

ECE 321 - Homework #5

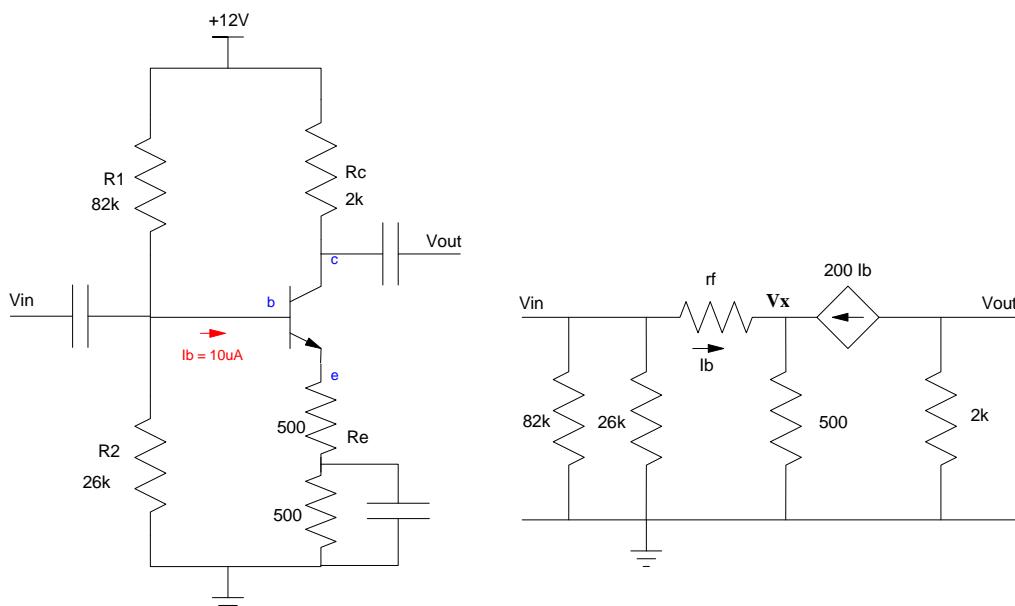
Common Emitter / Base / Collector Amplifiers. Due Monday, April 30th, 2018

For the following transistor amplifiers, assume

- $\beta = 200$
- The Q-point (DC operating point) is
 - $V_{ce} = 6V$
 - $I_c = 2mA$
 - $I_b = 10\mu A$

1) Common Emitter:

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



Determine the 2-port model

R_{in} : Apply 1V to V_{in} , short V_{out} , determine I_{in}

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

$$V_x = 0.9508V$$

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

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

A_{in} : Apply 1V to V_{out} . Compute V_{in}

$$V_{in} = 0$$

R_{out} : Short V_{in} . Find the resistance at the output

When $V_{in} = 0$, $V_x = 0$ and $I_b = 0$.

$$R_{out} = 2k$$

Ao: Apply 1V at Vin, Compute Vout

From before

$$V_x = 0.9508$$

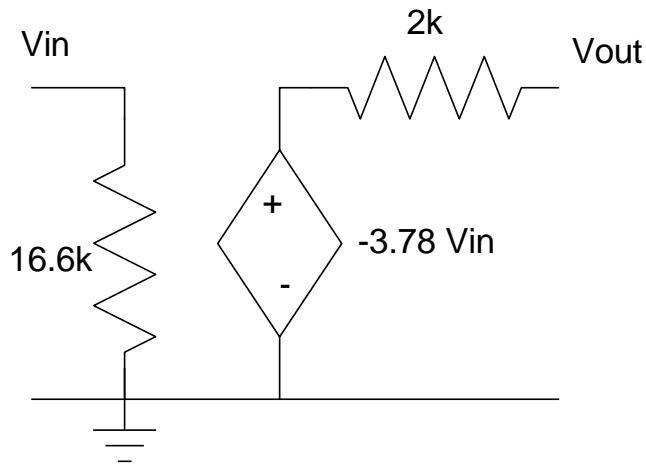
$$I_b = \left(\frac{1-0.9508}{5200} \right) = 9.46\mu A$$

