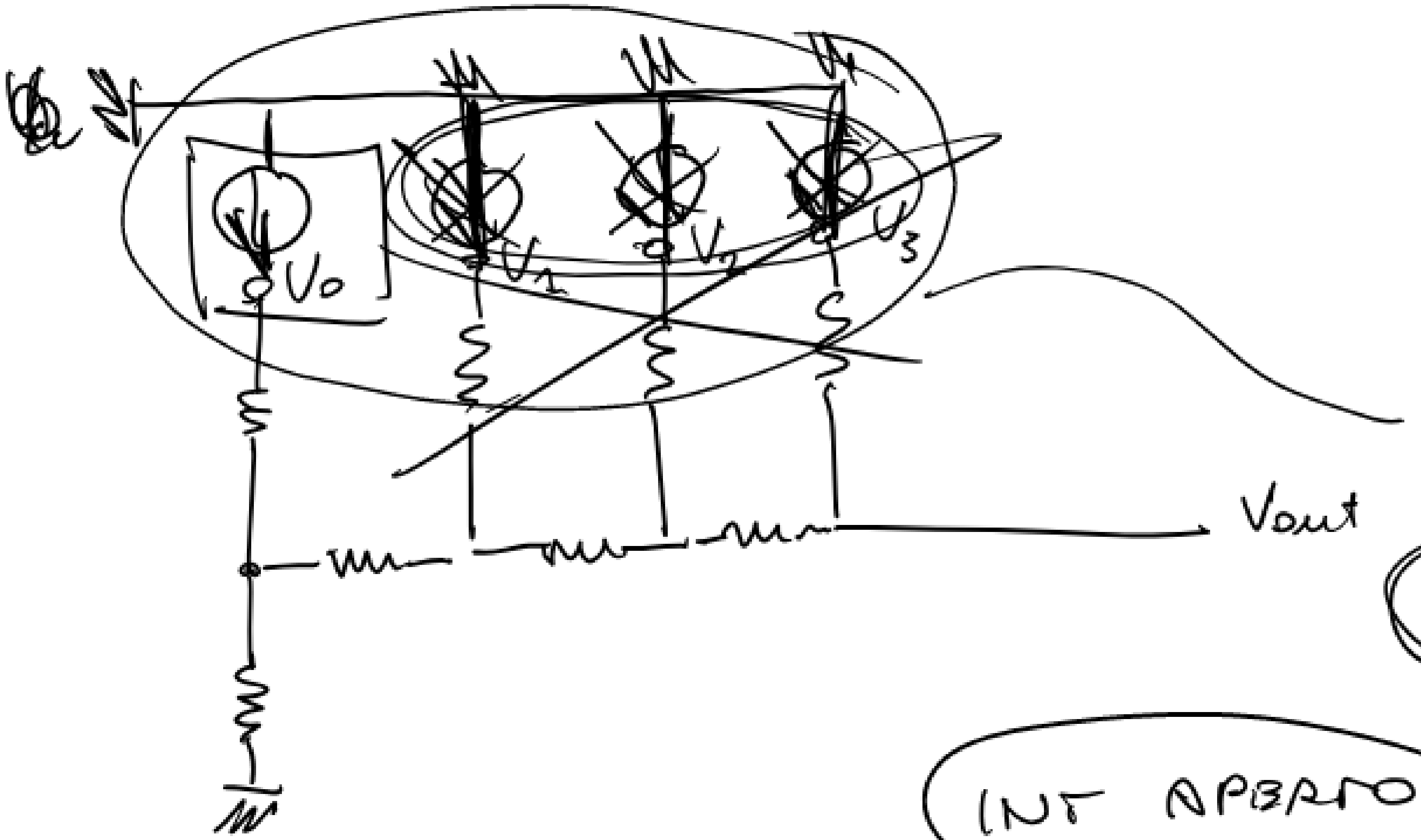
EL. ANALOGICA

DAC "a vuoto"



~~Principio Sovrapposizione~~

V_{out} (0) (1) (2) (3)

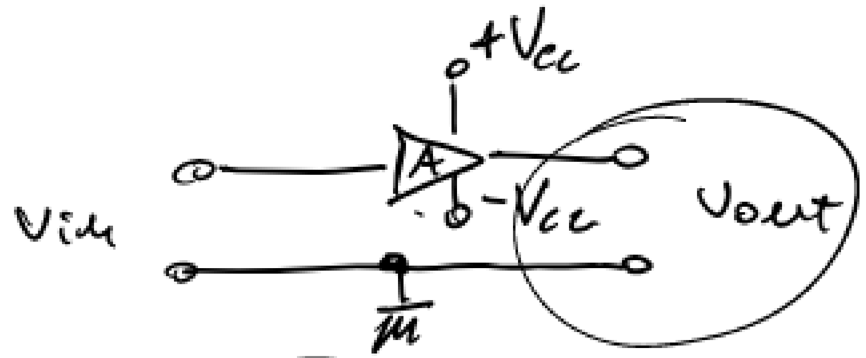
SI PRINC SOVRAPP.

