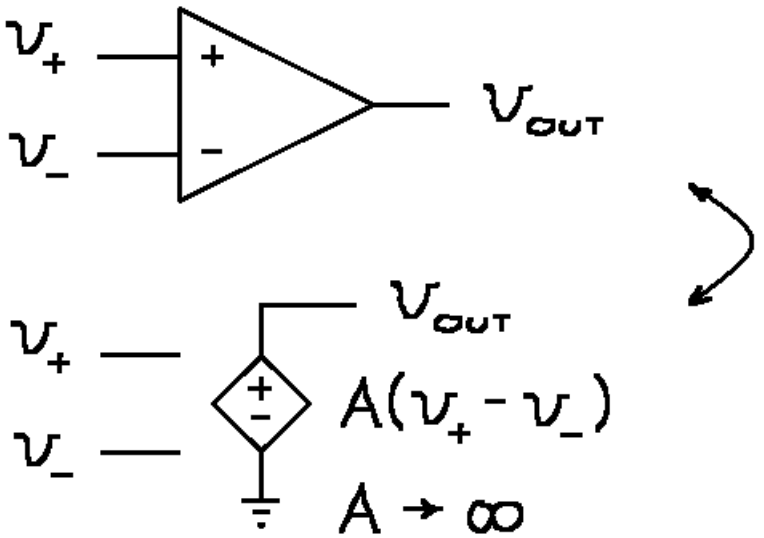
6.002 - Lecture 08

Op Amps & Amplifiers

- Ideal Op Amps
- Superposition
- Op-Amp-Based Amplifiers

Ideal Op Amp



v_+, v_- and v_{OUT} are referenced to ground

- Zero input currents
- Zero output resistance
- Algebraic differential output voltage
- Differential gain $A \to \infty$