$$200I_b = 1.89mA$$

$$2000 \cdot 200I_b = 3.78$$

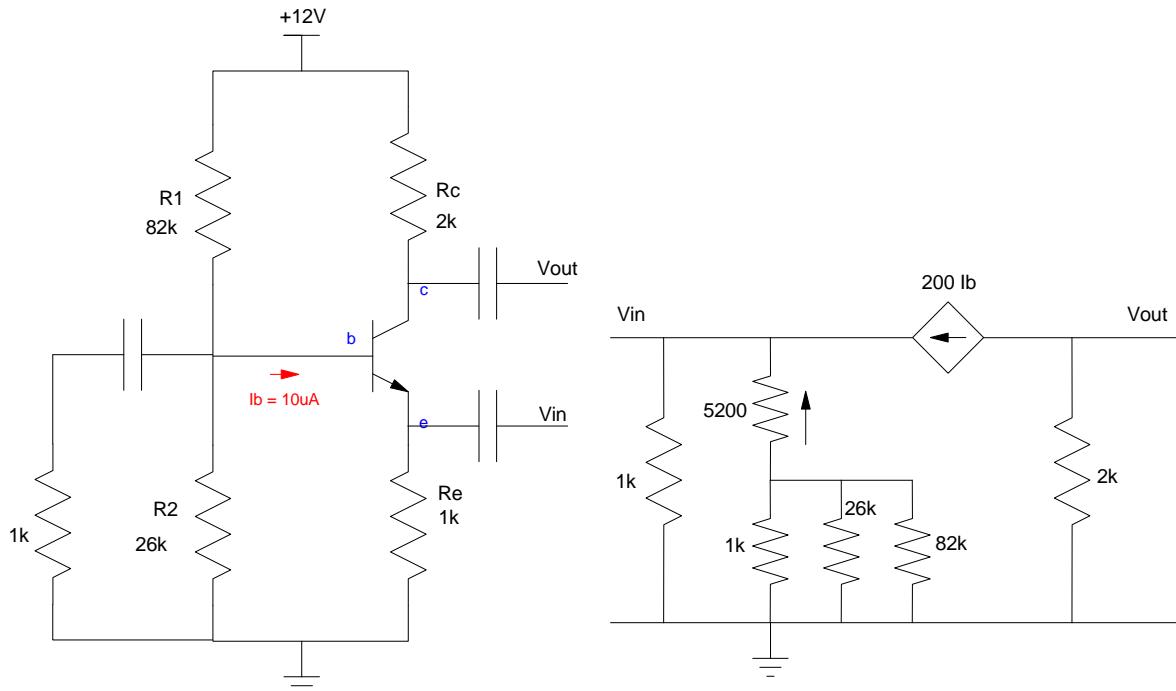
Current goes in from bottom to top, so you get a minus sign

