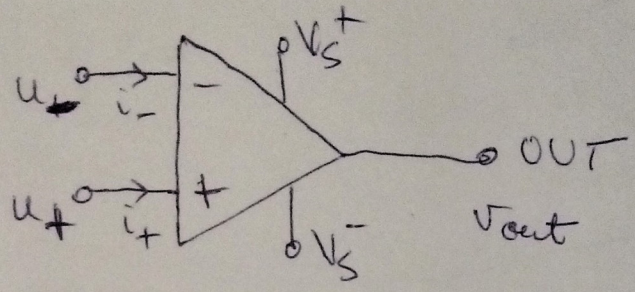
SEMINAR 5 EL II

Amplificatorul operational

AO → c.i.



AO IDEAL:

A_d - open-loop gain

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

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

$z_{in} = \infty$

$z_{out} = 0$

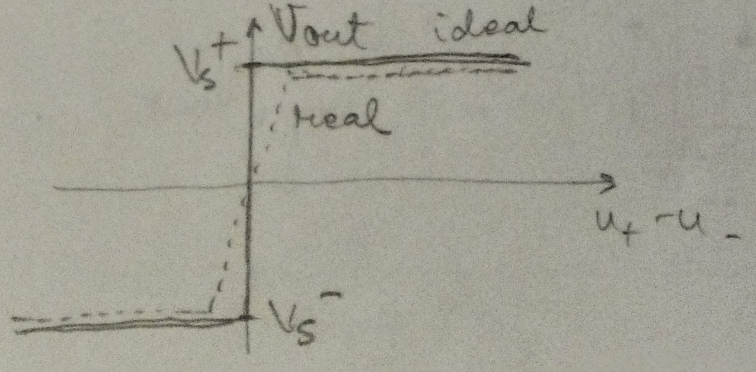
A.O REAL:

