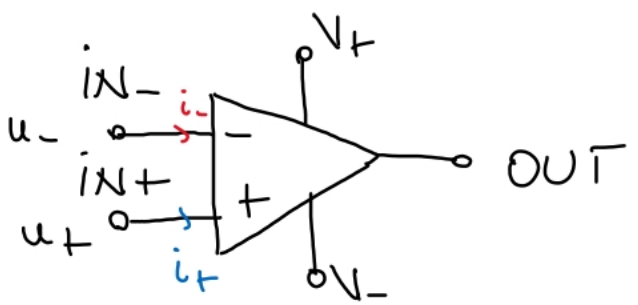
Laborator 6 FT:

Amplificatorul operațional: „op-amp"

A.O. → circuit integrat → rezistori
→ tranzistori (BJT, ~~FET~~)
→ condensatori



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

A_d – factorul de amplificare în buclă deschisă.
(„open loop gain").

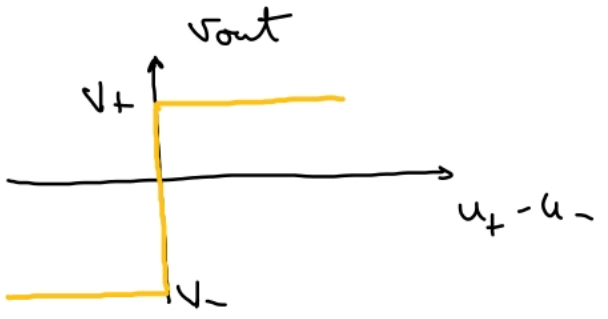
A.O. ideal:

$A_d = \infty$

$Z_{in} = \infty$

$Z_{out} = 0$

$i_+, i_- = 0$



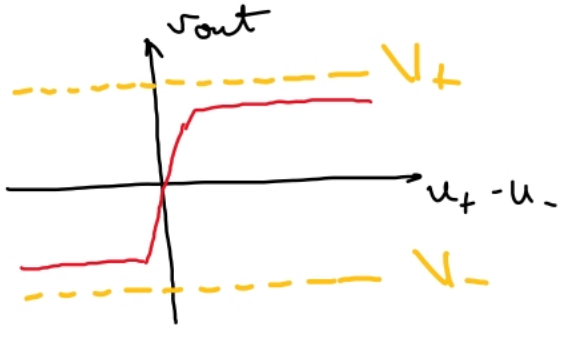
A.O. real:

$A_d \geq 10^5$

$Z_{in} \geq M\Omega$

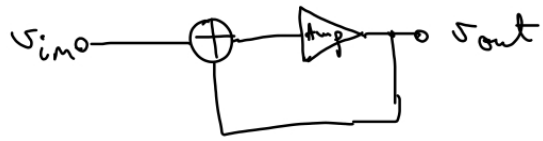
$Z_{out} \geq 100\,\Omega$

$i_+, i_- \simeq nA - pA$

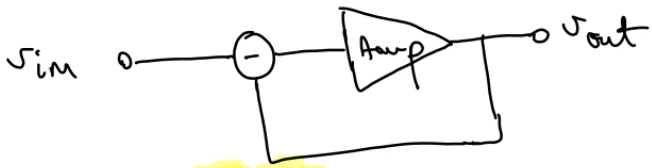


Reacția ("feedback")

·) Reacție pozitivă

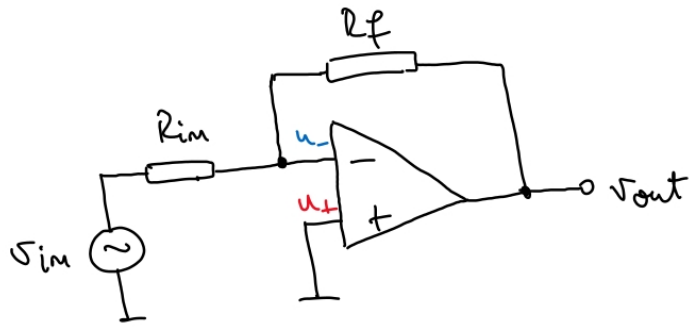


·) Reacție negativă



Considerăm AO ideal

·) Conexiunea inversoare:



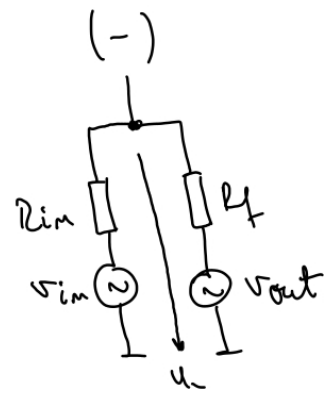
$v_{out} = ? = f(v_{in}, R_{in}, R_f)$

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

$$A_d = \infty$$

$$u_+ = 0$$

Schema echivalentă a intrării inversoare



T. lui Millman

$$u_{ech} = \frac{\frac{E_1}{u_1} + \frac{E_2}{u_2} + \dots + \frac{E_n}{u_n}}{\frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}}$$

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

$$v_{out} = A_d\left(0 - \frac{v_{in}R_f + R_{in}v_{out}}{R_{in}+R_f}\right)$$

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

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

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

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

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

$\frac{R_{in}+R_f}{A_d} \to 0$

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

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

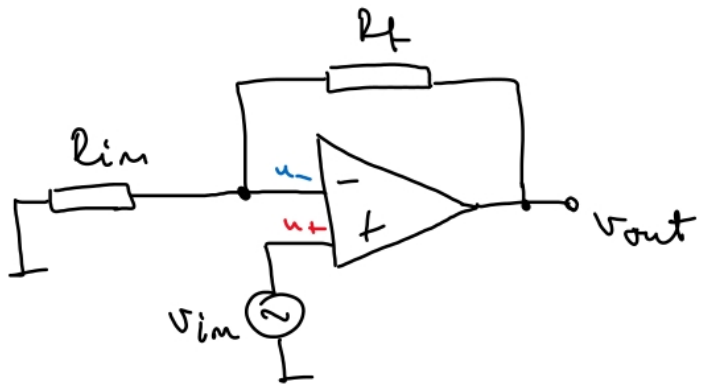
$$A_{inv} = -\frac{R_f}{R_{in}}$$

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

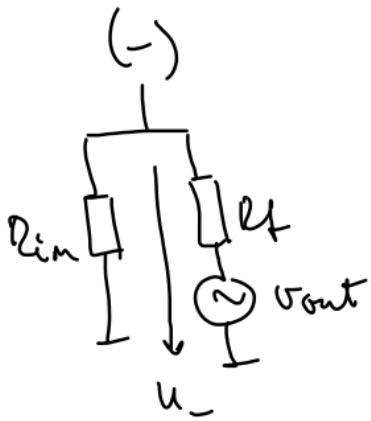
$$= \frac{v_{in}R_f - R_f v_{in}}{R_{in}+R_f} = 0$$

Concluzie: dacă avem r. negativă $\Rightarrow$ $u_+ \cong u_-$

• Conexiunea neinversoare:



$u_+ = v_{in}$



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

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

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

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

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

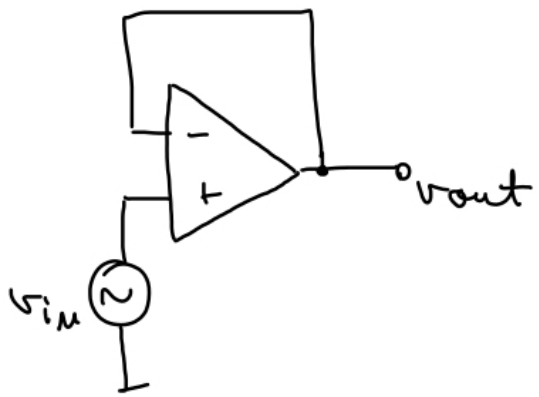
$v_{out} = A_{neinv}\, v_{in}$

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

·) Conexiunea repetoare: „buffer"

