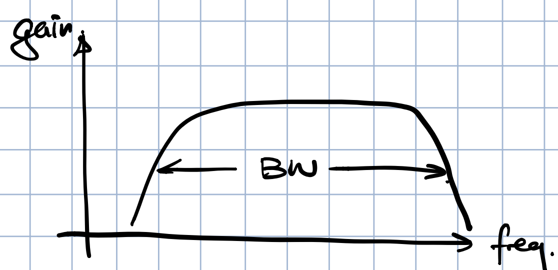
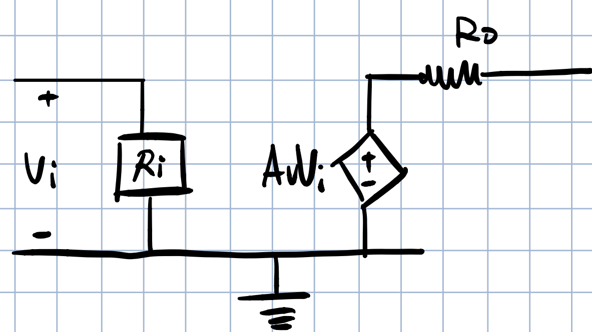
Ideal Op-amp circuits.

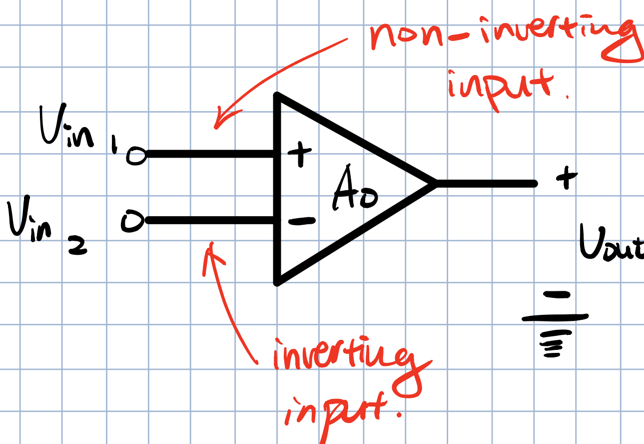
Operational Amplifier. (op-amp)

	Ideal amplifier.	741	modern IC op-amp.
A_o	∞	100,000	50 - 100
Input Impedance.	∞	few MΩ	few MΩ
Output Impedance.	0	< 100 Ω	few kΩ
BW.	∞	1.5 MHz	few GHz
power diss.	0	50 mW	5-10 mW
cost.	0	< \$1	$\$10^{-5}$

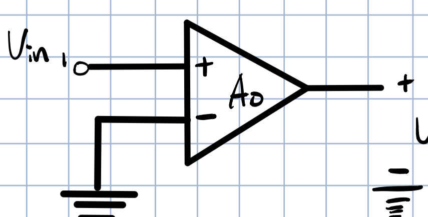




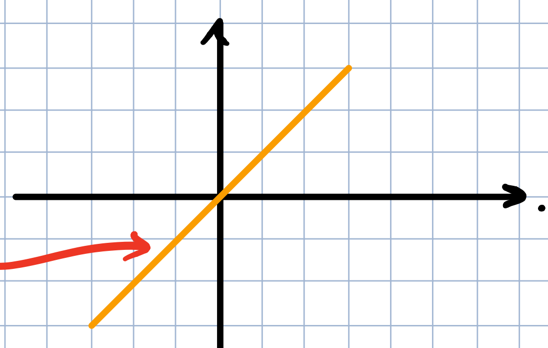
Op-Amp Basics.

