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

DC Analysis (review):

To use a transistor as a Class-A amplifier

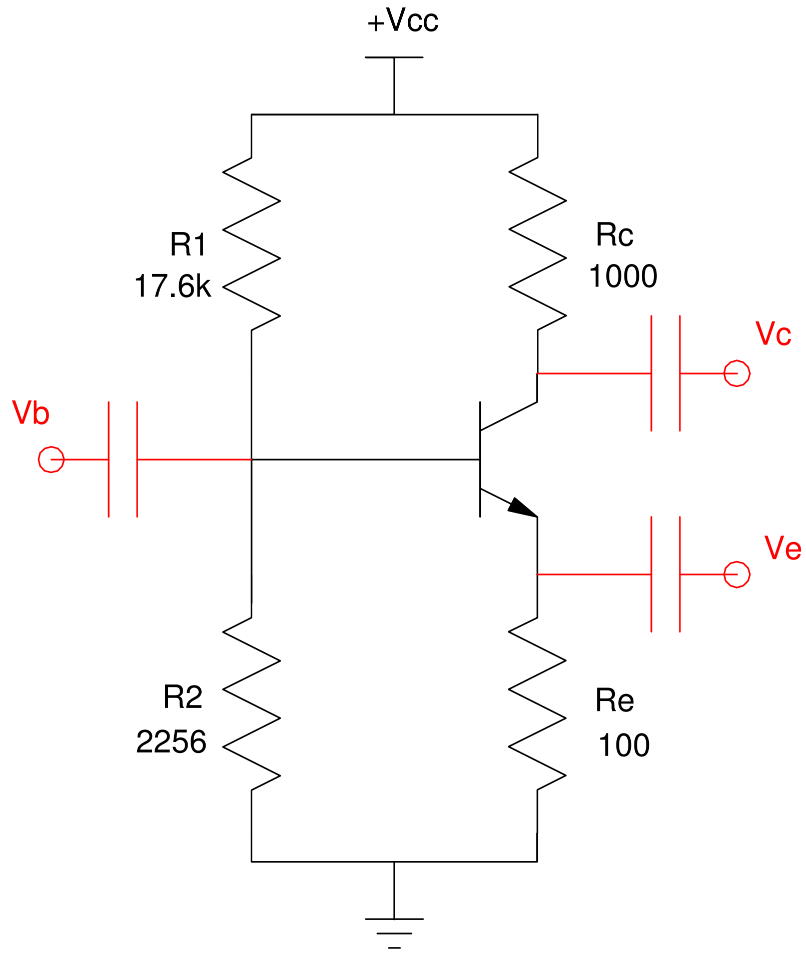
- Use Re to stabilize the Q-point
- Use R1 and R2 to set the Q-point

Assume the Q-point is

$$Ic = 6mA$$

$$Vc = 6V$$

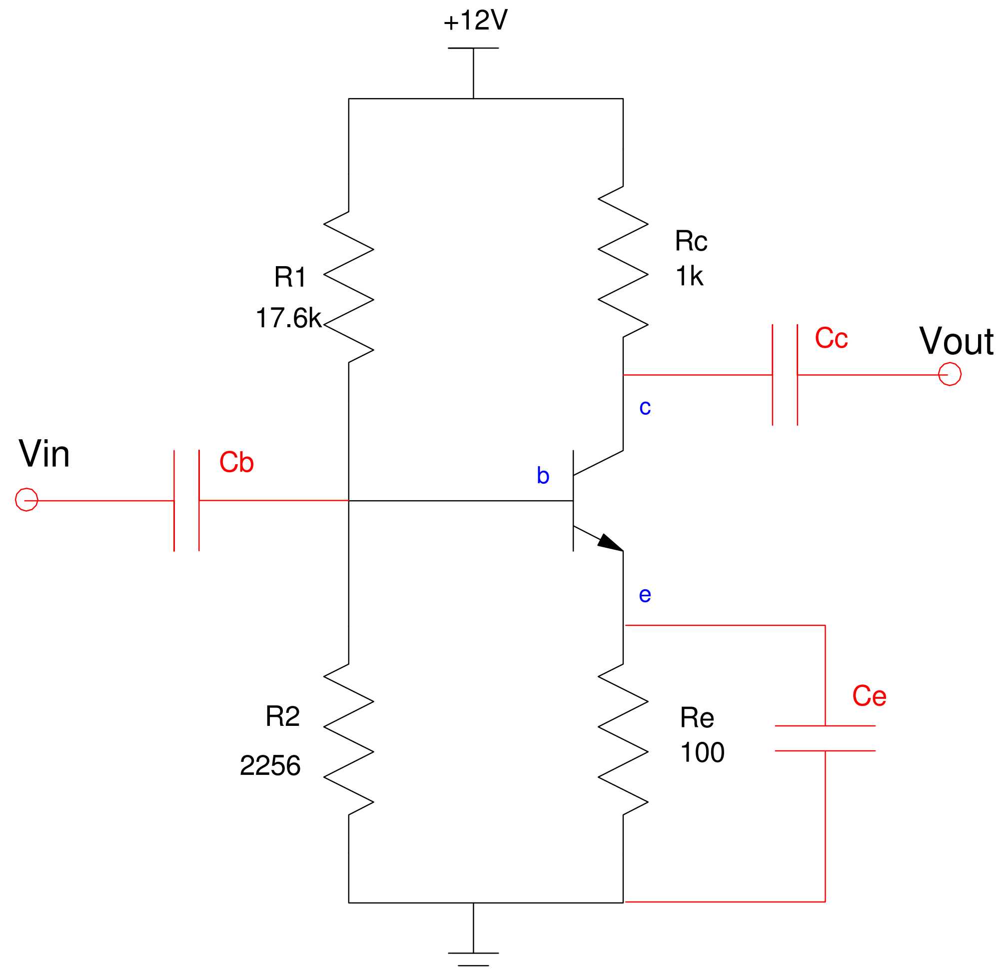
Capacitors isolate the circuit at DC



Common Emitter Amplifier

Connect

- Ce to ground.
- Cb to the input
- Cc ot 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

