V_{in} = \left(\frac{1000}{1000+500}\right)1V = 0.67V$$

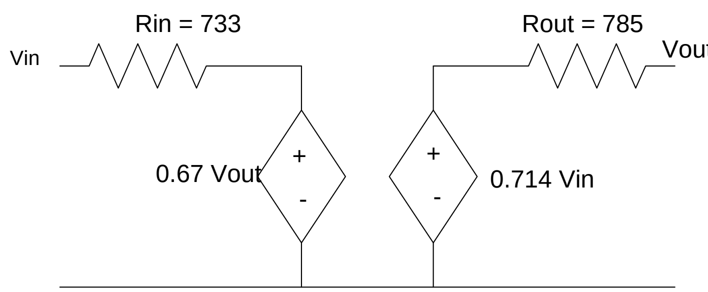
Rout: Short Vin. Measure the resistance at the output

$$R_{out} = 500 + 400 || 1000 = 785\Omega$$

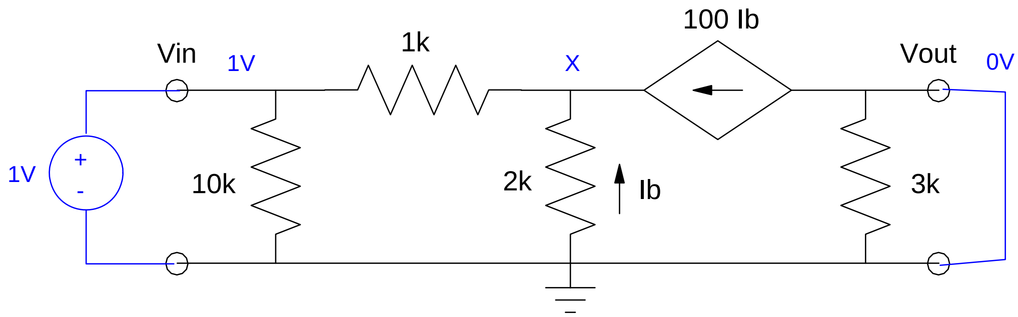
Ao: Apply 1V at the input. Measure the voltage at the output

$$A_o = \left(\frac{1000}{1000+400}\right)1V = 0.714V$$





2) Determine the 2-port model for the following circuit.



Rin: Short the output. Measure the resistance at the input.

This isn't obvious, so apply a 1V test voltage and see how much current it draws.

$$\left(\frac{X-1}{1k}\right)+\left(\frac{X}{2k}\right)-100\left(\frac{0-X}{2k}\right)=0$$

$$X=0.0194V$$

$$I_{in}=\left(\frac{1V}{10k}\right)+\left(\frac{1-0.0194}{1k}\right)=1.081mA$$

$$R_{in}=\frac{V_{in}}{I_{in}}=\frac{1V}{1.081mA}=925\Omega$$

Ai: Apply 1V at the output and measure the voltage at the input. Turns out 0V makes the currents balance

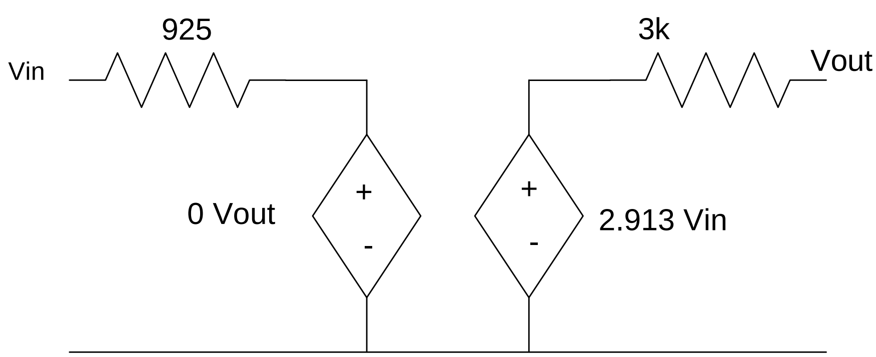
Ai = 0

Rout: Short the input. Measure the resistance at the output

- X = 0 makes the currents balance, so X = 0.
- All you see at the output is 3k
- Rout = 3k

