
Common Base & Common Collector Amplifiers

ECE 321: Electronics II

Lecture #15

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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

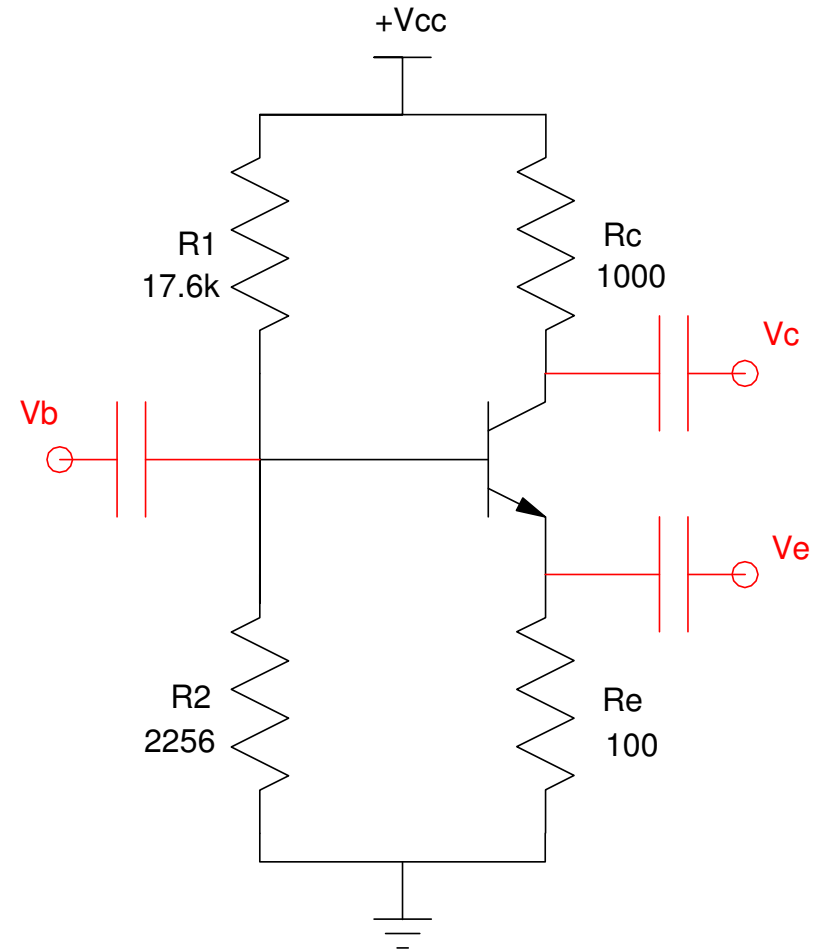
- Use R_e to stabilize the Q-point
- Use R_1 and R_2 to set the Q-point

Assume the Q-point is

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

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

Capacitors isolate the circuit at DC

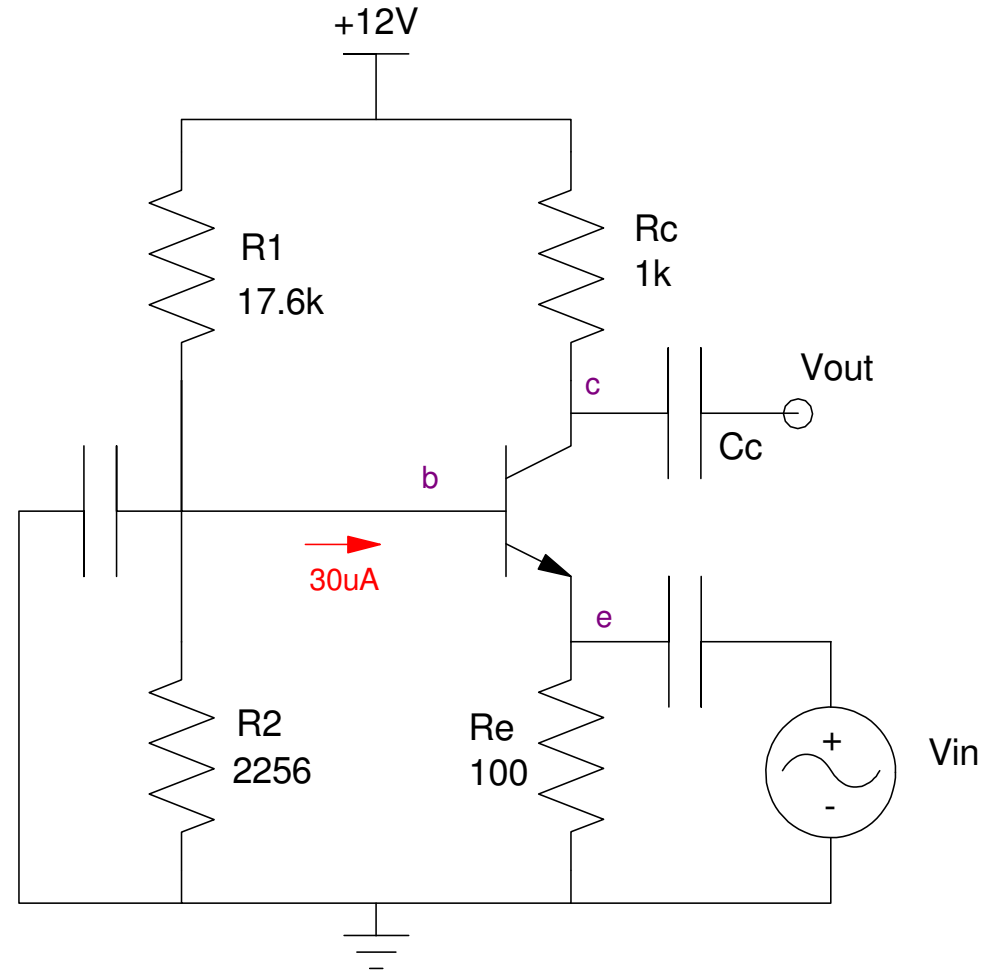


Common Base Amplifier:

- Connect the base to ground
- Connect the input to V_e
- Connect the output to V_c :

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

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



Small-Signal Model (AC Model)

Replace the transistor with its AC model

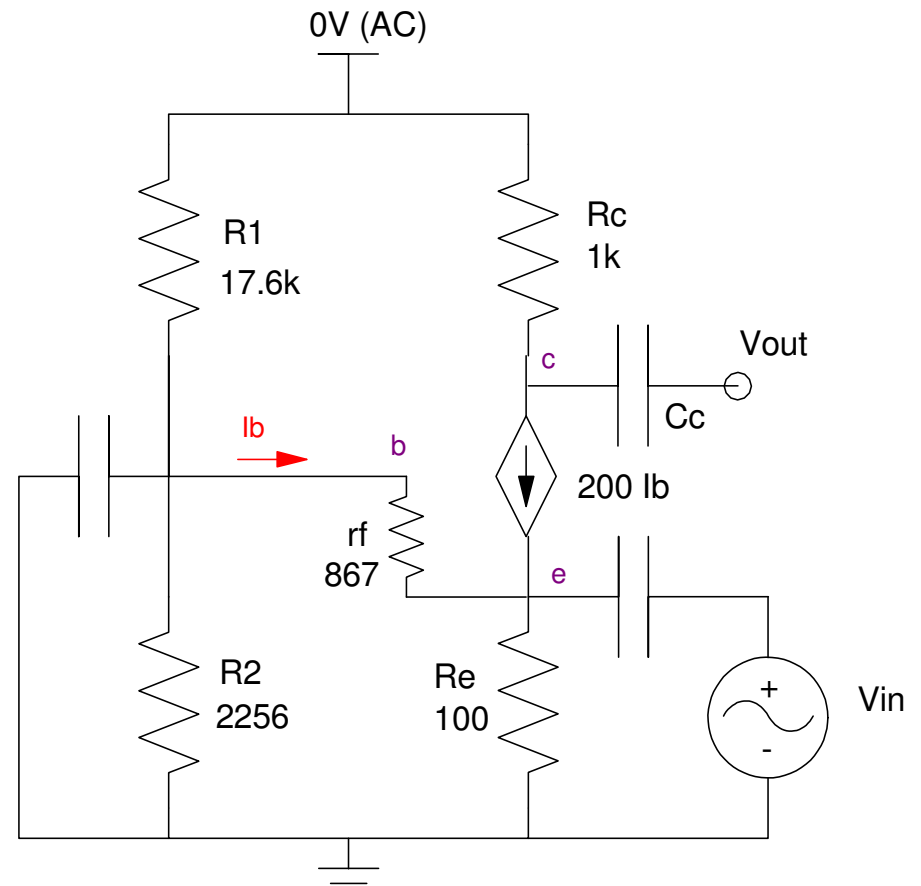
- Ignore the DC terms (already computed)
- Diode becomes r_f (867 Ohms)

Note:

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

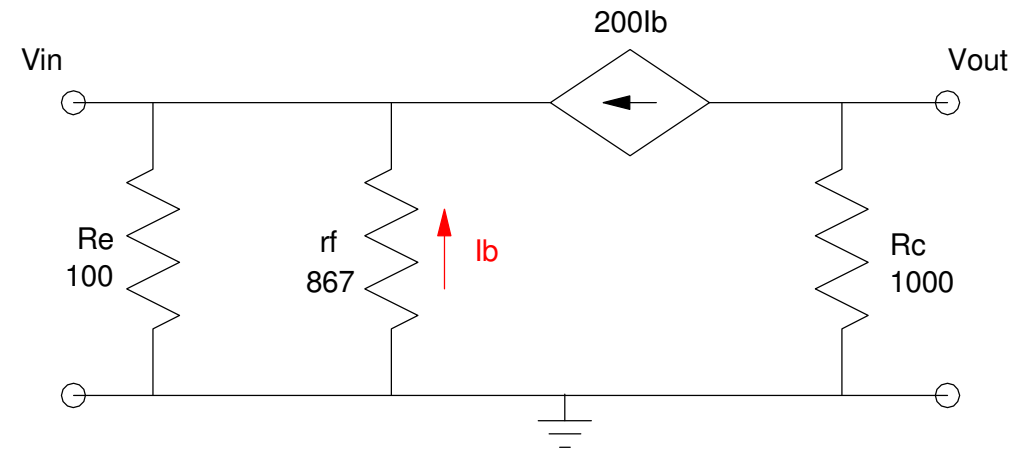
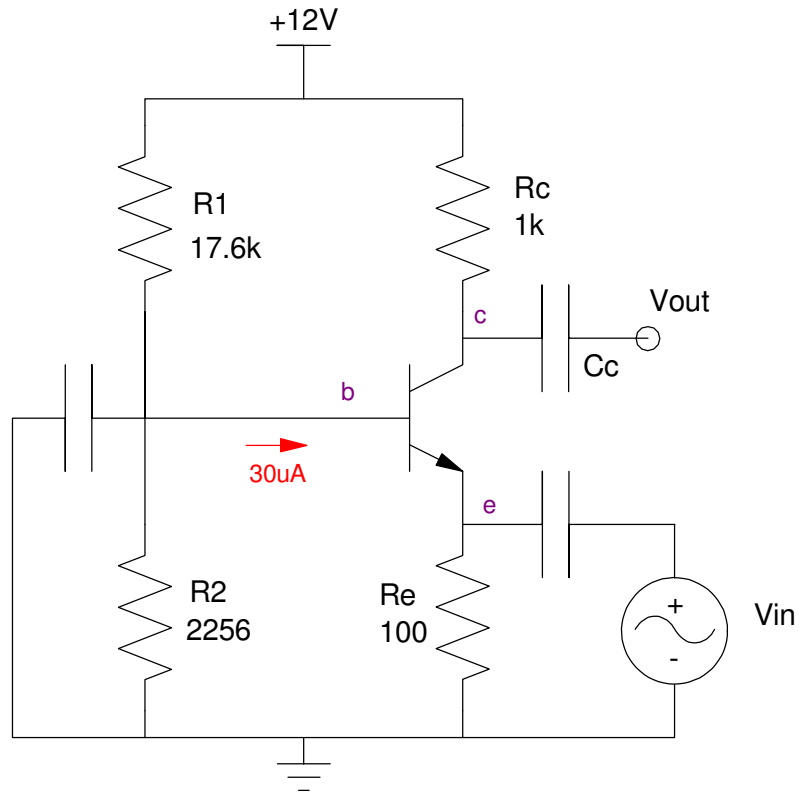
Using superposition

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



Redraw the circuit

- Small signal (AC) model from V_{in} to V_{out}



Find the 2-port parameters:

R_{in} : Set $V_o = 0V$ and measure the input resistance.

- Apply 1V to V_{in} and compute I_{in}

$$I_{in} = \frac{1V}{R_e} + \frac{1V}{r_f} + \beta I_b$$

$$I_{in} = \frac{1V}{R_e} + \frac{1V}{r_f} + \frac{\beta}{r_f}$$

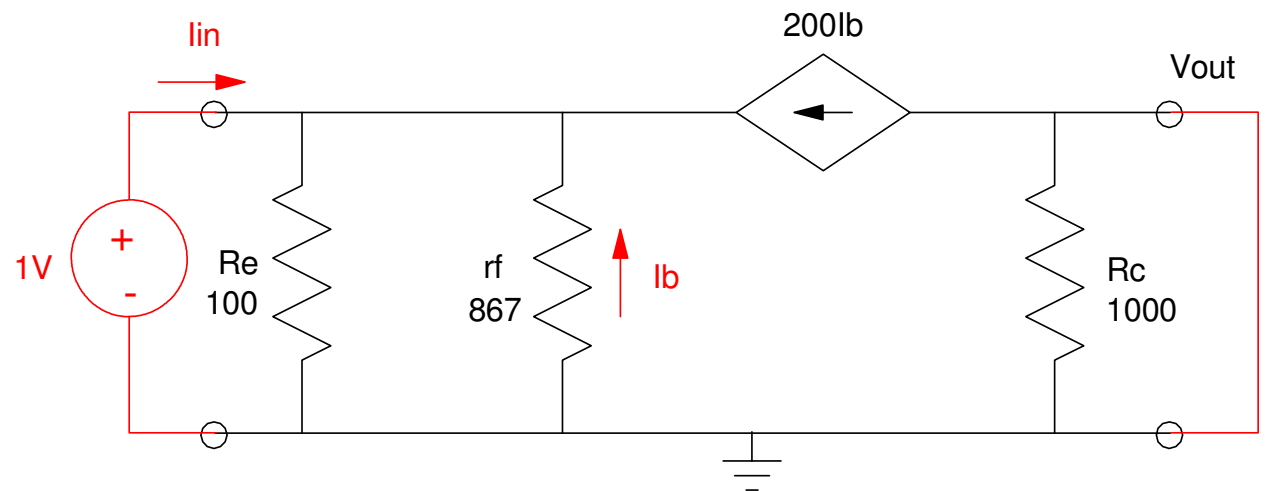
SO

$$R_{in} = \left(\frac{1}{R_e} + \frac{1}{r_f} + \frac{\beta}{r_f} \right)^{-1}$$

Note that this is also

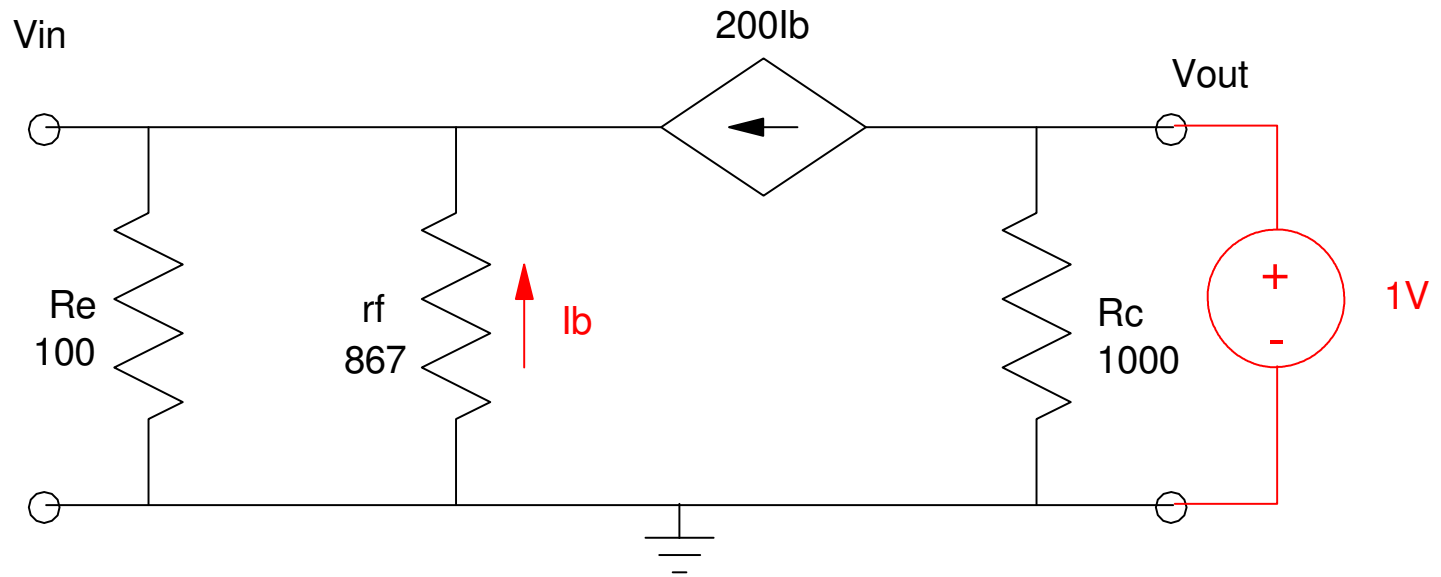
$$R_{in} = R_e || r_f || \frac{r_f}{\beta}$$

$$R_{in} = 4.13\Omega$$



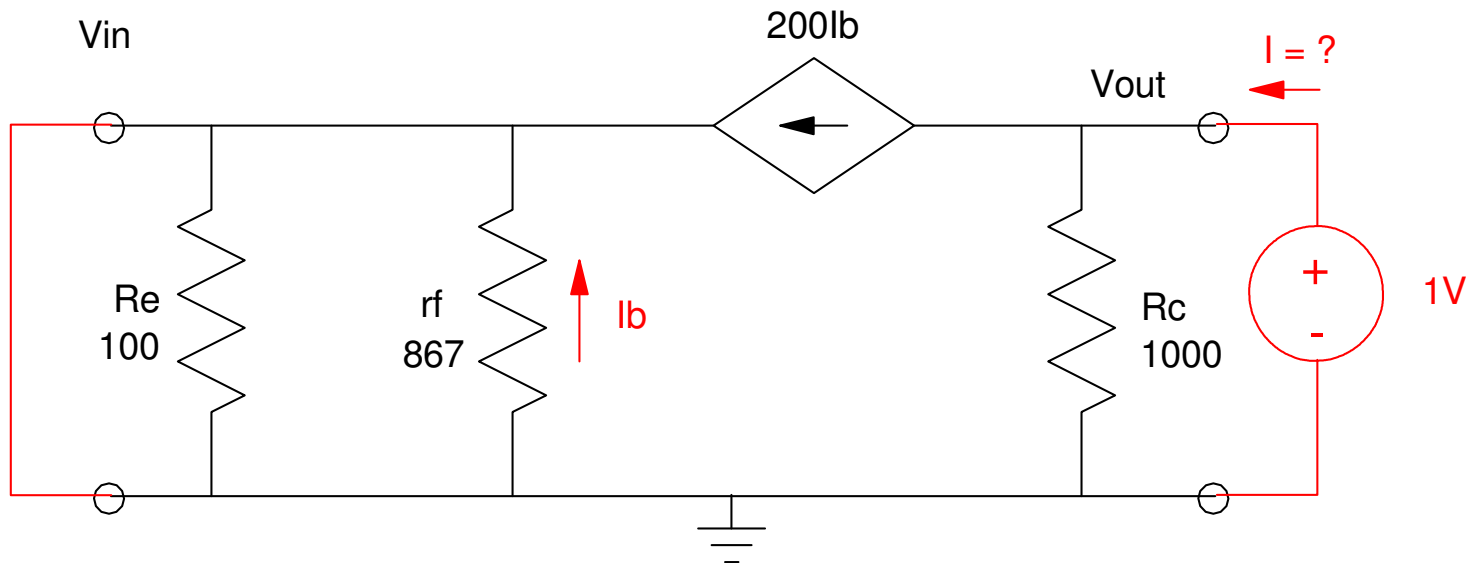
Ain: Set $V_o = 1V$ and measure the voltage at the input.