$V_i \neq 0$ $V_j = 0$

INT APERTO

OGNI COMBINAZIONE → PRINCIPIO DI SOVRAPPOS

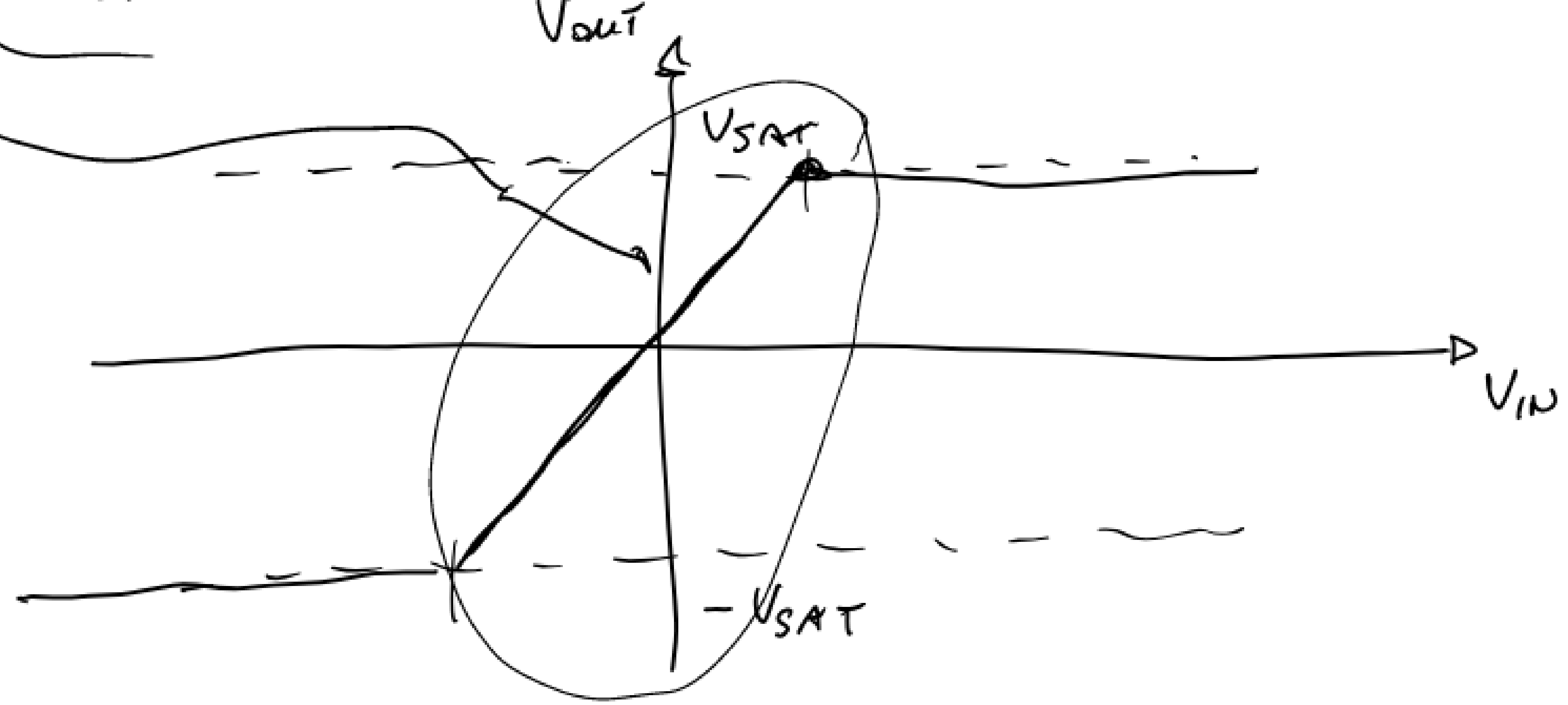
AMPLI. TENSIONE



$$V_{out} = A \cdot V_{in}$$

$$A > 1$$

$$V_{SAT} = V_{out}^{MAX} \Rightarrow V_{SAT} = A \cdot V_{IN}^{MAX} \Rightarrow V_{IN}^{MAX} = \frac{V_{SAT}}{A}$$

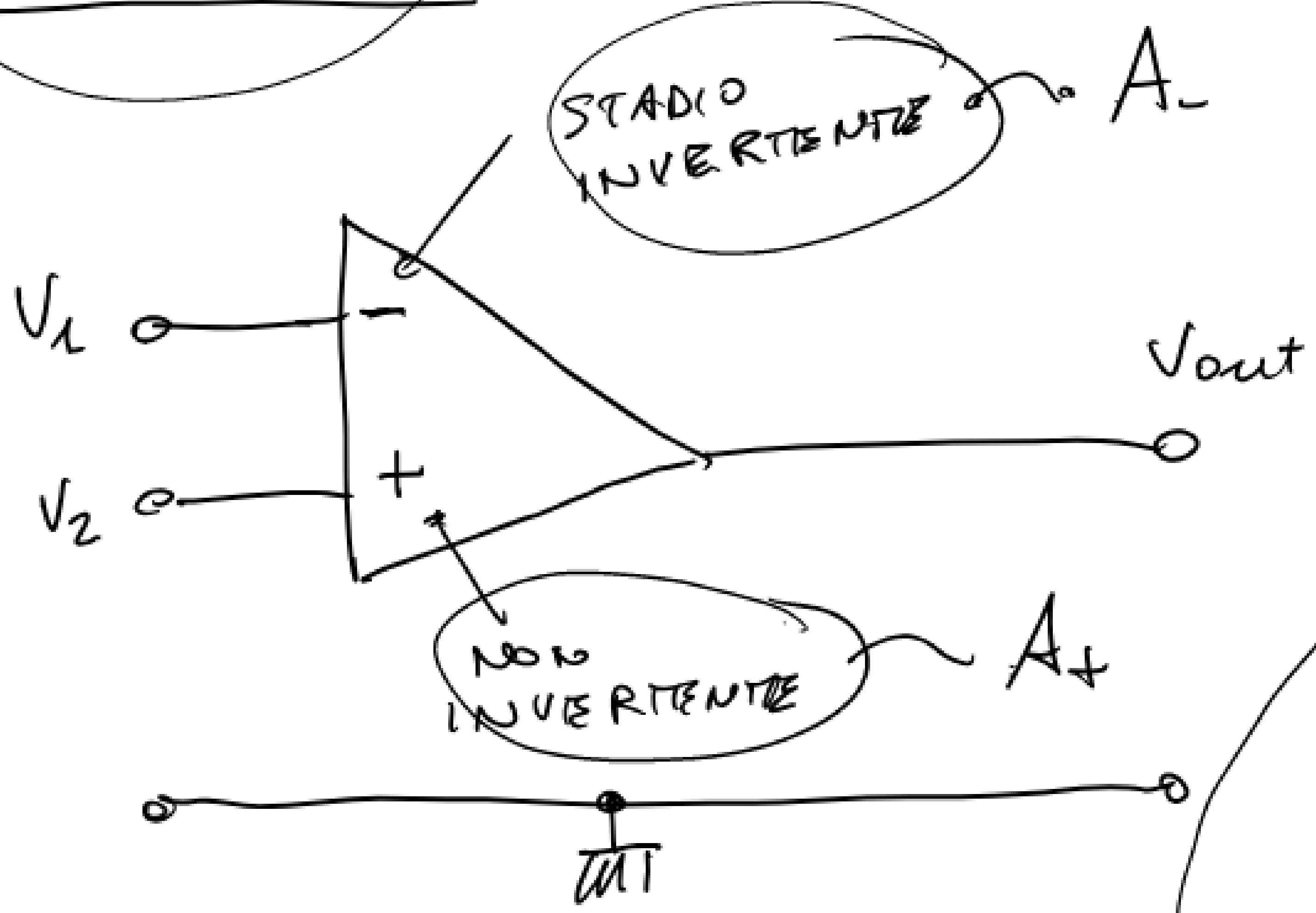


$$Z_{IN} = +\infty$$

$$Z_{OUT} \approx 0$$

AMPLI OPERAZIONALI

AMPLI DIFFERENZIALI



$$V_{out} = A(V_2 - V_1)$$

IDEALE $A_+ = A_- = A$ → IDEALE

REALE $A_+ \simeq A_-$.

