ECE 321 - Homework #5

2-port models, CE, CB, CC Amplifiers. Due Monday, December 4th, 2017

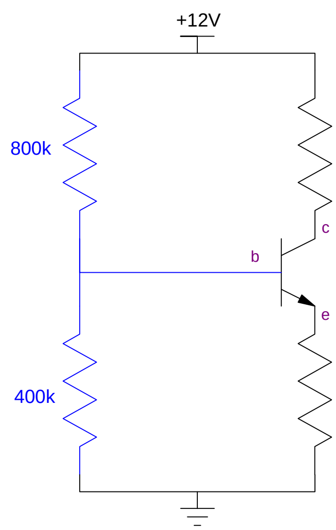
1) Determine the Q-point for the following circuit. Assume a 3904 transistor ($\beta = 200$)

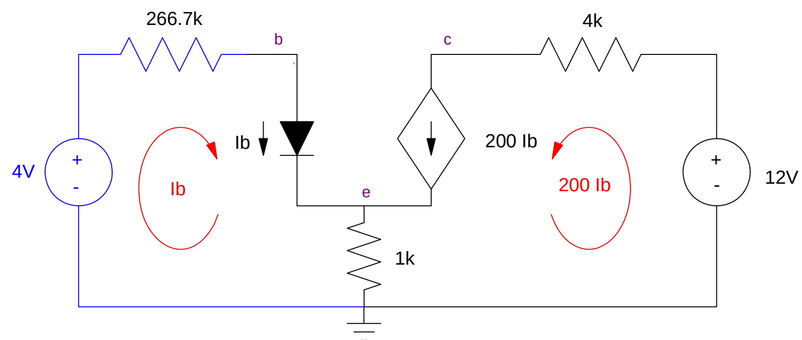
Redraw using the Thevenin equivalent at the base

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

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

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

2) 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

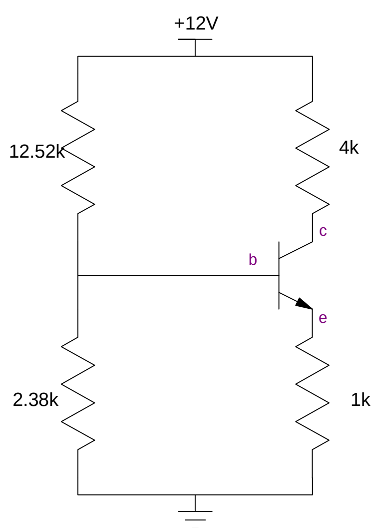
$$\left(\frac{R_1R_2}{R_1+R_2}\right) = 2k$$

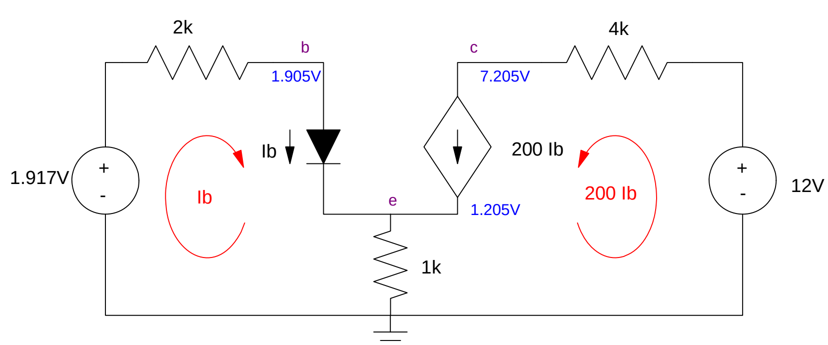
$$\left(\frac{R_2}{R_1+R_2}\right)12V = 1.917V$$

