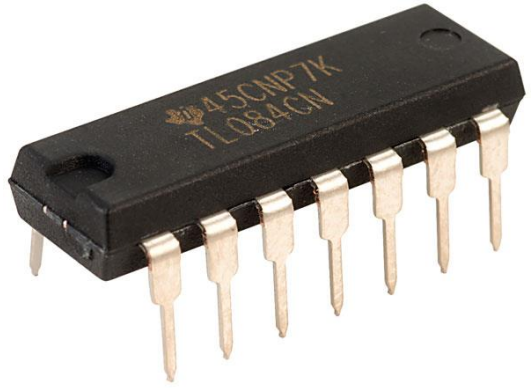
Bazele Circuitelor Electronice

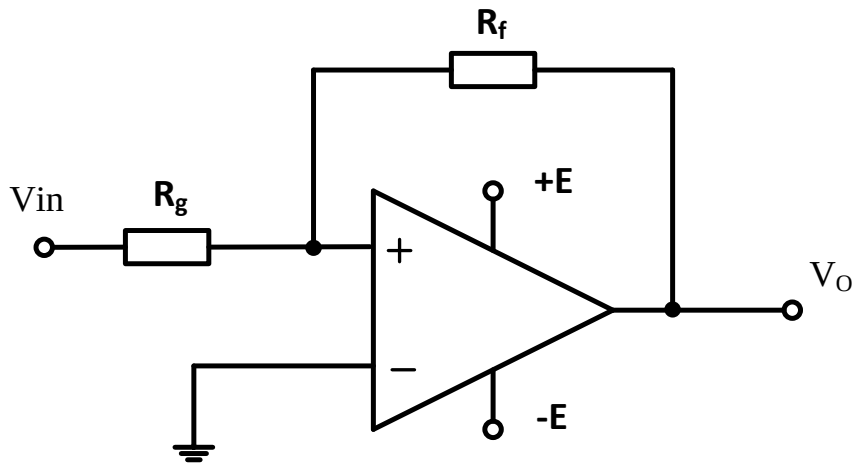
Amplificatoare Operaționale



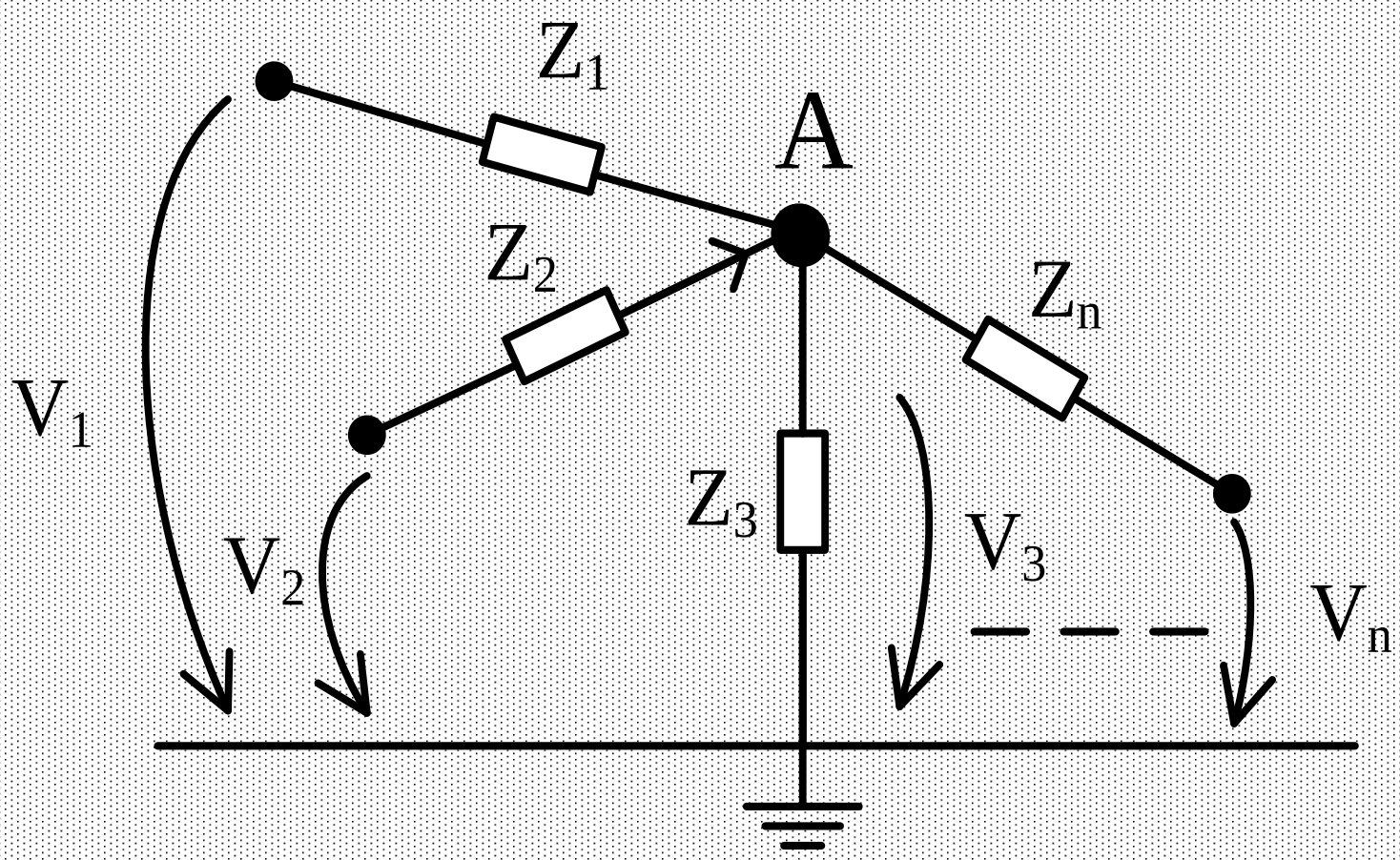
Circuite cu AO

- fără Reacție
  - Comparator neinversor fără Reacție
  - Comparator inversor fără Reacție
- cu Reacție
  - Reacție Pozitivă
    - Comparator neinversor cu Reacție
    - Comparator inversor cu Reacție
  - Reacție Negativă
    - Amplificator neinversor
    - Amplificator inversor

Comparator neinversor cu reacție

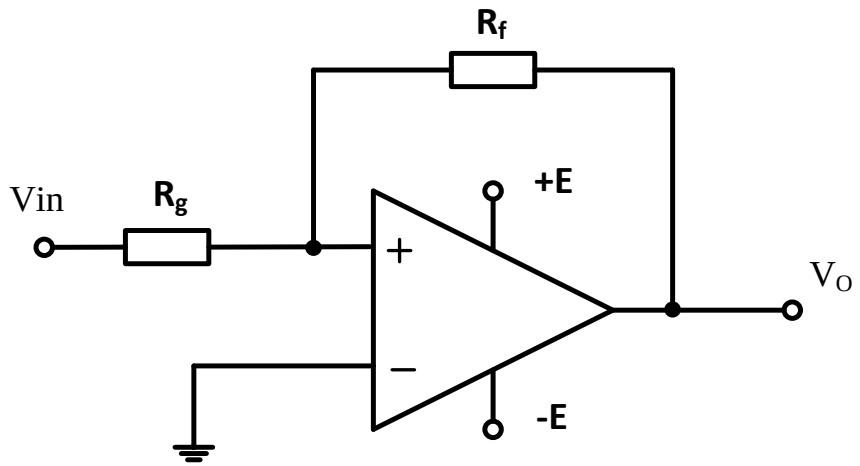


Teorema lui Millman



$$V_A = \frac{\sum_{i=1}^{n} \frac{V_i}{Z_i}}{\sum_{i=1}^{n} \frac{1}{Z_i}}$$

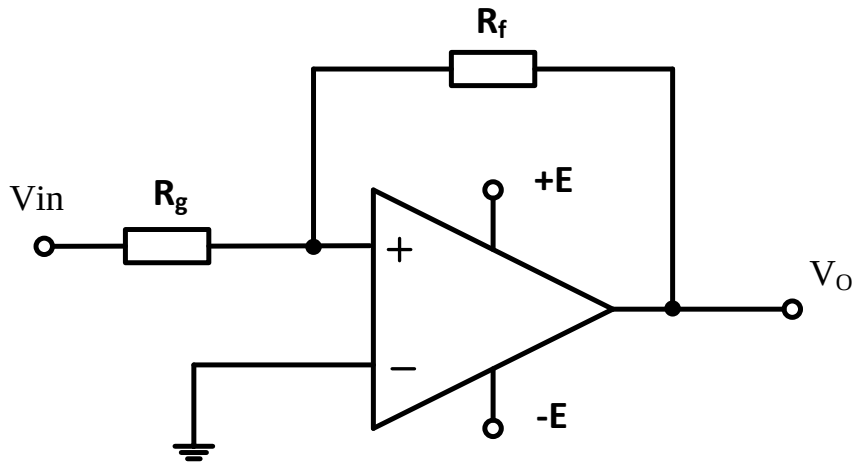
Comparator neinversor cu reacție



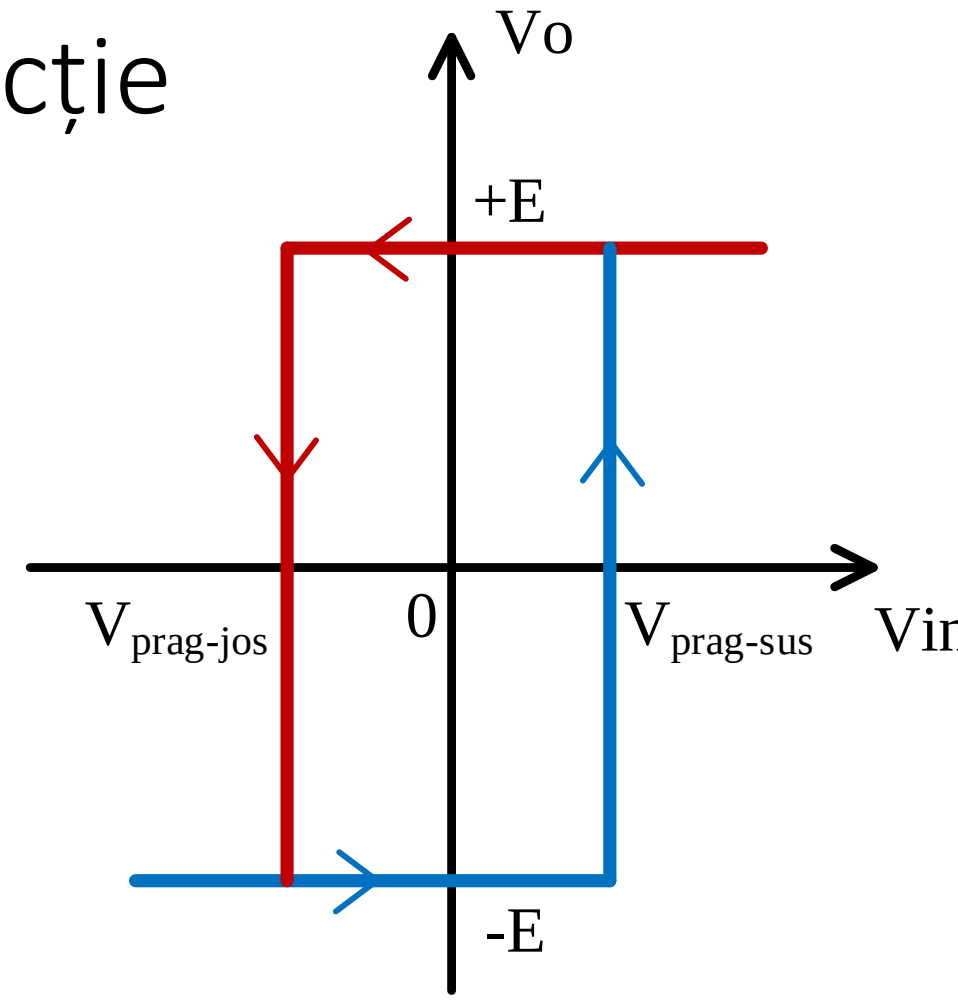
$$\begin{cases} v^- = 0 \\ v^+ = \dfrac{\dfrac{v_o}{R_f} + \dfrac{v_i}{R_g}}{\dfrac{1}{R_f} + \dfrac{1}{R_g}} \end{cases} \Rightarrow \frac{v_o}{R_f} + \frac{v_i}{R_g} = 0 \Rightarrow \frac{V_{prag}}{R_g} = -\frac{v_o}{R_f}$$

$$\Rightarrow \frac{V_{prag}}{R_g} = -\frac{\pm E}{R_f} \Rightarrow \boxed{V_{prag} = \pm \frac{R_g}{R_f} E}$$