$$V_{out} = A_+ \cdot V_2 - A_- \cdot V_1 \quad \left[= A(V_2 - V_1) \right]$$

$$A_+ = A_d + \frac{A_{CM}}{2} \qquad A_- = A_d - \frac{A_{CM}}{2}$$

A_d = guadagno differenziale

A_{CM} = guadagno di MODO COMUNE

28/04 ②

$V_{out} = A_+ V_2 - A_- V_1 \qquad A_+ = A_d + \frac{A_{CM}}{2} \qquad A_- = A_d - \frac{A_{CM}}{2}$

$$V_{out} = \left(A_d + \frac{A_{CM}}{2}\right) V_2 - \left(A_d - \frac{A_{CM}}{2}\right) V_1 =$$

$$V_{out} = A_d (V_2 - V_1) + A_{CM} \frac{V_1 + V_2}{2}$$

$V_1 = V_2 = V_{in}$ $\quad A_{CM} V_{in}$

V MEDIO fra V_1 e V_2

IDEALE

A_d

$A_{CM} = 0$

REALE $A_{CM} \ll A_d$

$A_{CM} \approx 0$

1) Misura A_d $\qquad A_{CM} \frac{V_1 + V_2}{2} = 0$ $\qquad V_1 = -V_2$

2) Misura A_{CM} $\qquad A_d (V_2 - V_1) = 0$ $\qquad V_1 = V_2$

$V_{out} = A_d \, \Delta V + CM$

$\Delta V = \text{cost.}$ $\qquad V_{out}^{CM} \neq \text{cost.}$

ΔV V_2, V_1 → V_{out}^{CM}

$\neq$

ΔV V_2, V_1 → V_{out}^{CM}

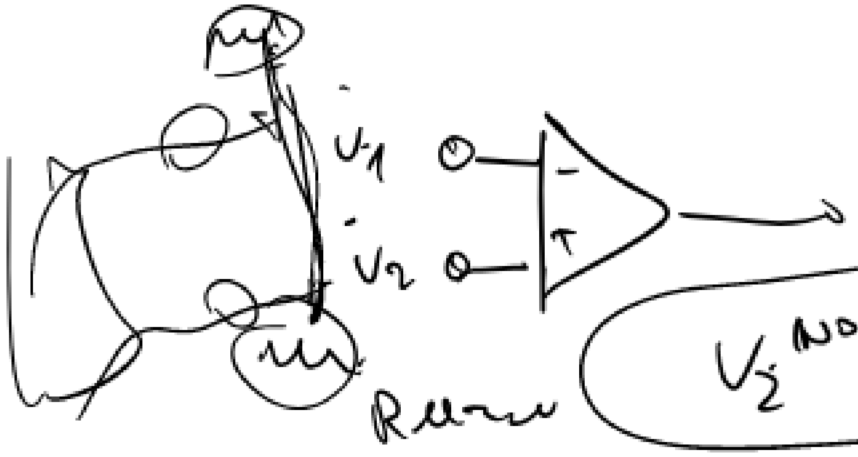
Rapporto di Reiezione di modo comune:

$$CMRR = \frac{|A_d|}{|A_{CM}|}$$

→ $+\infty$ IDEALE

→ 60-80 dB REALE

$\approx 10^7$



$$V_2^{noise} - V_1^{noise} = 0$$

CMRR
COMMON
MODE
REJECTION
RATIO

AMP. OPERAZIONALE

è amp. diff.

$$A_d = +\infty \text{ (ideale)} \approx 10^5 \text{ (reale)}$$ ⇒ SATURAZIONE ANELLO APERTO

	IDEALE	REALE
Z_i	$+\infty$	$> 1\,M\Omega$
Z_o	0	$< 10\,\Omega$
A_d	$+\infty$	10^5 ⇒ SAT
BW	$+\infty$	limitata
V_{SAT}	$+\infty$	$\pm V_{cc}$
CMRR	$+\infty$	60 - 80 dB (10^7)
Slew Rate	$+\infty$	$\approx 10\ V/\mu s$