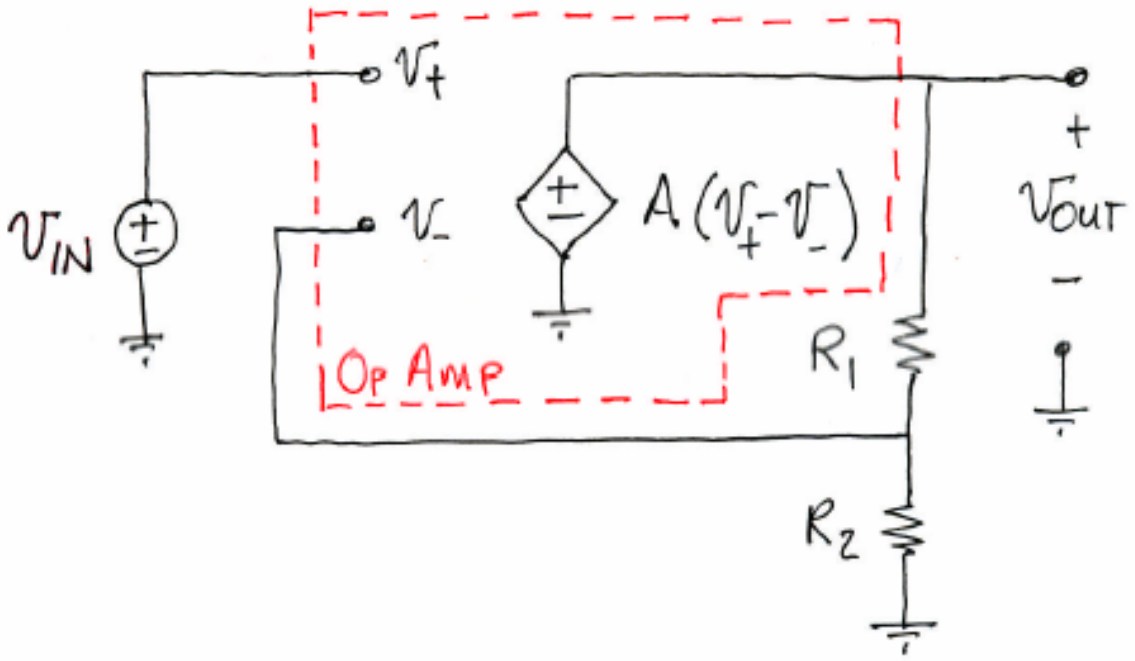
$V_+ = V_-$

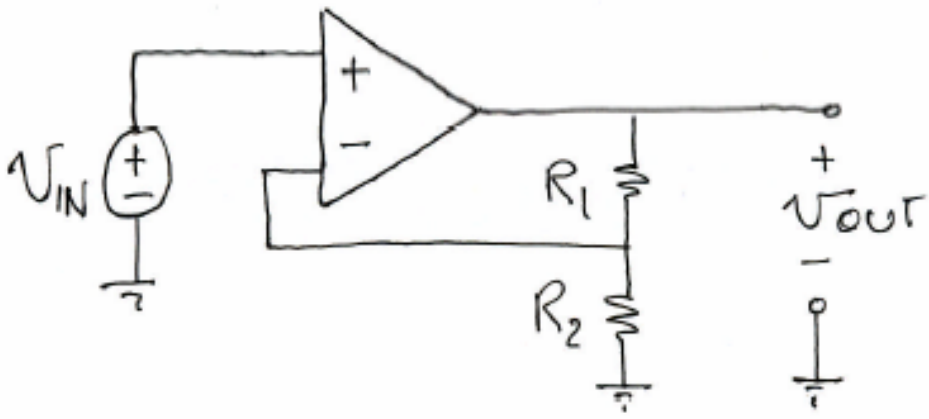
- Ideal op amp $\Rightarrow$ $v_+ - v_- = v_{OUT}/A$
- Stable system $\Rightarrow$ finit v_{OUT}
- Lim $A \to \infty$ $\Rightarrow$ $v_+ - v_- = v_{OUT}/A \to 0$

$\Rightarrow$ $\boxed{v_+ = v_-}$

Non-Inverting Amplifier

Use negative feedback to trade gain for more ideal performance.





Power supply connections not shown.

Old Analysis

Node Method: $\frac{v_-}{R_2} + \frac{v_- - A(v_+ - v_-)}{R_1} = 0$ ($v_+ = v_{IN}$)

