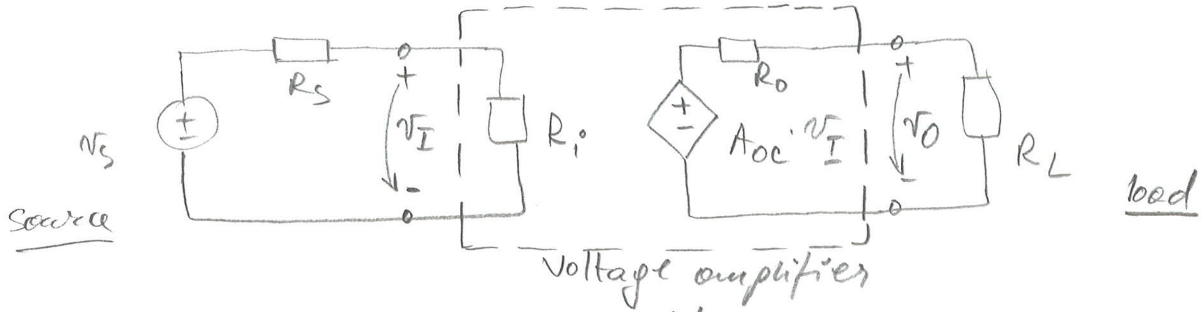
1 – Voltage amplifier : amplification, loading



$A_{oc} \overset{def.}{=}$ voltage gain factor, open-circuit / unloaded.

$$A_{v_S} = \frac{v_O}{v_S} = \frac{R_i}{R_S + R_i} \cdot A_{oc} \cdot \frac{R_L}{R_o + R_L}$$

$A_{v_S} \overset{def}{=}$ source to load gain or amplification.

Attenuations referred to as loading

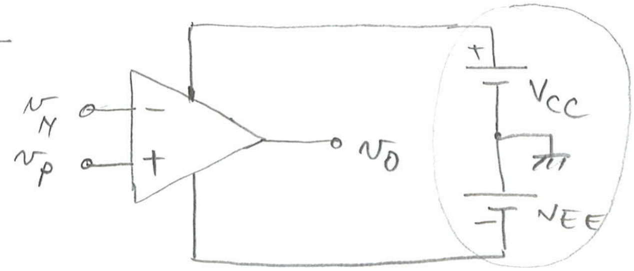
because of which $|A_{v_S}| \leq |A_{oc}|$ which is undesirable!

Minimize Loading by $R_S \downarrow$ & $R_i \uparrow$ and $R_L \uparrow$ & $R_o \downarrow$

– The Operational Amplifier (Op Amp) (OA)

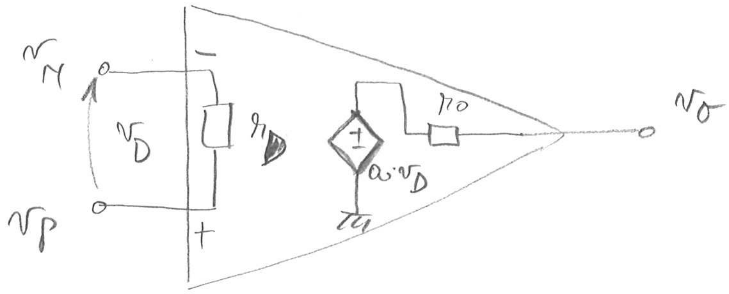
A voltage amplifier with extremely high gain/amplification.

Symbol



typically not drawn but present all the time!

"–" inverting input
"+" noninverting input.



$v_D = v_P - v_N \overset{def}{=}$ differential input voltage.

$$\boxed{v_O = a\, v_D = a(v_P - v_N)} \iff \boxed{v_D = \frac{v_O}{a}}$$

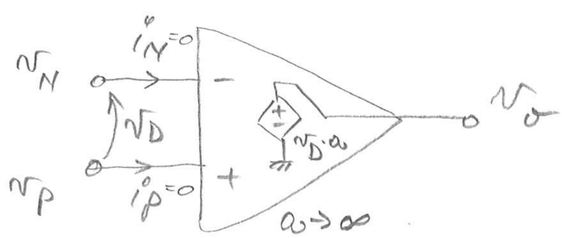
$\begin{cases} a \overset{def}{=} \text{unloaded gain, because when the loading is absent we have:} \\ r_O \triangleq \text{output resistance} \\ r_D \triangleq \text{differential input resistance.} \end{cases}$

Example: $\mu A\, 741$

$$\begin{cases} r_d = 2\,M\Omega \\ r_O = 75\ \Omega \\ a = 200.000\,\frac{V}{V} = 200\,\frac{V}{mV}. \end{cases}$$

2 **Ideal Op Amp**

Desired: $\begin{cases} r_d \to \infty \\ r_O \to 0 \\ a \to \infty \end{cases}$



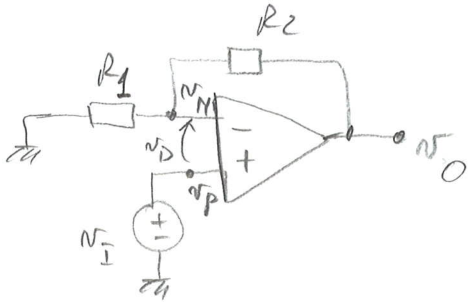
Because we want to minimize loading! and have a gain as big as possible!