$$A_{cm} \approx 10^{-2}$$

$$\frac{A_d}{A_{cm}} = \frac{10^5}{10^{-2}} = 10^7$$

Saturazione

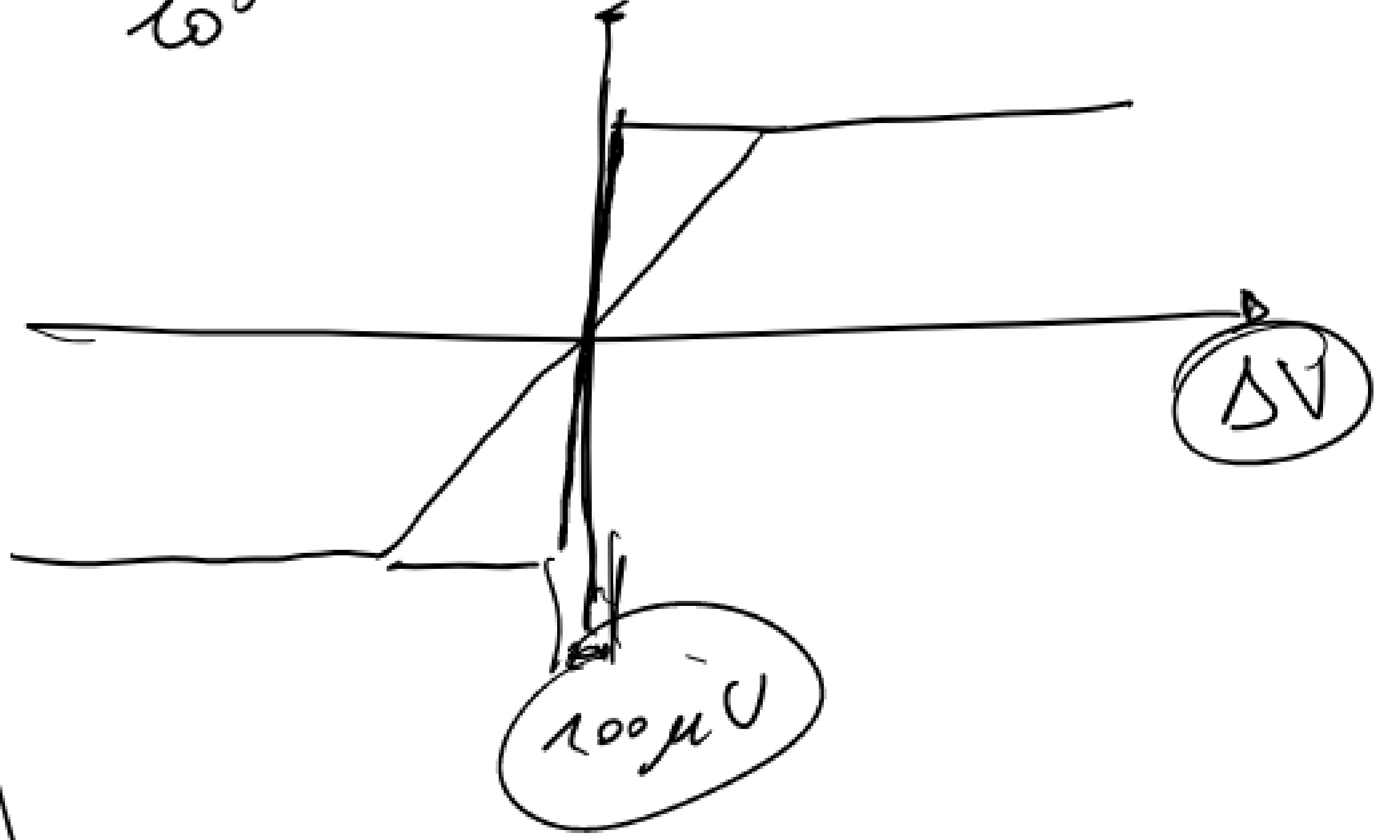
A grande $\quad \Delta V_i = (V_2 - V_1)$

$\Rightarrow V_{SAT}$

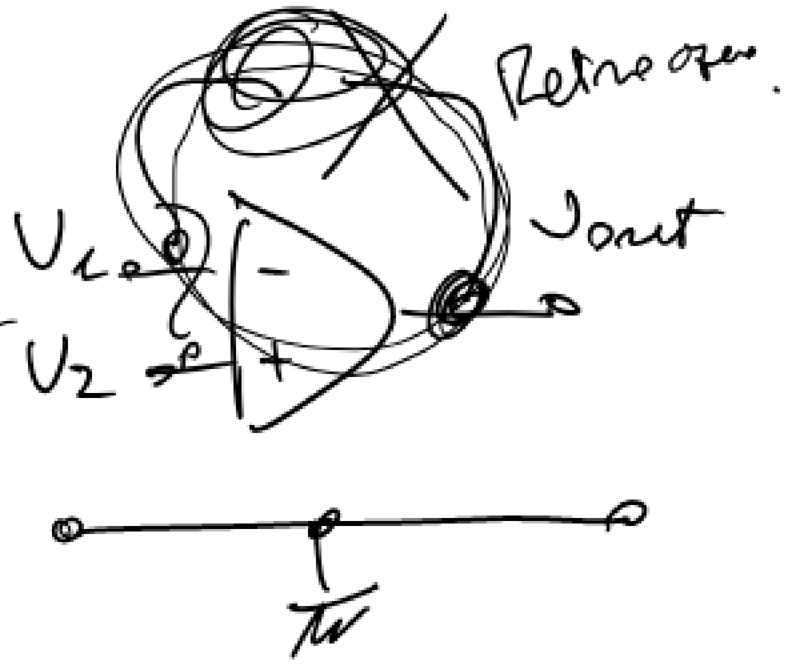
$$\Delta V_i > \frac{V_{SAT}}{A}$$

$V_{SAT} = 10\,V \qquad A = 10^5$

$$\Delta V_i = \frac{10\,V}{10^5} = 10^{-4}\,V = 0{,}1\,mV = 100\,\mu V$$



Zona lineare molto limitata



$\Rightarrow$ ANELLO APERTO $\Rightarrow$ SAT

PRINCIPIO DEL CORTO CIRCUITO VIRTUALE

$V_{out} = A(V_2 - V_1) = A \cdot \Delta V$

$V_2 \simeq 100\,\mu V$

$V_1 \simeq 100{,}1\,\mu V$

$\Delta V \simeq 100\,\mu V \Rightarrow$ SAT

Pratica $V_1 \simeq V_2 \Rightarrow \Delta V \simeq 0$

$- \; , \; +$

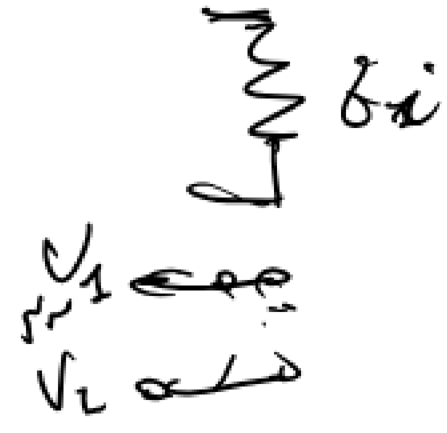
CORTO CIRCUITO

$\Delta V \neq 0$ (piccolo confronto V_1, V_2) $\Rightarrow$ i due ingressi sono allo stesso potenziale.