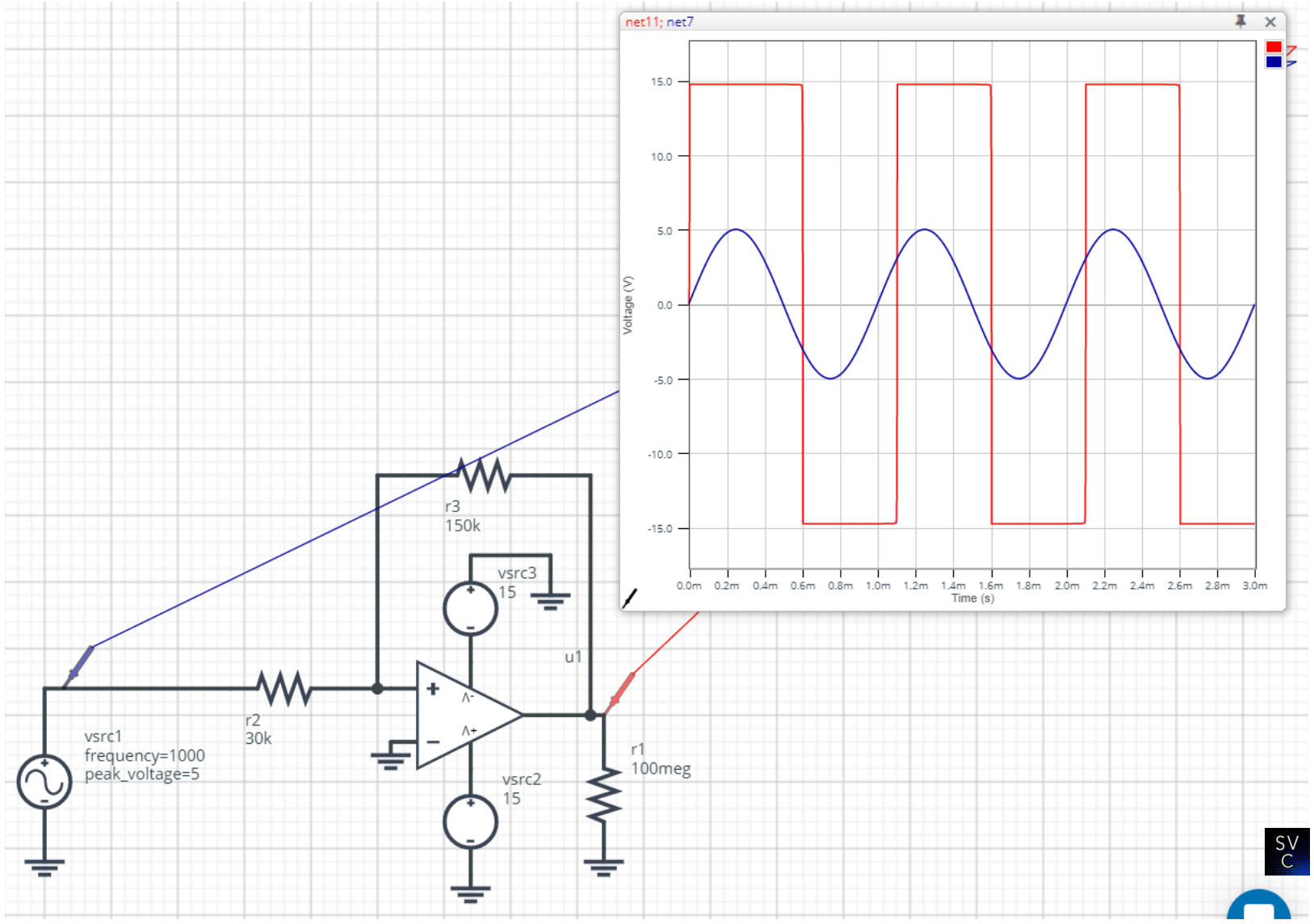
Comparator neinversor cu reacție



$$V_{prag} = \pm \frac{R_g}{R_f} E$$



Comparator neinversor cu reacție

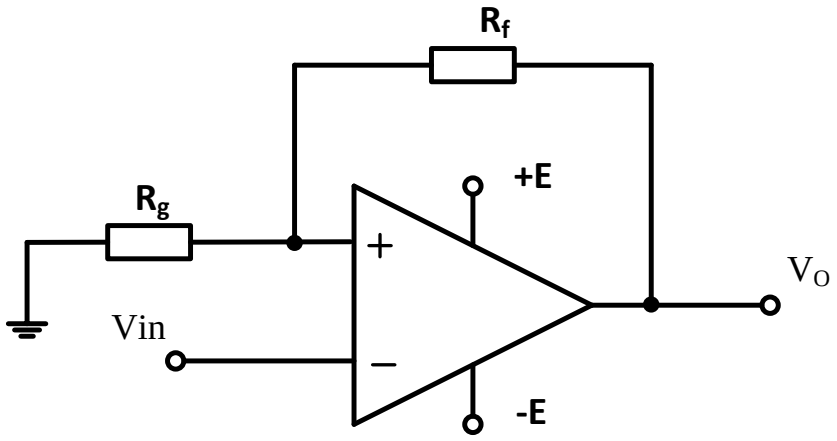


Comparator neinversor cu reactie

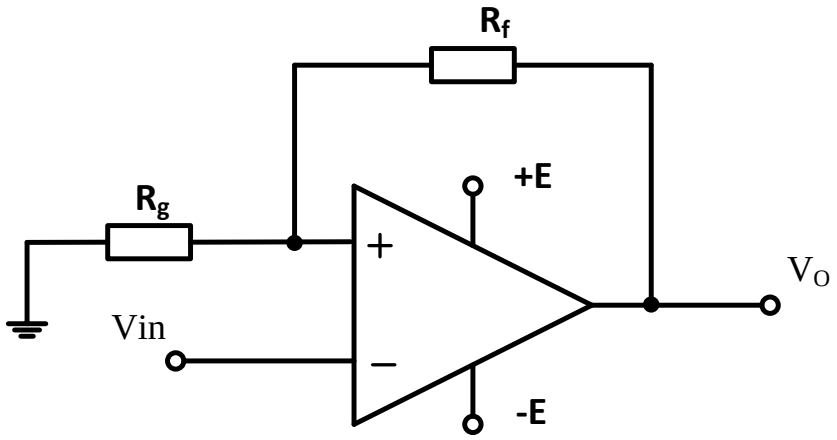
Circuite cu AO

- fără Reacție
  - Comparator neinversor fără Reacție
  - Comparator inversor fără Reacție
- cu Reacție
  - Reacție Pozitivă
    - Comparator neinversor cu Reacție
    - Comparator inversor cu Reacție
  - Reacție Negativă
    - Amplificator neinversor
    - Amplificator inversor

Comparator inversor cu reacție



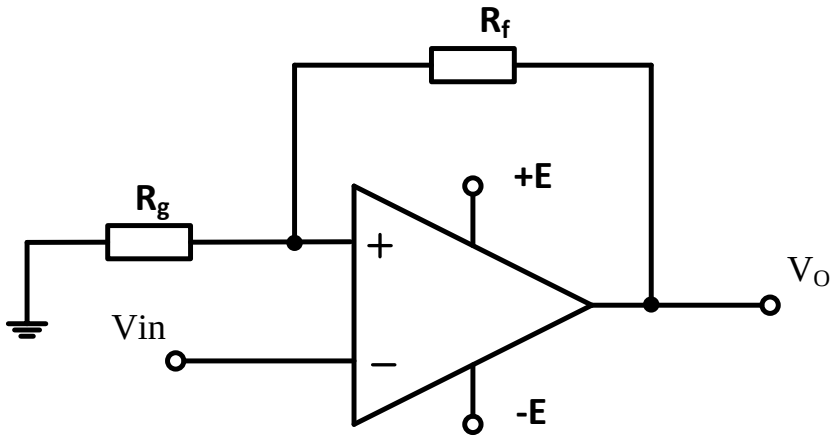
Comparator inversor cu reacție



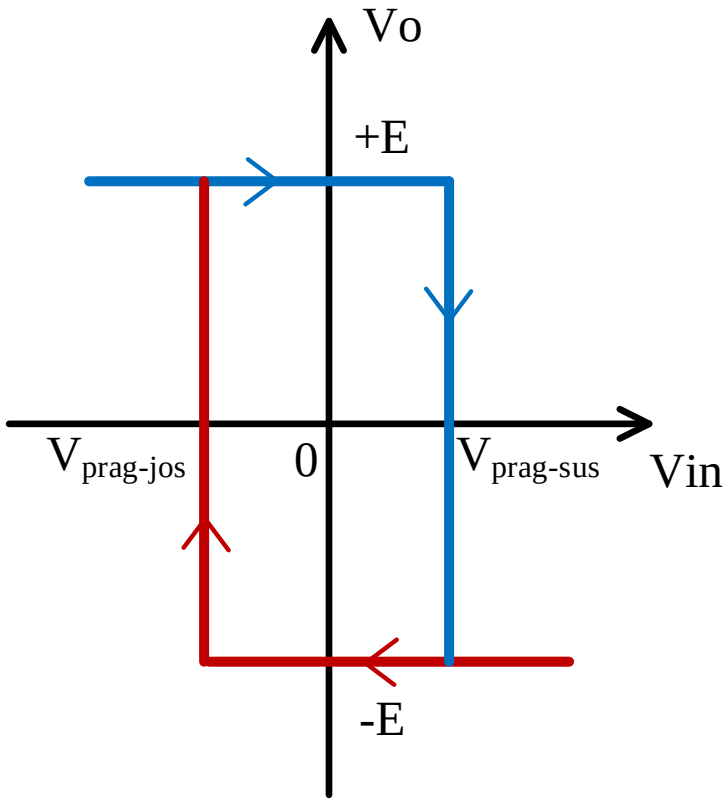
$$\left.\begin{aligned} V^- &= v_{in} \\ V^+ &= \frac{\frac{0}{R_g}+\frac{v_o}{R_f}}{\frac{1}{R_g}+\frac{1}{R_f}} \end{aligned}\right\} \Rightarrow V^+ = V^- \Rightarrow \frac{\frac{\pm E}{R_f}}{\frac{1}{R_g}+\frac{1}{R_f}} = V_{prag}$$

$$\Rightarrow \boxed{V_{prag} = \pm \frac{R_g}{R_g + R_f} E}$$

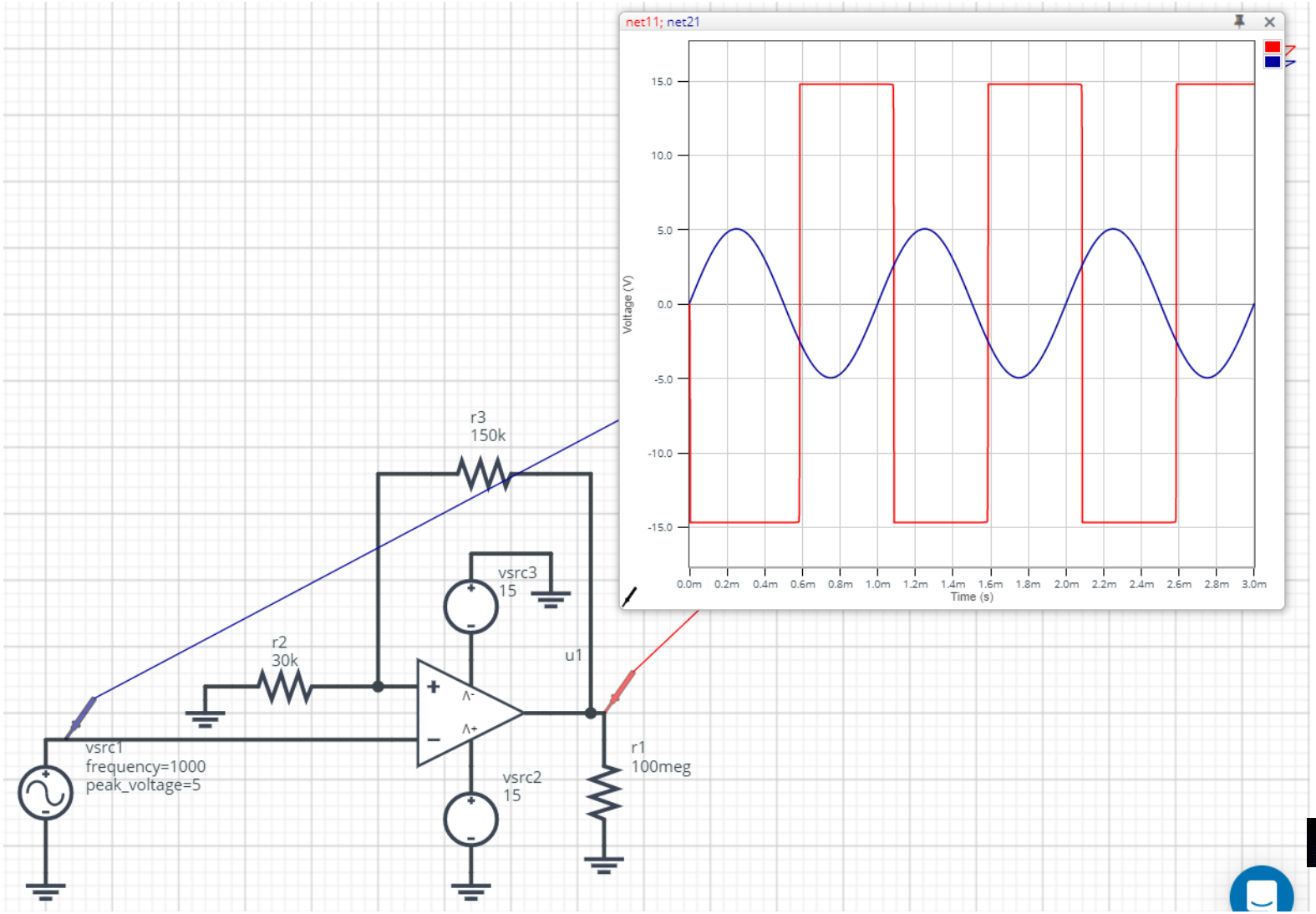
Comparator inversor cu reacție



$$V_{prag} = \pm \frac{R_g}{R_g + R_f} E$$



Comparator inversor cu reacție

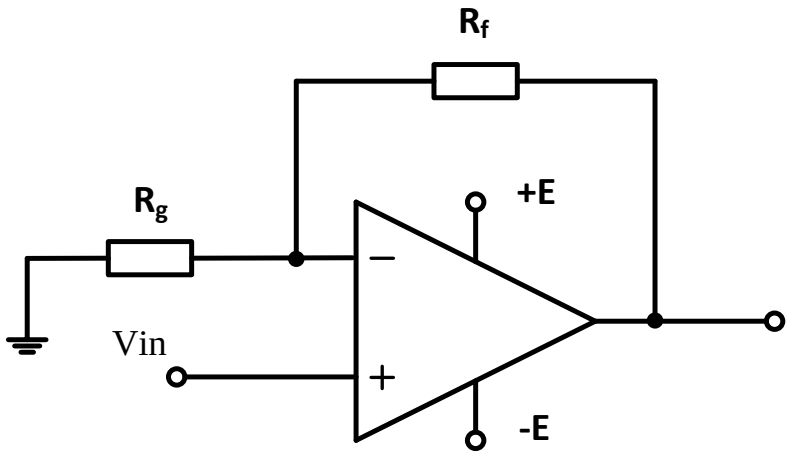


Comparator inversor cu reactie

Circuite cu AO

- fără Reacție
  - Comparator neinversor fără Reacție
  - Comparator inversor fără Reacție
- cu Reacție
  - Reacție Pozitivă
    - Comparator neinversor cu Reacție
    - Comparator inversor cu Reacție
  - Reacție Negativă
    - Amplificator neinversor
    - Amplificator inversor