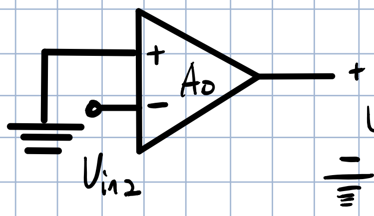


$$V_{out} = A_o(V_{in_1} - V_{in_2})$$

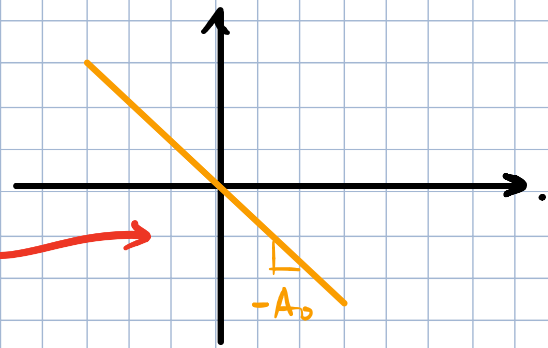


$$V_{out} = A_o(V_{in_1} - 0) = A_o V_{in_1}$$

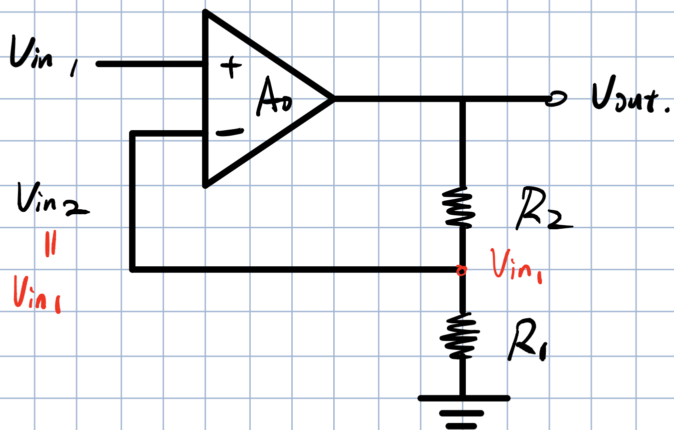




$$V_{out} = A_0(0 - V_{in_2}) = -A_0 V_{in_2}$$



non-inverting amplifier.



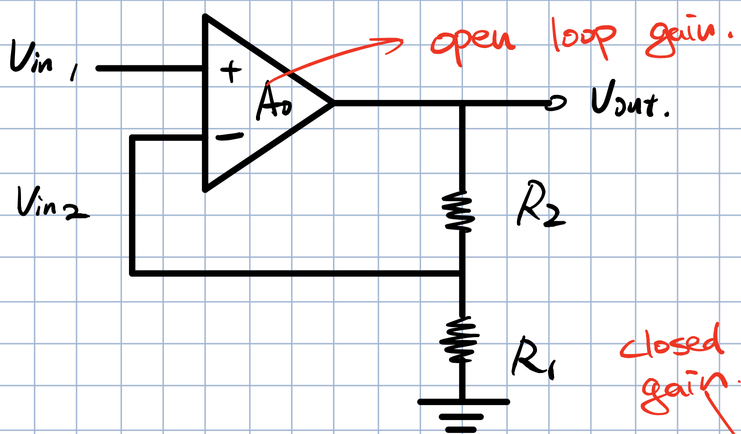
Case 1: $A_0 \to \infty$

$$\underset{\text{finite \#}}{V_{out}} = \underset{\infty}{A_0}\,\underbrace{(V_{in_1} - V_{in_2})}_{0}$$

i.e. $V_{in_1} = V_{in_2}$

$$V_{in_1} = \frac{R_1}{R_1+R_2} V_{out} \rightarrow \frac{V_{out}}{V_{in}} \simeq \frac{R_1+R_2}{R_1}$$

$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_2}{R_1}$$



Case 2: $A_0 \neq \infty$

$$V_{in_2} = \frac{R_1}{R_1+R_2} V_{out}$$

$$V_{out} = A_0(V_{in_1} - V_{in_2})$$

$$= A_0\left(V_{in_1} - \frac{R_1}{R_1+R_2} V_{out}\right)$$

closed loop gain.

$$\frac{V_{out}}{V_{in}} = \frac{A_0}{1 + \frac{R_1}{R_1+R_2} A_0} = \frac{1 + R_2/R_1}{1 + (1 + R_2/R_1)/A_0}$$

if $A_0 \to \infty$,

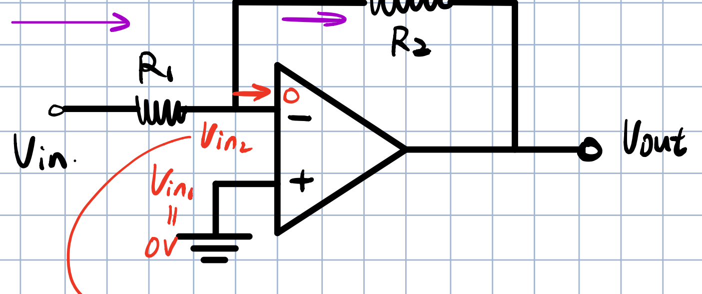
$$\frac{V_{out}}{V_{in}} \simeq 1 + \frac{R_2}{R_1} \quad \text{(Agrees w/ previous)}$$

(closed loop gain in this case is independent of A_0)

Inverting Amplifier.

