ECE 321 - Homework #5

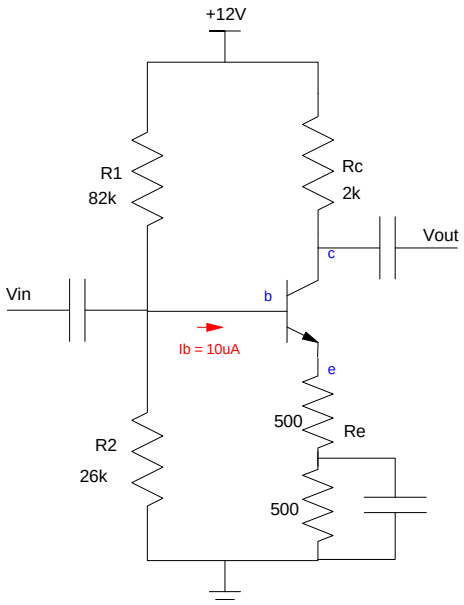
Common Emitter / Base / Collector Amplifiers. Due Monday, April 30th, 2018

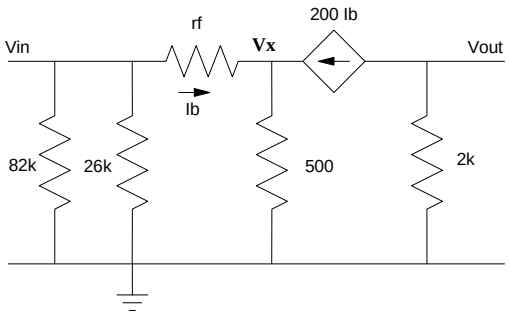
For the following transistor amplfiers, assume

- β = 200
- The Q-point (DC operating point) is
  - Vce = 6V
  - Ic = 2mA
  - Ib = 10uA

1) Common Emitter:

Draw the small signal model for the amplifier connected in a common-emitter configuration (note: Ce = 0)





Determine the 2-port model

Rin: Apply 1V to Vin, short Vout, determine Iin

$$\left(\frac{V_x-1}{5200}\right)+\left(\frac{V_x}{500}\right)+200\left(\frac{V_x-1}{5200}\right)=0$$

$$V_x = 0.9508V$$

$$I_{in} = \frac{1}{82k}+\frac{1}{26k}+\left(\frac{1-0.9508}{5200}\right) = 60.1\mu A$$

$$R_{in} = \frac{1}{I_{in}} = 16.6k$$

Ain: Apply 1V to Vout. Compute Vin

Vin = 0

Rout: Short Vin. Find the resistance at the output

When Vin = 0, Vx = 0 and Ib = 0.

Rout = 2k

Ao: Apply 1V at Vin, Compute Vout

From before

Vx = 0.9508

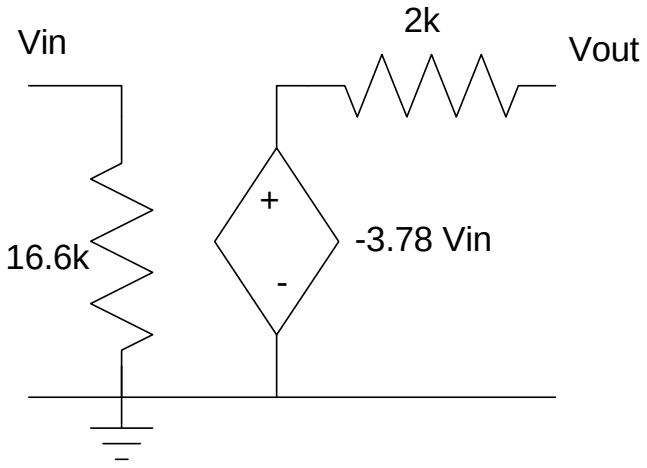
$$I_b = \left(\frac{1-0.9508}{5200}\right) = 9.46\mu A$$