- $V_{in} = 0V$
- $A_o = 0$



Rout:

- Set $V_{in} = 0V$
- Apply 1V test to V_{out}
- Compute I: $I = 1mA$
- $R_{out} = 1/I = 1000\text{ Ohms}$



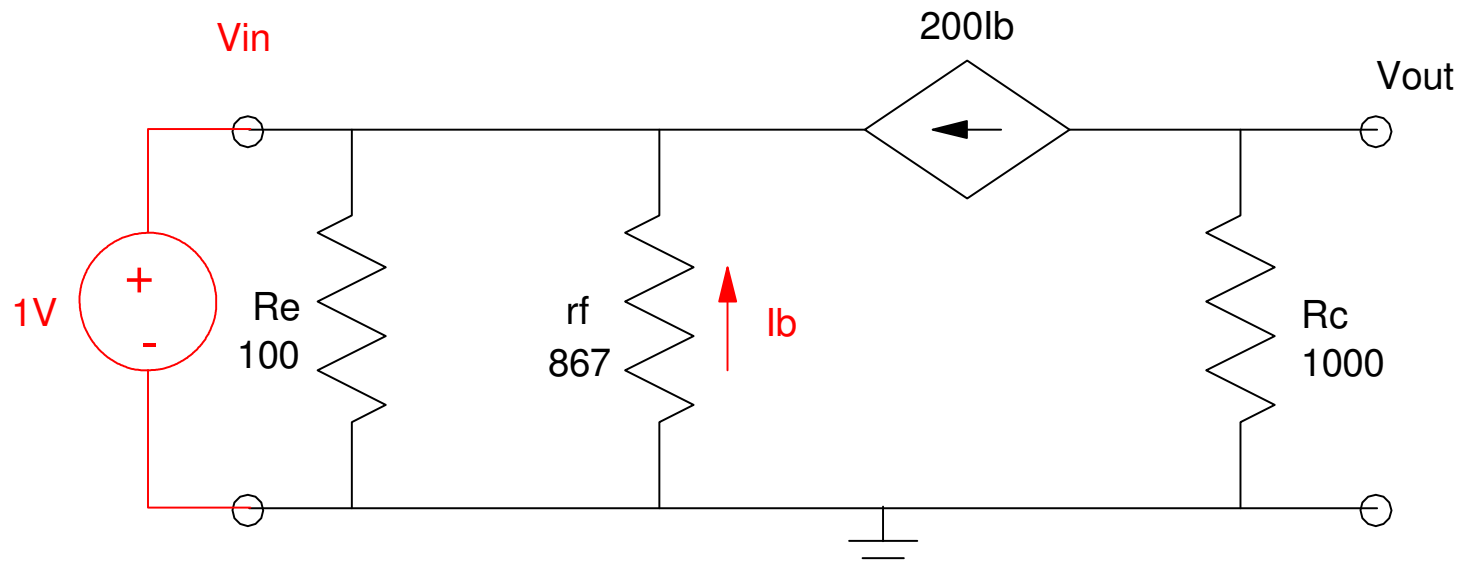
Ao: Set $V_{in} = 1V$ and measure the voltage at the output.

$$I_b = \frac{1}{r_f}$$

$$I_c = \beta I_b$$

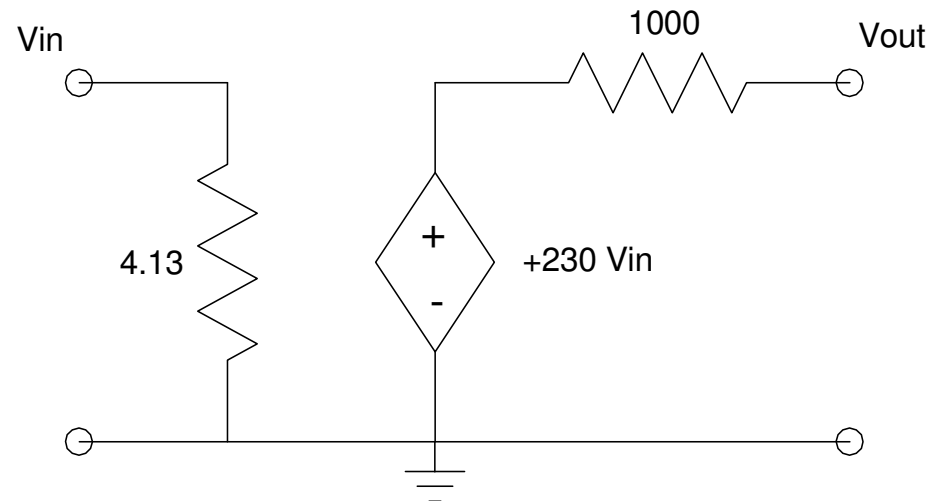
$$A_o = V_o = \frac{\beta R_c}{r_f}$$

$$A_o = +230$$



Resulting 2-Port Model

- Feature: Low Input Impedance
- First stage of an amplifier if you need a low-impedance load

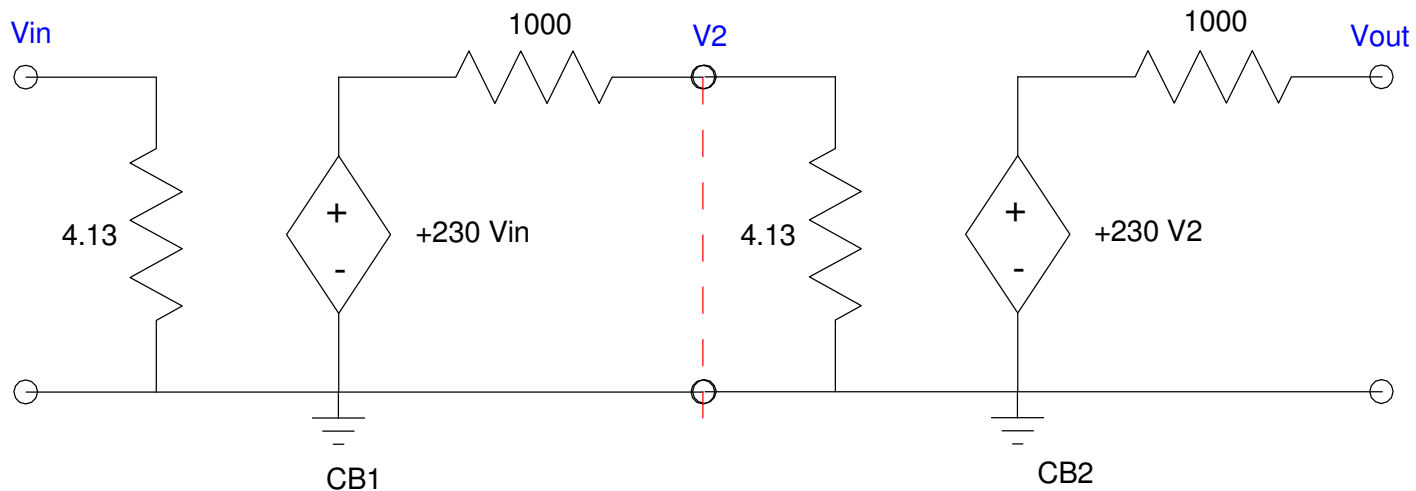


Cascading CB Amplifiers

- CB amplifiers have a low input impedance (can be good)
- They don't work well as voltage amplifiers
- Ao actually gets worse when you cascade CB amplifiers:
- Apply 1V to V_{in}

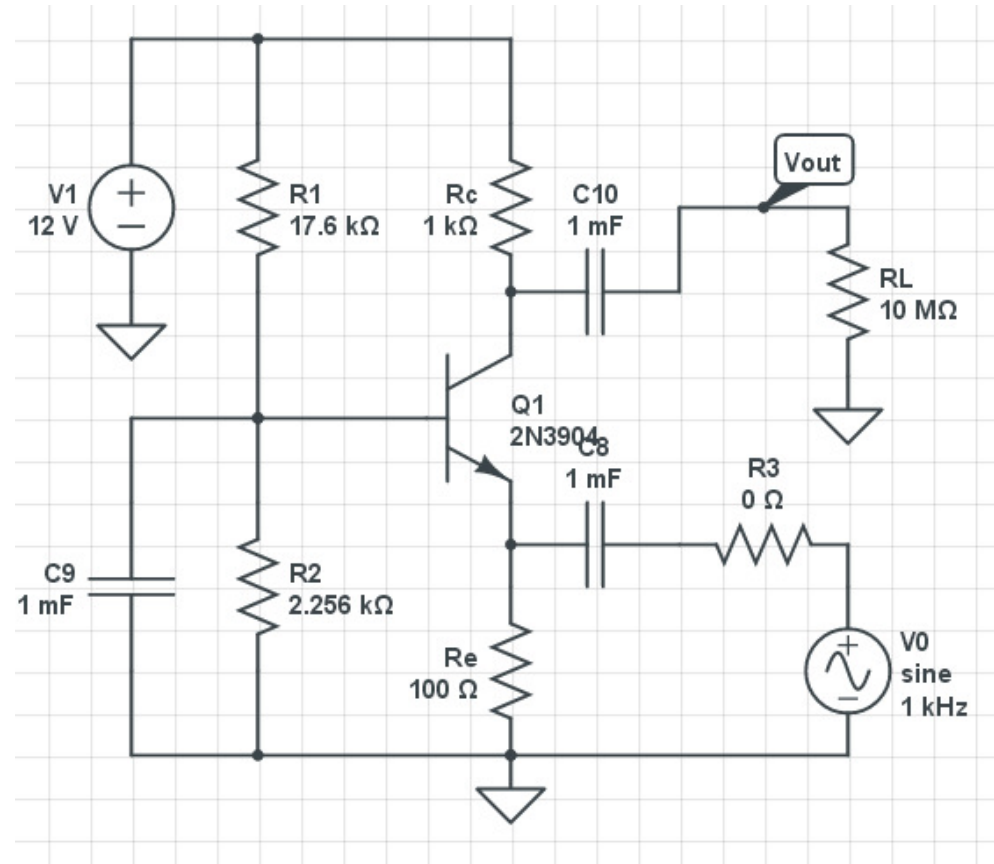
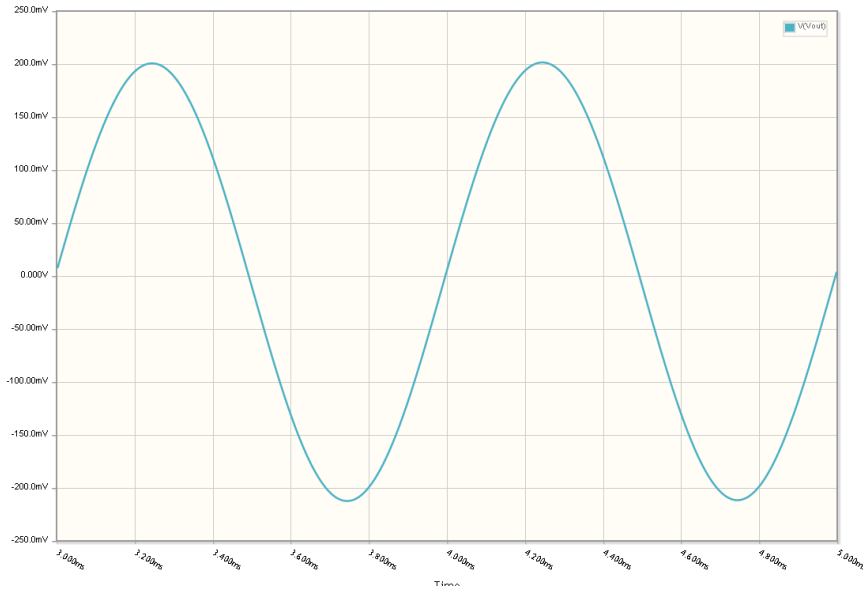
$$V_2 = \left(\frac{4.13}{4.13+1000} \right) \cdot 230V = 0.946V$$

