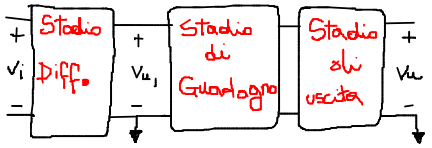
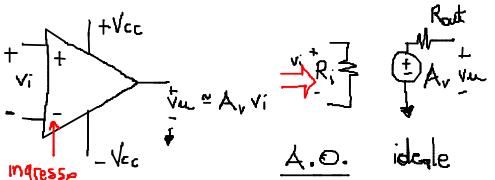
Amplificatori operazionali

Amplificatore DIFFERENZIALE a più stadi



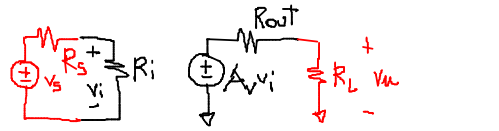
Simbolo



A.O. ideale

- $R_i \sim \infty$
- $R_{out} = 0$
- $A_v \sim \infty$
- $CMRR \sim \infty$
- $f_H \sim \infty$

Ampli. ideale di V



$$v_i = v_S \frac{R_i}{R_i + R_S} \qquad v_u = \frac{R_L}{R_L + R_{out}} A_v v_i$$

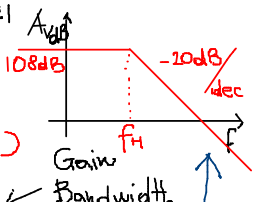
$$\frac{v_u}{v_S} = A_v \frac{R_L}{R_L + R_{out}} \cdot \frac{R_i}{R_i + R_S}$$

NON DIPENDE DA R_L, R_S

se $R_i \to \infty$, $R_{out} = 0$ $\to$ $\frac{v_u}{v_S} = A_v$ Amplificatore di tensione ideale

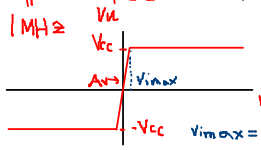
A.O. Reale $\to$ μA741

$R_i \sim 2M\Omega$
$R_{out} \sim 25\Omega$
$A_v \sim 250\,000$
$CMRR \sim 10^5$ (100 dB)
$f_H \sim 4Hz$

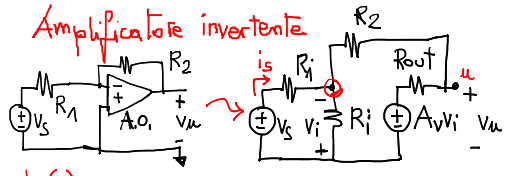


$A_v f_H = GBP$ PGB

$= 1MHz$



Amplificatore invertente



nodo (-)

$$-v_i' \left[\frac{1}{R_1} + \frac{1}{R_i'} + \frac{1}{R_2}\right] - v_S \frac{1}{R_1} - v_u \frac{1}{R_2} = 0$$

nodo (u)

$$v_u \left[\frac{1}{R_{out}} + \frac{1}{R_2}\right] - A_v v_i' \frac{1}{R_{out}} + v_i' \frac{1}{R_2} = 0$$

$$\frac{v_u \left[\frac{1}{R_{out}} + \frac{1}{R_2}\right]\left[\frac{1}{R_1} + \frac{1}{R_i'} + \frac{1}{R_2}\right]}{\frac{A_v}{R_{out}} - \frac{1}{R_2}} + \frac{v_u}{R_2} = \frac{v_S}{R_1}$$

se $A_v \to \infty$ $\to$ $v_u = -\frac{R_2}{R_1} v_S$

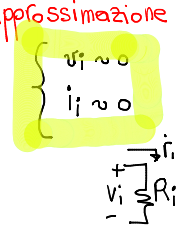
$i_S = \frac{v_S - v_i'}{R_1}$ $\qquad v_i' = \frac{v_u}{A_v} \left[\frac{1}{R_{out}} + \frac{1}{R_2}\right] \Big/ \left[\frac{A_v}{R_{out}} - \frac{1}{R_2}\right]$

se $A_v \to \infty$ $v_i \to 0$

$i_S \to \frac{v_S}{R_1}$ $\to$ $R_i' = \frac{v_S}{i_S} = R_1$

se $A_v \to \infty$ NON DIPENDONO DAI PARAMETRI dell A.O.

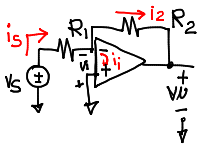
Approssimazione di corto circuito virtuale



$v_i = \frac{v_u}{A_v}$ se l'A.O funziona in zona lineare

$i_i = \frac{v_i}{R_i}$

NON è un corto circuito reale (perché anche $i_i \simeq 0$)



ccv $v_i = 0$ $v^- = 0$

$i_S = v_S / R_1$

$i_2 = i_S - i_i$

ccv $i_i = 0$

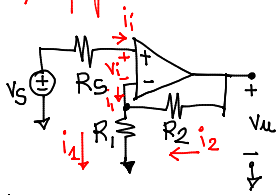
$i_2 = i_S$

$v_u = v^- - R_2 i_2 = -\frac{R_2}{R_1} v_S$ ($v^- \simeq 0$)

