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

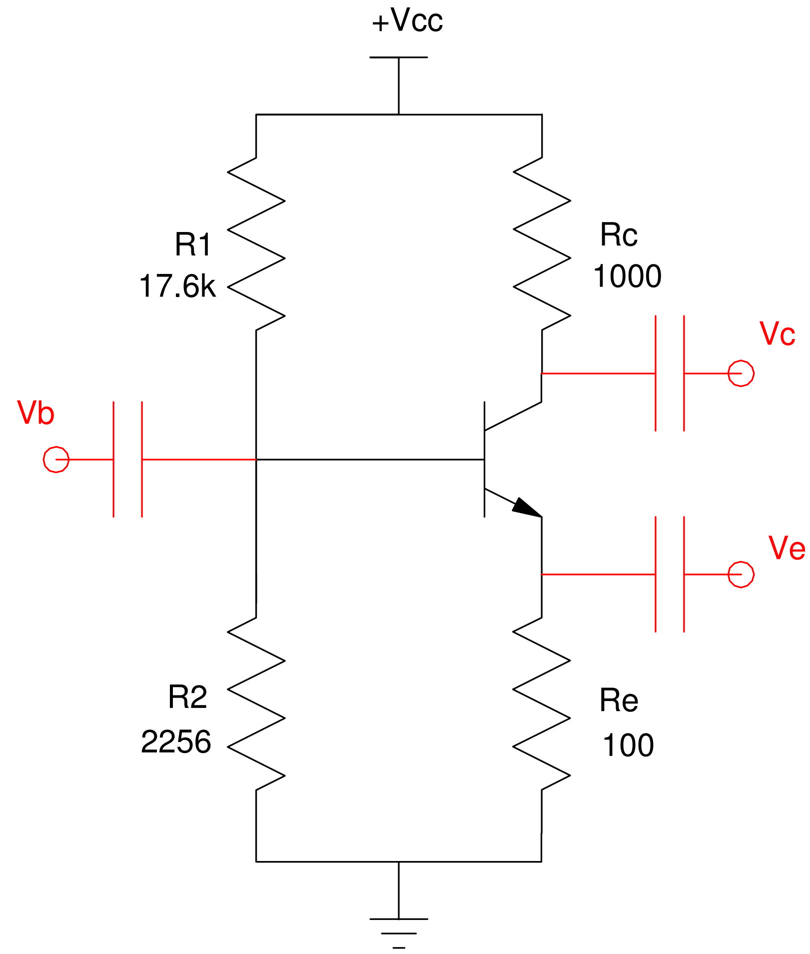
- Use Re to stabilize the Q-point
- Use R1 and R2 to set the Q-point

Assume the Q-point is

Ic = 6mA

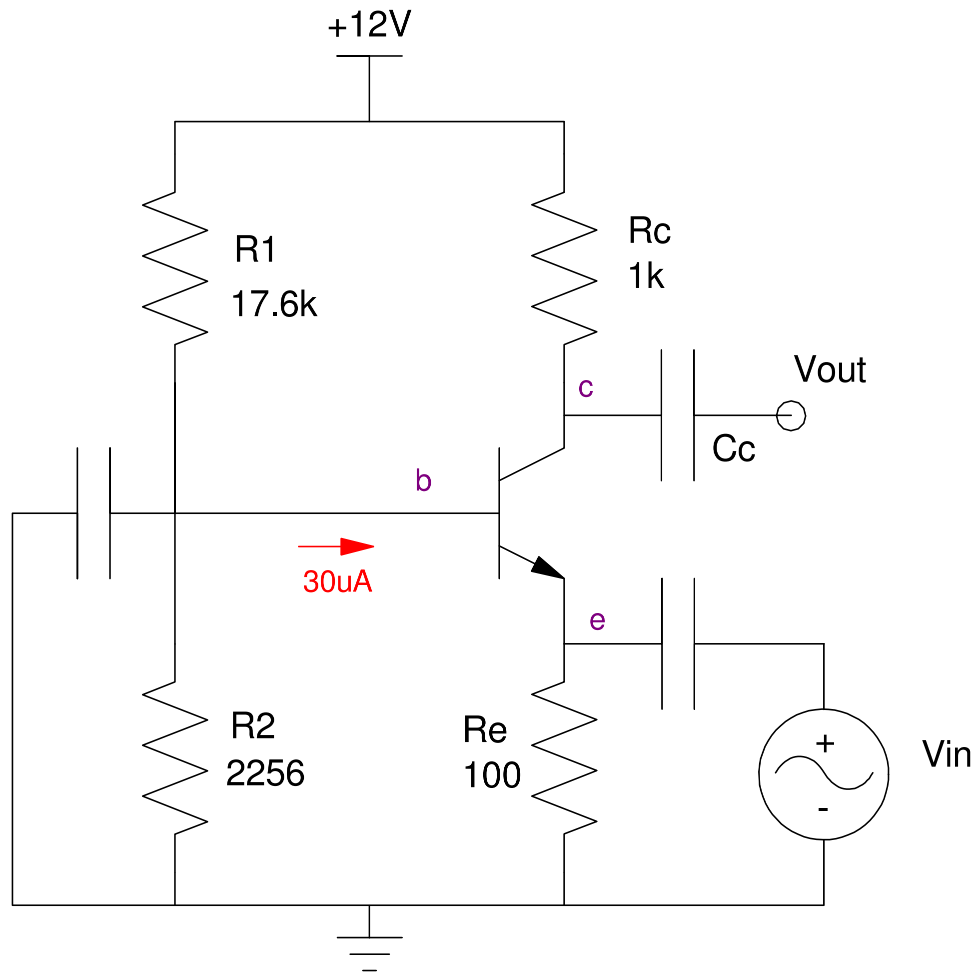
Vc = 6V

Capacitors isolate the circuit at DC



Common Base Amplifier:

- Connect the base to ground
- Connect the input to Ve
- Connect the output to Vc:



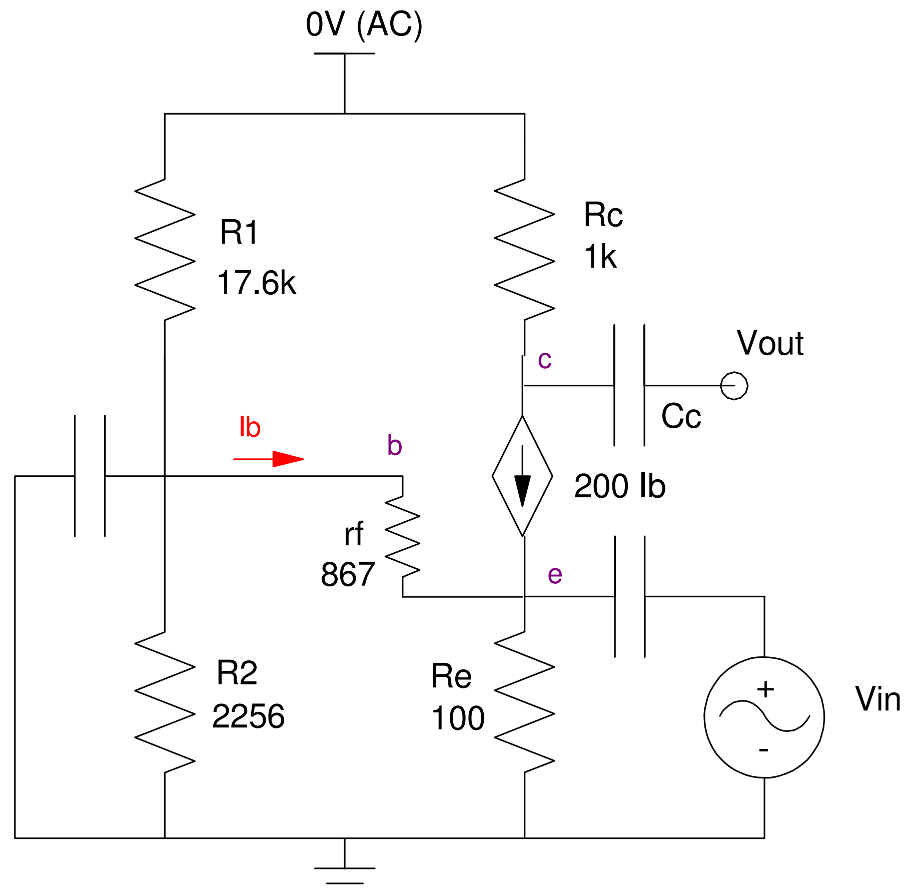
What is the 2-port model for the resulting AC circuit?

