
Multi-Stage Amplifiers

ECE 321: Electronics II

Lecture #16

Jake Glower

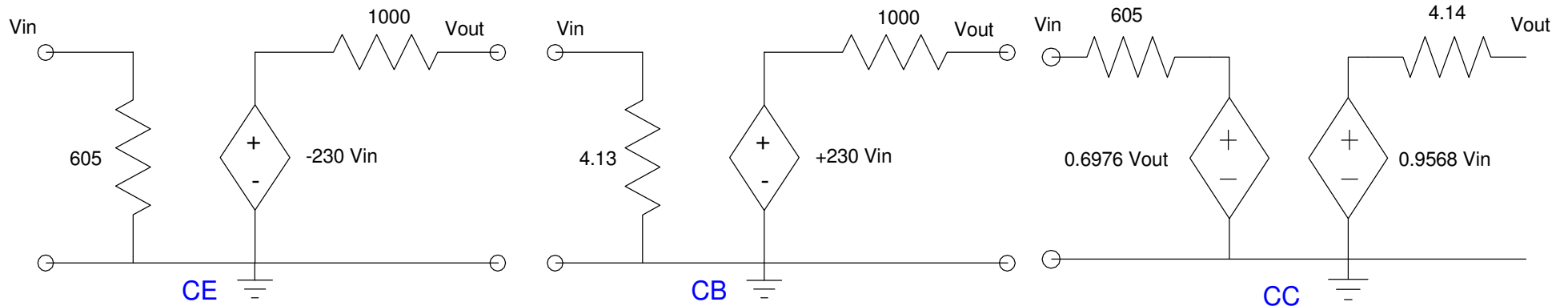
Please visit [Bison Academy](#) for corresponding
lecture notes, homework sets, and solutions



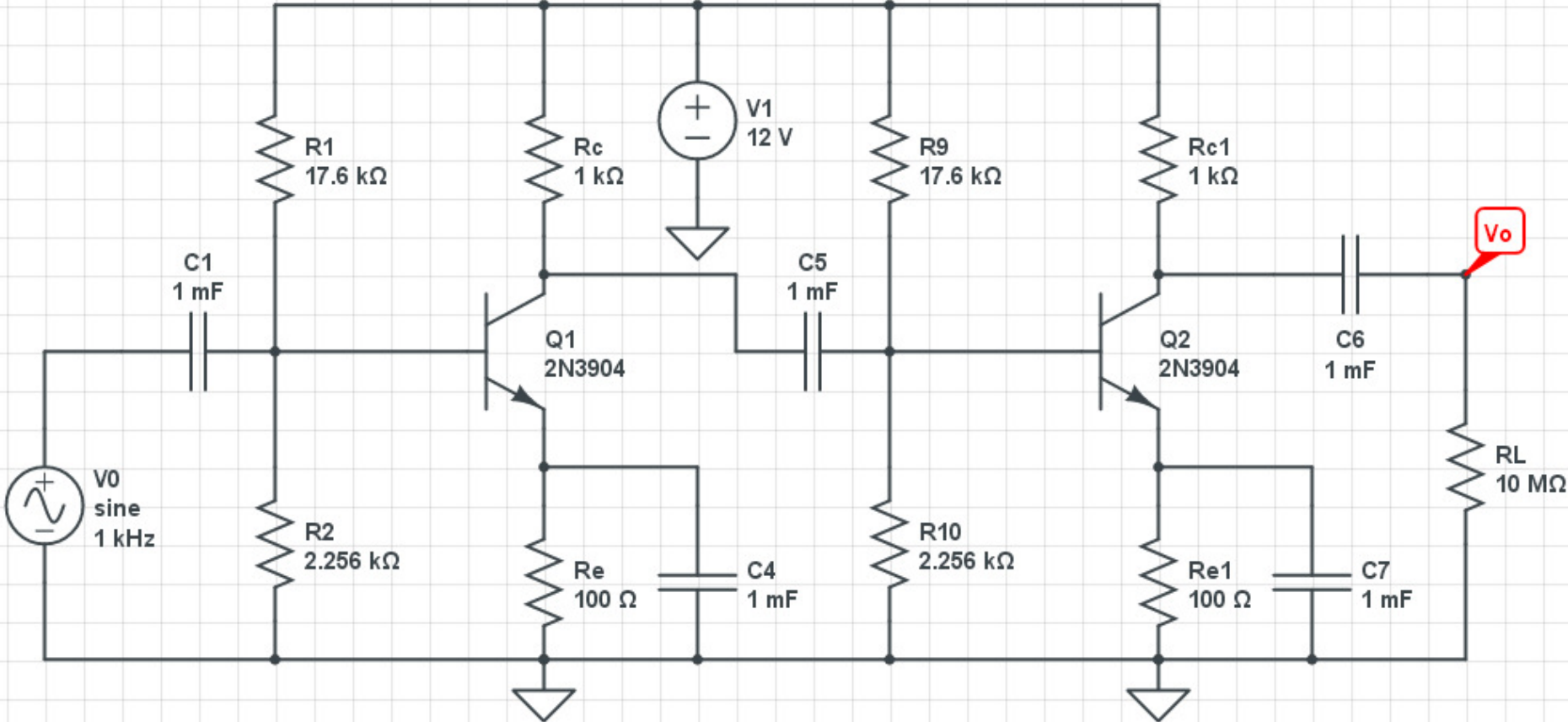
Recap:

CE, CB, CC Amplifiers

What do you get when you cascade amplifiers?

