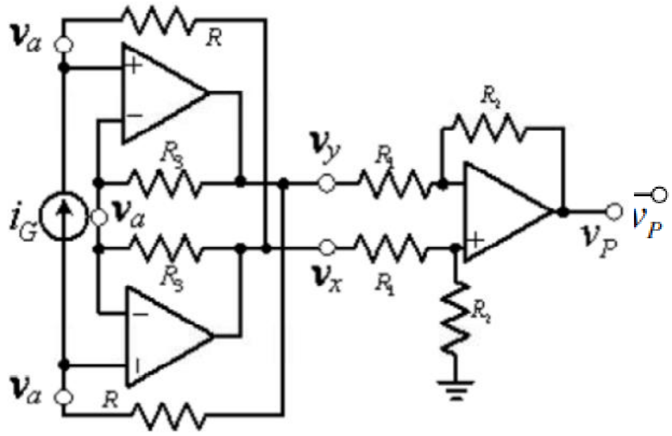
Jul 2020

**4.** [15] U kolu sa slike odrediti zavisnost $v_P = f(i_G)$. Smatrati da su otpornosti svih otpornika u kolu poznate, da su svi operacioni pojačavači idealni i da rade u linearnom režimu.




Svi pojačavači sa šeme su sa negativnom povratnom spregom pa je na svim ulazima prva dva prisutan potencijal $v_a$. S obzirom da je struja kroz pojačavače jednaka 0,

$v_y = v_a + i_G R$

$v_x = v_a - i_G R$

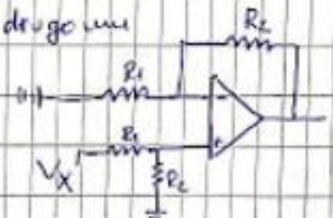
} a ova dva napona se dovode na treći pojačavač preko otpornika $R_1$

Izlaz $v_p$ možemo dobiti superpozicijom.

U prvom slučaju:


$v_p' = -\frac{R_2}{R_1} v_y$ (invertujući pojačavač)

U drugom:




$v_p'' = v_x \frac{R_2}{R_1+R_2} \cdot \left(1 + \frac{R_2}{R_1}\right)$ (neinvertujući pojačavač)

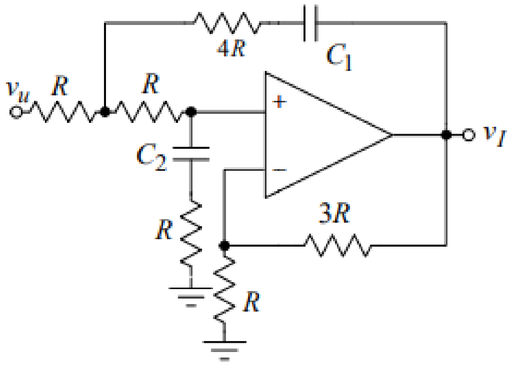
$v_p' = -\frac{R_2}{R_1} \cdot (v_a + i_G R) = -\frac{R_2}{R_1} v_a - i_G R \cdot \frac{R_2}{R_1}$

$v_p'' = v_x \frac{R_2}{R_1+R_2} \cdot \frac{R_1+R_2}{R_1} = v_x \frac{R_2}{R_1} = (v_a - i_G R)\frac{R_2}{R_1} = v_a \frac{R_2}{R_1} - i_G R \frac{R_2}{R_1}$

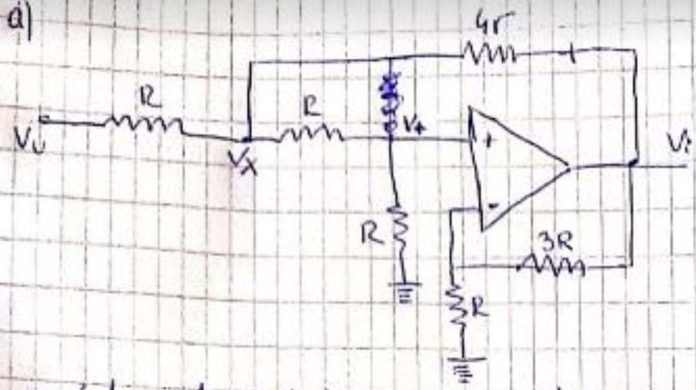
$v_p = -2 i_G R \frac{R_2}{R_1}$

Februar 2020

**4.** a) [25] Ako je $v_u$ = 1mV sin$\omega t$ a $C_1$ i $C_2$ teže beskonačnosti, odrediti izlazni napon.
b) [15] Pod uslovima iz prethodne tačke, i ako je napajanje operacionog pojačavača +5V i -3V, kolika je maksimalna moguća amplituda ulaznog sinusoidalnog signala tako da izlazni signal bude bez izobličenja?
c) [10] Ako je $V_U$ = 1V, odrediti napon na izlazu.