$$200I_b = 1.89mA$$

$$2000 \cdot 200I_b = 3.78$$

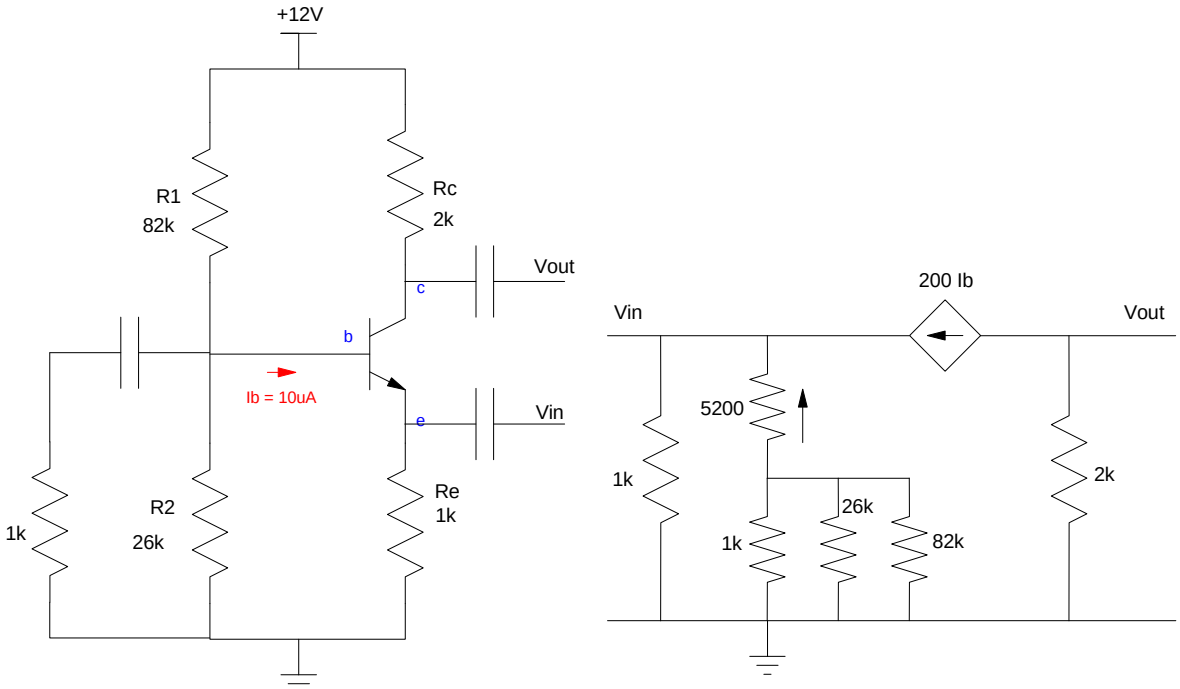
Current goes in from bottom to top, so you get a minus sign

Ao = -3.78



2) Common Base:

Draw the small signal model for the amplifier connected in a common-base configuration



Determine the 2-port model

Rin: Short Vout. Apply 1V to Vin. Compute the current

$$I_{in} = \left(\frac{1}{1k}\right) + \left(\frac{1}{5200+1k||26k||82k}\right) + 200\left(\frac{1}{5200+1k||26k||82k}\right)$$

$$I_{in} = \left(\frac{1}{1k}\right) + \left(\frac{1}{6152}\right) + \left(\frac{200}{6152}\right)$$

$$I_{in} = 33.67mA$$

$$R_{in} = \frac{1}{I_{in}} = 29.7\Omega$$

Ai: Apply 1V to the output, measure Vin

Vin = 0

Ai = 0

Rout: Short Vin. Measure the resistance at the output

If Vin = 0, Ib = 0

Rout = 2k

Ao: Apply 1V to the input. Compute the output voltage.