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

Taylor's Series (2-terms):

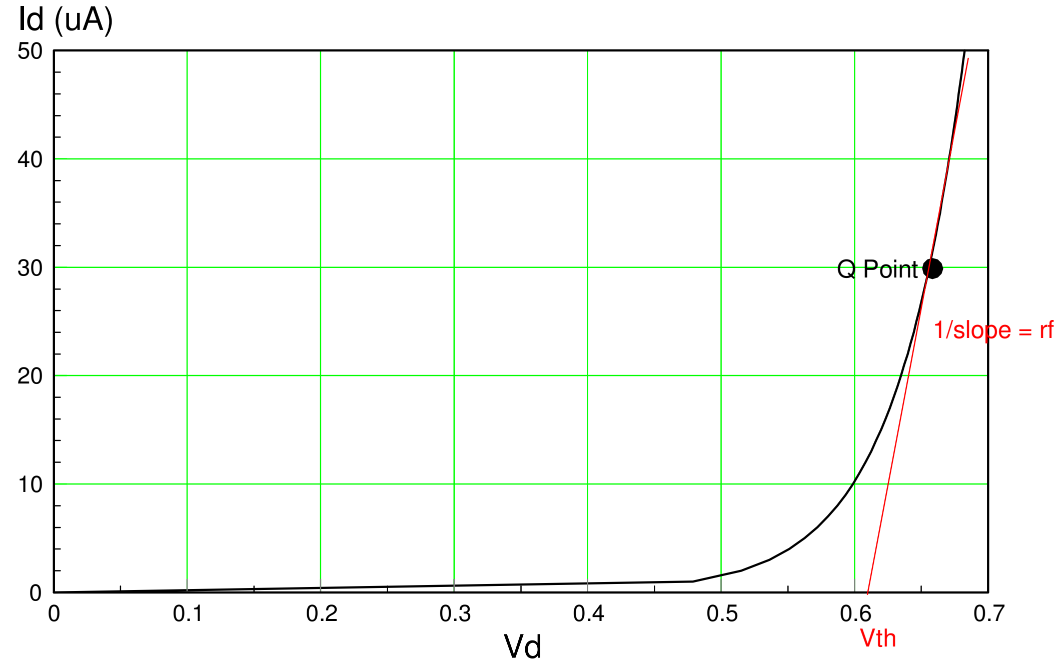
$$V_d \approx V_{th} + i_d r_f$$

Taking the derivative:

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

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

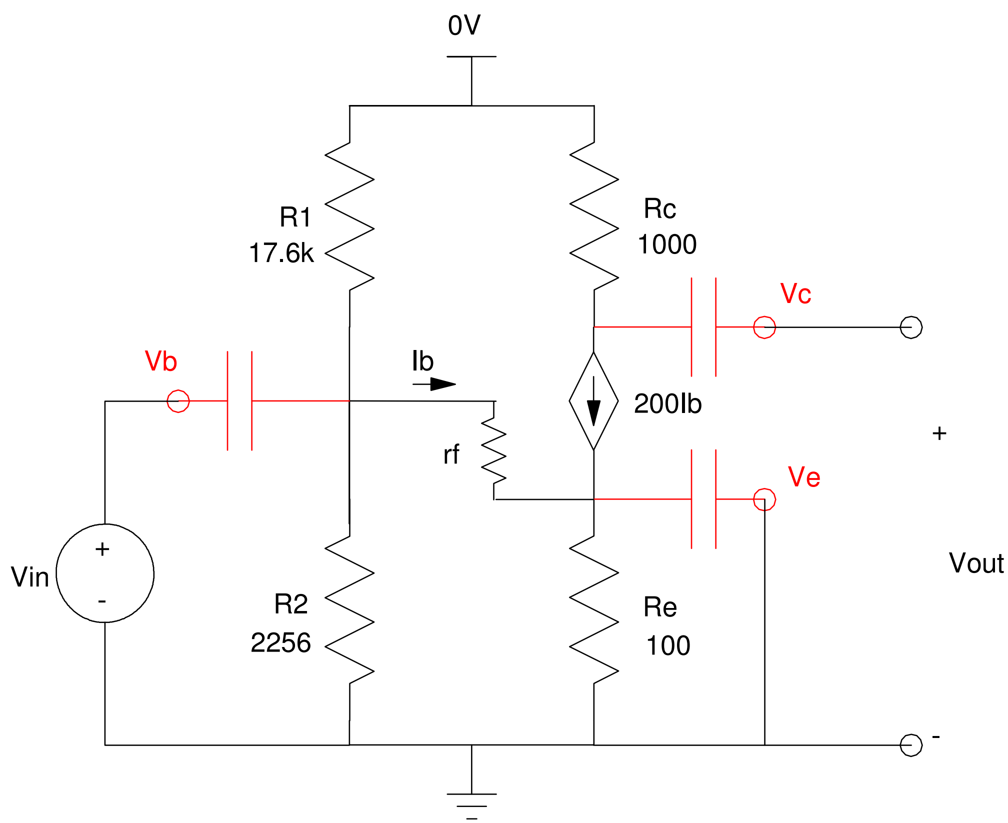
$$r_f = \left(\frac{0.026V}{30\mu A}\right) = 867\Omega$$



Small-Signal Model (AC Model)