a)




$$V_x\left(\frac{1}{R}+\frac{1}{4R}+\frac{1}{2R}\right)=V_u\frac{1}{R}+V_i\frac{1}{4R} \quad /\cdot 4R$$

$$V_x(4+1+2)=4V_u+V_i$$

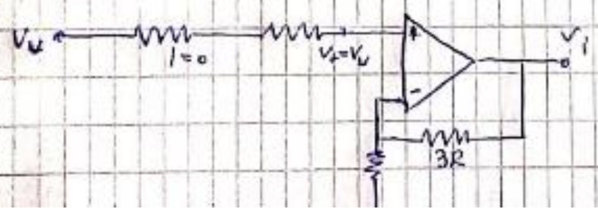
$$7V_x=4V_u+V_i$$

$$V_+=\frac{V_x}{2} \qquad V_i=V_+\cdot\left(1+\frac{3R}{R}\right)=V_+\cdot 4=2V_x \Rightarrow V_x=\frac{V_i}{2}$$

$$7\frac{V_i}{2}=4V_u+V_i \Rightarrow \frac{5}{2}V_i=4V_u \Rightarrow V_i=\frac{8}{5}V_u=1{,}6\,\text{mV}\sin\omega t$$

b) $V_{izl\,max}=\min(|5V|,|-3|)=3V \qquad a=\frac{8}{5} \Rightarrow V_{ul\,max}=\frac{3V}{\frac{8}{5}}=\frac{15}{8}V=1{,}875V$

c) Uklanjaju se grane sa kondenzatorima! DC ulaz $V_U=1V$



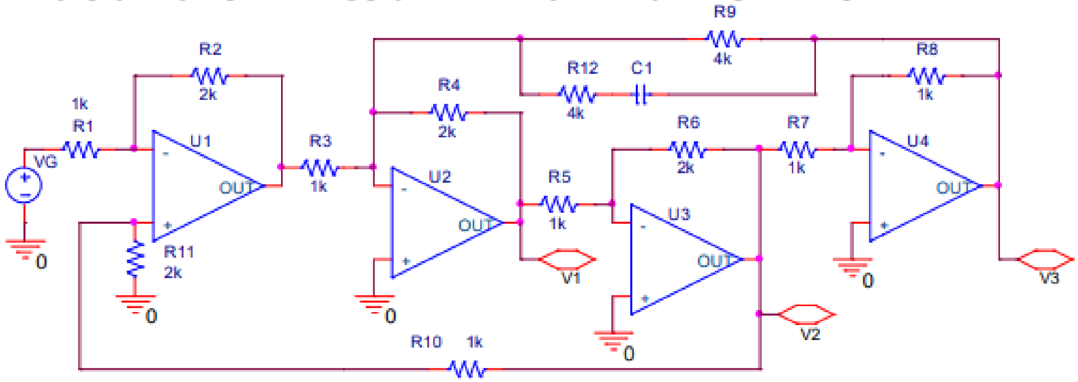

neinvertujući pojačavač

$$V_i=V_+\left(1+\frac{3R}{R}\right)=4V_+=4V$$

$$V_i=4V$$

Januar 2020

**3.** U kolu sa slike operacioni pojačavači su idealni osim ako se drugačije ne kaže.
a) [40] Ako je $v_G$= 1V sin($\omega t$) a C1 $\rightarrow\infty$, odrediti potencijale $v_1(t)$, $v_2(t)$ i $v_3(t)$.
b) [30] Ako je $V_G$=1V odrediti potencijale V1, V2 i V3.
c) [30] Ako je pojačanje operacionog pojačavača U4 jednako jedan, ponoviti prethodnu tačku.