$R_b \simeq 0$ perché v_u non dipende da R_L

$R_{i_2} = \frac{v_S}{i_S} = R_1$

Amplificatore NON-INVENTENTE



$v_S = R_S i_i + v_i + R_1 i_1$ (ccv)

$v_S = R_1 i_1$

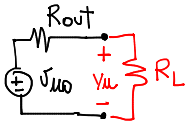
$i_i + i_2 = i_1$ (ccv)

$v_u = R_2 i_2 + R_1 i_1 =$

$v_u = \left(\frac{R_2}{R_1} + 1\right) v_S$

$R_{in} = \frac{v_S}{i_i} \to \infty$ ccv

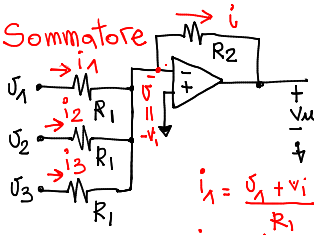
$R_{out} \simeq 0$ ccv [perché v_u non dipende da R_L]



$v_u = v_{uo} \frac{R_L}{R_L + R_{out}}$

Se $R_{out} = 0$ ⇕ v_u NON dipende da R_L

Sommatore



ccv

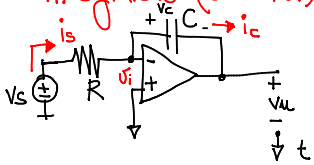
$i_1 = \frac{v_1 + v_i}{R_1} = \frac{v_1}{R_1}$

ccv $i_2 = \frac{v_2}{R_1}$ $i_3 = \frac{v_3}{R_1}$

$i_1 + i_2 + i_3 = i + i_i$

$v_u = v^- - iR_2 = -\left[\quad\right] \frac{R_2}{R_1}$ (ccv)

Integratore (di Miller)

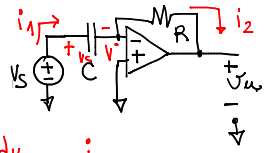


$i_S = \frac{V_S + v_i}{R} \overset{ccv}{=} \frac{V_S}{R}$

$i_C = i_S + i_i \overset{ccv}{=} i_S$

$v_u(t) = -v_i(t) - v_c(0) - \int_0^t \frac{i_c(t')}{C}\,dt'$ (ccv: v_i)

$v_u(t) = v_u(0) - \frac{1}{RC}\int_0^t v_S(t')\,dt'$



$\frac{dv_c}{dt} = \frac{i_1}{C}$ $\qquad$ $V_c = V_S + v_i \overset{ccv}{=} V_S$

$i_2 = i_1 + i_i \overset{ccv}{=} i_1$ $\qquad$ $v_u = -v_i - Ri_2 \overset{ccv}{=} -Ri_2$

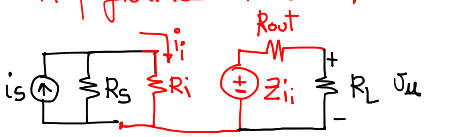
$v_u = -RC\,\frac{dv_S}{dt}$

Classificazione degli amplificatori (ideali)

fdt indipendente da carico e gen.

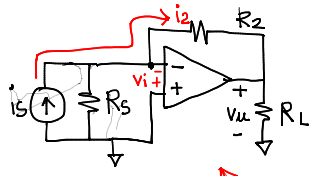
	R_i	R_{out}	
Amplificatore di tensione	∞	0	$A_v = \frac{v_u}{v_i}$
Amplificatore di corrente	0	∞	$A_i = \frac{i_u}{i_i}$
Amplificatore transresistivo	0	0	$R = \frac{v_u}{i_i}$
Amplificatore transconduttivo	∞	∞	$G = \frac{i_u}{v_i}$

Amplificatore transresistivo



$i_i = i_S \frac{R_S}{R_S + R_i}$ $\qquad$ $v_u = Z i_i \frac{R_L}{R_L + R_{out}}$

$\frac{v_u}{i_S} = Z \cdot \frac{R_S}{R_S + R_i} \cdot \frac{R_L}{R_L + R_{out}}$



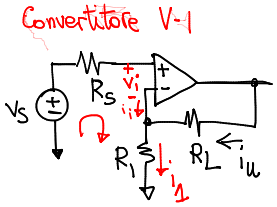
$i_2 = i_S$

$v_u = -v_i - R_2 i_2 \overset{ccv}{=}$

$v_u = -R_2 i_S$ — Convertitore I-V

$\frac{v_u}{i_S} = -R_2$ — transresistenza

Convertitore V-I



$v_S = R_S i_S + v_i + R_1 i_1 \overset{ccv}{=}$

$i_1 = i_u + i_i$

$i_u = \frac{V_S}{R_1}$

A_i transconduttivo

A. di corrente

$$i_i = i_s \frac{R_S}{R_S + R_i} \qquad i_u = A_i i_i \frac{R_{out}}{R_{out} + R_L}$$

$$\frac{i_u}{i_s} = A_i \frac{R_S}{R_S + R_i} \frac{R_{out}}{R_{out} + R_L}$$

Se $R_{out} \to \infty$, $R_i \to 0$ $\Rightarrow$ $A_i \to \frac{i_u}{i_s}$