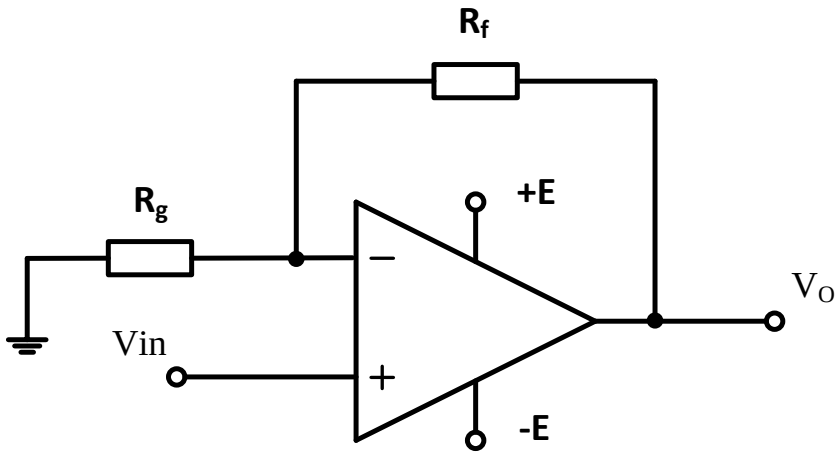
Amplificator neinversor



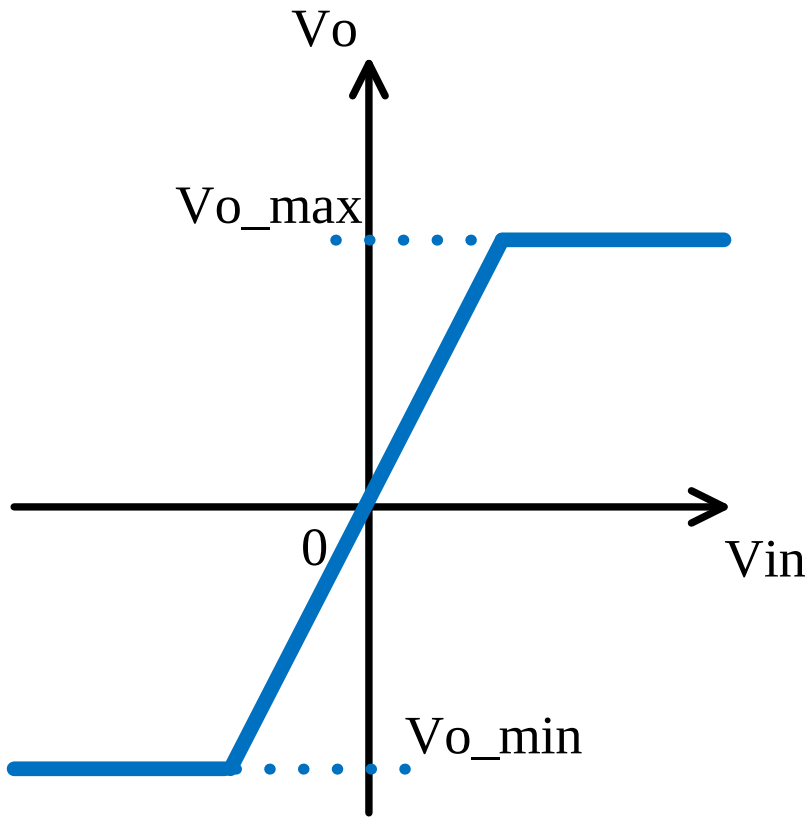
$$\left.\begin{aligned} V^- &= \frac{\frac{0}{R_g}+\frac{v_o}{R_f}}{\frac{1}{R_g}+\frac{1}{R_f}} \\ V^+ &= v_{in} \end{aligned}\right\} \Rightarrow V^+ = V^- \Rightarrow v_o = R_f\left(\frac{1}{R_g}+\frac{1}{R_f}\right)\cdot v_{in} \Rightarrow v_o = \left(1+\frac{R_f}{R_g}\right)\cdot v_{in}$$

$$A = \frac{v_o}{v_{in}} = 1+\frac{R_f}{R_g}$$

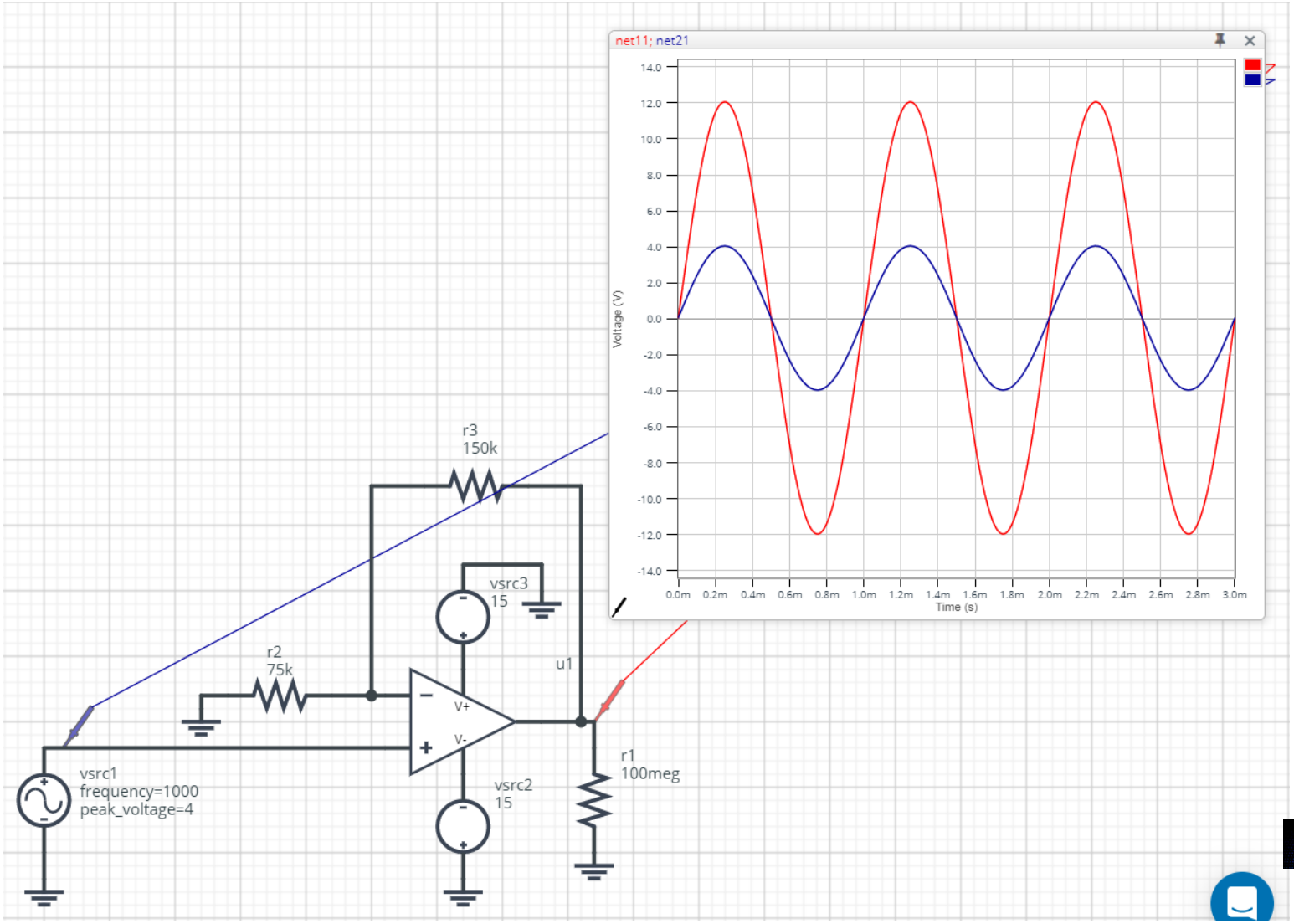
Amplificator neinversor



$$A = \frac{v_o}{v_{in}} = 1 + \frac{R_f}{R_g}$$



Amplificator neinversor

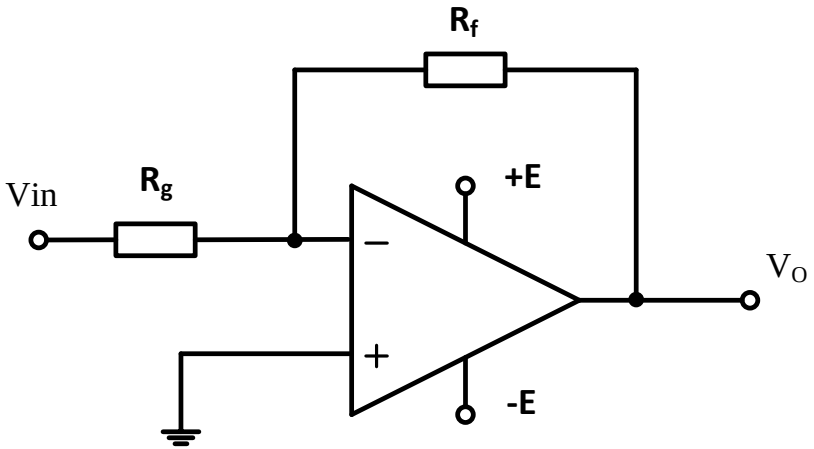


SV C Amplificator neinversor

Circuite cu AO

- fără Reacție
  - Comparator neinversor fără Reacție
  - Comparator inversor fără Reacție
- cu Reacție
  - Reacție Pozitivă
    - Comparator neinversor cu Reacție
    - Comparator inversor cu Reacție
  - Reacție Negativă
    - Amplificator neinversor
    - Amplificator inversor

Amplificator inversor

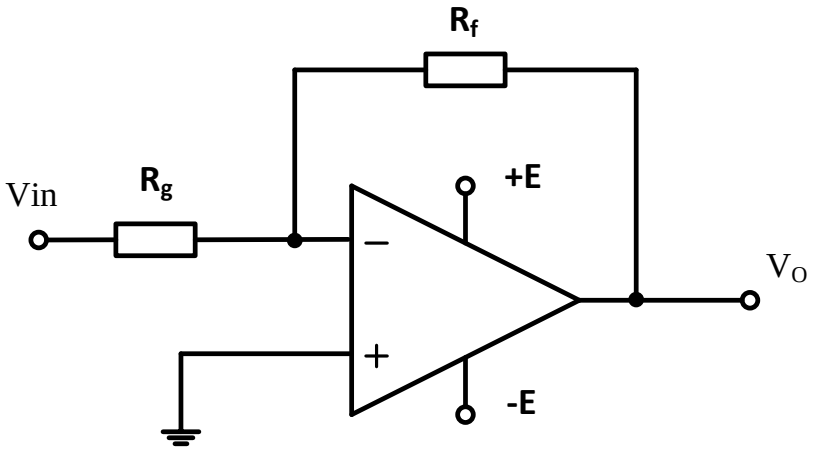


$$\left.\begin{aligned} V^- &= \frac{\frac{v_{in}}{R_g}+\frac{v_o}{R_f}}{\frac{1}{R_g}+\frac{1}{R_f}} \\ V^+ &= 0 \end{aligned}\right\} \Rightarrow V^+ = V^- \Rightarrow \frac{\frac{v_{in}}{R_g}+\frac{v_o}{R_f}}{\frac{1}{R_g}+\frac{1}{R_f}} = 0$$

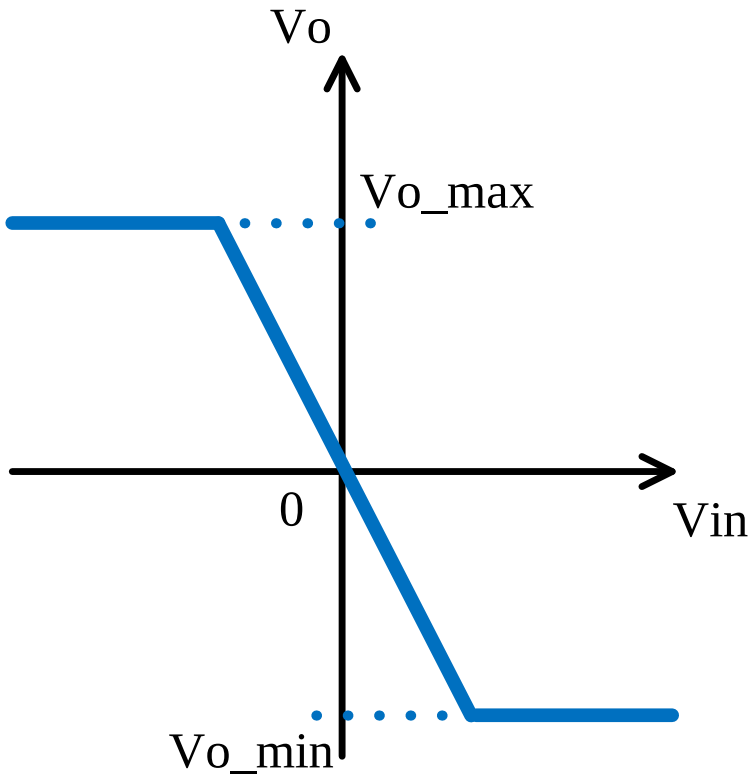
$$\Rightarrow \frac{v_{in}}{R_g}+\frac{v_o}{R_f}=0 \Rightarrow v_o = -\frac{R_f}{R_g}\cdot v_{in}$$