Replace the transistor with it's AC model

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



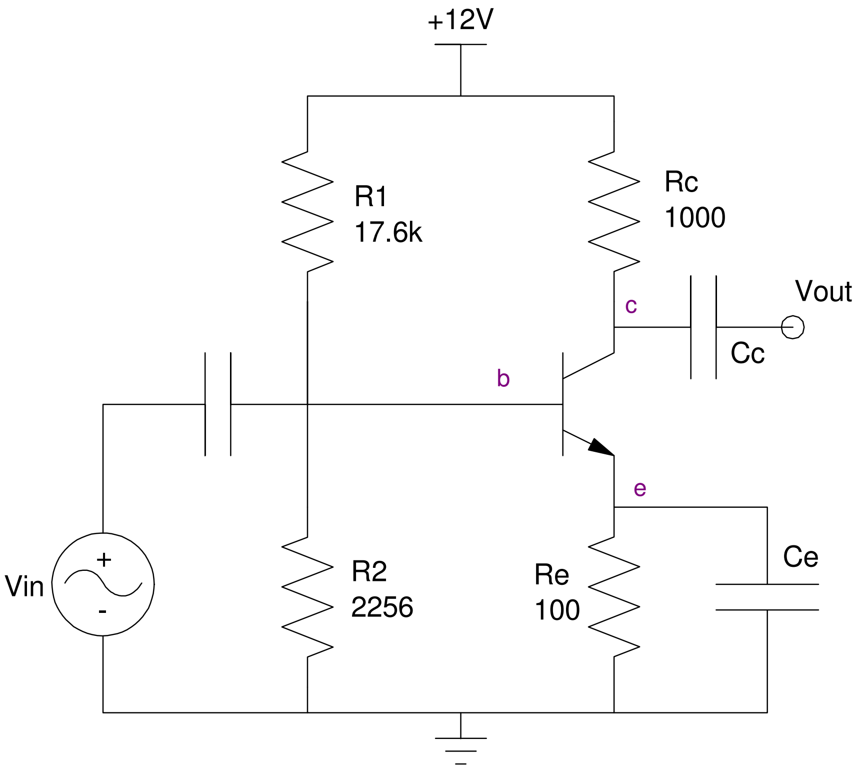
Note:

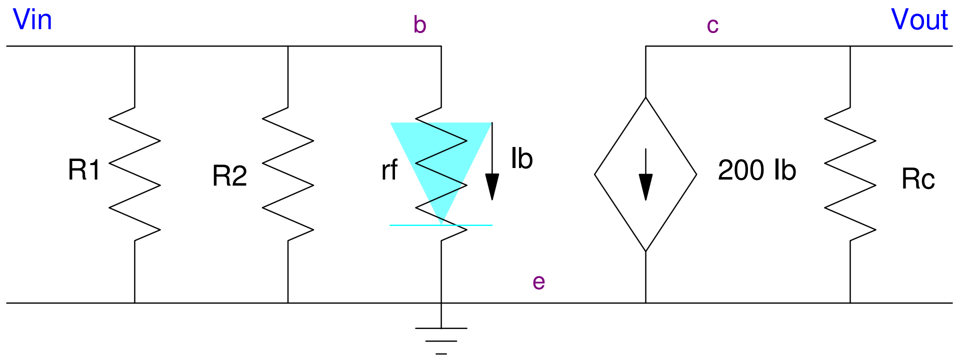
- Vcc = 12V (DC) + 0V (AC)
- This is AC analysis

Using superposition

- V(total) = DC + AC

Redraw the Circuit





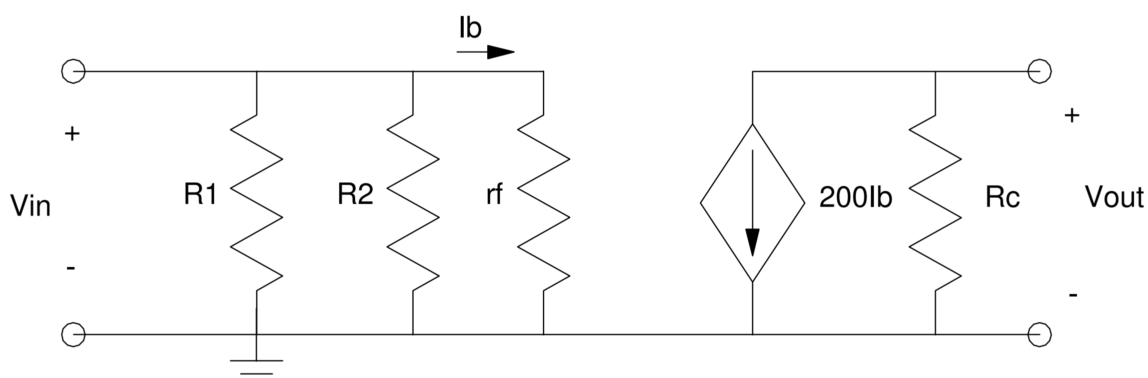
Convert to a 2-Port Model

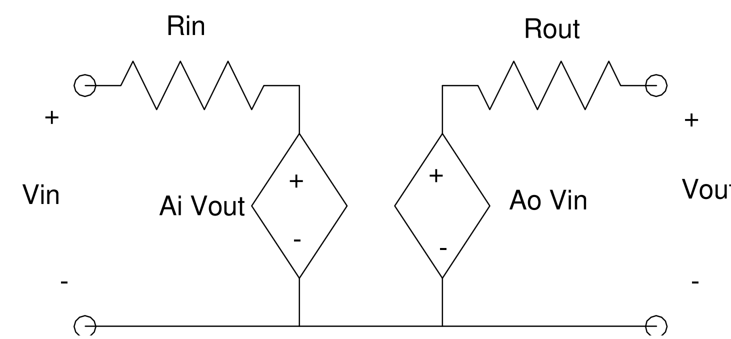
Rin: For the 2-port model, short Vo so that Vo=0 and $A_i V_{out} = 0$. Measure the resistance at the input. Doing the same for the CE amplifier, this results in

