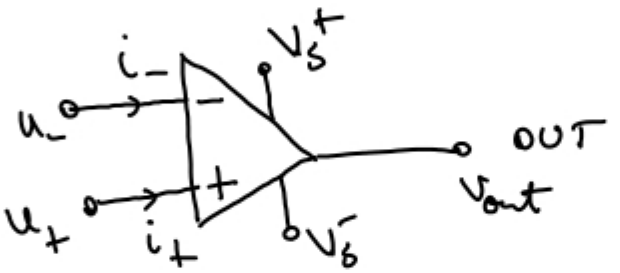
Curs 2 SIS

Amplificatorul operațional în procesele de măsură.

A.O. → circuit integrat → BJT / JFET / MOSFET

Amplificatorul operațional ideal



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

A_d - factorul de amplificare în buclă deschisă
A_d - open-loop gain

Caracteristicile AO ideal:

$A_d \to \infty$ $\quad i_- = 0$

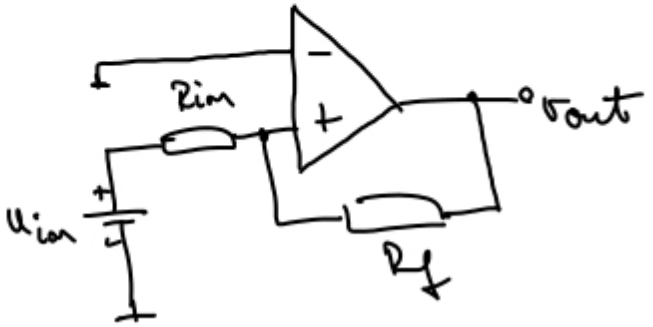
$Z_{in} \to \infty$ $\quad i_+ = 0$

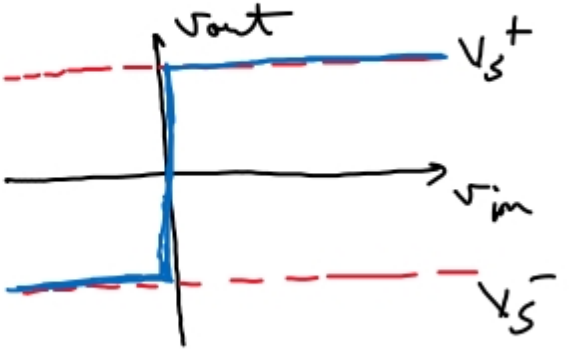
$Z_{out} \to 0$

$A_d \to \infty$, v_{out} - finit $\Rightarrow u_+ - u_- = 0 \Rightarrow u_+ = -u_-$

Conexiuni ale amplificatorului operațional:

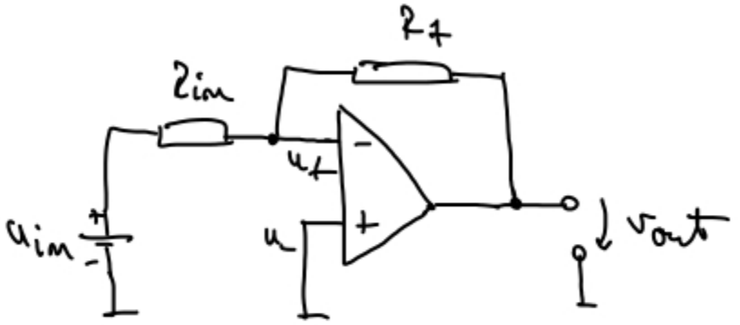
- reacție pozitivă



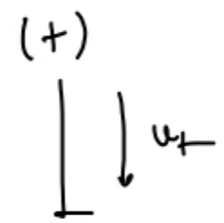


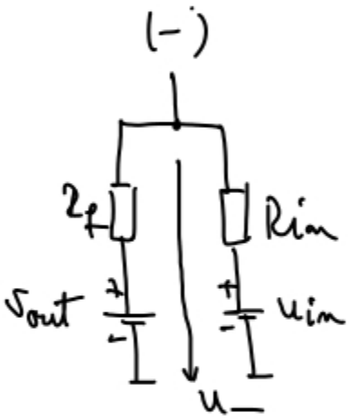
- reacția negativă ("negative feedback").