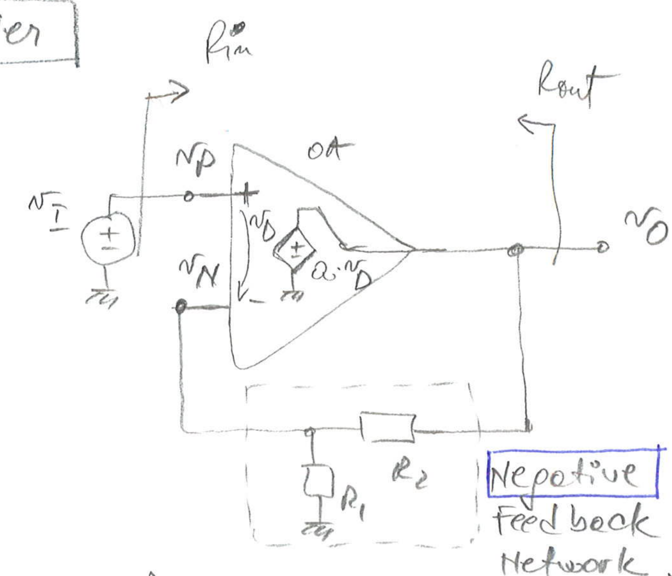
Desired also: $\begin{cases} i_N = 0 \\ i_P = 0 \end{cases}$

Very commonly use in a "first phase" analysis of a given circuit that uses Op Amp's!

Basic Op Amp configurations

3 The Noninverting Amplifier





$$\left.\begin{array}{l} v_D = v_P - v_N \\ \begin{cases} v_P = v_I \\ v_N = \dfrac{R_1}{R_1+R_2}\cdot v_O \end{cases}\end{array}\right\} \Rightarrow \left.\begin{array}{l} v_D = v_I - \dfrac{R_1}{R_1+R_2} v_O \\ v_D \cdot a = v_O = a(v_P - v_N)\end{array}\right\} \Rightarrow$$

$$\Rightarrow v_O = a\left[v_I - \frac{R_1}{R_1+R_2}\cdot v_O\right] \Leftrightarrow v_O\left(1 + a\frac{R_1}{R_1+R_2}\right) = a v_I$$

$$\Rightarrow A_v = \frac{v_O}{v_I} = \frac{a}{1 + a\dfrac{R_1}{R_1+R_2}} = \frac{R_1+R_2}{R_1}\cdot\frac{a}{a + \dfrac{R_1+R_2}{R_1}}$$

pull out

$$\boxed{A_v = \frac{v_O}{v_I} = \underbrace{\left(1 + \frac{R_2}{R_1}\right)}_{\triangleq A_{ideal}} \cdot \frac{1}{1 + \left(1 + \dfrac{R_2}{R_1}\right)\cdot\dfrac{1}{a}}}$$

It's an amplifier! Noninverting.

because $A_v \xrightarrow[a\to\infty]{} A_{ideal} = 1 + \frac{R_2}{R_1}$

Terminology: $a \triangleq$ also known as the open-loop gain

$A_v \triangleq$ closed-loop voltage gain.

$\boxed{A_{ideal}}$ becomes independent of $\boxed{a}$. Depends only on external R_1, R_2

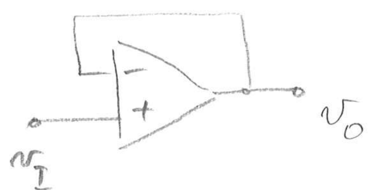
$\Rightarrow$ Controllability, Stability with temp. variations.

The price paid: gain ∞ (eg. 200.000) is now $1+\frac{R_2}{R_1}$ (eg. 10) !

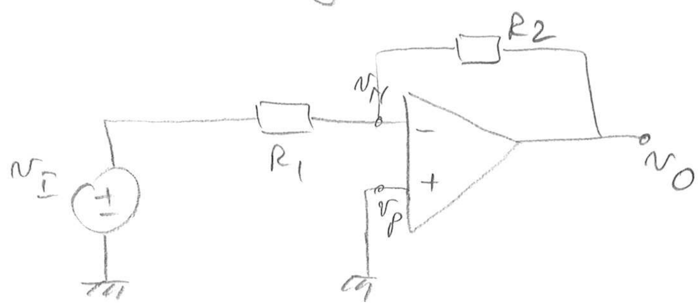
Input and Output resistances:

$$\begin{cases} R_i = \infty \\ R_o = 0 \end{cases}$$

- Voltage follower



(4) The inverting amplifier



Homework: Derive $A_v = \frac{v_O}{v_I}$ similarly as we did for the non inverting configuration.

$$\boxed{A_v = \frac{v_O}{v_I} = \left(-\frac{R_2}{R_1}\right)\cdot \frac{1}{1+\left(1+\frac{R_2}{R_1}\right)\cdot a}}$$