CORTO CIRCUITO VIRTUALE

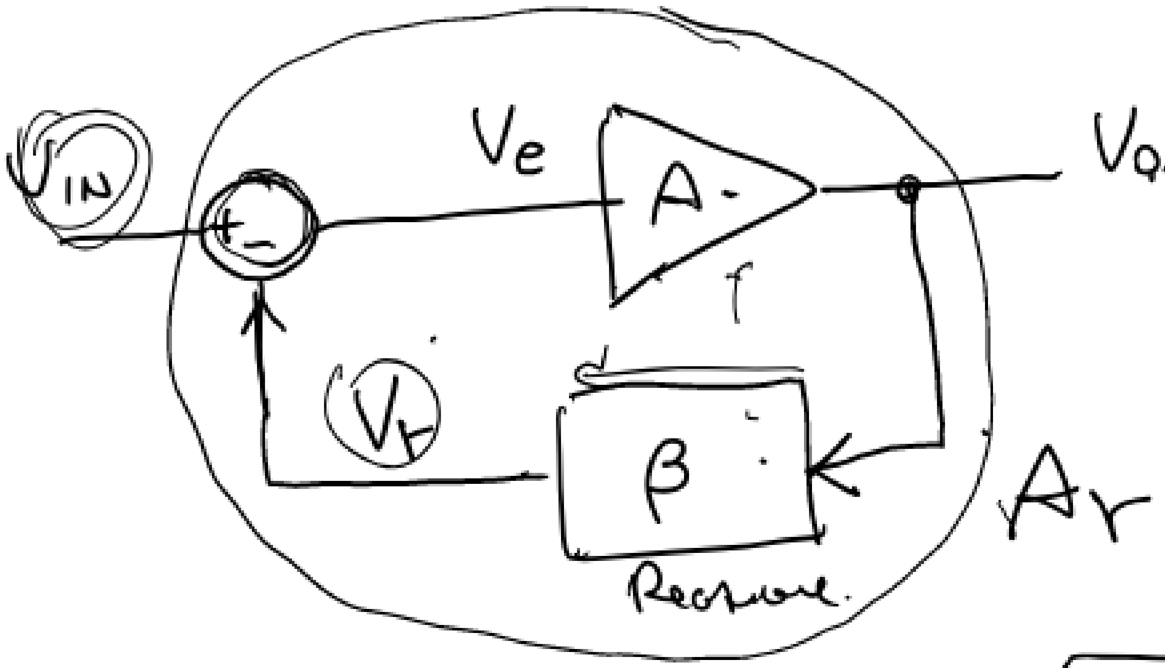
potenziali $\neq$

$Z_i \simeq +\infty$



28/04 (8)

REAZIONE (RETROAZIONE)



$$A = \frac{V_{out}}{V_e} \qquad \beta = \frac{V_r}{V_{out}} \qquad \boxed{A_r = \frac{V_{out}}{V_{in}}} \qquad A_r = f(A, \beta)$$

$$V_e = V_{in} - V_r \Rightarrow V_{in} = V_e + V_r$$

$$A_r = \frac{V_{out}}{V_{in}} = \frac{V_{out}/V_e}{(V_e + V_r)/V_e} = \frac{A}{1 + \frac{V_r}{V_e}\frac{V_{out}}{V_{out}}} = \frac{A}{1 + \beta A}$$

($\frac{V_{out}}{V_e} \to A$, $\frac{V_r}{V_{out}} \to \beta$)

$$\boxed{A_r = \frac{A}{1 + \beta A}}$$

$$A_r = \frac{A}{1+\beta A}$$

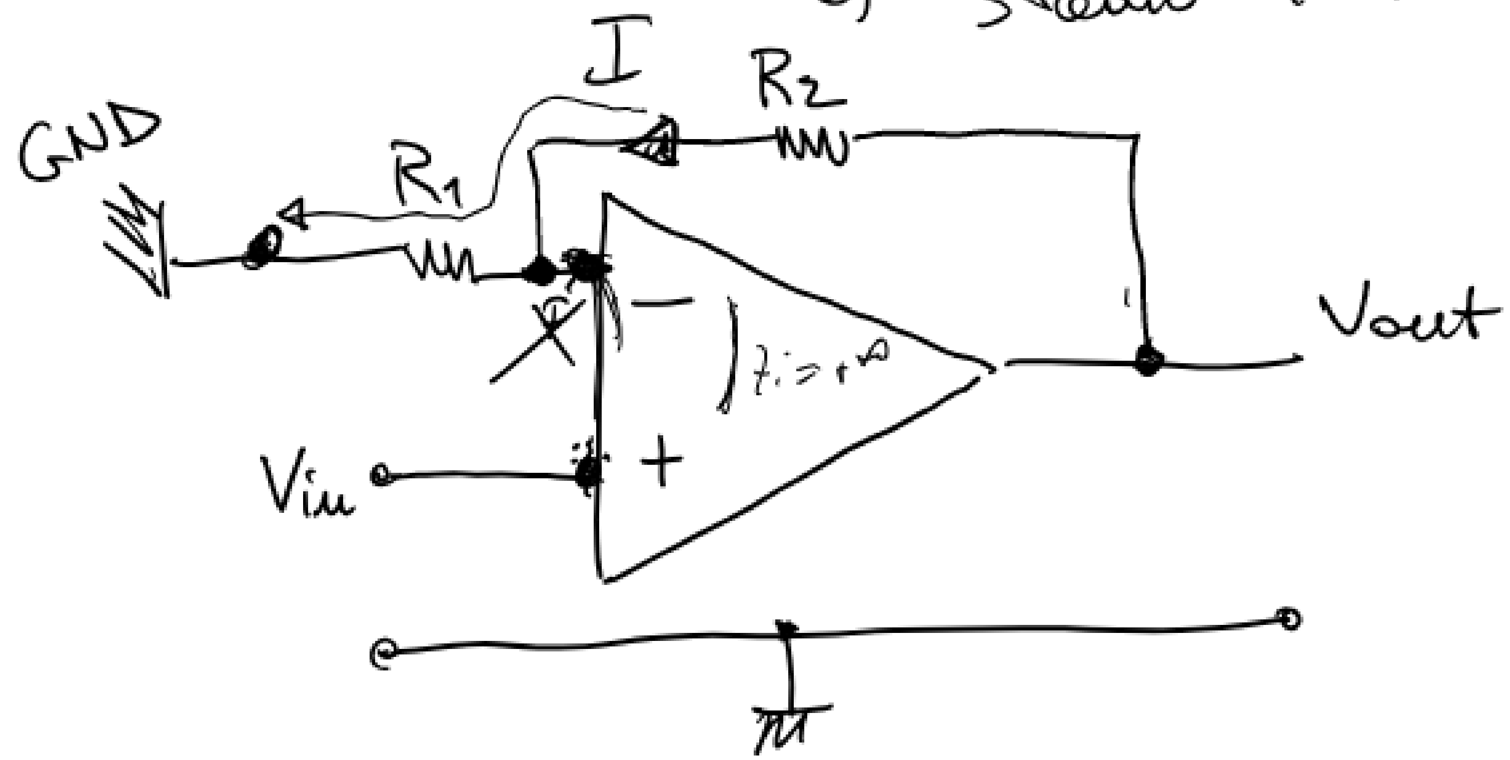
- $1+\beta A > 1$ → REAZIONE NEGATIVA $\quad A_r < A$
- $1+\beta A < 1$ → REAZIONE POSITIVA $\quad A_r > A$
- $1+\beta A$ ~~$= 1$~~ → NO REAZIONE $\quad A_r = A$
- $1+\beta A = 0$, $\beta A = -1$ → $A_r \to +\infty$