$\frac{V_{in} - 0}{R_1}$

Case 1: $A_0 \to \infty$



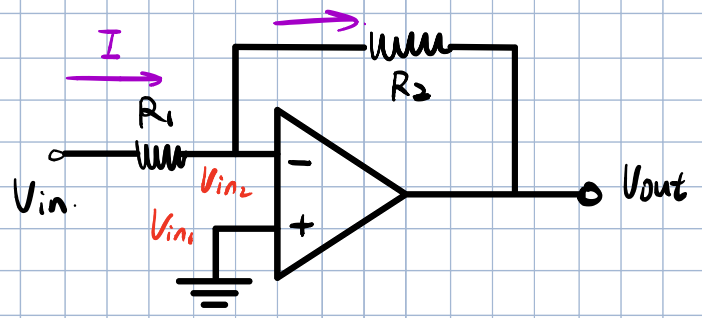
$\approx V_{in_1} = 0V$ (virtual ground)

Case 1: $A_0 \to \infty$

$$\underset{\text{bound}}{V_{out}} = \underset{\infty}{A_0}\,(\underbrace{V_{in_1} - V_{in_2}}_{V_{in_1} \simeq V_{in_2}})$$

$$V_{out} = \underset{0}{V_{in_2}} - \frac{V_{in}}{R_1} R_2$$

$$\frac{V_{out}}{V_{in}} \approx -\frac{R_2}{R_1}$$



Case 2: $A_0 \neq \infty$

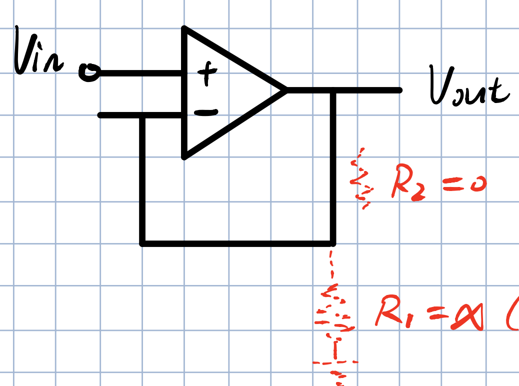
$$V_{out} = A_0(V_{in_1} - V_{in_2})$$
$$= A_0(0 - V_{in_2})$$
$$V_{in_2} = -\frac{V_{out}}{A_0}$$

$$I = \frac{V_{in} - V_{in_2}}{R_1} = \frac{V_{in} + \frac{V_{out}}{A_0}}{R_1}$$

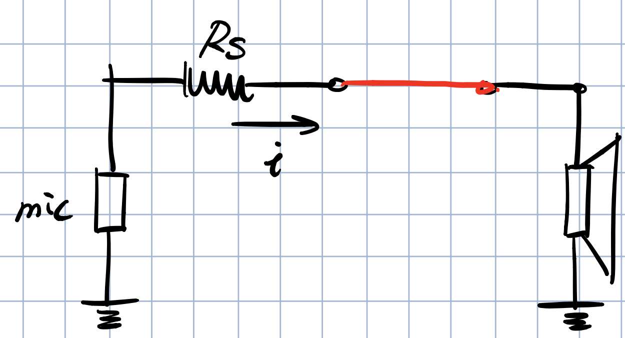
$$V_{out} = V_{in_2} - IR_2, \longrightarrow \frac{V_{out}}{V_{in}} = \frac{-R_2/R_1}{1 + (1 + R_2/R_1)/A_0}$$

Application of the two basic configuration.

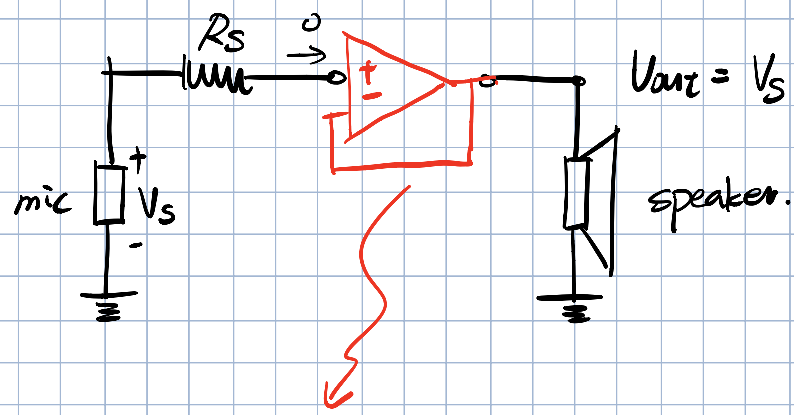
① Unity gain buffer.



$$\frac{V_{out}}{V_{in}} = \simeq 1 + \frac{\overset{\to 0}{R_2}}{\underset{\uparrow \infty}{R_1}} \simeq 1$$



$$V_{out} = V_s - R_s i$$



A buffer has high input impedance, which let the circuit sense (detect) voltage w/o loading the circuit.