a)

$v_3 = -\frac{R_8}{R_7} v_2 = -v_2 = 2v_1$

$v_2 = -\frac{R_6}{R_5} v_1 = -2v_1$

$v_1 = -\frac{R_4}{R_3} \cdot v_x - \frac{R_4}{R_{99}} v_3 \quad , \quad R_{99} = \frac{R_9 \cdot R_{12}}{R_9 + R_{12}} = 2k\Omega$

$v_1 = -2v_x - v_3 = -2v_x - 2v_1$

$3v_1 = -2v_x$

$v_1 = -\frac{2}{3} v_x \; ; \quad -\frac{3}{2} v_1 = v_x$

$v_x = -\frac{R_2}{R_1} v_g + \frac{R_{11}}{R_{10}+R_{11}} v_2 \cdot \left(1 + \frac{R_2}{R_1}\right)$

$v_x = -2v_g + \frac{2}{3} v_2 \cdot (1+2)$

$v_x = -2v_g + 2v_2 = -4v_1 - 2v_g = -\frac{3}{2} v_1$

$-4v_1 + \frac{3}{2} v_1 = 2v_g$

$-\frac{5}{2} v_1 = 2v_g \quad v_1 = -\frac{4}{5} v_g \; , \; v_2 = \frac{8}{5} v_g \; , \; v_3 = -\frac{8}{5} v_g$

$v_g = 1V\sin(\omega t) \Rightarrow v_1 = -0{,}8V\sin(\omega t) \; , \; v_2 = 1{,}6V\sin(\omega t) \; v_3 = -1{,}6V\sin(\omega t)$

b) $V_1 = -2V_x - \frac{R_4}{R_9} V_3 = -2V_x - \frac{V_3}{2} = -2V_x - V_1$

$2V_1 = -2V_x \Rightarrow V_1 = -V_x$

$V_x = 2V_2 - 2V_G = -4V_1 - 2V_G$

$-V_1 = -4V_1 - 2V_G$

$3V_1 = -2V_G$

$V_1 = -\frac{2}{3} V_G \; , \; V_2 = \frac{4}{3} V_G \; , \; V_3 = -\frac{4}{3} V_G$

$V_G = 1V$
$V_1 = -0{,}667V$
$V_2 = 1{,}333V$
$V_3 = -1{,}333V$


c)

$V_3 = -V^- = -\frac{(V_2+V_3)}{2} \Rightarrow 3V_3 = -V_2 \; , \; V_3 = -\frac{V_2}{3} = \frac{2V_1}{3}$

$V_1 = -2V_x - \frac{R_4}{R_9} V_3 = -2V_x - \frac{V_1}{3} \Rightarrow V_x = \frac{-2V_1}{3}$

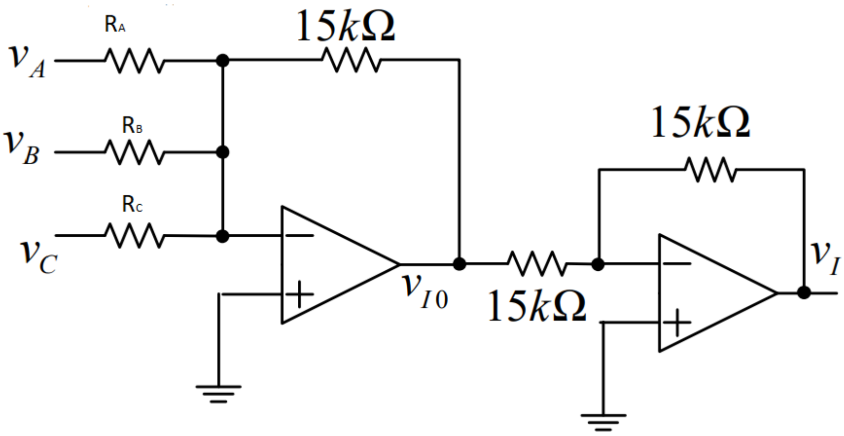
$\left.\begin{array}{l} V_x = 2V_2 - 2V_g \\ V_x = -\frac{2V_1}{3} \end{array}\right\} \Rightarrow -\frac{2V_1}{3} = -4v_1 - 2V_g \; , \; \frac{10}{3} V_1 = -2V_G \Rightarrow v_1 = -\frac{3}{5} V_G$