$A_d = 2 \cdot 10^5$

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

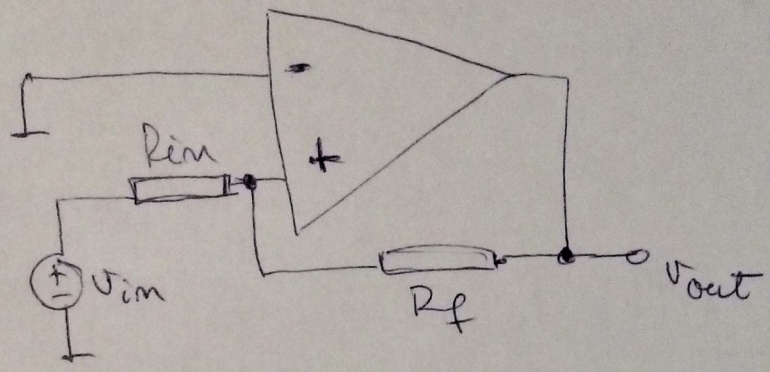
$z_{out} = 10^2 - 10^3 \ \Omega$

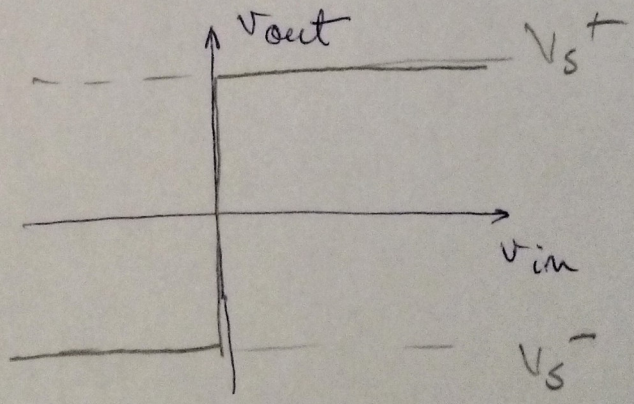
$i_+, i_- = 10^{-12} - 10^{-9}$ A



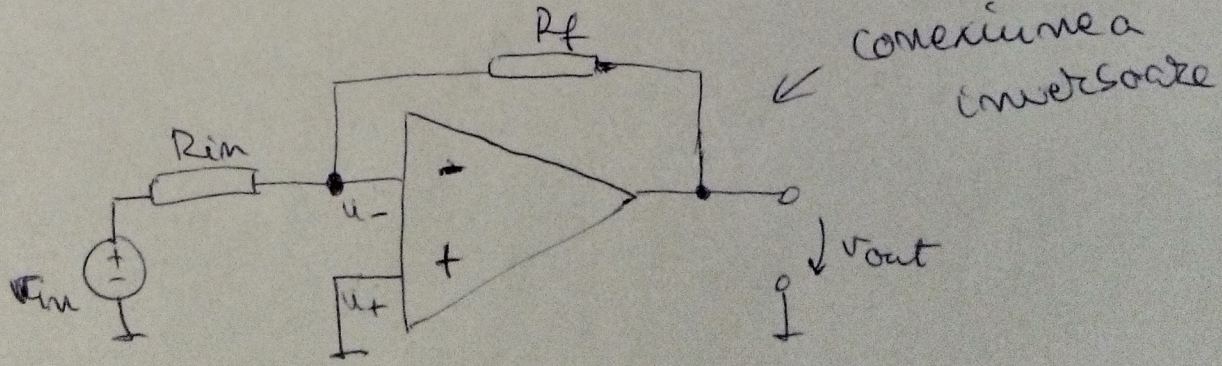
Reacția:

- reacție pozitivă

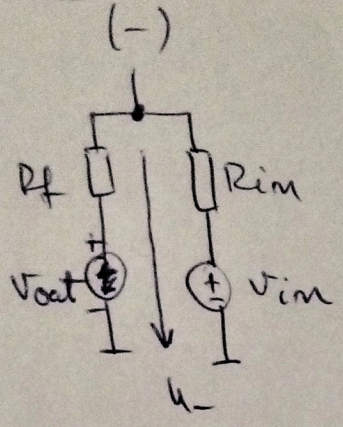




- reacție negativă:



$u_+ = 0$



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

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

$$u_- = \frac{R_f V_{in} + R_{in}\left(-\frac{R_f}{R_{in}} V_{in}\right)}{R_{in} + R_f} \Rightarrow$$

$$\Rightarrow u_- = 0$$

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

$$V_{out} = -\frac{A_d (R_f V_{in} + R_{in} V_{out})}{R_{in} + R_f}$$

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

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

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

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

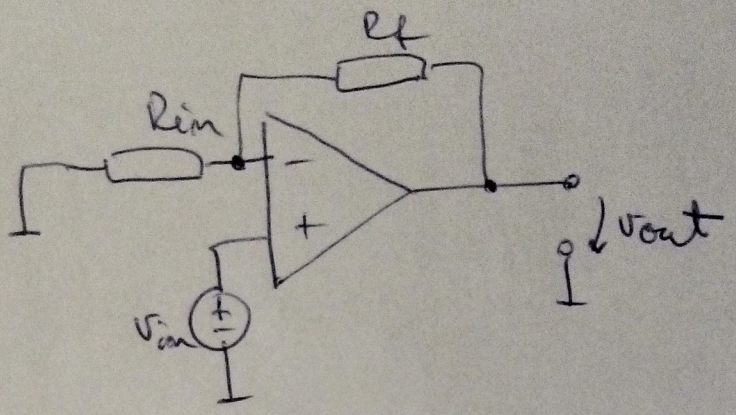
$$V_{out} = -\frac{R_f}{R_{in} + \frac{R_{in} + R_f}{A_d}} \cdot V_{in} \Rightarrow$$

