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# **Common Emitter Amplifier**

## **ECE 321: Electronics II**

**Lecture #14**

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Please visit [Bison Academy](#) for corresponding  
lecture notes, homework sets, and solutions

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## DC Analysis (review):

To use a transistor as a Class-A amplifier

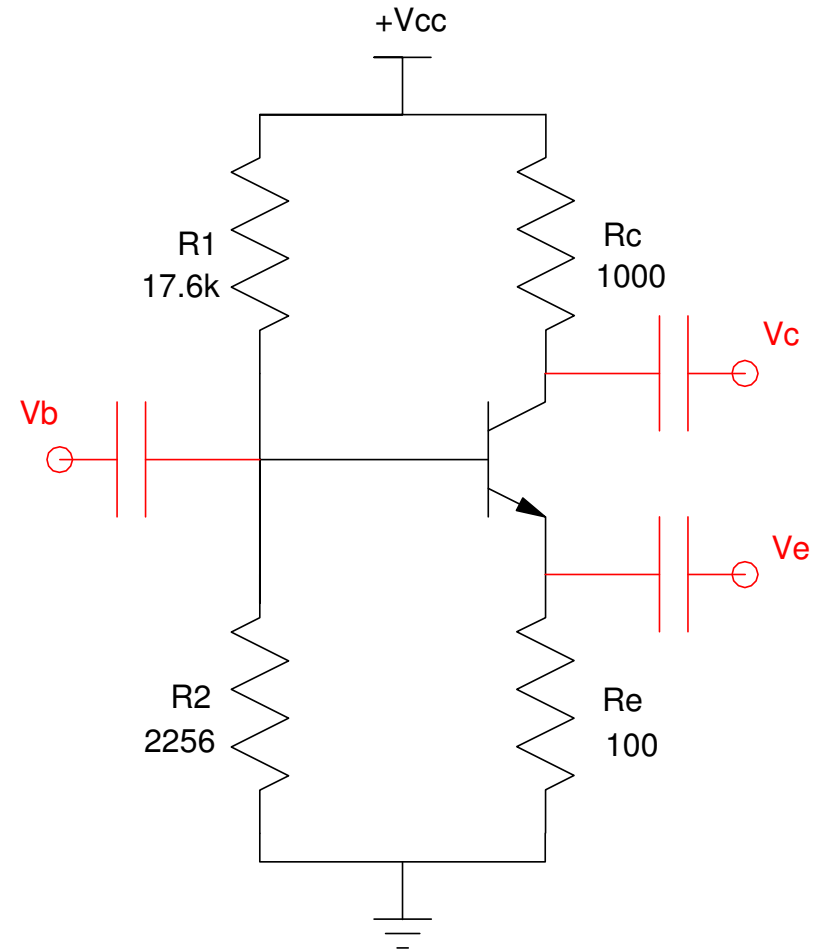
- Use  $R_e$  to stabilize the Q-point
- Use  $R_1$  and  $R_2$  to set the Q-point

Assume the Q-point is

$$I_c = 6\text{mA}$$

$$V_c = 6\text{V}$$

Capacitors isolate the circuit at DC



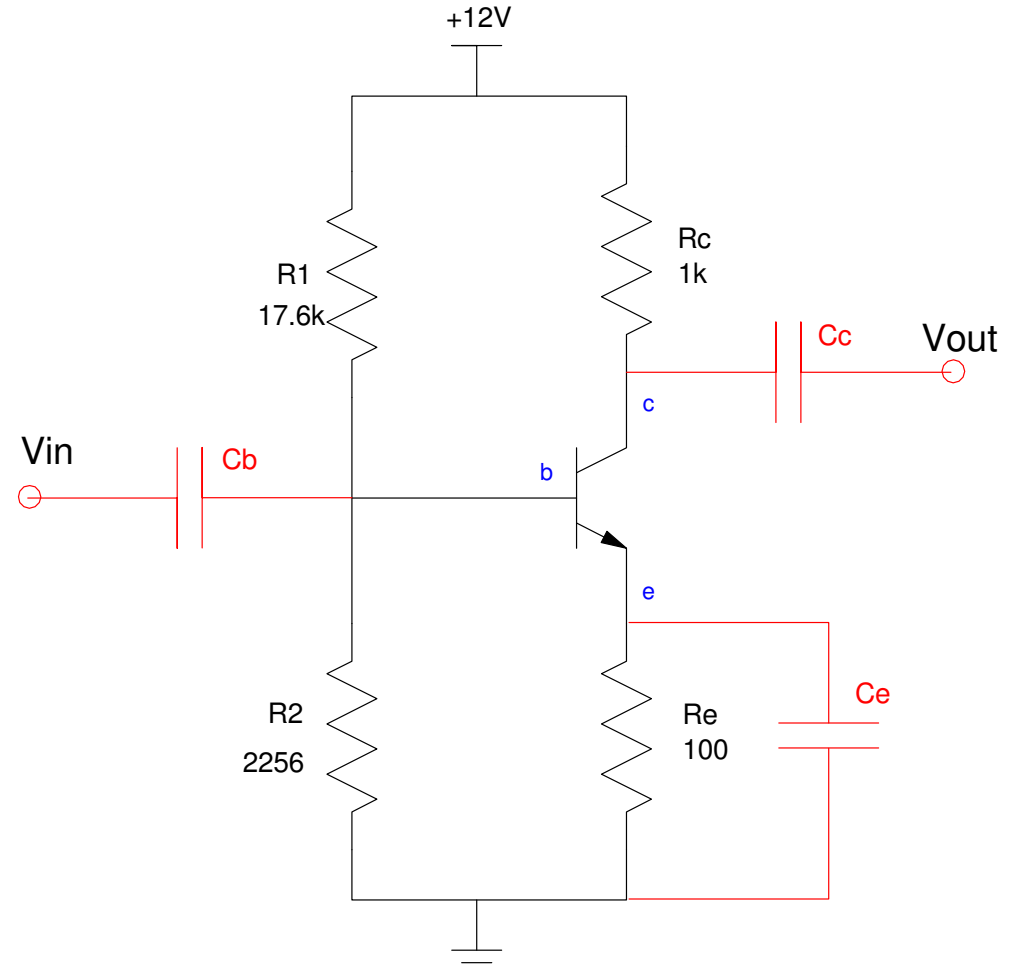
# Common Emitter Amplifier

## Connect

- $C_e$  to ground.
- $C_b$  to the input
- $C_c$  at the output

What is the 2-port model for the resulting AC circuit?