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

Ai: For the 2-port model, apply 1V to Vout. Measure the resulting voltage at Vin. Doing the same for the CE amplifier results in Vin = 0V, so

$$Ai = 0$$



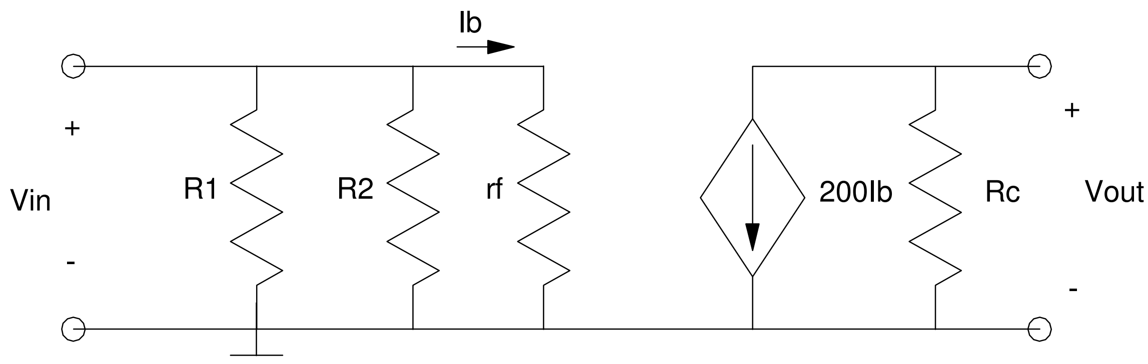


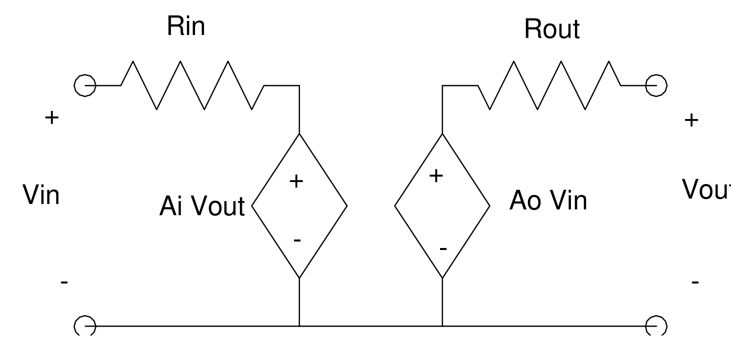
Rout: For the 2-port model, short Vi so that Vi=0 and $A_o V_{in} = 0$. Measure the resistance at the output. Doing the same for the CE amplifier, this results in

$$R_{out} = R_c$$

Ao: For the 2-port model, apply 1V to Vin. Measure the resulting voltage at Vout. Doing the same for the CE amplifier results in

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



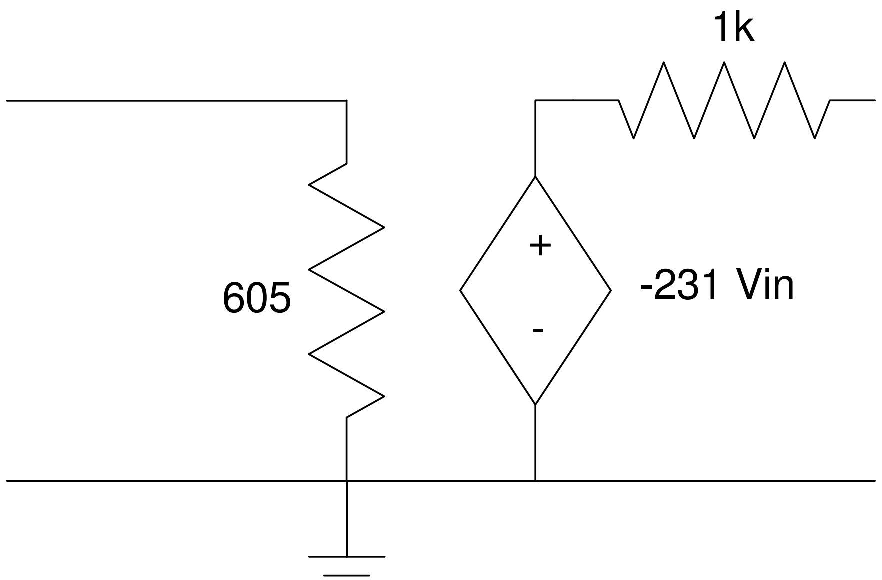


2-Port Model:

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

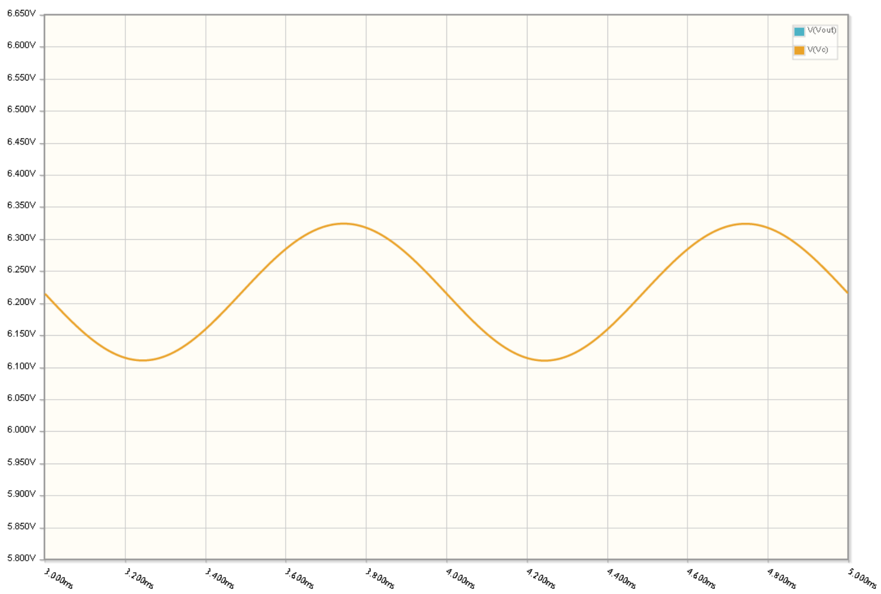
$$R_{out} = 1k\Omega$$

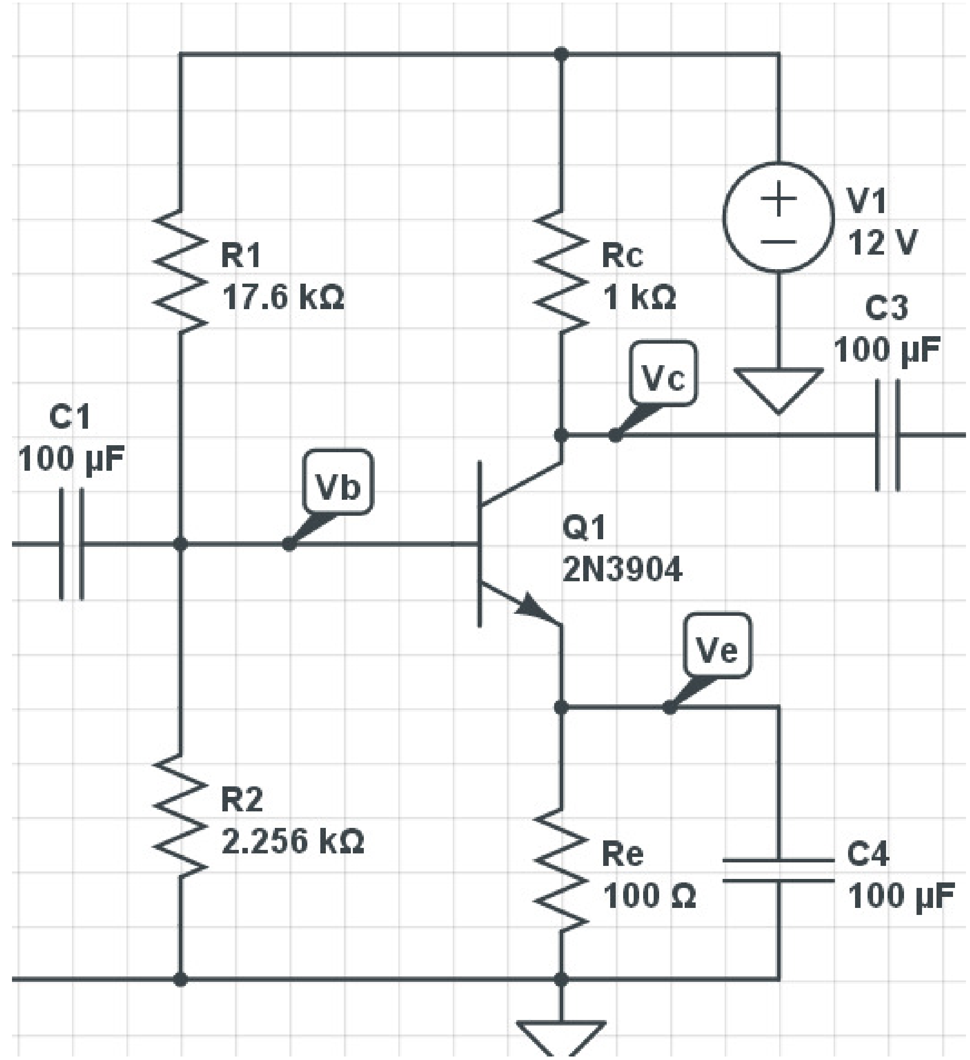
$$A_o = -231$$



Simulation Results

- Vin = 1mV 1kHz sine wave
- Vc has a DC offset
- Plus an AC component (1kHz)



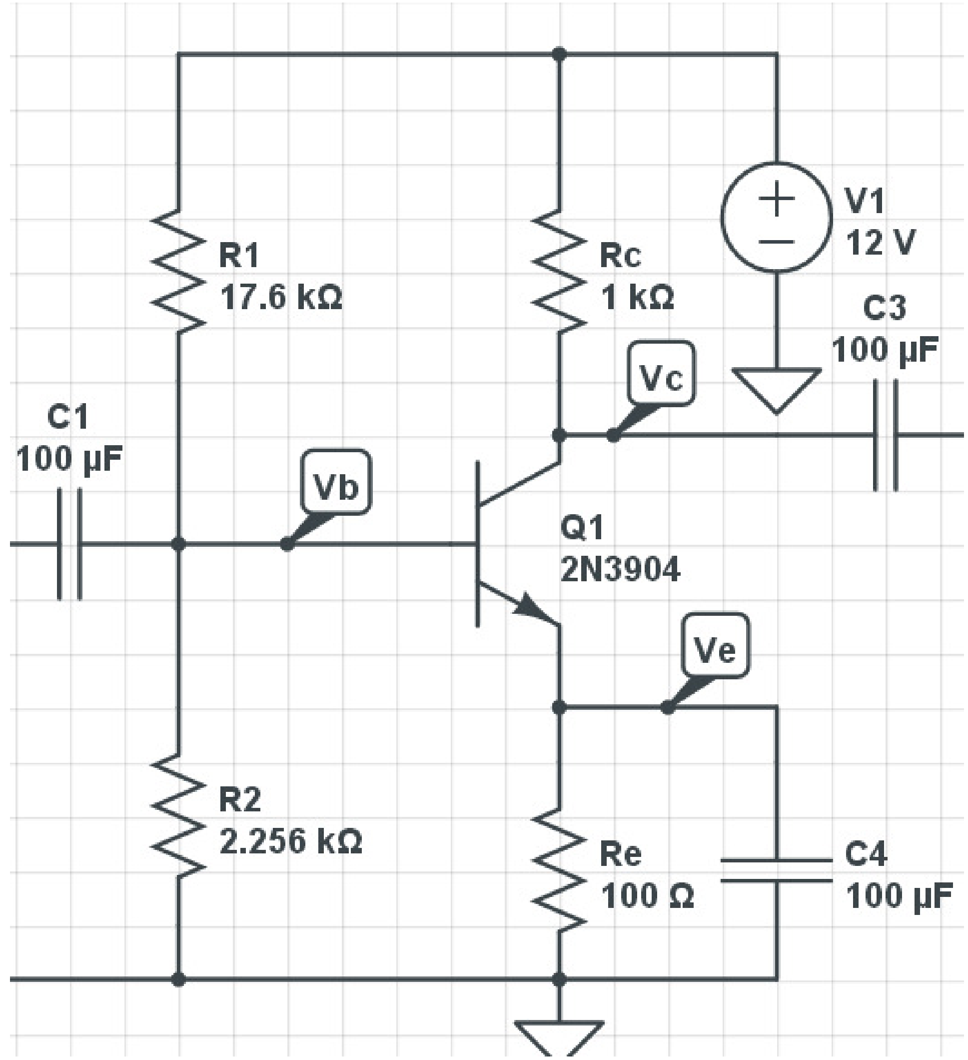


Simulation Results (DC)

