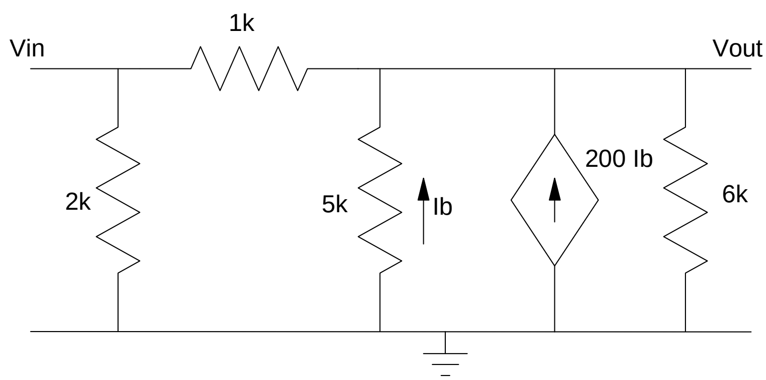
ECE 321 - Homework #4

2-Port Models, Transistor Amplifiers. Due Monday, December 9th

2-Ports

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



Rin: Short Vout. Measure the resistance at Vin

$$R_{in} = 2k || 1k = 666.7\Omega$$

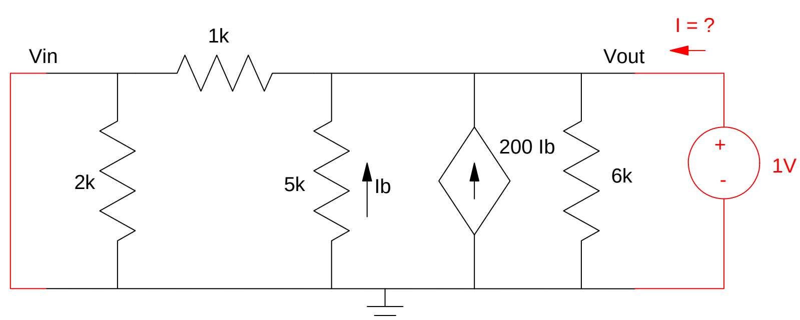
Ai: Apply 1V to Vout. Measure Vin.

From voltage division

$$A_i = \left(\frac{2k}{2k+1k}\right) \cdot 1V = 0.667$$

Rout: Short Vin. Measure the resistance.

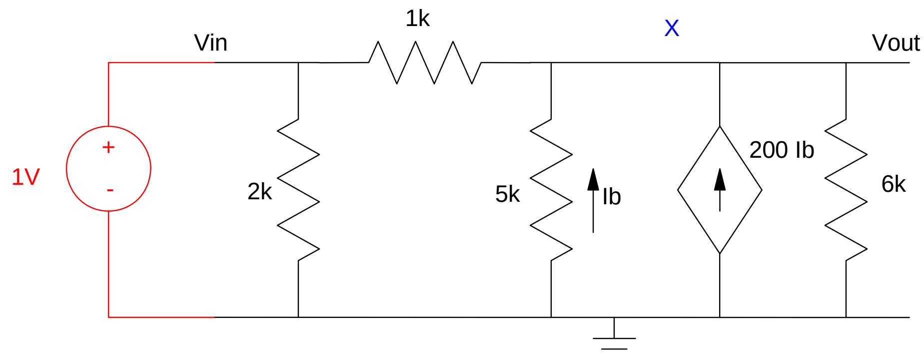
This isn't obvious, so apply a 1V test to Vout and measure the current



$$I = \frac{1}{6k} + \frac{1}{1k} + \frac{1}{5k} + 200\left(\frac{1}{5k}\right) = 41.37mA$$