- a.k.a. the *Small Signal Model*



# Problem: How to model the diode

Recall that for a silicon diode that

$$V_d = \eta V_T \cdot \ln(I_d/I_o + 1)$$

Taylor's Series (2-terms):

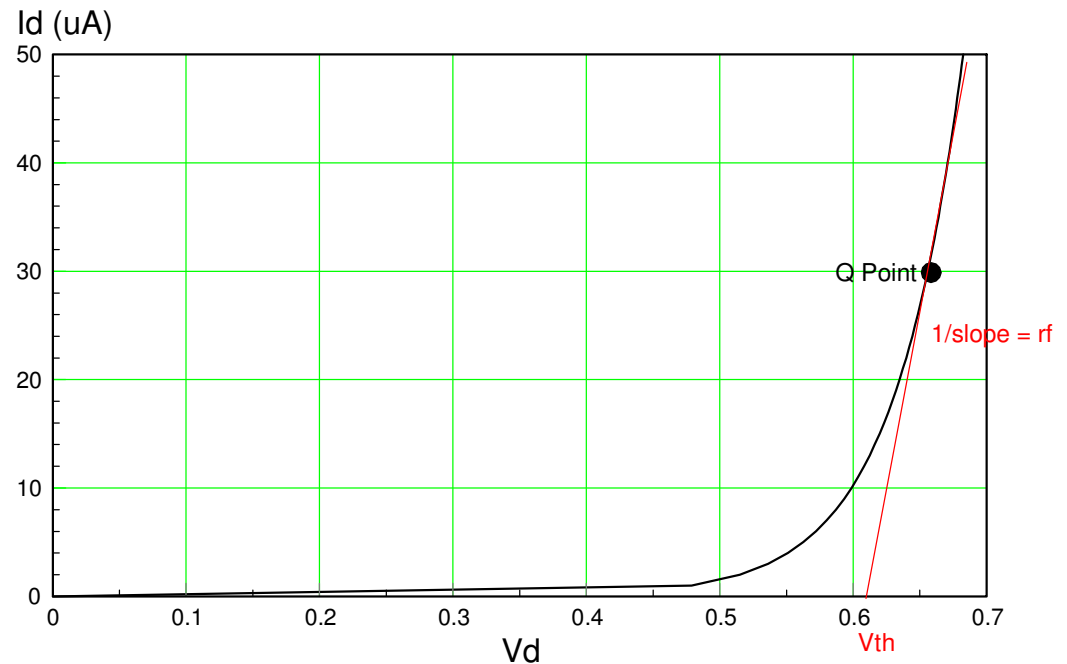
$$V_d \approx V_{th} + i_d r_f$$

Taking the derivative:

$$r_f = \frac{dV_d}{dI_d} = \frac{d}{dI_d} \left( \eta V_T \cdot \ln \left( \frac{I_d}{I_o} + 1 \right) \right)$$

$$r_f \approx \left( \frac{\eta V_T}{I_d} \right)$$

$$r_f = \left( \frac{0.026V}{30\mu A} \right) = 867\Omega$$



# Small-Signal Model (AC Model)

Replace the transistor with its AC model

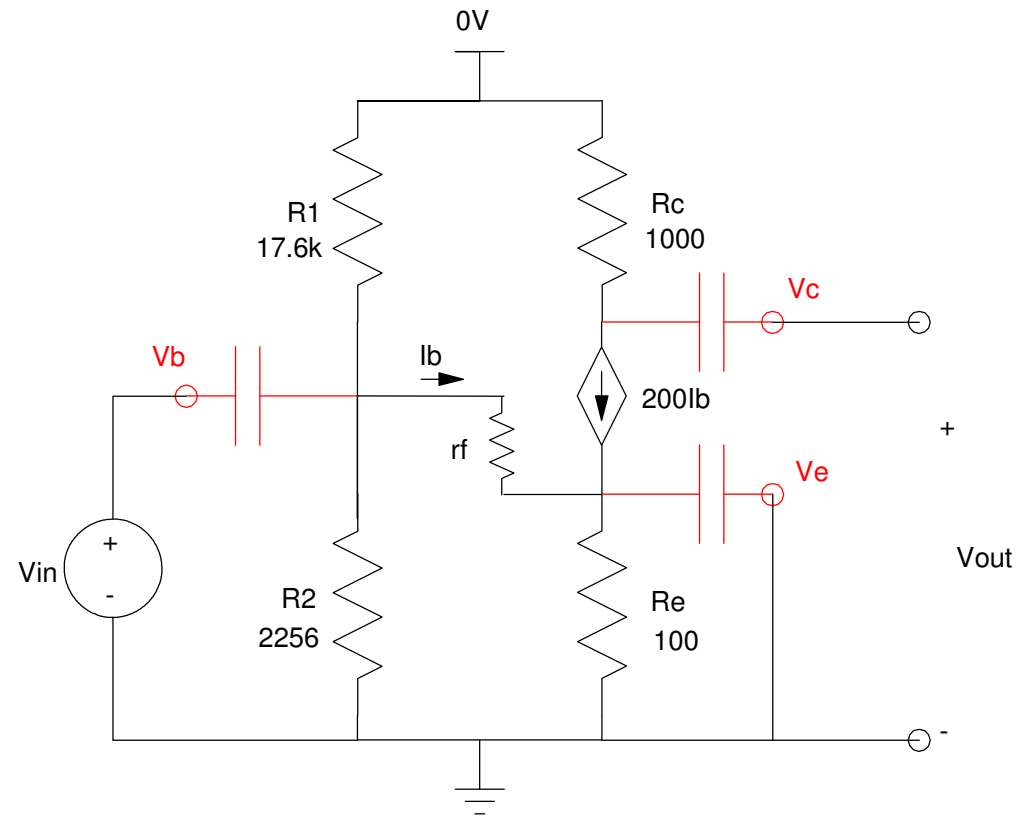
- Ignore the DC terms (already computed)
- Diode becomes  $r_f$  (867 Ohms)

Note:

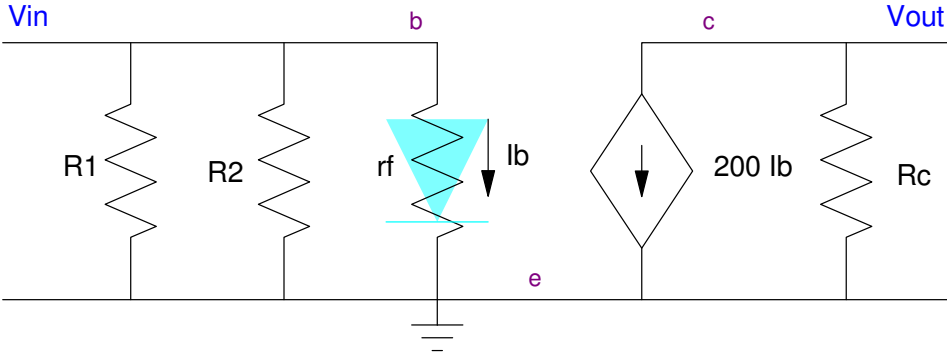
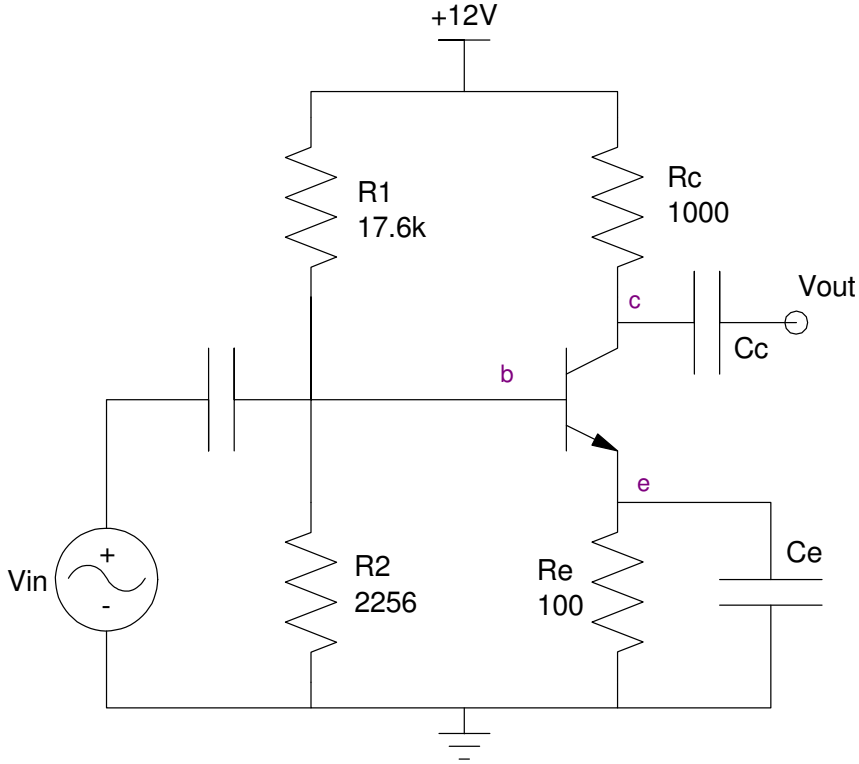
- $V_{cc} = 12V$  (DC) +  $0V$  (AC)
- This is AC analysis

Using superposition

- $V(\text{total}) = \text{DC} + \text{AC}$



# Redraw the Circuit



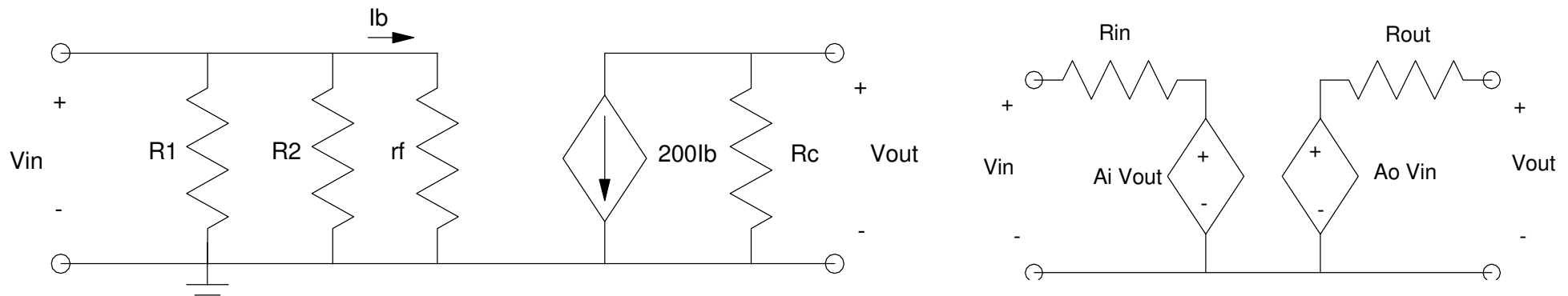
## Convert to a 2-Port Model

**Rin:** For the 2-port model, short  $V_o$  so that  $V_o=0$  and  $A_i V_{out} = 0$ . Measure the resistance at the input. Doing the same for the CE amplifier, this results in

$$R_{in} = R_1 || R_2 || r_f$$

**Ai:** For the 2-port model, apply 1V to  $V_{out}$ . Measure the resulting voltage at  $V_{in}$ . Doing the same for the CE amplifier results in  $V_{in} = 0V$ , so