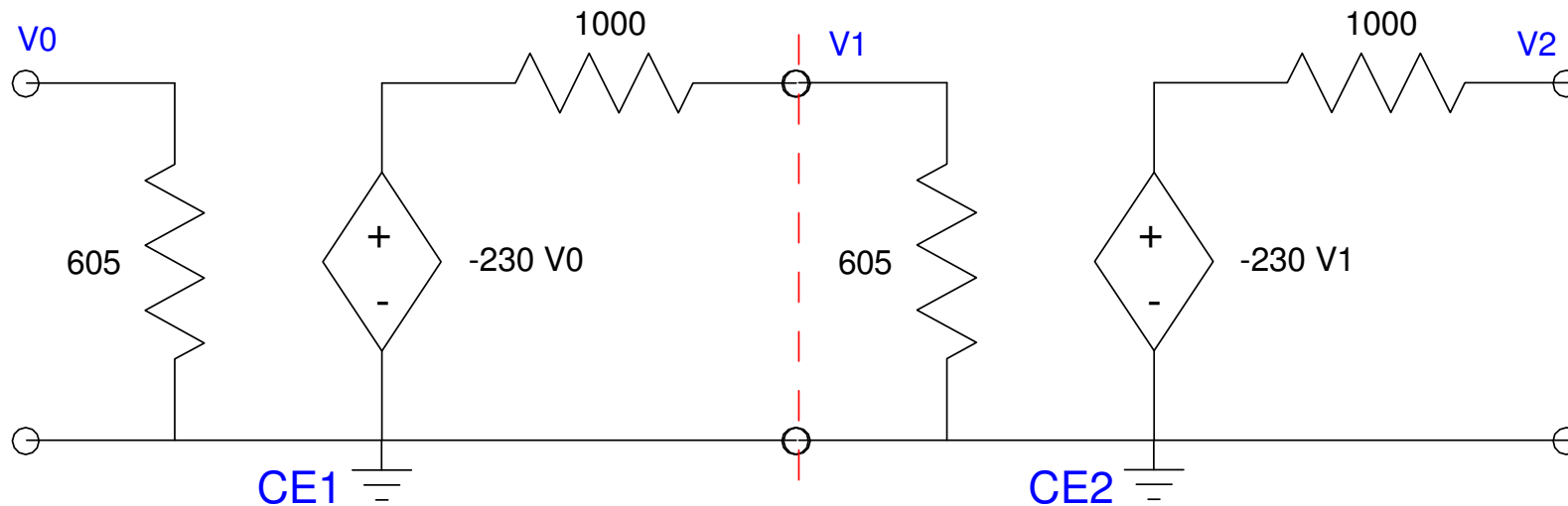


CE : CE



Replace with 2-Port Models

- $R_{in} = 605$
- $A_i = 0$
- $R_{out} = 1000$
- $A_o = (-230) \left(\frac{605}{1000+605} \right) (-230) = 19,940$

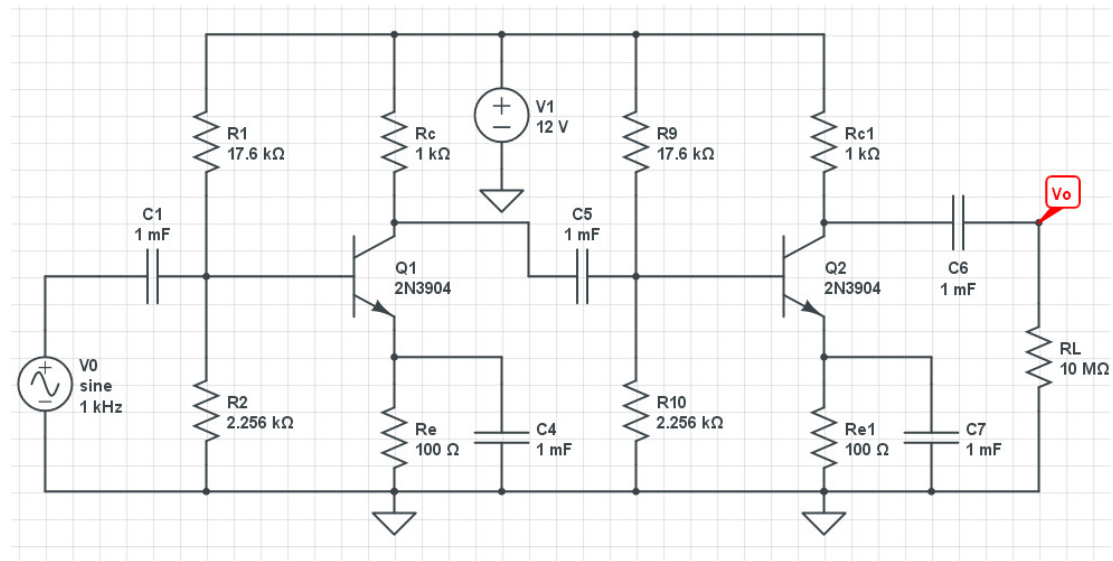


CircuitLab Results:

- $V_{out} = 1.34V$
- $A_o = \frac{1.34V}{0.1mV} = 13,400$

Change RL from 10M to 1k

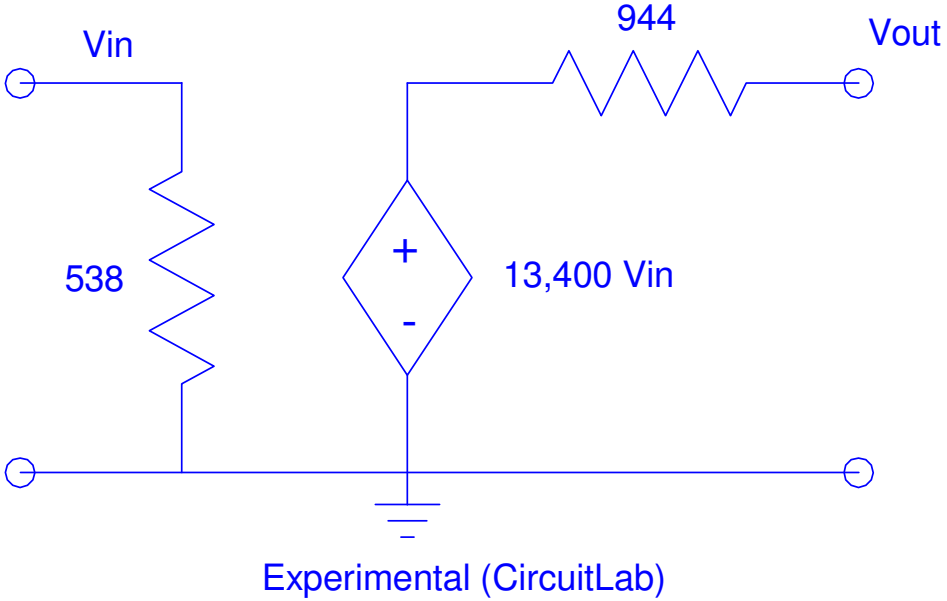
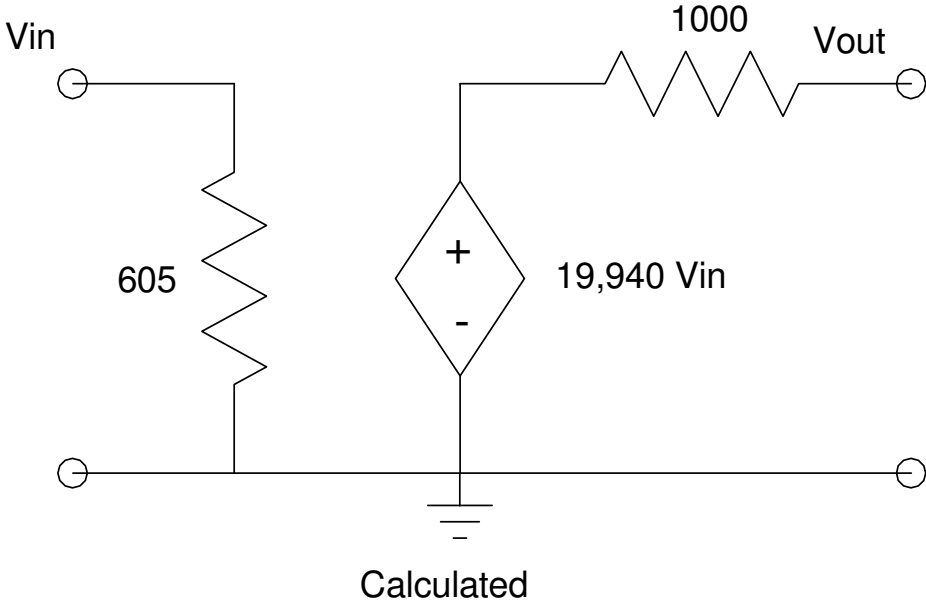
- V_o drops to 689mV
- $R_{out} = \left(\frac{1.34V - 689mV}{689mV} \right) 10000\Omega$
- $R_{out} = 944\Omega$