$$A_v = \frac{v_o}{v_{in}} = -\frac{R_f}{R_g}$$

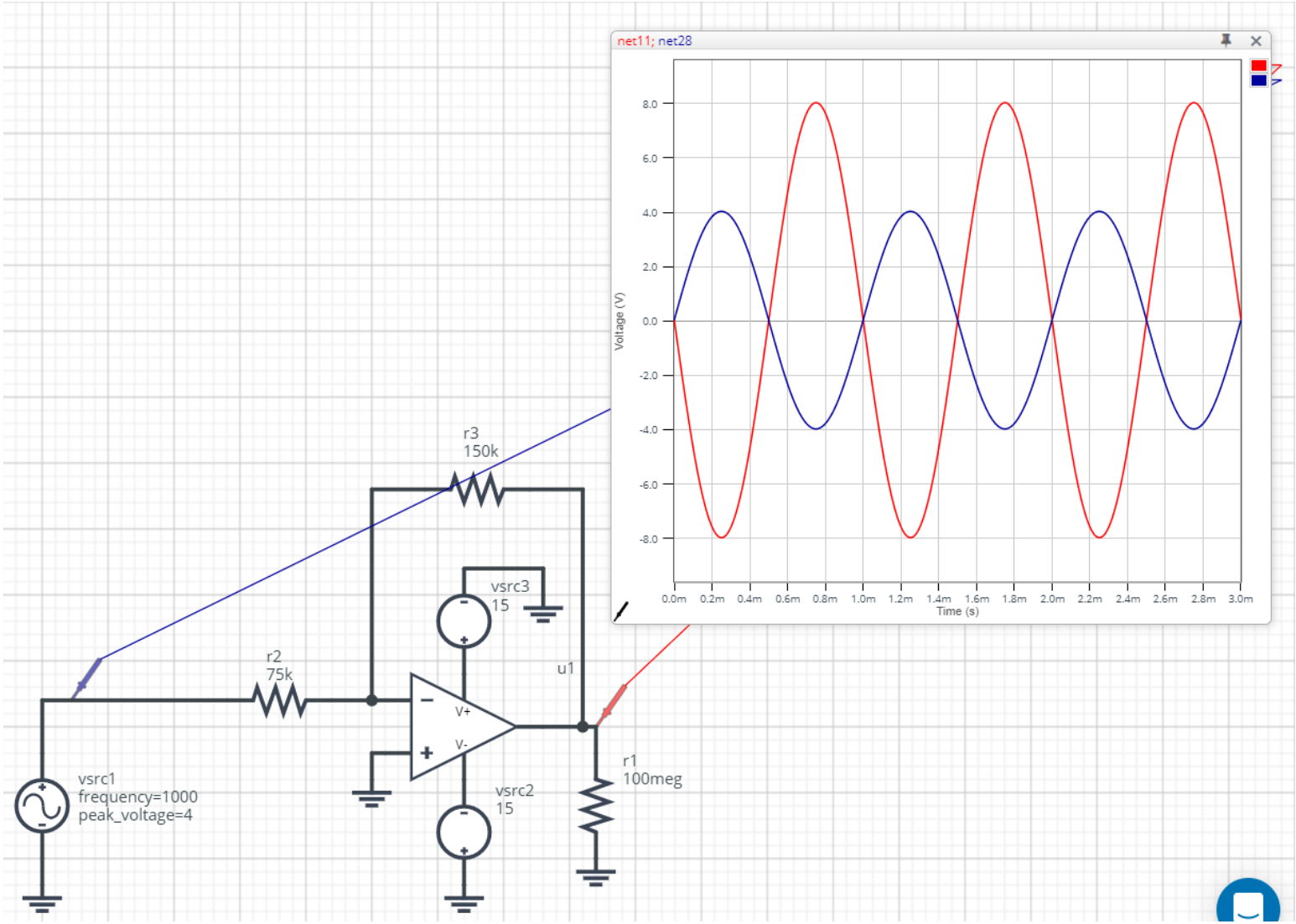
Amplificator inversor



$$A_v = \frac{v_o}{v_{in}} = -\frac{R_f}{R_g}$$



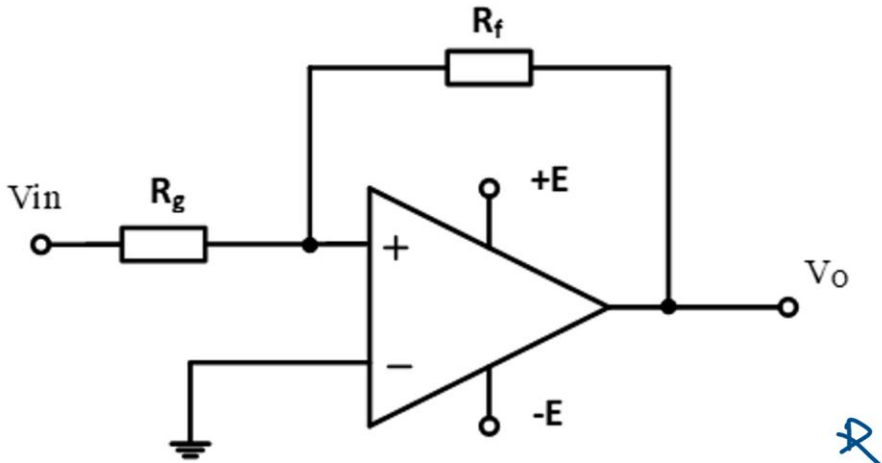
Amplificator inversor

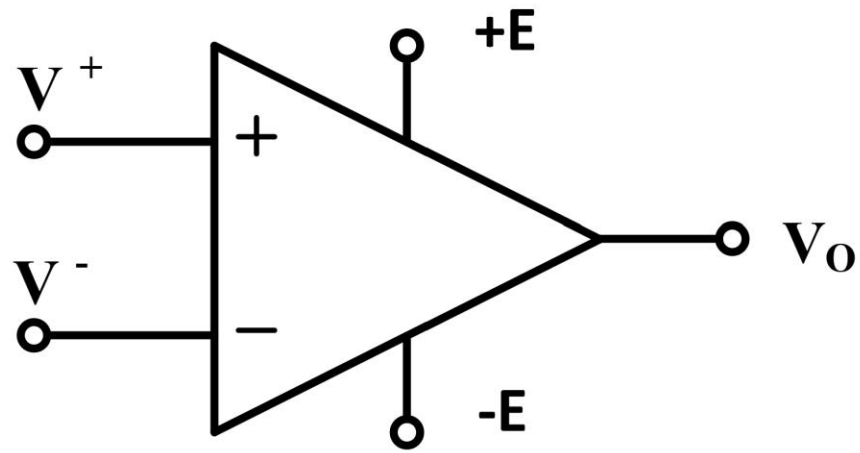


Amplificator inversor

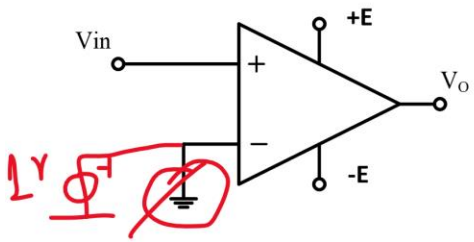
NOTIȚE

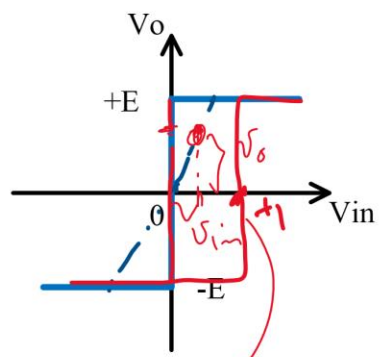
= marți =



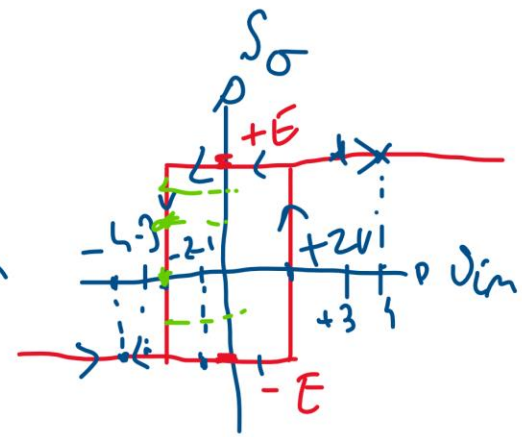


$A_D \to \infty$

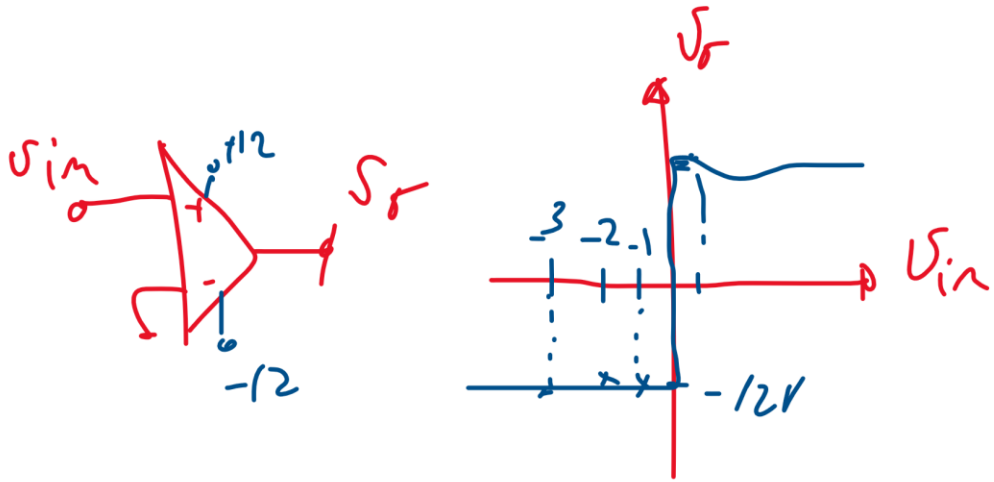


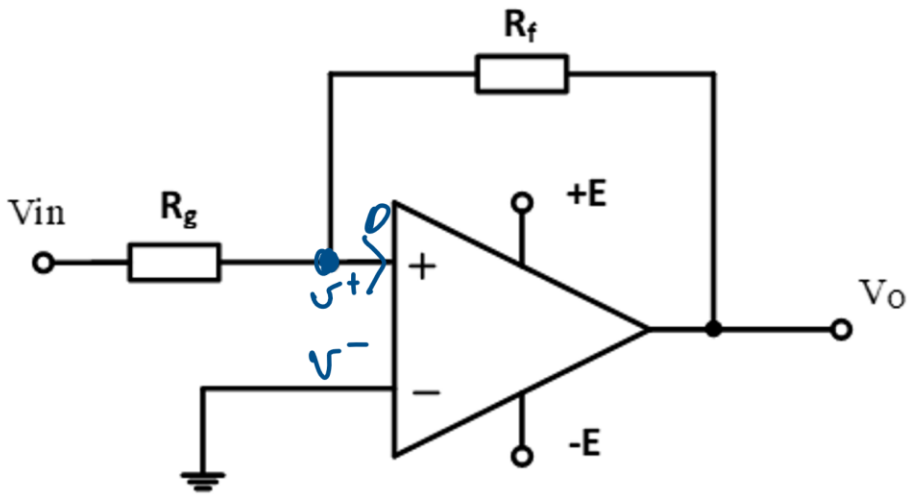


$$v_o = \begin{cases} +E, v_{in} \geq 0 \\ -E, v_{in} < 0 \end{cases}$$



$$A_D = \frac{v_o}{v_{in}} \to \infty$$





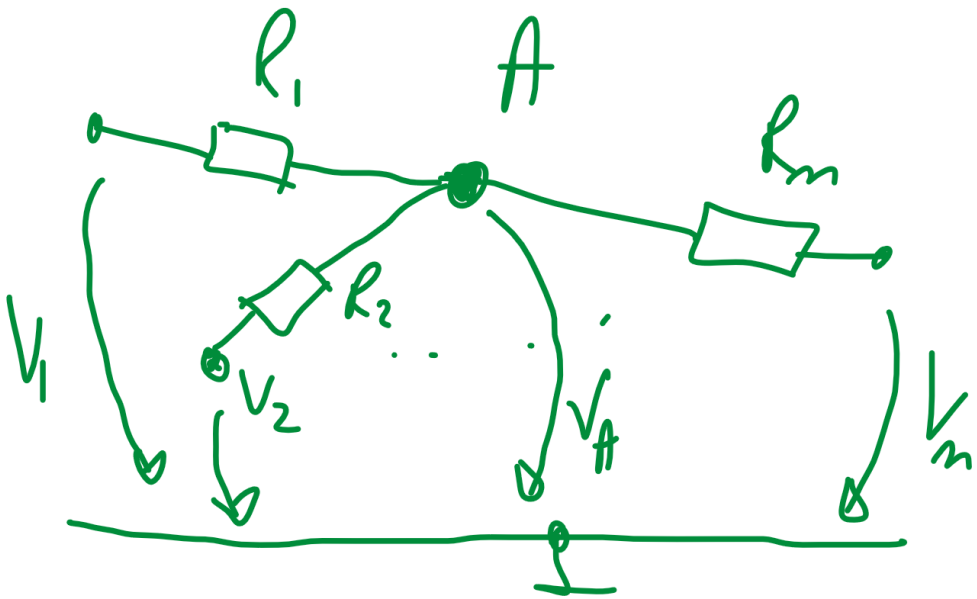
$v_o = A_D \cdot (v^+ - v^-)$ dar pentru $v_i = V_p$

$v_o = \infty \cdot 0$

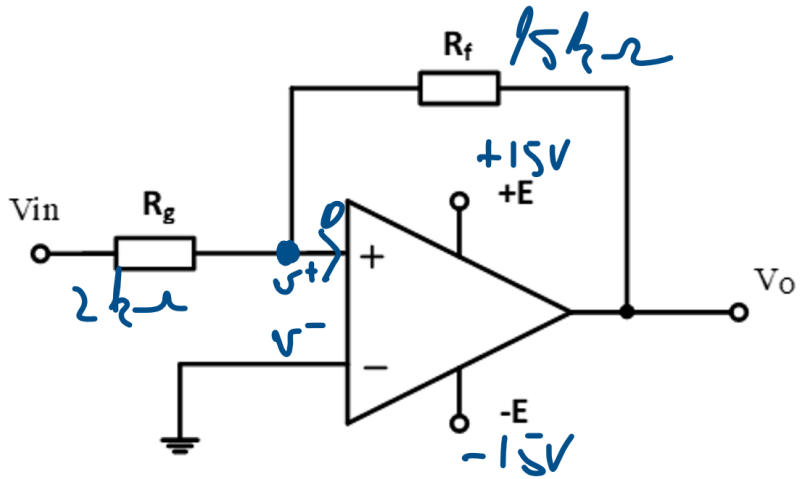
$Rf \Rightarrow$ dacă $v_{in} = V_p \Rightarrow v^+ = v^-$

$v \cong 0V$

T. MILLMAN



$$V_A = \frac{\frac{V_1}{R_1} + \frac{V_2}{R_2} + \cdots + \frac{V_m}{R_m}}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_m}} = \frac{\sum_{i=1}^{n} \frac{V_i}{R_i}}{\sum_{i=1}^{n} \frac{1}{R_i}}$$

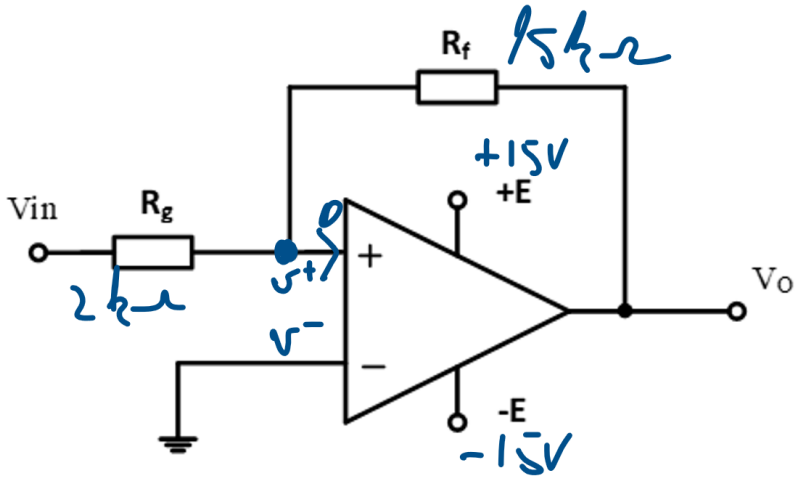


RP=0 daca $v_{in} = V_p \Rightarrow v^+ = v^-$

$v = 0V$

$$v^+ = \frac{\frac{V_{in}}{R_g} + \frac{V_o}{R_f}}{\frac{1}{R_g} + \frac{1}{R_f}} \quad \left.\begin{array}{l} \\ \\ \end{array}\right\} v_{in} = V_p \Rightarrow \frac{\frac{V_p}{R_g} + \frac{V_o}{R_f}}{\frac{1}{R_g} + \frac{1}{R_f}} = 0$$

$$\left.\begin{array}{l} \frac{V_p}{R_g} + \frac{V_o}{R_f} = 0 \\ V_o = \pm E \end{array}\right\} \Rightarrow \frac{V_p}{R_g} + \frac{\pm E}{R_f} = 0 \Rightarrow \boxed{V_{P_{1,2}} = \pm \frac{R_g}{R_f} E}$$