$$R_{in} = \frac{1V}{41.37mA} = 24.17\Omega$$

Aout: Apply1V to Vin. Compute Vout

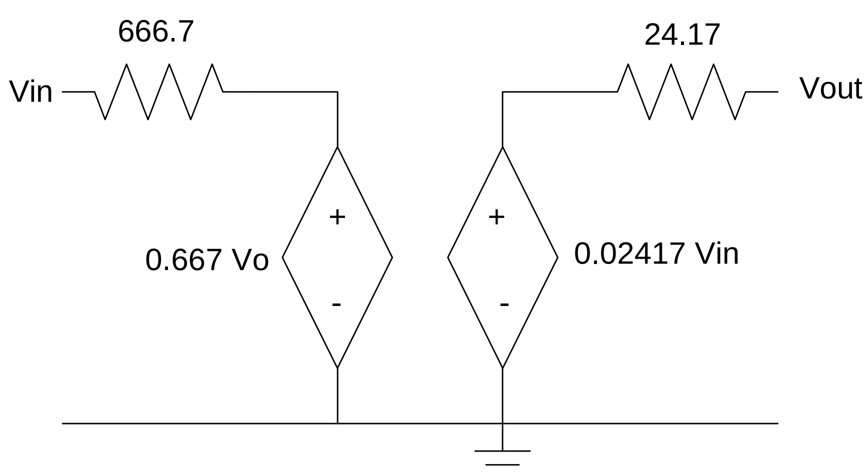


Using voltage nodes

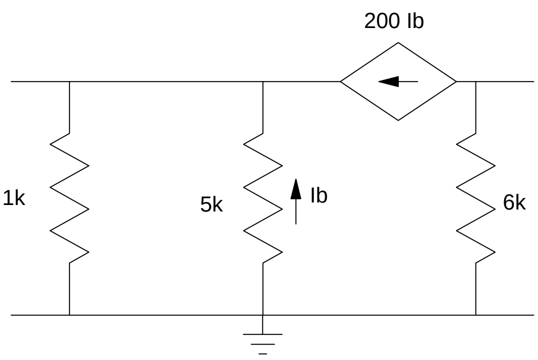
$$\left(\frac{X-1}{1k}\right)+\left(\frac{X}{5k}\right)+200\left(\frac{X}{5k}\right)+\left(\frac{X}{6k}\right)=0$$

$X = 0.02417$ = Ao

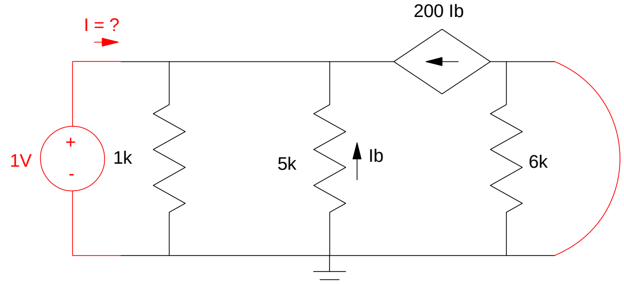
The 2-port model is then



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



Rin: Short Vout. Measure the resistance looking in. This isn't obvious so apply a 1V test voltage



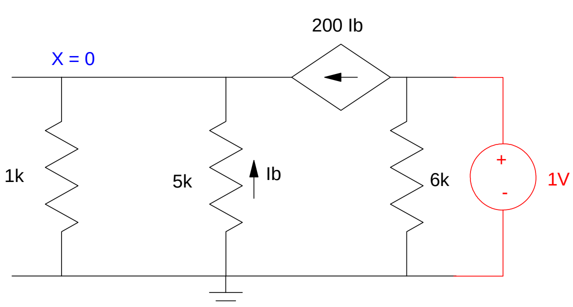
$$I = \frac{1}{1k} + \frac{1}{5k} + 200\left(\frac{1}{5k}\right) = 41.20mA$$

$$R_{in} = \frac{1V}{41.20mA} = 24.27\Omega$$

Ai: Apply 1V at the output. Compute Vin.

Turns out that Vin = 0V

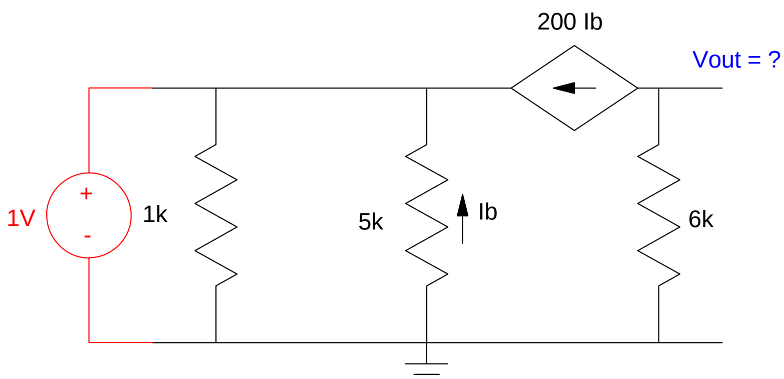
Ai = 0.



