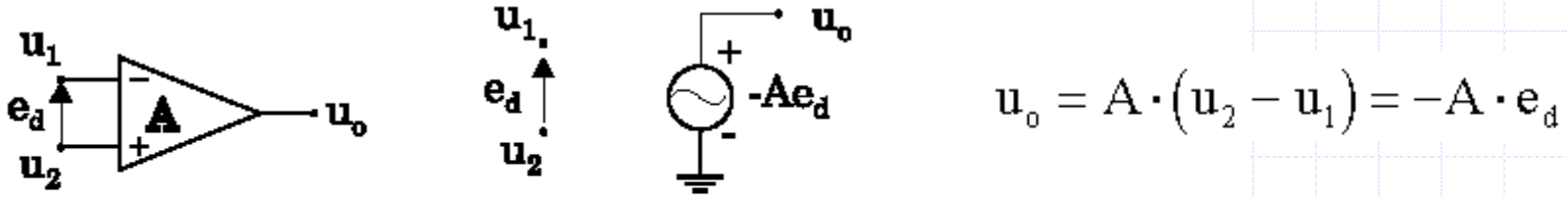
PRIMENA OPERACIONIH POJAČAVAČA

Operacioni pojačavač

- beskonačno diferencijalno pojačanje $(A \to \infty)$
- nulto pojačanje srednje vrednosti signala $(A_{sr} = 0)$
- beskonačni faktor potiskivanja srednje vrednosti signala $\left(CMRR = \frac{A}{A_{sr}} \to \infty\right)$
- nulte ulazne struje polarizacije $(I_{B1} = I_{B2} = 0)$
- nulti ulazni strujni ofset $(I_{os} = I_{B1} - I_{B2} = 0)$
- nulti ulazni naponski ofset $(V_{os} = 0, \quad \text{tj. } u_o = 0, \text{za } u_1 = u_2)$
- beskonačnu ulaznu impedansu $(Z_i \to \infty)$
- nultu izlaznu impedansu $(Z_o = 0)$
- beskonačni propusni opseg $(f_T \to \infty)$, za male i velike signale
- nulti fazni pomeraj $(\Theta = 0)$.



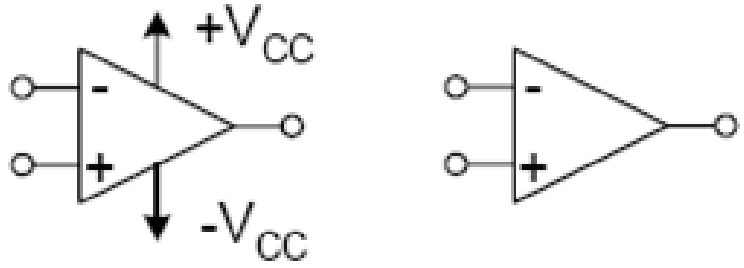
$$u_o = A \cdot (u_2 - u_1) = -A \cdot e_d$$

Slika 2.1 Simbol (a) i ekvivalentna šema (b) idealnog operacionog pojačavača

1. Operacioni Pojačavači

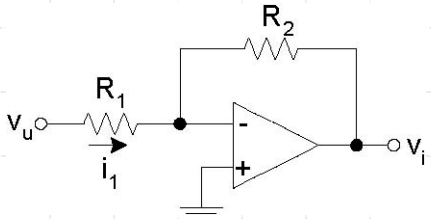
Operacioni pojačavač je kolo koje pojačava razliku napona na njegovim ulazima.