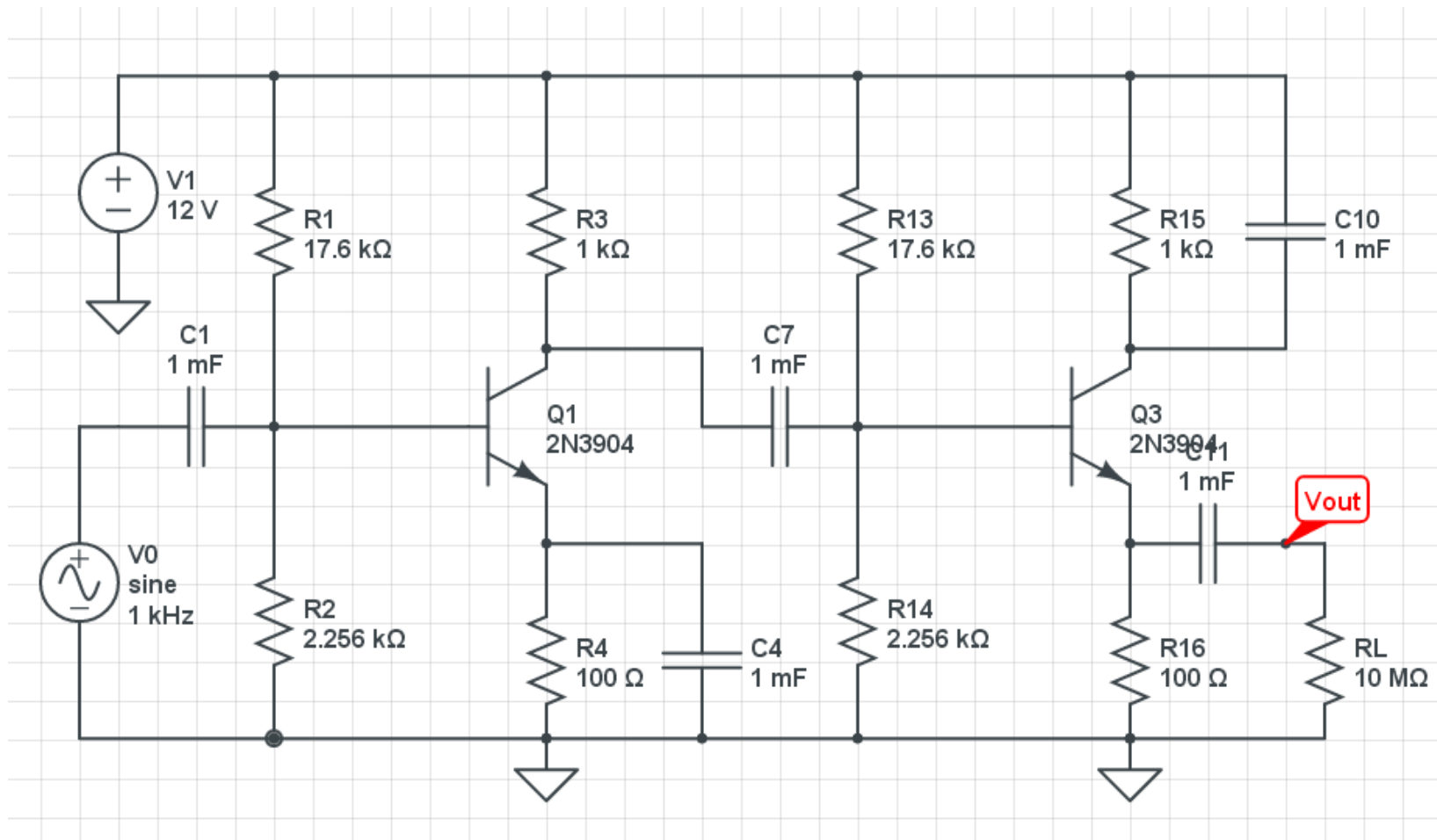
Change RL = 0 Ohms

- $I(C1) = 185.8nA$
- $R_{in} = \left(\frac{0.1mV}{185.8nA} \right) = 538\Omega$

CE : CE Results



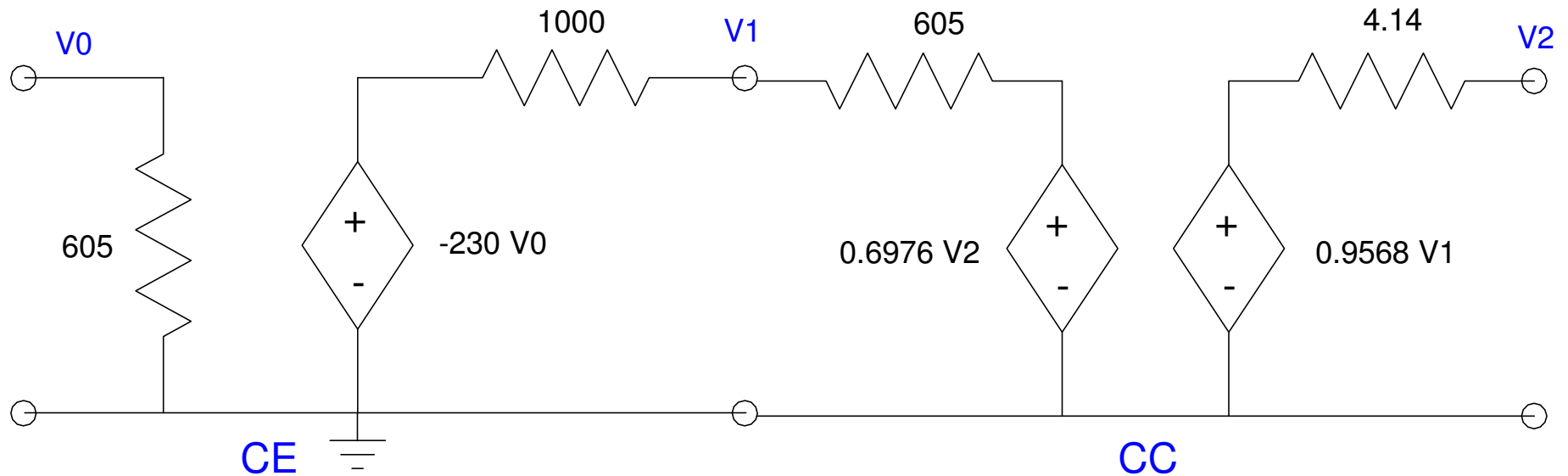
CE : CC



CE : CC

Step 1: Replace each stage with its 2-port model

- $R_{in} = 605$
- $A_i = 0$



Ao:

- Apply 1V at the input
- Compute V2
- Voltage Node equations...