Rout: Short Vin. Compute the resistance at the output

$$R_{out} = 6k$$

Ao: Apply 1V to Vin. Compute Vout

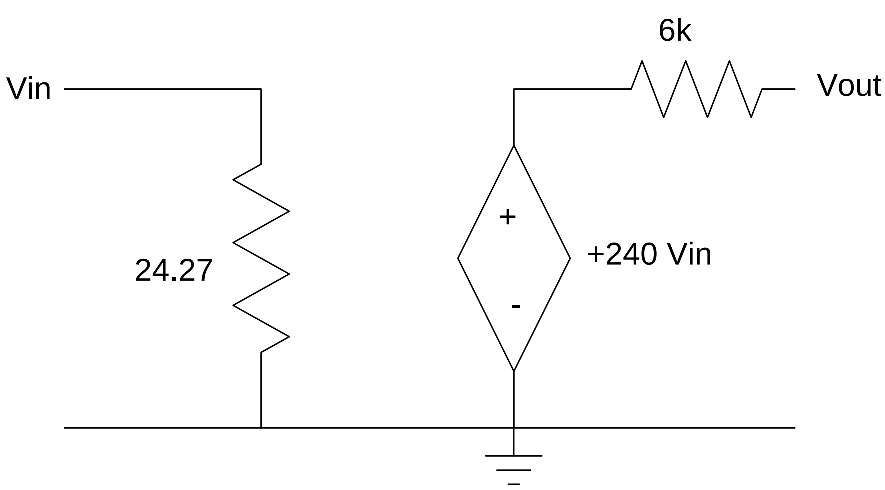


$$I_b = \frac{1V}{5k} = 200\mu A$$

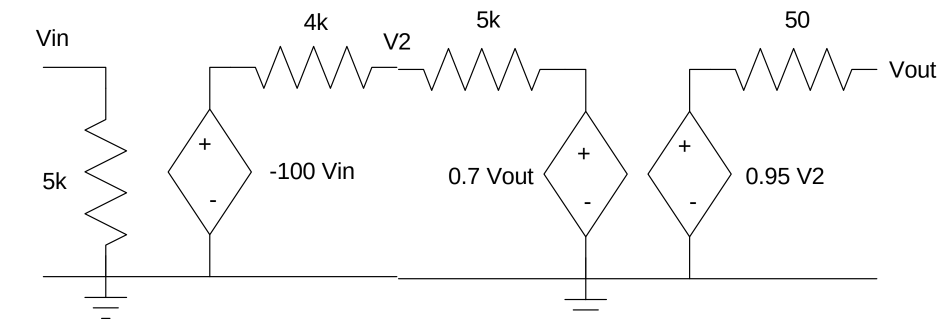
$$200 I_b = 40mA$$

$$V_o = 6000 \cdot 40mA = +240$$

The 2-port model is then



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

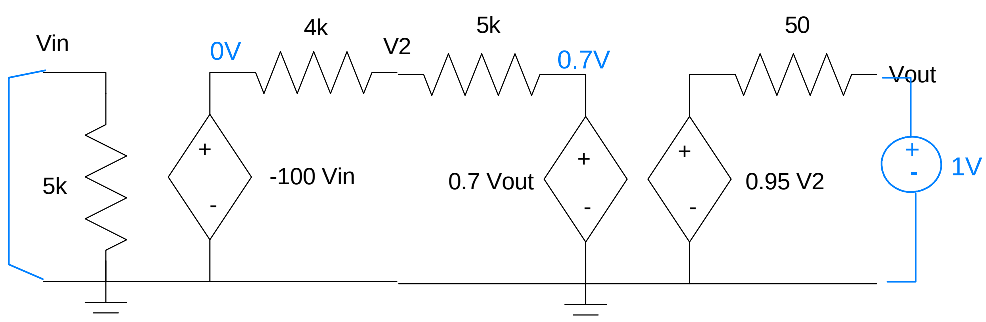


By inspection

Rin = 5k

Ai = 0

Rout: Short Vin. Measure the resistance at Vout. This isn't obvious so add a 1V source to Vout and compute the current