Solving

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

$$R_2 = 2.38k$$

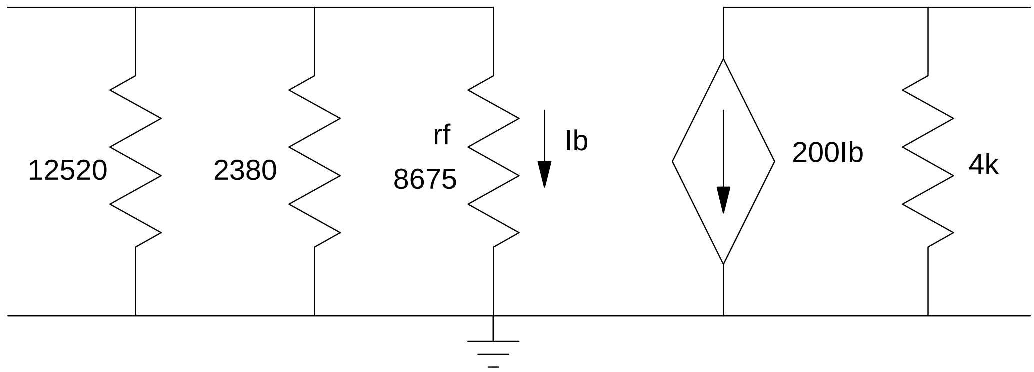




3a) Draw the small-signal model for your circuit of problem #2 when set up as a common emitter (CE) configuration

$$I_b = 5.994\mu A$$

$$r_f = \frac{0.052}{I_b} = 8675\Omega$$



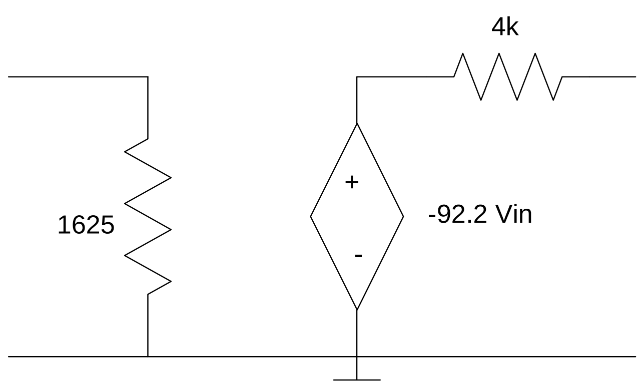
3b) Determine the 2-port model for this amplifier in a CE configuration.

$$R_{in} = 12520||2380||8675 = 1625\Omega$$

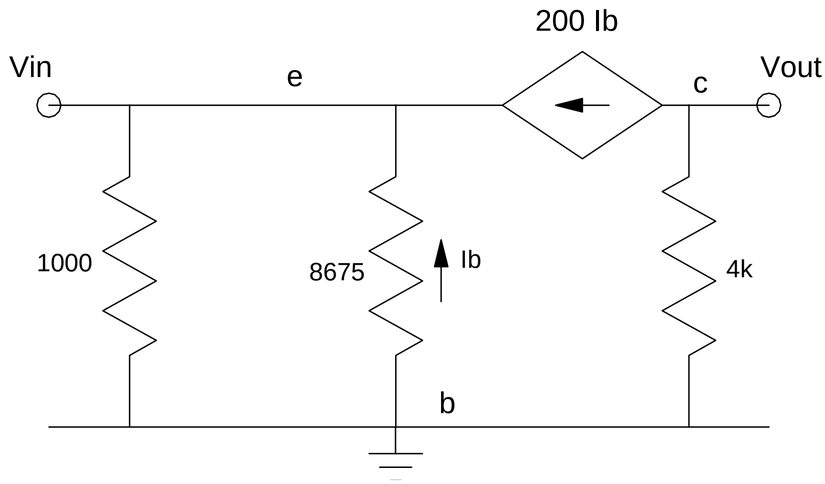
$$A_{in} = 0$$

$$R_{out} = 4k$$

$$A_{out} = -\frac{200 \cdot 4k}{8675} = -92.2$$



4a) Draw the small-signal model for your circuit of problem #2 when set up as a common base (CB) configuration



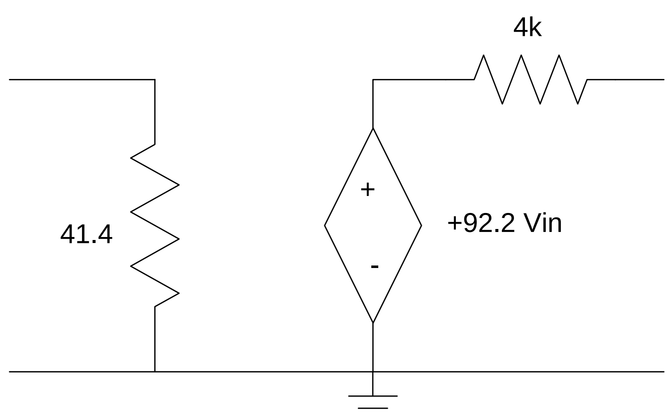
4b) Determine the 2-port model for this amplifier in a CB configuration.