$$v_- = \frac{A R_2}{R_1 + (A+1) R_2} v_{IN}$$

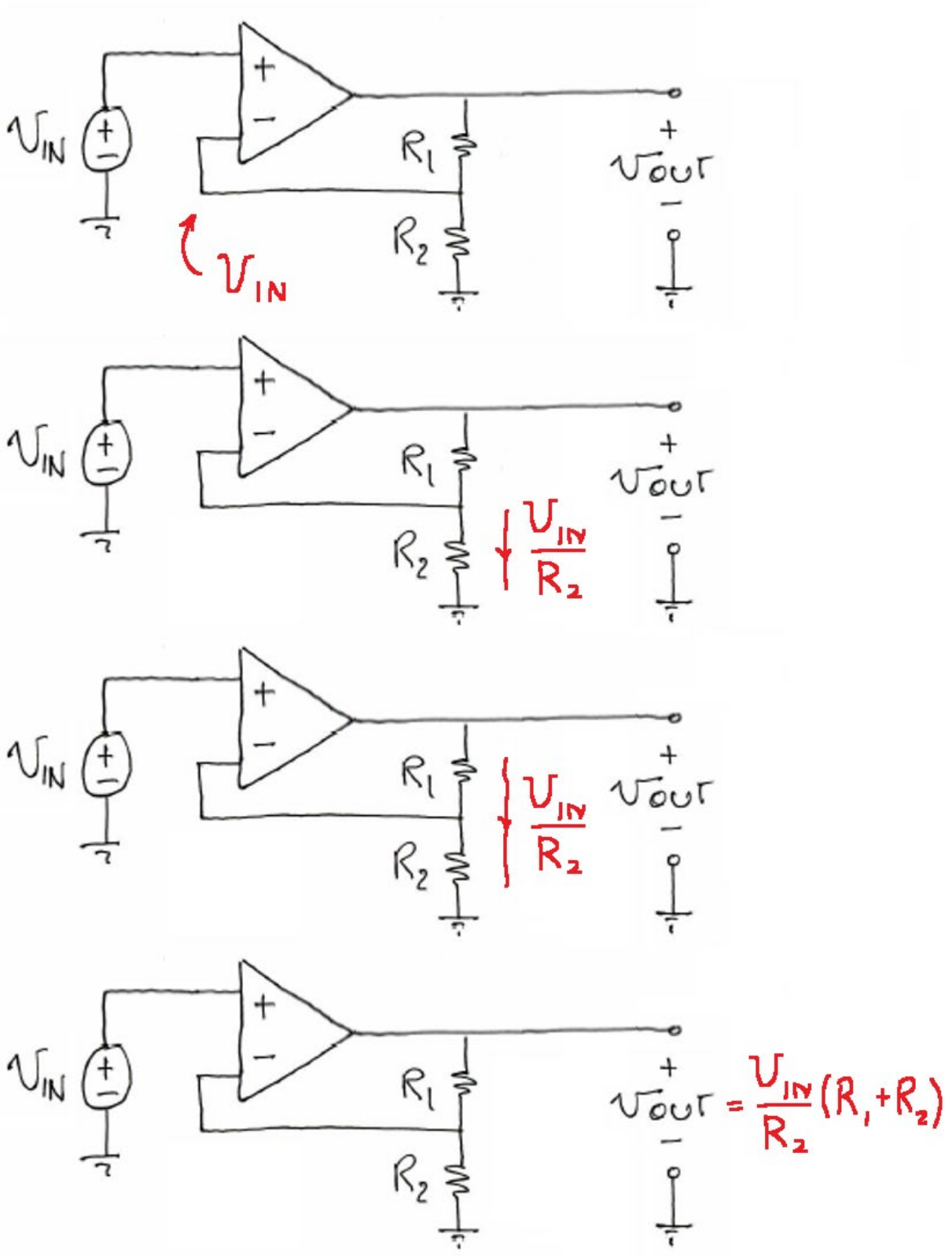
$$v_{out} = A(v_+ - v_-) \quad (v_+ = v_{IN})$$

$$= \frac{A \cdot G}{A + G} v_{IN} \qquad G \equiv \frac{R_1 + R_2}{R_2}$$

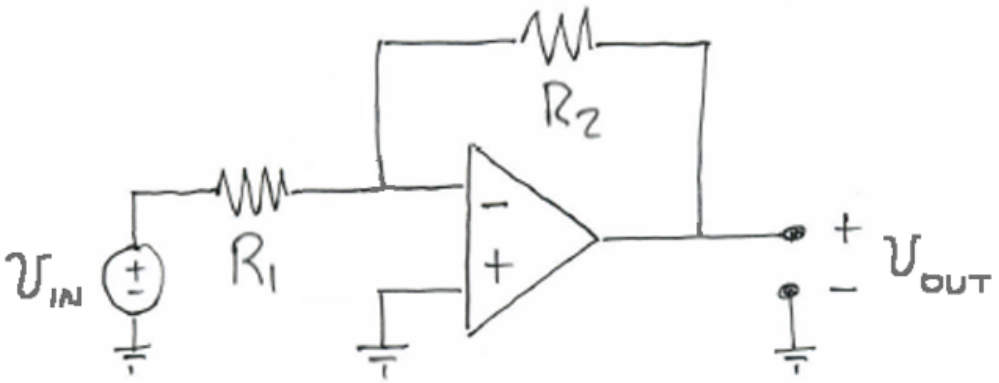
If $A \gg G$ then $v_{OUT} = G\, v_{IN}$