$$A_i = 0$$

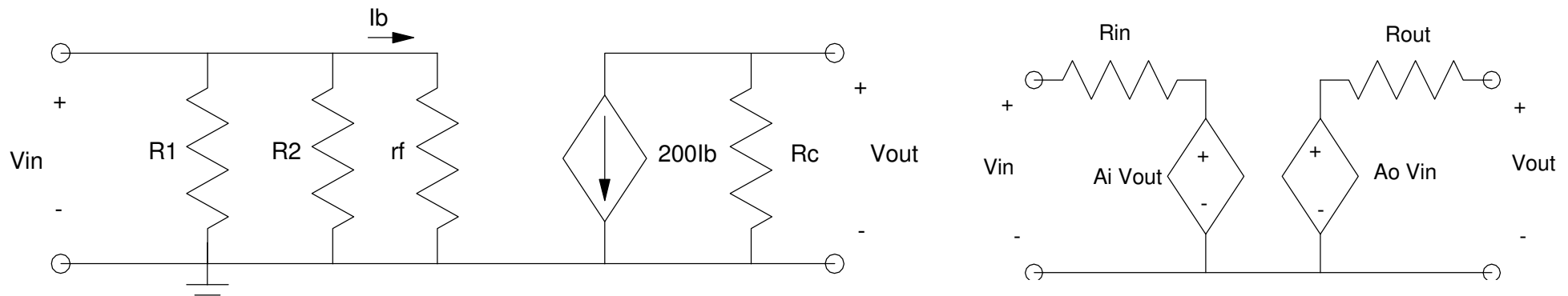


**R<sub>out</sub>:** For the 2-port model, short  $V_i$  so that  $V_i=0$  and  $A_o V_{in}=0$ . Measure the resistance at the output. Doing the same for the CE amplifier, this results in

$$R_{out} = R_c$$

**A<sub>o</sub>:** For the 2-port model, apply 1V to  $V_{in}$ . Measure the resulting voltage at  $V_{out}$ . Doing the same for the CE amplifier results in

$$A_o = V_{out} = -R_c I_c = -\frac{\beta R_c}{r_f}$$





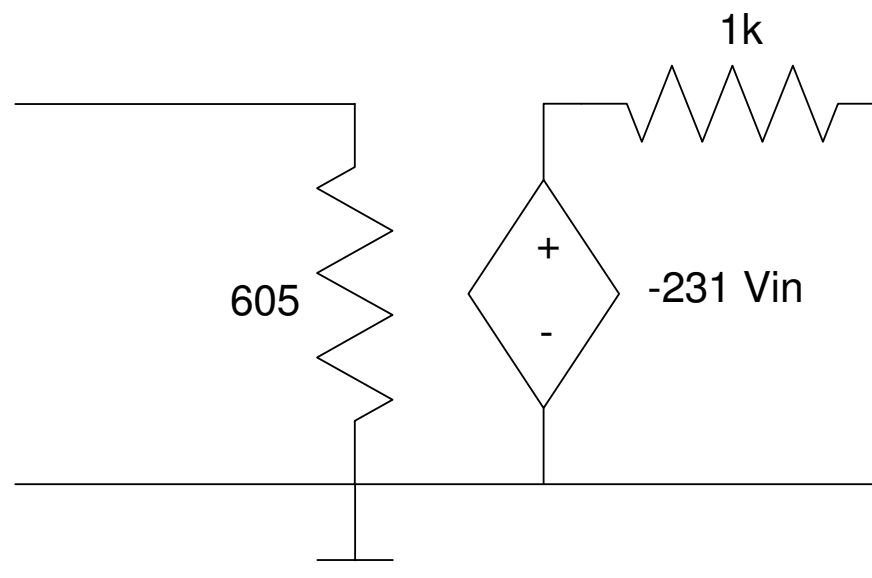
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## 2-Port Model:

$$R_{in} = 605\Omega$$

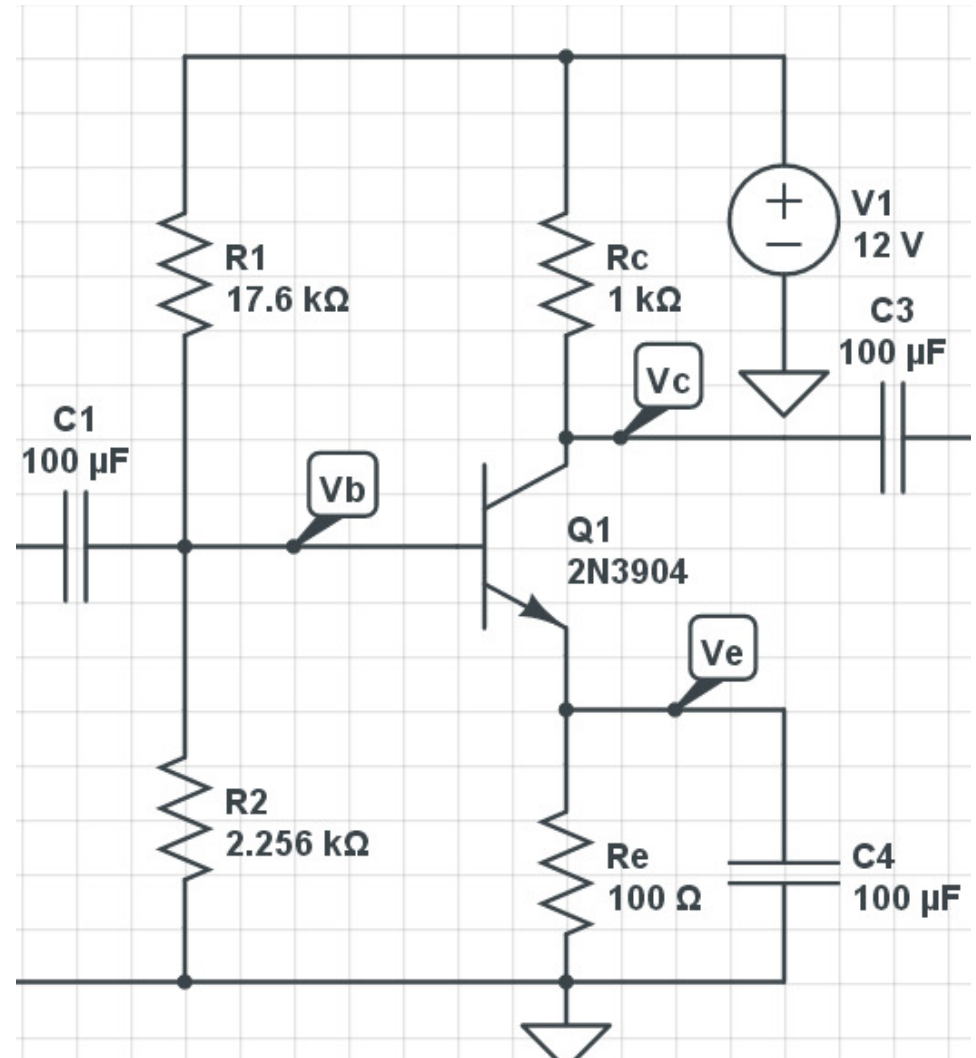
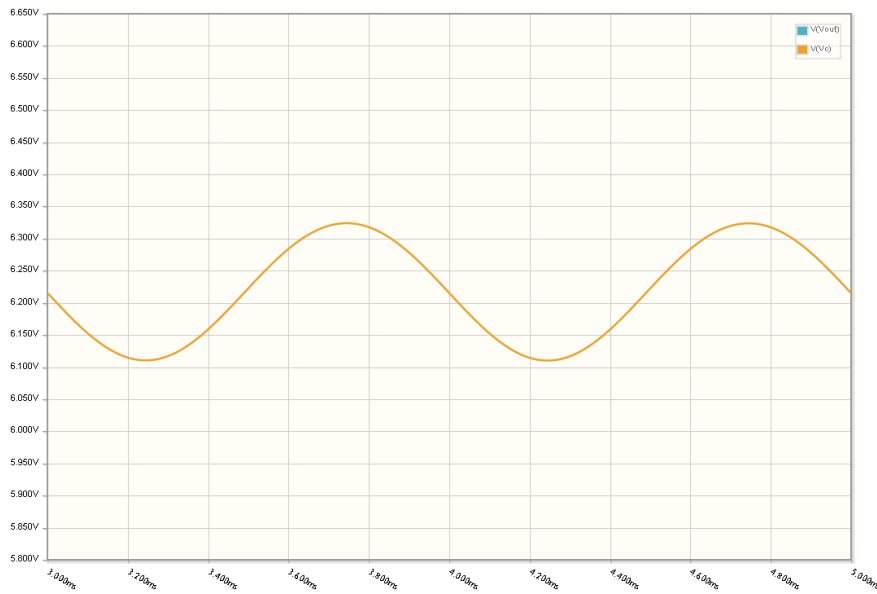
$$R_{out} = 1k\Omega$$