$$I_b = \left(\frac{-1}{5200+1k||26k||82k}\right)$$

$$I_b = -162.6\mu A$$

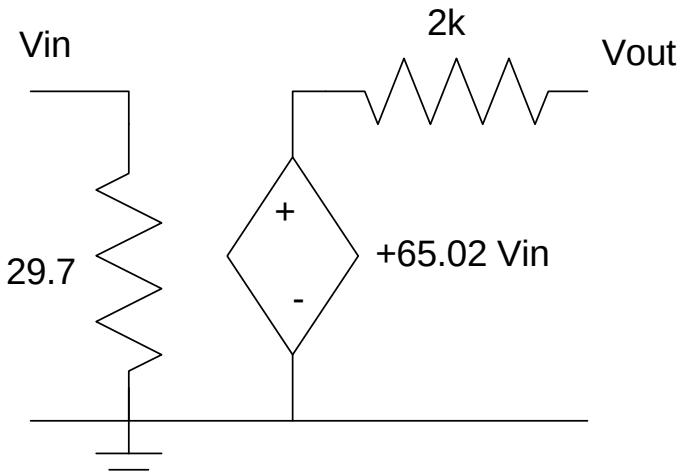
$$200I_b = -32.51mA$$

$$V_{out} = -2000I_b$$

$$V_{out} = 65.02$$

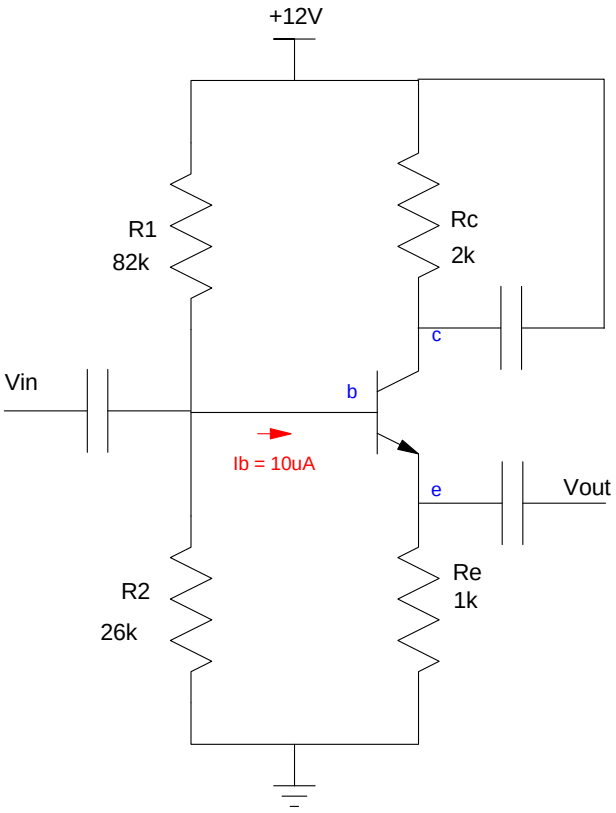
Aout = +65.02

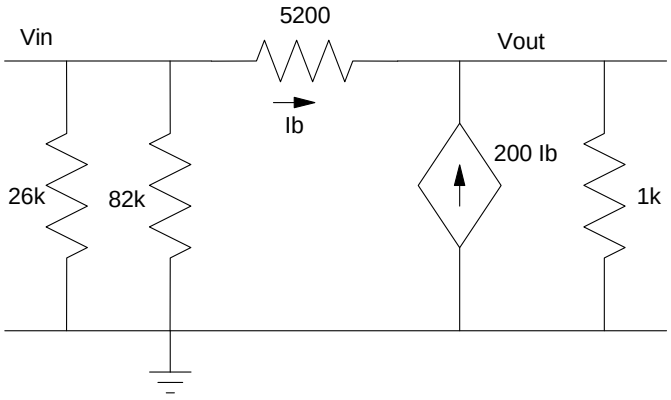
The net 2-port model is then:



3) Common Emitter:

Draw the small signal model for the amplifier connected in a common-collector configuration





Determine the 2-port model

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

$$R_{in} = 26k||82k||5200$$

$$R_{in} = 4116\Omega$$

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

$$V_{in} = \left(\frac{26k||82k}{26k||82k+5200}\right)$$

$$V_{in} = 0.7915$$

Ai = 0.7915

Rout: Short Vin. Apply 1V at Vout. Measure Iout

$$I_{out} = \left(\frac{1}{5200}\right) + 200\left(\frac{1}{5200}\right)$$

$$I_{out} = 38.65mA$$

$$R_{out} = \frac{1}{I_{out}} = 25.87\Omega$$

Ao: Apply 1V to Vin. Measure Vout.

Write the voltage node equation at Vout:

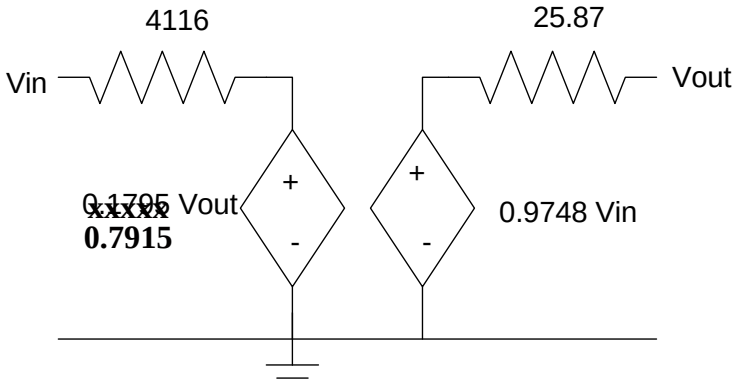
$$\left(\frac{V_{out}-1}{5200}\right)+200\left(\frac{V_{out}-1}{5200}\right)+\left(\frac{V_{out}}{1k}\right)=0$$

$$V_{out}=\left(\frac{\left(\frac{201}{5200}\right)}{\left(\frac{201}{5200}\right)+\left(\frac{1}{1000}\right)}\right)$$

$$V_{out}=0.9748$$

Ao = 0.9748

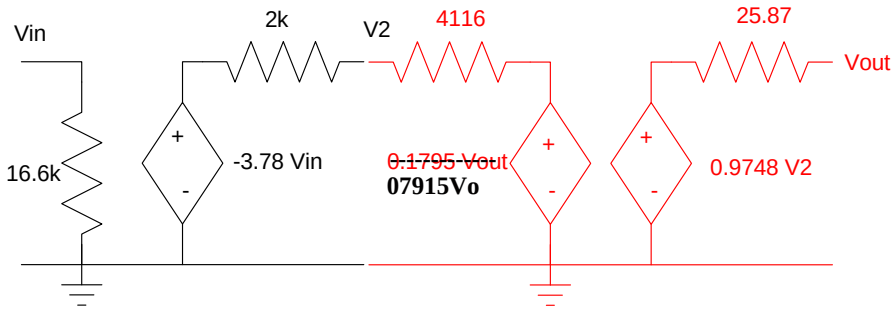
The net 2-port model is then:



4) Using your resulting 2-port models, find the 2-port model for a four-stage amplifier:

CB : CE : CE : CC

Start with a CE : CC



The 2-port model for this is...