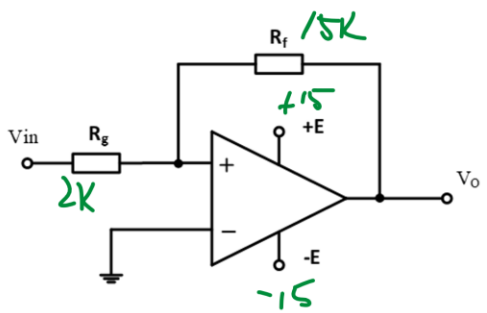


$$\frac{R_g}{R_f} \cdot E = 2$$

$$\pm E = \pm 15\,V$$

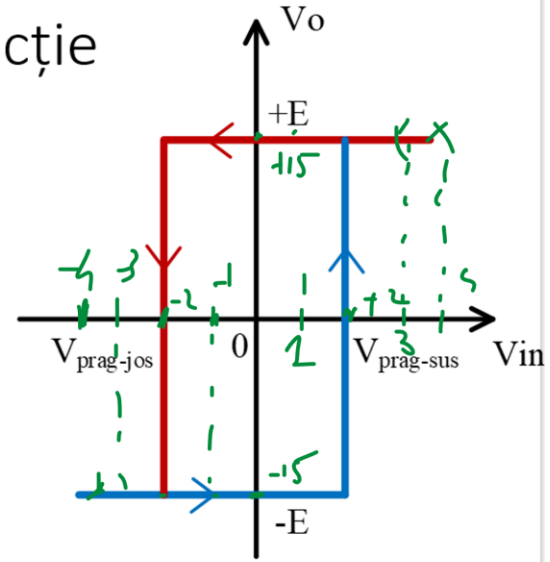
$$\text{deci } R_f = 15k\Omega \Rightarrow \frac{R_g}{15K} \cdot 15 = 2 \Rightarrow R_g = 2k\Omega$$

Comparator neinversor cu reacție



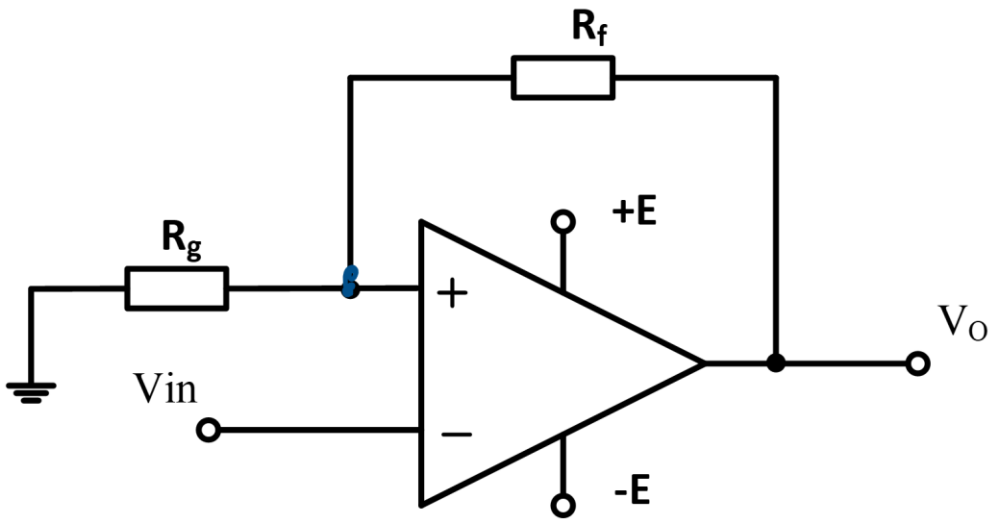
$$V_{prag} = \pm \frac{R_g}{R_f} E$$

$V_p = \pm 2V$



HISTEREZA

Comparator inversor cu reacție



RP ⇒ dacă $v_{in} = V_p \Rightarrow v^+ = v^-$

$v^- = v_{in}$

$$v^f = \frac{\frac{0}{R_g} + \frac{v_o}{R_f}}{\frac{1}{R_g} + \frac{1}{R_f}} = \frac{\frac{v_o}{R_f}}{\frac{1}{R_g} + \frac{1}{R_f}}$$

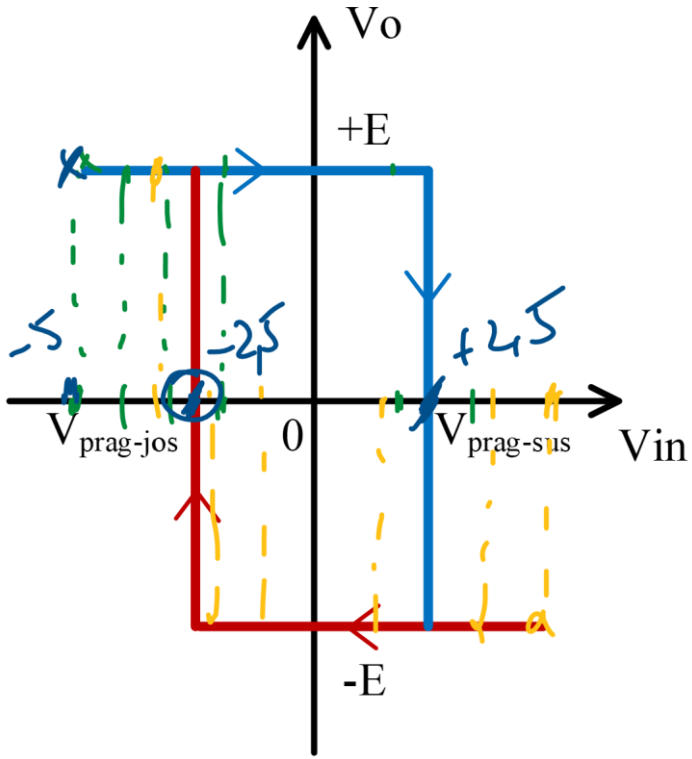
$v_{in} = V_p \Rightarrow v^+ = v^-$

$$V_p = \frac{\frac{v_o}{R_f}}{\frac{R_g + R_f}{R_g \cdot R_f}}$$

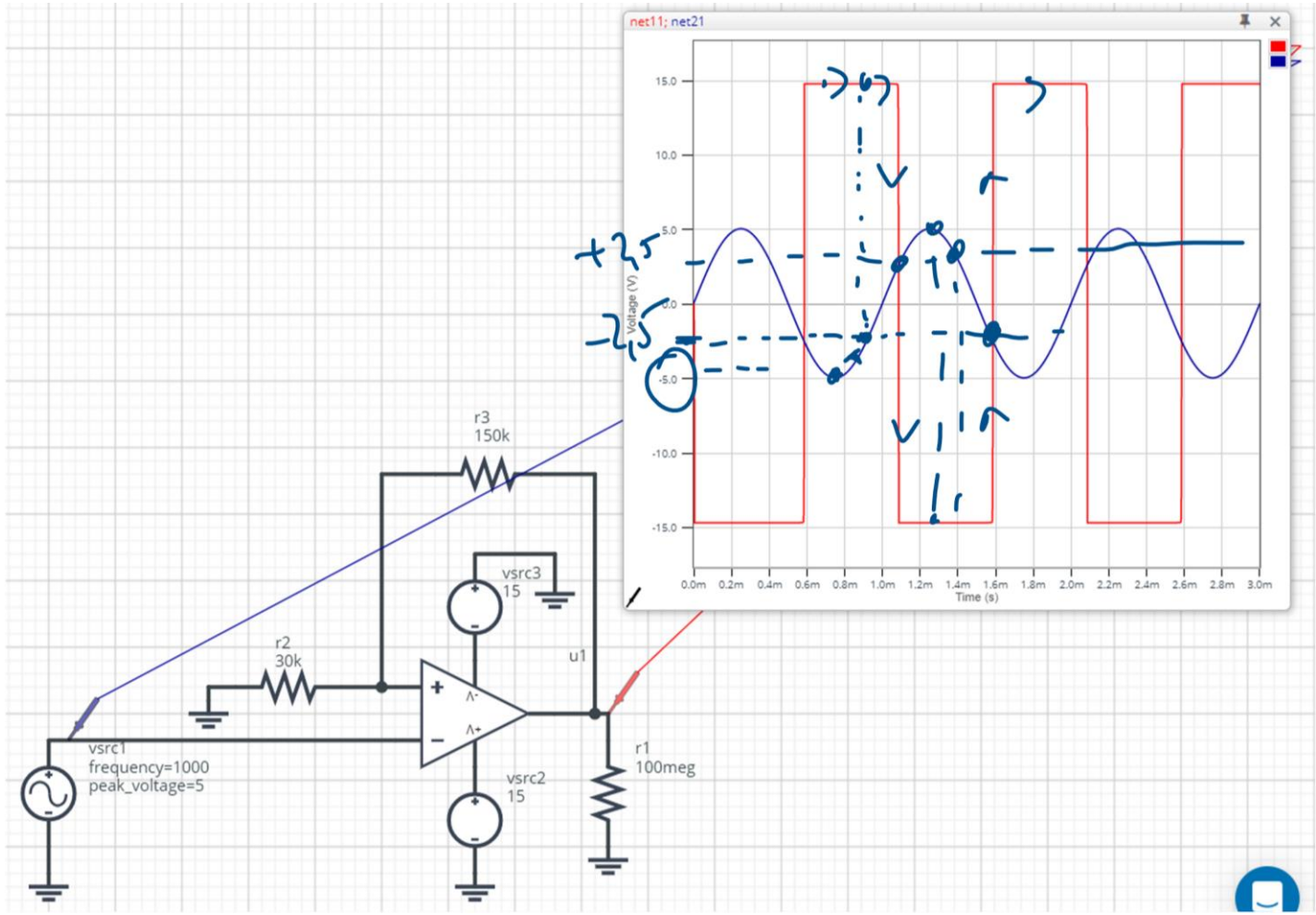
$v_o = \pm E$

$$\Rightarrow V_p = \frac{\frac{\pm E}{R_f}}{\frac{R_g + R_f}{R_g \cdot R_f}}$$

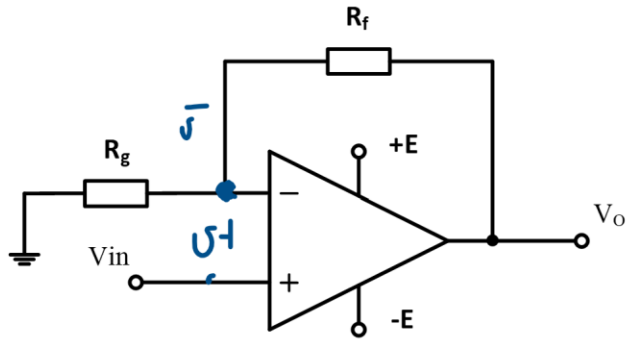
$$V_{p_{1,2}} = \pm \frac{R_g}{R_g + R_f} E$$



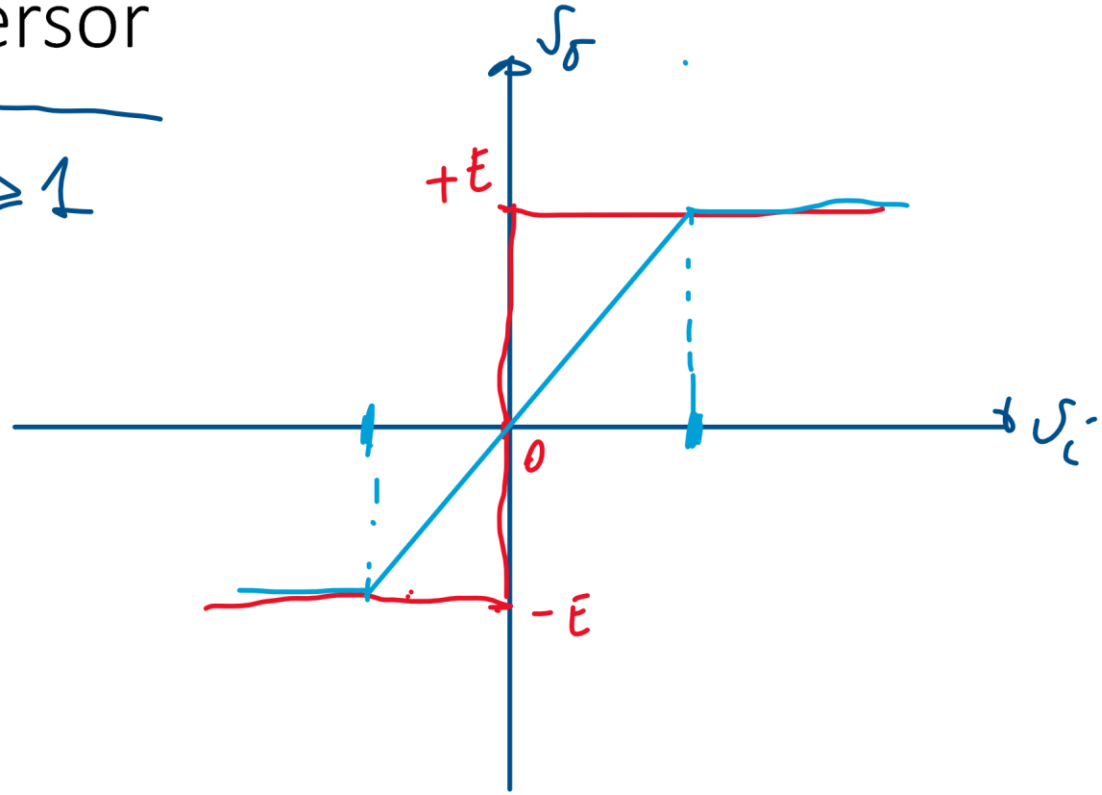
$$V_p = t \frac{30k}{30k + 150k} \times 15V = \pm 2{,}5V$$

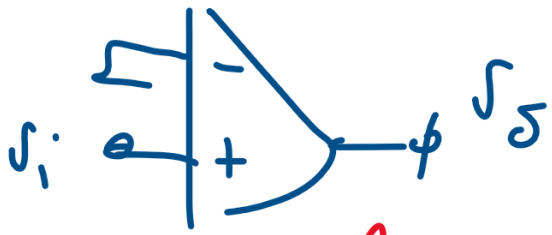


Amplificator neinversor



$A \geq 1$





$A_D \to \infty$

$v_o = A_D \cdot (v^+ - v^-)$ - sal. funcție

$\infty \cdot ? \Rightarrow$ sal. fin. lor

$\Rightarrow v^+ - v^- = 0$

RN ⇒ $v^+ = v^-$

$$v^+ = v_{in}$$

$$v^- = \frac{\frac{0}{R_g} + \frac{v_o}{R_f}}{\frac{1}{R_g} + \frac{1}{R_f}}$$

$$\Rightarrow \quad v_{in} = \frac{\frac{v_o}{R_f}}{\frac{R_g + R_f}{R_g \cdot R_f}} \quad \Rightarrow \quad \frac{v_o}{R_f} = \frac{R_g + R_f}{R_g \cdot R_f} \cdot v_{in}$$