$$A_o = -231$$



# Simulation Results

- $V_{in} = 1\text{mV}$  1kHz sine wave
- $V_c$  has a DC offset
- Plus an AC component (1kHz)

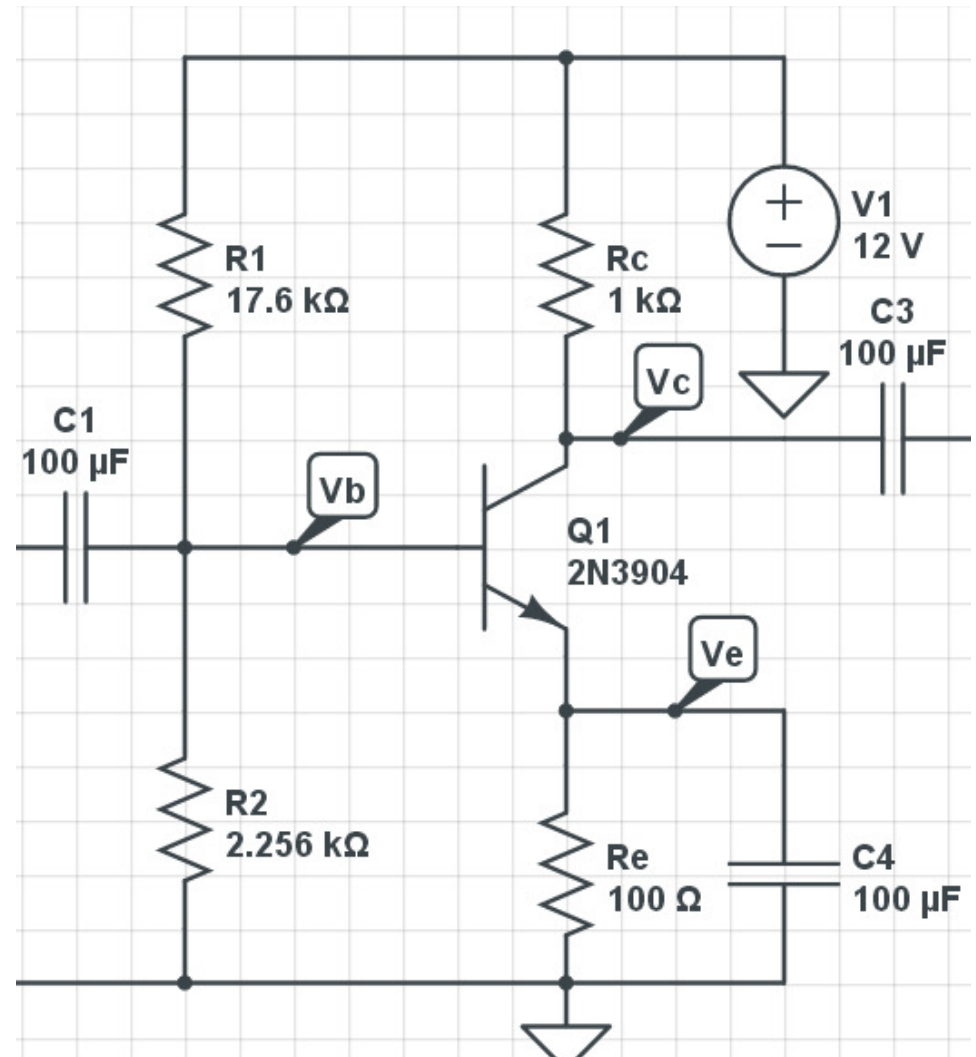


## Simulation Results (DC)

- $V_b = 1.287V$
- $V_c = 6.217V$
- $V_e = 0.582V$
- $I_c = 5.783mA$
- $I_b = 38.39\mu A$