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

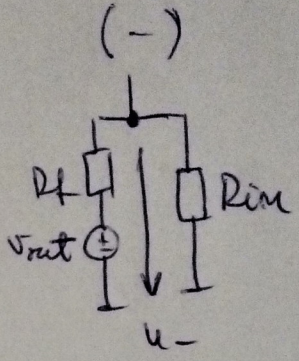
$$\boxed{V_{out} = -\frac{R_f}{R_{in}} \cdot V_{in}}$$

A_{inv}

- conexiunea neinversoare:



$u_+ = v_{in}$



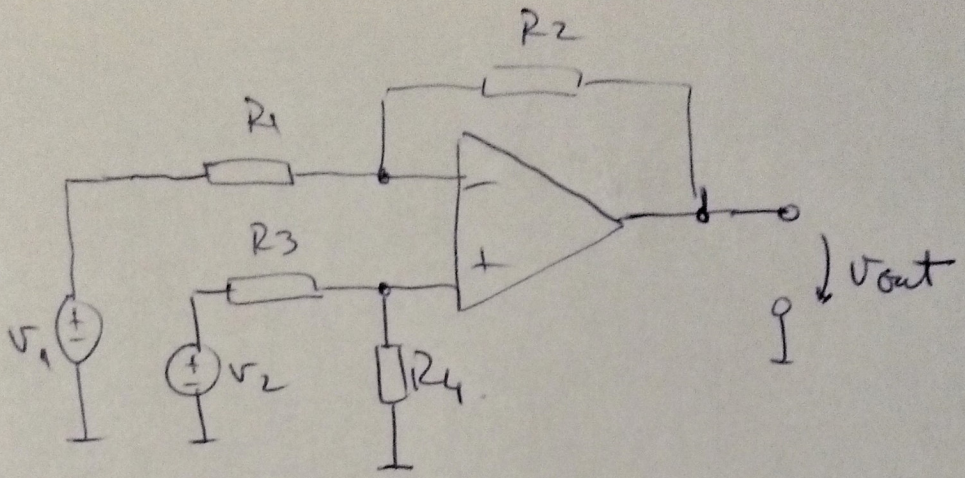
$$u_- = \frac{\frac{v_{out}}{R_f} + \frac{0}{R_{in}}}{\frac{1}{R_f} + \frac{1}{R_{in}}} =$$

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

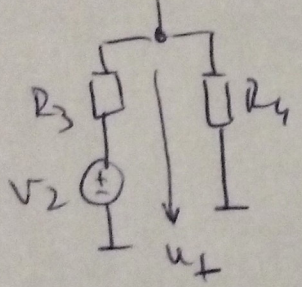
$$u_+ = u_- \Rightarrow \frac{v_{out} R_{in}}{R_{in}+R_f} = v_{in} \Rightarrow$$

$$\Rightarrow v_{out} = \frac{R_{in}+R_f}{R_{in}} \cdot v_{in} = \underbrace{\left(1 + \frac{R_f}{R_{in}}\right)}_{A_{neinv.}} v_{in}$$

- conexiunea diferențială.

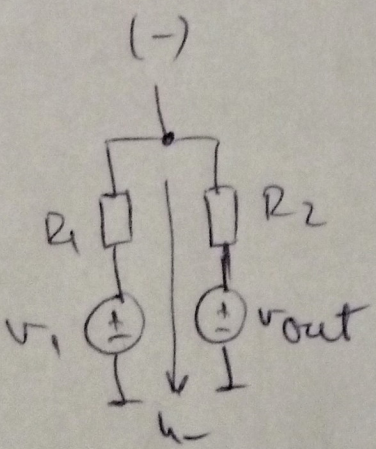


(+)



$$u_+ = \frac{\frac{V_2}{R_3} + \frac{0}{R_4}}{\frac{1}{R_3} + \frac{1}{R_4}} = \frac{\frac{V_2}{R_3}}{\frac{R_3+R_4}{R_3R_4}} = \frac{V_2 R_4}{R_3+R_4}$$