Rin = 16.6k

Ain = 0

Rout: Short Vin. Apply 1V to Vout. Measure Iout

V2 is

$$V_2 = \left(\frac{2k}{2k+4116}\right)(0.7915) = 0.2588$$

$$0.9748V_2 = 0.2523$$

$$I_{out} = \left(\frac{1-0.2523}{25.87}\right) = 28.9mA$$

$$R_{out} = \frac{1}{I_{out}} = 34.6\Omega$$

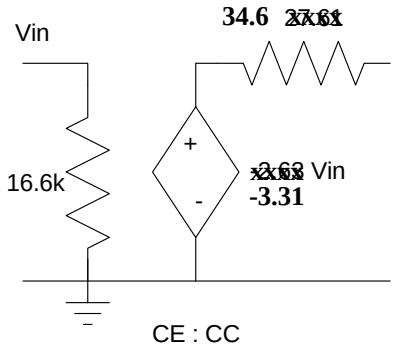
Ao: Apply 1V to Vin. Compute Vout

$$V_2 = \left(\frac{4116}{4116+2000}\right)(-3.78) + \left(\frac{2k}{2k+4116}\right)(0.7915)(0.9748V_2)$$

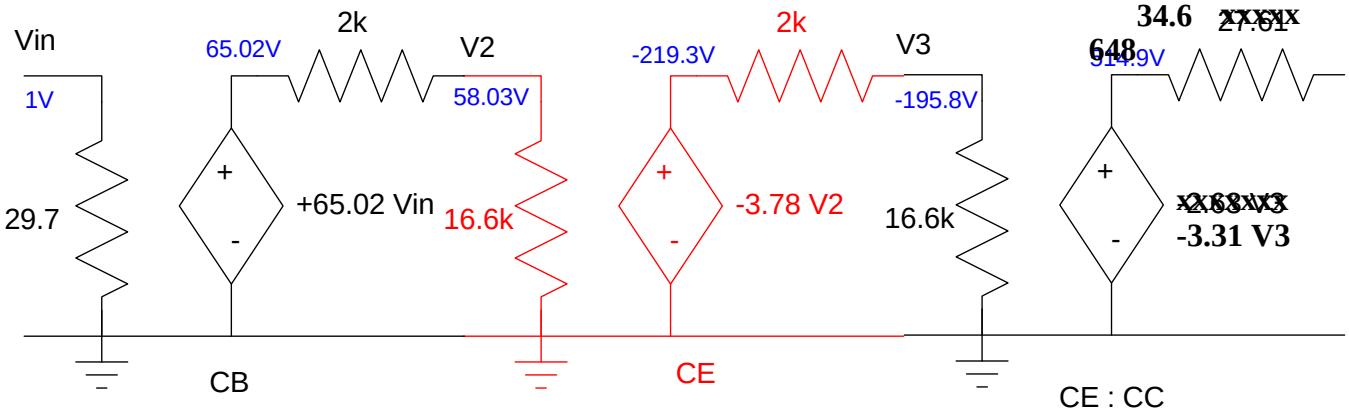
$$V_2 = -3.40$$

$$V_{out} = 0.9748V_2 = -3.31$$

So the 2-port model for a CE : CC amplifier is



Adding in the CB : CE



The net 2-port model is:

Rin = 29.7

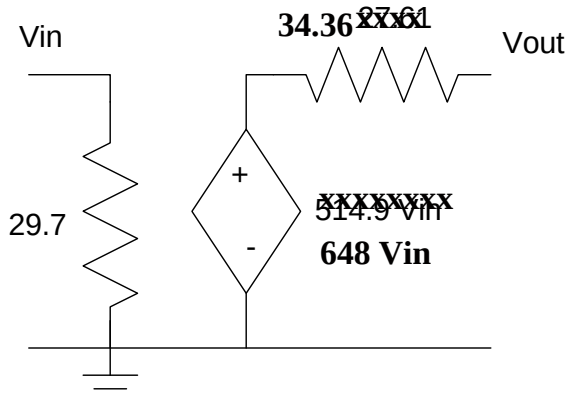
Ain = 0

Rout = 27.61

Aout: Apply 1V to the input. Compute Vout

Ao = Vout = 648

The net 2-port model of a CB : CE : CE : CC amplifier is



5) (Lab - 20pt) Build the three-stage circuit from homework #4 and collect data in lab to verify it meets the overall requirements.