V2 is then

$$V_2 = \left(\frac{4k}{4k+5k}\right)0.7V = 0.3111V$$

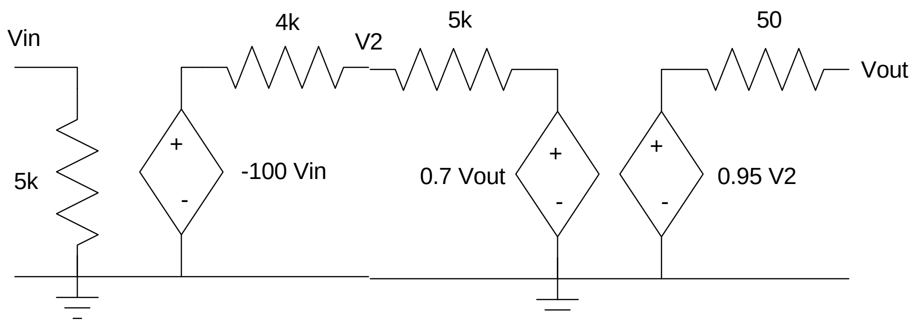
I and Rout is then

$$0.95V_2 = 0.2956V$$

$$I = \left(\frac{1V-0.2956V}{50}\right) = 14.09mA$$

$$R_{out} = \frac{1V}{14.09mA} = 70.98\Omega$$

Ao: Apply 1V to the input. Compute Vout.



Writing a voltage node at V2

$$\left(\frac{V_2-(-100)}{4k}\right)+\left(\frac{V_2-0.7V_{out}}{5k}\right)=0$$

$$V_{out}=0.95V_2$$

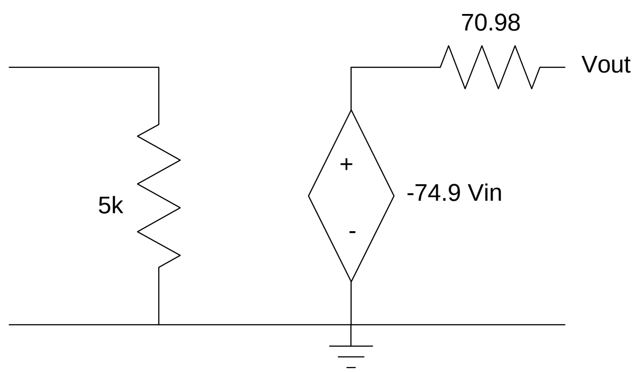
Substituting

$$\left(\frac{V_2-(-100)}{4k}\right)+\left(\frac{V_2-0.7(0.95V_2)}{5k}\right)=0$$