$$R_{in} = 1000||8675||\frac{8675}{\beta} = 41.4\Omega$$

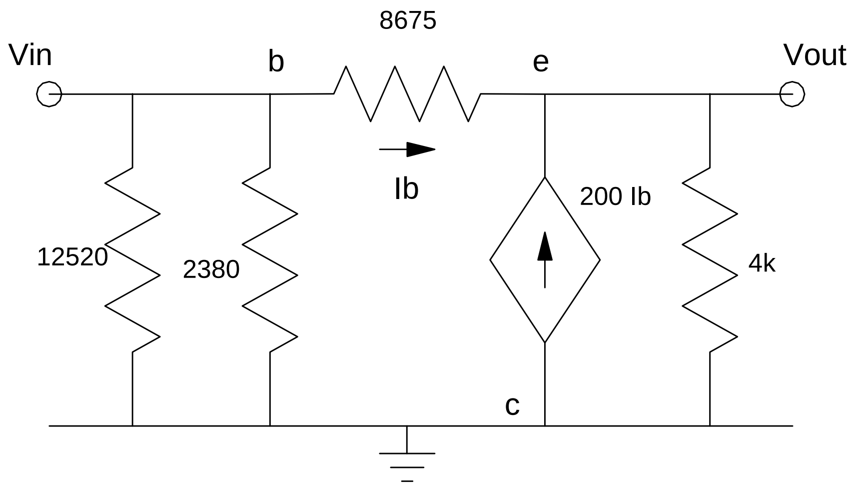
$$A_{in} = 0$$

$$R_{out} = 4k$$

$$A_{out} = +\frac{200 \cdot 4k}{8675} = +92.2$$



5a) Draw the small-signal model for your circuit of problem #2 when set up as a common collector (CC) configuration



5b) Determine the 2-port model for this amplifier in a CC configuration.

$$R_{in} = 12520||2380||8675 = 1625\Omega$$

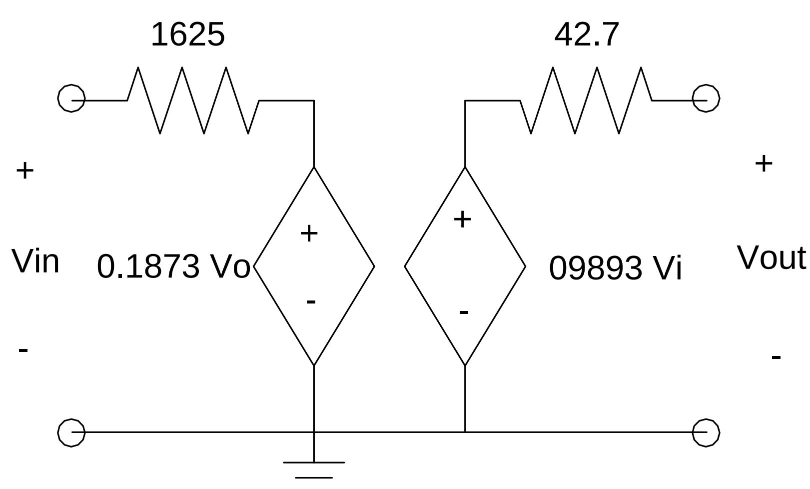
$$A_{in} = \left(\frac{12520||2380}{12520||2380+8675}\right) = 0.1873$$

$$R_{out} = 4k||8675||\frac{8675}{\beta} = 42.7\Omega$$

Aout: Apply 1V at the input, vind Vout (X)

$$\left(\frac{X-1}{8675}\right) + 200\left(\frac{X-1}{8675}\right) + \left(\frac{X}{4000}\right) = 0$$