OSCILLATORE

generatore segnale in uscita anche senza ~~V_{in}~~

A.O. CONNESSIONE NON INVERTENTE

- Segnale V_{in} allo stadio non invertente.
- Stadio invertente reazione



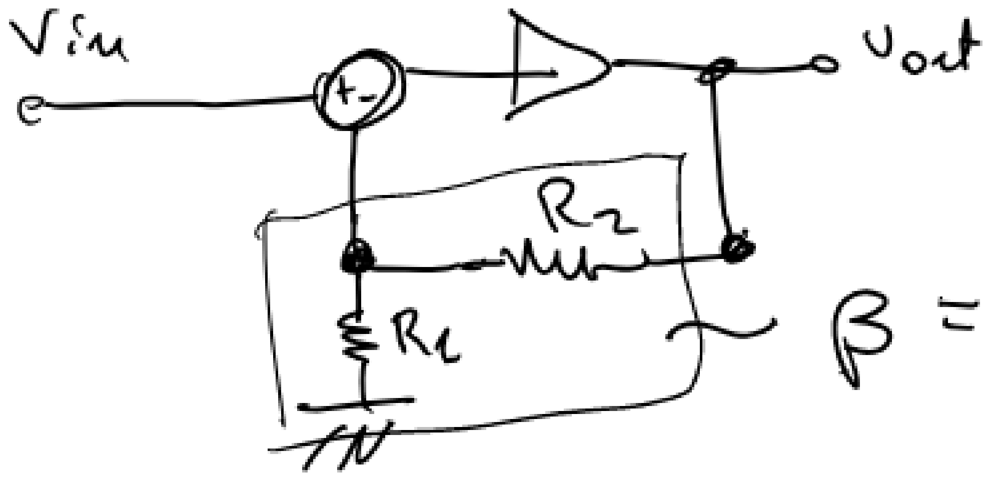
MODO 1

1) $Z_i = +\infty$. I uguale R_1, R_2 $\quad V_{out} = (R_1 + R_2) \cdot I$

2) Principio c.c.v. $\quad V_{in}$ d.d.p. ai capi $R_1 \Rightarrow V_{in} = R_1 \cdot I$

$$A_v = \frac{V_{out}}{V_{in}} = \frac{(R_1+R_2) I}{R_1 \cdot I} = 1 + \frac{R_2}{R_1} \Rightarrow \boxed{A_v = \left(1 + \frac{R_2}{R_1}\right)}.$$

MODO II — A.O. CONN. NON INVER.



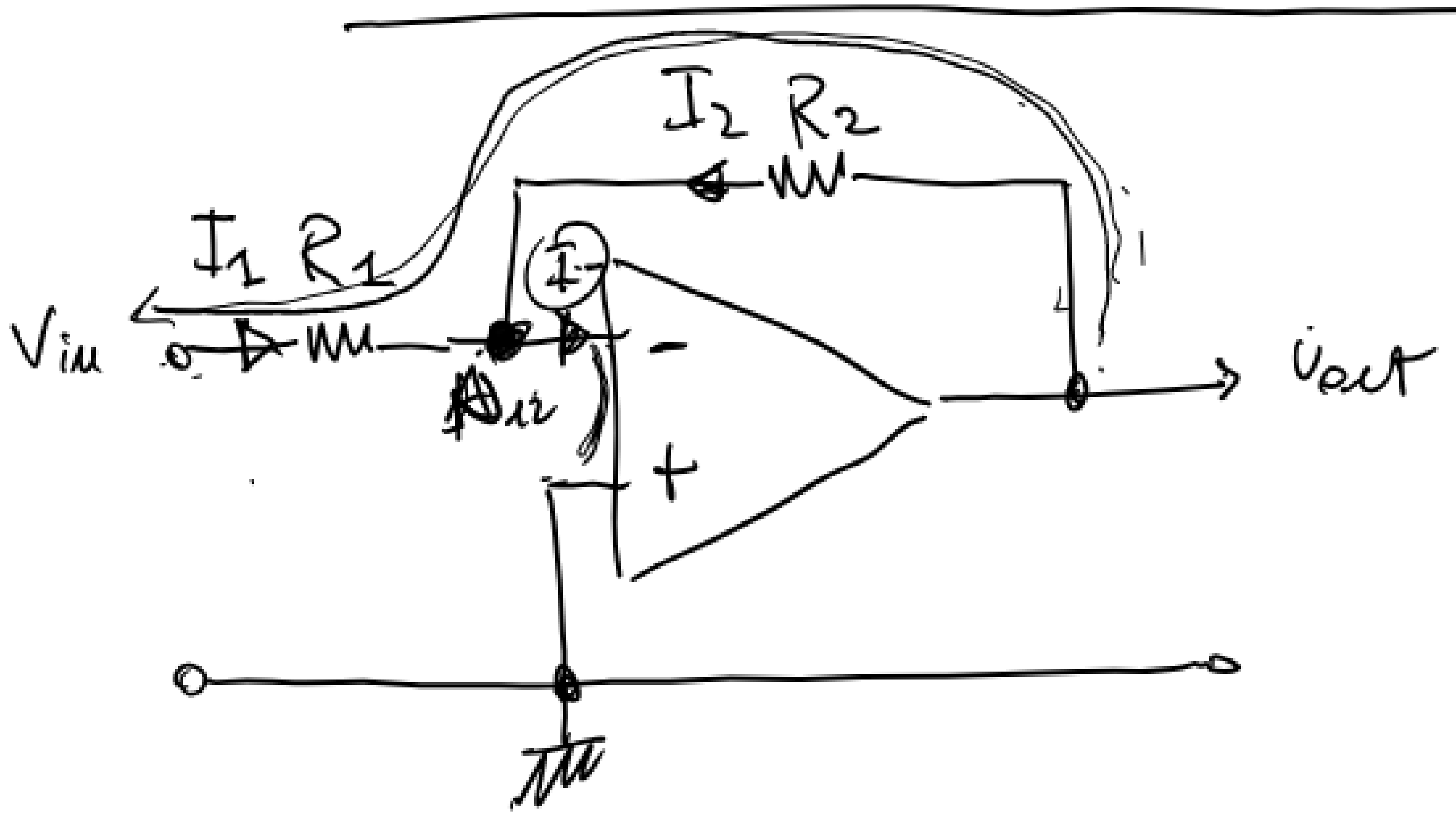
$$\beta = \frac{R_1}{R_1 + R_2}$$

$$A_r = \frac{A}{1+\beta A} = \frac{1}{\frac{1}{A}+\beta} \simeq \frac{1}{\beta} = \frac{R_1+R_2}{R_1} = 1 + \frac{R_2}{R_1}$$