Conexiunea inversoare:



$u_+ = 0$





T. lui Millman:

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

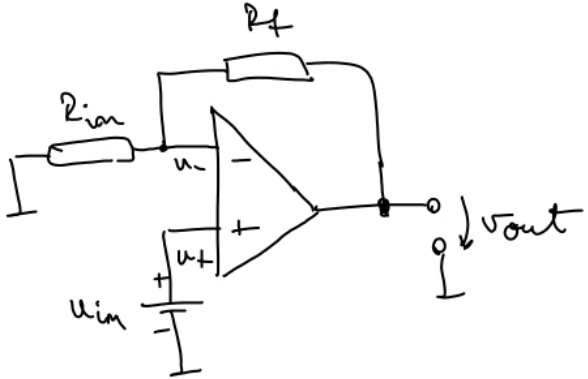
$u_+ = u_- \Rightarrow u_- = 0 \Rightarrow \dfrac{\frac{u_{in}}{R_{in}} + \frac{v_{out}}{R_f}}{\frac{1}{R_{in}} + \frac{1}{R_f}} = 0 \Rightarrow \dfrac{u_{in}}{R_{in}} = -\dfrac{v_{out}}{R_f} \Rightarrow$

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

$\Rightarrow v_{out} = A \cdot u_{in}$

$$\boxed{A = -\frac{R_f}{R_{in}}}$$

Conexiunea neinversoare:



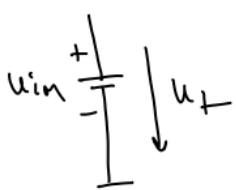
$$u_- = \frac{\frac{0}{R_{in}} + \frac{v_{out}}{R_f}}{\frac{1}{R_{in}} + \frac{1}{R_f}} = \frac{\frac{v_{out}}{R_f}}{\frac{1}{R_{in}} + \frac{1}{R_f}}$$

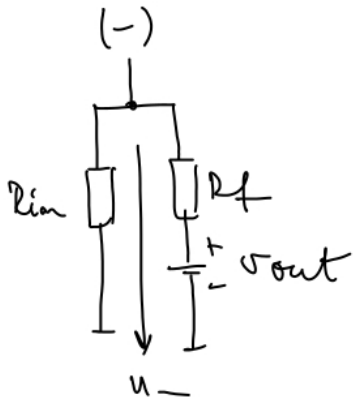
$u_+ = u_- \Rightarrow$

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

$u_+ = u_{in}$

(+)



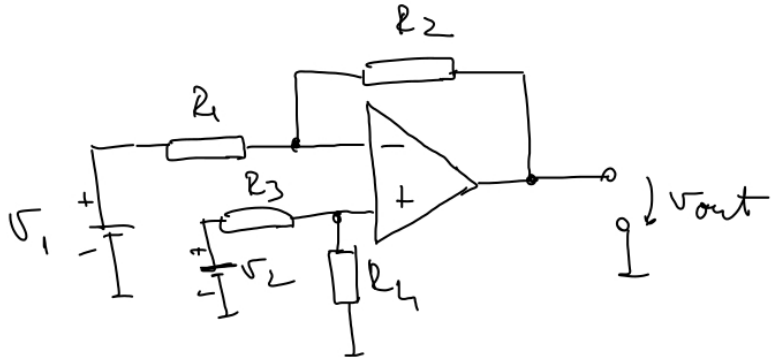


$$v_{out} = u_{in}\left(\frac{R_f}{R_{in}} + \frac{R_f}{R_f}\right) \rightarrow v_{out} = \underbrace{\left(1 + \frac{R_f}{R_{in}}\right)}_{A} \cdot u_{in}$$

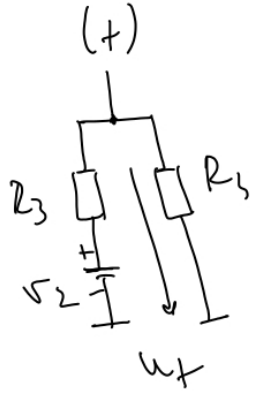
$$v_{out} = A \cdot u_{in}$$

$$A = 1 + \frac{R_f}{R_{in}}$$

Conexiunea diferențială 1

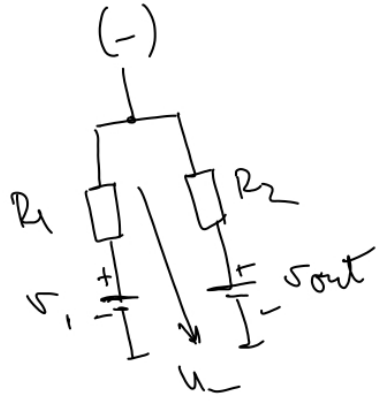


(+)



$$u_+ = \frac{\frac{v_2}{R_3} + \frac{0}{R_4}}{\frac{1}{R_3} + \frac{1}{R_4}} = \frac{\frac{v_2}{R_3}}{\frac{R_3 + R_4}{R_3 R_4}} = \frac{v_2 R_4}{R_3 + R_4}$$