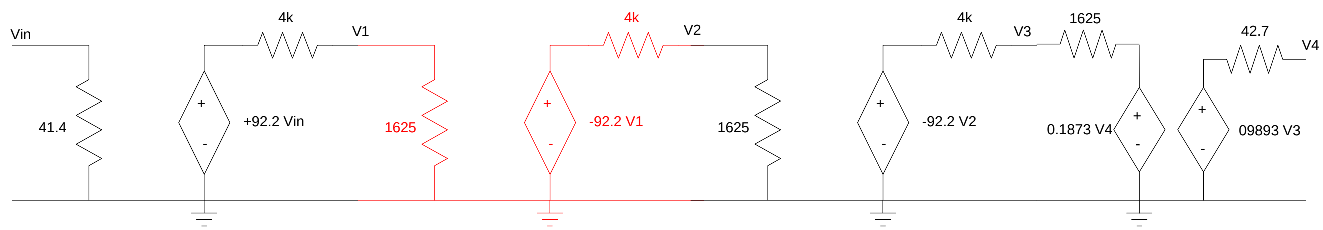
$$A_{out} = 0.9893$$



6) Determine the 2-port model for a 4-stage amplifier:

CB : CE : CE : CC

Draw the circuit using 2-port models

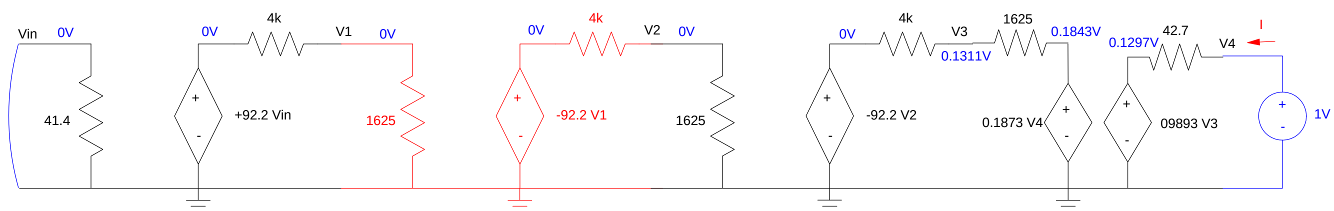


By inspection

Rin = 41.4

Ain = 0

Rout: Short Vin. Apply 1V to V4. Calculate the current draw



V4 = 1V

0.1873 V4 = 0.1873 V

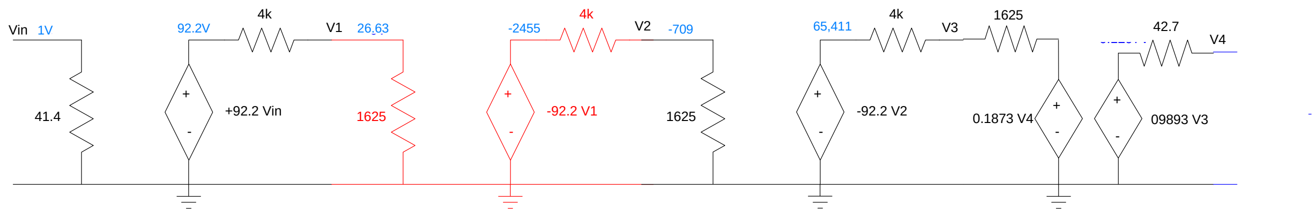
$$V_3 = \left(\frac{4k}{4k+1625}\right) \cdot 0.1873V = 0.1311V$$

$$0.9893V_3 = 0.1297V$$

$$I = \left(\frac{1-0.1297V}{42.7\Omega}\right) = 20.38mA$$

$$R_{out} = \frac{1V}{20.38mA} = 49.1\Omega$$

Aout: Apply 1V at Vin. Compute V4



$$V_3 = \left(\frac{1625}{1625+4000}\right)65411 + \left(\frac{4000}{4000+1625}\right)\cdot 0.1873 V_4$$

$$V_4 = 0.9893 V_3$$

Solving

$$V_3 = \left(\frac{18{,}896}{1-0.7111\cdot 0.1873\cdot 0.9893}\right) = 21,764$$

$$V_4 = 0.9893 V_3 = 21,531$$

$$A_o = 21,531$$