$$\left(\frac{V_1 - (-230)}{1000}\right) + \left(\frac{V_1 - 0.6976V_2}{605}\right) = 0$$

$$V_2 = 0.9568V_1$$

substituting for V2

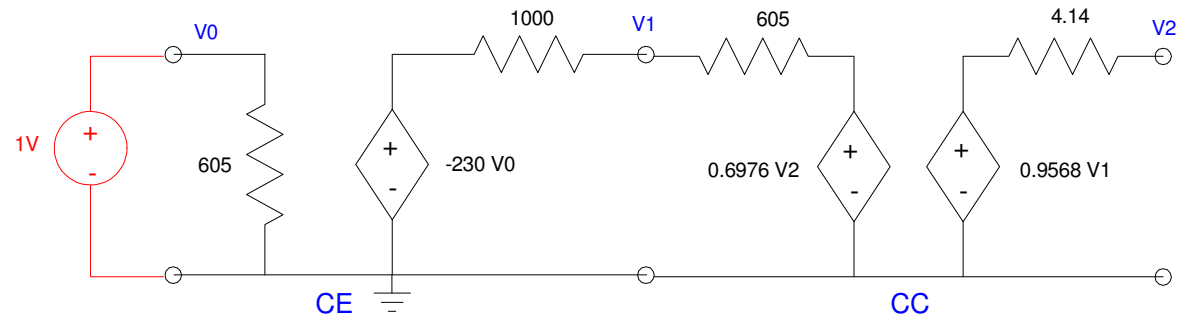
$$\left(\frac{V_1 + 230}{1000}\right) + \left(\frac{V_1 - 0.6976 \cdot 0.9568V_1}{605}\right) = 0$$

$$\left(\frac{1}{1000} + \frac{1 - 0.6976 \cdot 0.9568}{605}\right) V_1 = -\left(\frac{230}{1000}\right)$$

$$V_1 = -148.42$$

$$V_2 = 0.9568V_1 = -142.0$$

Ao = -142.0



Rout:

- Short V_{in}
- Apply 1V to V_{out}
- Compute the current

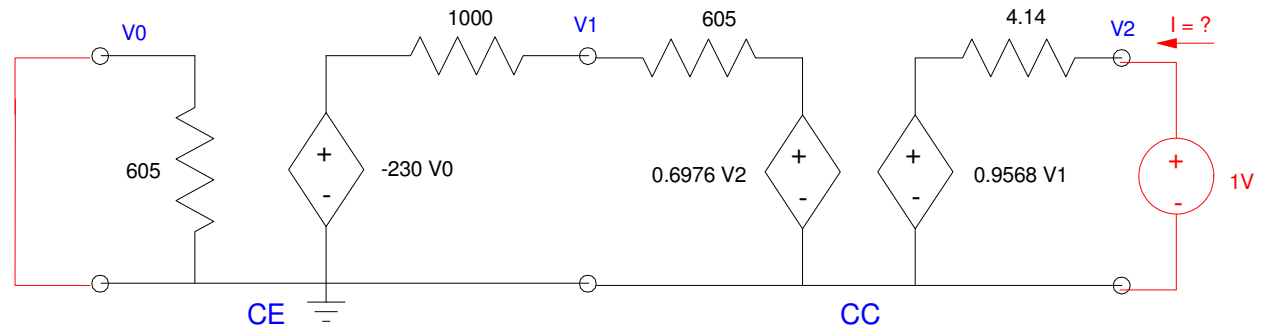
$$V_1 = \left(\frac{1000}{1000+605} \right) 0.6876V$$

$$V_1 = 0.4346V$$

$$0.9568V_1 = 0.4159$$

$$I = \left(\frac{1V - 0.4159V}{4.14\Omega} \right) = 141.1mA$$

$$R_{out} = \frac{1V}{141.1mA} = 7.087\Omega$$



Simulation Results

$A_o = 130.3$

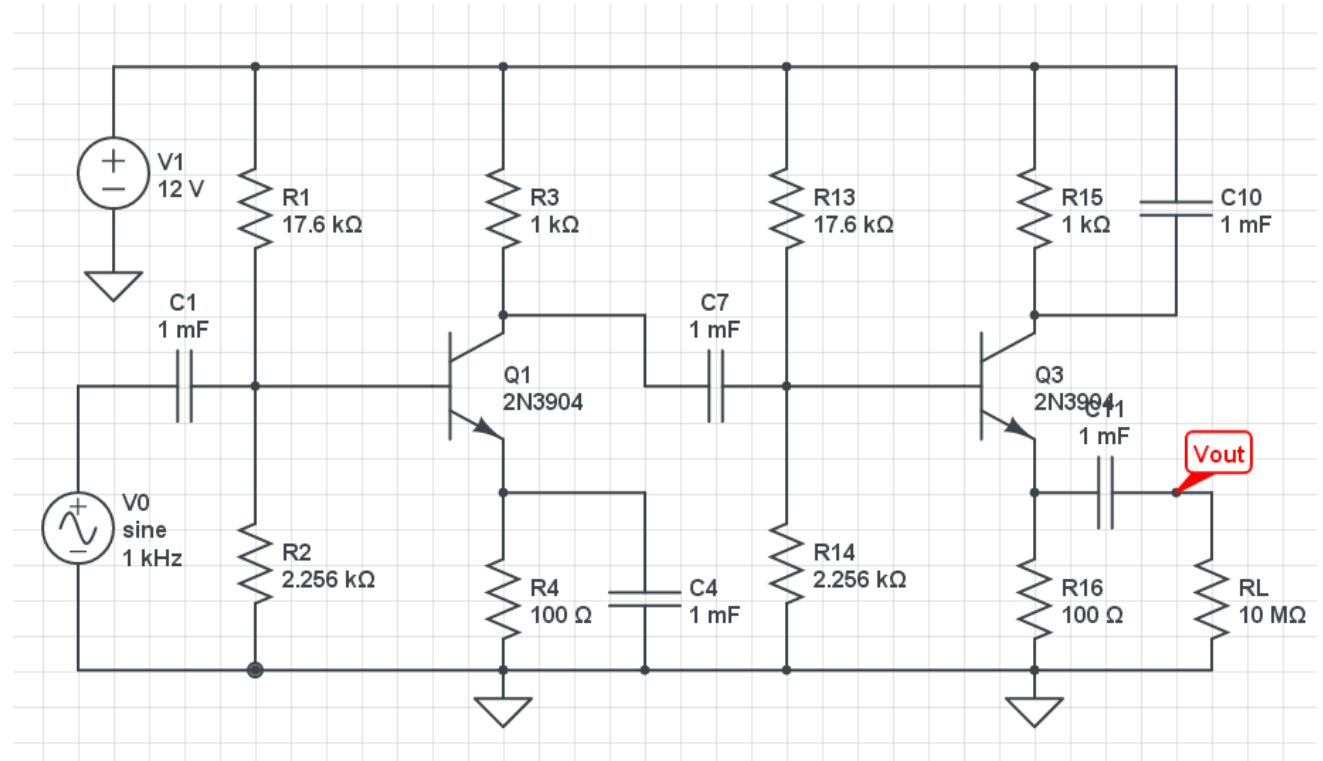
- $R_L = 10M$
- $V_0 = 1mV, 1kHz$
- $V_{out} = 130.3mV$