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

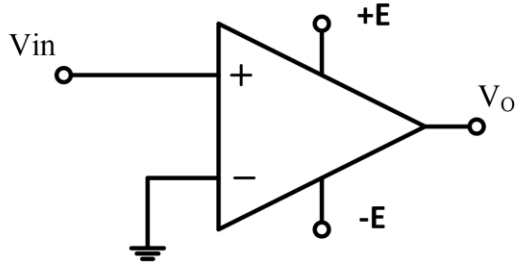
$$\boxed{A = \frac{v_o}{v_{in}} = 1 + \frac{R_f}{R_g}}$$

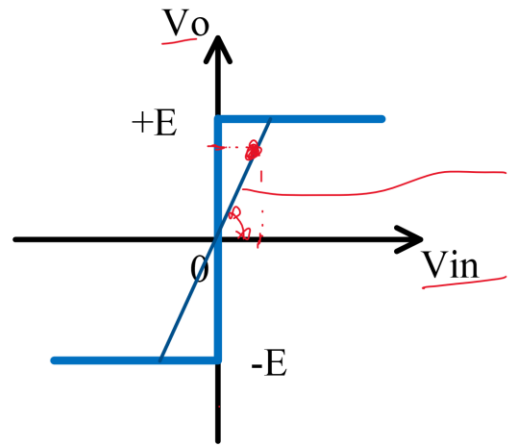
obs : $A \geq 1$

A nu depinde de $\pm E$

NOTIȚE

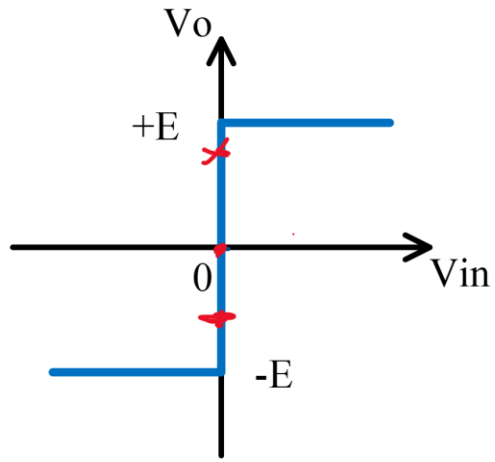
= joi =





$A \to \infty$

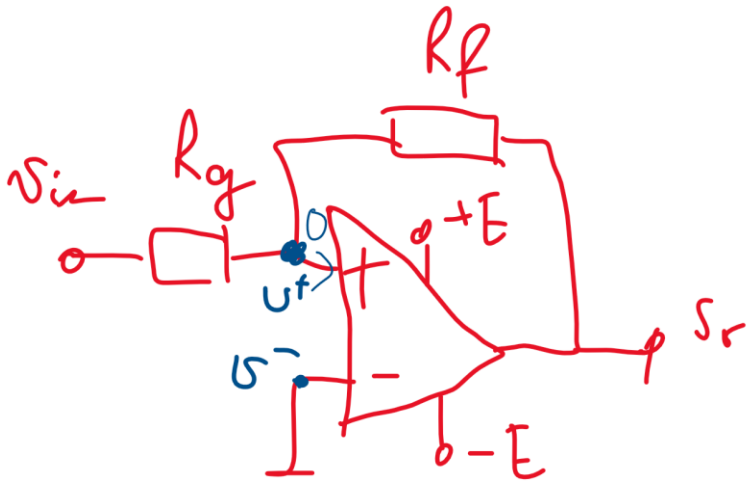
panta: $A = \frac{v_o}{v_{in}} \to \infty$



$v_o = \infty \left(v^+ - v^- \right) = \infty \left(v_{in} - 0 \right)$

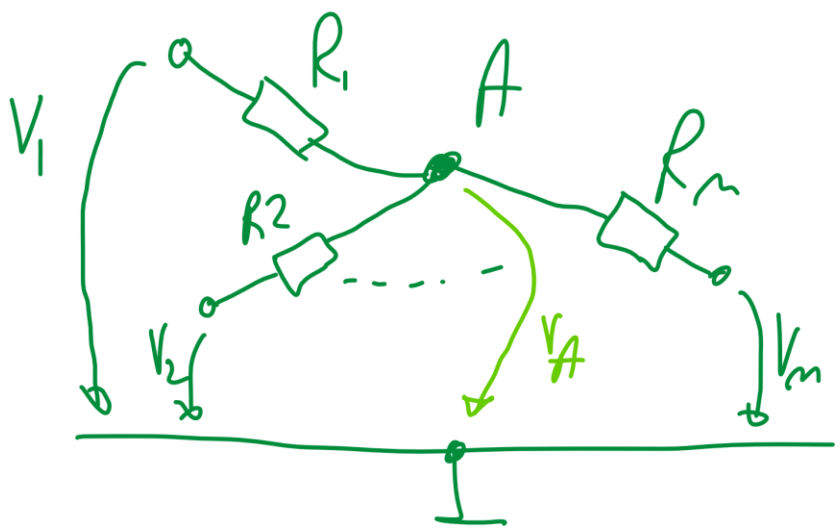
dacă $v_{in} = 0 \Rightarrow v_o$ - nedeterminat

$v_{in} = V_{ref} = V_p \Rightarrow v^+ = v^-$

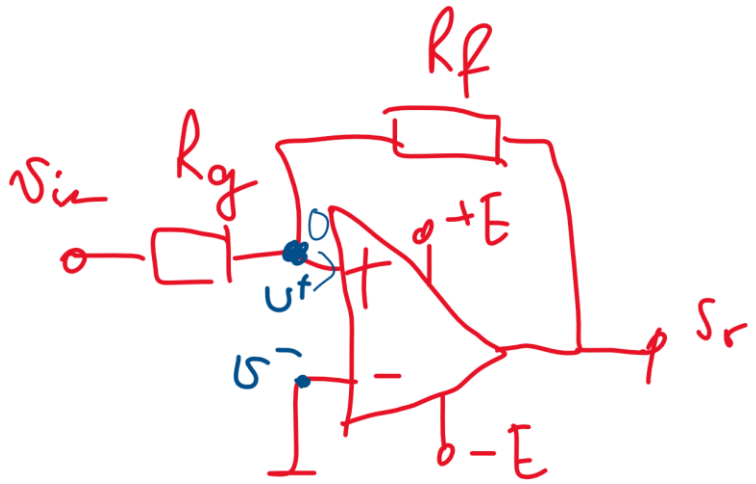


p.f. $U_{in} = V_p \approx 0 \Rightarrow U^+ = U^-$

T. MILLMAN



$$V_A = \frac{\sum_{i=1}^{n} \frac{V_i}{R_i}}{\sum_{i=1}^{n} \frac{1}{R_i}} = \frac{\frac{V_1}{R_1} + \frac{V_2}{R_2} + \ldots + \frac{V_n}{R_n}}{\frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}}$$



pf. $v_{in} = V_p \Rightarrow v^+ = v^-$

RP: pf. $v_{in} = V_p \Rightarrow v^+ = v^-$

$$v^- = 0$$

$$v^+ = \frac{\frac{v_{in}}{R_g} + \frac{v_o}{R_f}}{\frac{1}{R_g} + \frac{1}{R_f}}$$

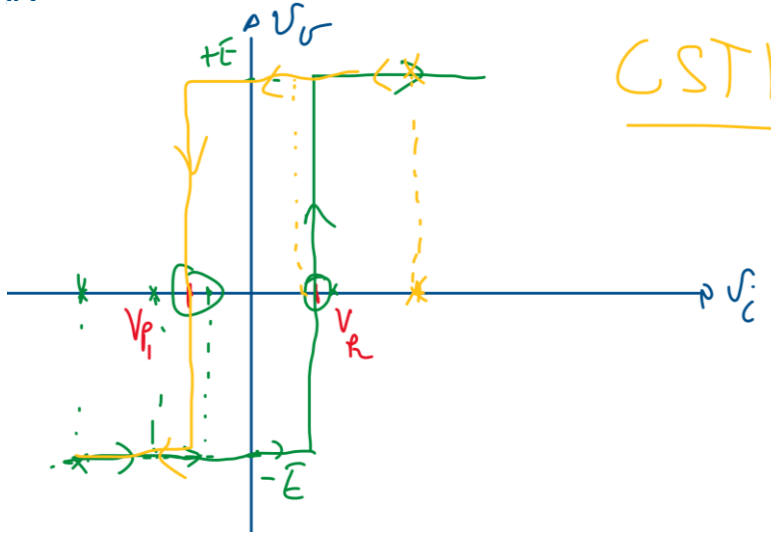
$v_{in} = V_p \Longrightarrow$

$$\frac{\frac{V_p}{R_g} + \frac{v_o}{R_f}}{\frac{1}{R_g} + \frac{1}{R_f}} = 0$$

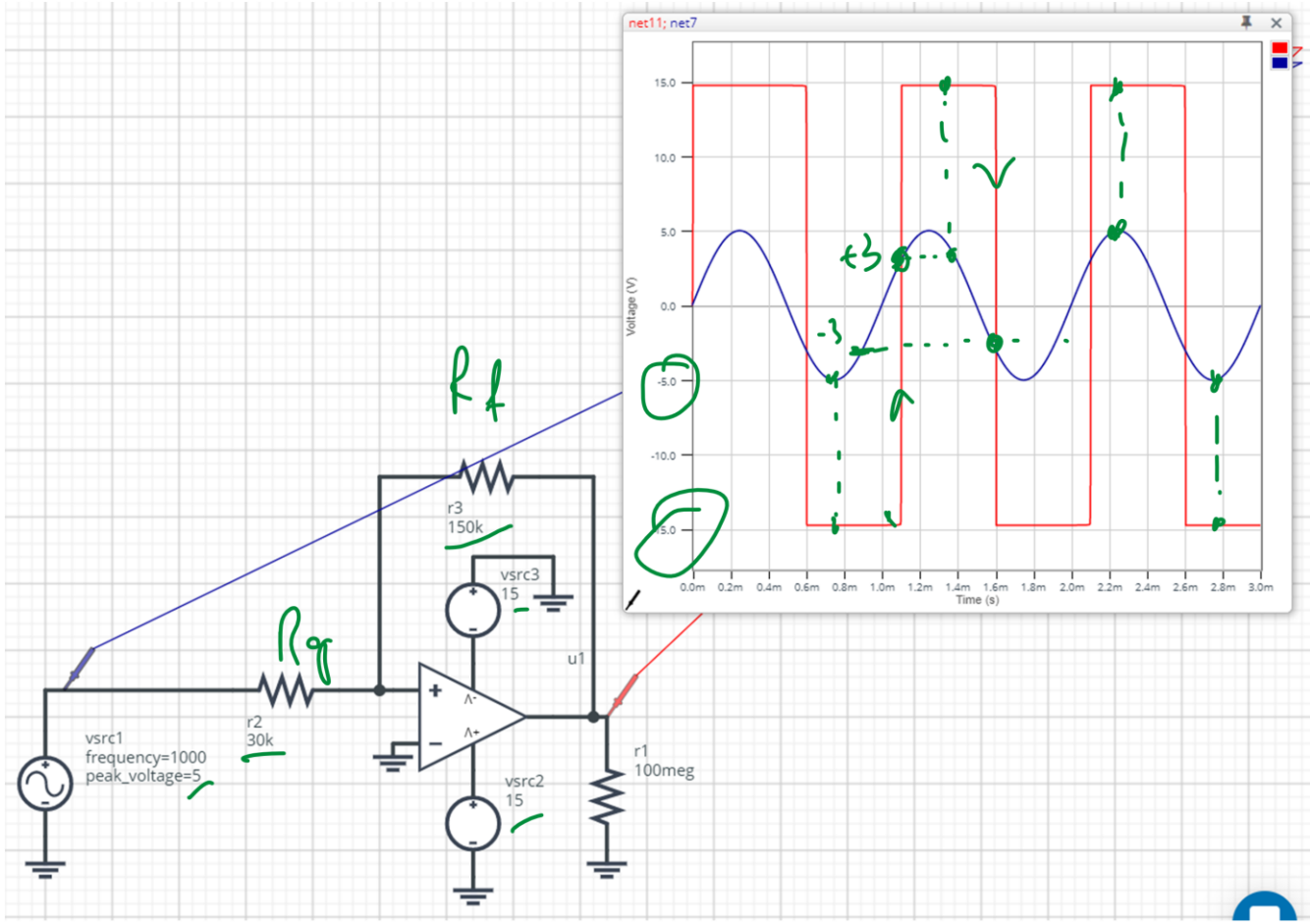
$$\frac{V_p}{R_g} + \frac{v_o}{R_f} = 0$$

$$v_o = \pm E$$

$$\Rightarrow \frac{V_p}{R_g} + \frac{\pm E}{R_f} = 0 \Rightarrow V_{p_{1,2}} = \pm \frac{R_g}{R_f} E$$