$$\beta = \frac{I_c}{I_b} = 151$$

$$r_f = \frac{0.026}{38.39\mu A} = 677\Omega$$

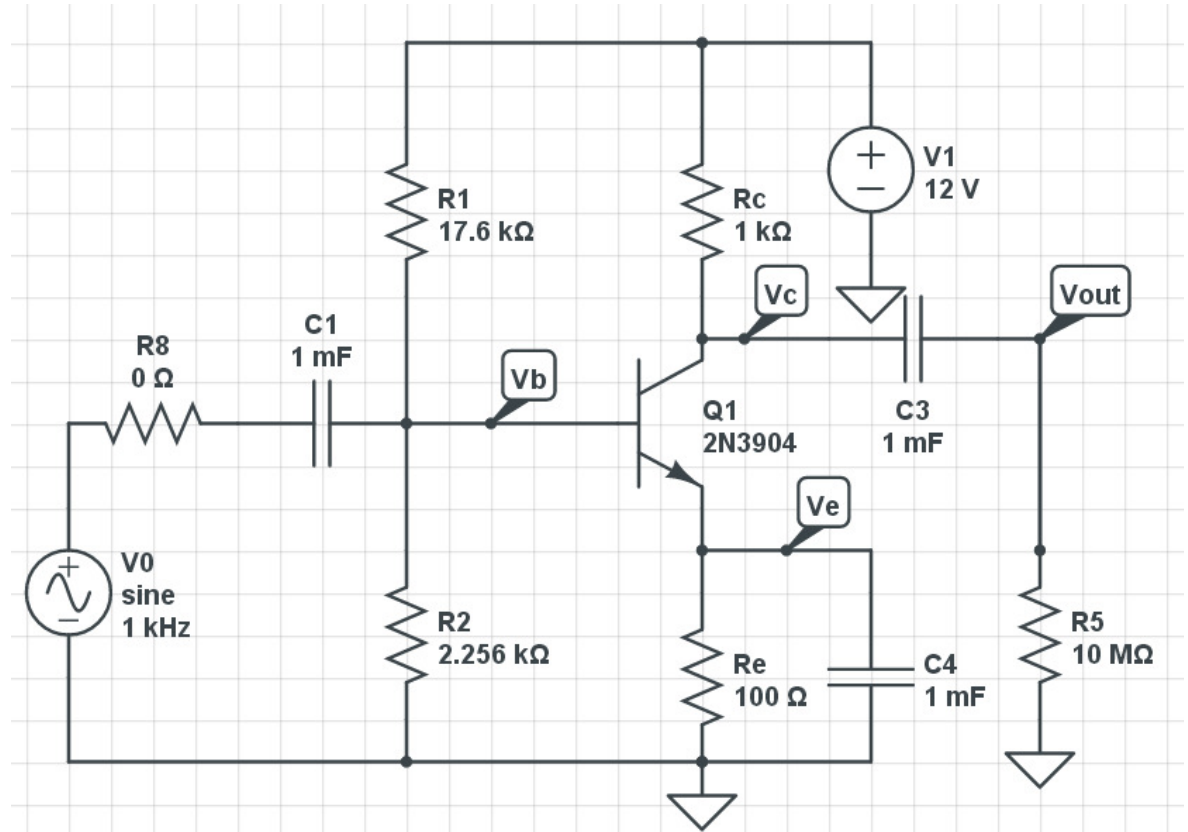


## CircuitLab: Ao:

- Apply 1mV to Vin
- Set R8 = 0
- Set R5 = 10M (large)
- Measure the Vout
- (time-domain simulation)

$V_{out} = 203.3\text{mV}$  (peak)

- $A_o = -203.3$
- Calculated = -230



## CircuitLab: Rin:

- Apply 1mV to Vin
- Set R8 = 605
- Set R5 = 10M (large)
- Measure the Vout
- (time-domain simulation)

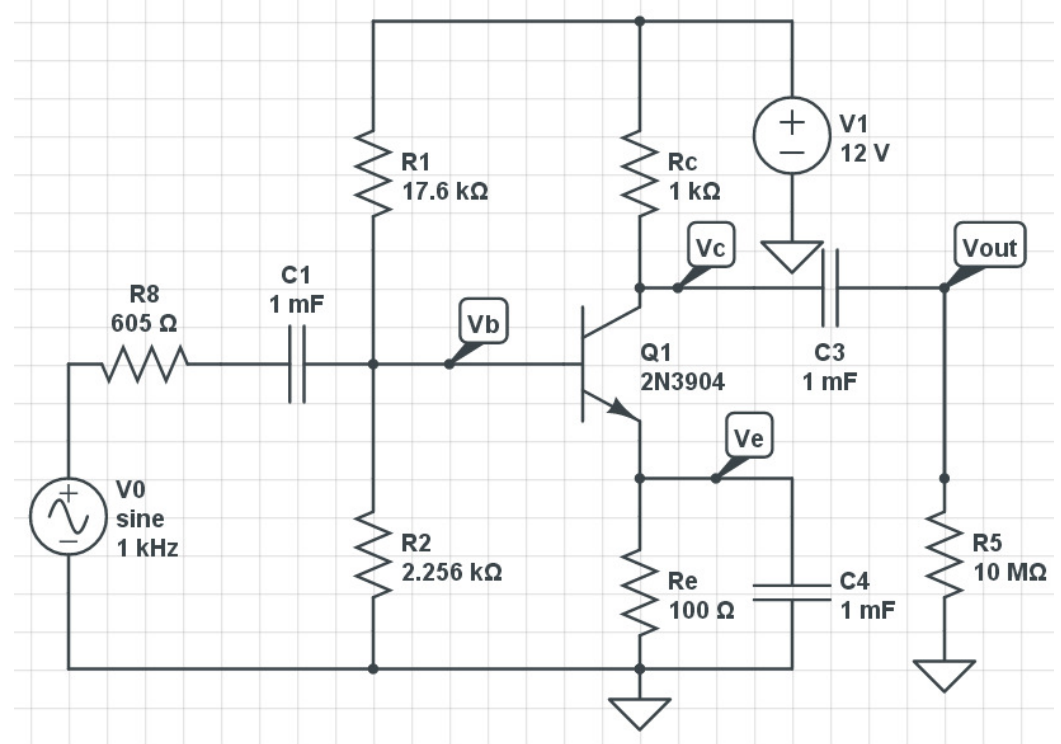
$V_{out} = 95.04mV$  (peak)

$$95.04mV = \left( \frac{R_{in}}{R_{in} + 605} \right) 203.3mV$$

$$R_{in} = \left( \frac{95.04mV}{203.3mV - 95.04mV} \right) 605\Omega$$

$$R_{in} = 769\Omega$$

- (vs. 605 Ohms calculated)



## CircuitLab: Rout:

- Apply 1mV to Vin
- Set R8 = 0
- Set R5 = 1k
- Measure the Vout
- (time-domain simulation)