$R_{in} = 506 \text{ Ohms}$

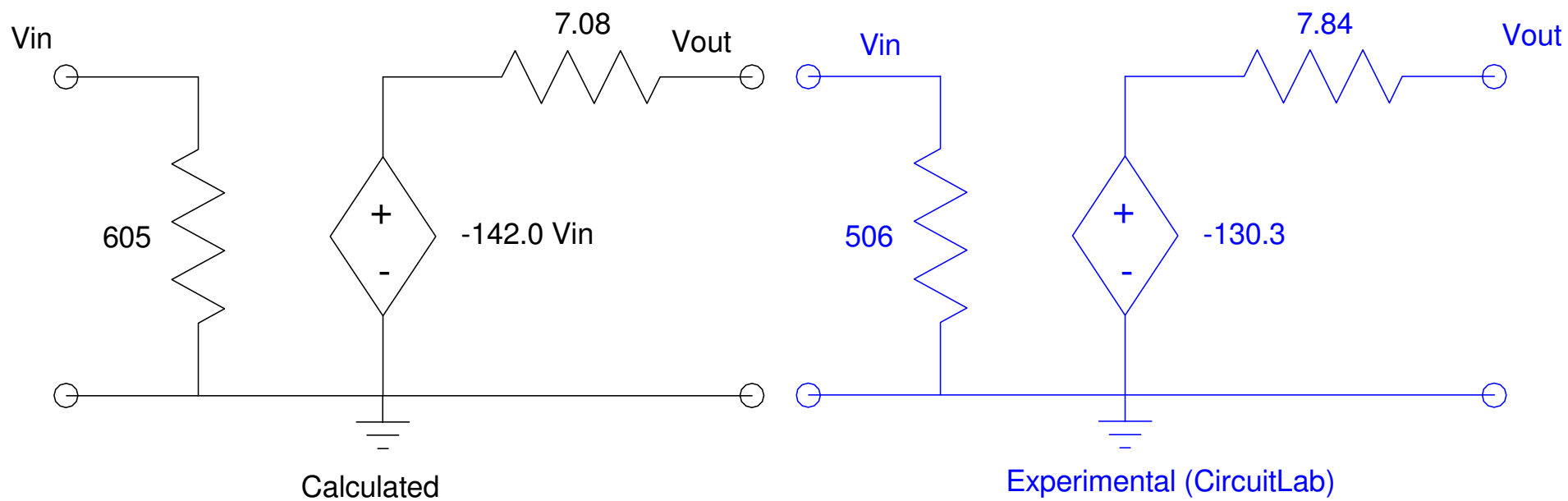
- $R_L = 0$
- $V_0 = 1mV, 1kHz$
- $I_0 = 1.974\mu A$
- $R_{in} = 1mV / 1.974\mu A$

$R_{out} = 7.84 \text{ Ohms}$

- $R_L = 8$
- $V_0 = 1mV, 1kHz$
- $V_{out} = 67.1mV$

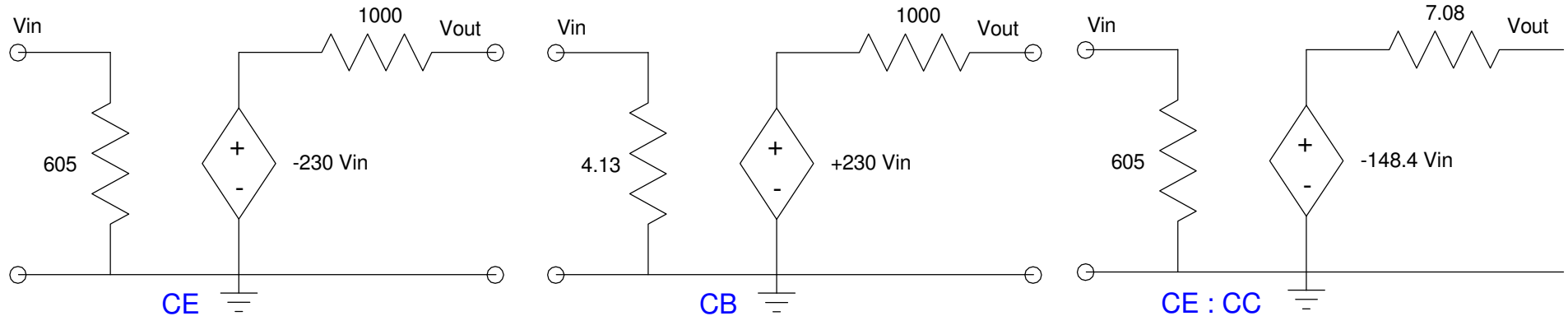


CE : CC Results



Multi-Stage Amplifiers.