$$A_o = -3.78$$



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

$$V_{in} = 0$$

$$A_i = 0$$

Rout: Short Vin. Measure the resistance at the output

If $V_{in} = 0$, $I_b = 0$

$$R_{out} = 2k$$

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

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

$$I_b = -162.6\mu A$$

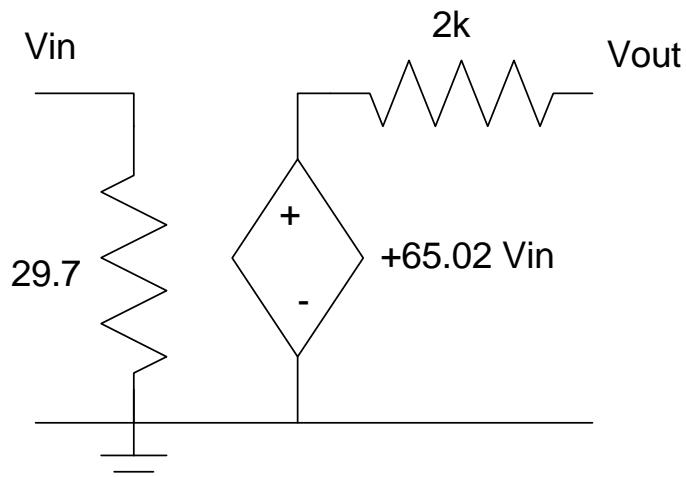
$$200I_b = -32.51mA$$

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

$$V_{out} = 65.02$$

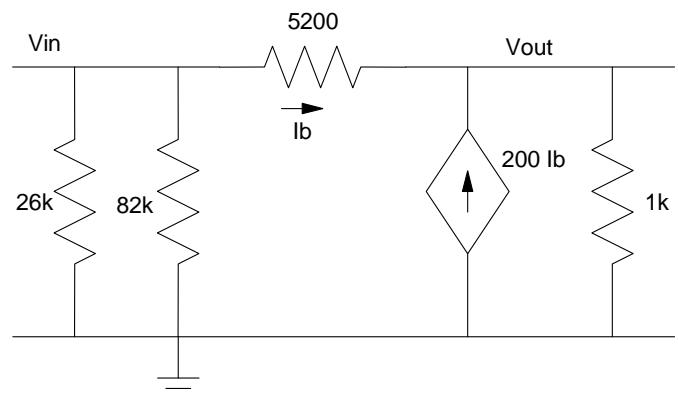
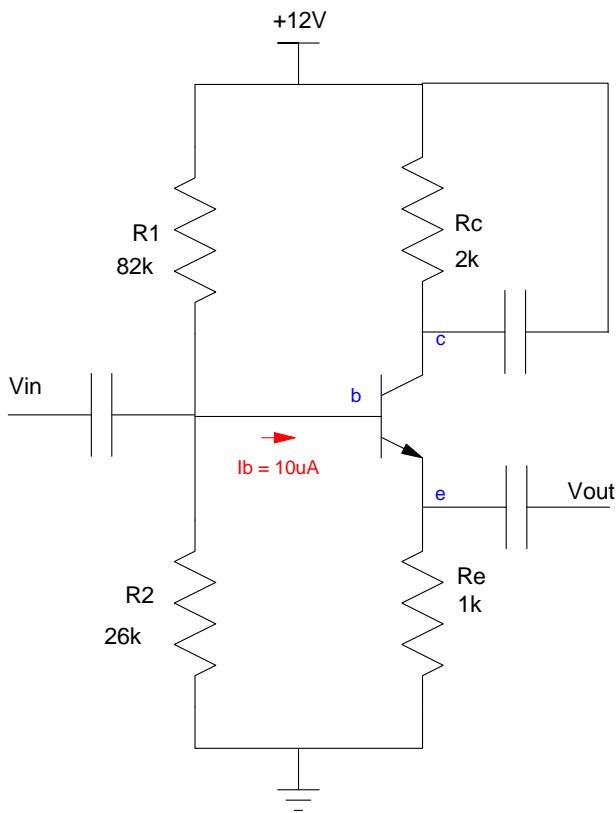
$$A_{out} = +65.02$$

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.

$$R_{in} = 26k \parallel 82k \parallel 5200$$

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

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

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

$$V_{in} = 0.7915$$

$$Ai = 0.7915$$

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:

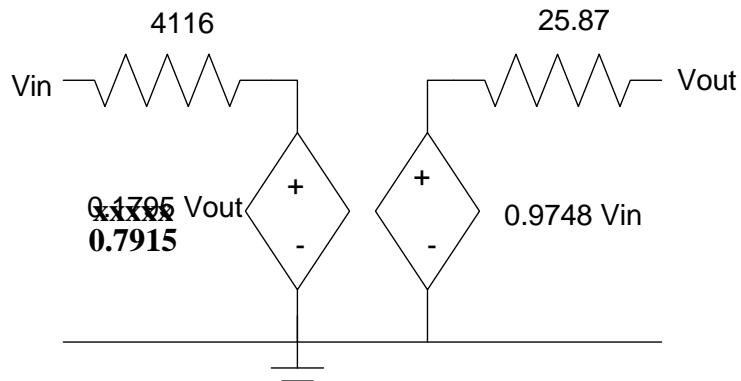
$$\left(\frac{V_{out}-1}{5200}\right) + 200\left(\frac{V_{out}-1}{5200}\right) + \left(\frac{V_{out}}{1k}\right) = 0$$

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

$$V_{out} = 0.9748$$

$$Ao = 0.9748$$

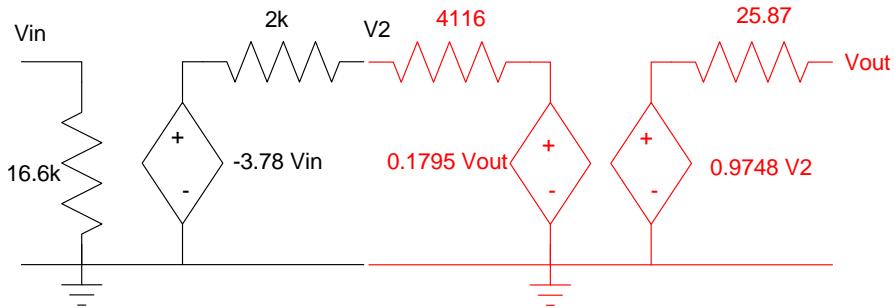
The net 2-port model is then:



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...

$$R_{in} = 16.6k$$

$$A_{in} = 0$$

R_{out} : Short V_{in} . Apply 1V to V_{out} . Measure I_{out}

V_2 is

$$V_2 = \left(\frac{2k}{2k+4116} \right) (0.1975) = 0.0658$$

$$0.9748V_2 = 0.06296$$

$$I_{out} = \left(\frac{1-0.06296}{25.87} \right) = 36.22mA$$

$$R_{out} = \frac{1}{I_{out}} = 27.61\Omega$$

A_{o} : Apply 1V to V_{in} . Compute V_{out}

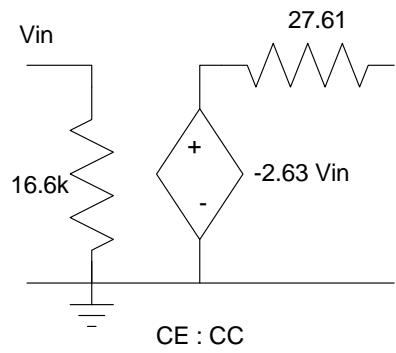
$$V_2 = \left(\frac{4116}{4116+2000} \right) (-3.78) + \left(\frac{2k}{2k+4116} \right) (0.1795)(0.9748V_2)$$

$$(1 - 0.05722)V_2 = -2.544$$

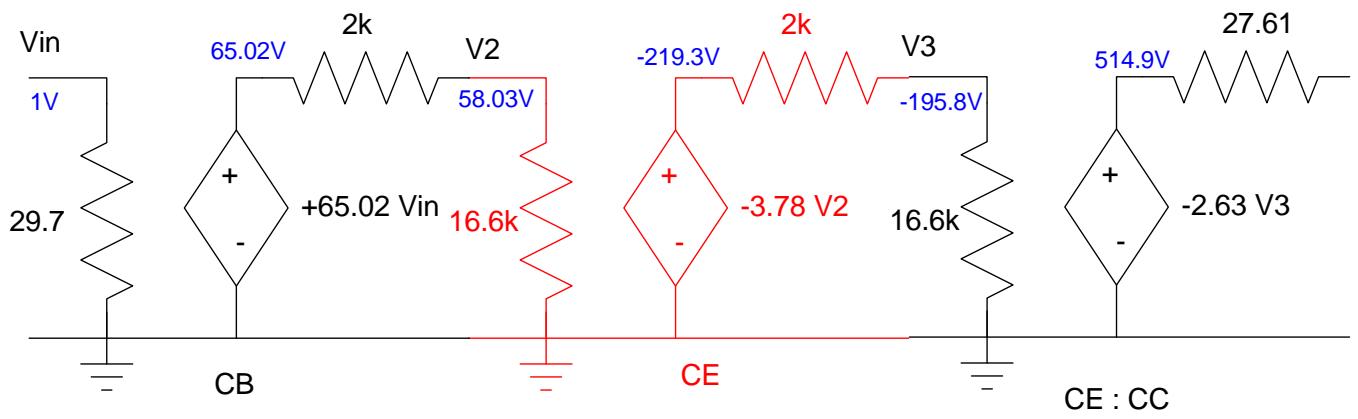
$$V_2 = -2.698$$

$$V_{out} = 0.9748V_2 = -2.63$$

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



Adding in the CB : CE



The net 2-port model is:

$$R_{in} = 29.7$$

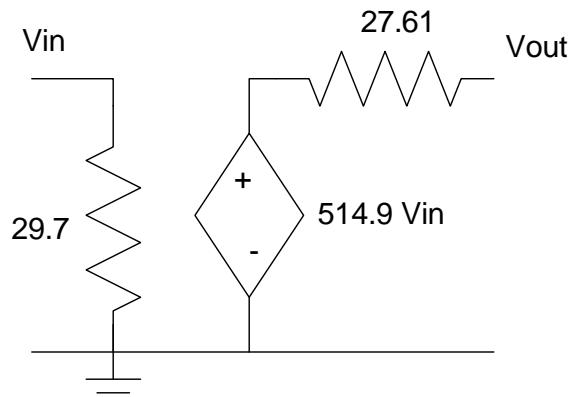
$$A_{in} = 0$$

$$R_{out} = 27.61$$

Aout: Apply 1V to the input. Compute Vout

$$A_o = V_{out} = 514.9$$

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.