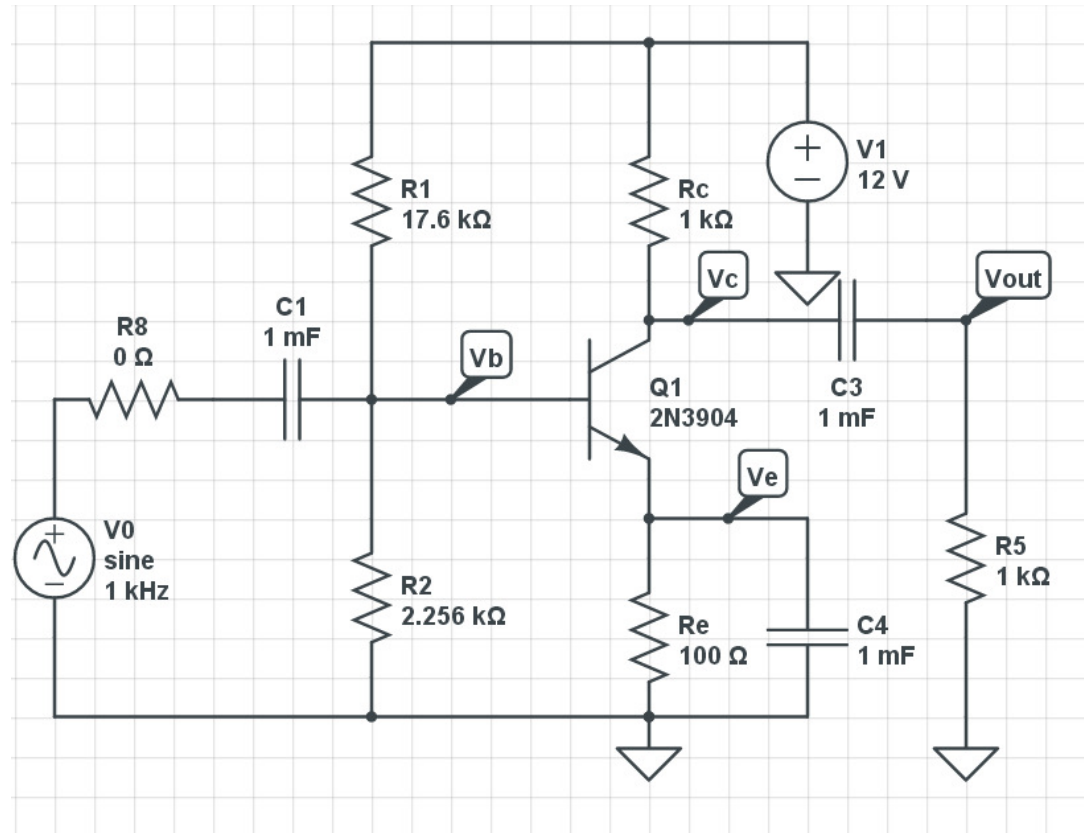
$V_{out} = 107.1\text{mV}$  (peak)

$$107.1\text{mV} = \left( \frac{1000}{R_{out} + 1000} \right) 203.3\text{mV}$$

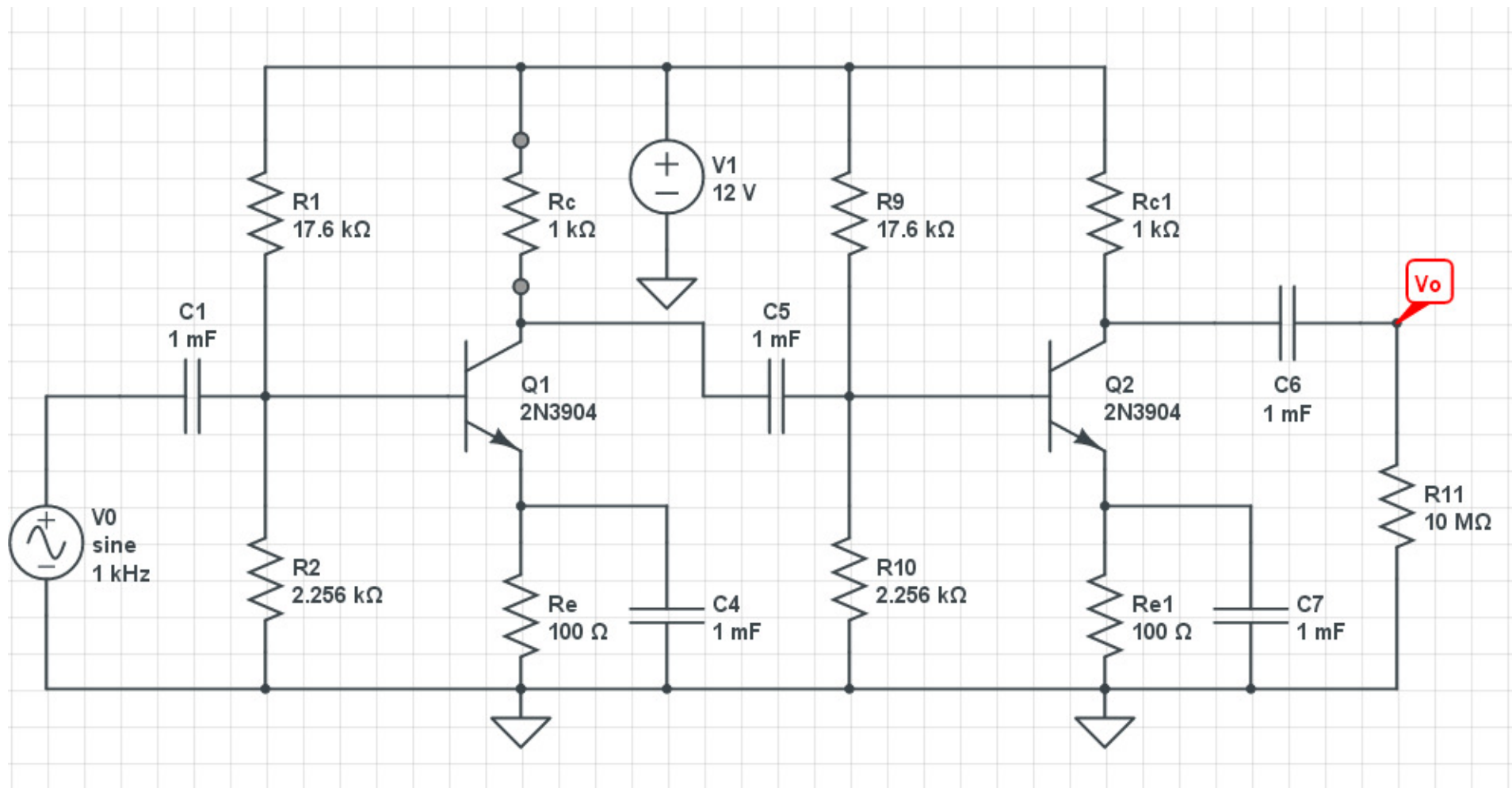
$$R_{out} = \left( \frac{203.3\text{mV} - 107.1\text{mV}}{107.1\text{mV}} \right) 1000\Omega$$