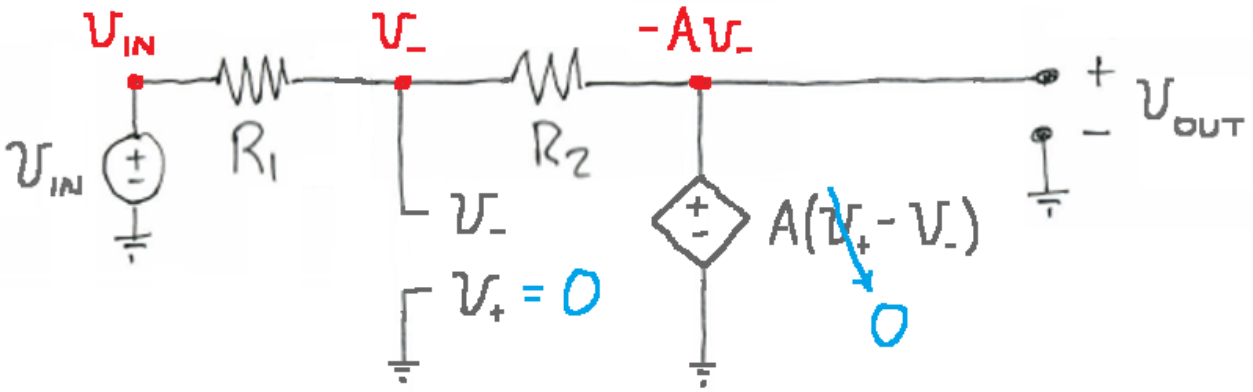
Dependent only on resistors.