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

Small-Signal Model (AC Model)

Replace the transistor with it's AC model

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



Note:

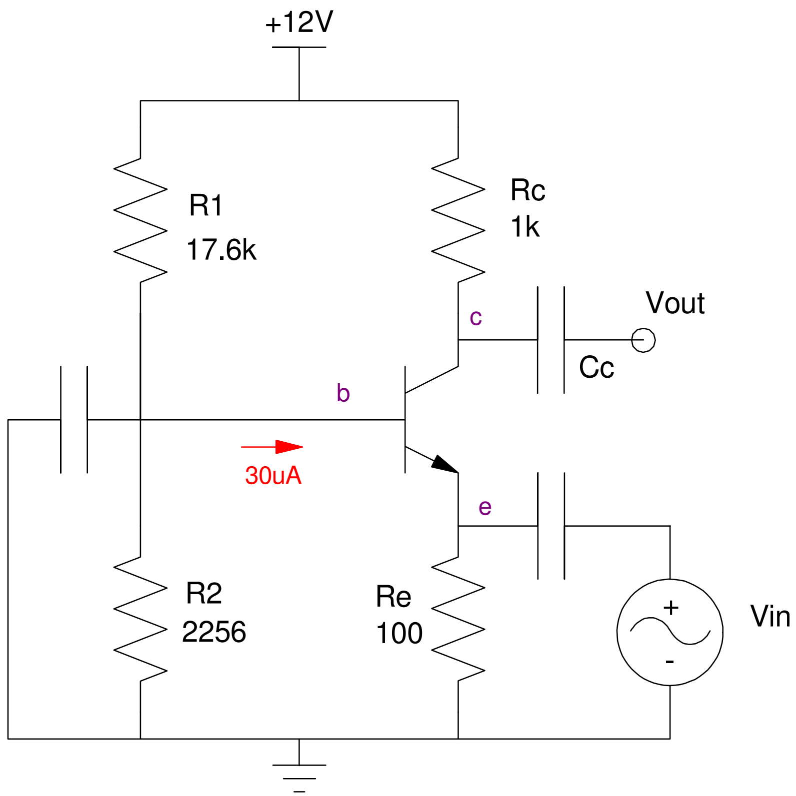
- Vcc = 12V (DC) + 0V (AC)
- This is AC analysis

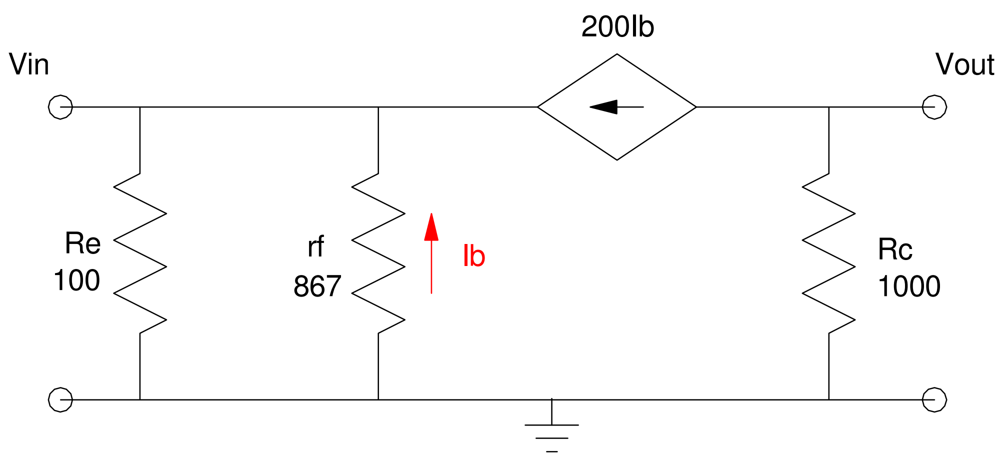
Using superposition

- V(total) = DC + AC

Redraw the circuit

- Small signal (AC) model from Vin to Vout





Find the 2-port parameters:

Rin: Set Vo = 0V and measure the input resistance.

- Apply 1V to Vin and compute Iin

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

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

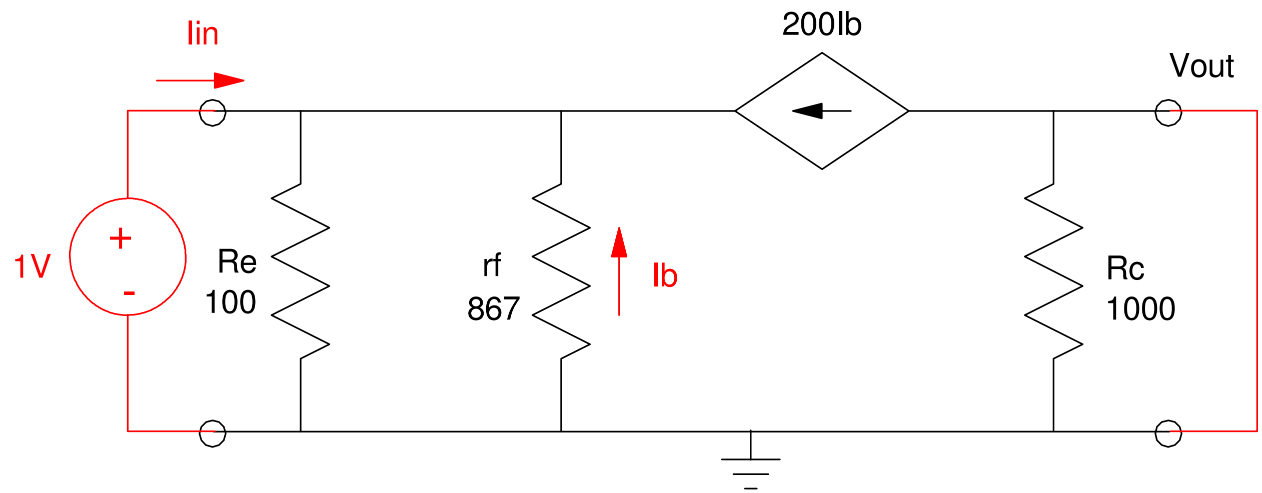
so

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

Note that this is also

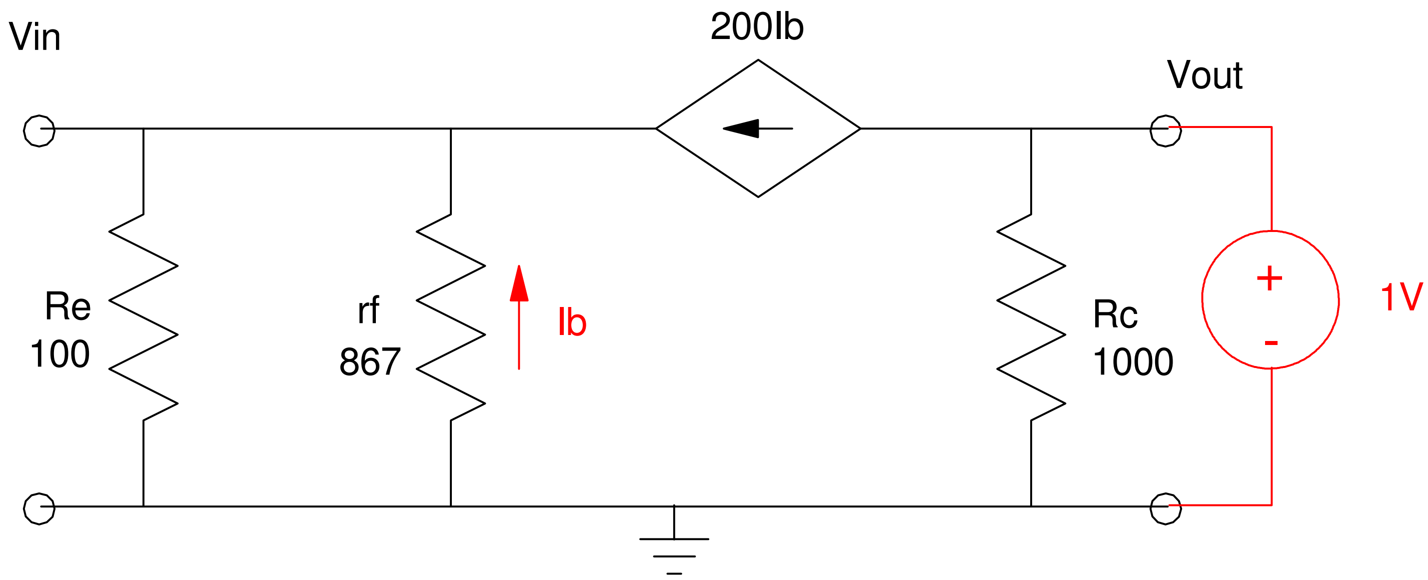
$$R_{in} = R_e || r_f || \frac{r_f}{\beta}$$

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



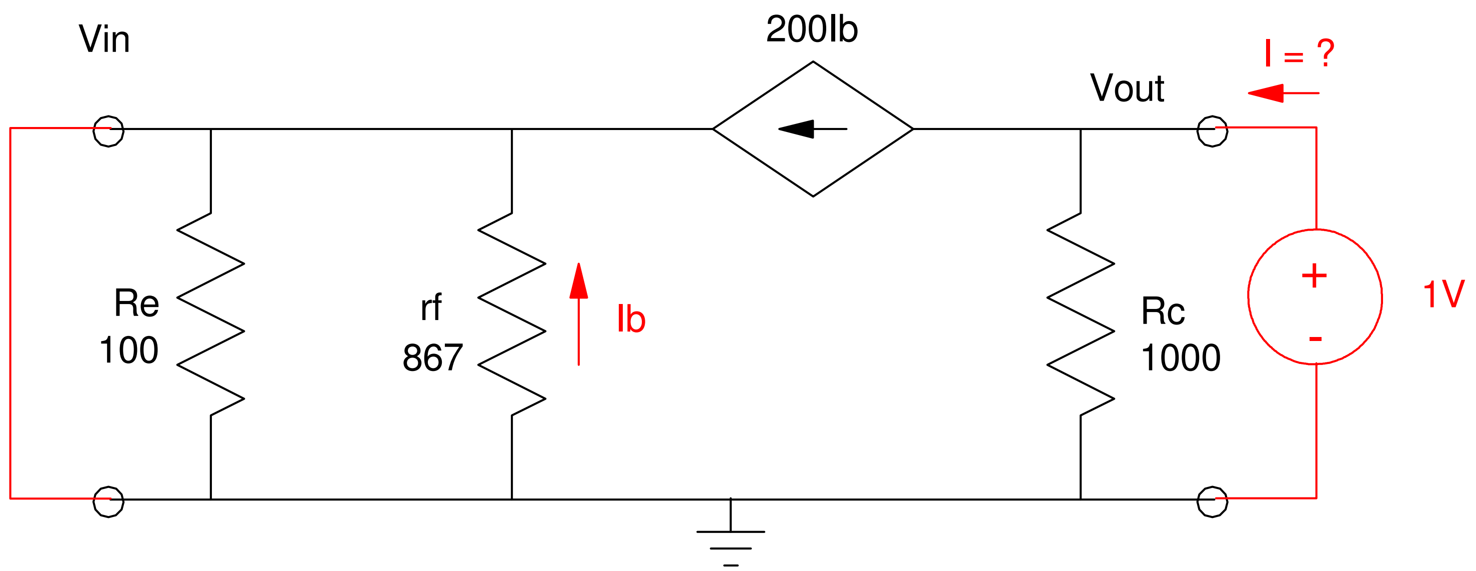
Ain: Set Vo = 1V and measure the voltage at the input.