CSTV



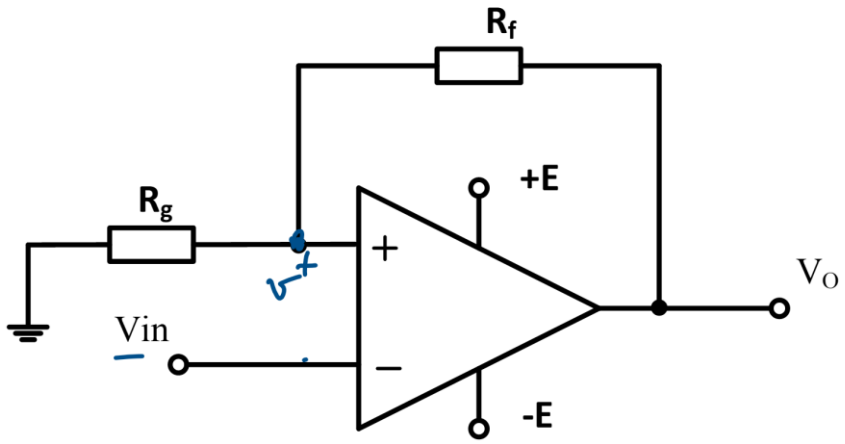
$$V_{P_{1,2}} = \pm \frac{R_g}{R_f} E = \pm \frac{30K\Omega}{150K\Omega} \times 15$$

$$V_{P_{1,2}} = \pm 3V$$

Low → High : $V_{P_1} = +3V$

High → Low : $V_{P_2} = -3V$

Comparator inversor cu reacție



RP ⇒ $v_{in} = V_p \Rightarrow v^+ = v^-$

$v^- = v_{in}$

$$v^+ = \frac{\frac{0}{R_g} + \frac{v_o}{R_f}}{\frac{1}{R_g} + \frac{1}{R_f}}$$

$v_{in} = V_p \Rightarrow$

$$\frac{\frac{v_o}{R_f}}{\frac{1}{R_g} + \frac{1}{R_f}} = V_p$$

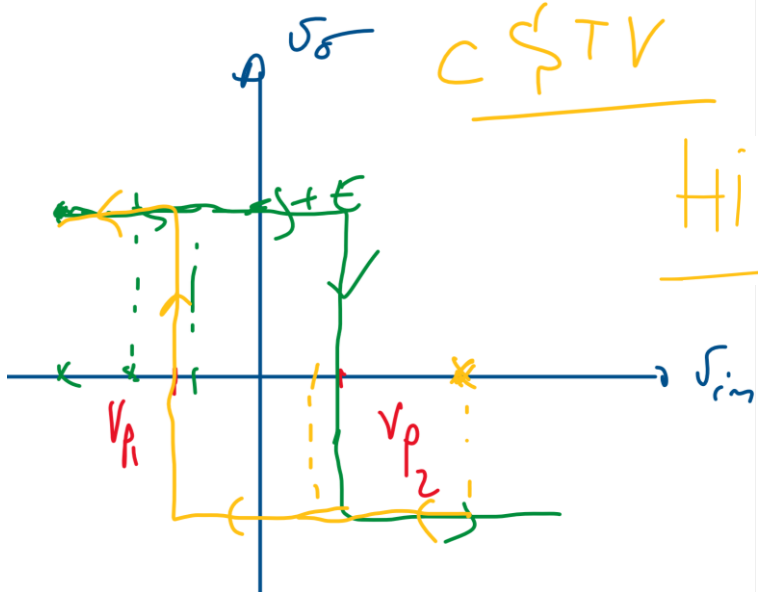
$$V_p = \frac{\frac{v_o}{R_f}}{\frac{R_f + R_g}{R_f \cdot R_g}}$$

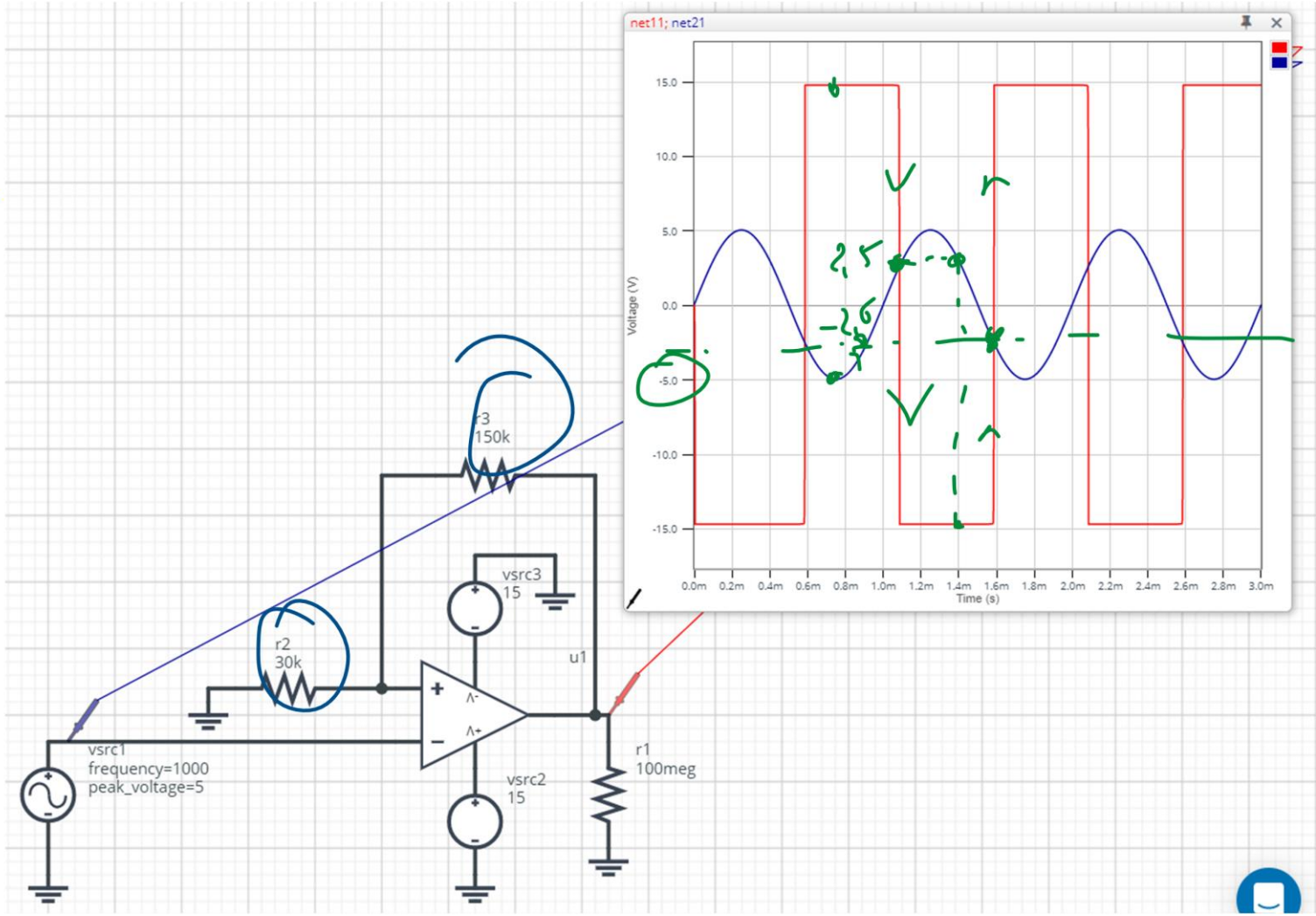
$v_o = \pm E$

$$\Rightarrow \boxed{V_{p_{1,2}} = \pm \frac{R_g}{R_g + R_f} E}$$

CSTV

HISTEREZĂ



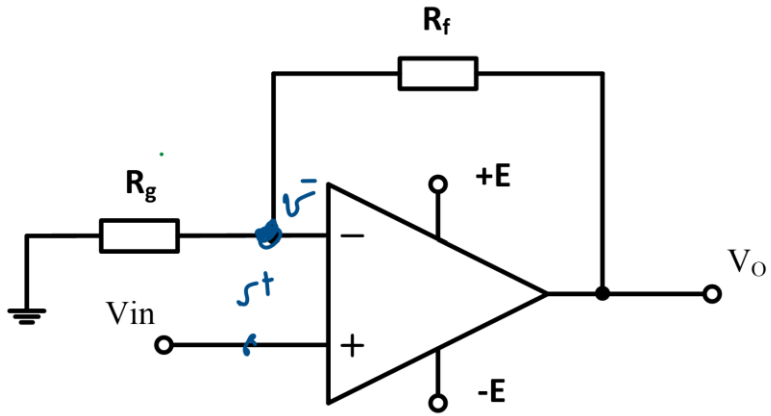


$$V_{P_{1,2}} = \pm \frac{30\,k\Omega}{180\,k\Omega} 15V = \pm 2{,}5V$$

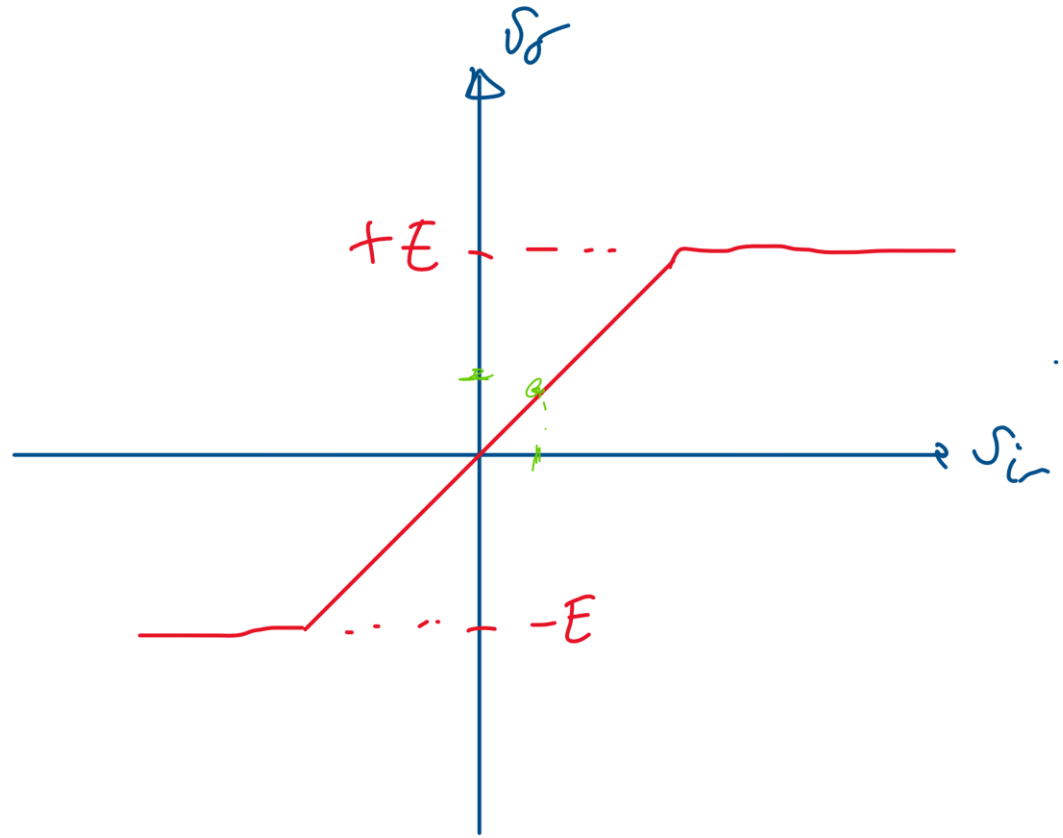
Low → High : $V_{P_1} = -2{,}5V$

High → Low : $V_{P_2} = +2{,}5V$

Amplificator neinversor



$$A = \frac{v_o}{v_{in}} = ?$$



$$v_o = A_D (v^+ - v^-) = \infty \cdot (v^+ - v^-)$$

$A_D \to \infty$

$(v^+ - v^-) \to 0$

$RN \rightarrow v^+ = v^-$

$v^+ = v_{in}$

$v^- = \dfrac{\frac{0}{R_g} + \frac{v_o}{R_f}}{\frac{1}{R_g} + \frac{1}{R_f}}$

$\Rightarrow v_{in} = \dfrac{\frac{v_o}{R_f}}{\frac{1}{R_g} + \frac{1}{R_f}}$

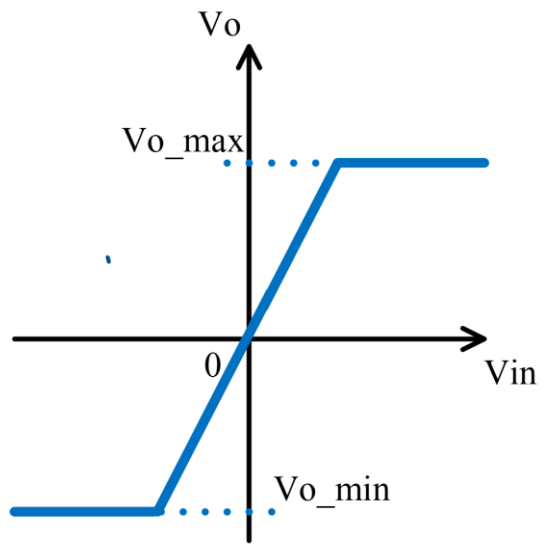
$\dfrac{v_o}{R_f} = \dfrac{R_g + R_f}{R_g \cdot R_f} \cdot v_{in} \Rightarrow$

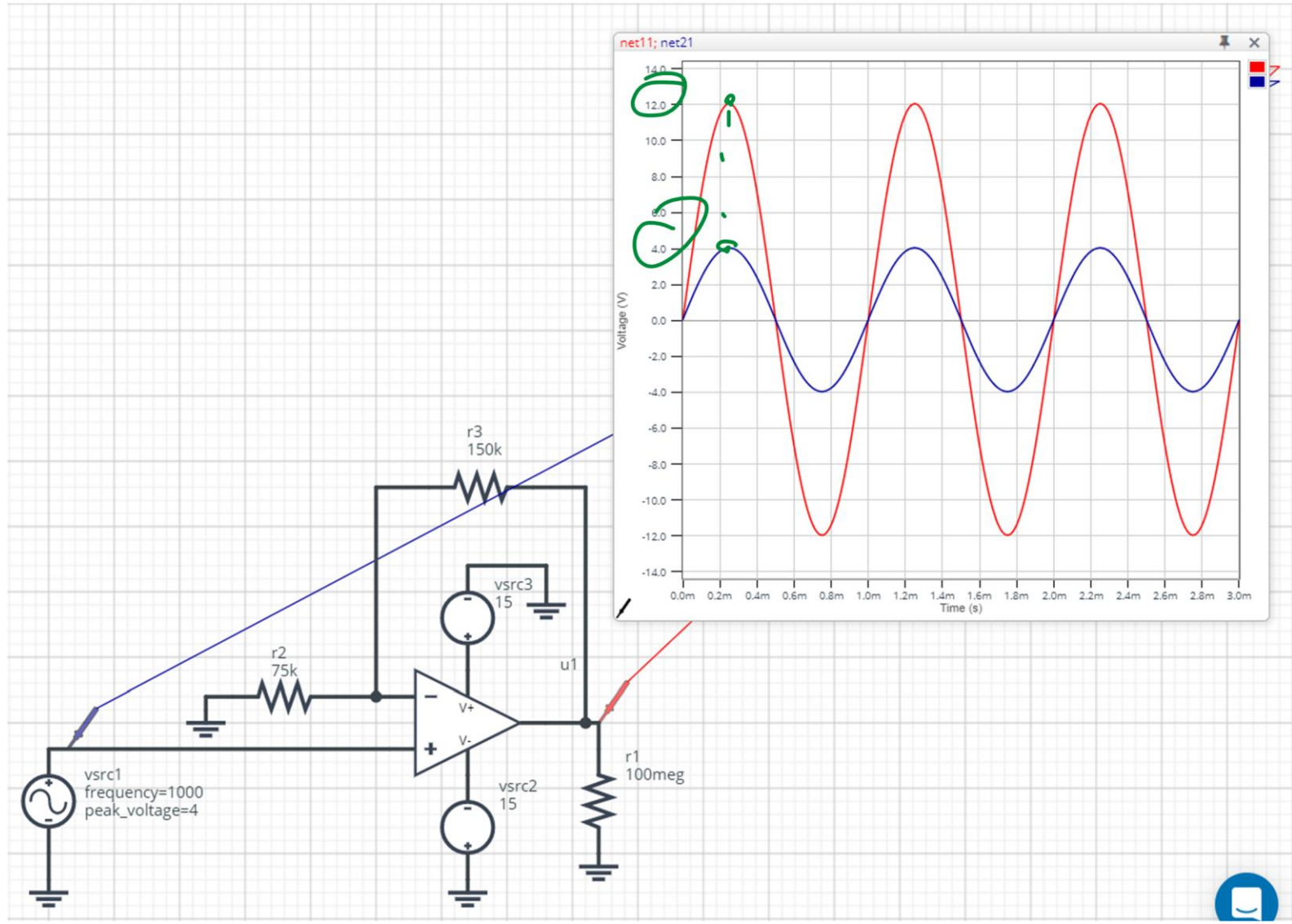
$$v_o = \left(1 + \frac{R_f}{R_g}\right) v_{in}$$

