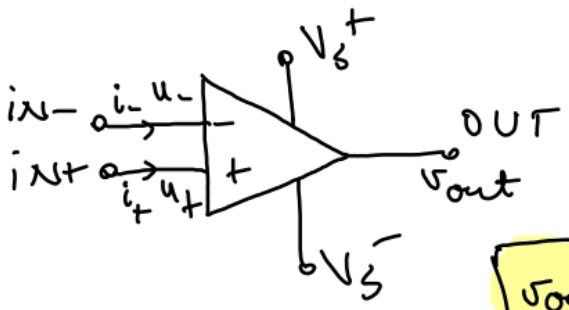
Laborator 6 FM2:

Amplificatorul operațional (AO)

„Op-amp"

AO - circuit integrat. → BJT, FET, MOSFET
→ rezistori
→ condensatori



V_S^+, V_S^- - tensiuni de alimentare (de regulă simetrice)

$$v_{out} = A_d (u_+ - u_-)$$

A_d - factor de amplificare în buclă deschisă („open-loop gain")

A.O. IDEAL:

$A_d = \infty$ $\quad i_-, i_+ = 0$

$z_{in} = \infty$

$z_{out} = 0$

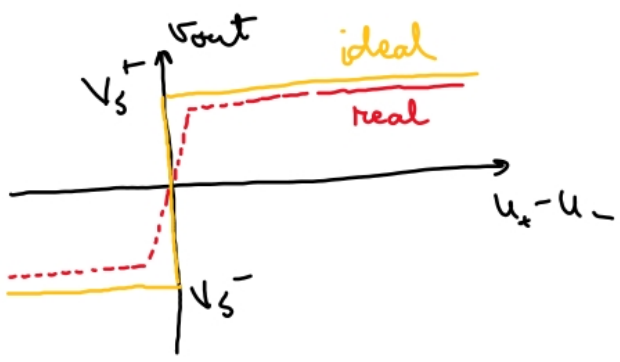
A.O REAL:

$A_d = 10^5$

$z_{in} = 10^6\ \Omega$

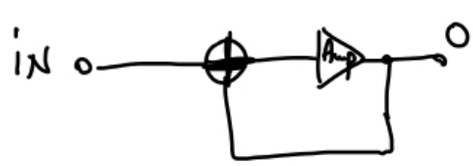
$z_{out} = 10^2 - 10^3\ \Omega$

$i_+, i_- \simeq 10^{-12} - 10^{-9}$ A

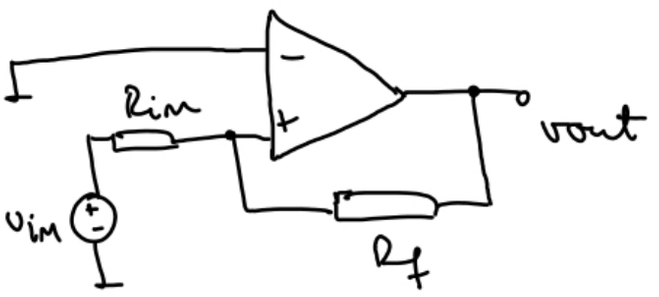


Reacția:

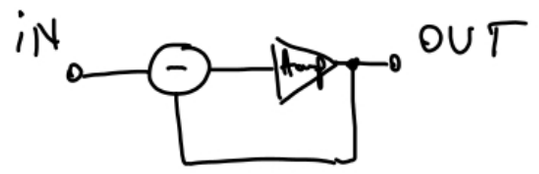
•) reacție pozitivă (positive feedback)



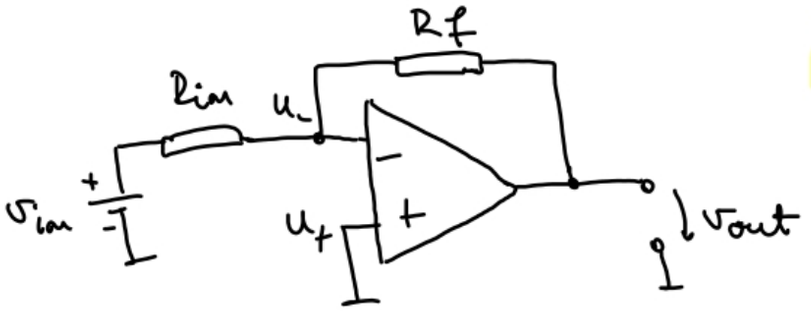
schemă bloc



•) reacția negativă (negative feedback)



Conexiunea inversoare:



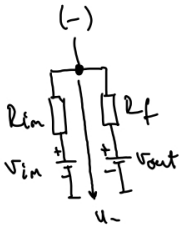
$v_{out} = ? = f(v_{in}, R_{in}, R_f)$.

$$v_{out} = A_d (u_+ - u_-)$$

considerăm A.O. ideal.