Ao: Applyu 1V at the niput and determine the voltage at the output (shown above)

- X = 0.0194V
- $I_b=\left(\frac{0-X}{2k}\right)=-9.709\mu A$
- $100I_b=-970.9\mu A$
- $V_{out}=-3k\cdot 100I_b=2.913V$



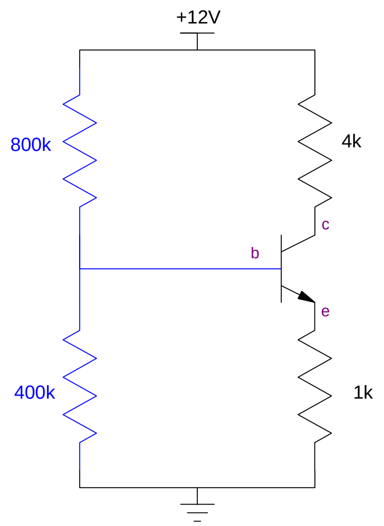
3) Determine the Q-point for the following circuit. Assume a 3904 transistor ($\beta = 200$)

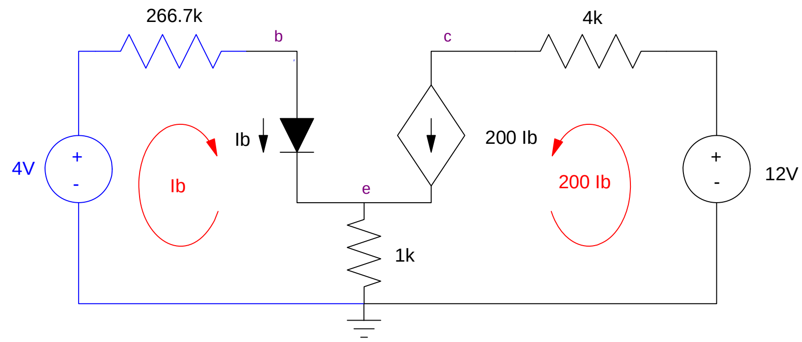
Redraw using the Thevenin equivalent at the base

$$R_{th} = 400k||800k = 266.7k$$

$$V_{th} = \left(\frac{400k}{400k+800k}\right) 12V = 4V$$

Replace the transistor with its model in the active region





Write the loop equation for Ib

$$-4 + 266.7kI_b + 0.7 + 1k \cdot (I_b + 200I_b) = 0$$

$$I_b = \left(\frac{4-0.7}{266.7k+201 \cdot 1k}\right) = 7.0563\mu A$$

$$I_c = \beta I_b = 1.411mA$$

Solve for the Q-point

$$V_c = 12 - 4k \cdot I_c = 6.355V$$

$$V_e = 1k \cdot (I_b + I_c) = 1.418V$$

$$V_{ce} = V_c - V_e = 4.937V$$

The Q-Point is

Vce = 4.937V

Ic = 1.411mA

4) Modify this circuit so that

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

First, redraw the circuit using the Thevenin equivalent for R1 and R2. Next, from the specs, determine the current Ic

$$V_{ce} = V_c - V_e$$

$$6V = (12 - 4000I_c) - 1000(I_b + I_c)$$

$$I_c = 200I_b$$

$$I_c = \left(\frac{12V-6V}{4000+1000\cdot\left(1+\frac{1}{200}\right)}\right) = 1.199mA$$

This means

$$I_b = \frac{I_c}{\beta} = 5.994\mu A$$

To stabilize the Q-point

$$R_b << (1+\beta)R_e = 20,100\Omega$$

Let Rb = 2k

$$V_b = V_{th} = 2k \cdot I_b + 0.7 + 1k \cdot (I_b + I_c) = 1.917V$$

Convert back to R1 and R2

$$\left(\frac{R_1 R_2}{R_1+R_2}\right) = 2k$$

$$\left(\frac{R_2}{R_1+R_2}\right)12V = 1.917V$$

Solving

$$R_1 = \left(\frac{12V}{1.917V}\right)2k = 12.52k$$

$$R_2 = 2.38k$$