$$R_{out} = 898\Omega$$

- vs. 1000 Ohms calculated



# Cascading CE Amplifiers



## Analysis:

- Use the 2-port model (x2)

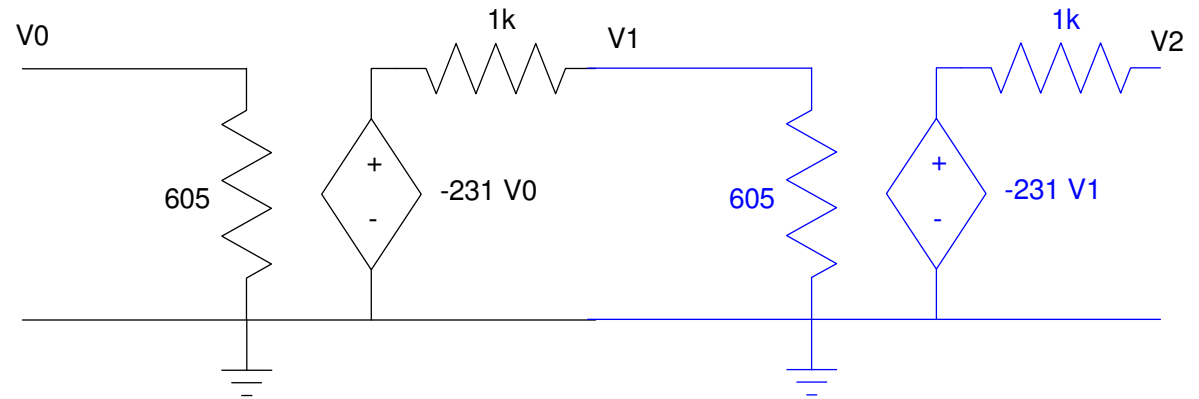
### By inspection

- $R_{in} = 605$
- $A_i = 0$
- $R_{out} = 1k$

$A_o$ : Apply 1V to the input

- $V_1 = \left( \frac{605}{605+1000} \right) (-231V)$
- $V_1 = -87.07V$
- $V_2 = -231V_1 = 20,114$

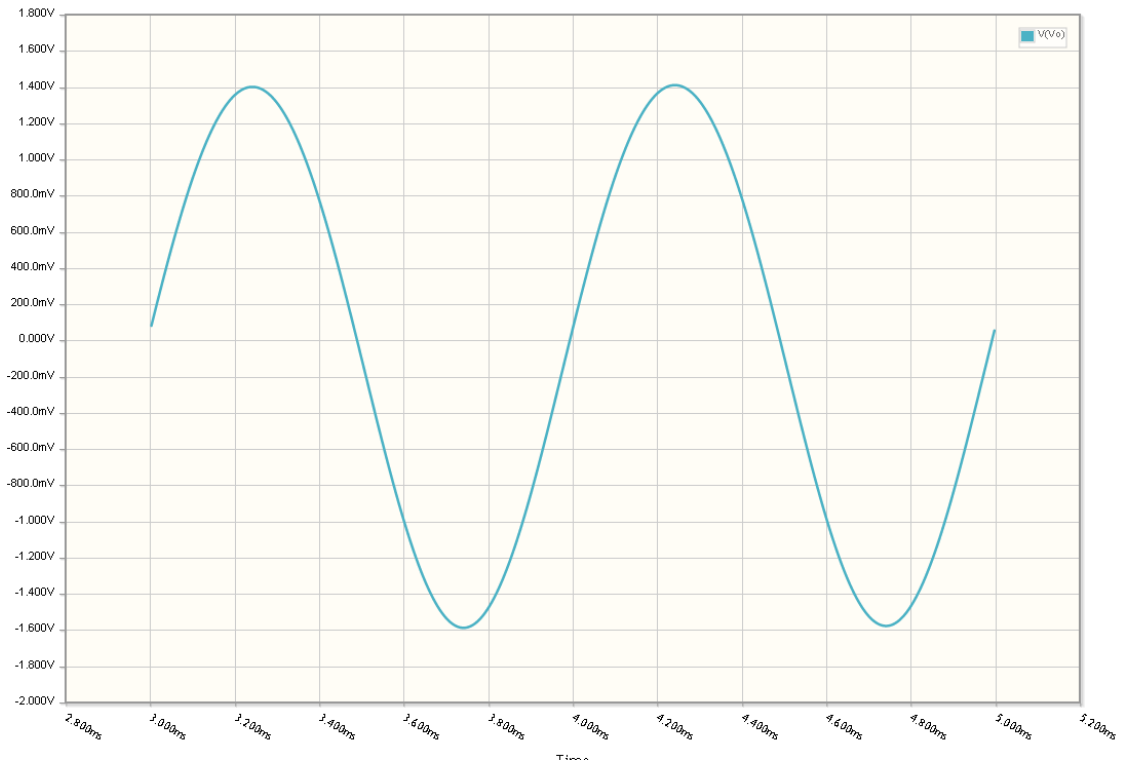
$A_o = 20,114$





# Simulation Results

- $V_{in} = 100\mu\text{V}$  1kHz sine wave
- $V_{out} = 1.409\text{V}$  sine wave
- Gain = 14,090
- (vs. 20,114 calculated)



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# Summary

- CE amplifiers provide high gain
  - The 2-port model simplifies analysis when cascading amplifiers
  - The capacitors block the DC offset
  - The capacitors prevent the source and load from changing the Q-point
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