(-)



$$u_- = \frac{\frac{V_{out}}{R_2} + \frac{V_1}{R_1}}{\frac{1}{R_2} + \frac{1}{R_1}} = \frac{\frac{V_{out}R_1 + V_1R_2}{R_1R_2}}{\frac{R_1+R_2}{R_1R_2}} =$$

$$= \frac{V_{out}R_1 + V_1R_2}{R_1+R_2}.$$

$$u_+ = u_- \rightarrow \frac{V_2R_4}{R_3+R_4} = \frac{V_{out}R_1 + V_1R_2}{R_1+R_2}$$

$$V_{out}R_1 + V_1R_2 = \frac{R_1+R_2}{R_3+R_4} \cdot V_2R_4$$

$$V_{out}R_1 = \frac{R_1+R_2}{R_3+R_4} V_2R_4 - V_1R_2.$$

$$V_{out} = \frac{R_1+R_2}{R_3+R_4} \cdot V_2 \cdot \frac{R_4}{R_1} - V_1 \cdot \frac{R_2}{R_1}$$

$R_3 = R_1$

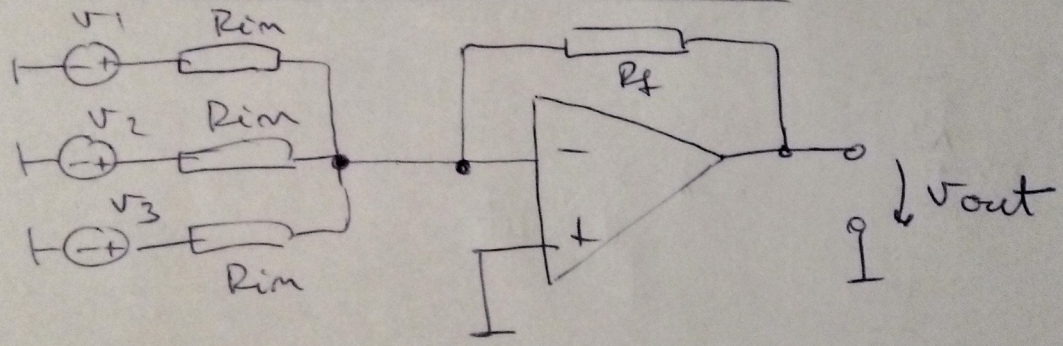
$R_4 = R_2$

$$V_{out} = V_2 \cdot \frac{R_2}{R_1} - V_1 \cdot \frac{R_2}{R_1}$$

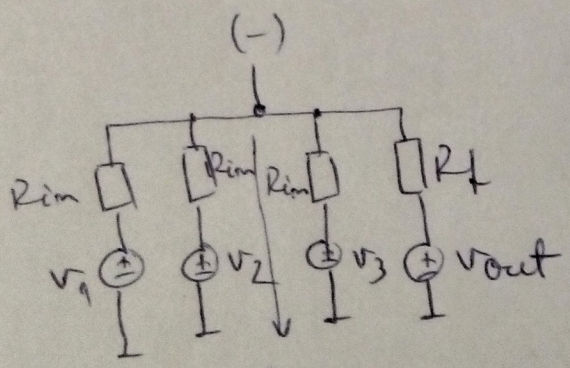
$$\boxed{V_{out} = \frac{R_2}{R_1}(V_2 - V_1)}$$

↓ Adif

- conexiunea sumatoare:



$u_+ = 0$



$$u_- = \frac{\frac{V_1}{R_{in}} + \frac{V_2}{R_{in}} + \frac{V_3}{R_{in}} + \frac{V_{out}}{R_f}}{\frac{1}{R_{in}} + \frac{1}{R_{in}} + \frac{1}{R_{in}} + \frac{1}{R_f}} =$$