(-)



$$u_- = \frac{\frac{v_{out}}{R_2} + \frac{v_1}{R_1}}{\frac{1}{R_2} + \frac{1}{R_1}} = \frac{\frac{v_{out} R_1 + v_1 R_2}{R_1 R_2}}{\frac{R_1 + R_2}{R_1 R_2}} = \frac{v_{out} R_1 + v_1 R_2}{R_1 + R_2}$$

$$u_+ = u_- \rightarrow \frac{v_2 R_4}{R_3 + R_4} = \frac{v_{out} R_1 + v_1 R_2}{R_1 + R_2} \Rightarrow$$

$$\Rightarrow \quad v_{out} R_1 + v_1 R_2 = \frac{R_1+R_2}{R_3+R_4} \cdot v_2 R_4$$

$$v_{out} = \frac{R_1+R_2}{R_3+R_4} \cdot v_2 \cdot \frac{R_3}{R_1} - v_1 \cdot \frac{R_2}{R_1}$$

De regulă $R_3 = R_1$

$R_4 = R_2$

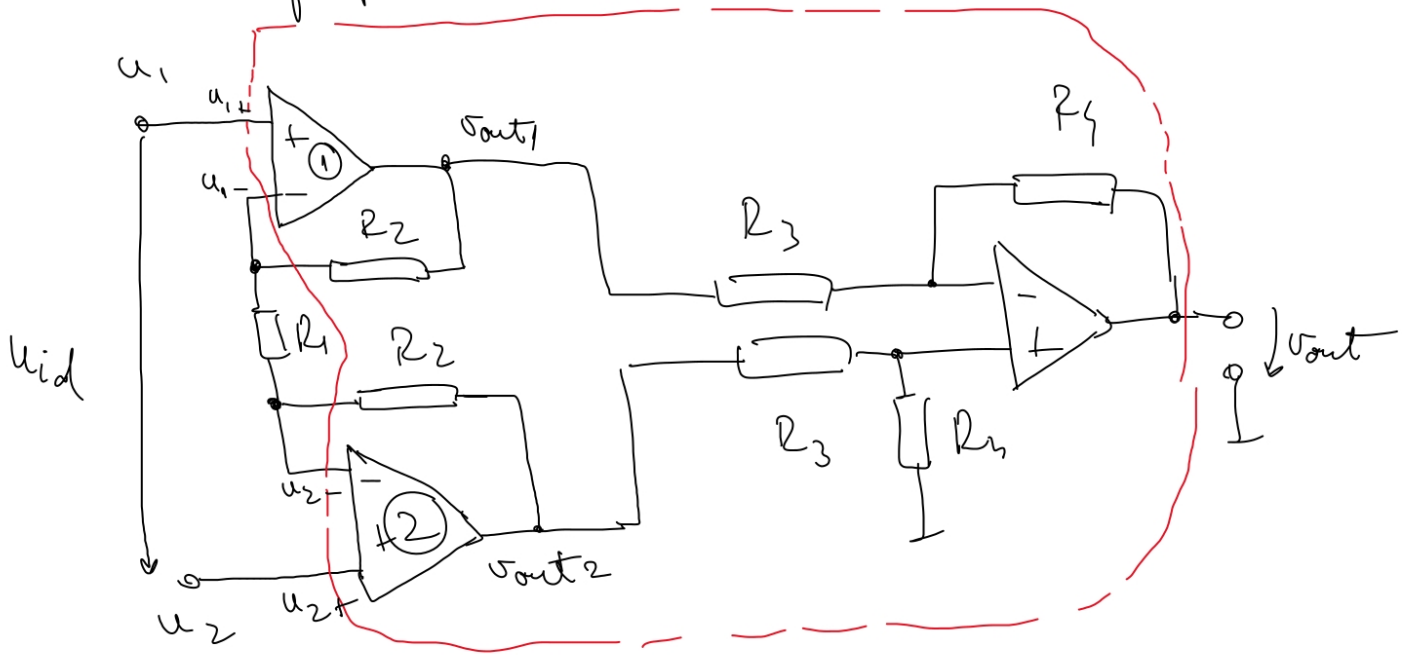
$$v_{out} = \frac{\cancel{R_1+R_2}}{\cancel{R_1+R_2}} \cdot v_2 \cdot \frac{R_2}{R_1} - v_1 \cdot \frac{R_2}{R_1}$$

$$\boxed{v_{out} = \frac{R_2}{R_1}(v_2 - v_1)}$$

$$v_{out} = A(v_2 - v_1)$$

$$A = \frac{R_2}{R_1}$$

Amplificatorul de instrumentație:



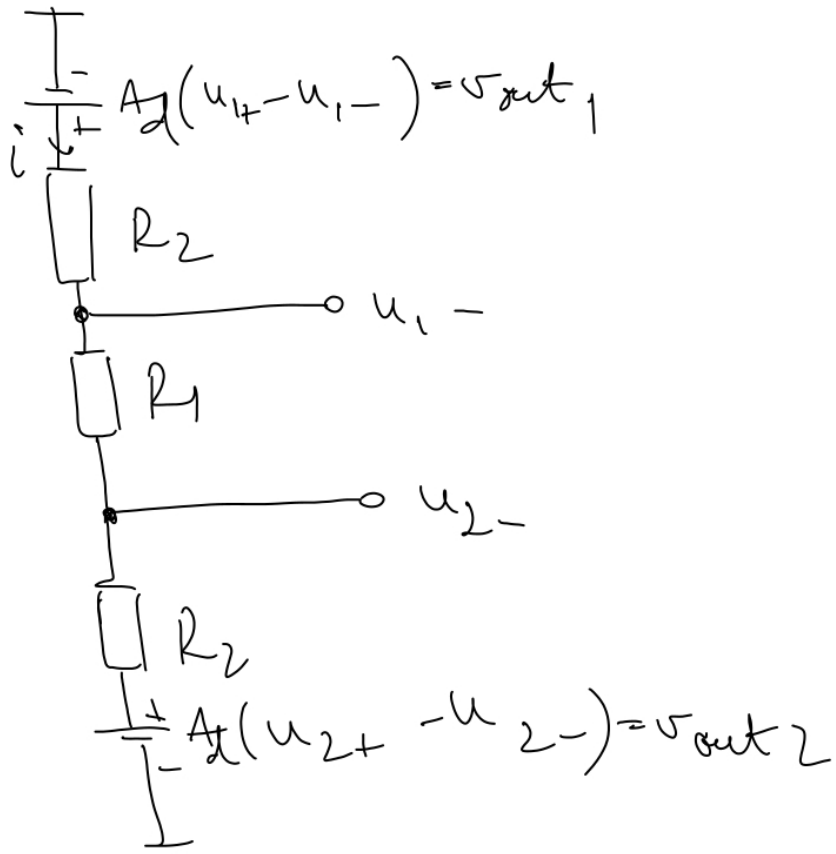
$$v_{out_1} = A_d (u_{1+} - u_{1-})$$

$$v_{out_2} = A_d (u_{2+} - u_{2-})$$

$$u_{1+} = u_1$$

$$u_{2+} = u_2$$

$$u_{id} = u_1 - u_2 = u_{1+} - u_{2+}$$



$$v_{out1} - v_{out2} = i(R_1 + 2R_2)$$

$$iR_1 = u_{1-} - u_{2-}$$

$$i = \frac{A_d \cdot u_{id} - iR_1 A_d}{R_1 + 2R_2}$$

$$i(R_1 + 2R_2) + iR_1 A_d = A_d \cdot u_{id}$$

$$i(R_1 + 2R_2 + A_d R_1) = A_d \cdot u_{id}$$

$$i = \frac{A_d \cdot u_{id}}{R_1 + 2R_2 + A_d R_1}$$

$$i = \frac{u_{id} \cdot \cancel{A_d}}{\cancel{A_d}\left(\underbrace{\frac{R_1 + 2R_2}{A_d}}_{\simeq 0} + R_1\right)}$$

$$i = \frac{u_{id}}{R_1}$$

$$v_{out} = \frac{R_4}{R_3}\left(v_{out2} - v_{out1}\right)$$

$$v_{out1} - v_{out2} = i(R_1 + 2R_2)$$

$$v_{out} = -\frac{R_4}{R_3} \cdot i(R_1 + 2R_2)$$

$$v_{out} = -\frac{R_4}{R_3} \cdot \frac{u_{id}}{R_1}(R_1 + 2R_2)$$

$$v_{out} = -\frac{R_4}{R_3}\frac{(u_1 - u_2)}{R_1}(R_1 + 2R_2)$$

$$v_{out} = \frac{R_4}{R_3}(u_2 - u_1)\left(1 + \frac{2R_2}{R_1}\right)$$

$$v_{out} = A_{inst.}(u_2 - u_1)$$

$$A_{inst.} = \frac{R_4}{R_3}\left(1 + \frac{2R_2}{R_1}\right)$$

R_4, R_3, R_2 - fixe pe chip -