New Analysis Using $v_+ = v_-$



Inverting Amplifier



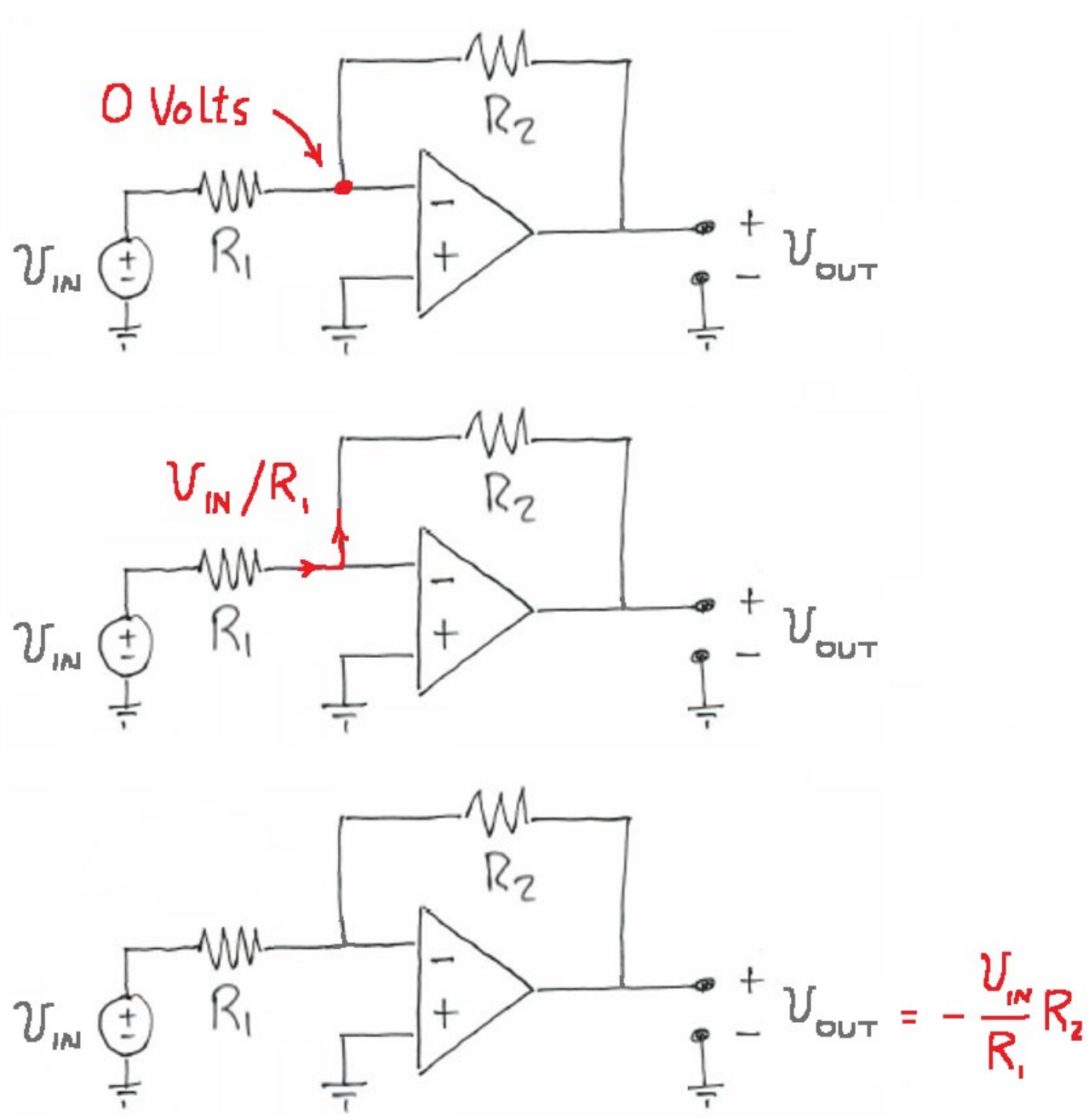


$$\frac{V_- - V_{IN}}{R_1} + \frac{V_- + AV_-}{R_2} = 0 \rightarrow V_- = \frac{R_2 V_{IN}}{(A+1)R_1 + R_2}$$

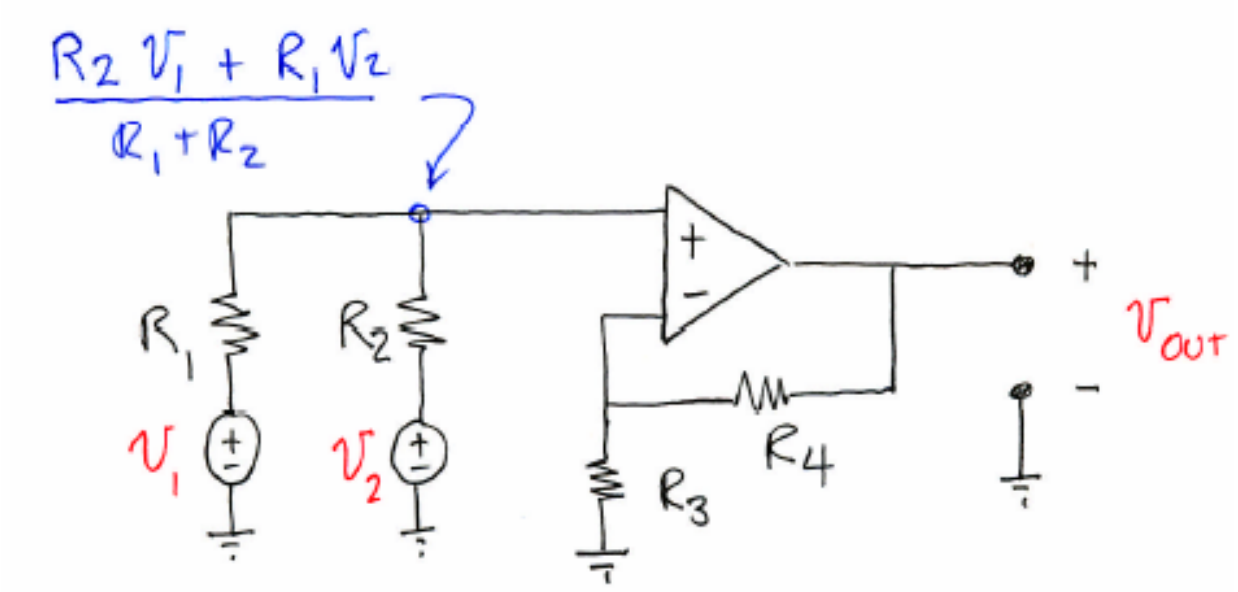
$$V_{OUT} = -AV_- = -\frac{AG}{A+1+G} V_{IN}, \quad G = R_2/R_1$$