$V_2 = -2v_1 = \frac{6}{5} V_G \; , \; V_3 = \frac{-\frac{6}{5} V_G}{3} = -\frac{2}{5} V_G$

$V_G = 1V \quad V_1 = -0{,}6V \quad V_2 = 1{,}2V \; , \; V_3 = -0{,}4V$

Kolokvijum 2 2020

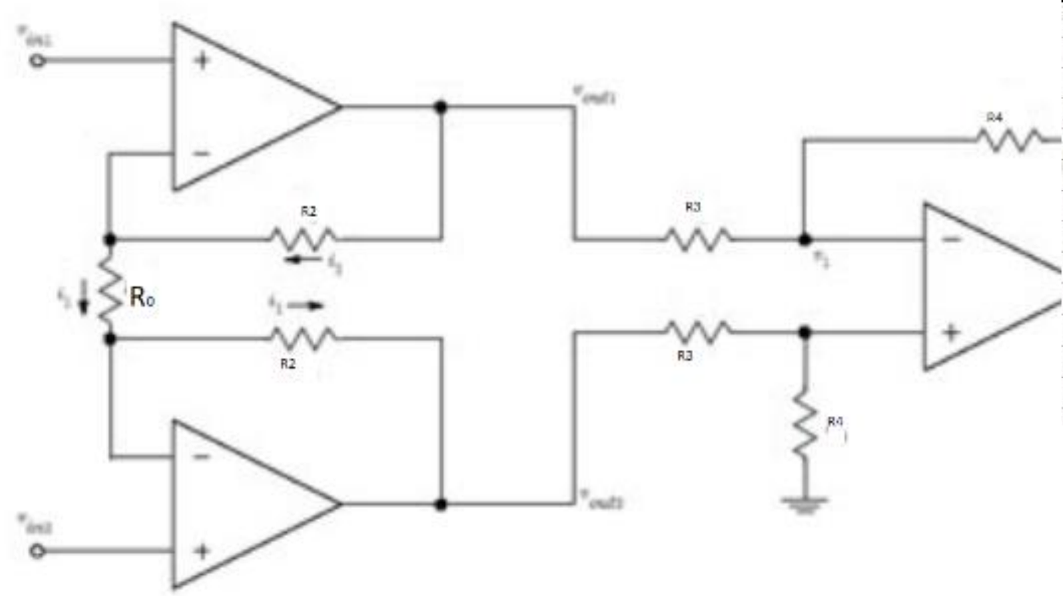
b) [5] Dat je sabirač sa 3 ulaza $v_A$, $v_B$ i $v_C$. Ako je otpornik u povratnoj sprezi operacionog pojačavača $R_F$=15kΩ, nacrtati kompletnu šemu sabirača i odrediti vrednosti ostalih otpornika u kolu tako da se dobije izlazni signal jednak $v_I=v_A+3v_B+5v_C$.
c) [5] Ako su, osim otpornika $R_0$ za podešavanje pojačanja, svi ostali otpornici u kolu instrumentacionog pojačavača jednaki 10kΩ, odrediti vrednost $R_0$ tako da ukupno pojačanje bude jednako 10.




$$V_i = V_A + 3V_B + 5V_C \Rightarrow V_{i0} = -V_A - 3V_B - 5V_C$$

$$V_{i0} = -\frac{15k\Omega}{R_A}V_A - \frac{15k\Omega}{R_B}V_B - \frac{15k\Omega}{R_C}V_C = -V_A - 3V_B - 5V_C$$

$$-\frac{15k\Omega}{R_A} = -1 \Rightarrow R_A = 15k\Omega; \; -\frac{15k\Omega}{R_B} = -3 \Rightarrow R_B = 5k\Omega; \; -\frac{15k\Omega}{R_C} = -5 \Rightarrow R_C = 3k\Omega$$




$$10 = \left(1 + \frac{20k\Omega}{R_0}\right) \cdot \frac{10k\Omega}{10k\Omega}$$

$$10 = \frac{R_0 + 20k\Omega}{R_0}$$

$$10R_0 = R_0 + 20k\Omega$$

$$9R_0 = 20k\Omega$$

$$R_0 = \frac{20k\Omega}{9}$$

$$V_{out} = \left(1 + \frac{2R_2}{R_0}\right)\frac{R_4}{R_3}(V_{in2} - V_{in1})$$