$$V_2=-78.8644V$$

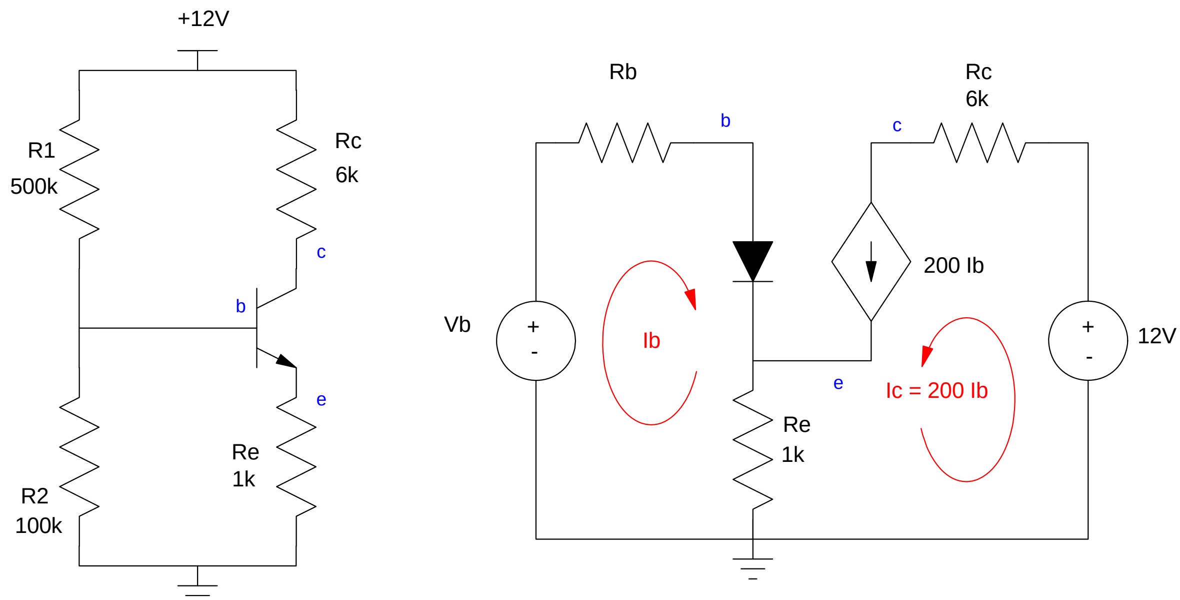
$$V_{out}=0.95V_2=74.9211V$$

The 2-port model is then



Transistor Amplfiers: DC Analysis

4) Determine the Q-point for the following transitor amplifier. Assume 3904 transistors with beta = 200 (nominal)



$$V_b = V_{th} = \left(\frac{100k}{100k+500k}\right) 12V = 2V$$

$$R_b = R_{th} = 100k || 500k = 83.33k$$

Writing the loop equation for Ib

$$-V_b + R_b I_b + 0.7 + 1k \cdot (I_b + 200 I_b) = 0$$

$$I_b = \left(\frac{V_b - 0.7}{R_b + (1+200)R_e}\right) = 4.572\mu A$$

$$I_c = 200 I_b = 914.4\mu A$$

Vc and Ve are then

$$V_e = R_e(I_b + I_c) = 0.919V$$

$$V_c = 12 - 6000 I_c = 6.513V$$

The Q-point is then

$$V_{ce} = V_c - V_e = 5.5494V$$

$$I_c = 914.4\mu A$$

5) Modify the circuit from problem #4 so that

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

To stabilize the Q-point

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

$$201k >> R_b$$

Let Rb = 20k

For Vce = 6V

$$6V = 12V - 6000I_c - 1000(I_c + I_b)$$

$$I_c = 856.5\mu A$$

$$I_b = \frac{I_c}{200} = 4.283\mu A$$

Vb is then

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

$$V_b = 1.646V$$

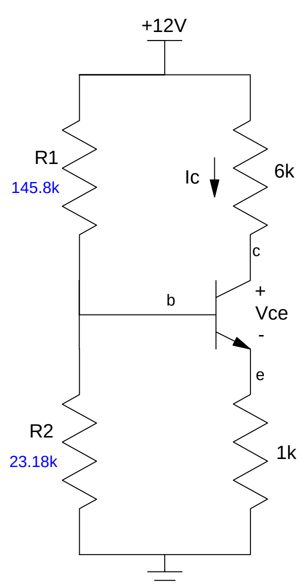
R1 and R2 are then

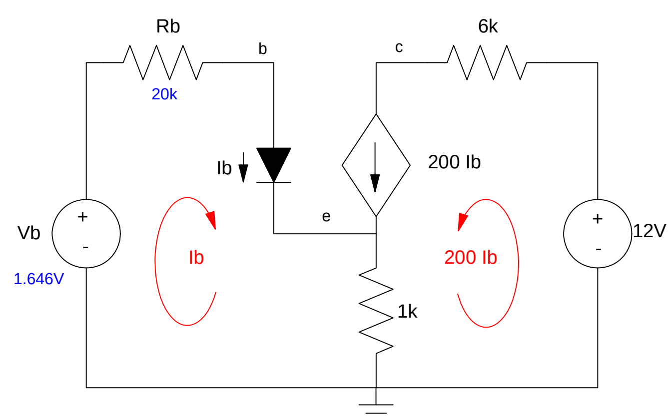
$$\left(\frac{R_1 R_2}{R_1+R_2}\right) = R_b = 20k$$