- Vin = 0V
- Ao = 0



Rout:

- Set Vin = 0V
- Apply 1V test to Vout
- Compute I: I = 1mA
- Rout = 1/I = 1000 Ohms



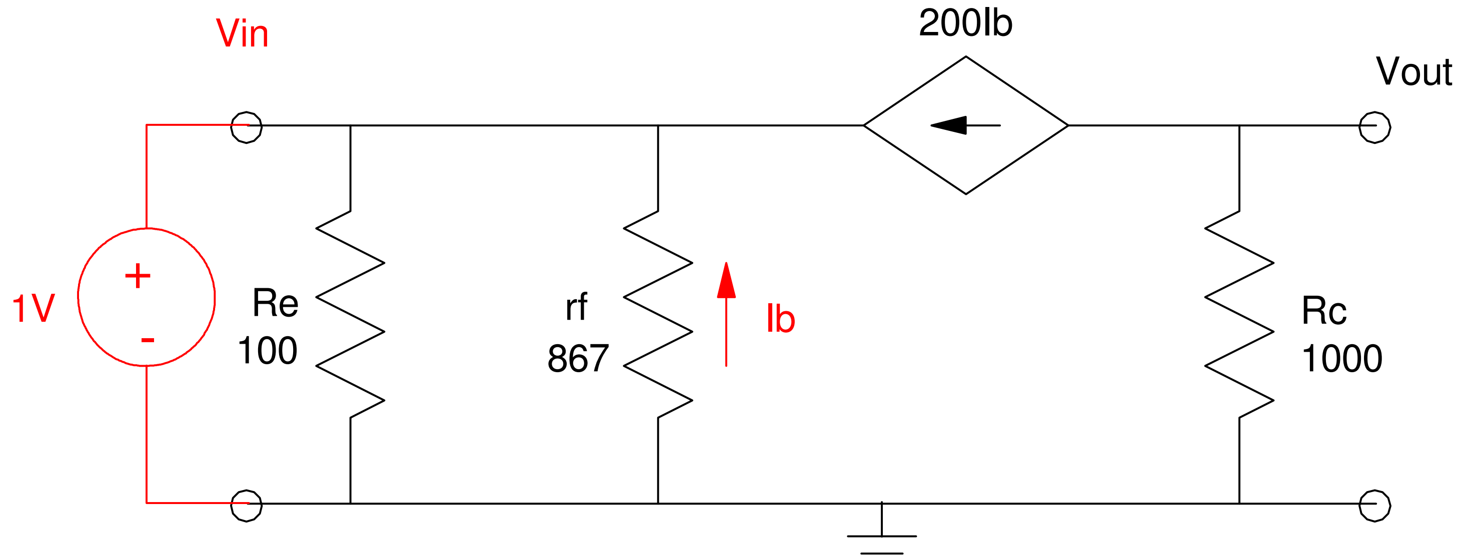
Ao: Set Vin = 1V and measure the voltage at the output.

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

$$I_c = \beta I_b$$

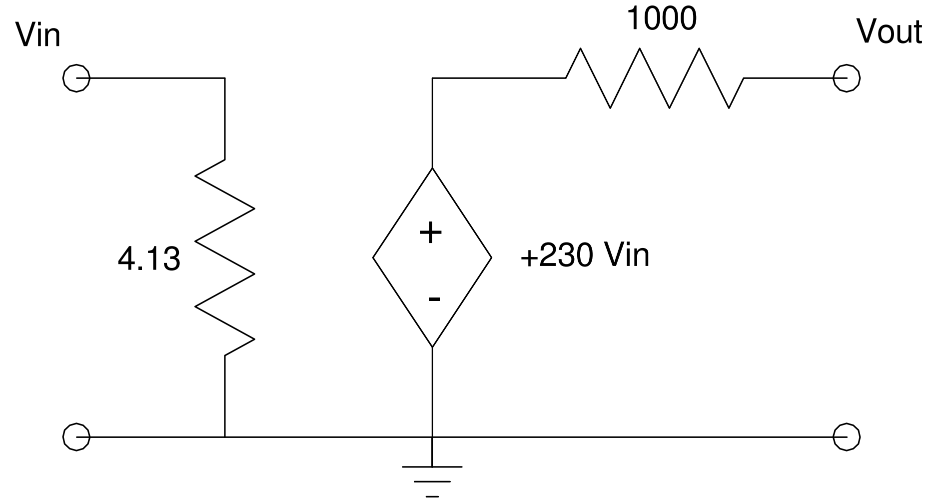
$$A_o = V_o = \frac{\beta R_c}{r_f}$$

$$A_o = +230$$



Resulting 2-Port Model

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

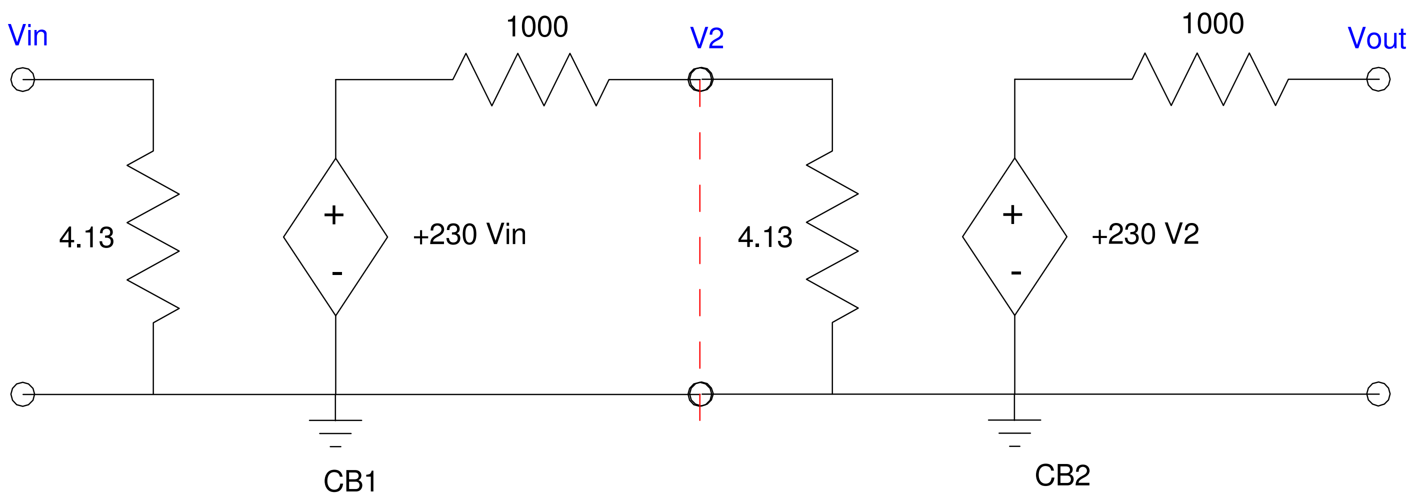


Cascading CB Amplifiers

- CB amplifiers have a low imput impedance (can be good)
- They don't work well as volage amplifiers
- Ao actually gets worse when you cascande CB amplifiers:
- Apply 1V to Vin

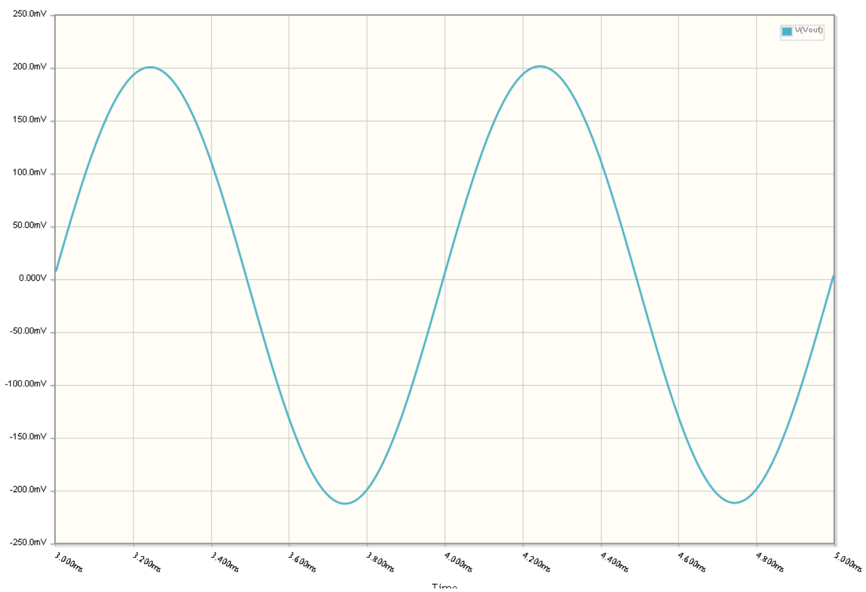
$$V_2 = \left(\frac{4.13}{4.13+1000}\right) \cdot 230V = 0.946V$$