The shopping list of amplifiers you have to play with are as follows:



In general:

- CE amplifiers are good for increasing the gain.
 - CB amplifiers are good for the first stage if you need a low input impedance.
 - CC amplifiers are good for the last stage if you are driving a low-impedance load, such as an 8-Ohm speaker.
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Problem: Design an amplifier

Input: Phonograph needle: $R_N = 10 \text{ Ohms}$

$$I_{in} = 1\mu A$$

Output: 8 Ohm Speaker

Relationship:

$$V_{out} > 10V_p$$

Design

Stage 1: CB

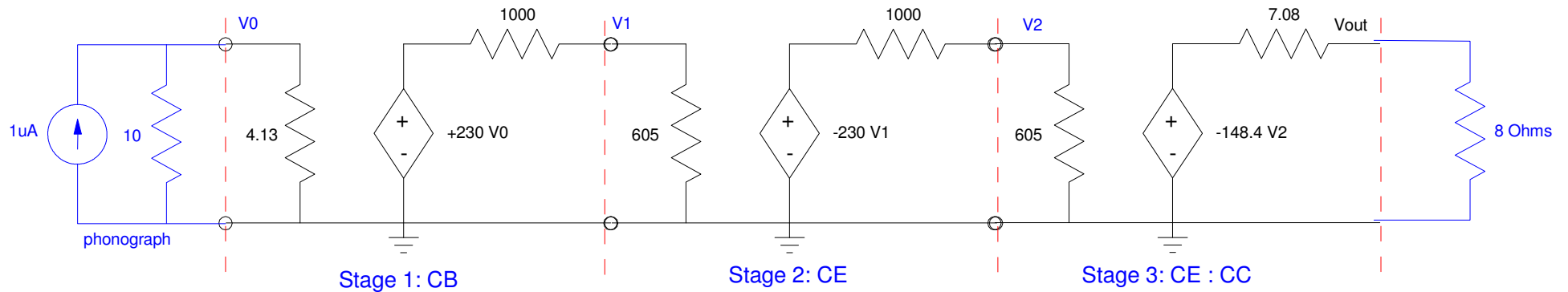
- Low input impedance (current source)

Stage N: CE : CC

- Low output impedance

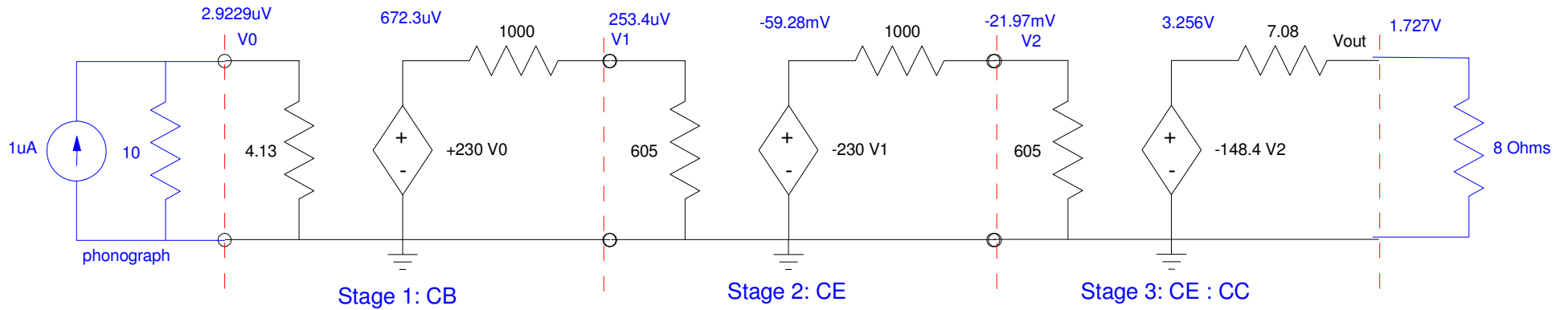
CE inbetween

- Adds gain



Voltage Analysis

- $I_{in} = 1\mu\text{A}$ (peak)
- $V_{out} = 1.727\text{V}$ (peak)