If $A \gg G$ then $V_{OUT} = -G V_{IN}$

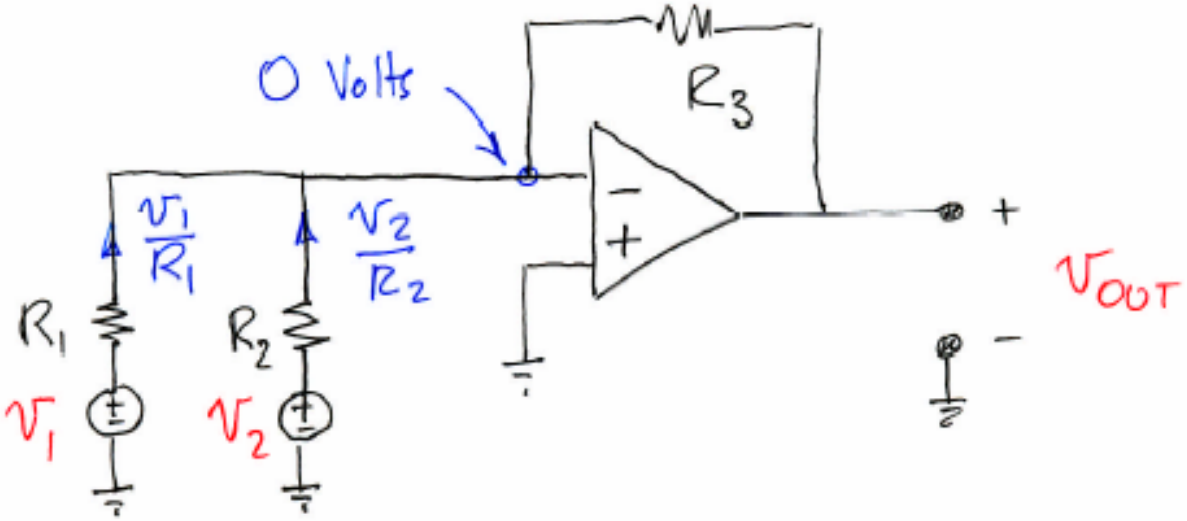
New Analysis Using $v_+ = v_-$



Addition

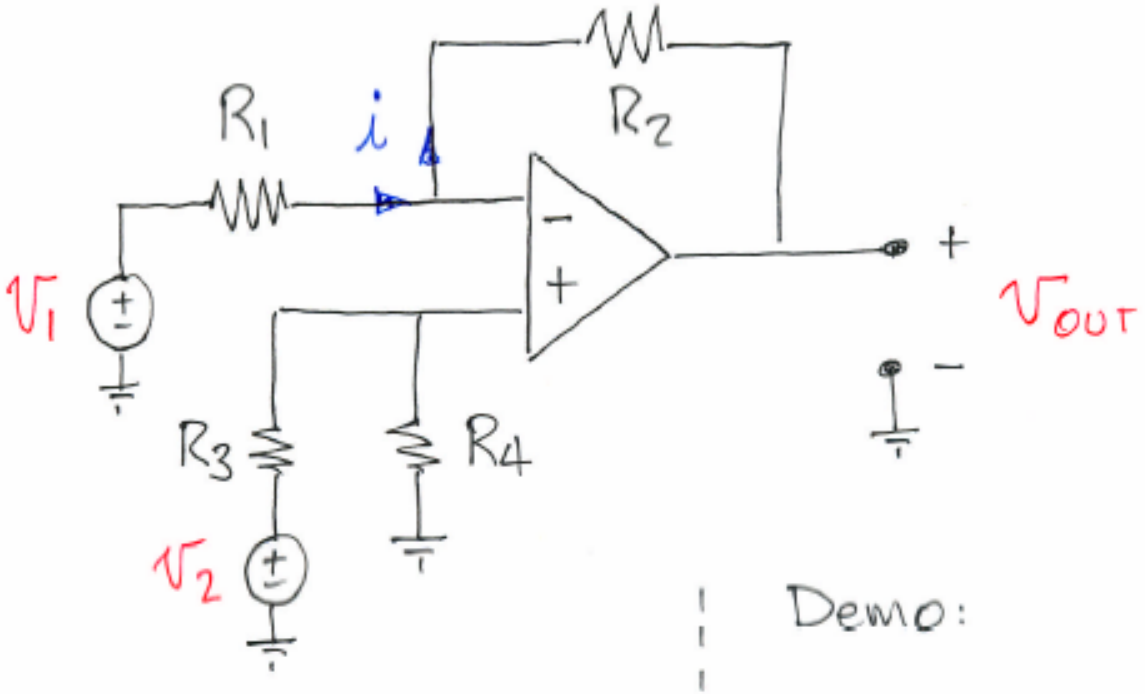


$$V_{OUT} = \frac{R_4 + R_3}{R_3} \left[\frac{R_2 V_1 + R_1 V_2}{R_1 + R_2} \right]$$



$$V_{OUT} = -R_3 \left[\frac{V_1}{R_1} + \frac{V_2}{R_2} \right]$$

Subtraction



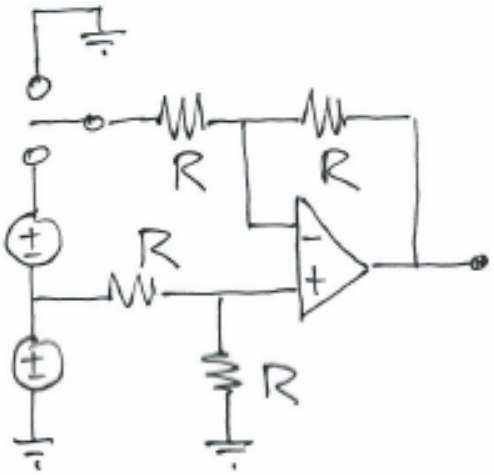
$$V_- \approx V_+ = \frac{R_4}{R_3+R_4} V_2$$