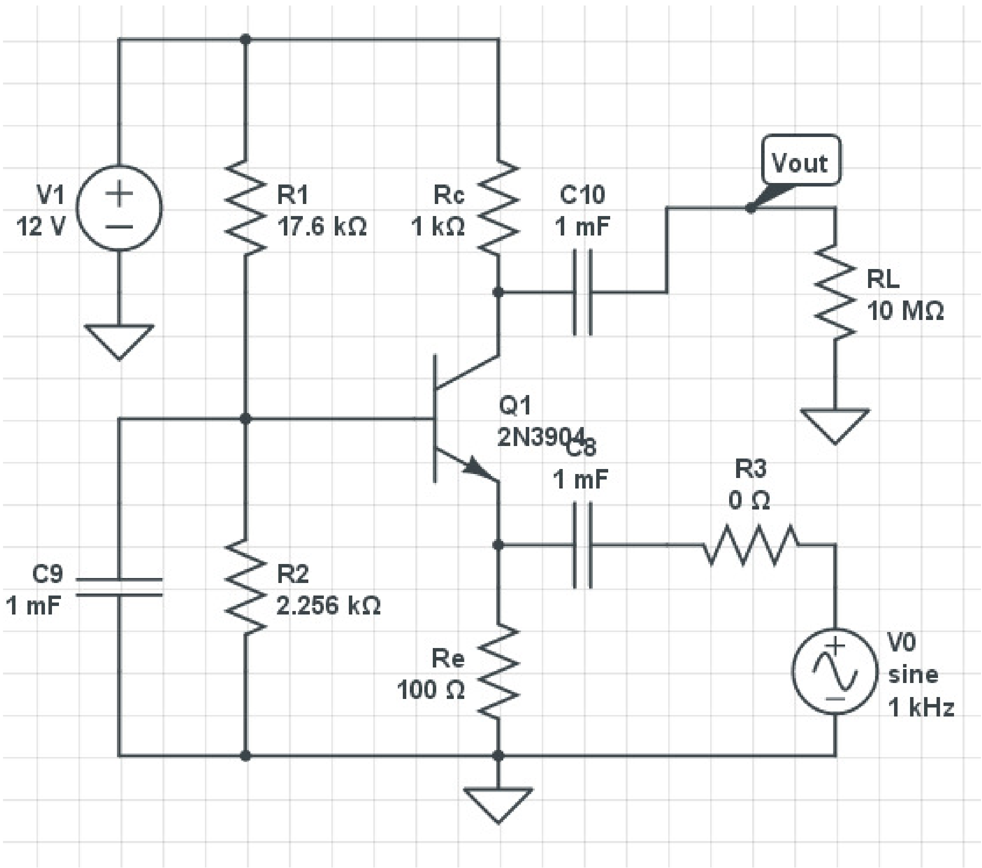
$$A_o = V_{out} = 230V_2 = 217.6$$



CircuitLab Simulation

- V0 = 1mV, 1kHz sine wave
- Vout = 200.9mV sine wave
- Ao = 200.9 (vs. 230 computed)





CircuitLab Simulation (Rin)

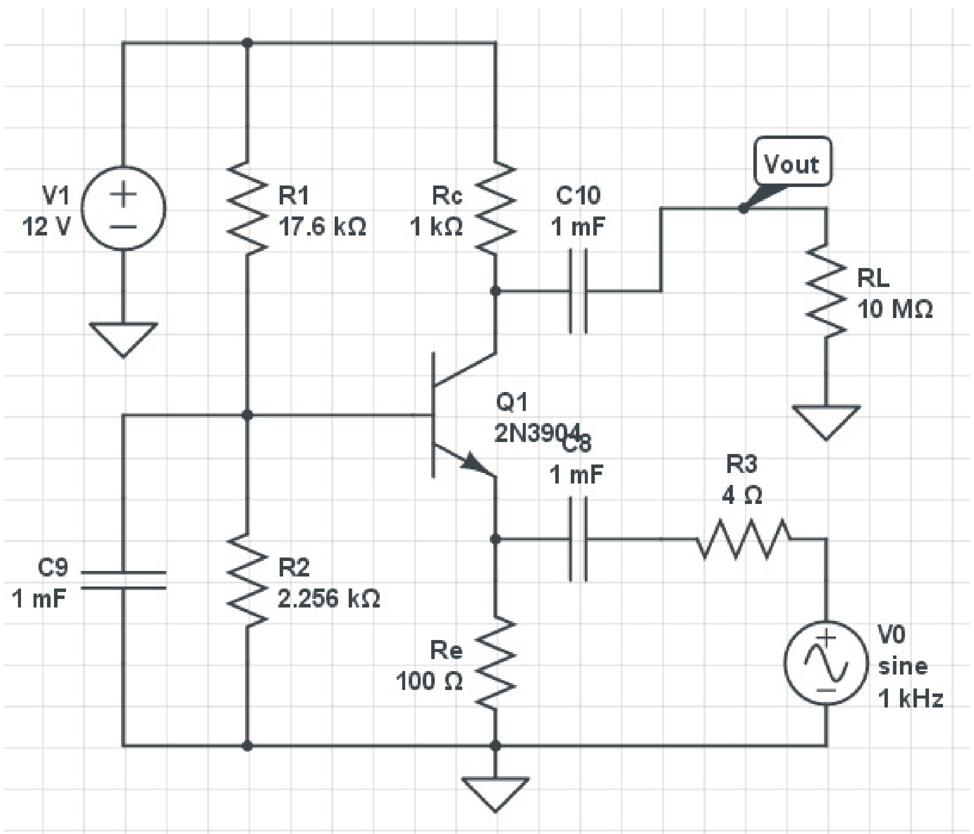
- Set R3 = 4 Ohms
- Set RL = 0 Ohms
- Mesure Vout = 108.5mV
- Comupte Rin

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

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

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

- vs. 4.13 Ohms computed



CircuitLab: Rout

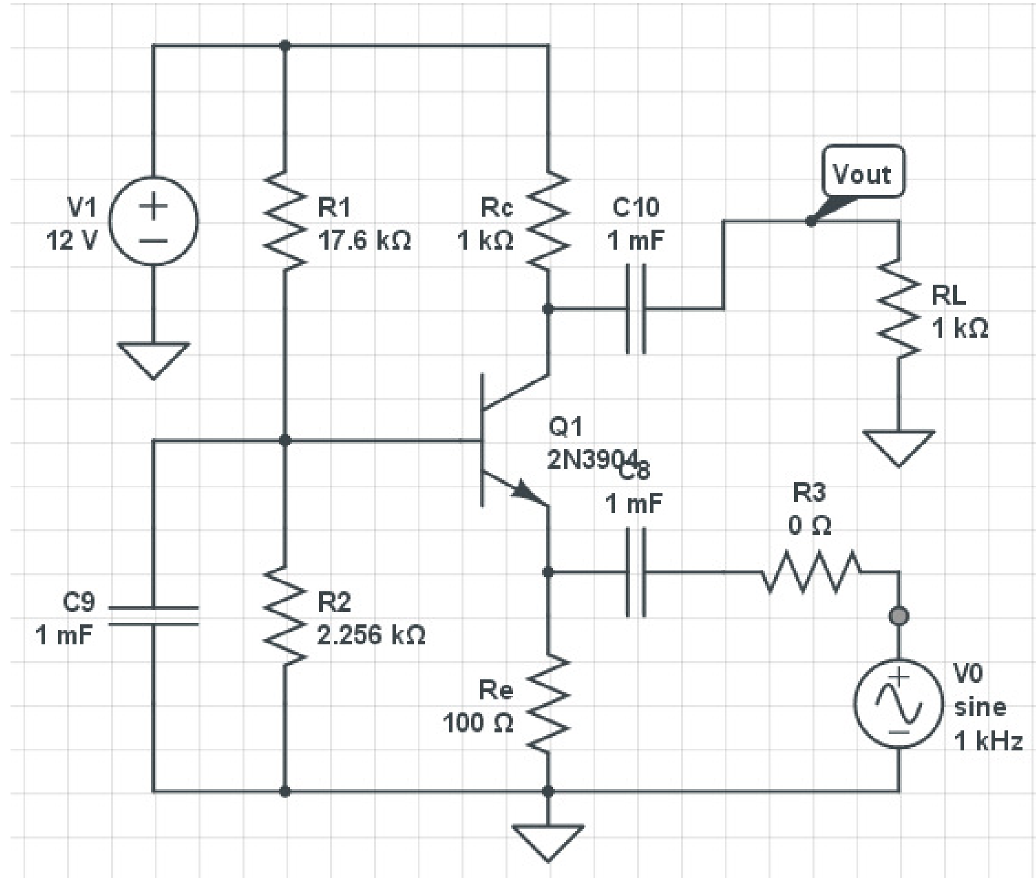
- Set R3 = 0 Ohms
- Set RL = 1000 Ohms
- Measure Vout = 104.1mV
- Compute Rout