$$\left(\frac{R_2}{R_1+R_2}\right)12V = V_b = 1.646V$$

Solving

R1 = 145.8k R2 = 23.18k





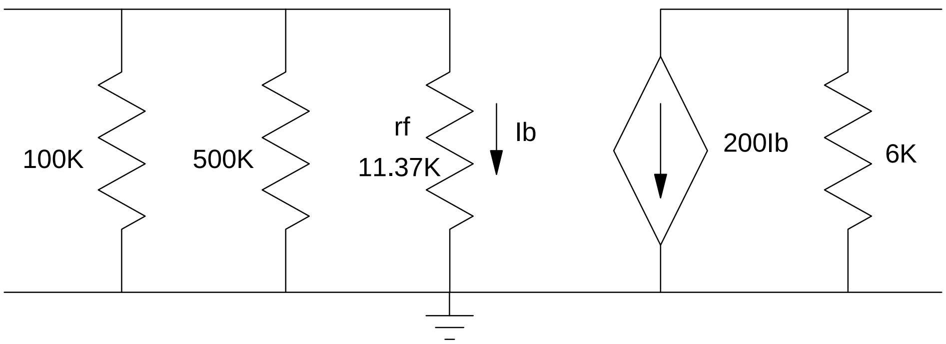
Transistor Amplifiers: AC Analysis

6) Draw the small-signal model (i.e. AC model) for a single CE amplfier (shown in red). Determine the 2-port model

$$I_b = 4.572\mu A$$

$$r_f = \left(\frac{0.052}{I_b}\right) = 11.37k$$

The small-signal model is then



The 2-port parameters are:

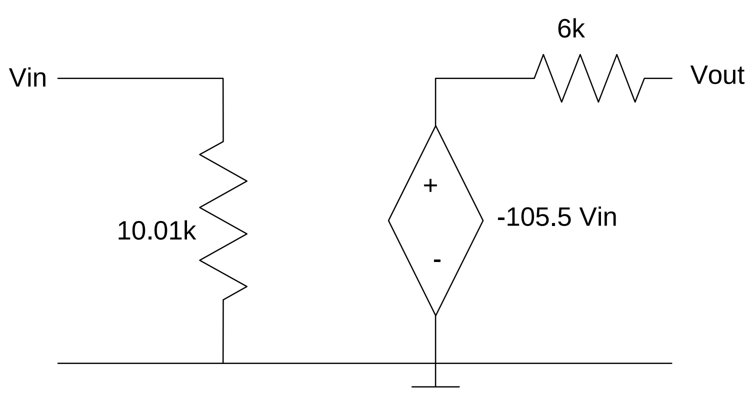
$$R_{in} = 100k||500k||r_f = 10.01k$$

$$A_{in} = 0$$

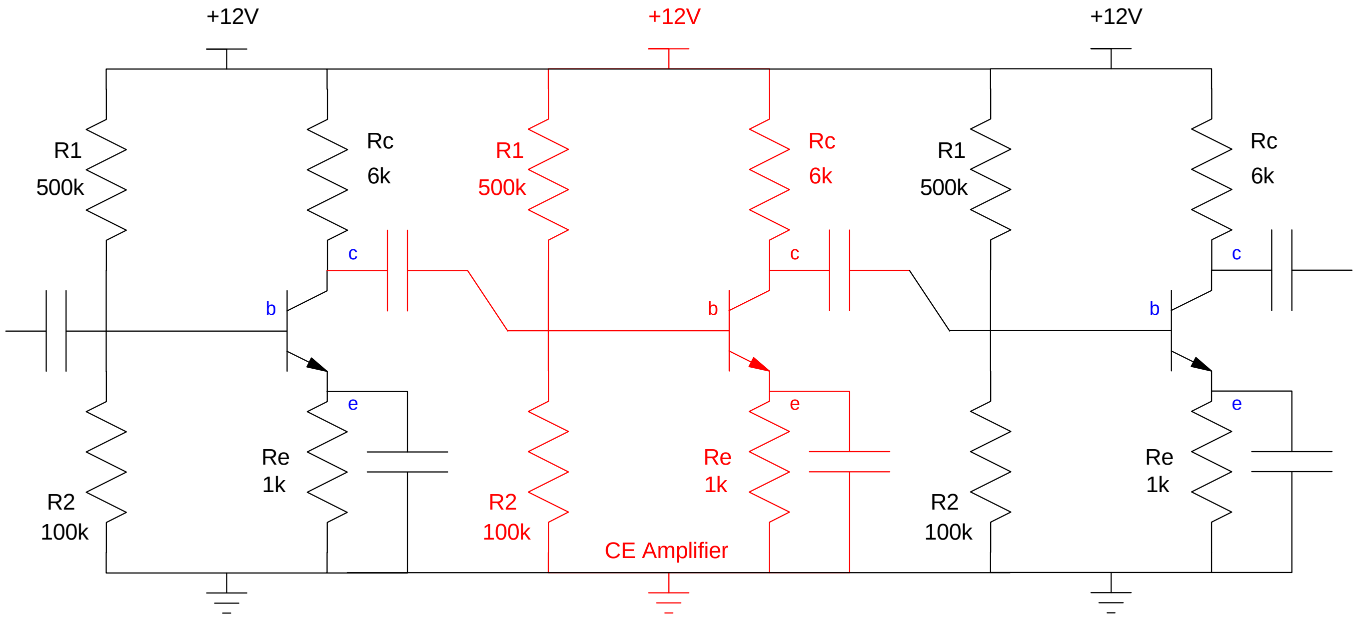
$$R_{out} = 6k$$

$$A_o = -\frac{\beta R_c}{r_f} = -105.5$$

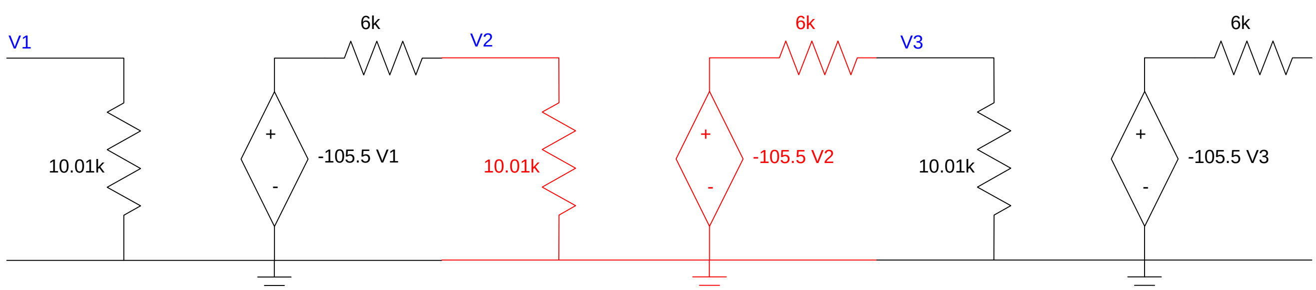
2-port parameters are then



7) Determine the 2-port model for three CE amplifiers cascaded back-to-back



Cascade three 2-port models



Simplify:

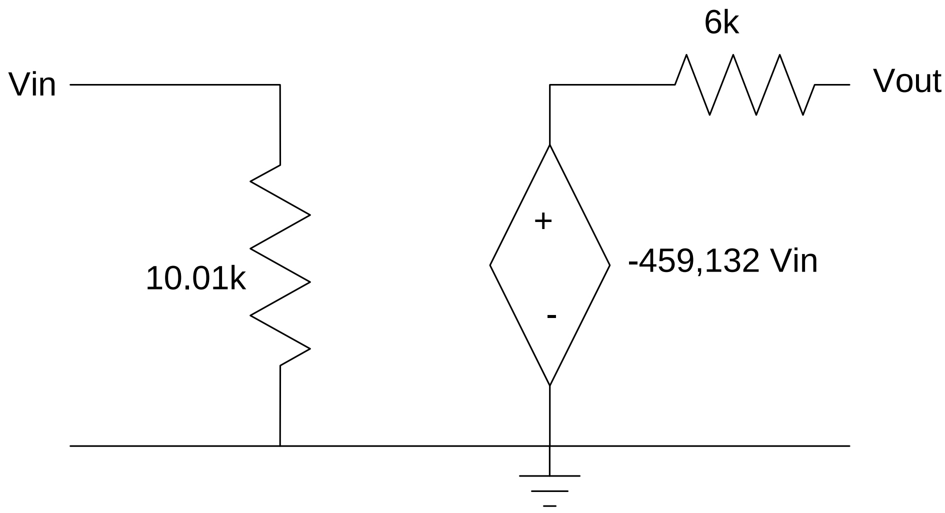
Rin = 10.01k

Ai = 0

Rout = 6k

$$A_o = (-105.5)\left(\frac{10.01k}{10.01k+6k}\right)(-105.5)\left(\frac{10.01k}{10.01k+6k}\right)(-105.5) = 459,132$$

The 2-port model is then



2-port model of three cascaded CE amplifiers