$u_+ = 0$

schema echivalentă pt. intrarea inversoare (−)



T. lui Millman

$$u_{ech} = \frac{\frac{v_1}{R_1} + \frac{v_2}{R_2} + \dots + \frac{v_m}{R_m}}{\frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_m}}$$

$$u_- = \frac{\frac{v_{in}}{R_{in}} + \frac{v_{out}}{R_f}}{\frac{1}{R_{in}} + \frac{1}{R_f}} =$$

$$= \frac{\frac{v_{in}R_f + v_{out}R_{in}}{R_{in}R_f}}{\frac{R_{in}+R_f}{R_{in}R_f}} =$$

$$= \frac{R_f v_{in} + R_{in} v_{out}}{R_{in} + R_f}$$

$$v_{out} = A_d(u_+ - u_-) = A_d\left(-\frac{R_f v_{in} + R_{in} v_{out}}{R_{in}+R_f}\right) =$$

$$= \frac{-A_d R_f v_{in} - R_{in} v_{out} A_d}{R_{in}+R_f}$$

$$(R_{in}+R_f)v_{out} = -A_d R_f v_{in} - A_d R_{in} v_{out}$$

$$(R_{in}+R_f+A_d R_{in})v_{out} = -A_d R_f v_{in}$$

$$v_{out} = -\frac{A_d R_f v_{in}}{A_d R_{in} + R_{in} + R_f}$$

$$v_{out} = -\frac{A_d R_f v_{in}}{A_d\left(R_{in} + \frac{R_{in}}{A_d} + \frac{R_f}{A_d}\right)}$$

($\frac{R_{in}}{A_d} \to 0$, $\frac{R_f}{A_d} \to 0$)

$$v_{out} = -\frac{R_f v_{in}}{R_{in}}$$

$$\boxed{v_{out} = -\frac{R_f}{R_{in}} \cdot v_{in}}$$

$$v_{out} = A_{inv} \cdot v_{in},$$

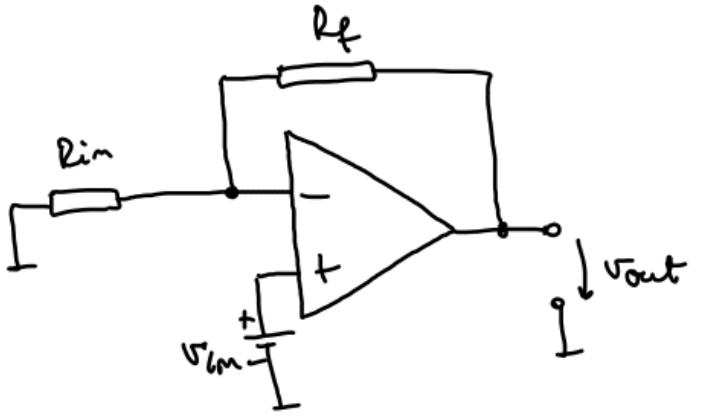
$$A_{inv} = -\frac{R_f}{R_{in}}.$$

$$u_- = \frac{R_f v_{in} + R_{in} v_{out}}{R_{in} + R_f} = \frac{R_f v_{in} - \frac{R_f}{R_{in}} v_{in} \cdot R_{in}}{R_{in}+R_f}$$

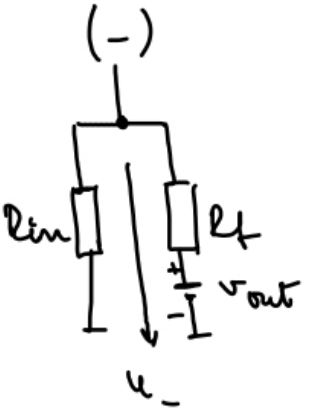
$$u_- = 0$$

Jm cobul r. neg. $\Rightarrow u_+ = u_-$

Conexiunea neinversoare:



$u_+ = v_{in}$



T. lui Millman

$$u_- = \frac{\frac{0}{R_{in}} + \frac{v_{out}}{R_f}}{\frac{1}{R_{in}} + \frac{1}{R_f}} =$$

$$= \frac{\frac{v_{out}}{R_f}}{\frac{R_{in}+R_f}{R_{in}R_f}} = \frac{v_{out}R_{in}}{R_{in}+R_f}$$