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

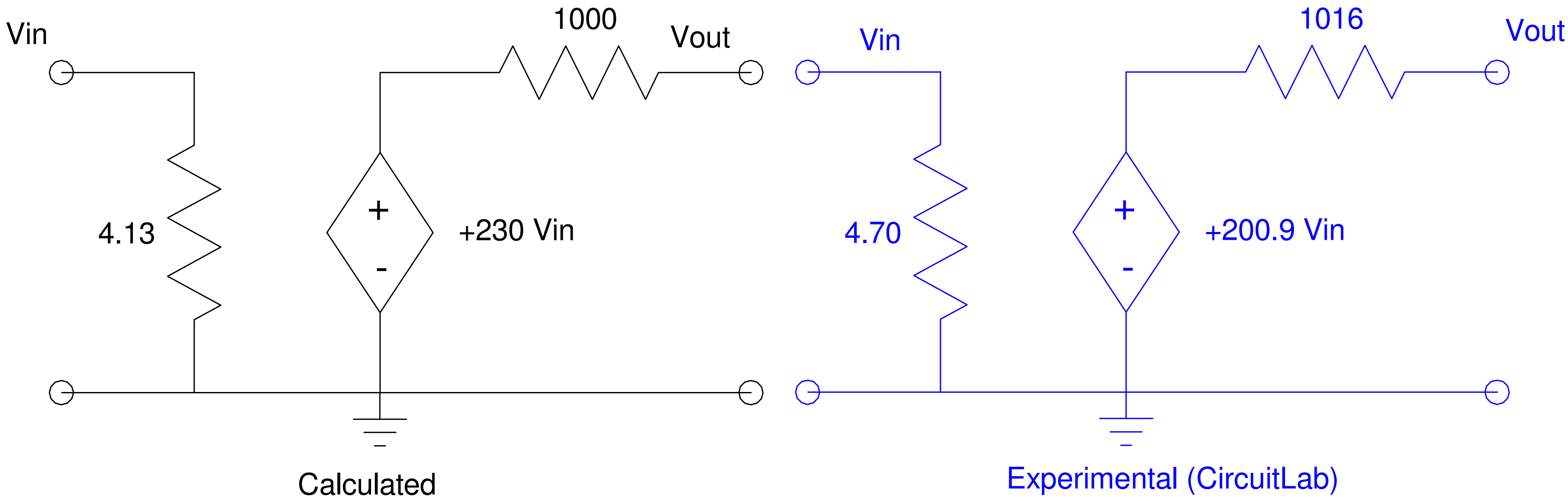
$$R_{out} = \left(\frac{209.9-104.1}{104.1}\right)1k\Omega$$

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

- vs 1000 Ohms computed

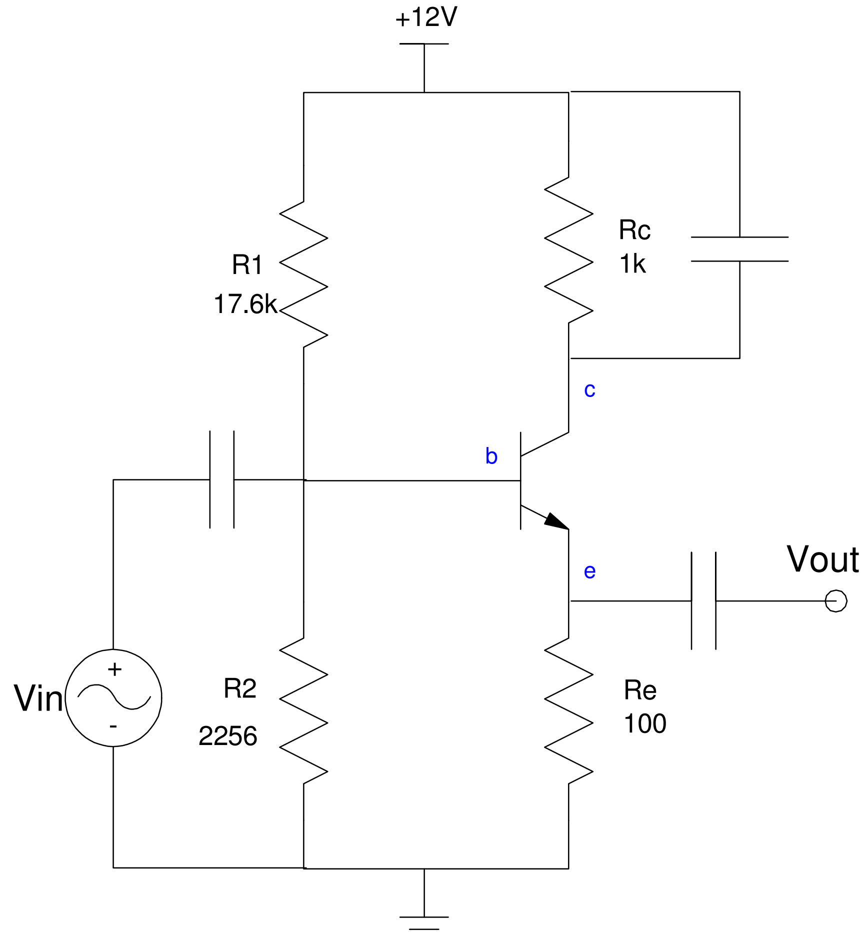


CB Amplfier: 2-Port Model (experimental)



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?

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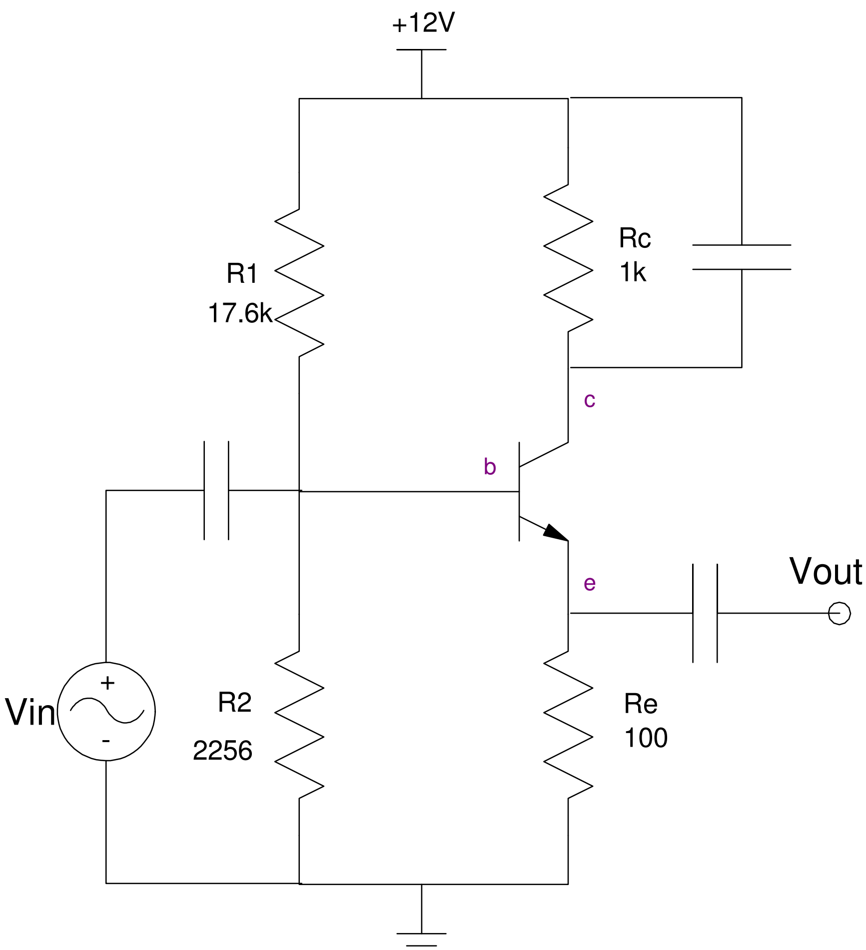
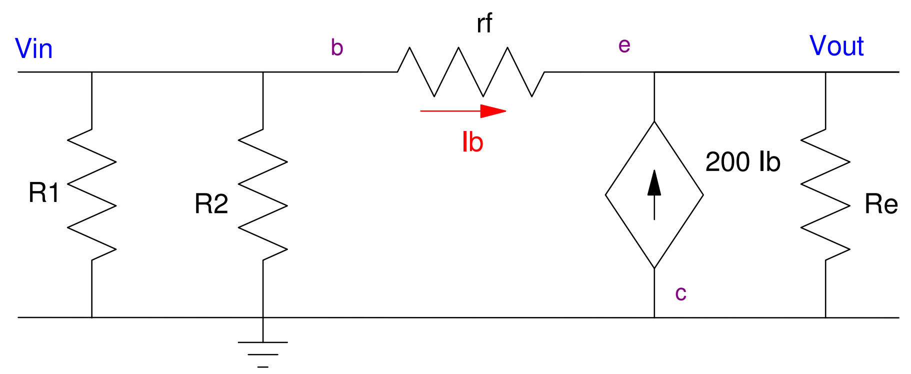
Redraw the Circuit



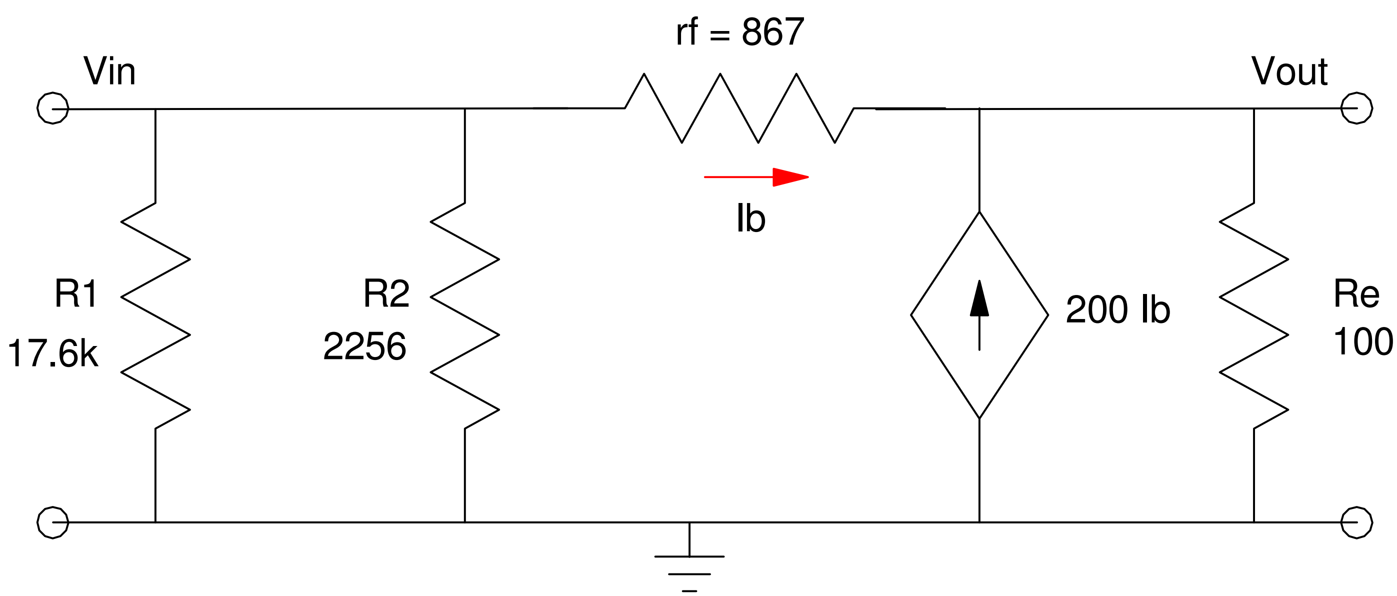


Find the 2-Port Parameters

Rin: Set Vo = 0V and measure the resisance at the input.