$$A_o = V_{out} = 230V_2 = 217.6$$



CircuitLab Simulation

- $V_0 = 1\text{mV}$, 1kHz sine wave
- $V_{out} = 200.9\text{mV}$ sine wave
- $A_o = 200.9$ (vs. 230 computed)



CircuitLab Simulation (Rin)

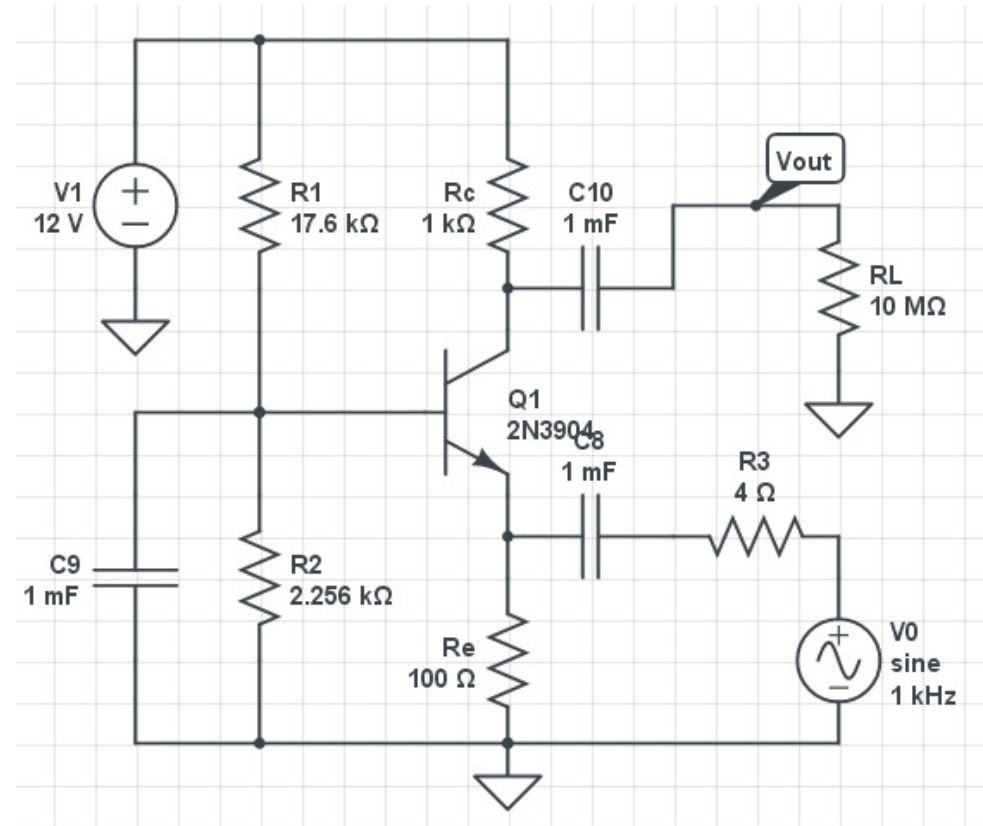
- Set R3 = 4 Ohms
- Set RL = 0 Ohms
- Measure Vout = 108.5mV
- Compute Rin

$$\left(\frac{R_{in}}{R_{in}+4}\right) 200.9mV = 108.5mV$$

$$R_{in} = \left(\frac{108.5}{200.9-108.5}\right) 4\Omega$$

$$R_{in} = 4.70\Omega$$

- vs. 4.13 Ohms computed



CircuitLab: Rout

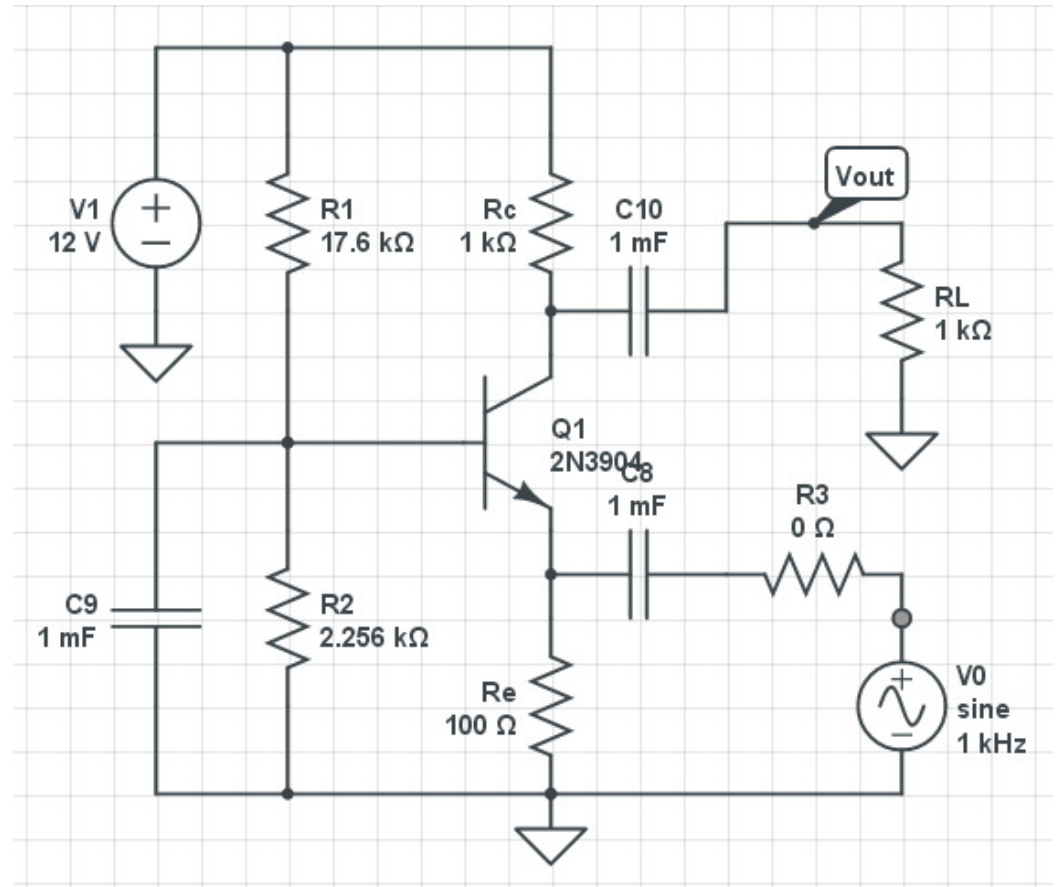
- Set $R3 = 0$ Ohms
- Set $R_L = 1000$ Ohms
- Measure $V_{out} = 104.1$ mV
- Compute R_{out}

$$\left(\frac{1000}{1000+R_{out}}\right) 209.9mV = 104.1mV$$

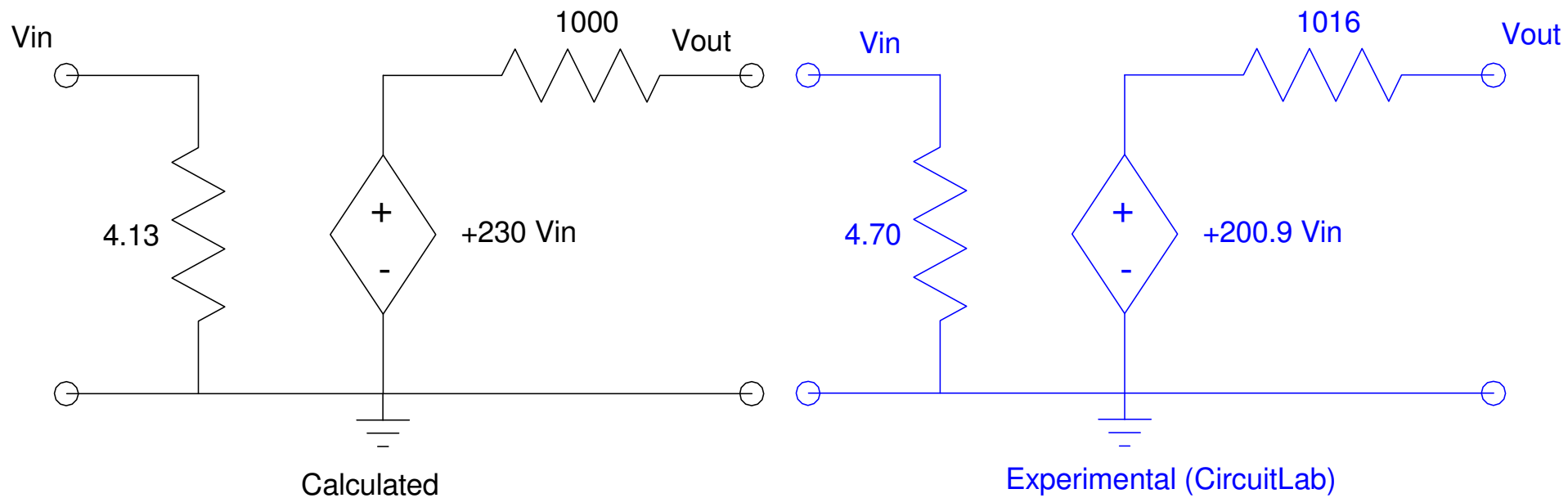
$$R_{out} = \left(\frac{209.9-104.1}{104.1}\right) 1k\Omega$$

$$R_{out} = 1016\Omega$$

- vs 1000 Ohms computed



CB Amplifier: 2-Port Model (experimental)