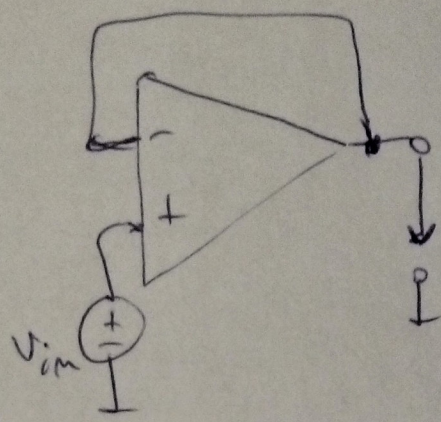
$$= \frac{\frac{R_f(V_1+V_2+V_3) + R_{in}V_{out}}{R_{in}R_f}}{\frac{3R_f + R_{in}}{R_{in}R_f}}$$

$u_+ = u_- \Rightarrow R_f(V_1+V_2+V_3) + R_{in}V_{out} = 0$

$$\boxed{V_{out} = -\frac{R_f}{R_{in}}(V_1+V_2+V_3)}$$

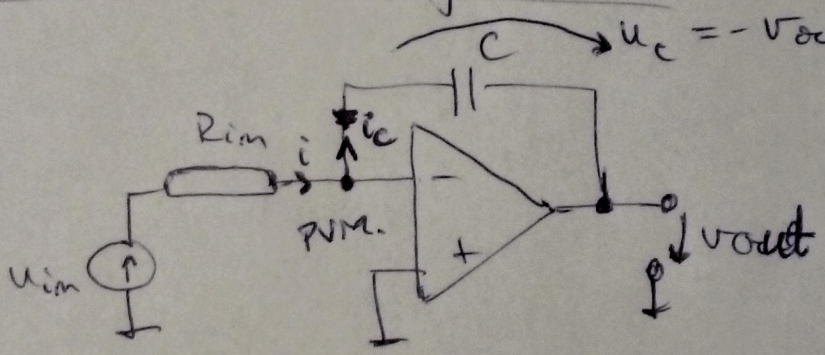
- conexiunea repetoare:

"buffer", „voltage follower".



$v_{out} = v_{in}$.

- conexiunea integratoare:



$$i = i_c$$

$$i_c = C \cdot \frac{du_c}{dt} = C \cdot \frac{d(-v_{out})}{dt}$$

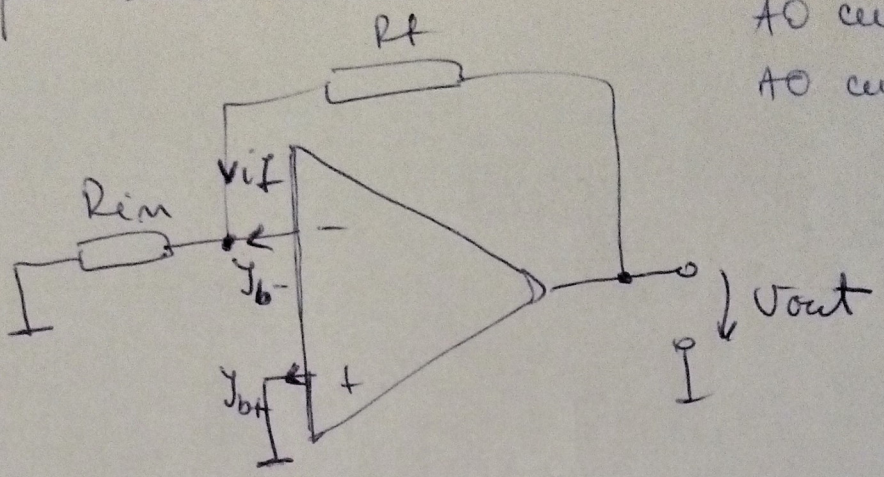
$$i = \frac{u_{in}}{R_{in}}$$

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

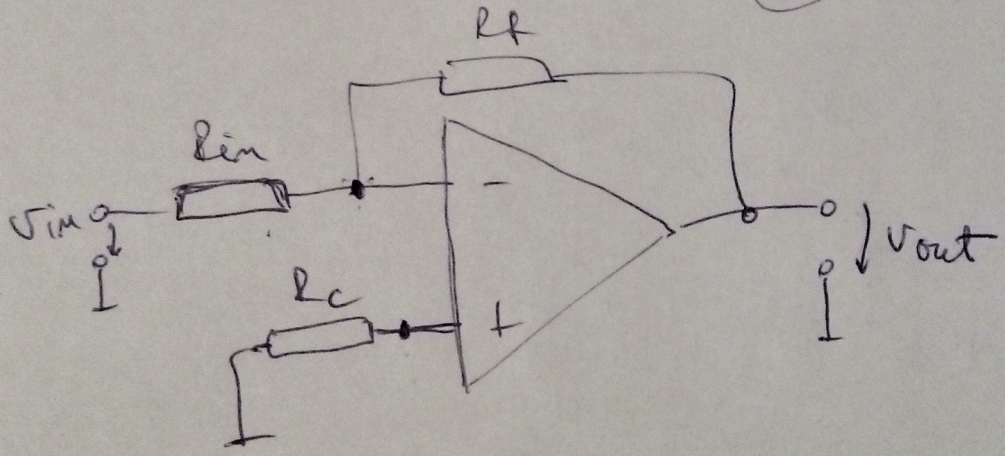
$$\boxed{v_{out} = -\frac{1}{R_{in}C} \int u_{in}\, dt}$$

·) input bias current.

AO cu TB ~ nA
AO cu TEC ~ pA



$$v_{out} = I_{b-} \cdot R_f$$



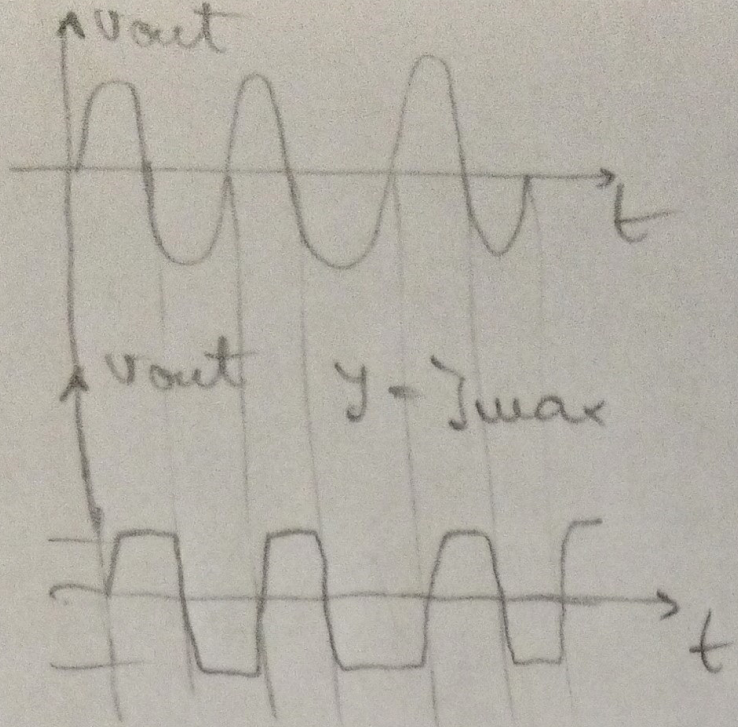
$$R_c = R_{in} \| R_f$$

$$v_{in} = 0 \Rightarrow v_{out} = I_{off} \cdot R_f =$$

$$= (I_{b+} - I_{b-}) \cdot R_f$$

·) Slew rate:

$$f_{max} = \frac{\text{slew rate}}{2\pi \cdot V_{max}}$$



Common-mode rejection ratio:

$$CMRR = \frac{A_d}{A_{CM}} \quad [dB].$$

Banda de trecere :