$$A = \frac{v_o}{v_{in}} = 1 + \frac{R_f}{R_g}$$

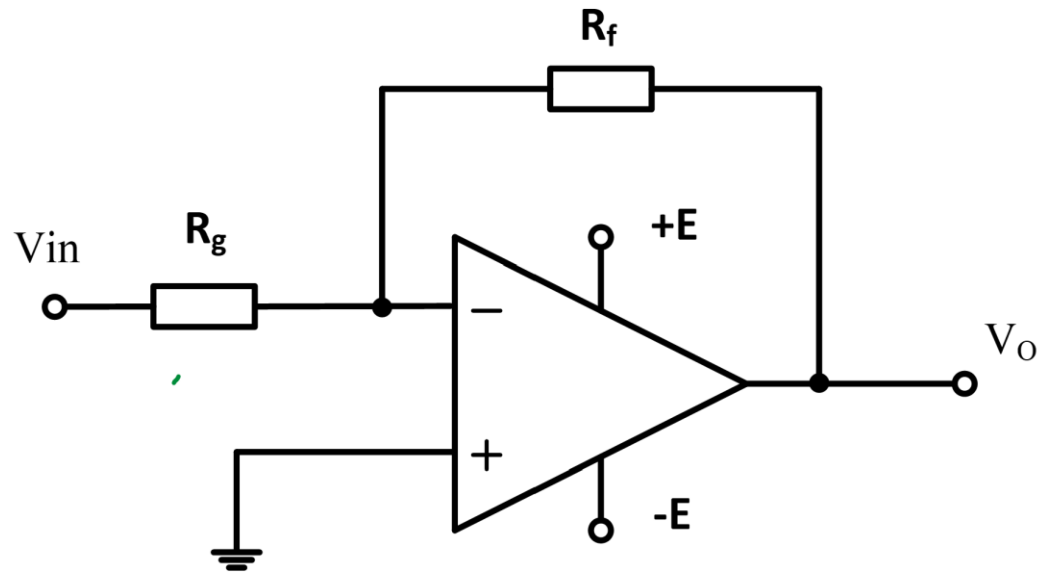
obs:

1. $A \geq 1$
2. $A \neq f(E)$




net11; net21
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
Voltage (V)
0.0m 0.2m 0.4m 0.6m 0.8m 1.0m 1.2m 1.4m 1.6m 1.8m 2.0m 2.2m 2.4m 2.6m 2.8m 3.0m
Time (s)
r3
150k
vsrc3
15
r2
75k
u1
V+
V-
vsrc1
frequency=1000
peak_voltage=4
vsrc2
15
r1
100meg

Amplificator inversor



$R_{IN} \Rightarrow v^+ = v^-$

$v^+ = 0$

$$v^- = \frac{\frac{v_{in}}{R_g} + \frac{v_o}{R_f}}{\frac{1}{R_g} + \frac{1}{R_f}}$$

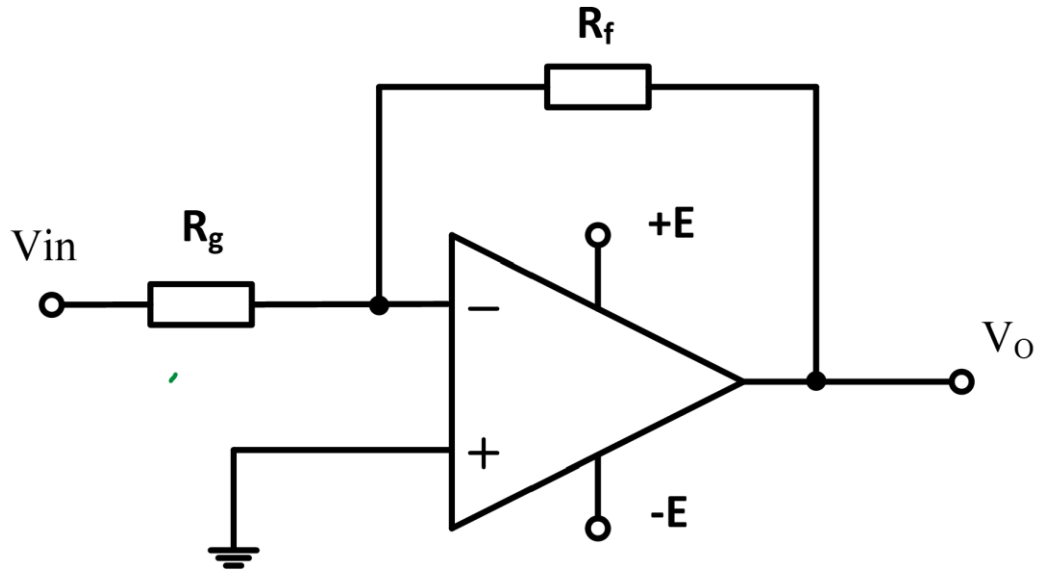
$$\Rightarrow \frac{v_{in}}{R_g} + \frac{v_o}{R_f} = 0 \Rightarrow \boxed{v_o = -\frac{R_f}{R_g} v_{in}}$$

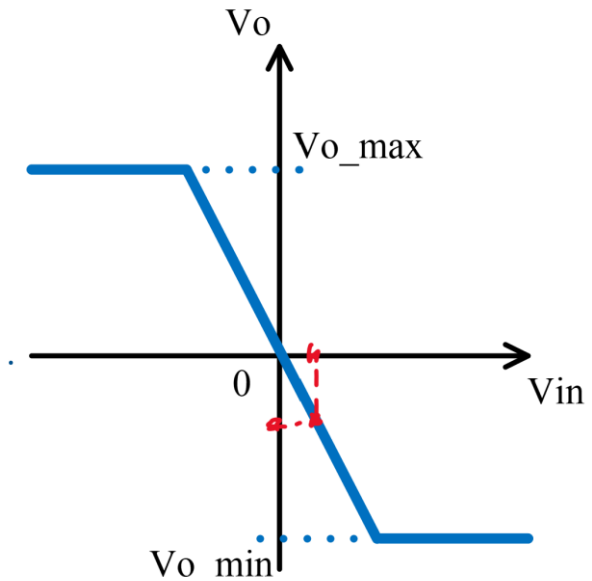
$$\boxed{A = \frac{v_o}{v_{in}} = -\frac{R_f}{R_g}}$$

Amplificator inversor

$$U_o = -\frac{R_f}{R_g} U_{in}$$

$$A = \frac{U_o}{U_{in}} = -\frac{R_f}{R_g}$$

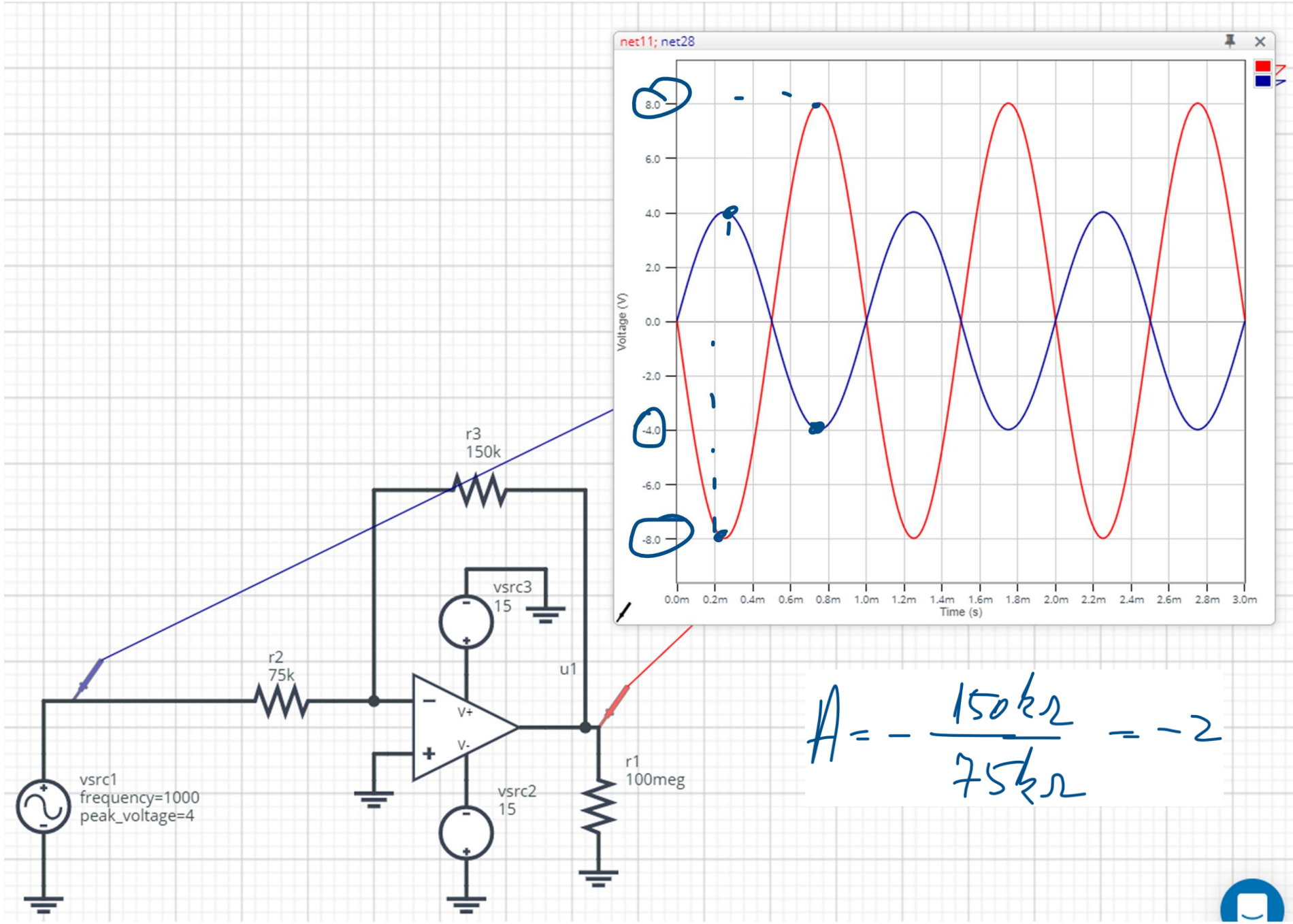




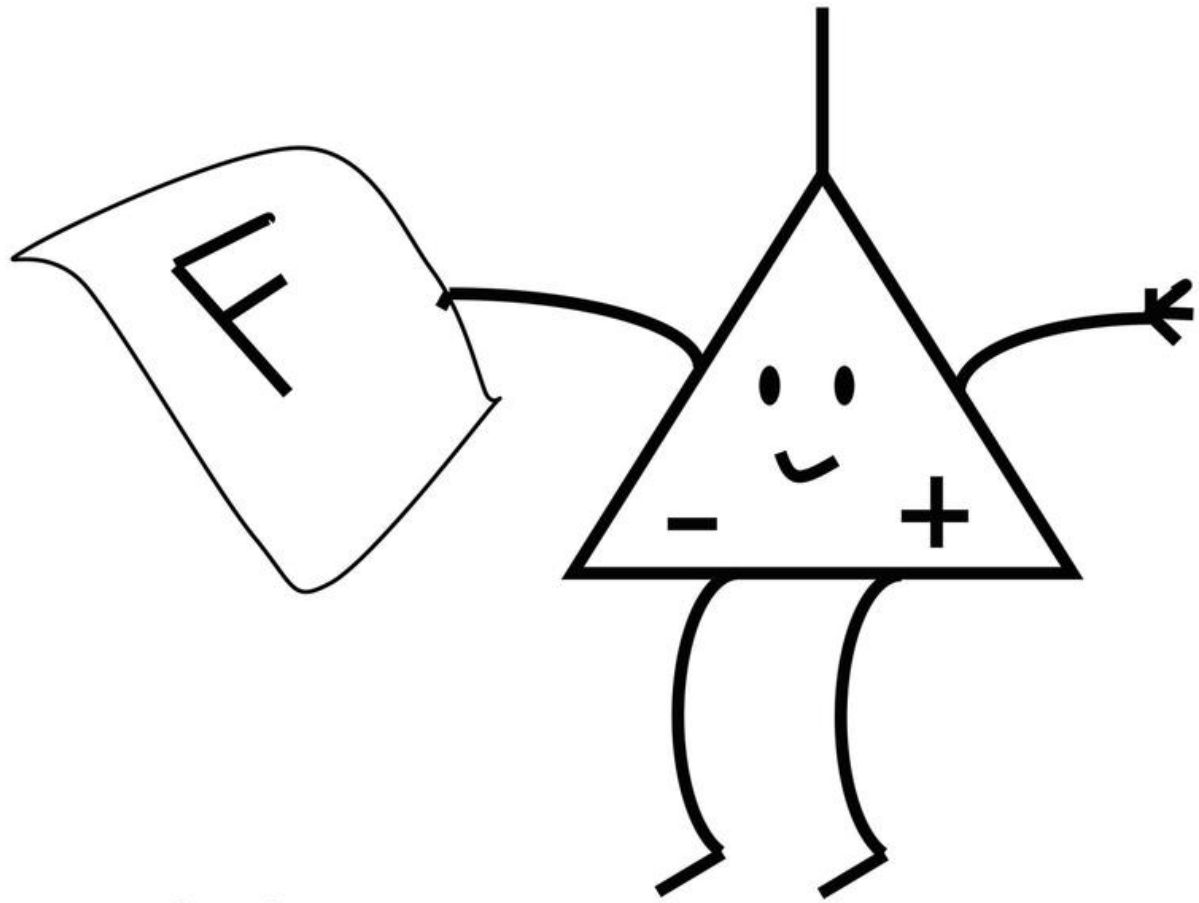
obs:

1. $|A| < 1$ $(R_f < R_g)$

2. $A \neq f(E)$



$$A = -\frac{150k\Omega}{75k\Omega} = -2$$



I don’t accept currents

I work well with negative feedback