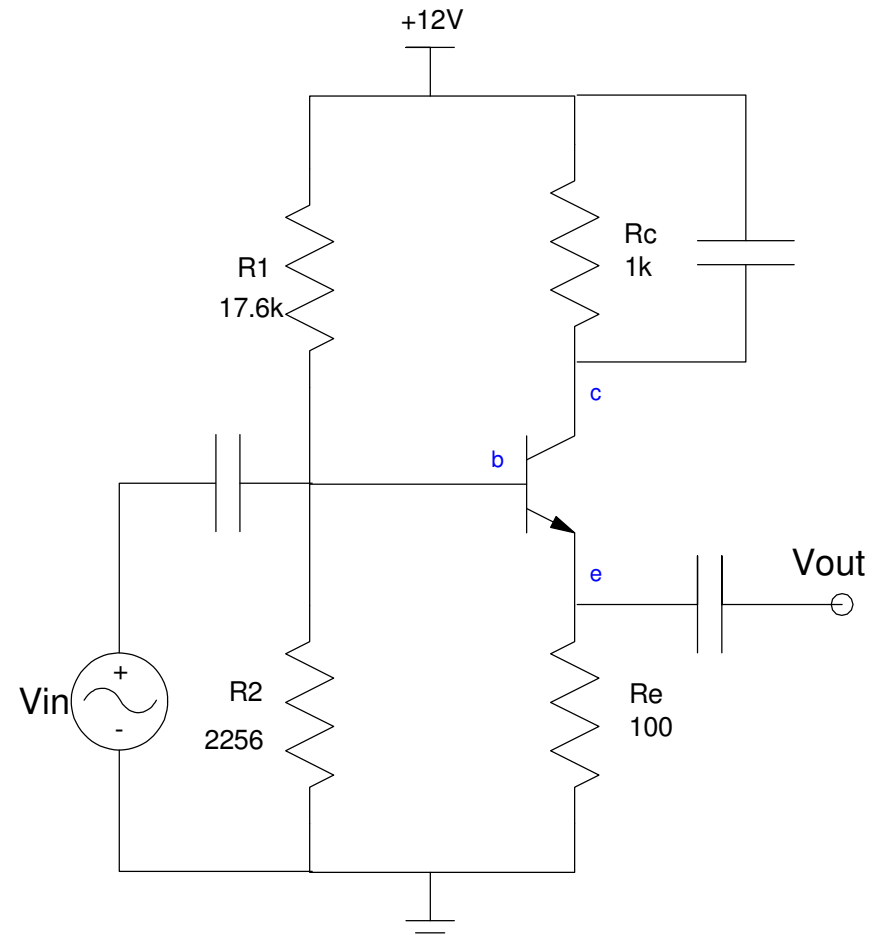


Common Collector Amplifier:

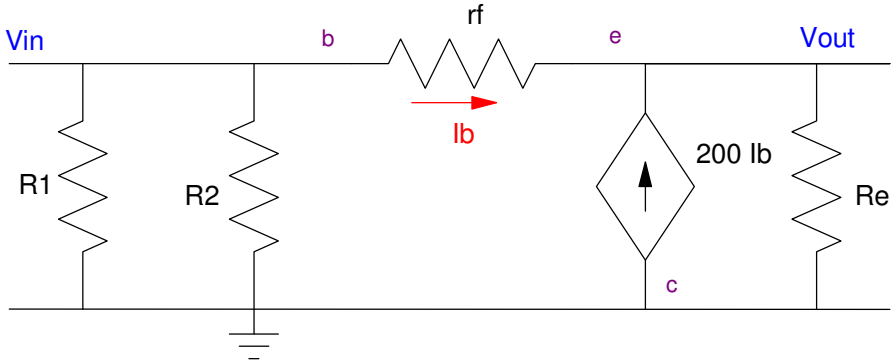
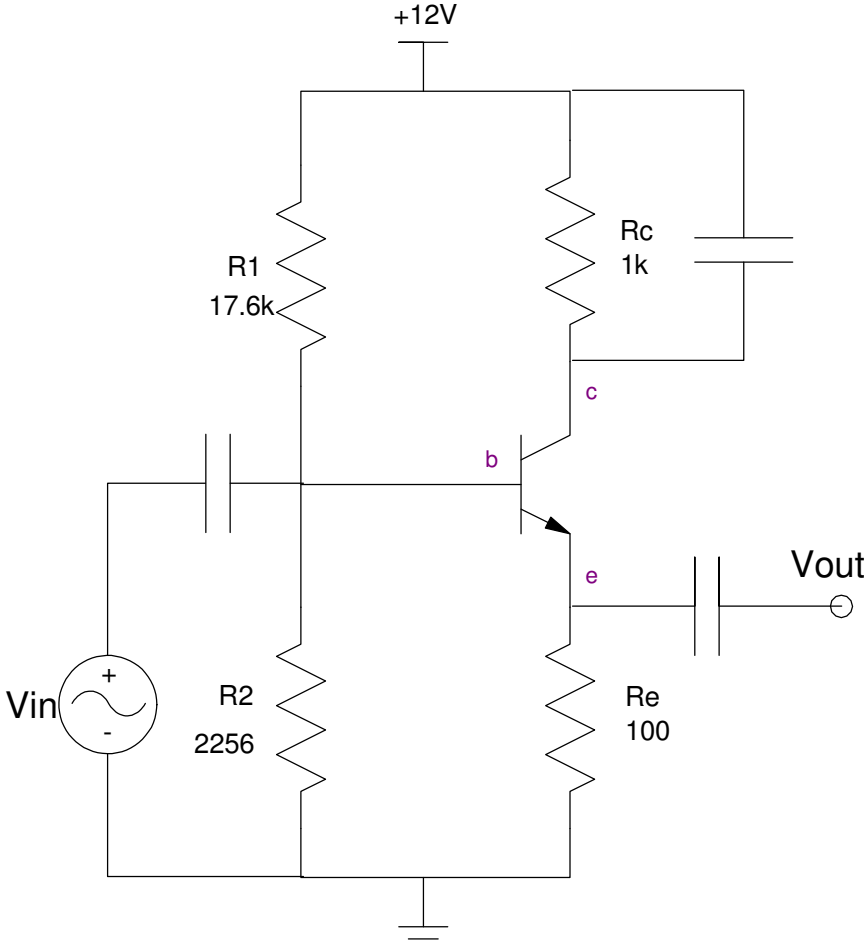
- Short the collector to ground
- Connect the input to the base
- Connect the output to the collector

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

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



Redraw the Circuit

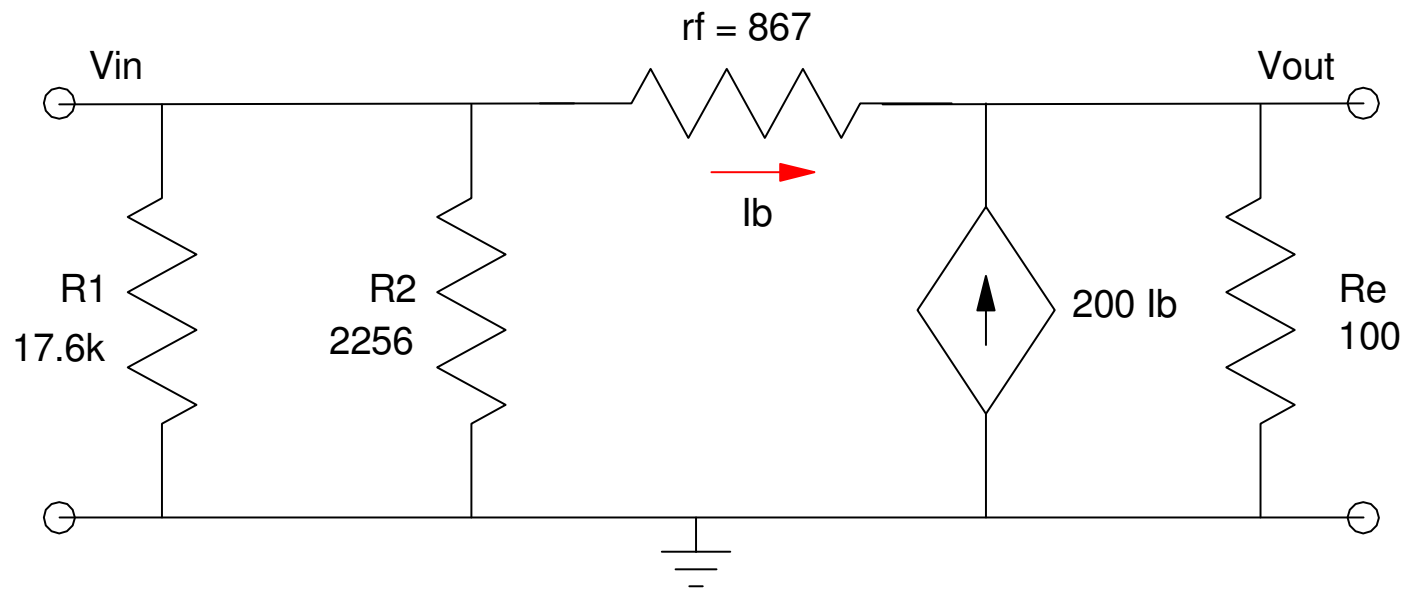


Find the 2-Port Parameters

R_{in} : Set $V_o = 0V$ and measure the resistance at the input.