S' obzirom na to da na njegovom izlazu mora postojati konačan napon, a da mu je naponsko pojačanje beskonačno veliko, napon između ulaznih krajeva mora biti jednak nuli.



tipovi pojačavača

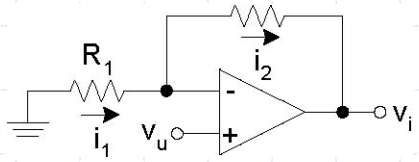
1. Invertorski pojačavač:



$$i_1 = \frac{v_u}{R_1} \qquad v_i = -R_2 i_1 = -\frac{R_2}{R_1} v_u$$

$$A_v = \frac{v_i}{v_u} = \frac{R_2}{R_1}$$

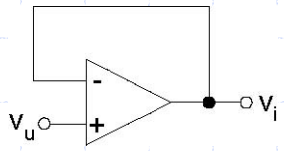
2. Neinvertorski pojačavač:



$$i_1 = \frac{v_u}{R_1} \qquad i_2 = \frac{v_i - v_u}{R_2} = i_1 = \frac{v_u}{R_1}$$

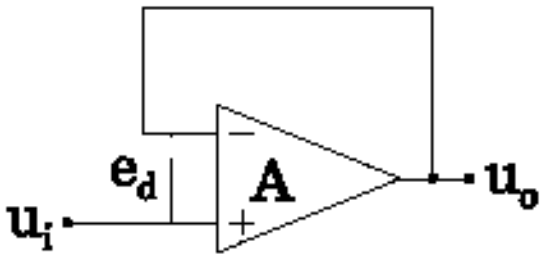
$$A_v = \frac{v_i}{v_u} = \frac{R_1 + R_2}{R_1} = 1 + \frac{R_2}{R_1}$$

3. Jedinični pojačavač:



3 OSNOVNA KOLA SA OPERACIONIM POJAČAVAČIMA

3.1 Jedinični pojačavač



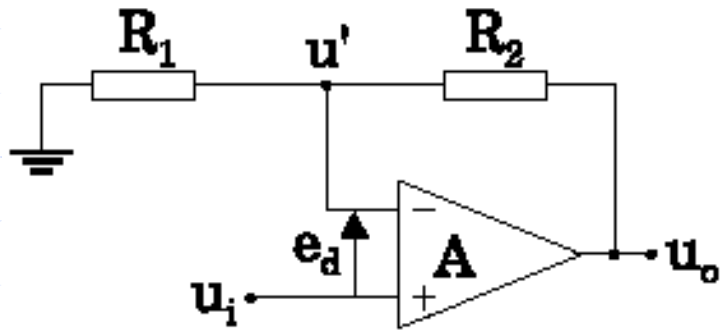
$e_d = 0 \qquad (A \to \infty)$

$$u_o = u_i$$

ULAZNA IMPEDANSA JE BESKONAČNA

IZLAZNA IMPEDANSA JE JEDNAKA NULI

3.2 NEINVERTUJUĆI POJAČAVAČ



$e_d = 0 \quad (u' = u_i)$.

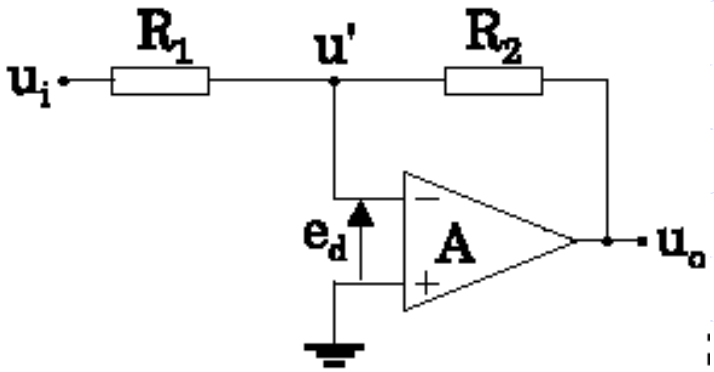
$$\frac{u_i}{R_1} + \frac{u_i - u_o}{R_2} = 0$$