$A \to +\infty$ ⇒ $\frac{1}{A} \to 0$ ⇐ questa stessa considerazione deriva dal princ. C.C.V.

$$\Rightarrow \boxed{A_r = 1 + \frac{R_2}{R_1}}$$

A.O. CONNESSIONE INVERTENTE



1) Prim. c.c.v. $N_{12} \simeq GND$

$$\begin{cases} V_{out} = R_2 \cdot I_2 \\ V_{in} = R_1 \cdot I_1 \end{cases}$$

2) $Z_i = +\infty \Rightarrow I_- \simeq 0$ $\quad |I_1| = |I_2|$ $\quad \boxed{I_1 = -I_2}$ $\quad \boxed{I = I_2}$

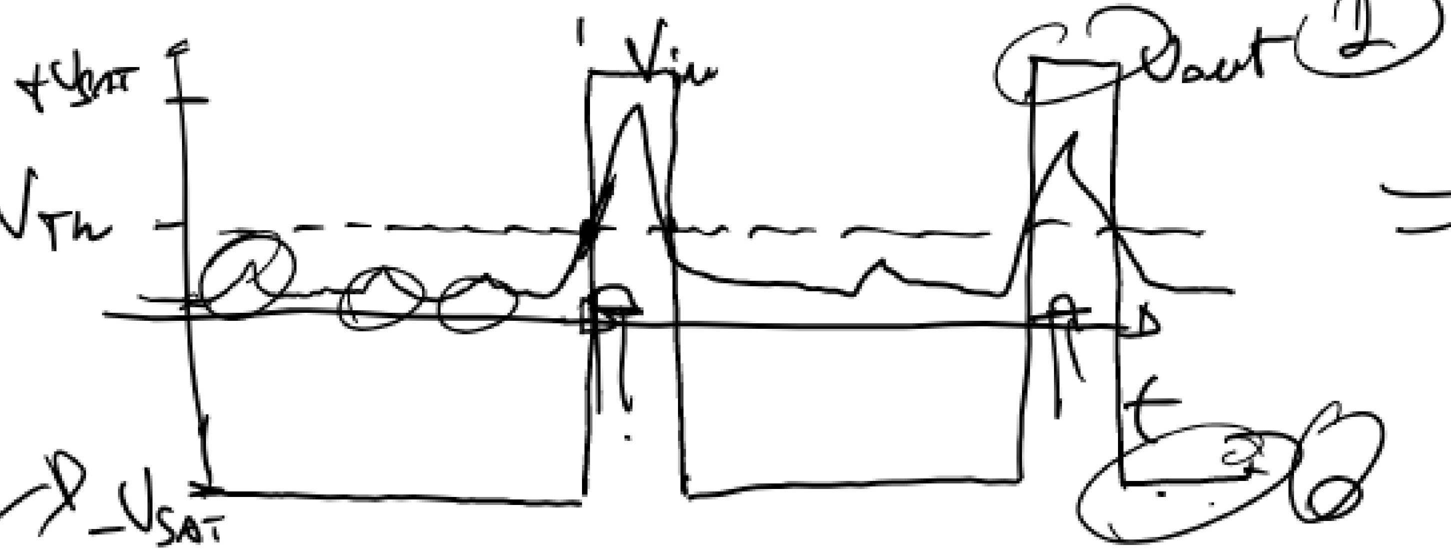
$I_1 = -I$

$$\left. \begin{aligned} V_{out} &= R_2 \cdot I \\ V_{in} &= -R_1 \cdot I \end{aligned} \right\}$$

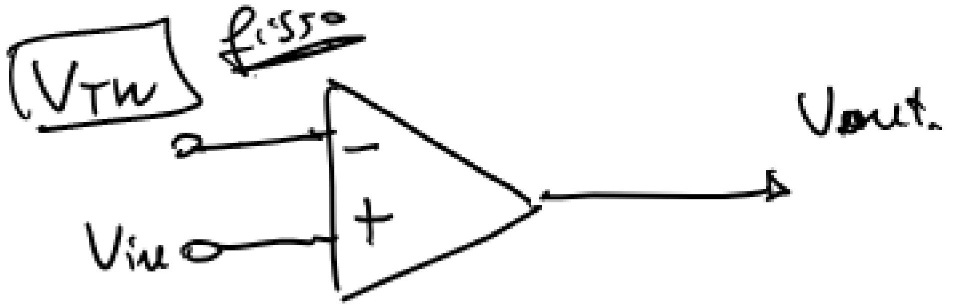
$$\Rightarrow A_v = \frac{V_{out}}{V_{in}} = -\frac{R_2 \cancel{I}}{R_1 \cancel{I}} \Rightarrow \boxed{A_v = -\frac{R_2}{R_1}}$$

Applicazioni A.O.