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

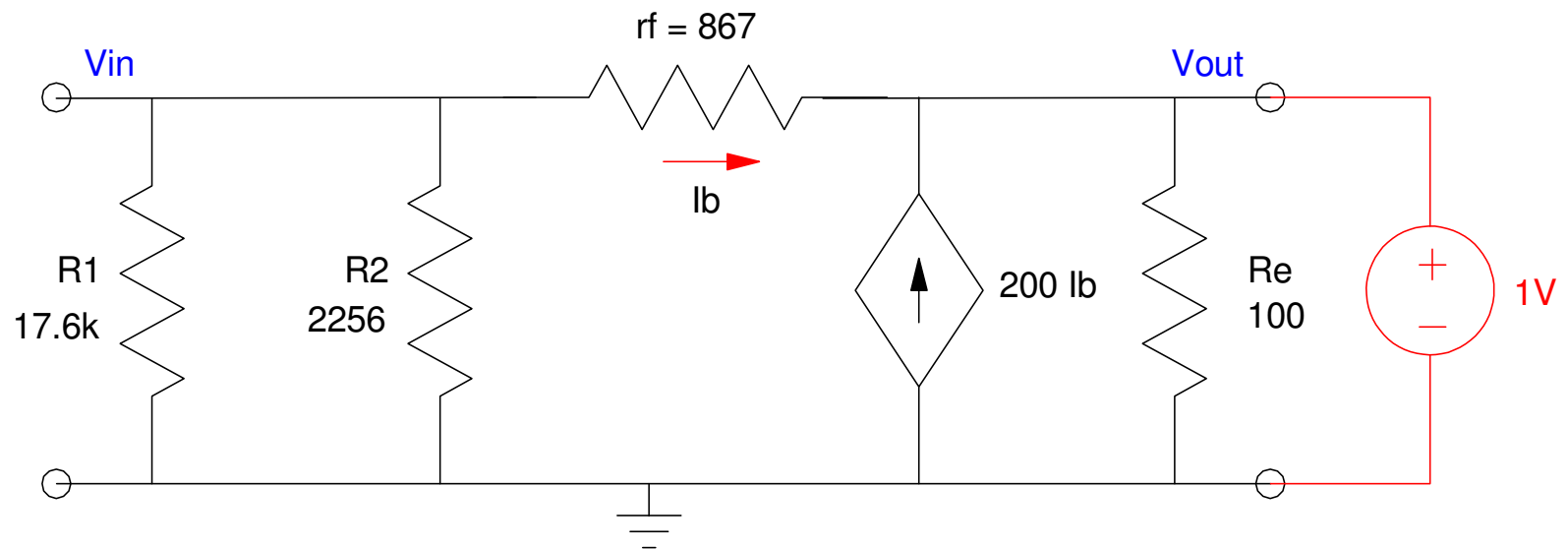
$$R_{in} = 605\Omega$$



A_{in} : Set $V_o = 1V$ and measure the voltage at the input. By voltage division

$$A_{in} = \left(\frac{R_1 || R_2}{R_1 || R_2 + r_f} \right)$$

$$A_{in} = 0.6976$$



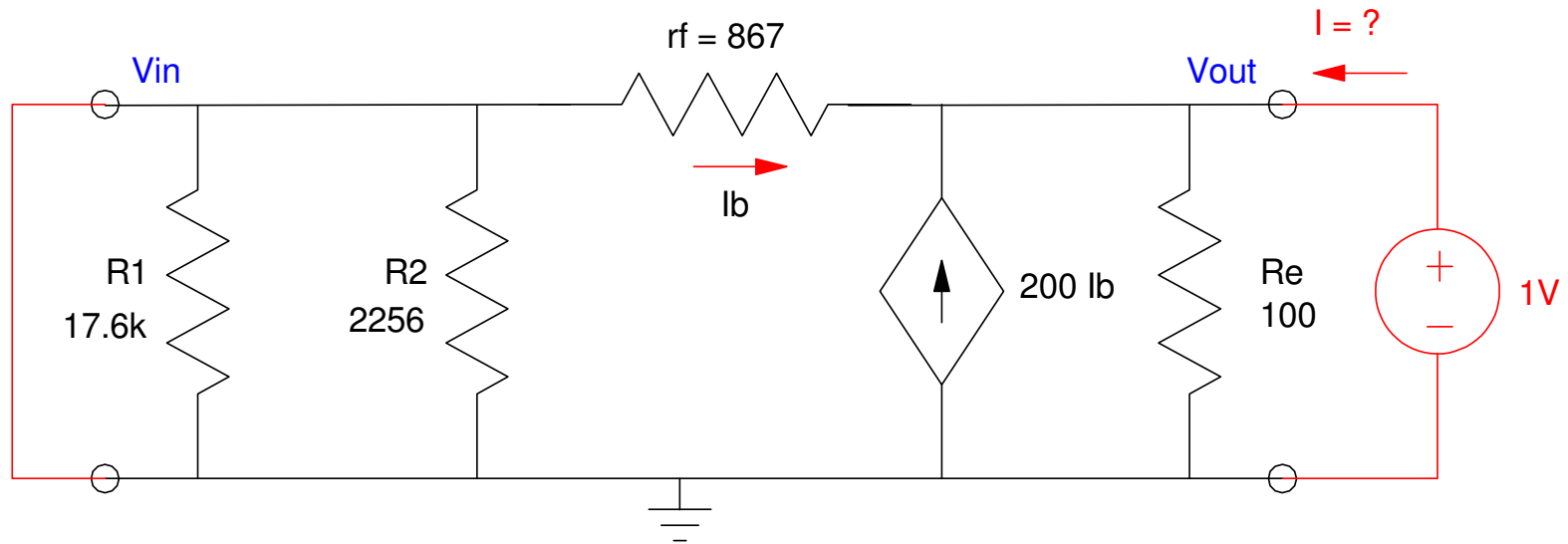
Rout: Set $V_{in} = 0V$

- Apply 1V to V_{out} and compute the current

$$I = \frac{1}{r_f} + \frac{1}{R_e} - \beta(-I_b)$$

$$I = \frac{1}{r_f} + \frac{1}{R_e} + \frac{\beta}{r_f}$$

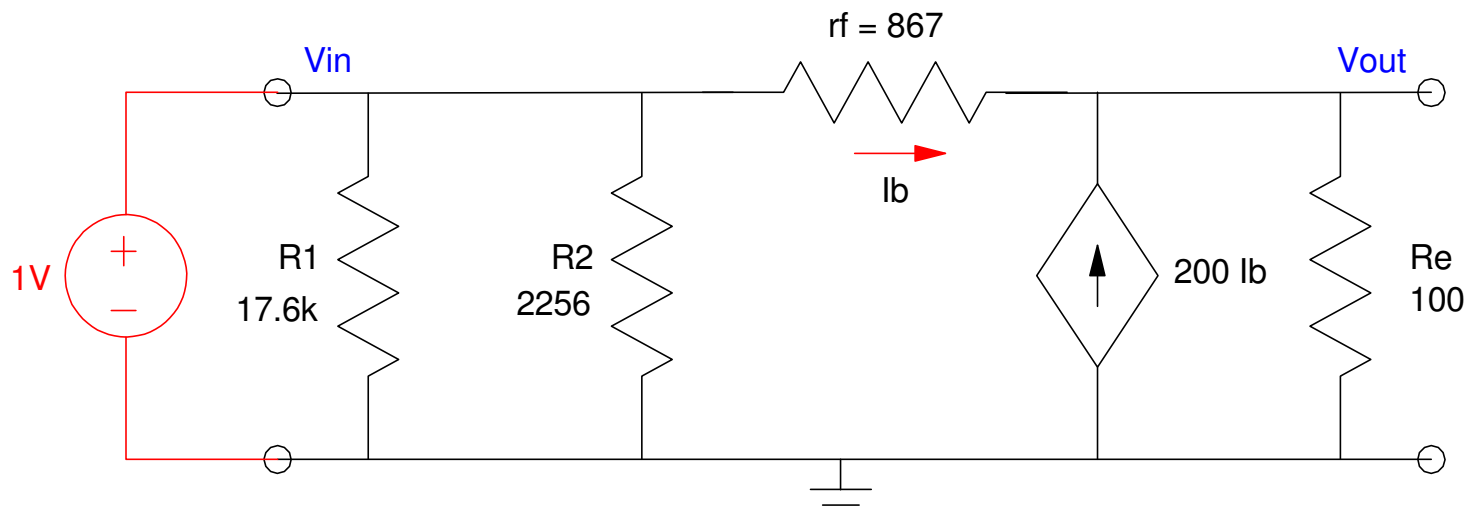
$$R_{out} = \left(\frac{1}{r_f} + \frac{1}{R_e} + \frac{\beta}{r_f} \right)^{-1} = r_f \parallel R_e \parallel \frac{r_f}{\beta} = 4.14\Omega$$