$$u_o = \left(1 + \frac{R_2}{R_1}\right) \cdot u_i$$

ULAZNA IMPEDANSA JE BESKONAČNA

IZLAZNA IMPEDANSA JE JEDNAKA NULI

3.3 INVERTUJUĆI POJAČAVAČ



$$u' = 0$$

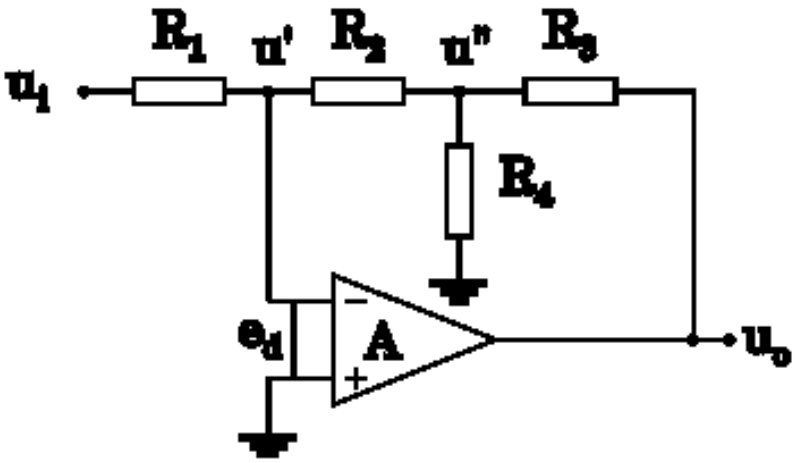
$$-\frac{u_i}{R_1} - \frac{u_o}{R_2} = 0$$

$$u_o = -\frac{R_2}{R_1} \cdot u_i$$

ULAZNA IMPEDANSA JE R1

IZLAZNA IMPEDANSA JE JEDNAKA NULI

Invertujući pojačavač sa malim otpornicima



$$u' = 0$$

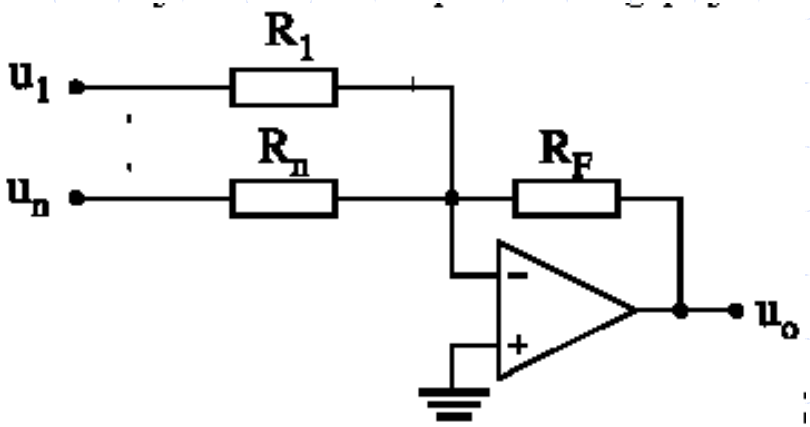
$$-\frac{u_i}{R_1} - \frac{u''}{R_2} = 0$$

$$\frac{u''}{R_2} + \frac{u''}{R_4} + \frac{u'' - u_o}{R_2} = 0$$

$$u'' = \frac{R_2 R_4}{R_2 R_3 + R_2 R_4 + R_3 R_4} \cdot u_o$$

$$A = \frac{u_o}{u_i} = -\frac{R_2 R_3 + R_2 R_4 + R_3 R_4}{R_1 R_4}$$

3.4 SABIRAČ NA INVERTUJUĆEM ULAZU

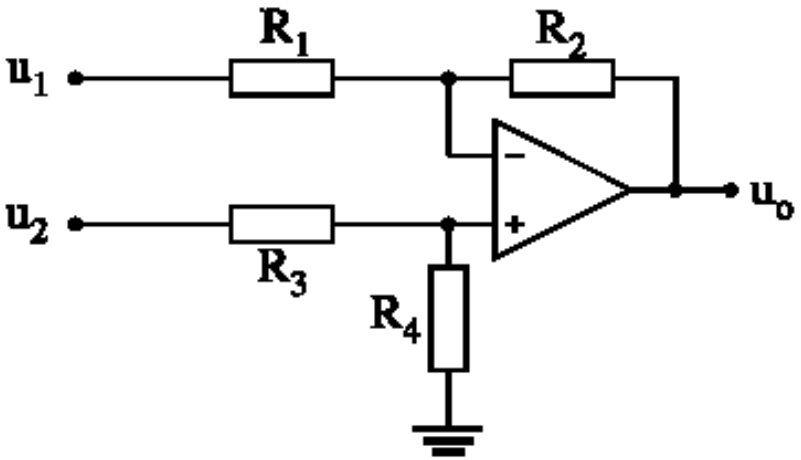


U1/R1+…+Un/Rn+Uo/RF=0

$$u_o = -\sum_{i=1}^{n} \frac{R_F}{R_i} u_i$$

ulazne impedanse posmatrane sa ulaza $u_1,\ldots,u_n$ iznose $R_1,\ldots,R_n$.