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

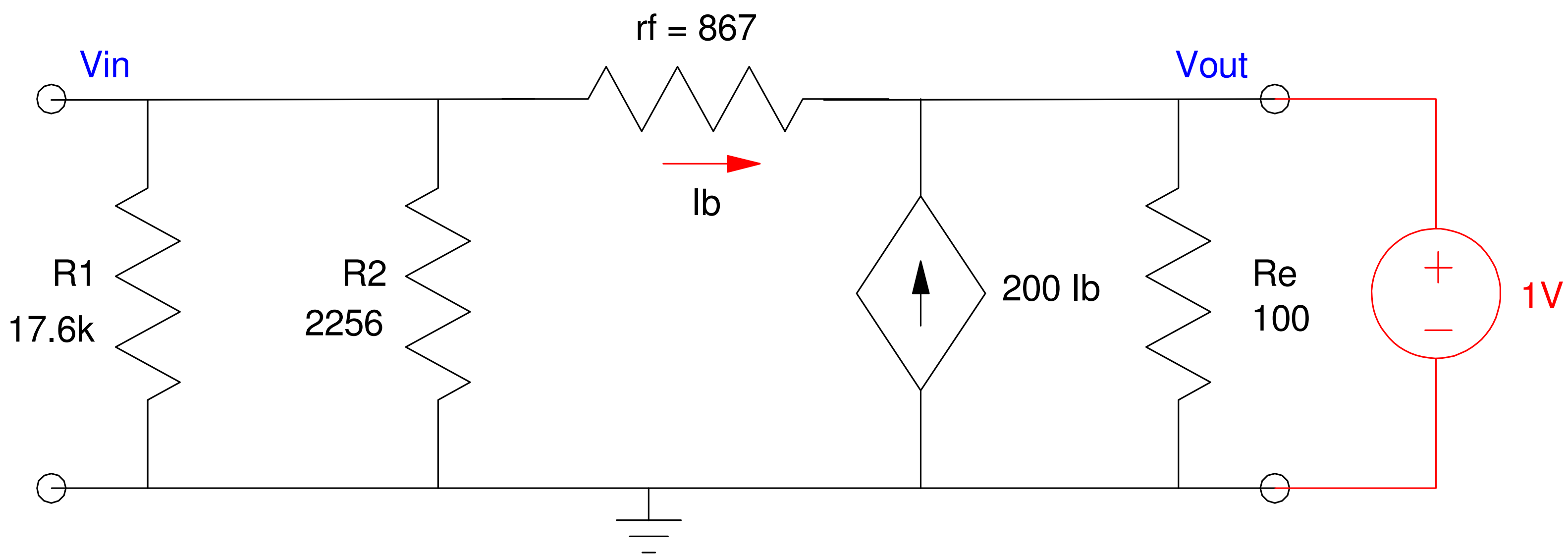
$$R_{in} = 605\Omega$$



Ain: Set Vo = 1V and measure the voltage at the input. By voltage division

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

$$A_{in} = 0.6976$$



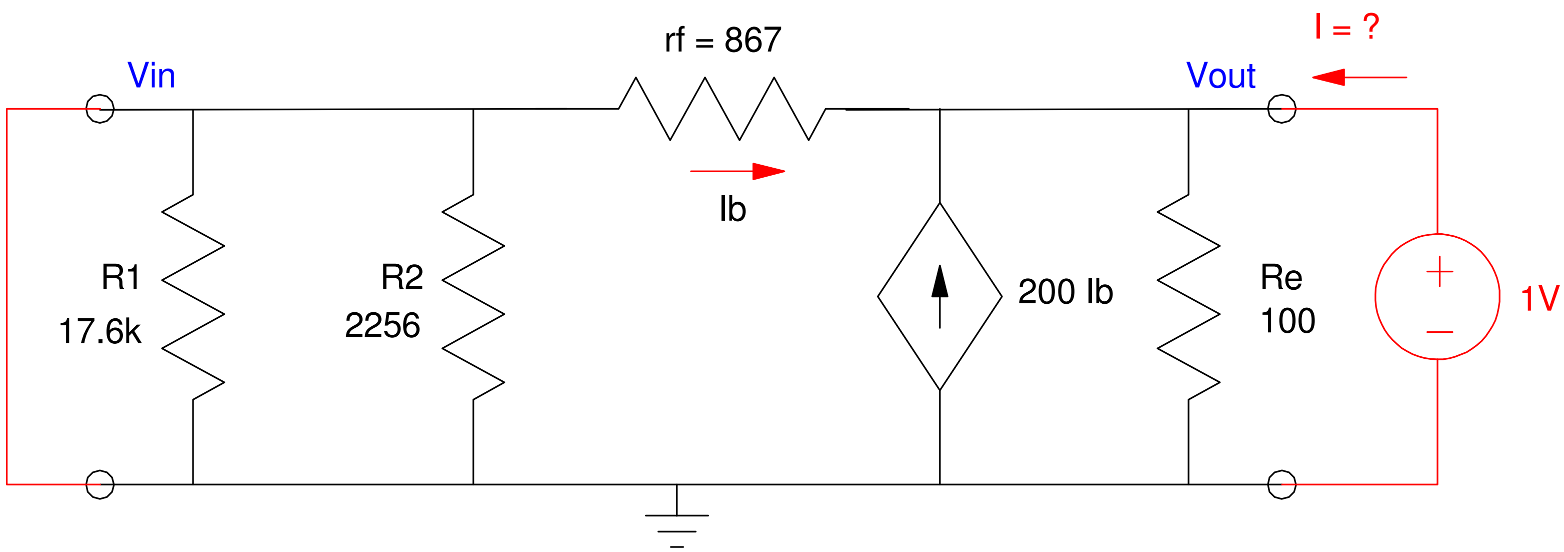
Rout: Set Vin = 0V

- Apply 1V to Vout and compute the current

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

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

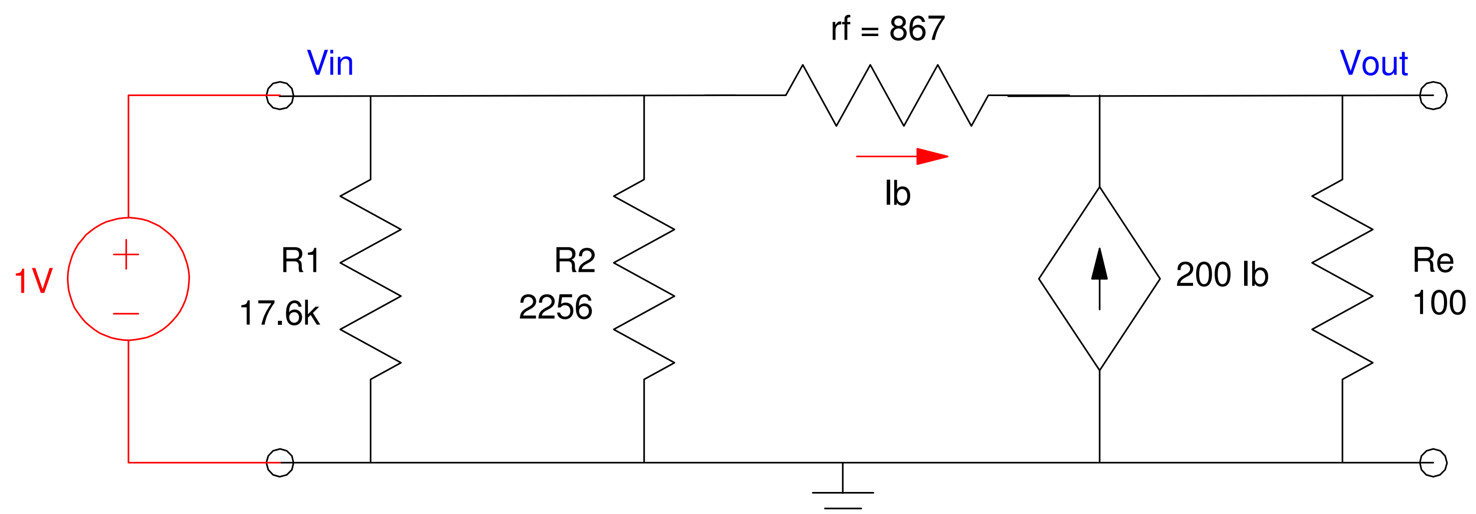
$$R_{out} = \left(\frac{1}{r_f} + \frac{1}{R_e} + \frac{\beta}{r_f}\right)^{-1} = r_f \,||\, R_e \,||\, \frac{r_f}{\beta} = 4.14\Omega$$