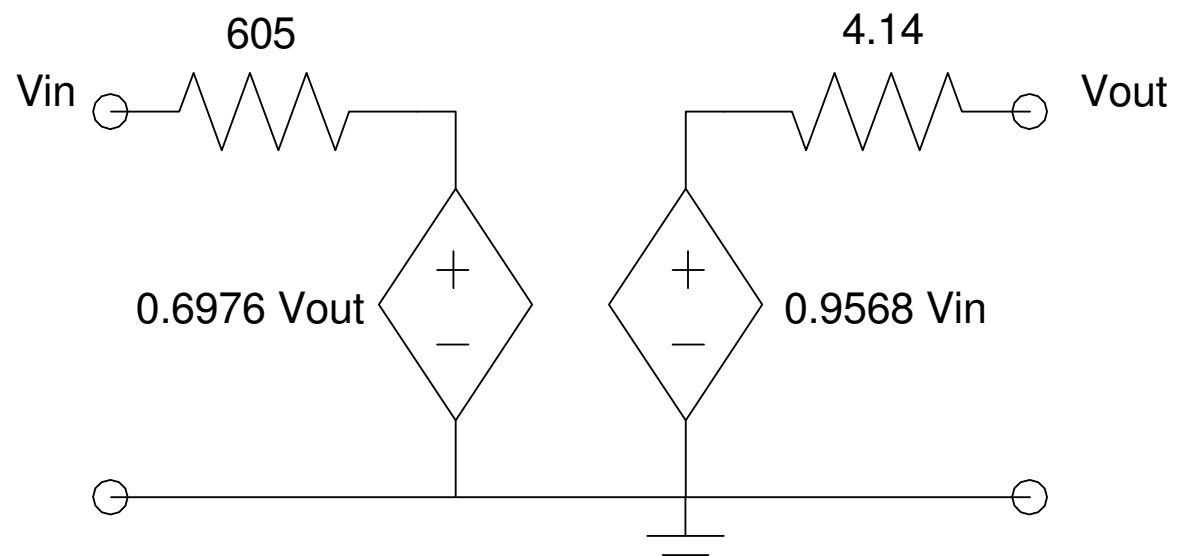
Ao: Set $V_{in} = 1V$ and measure the voltage across the output. Using voltage node analysis:

$$\left(\frac{V_o-1}{r_f}\right) + \left(\frac{V_o}{R_e}\right) + 200\left(\frac{V_o-1}{r_f}\right) = 0$$

$$V_o = \left(\frac{\frac{201}{r_f}}{\frac{201}{r_f} + \frac{1}{R_e}}\right) = 0.9568$$



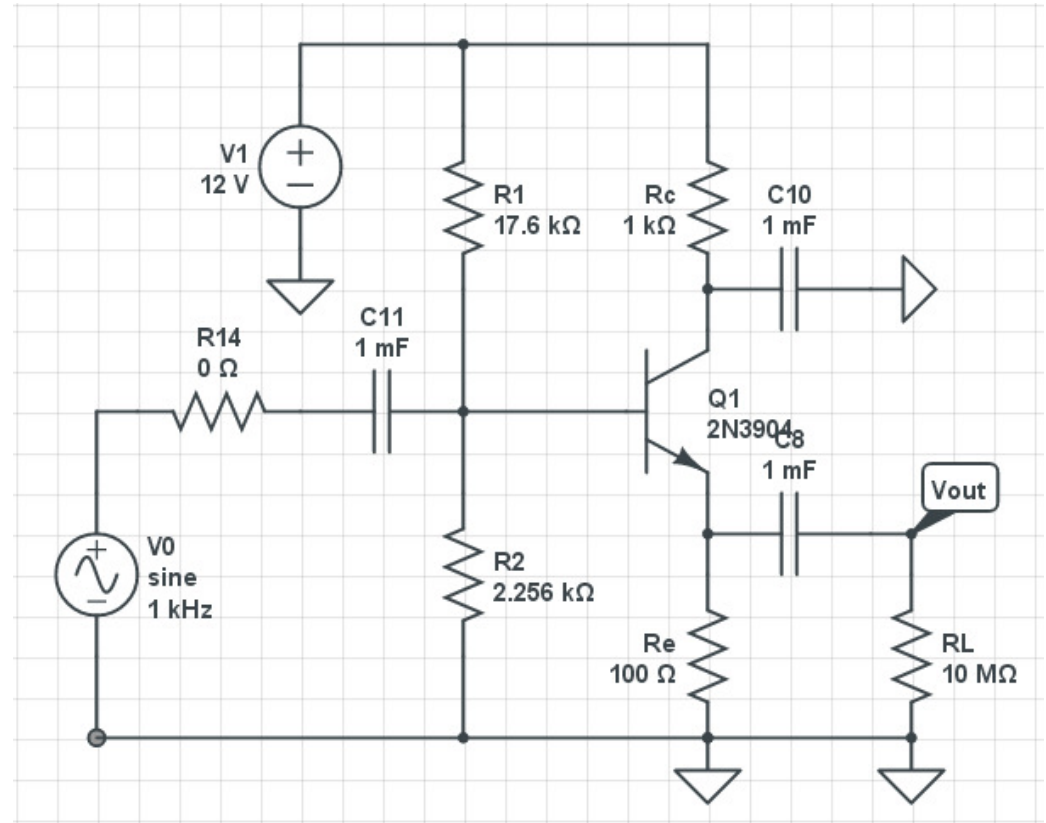
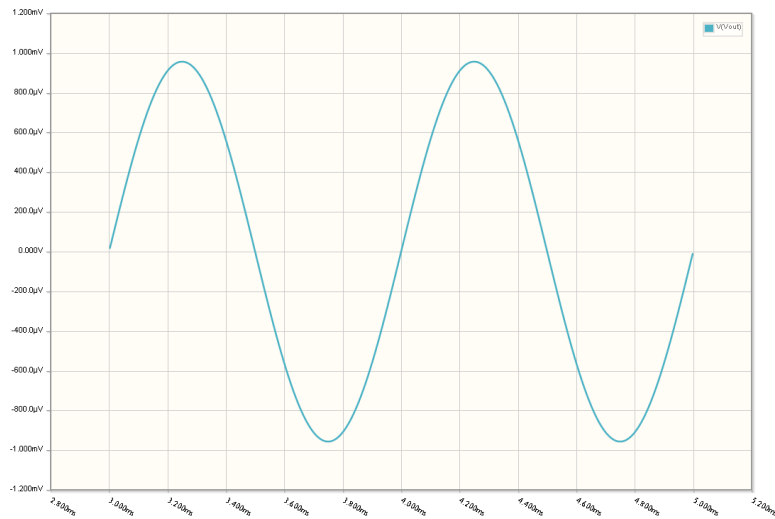
Result: CC Amplifier



Experimental Results: CC Amp

A_o

- Set $V_{in} = 1\text{mV}_p$, 1kHz sine wave
- Set $R_{14} = 0$
- Set $R_L = 10\text{M}$
- $A_o = V_o = 0.956\text{mV}$



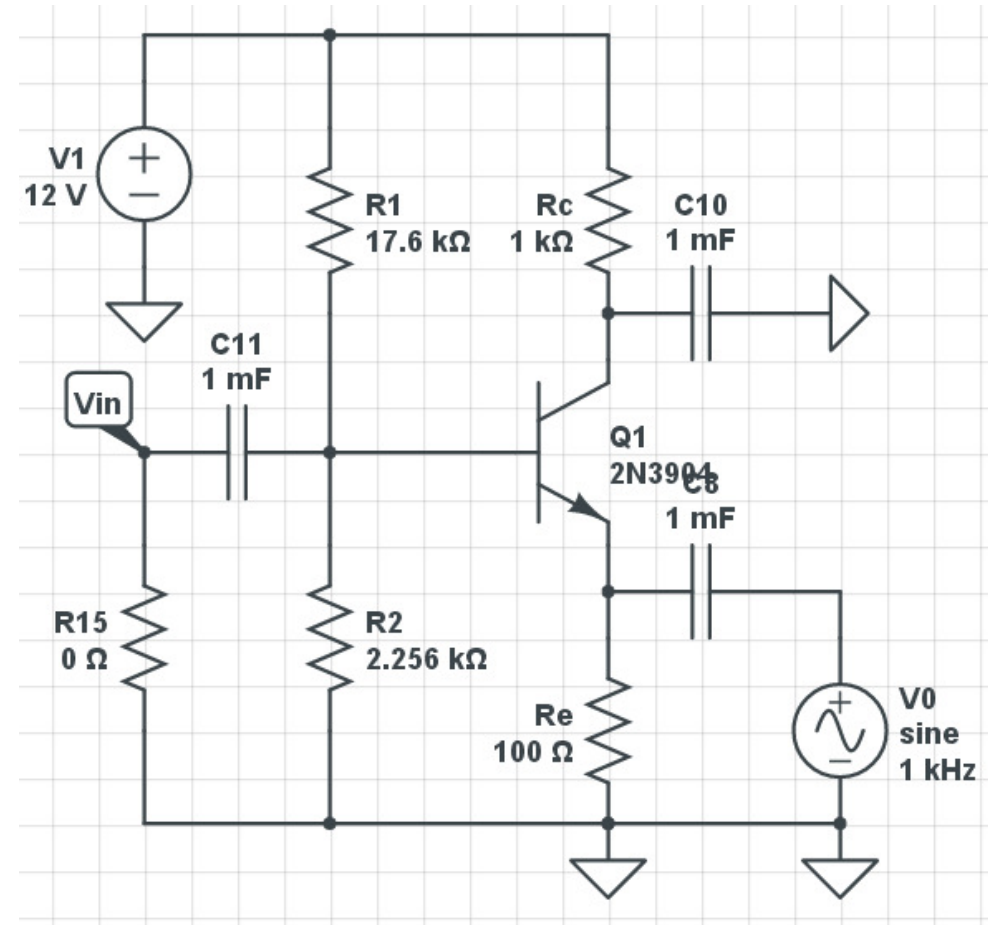
- $A_o = 0.956$ (0.9568 computed)

Rout:

- Connect V_{in} to 0V
- Apply a 1V 1kHz sine wave to V_{out}
- Measure the current, I_{out}
- $I_{out} = 227.1\mu A$

meaning

- $R_{out} = \frac{1mV}{227\mu A} = 4.41\Omega$
- Computed = 4.14 Ohms

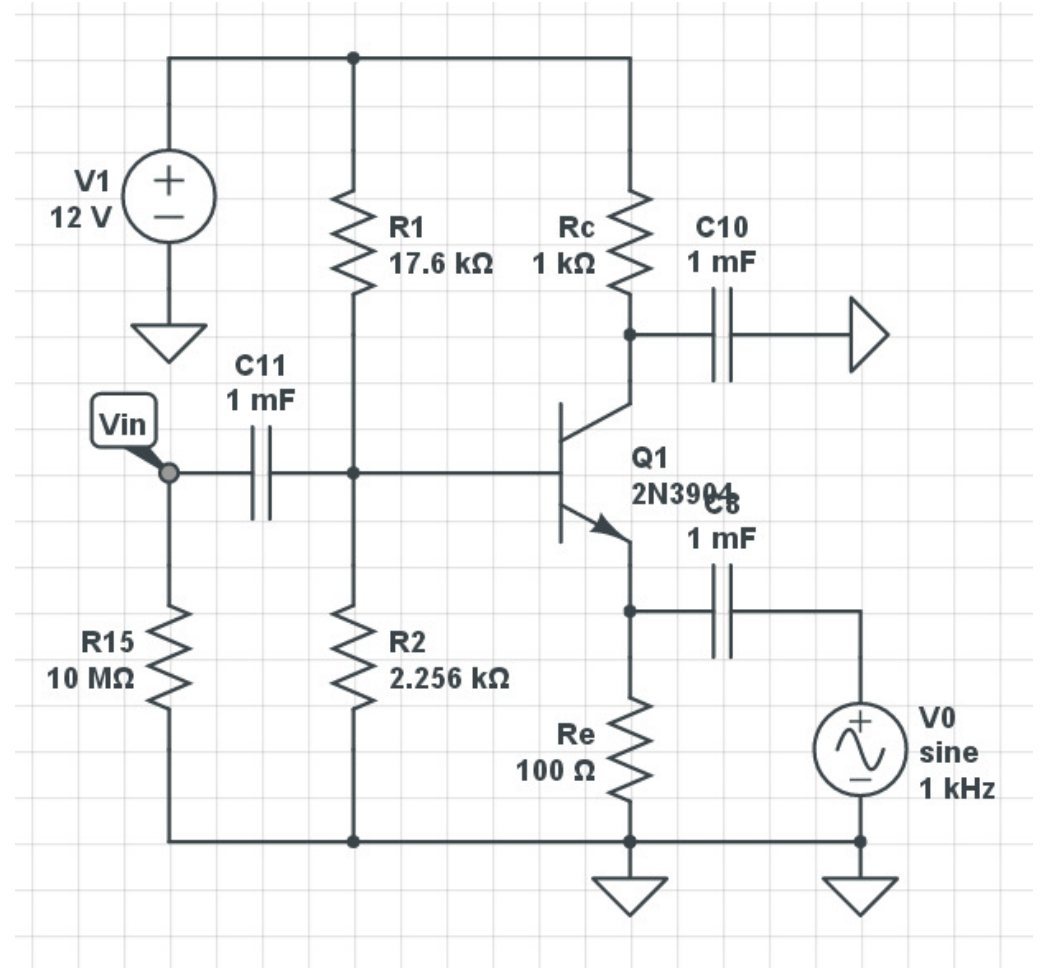


Ain

- Set $V_{out} = 1\text{mV}_p$, 1kHz sine wave
- Connect 10M Ohms to V_{in}
- Measure V_{in}

Result:

- $V_{in} = 736\mu\text{V}$
- $A_{in} = 0.736$
- (0.6976 computed)

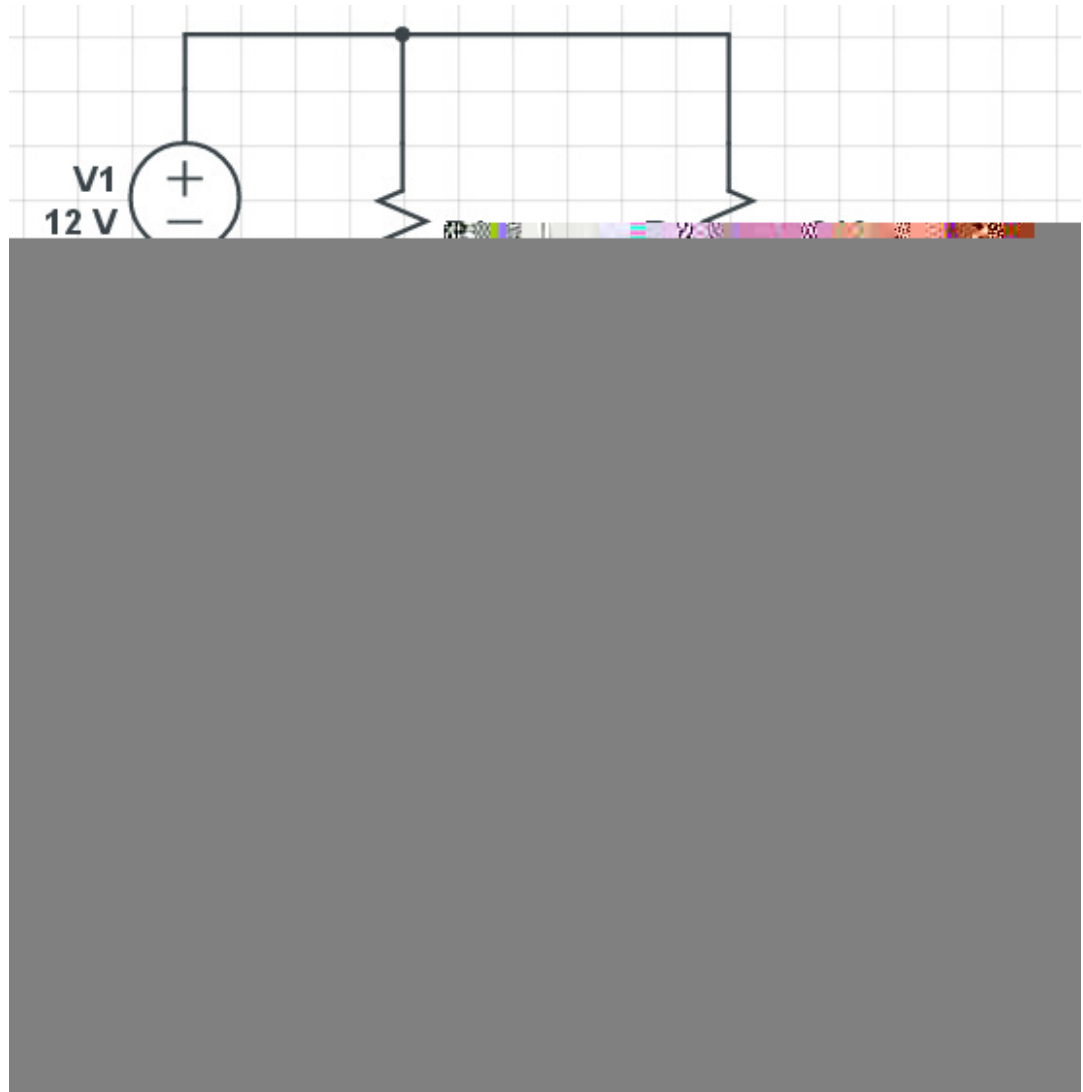


R_{in}

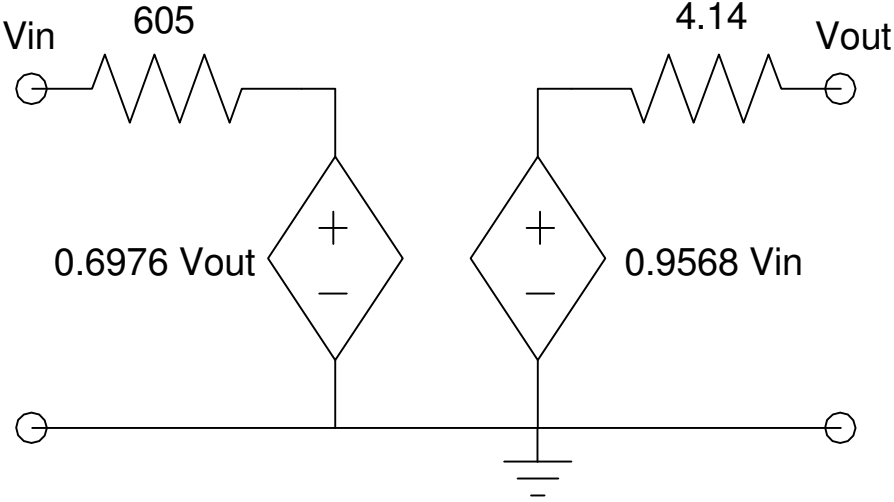
- Set V_{out} = 0V (0 Ohms)
- Apply 1mV, 1kHz to V_{in}
- Measure the current draw
- I_{cb} = 1.968μA

$$R_{in} = \frac{1mV}{1,968\mu A} = 508\Omega$$

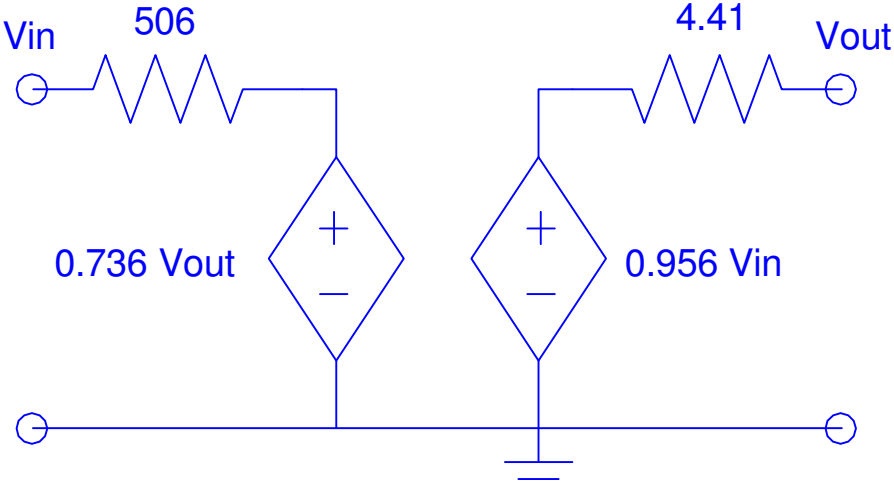
- vs 605 Ohms computed



Resulting 2-Port Model



Calculated



Experimental (CircuitLab)

Summary

By changing how you connect the transistor circuit, you can get three different amplifiers

- CE, CB, CC
- Shopping list of amplifiers you can use

Each has a different 2-port model