3.5 DIFERENCIJALNI POJAČAVAČ



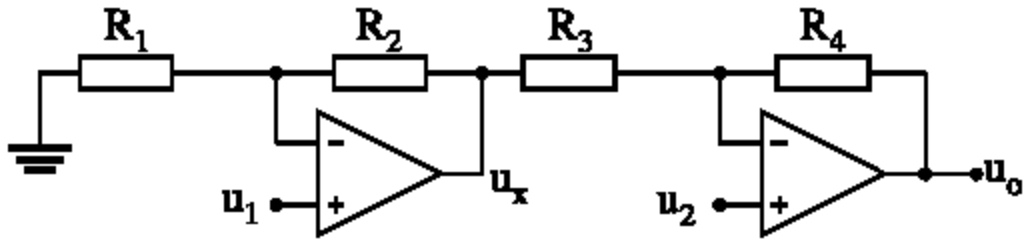
$$u_o = -\frac{R_2}{R_1}\cdot u_1 + \frac{R_4}{R_3+R_4}\cdot\left(1+\frac{R_2}{R_1}\right)\cdot u_2$$

$$\frac{R_2}{R_1} = \frac{R_4}{R_3+R_4}\cdot\frac{R_1+R_2}{R_1}$$

$$\frac{R_2}{R_1} = \frac{R_4}{R_3}$$

$$u_o = \frac{R_2}{R_1}\left(u_2 - u_1\right)$$

Diferencijalni pojačavač sa dva operaciona pojačavača

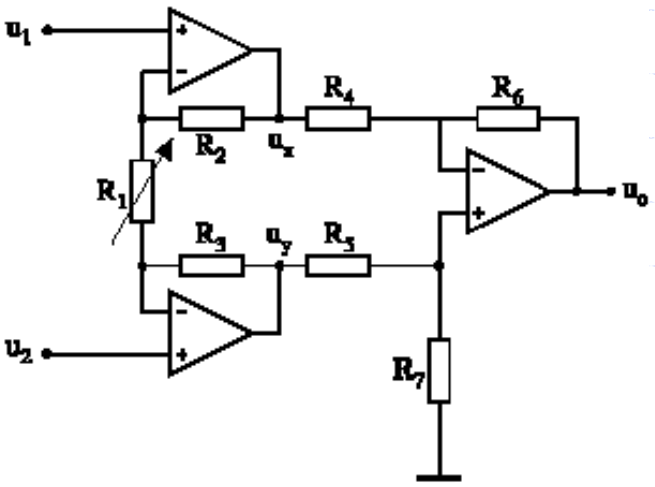


$$u_o = \left(1 + \frac{R_4}{R_3}\right) \cdot u_2 - \frac{R_4}{R_3} \cdot \left(1 + \frac{R_2}{R_1}\right) \cdot u_1$$