- Vb = 1.287V
- Vc = 6.217V
- Ve = 0.582V
- Ic = 5.783mA
- Ib = 38.39uA

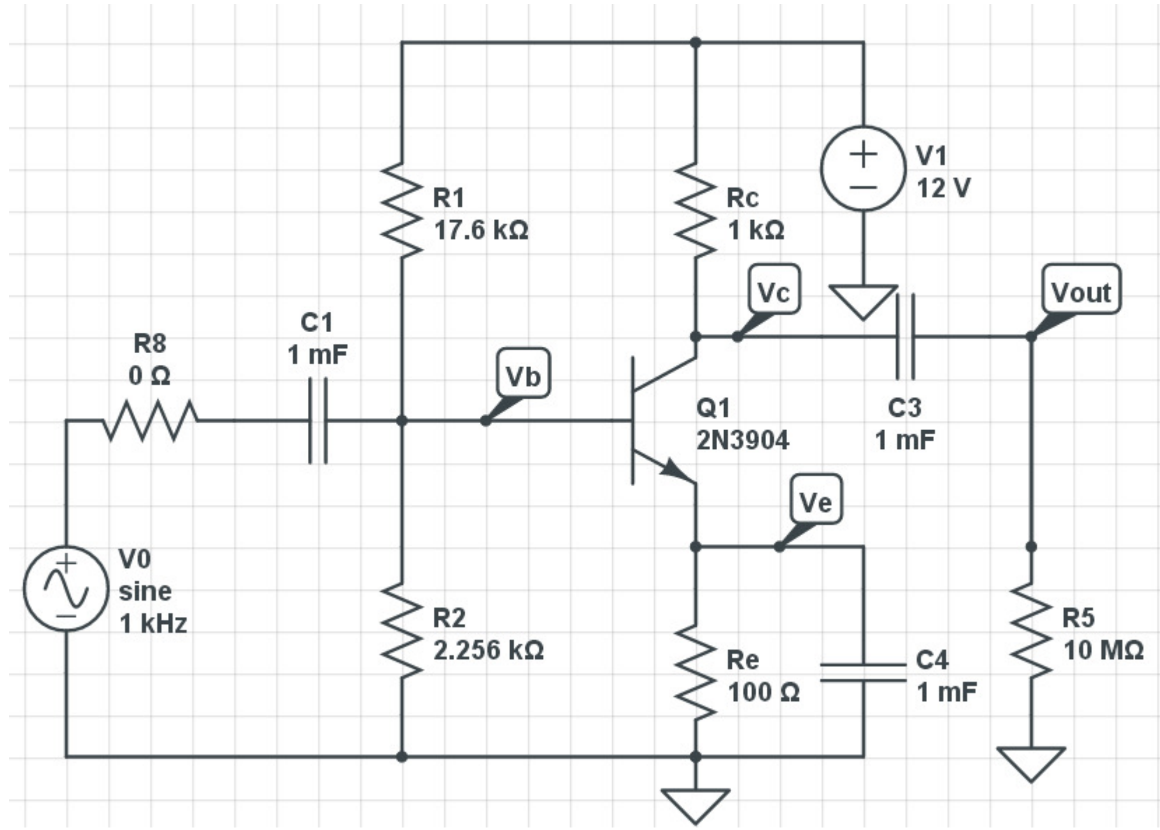
$$\beta = \frac{I_c}{I_b} = 151$$

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



CircuitLab: Ao:

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

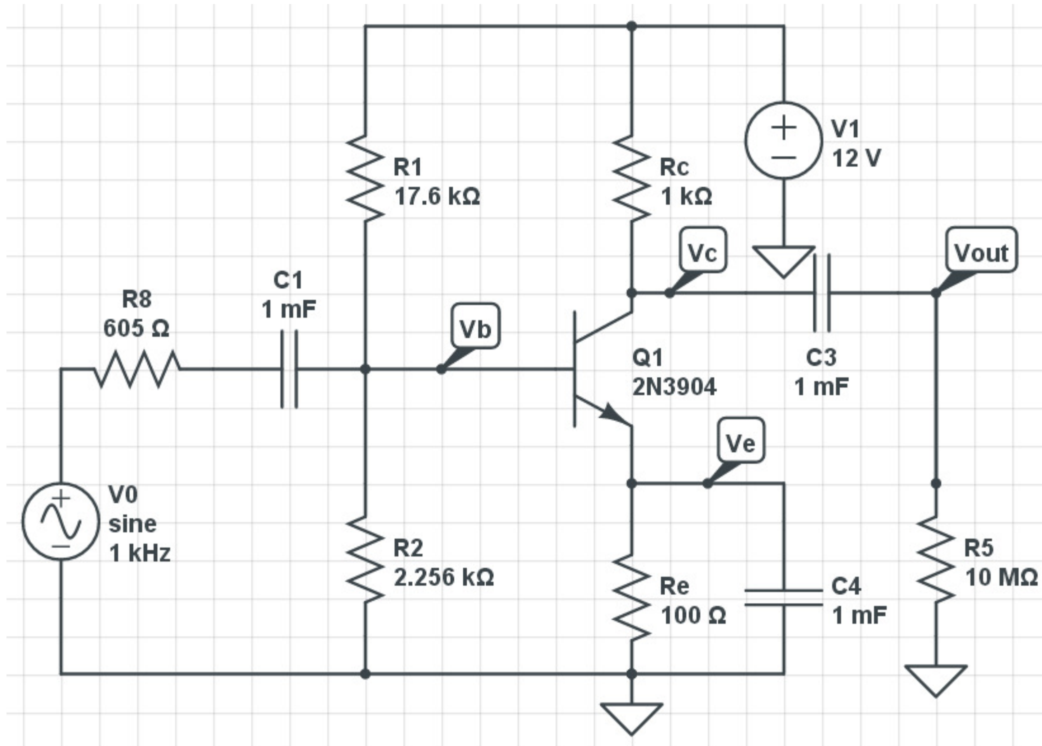


Vout = 203.3mV (peak)