$$i = \frac{V_1 - V_-}{R_1}$$

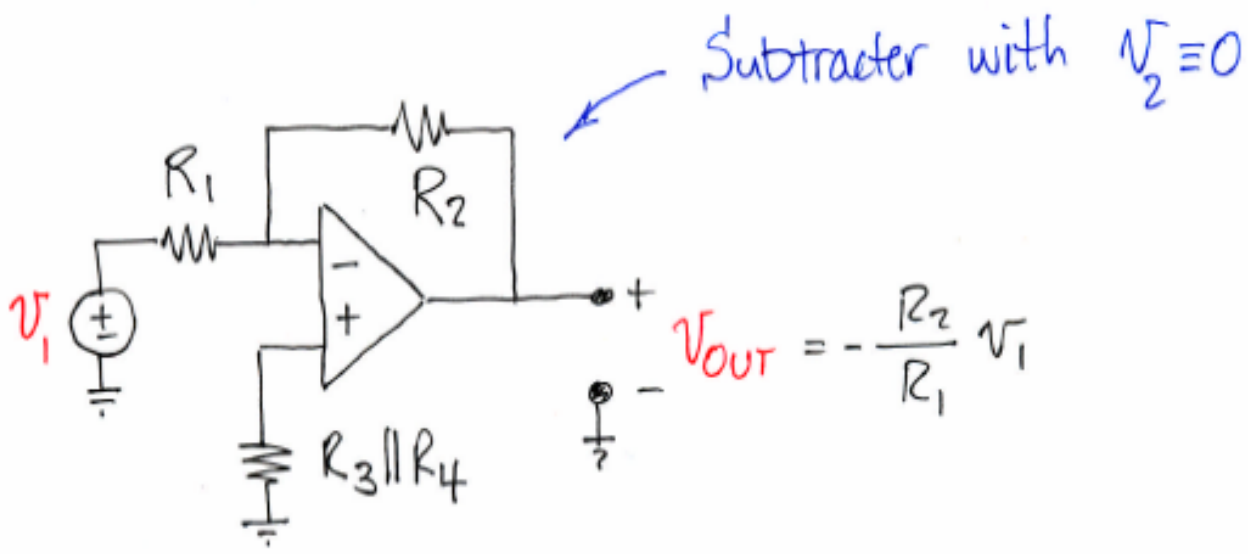
$$V_{OUT} = V_- - R_2 i$$

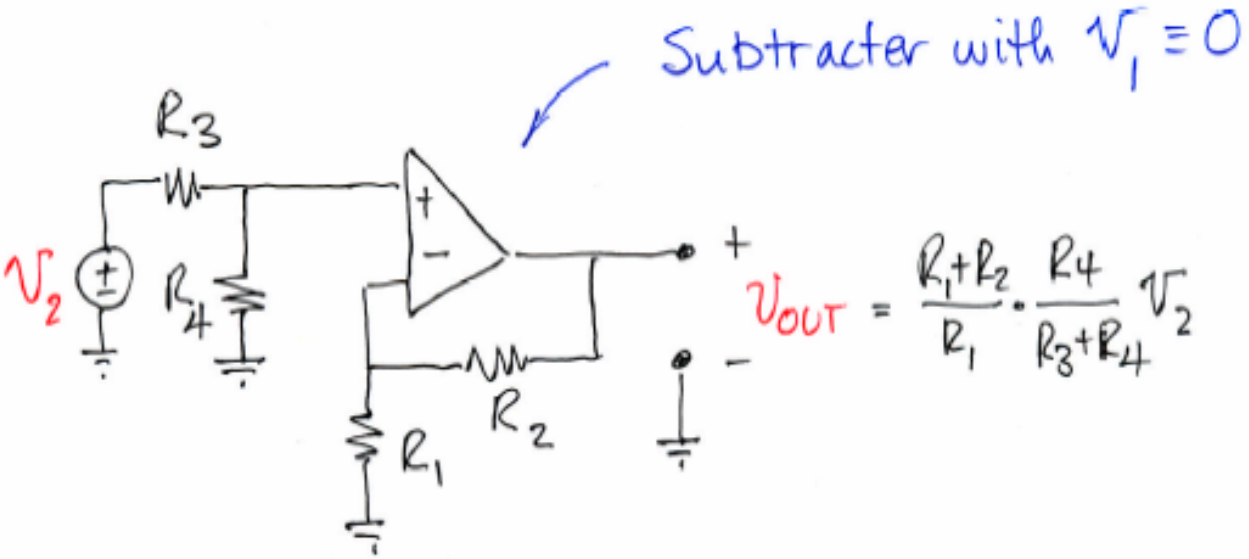
$$V_{OUT} = \frac{R_4}{R_3+R_4} \cdot \frac{R_1+R_2}{R_1} V_2 - \frac{R_2}{R_1} V_1$$

Demo:



Subtraction By Superposition





Subtracter: $V_{OUT} = \frac{R_1+R_2}{R_1} \cdot \frac{R_4}{R_3+R_4} V_2 - \frac{R_2}{R_1} V_1$

Differential Instrumentation Amp