$u_+ \simeq u_-$

$$\Rightarrow \frac{v_{out}R_{in}}{R_{in}+R_f} = v_{in}$$

$$v_{out}R_{in} = v_{in}(R_{in}+R_f)$$

$$v_{out} = \frac{R_{in}+R_f}{R_{in}} v_{in}$$

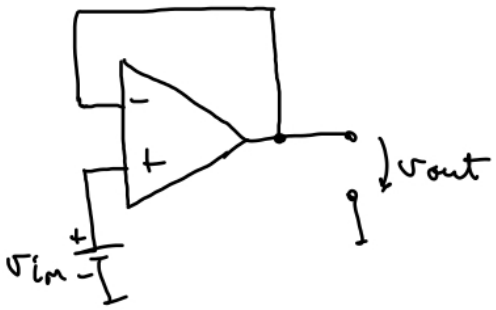
$$v_{out} = \left(1 + \frac{R_f}{R_{in}}\right) v_{in}$$

$$v_{out} = A_{neinv}\, v_{in}$$

$$A_{neinv} = 1 + \frac{R_f}{R_{in}}$$

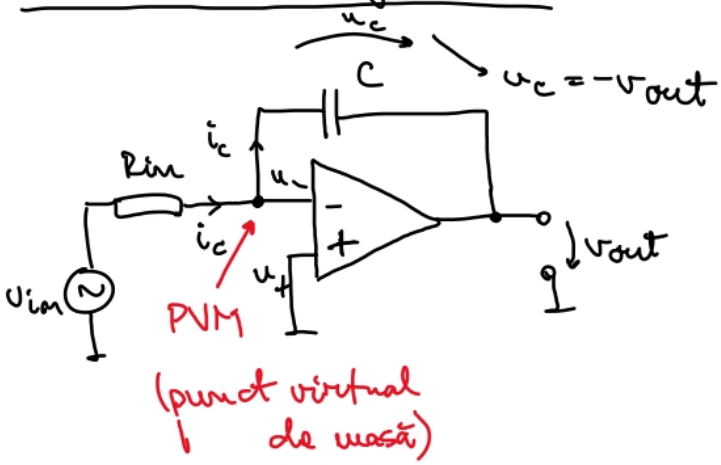
Conexiunea repetoare:

(„buffer", „voltage follower")



$u_+ = v_{in}$
$u_- = v_{out}$
$u_+ \approx u_-$
$\Rightarrow$
$\Rightarrow v_{out} = v_{in}$

Conexiunea integratoare:



Legea lui Ohm pt. capacități:

$$i_C = C \cdot \frac{du_C}{dt} = C \cdot \frac{d(-v_{out})}{dt}$$

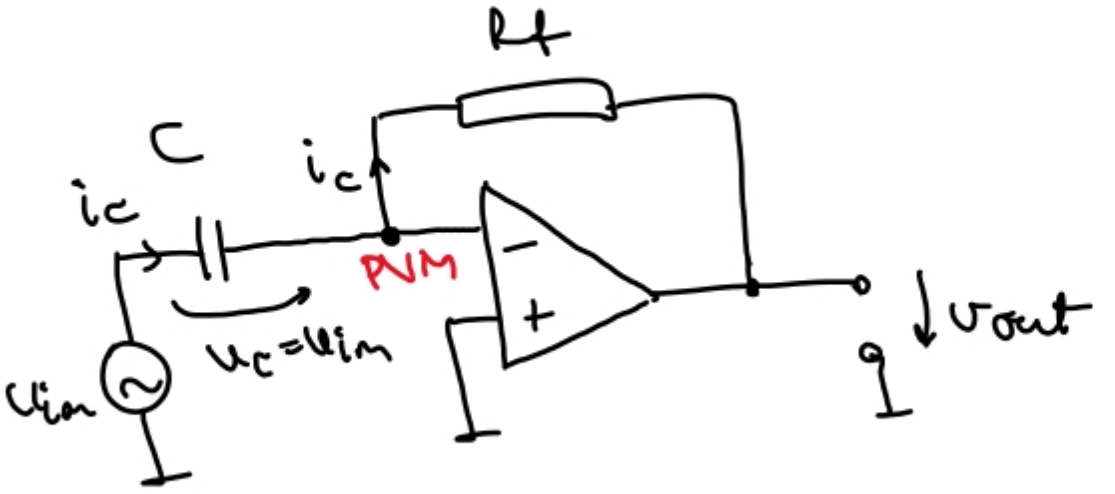
$$i_C = \frac{v_{in}}{R_{in}}$$

$$\frac{u_{in}}{R_{in}} = -C \cdot \frac{dv_{out}}{dt}$$

$$-C\,dv_{out} = \frac{u_{in}}{R_{in}}\,dt \quad \Big| \int$$

$$\boxed{v_{out} = -\frac{1}{CR_{in}} \cdot \int u_{in}\,dt}$$

Conexiunea derivatoare:



$$i_C = C \cdot \frac{du_C}{dt} = C \cdot \frac{du_{in}}{dt}$$

$$v_{out} = -i_C R_f \Rightarrow i_C = -\frac{v_{out}}{R_f}$$

$$-\frac{v_{out}}{R_f} = C \cdot \frac{du_{in}}{dt}$$

$$v_{out} = -R_f C \cdot \frac{du_{in}}{dt}$$