- Ao = -203.3
- Calculated = -230

CircuitLab: Rin:

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



Vout = 95.04mV (peak)

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

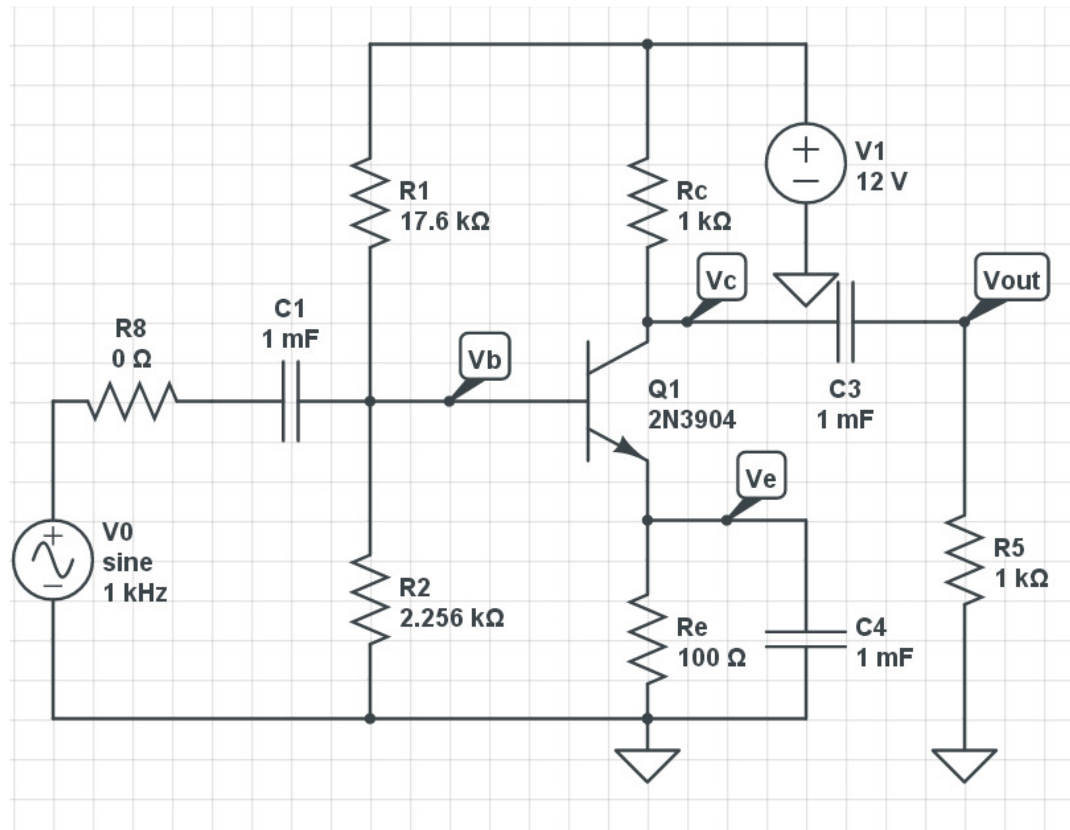
$$R_{in} = \left(\frac{95.04mV}{203.3mV - 95.04mV}\right)605\Omega$$

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

- (vs. 605 Ohms calculated)

CircuitLab: Rout:

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



Vout = 107.1mV (peak)

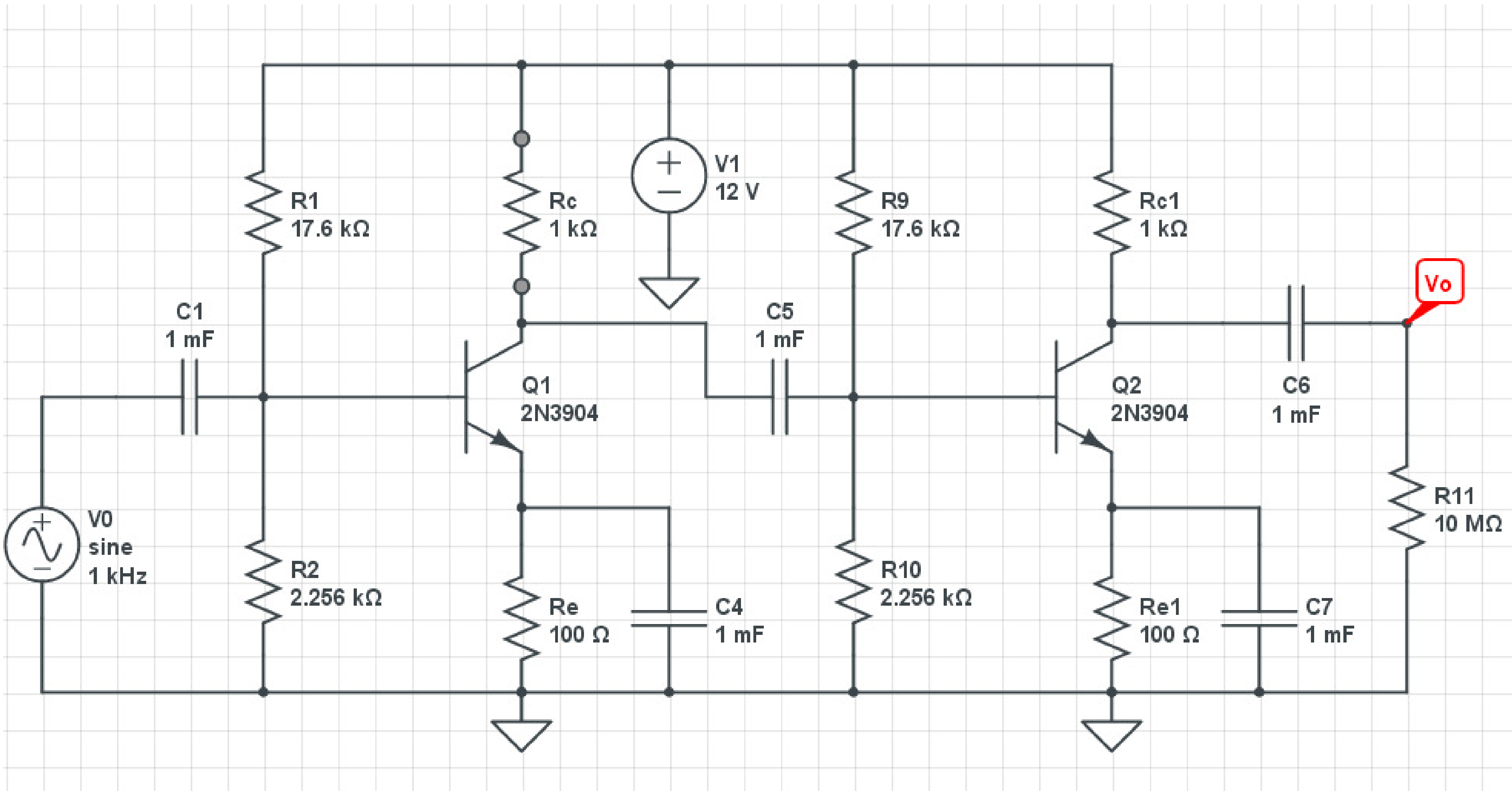
$$107.1mV = \left(\frac{1000}{R_{out}+1000}\right)203.3mV$$