DISCRIMINATORE — A.O. ANELLO APERTO



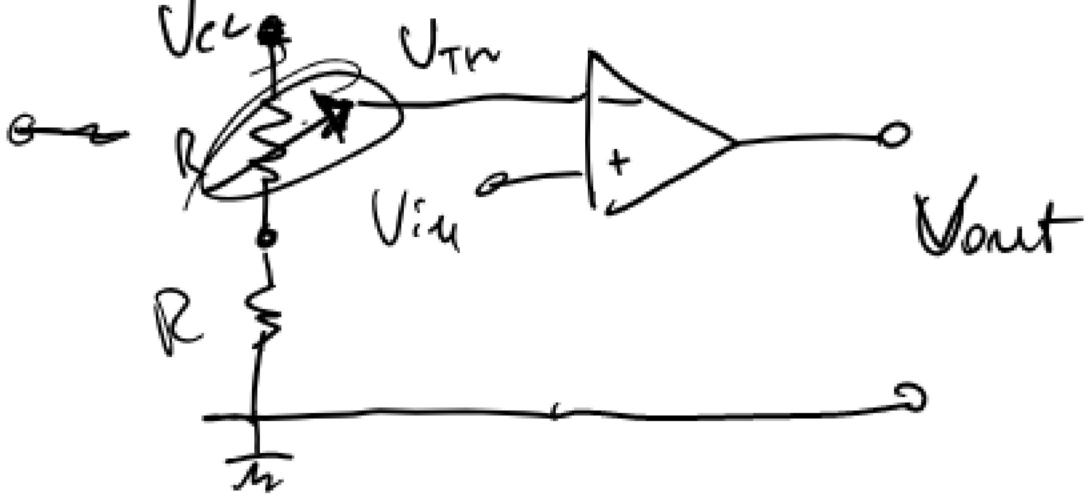
⇒ c'è evento buono / non c'è



$$V_{out} = A\,(V_{in} - V_{TH}) \;\to\; +V_{SAT} \;/\; \to\; -V_{SAT}$$

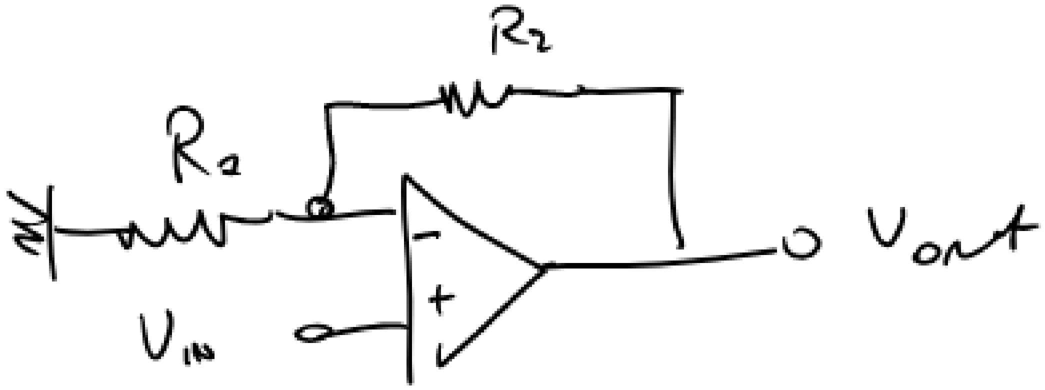
$V_{in} > V_{TH} \Rightarrow V_{out} = +V_{SAT}$

$V_{in} < V_{TH} \Rightarrow V_{out} = -V_{SAT}$



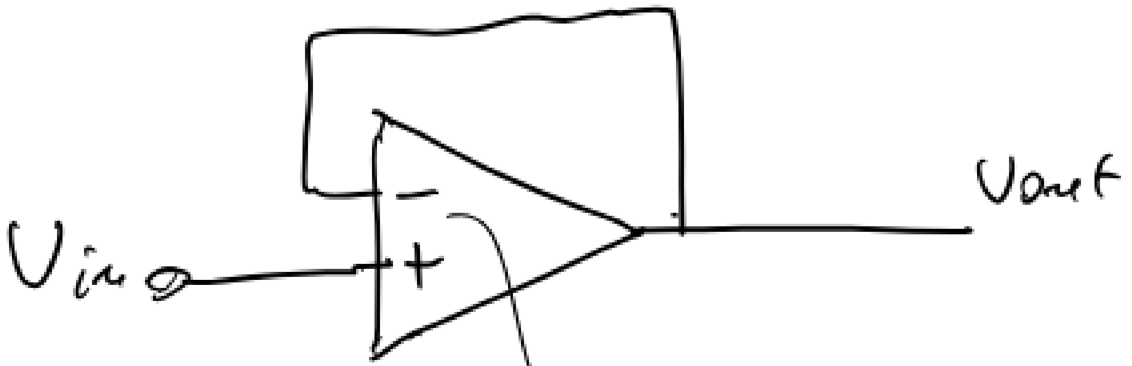
INSEGUITORE DI TENSIONE

A.O. CONN. NON INVERTENTE



$A_v = 1 + \frac{R_2}{R_1}$ ($R_2 \to 0$, $R_1 \to +\infty$)

$R_2 = 0$
$R_1 = +\infty$

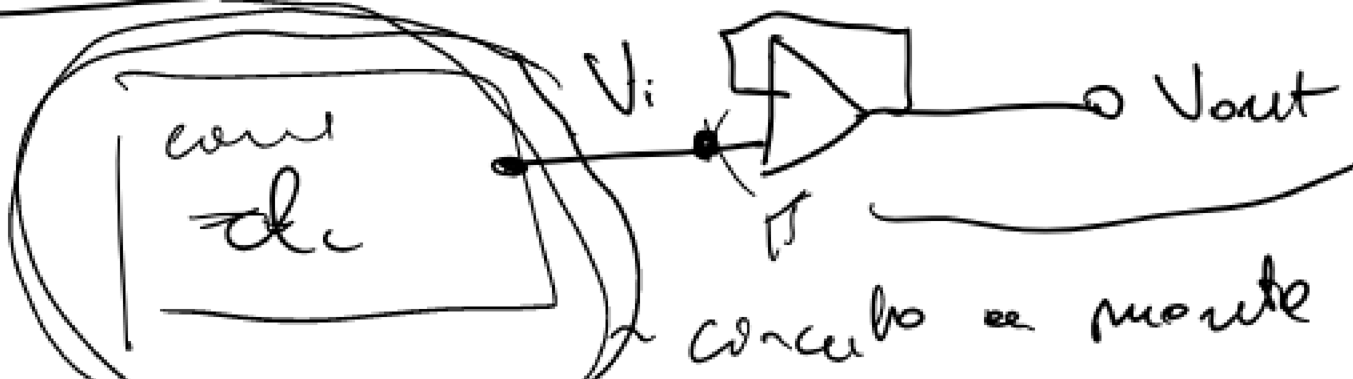


$A_v = 1$

$V_{out} = V_{in}$

$Z_i = +\infty$

ADATTAMENTO DI IMPEDENZA



circuito a monte NON SENTE A.O. come un carico

$V_0 - R_i I \Rightarrow V_{in} = \frac{R_U}{R_i + R_U} V_0$

GIOVEDI' 30/04

28/04

Introduzione ESP. SIM. A.O.

- Ad Acm
- Conn. non. invert / invert.
- DISCRIMINATORE
- INSEGUITORE TENSIONE
- OSCILLATORE (?)

NON INSTALLARE

LABVIEW