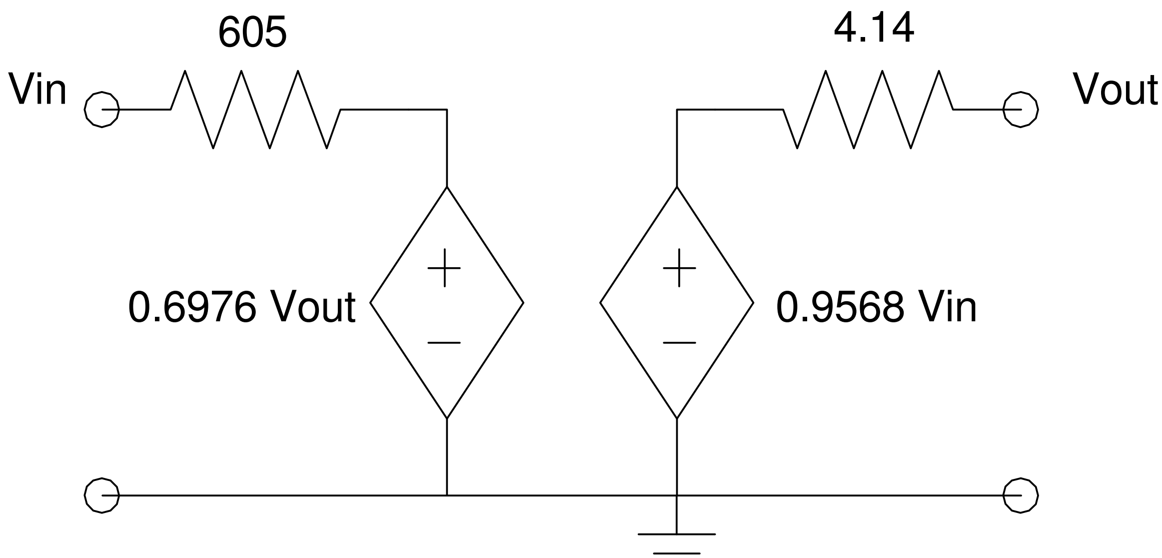
Ao: Set Vin = 1V and measure the voltage across the output. Using voltage node analysis:

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

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



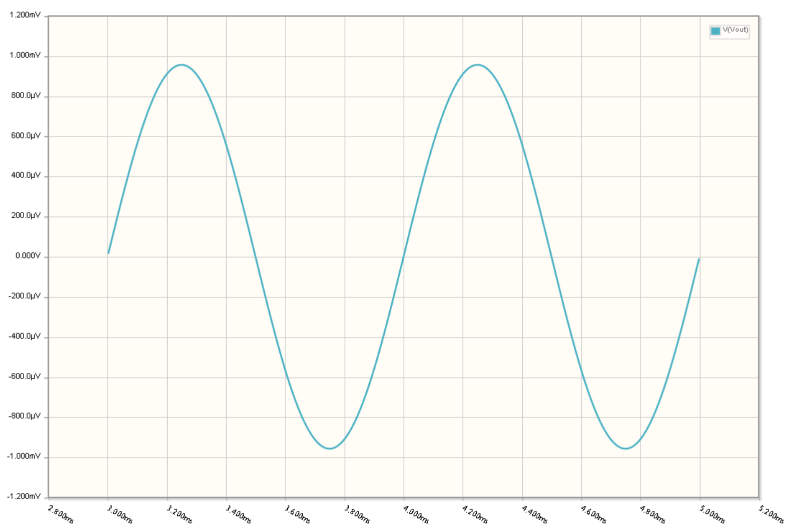
Result: CC Amplfier

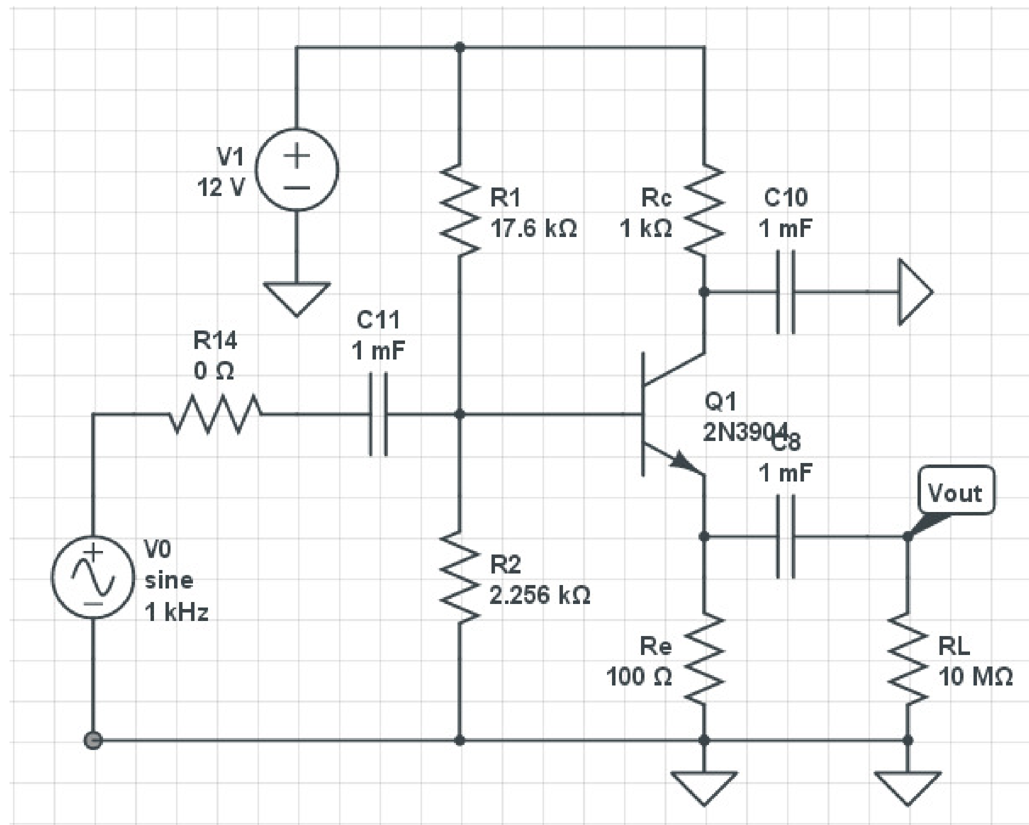


Experimental Results: CC Amp

Ao

- Set Vin = 1mVp, 1kHz sine wave
- Set R14 = 0
- Set RL = 10M
- Vo = 0.956mV
- Ao = 0.956   (0.9568 computed)



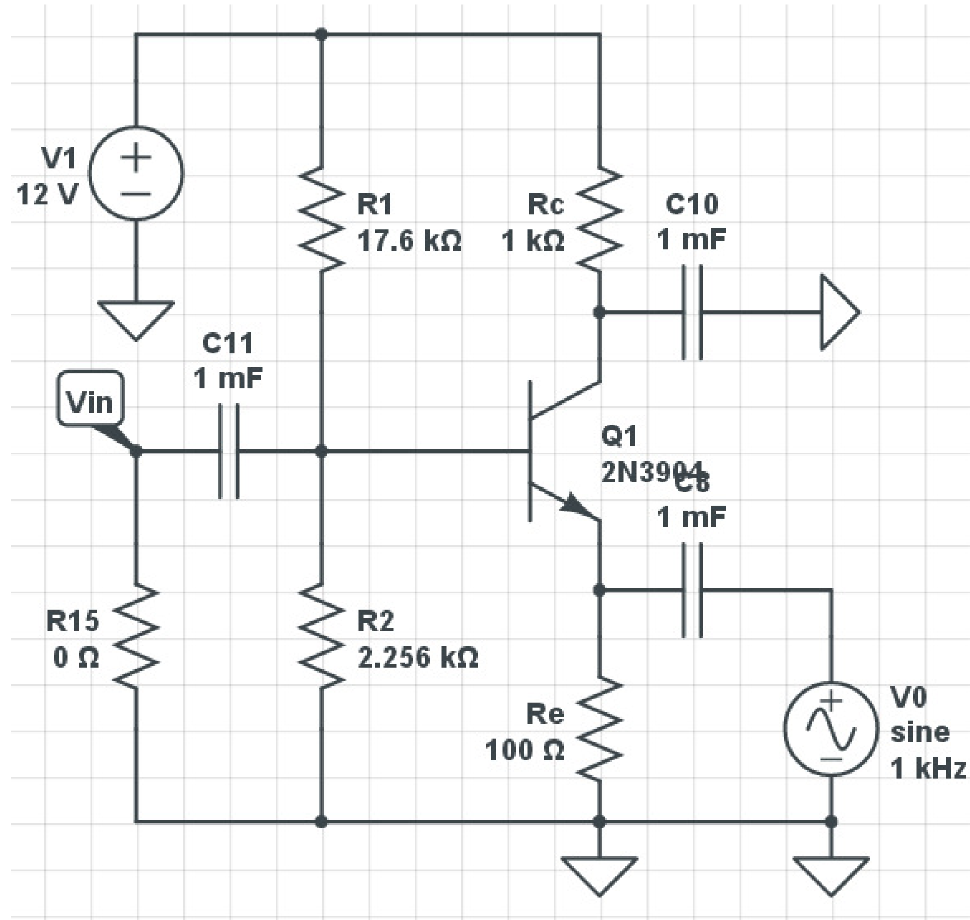


Rout:

- Connect Vin to 0V
- Apply a 1V 1kHz sine wave to Vout
- Measure the current, Iout
- Iout = 227.1uA

meaning

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

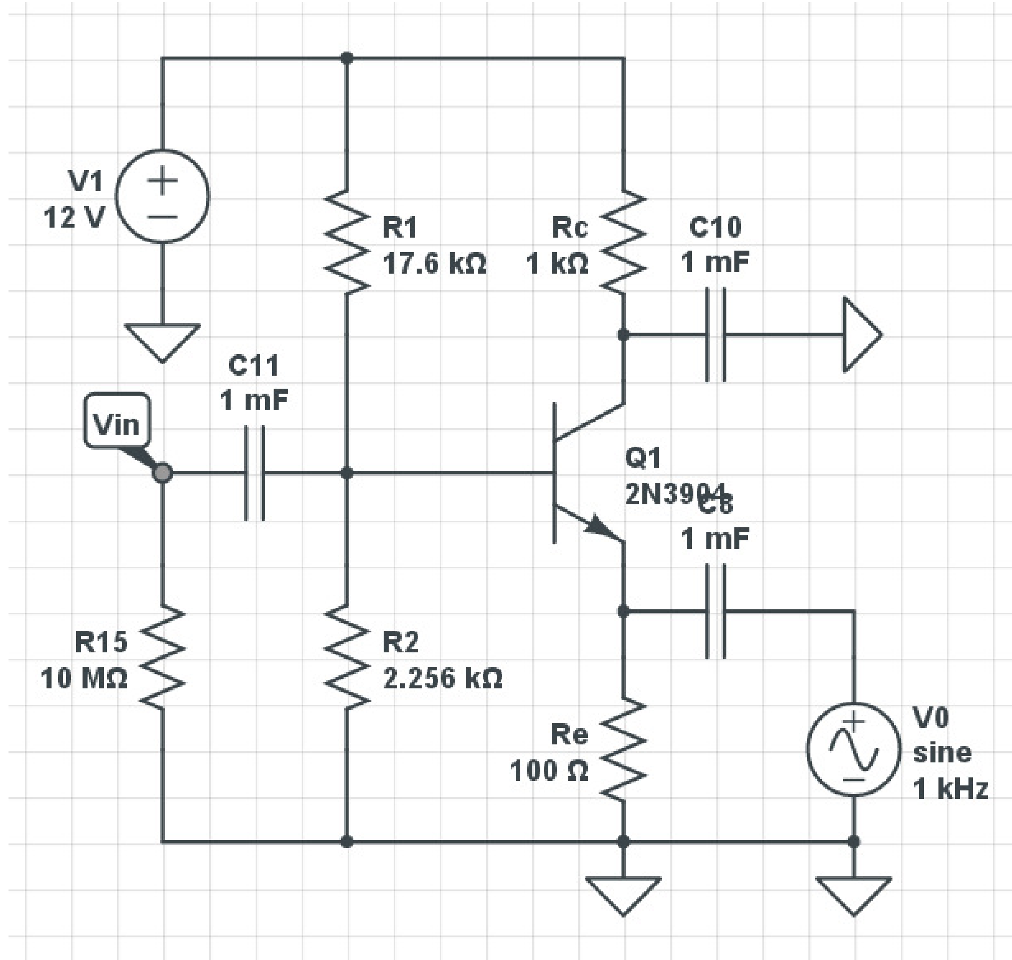


Ain

- Set Vout = 1mVp, 1kHz sine wave
- Connect 10M Ohms to Vin
- Measure Vin

Result:

- Vin = 736uV
- Ain = 0.736
- (0.6976 computed)

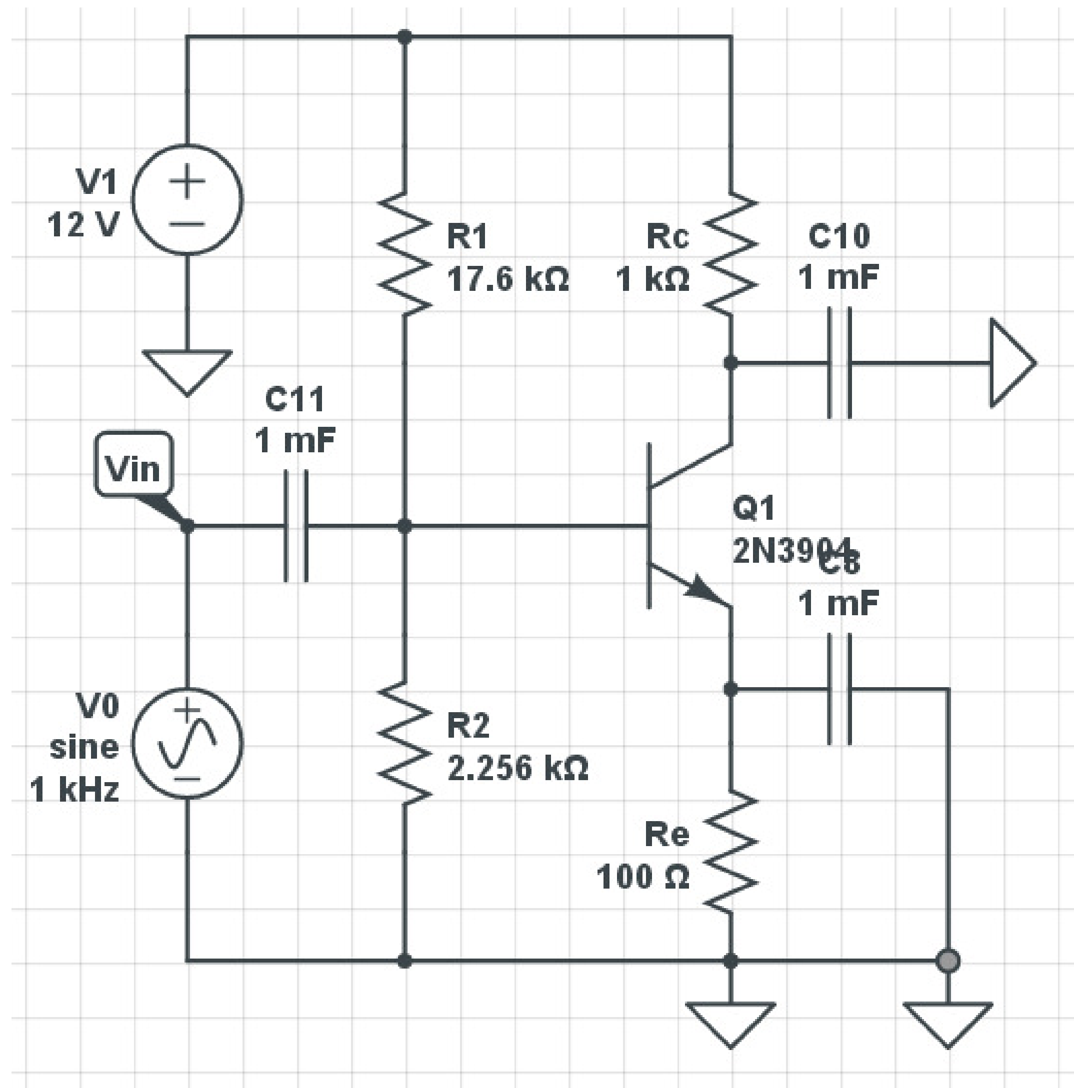


Rin

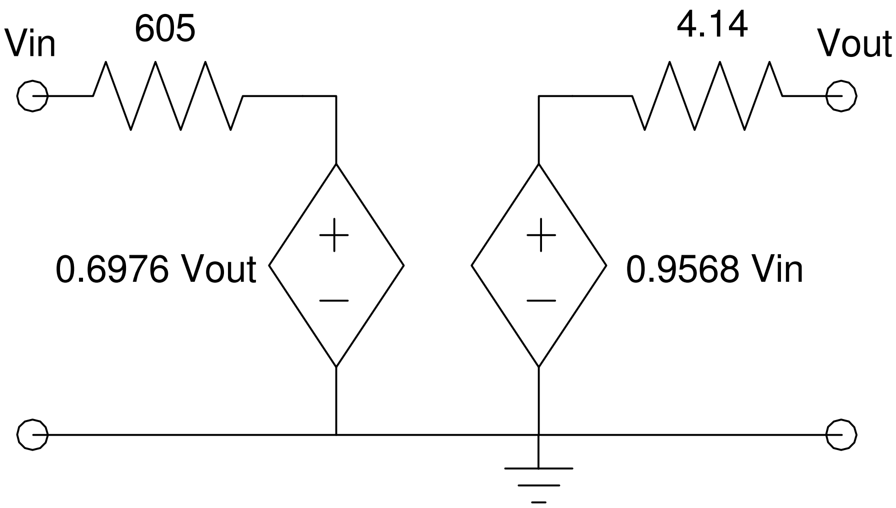
- Set Vout = 0V (0 Ohms)
- Apply 1mV, 1kHz to Vin
- Measure the current draw
- Icb = 1.968uA

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

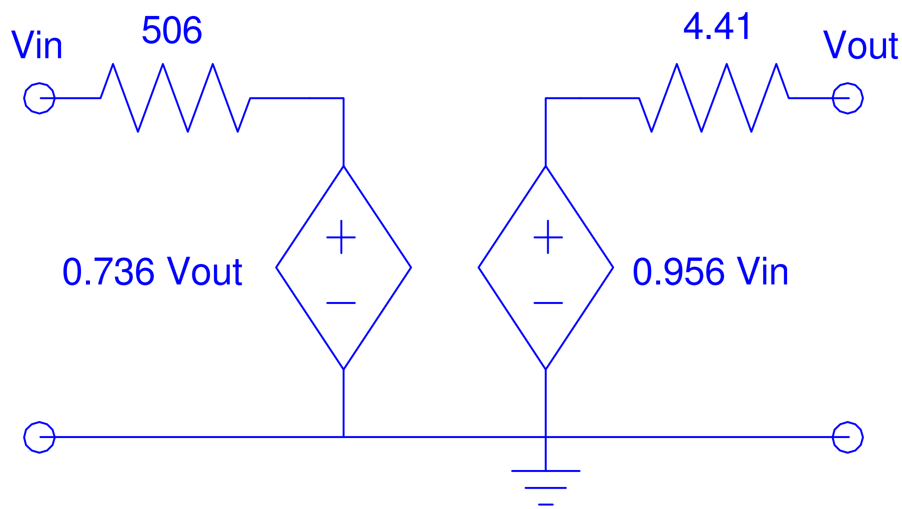
- vs 605 Ohms computed



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