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

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

- vs. 1000 Ohms calculated

Cascading CE Amplifiers

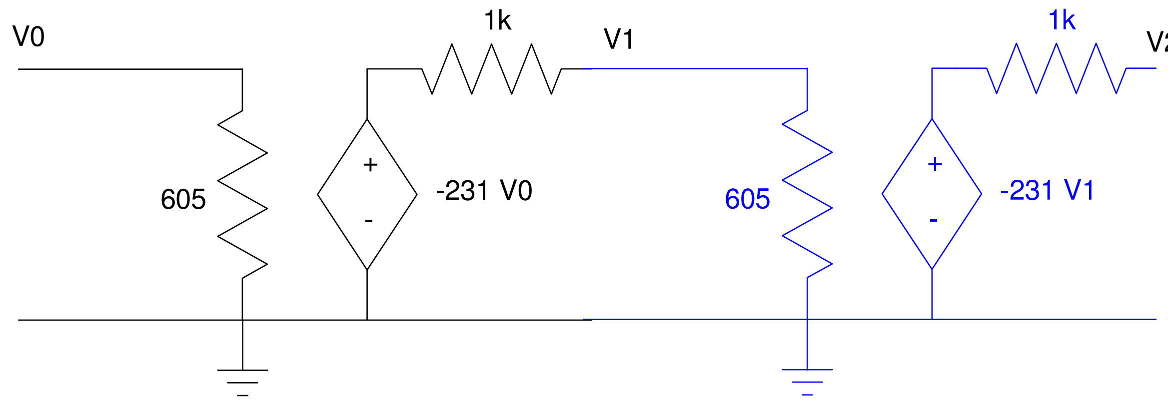


Analysis:

- Use the 2-port model (x2)

By inspection

- Rin = 605
- Ai = 0
- Rout = 1k



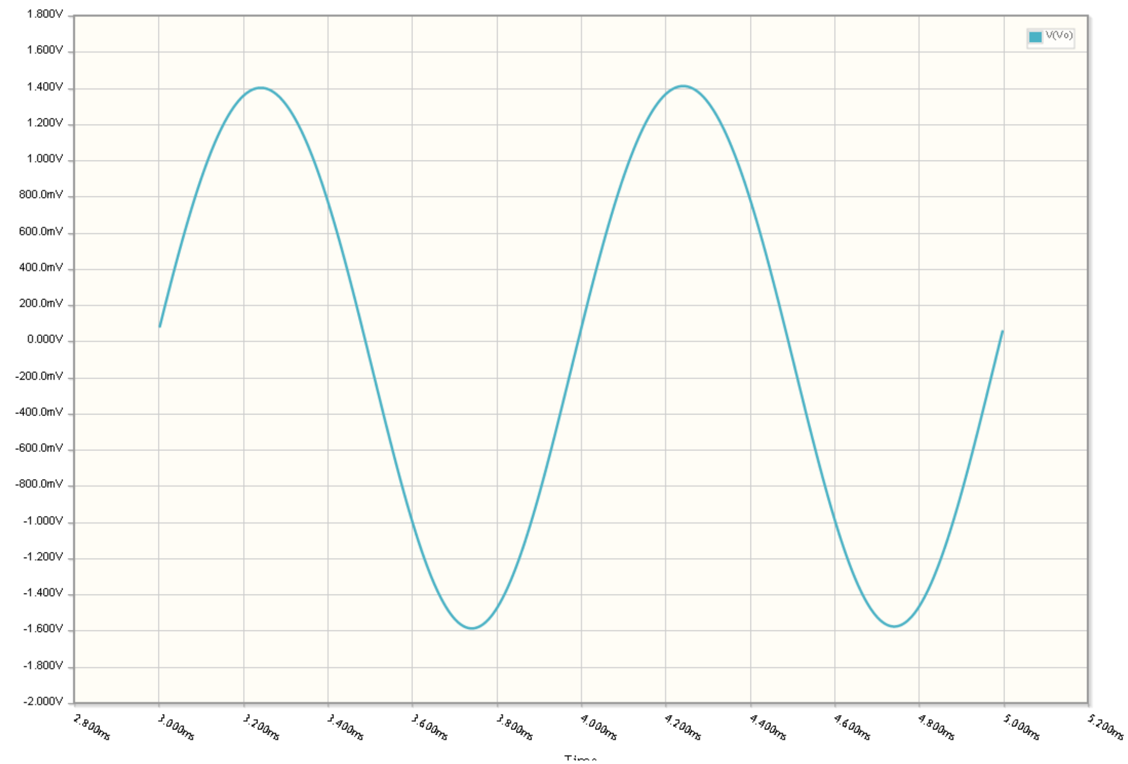
Ao: Apply 1V to the input

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

Ao = 20,114

Simulation Results

- Vin = 100uV 1kHz sine wave
- Vout = 1.409V sine wave
- Gain = 14,090
- (vs. 20,114 calculated)



Summary

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