$$\frac{R_4}{R_3} = \frac{R_1}{R_2}$$

$$u_o = \left(1 + \frac{R_4}{R_3}\right) \cdot \left(u_2 - u_1\right)$$

Instrumentacioni pojačavač



$$u_x = \left(1 + \frac{R_2}{R_1}\right) \cdot u_1 - \frac{R_2}{R_1} \cdot u_2$$

$$u_y = \left(1 + \frac{R_3}{R_1}\right) \cdot u_2 - \frac{R_3}{R_1} \cdot u_1$$

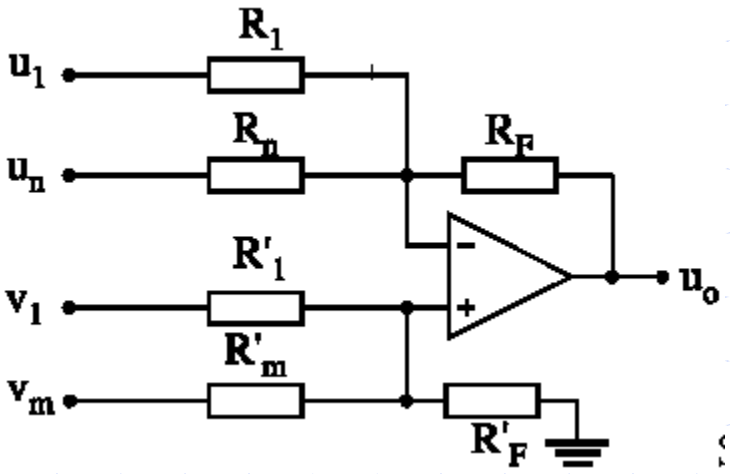
$$u_o = -\frac{R_6}{R_4} \cdot u_x + \frac{R_7}{R_5 + R_7} \cdot \left(1 + \frac{R_6}{R_4}\right) \cdot u_y$$

$$u_o = \left[\frac{R_2}{R_1}\frac{R_6}{R_4} + \frac{R_7}{R_5 + R_7}\left(1 + \frac{R_6}{R_4}\right) \cdot \left(1 + \frac{R_3}{R_1}\right)\right] \cdot u_2 - \left[\frac{R_6}{R_4}\left(1 + \frac{R_2}{R_1}\right) + \frac{R_3}{R_1}\frac{R_7}{R_5 + R_7}\left(1 + \frac{R_6}{R_4}\right)\right] \cdot u_1$$

$$R_2 = R_3, \quad R_4 = R_6 \quad \text{i} \quad R_5 = R_7$$

$$u_o = \left(1 + \frac{2 \cdot R_2}{R_1}\right) \cdot (u_2 - u_1)$$

3.6 ALGEBARSKI SABIRAČ



$$\sum_{i=1}^{n}\frac{u_F-u_i}{R_i}+\frac{u_F-u_o}{R_F}=0$$

$$\sum_{j=1}^{m}\frac{u_F-v_j}{R'_j}+\frac{u_F}{R_F}=0$$

$$u_F=\frac{\sum_{j=1}^{m}\frac{R'_F}{R'_j}\cdot v_j}{1+\sum_{j=1}^{m}\frac{R'_F}{R'_j}}$$

$$u_o=\frac{\sum_{j=1}^{m}\frac{R'_F}{R'_j}\cdot v_j}{1+\sum_{j=1}^{m}\frac{R'_F}{R'_j}}\cdot\left(1+\sum_{i=1}^{n}\frac{R_F}{R_i}\right)-\sum_{i=1}^{n}\frac{R_F}{R_i}\cdot u_i$$

$$\sum_{i=1}^{n}\frac{R_F}{R_i}=\sum_{j=1}^{m}\frac{R'_F}{R'_j})$$

$$u_o=\sum_{j=1}^{m}\frac{R'_F}{R'_j}\cdot v_j-\sum_{i=1}^{n}\frac{R_F}{R_i}\cdot u_i$$

Nastavak

$$x = 2 - 1.5 \cdot y\,; \quad y = 5 - 2 \cdot x$$

$$x = \frac{R'_F}{R'_{x1}} \cdot 2V - \frac{R_F}{R_{x1}} \cdot y$$

$$\sum_{i=1}^{n} \frac{R_F}{R_i} = \sum_{j=1}^{m} \frac{R'_F}{R'_j}$$

$$R'_{XX} = R'_F / 0.5$$

$$y = \frac{R'_F}{R'_{y1}} \cdot 5V - \frac{R_F}{R_{y1}} \cdot x$$

$$\sum_{i=1}^{n} \frac{R_F}{R_i} = \sum_{j=1}^{m} \frac{R'_F}{R'_j}$$

$$R'_{yy} = R'_F$$