Z_{in} - f. mare

Z_{out} - f. mic

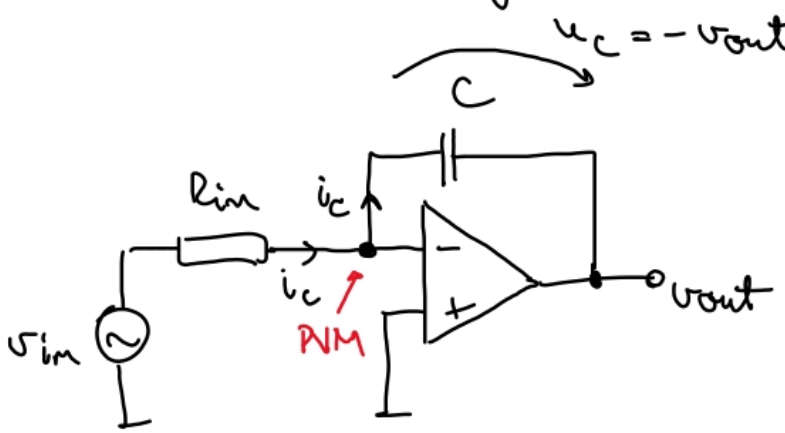


$u_+ \cong u_-$

$v_{out} = v_{in}$

$A_{repetor} = 1$

·) Conexiunea integratoare:



PVM = punct virtual de masă

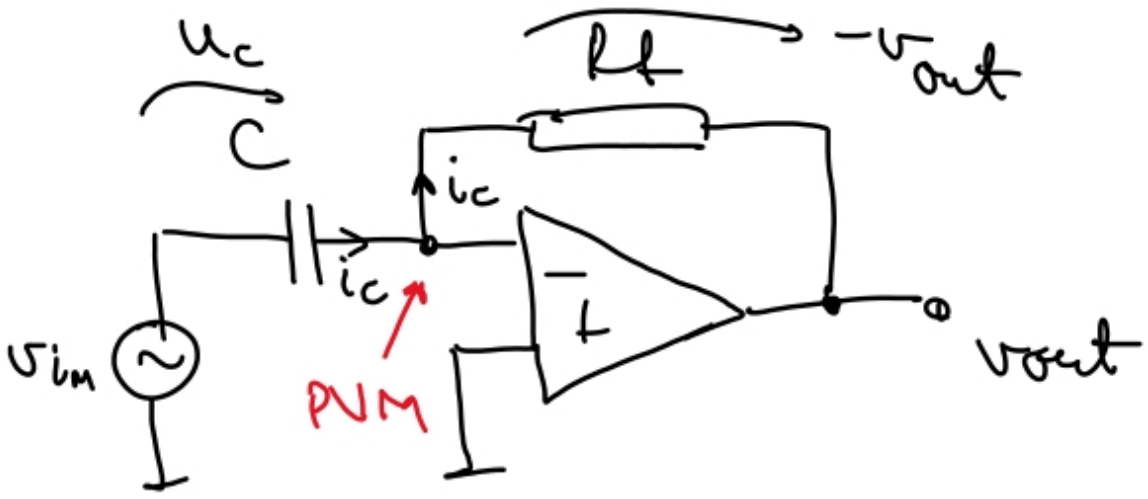
Legea lui Ohm pt. capacitări

$$\left.\begin{aligned} i_C &= C \cdot \frac{dv_C}{dt} \\ i_C &= \frac{v_{in}}{R_{in}} \end{aligned}\right\} \Rightarrow \frac{v_{in}}{R_{in}} = -C \cdot \frac{dv_{out}}{dt}$$

$$v_{in}\,dt = -R_{in}C \cdot dv_{out}$$

$$\boxed{v_{out} = -\frac{1}{R_{in}C}\int_0^t v_{in}\,dt}$$

·) Conexiunea derivatoare



$$-v_{out} = R_f \cdot i_c$$

$$i_c = -\frac{v_{out}}{R_f}$$

$$i_c = C \cdot \frac{du_c}{dt} = C \cdot \frac{dv_{im}}{dt}$$

$$-\frac{v_{out}}{R_f} = C \cdot \frac{dv_{im}}{dt}$$

$$\boxed{v_{out} = -RC \cdot \frac{dv_{im}}{dt}}$$