Add another CE amplifier

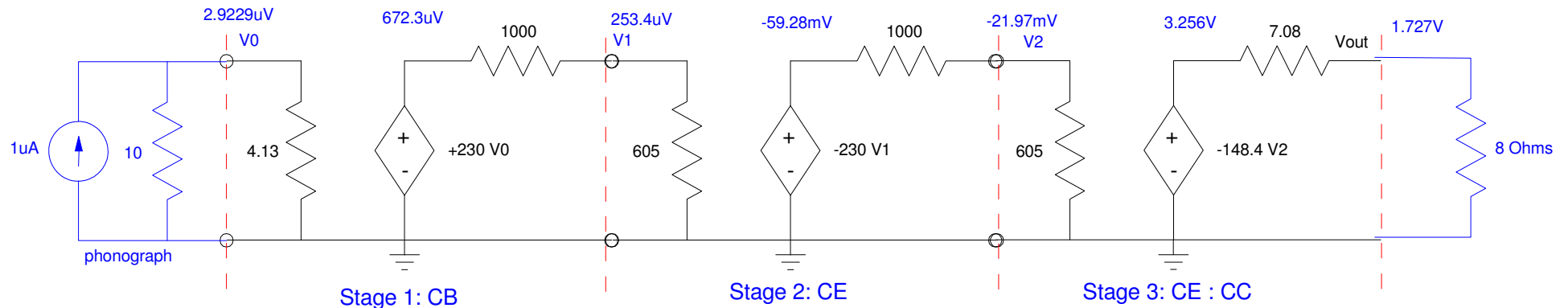
- Adds another gain of 86.7

$$-230 \left(\frac{605}{1000+605} \right) = 86.7$$

- Increases V_{out} to 149.7V

Reduce the gain so that $V_{out} = 10.00V$

- Add a resistor in series in stage #2a or Stage #2b to reduce the gain
- Last stage wastes power (bad)
- First stage decreases the signal (hurts signal to noise ratio - also bad)



Options for Driving a Speaker

Make the last stage CE : CC

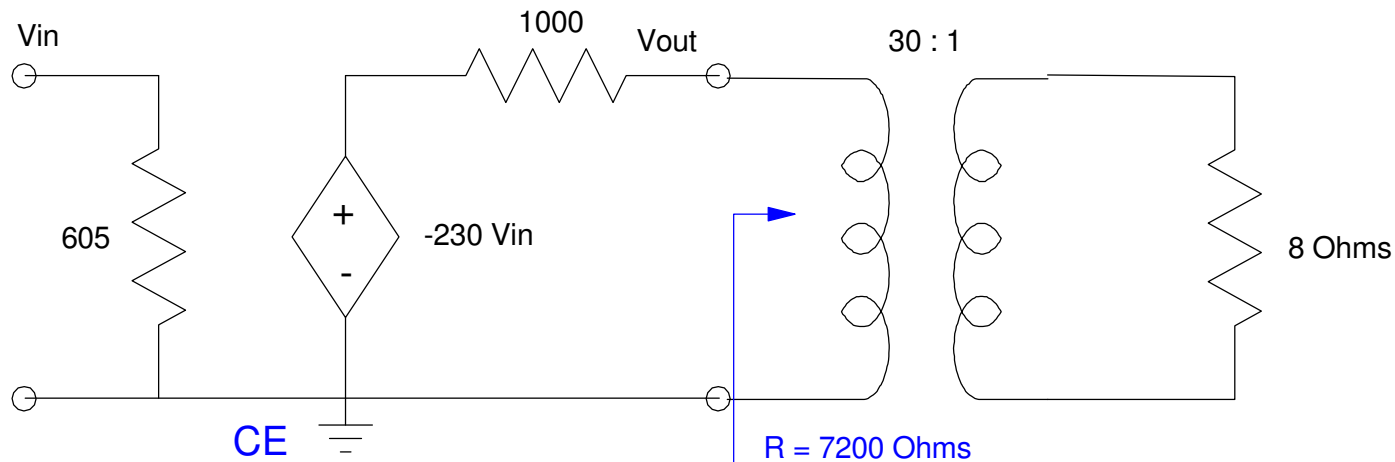
- Low output impedance

Have the last stage (CE) drive a push-pull amplifier

- Uses a transistor to amplify the current
- Input impedance is 4G Ohms (MCP602)

Add a transformer before the speaker

- Impedances go through a transformer as the turn-ratio squared



Summary

Mix and match CE, CB, CC amplifiers to create a multi-stage amplifier

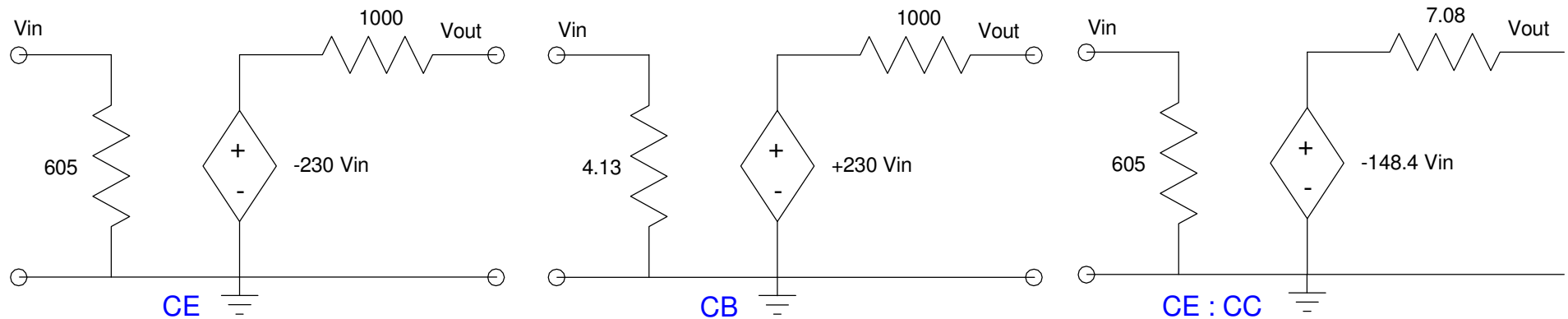
First stage is either CE or CB

- CE for high input impedance, CB for low input impedance

Middle stages are CE

- Each CE increases the gain by 86

Last stage is either CE or CC



- CE if high output impedance is OK (driving a push-pull amplifier), CC if not
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