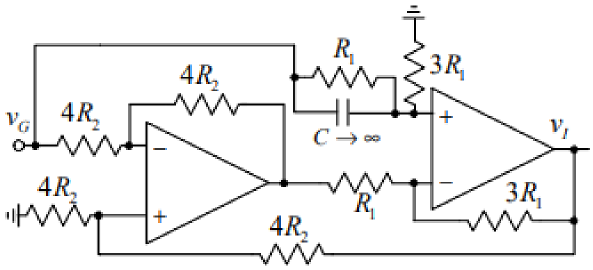
Vidi Instrumencioni pojacavac

**5.** Na slici je prikazan višestepeni pojačavač. Ukoliko nijedan operacioni pojačavač ne odlazi u zasićenje odrediti:

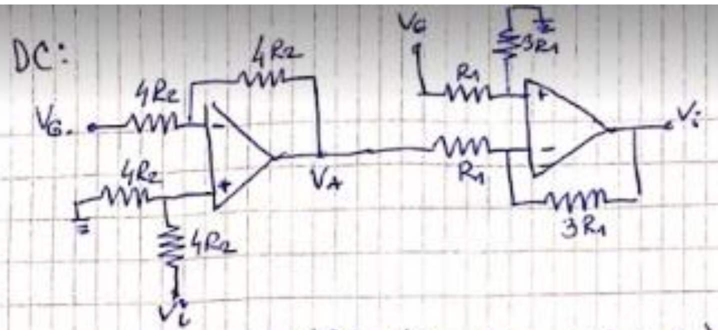
a) [10] jednosmerno pojačanje;

b) [10] naizmenično pojačanje;

c) [5] $v_I(t)$ ako je $v_G(t)$=4mV–8mVcos($\omega t$).




DC:




$$V_A = -\frac{4R_2}{4R_2}V_G + \left(1+\frac{4R_2}{4R_2}\right)\cdot\frac{4R_2}{4R_2+4R_2}V_i = -V_G + 2\cdot\frac{V_i}{2} = V_i - V_G$$

$$V_I' = \frac{3R_1}{4R_1}\cdot V_G\cdot\left(1+\frac{3R_1}{R_1}\right) = \frac{3}{4}V_G\cdot 4 = 3V_G$$

$$V_i'' = -V_A\cdot\frac{3R_1}{R_1} = -3V_A$$

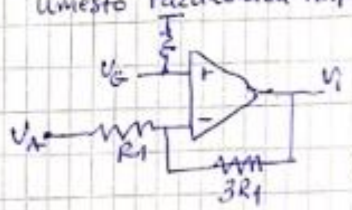
$$V_i = 3V_G - 3V_A = 3V_G - 3(V_i - V_G)$$

$$4V_i = 6V_G$$

$$V_i = \frac{3}{2}V_G$$

AC: $v_A = v_i - v_G$ - (nije bila promena u ovom delu kola)

umesto razdelnika napona sada na neinvertujućem delu imamo $v_g$




$$\Rightarrow v_i = v_G\left(1+\frac{3R_1}{R_1}\right) - v_A\frac{3R_1}{R_1} = 4v_G - 3v_A$$

$$v_i = 4v_G - 3(v_i - v_G)$$

$$4v_i = 7v_g$$

$$v_i = \frac{7}{4}v_g$$

c)

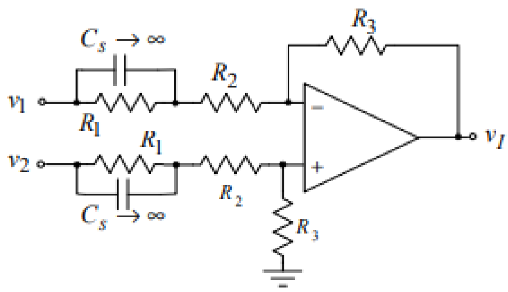
$$V_{G(t)} = 4mV - 8mV\cos\omega t$$

$$v_{i(t)} = 4mV\cdot\frac{3}{2} - \frac{7}{4}\cdot 8mV\cos\omega t$$

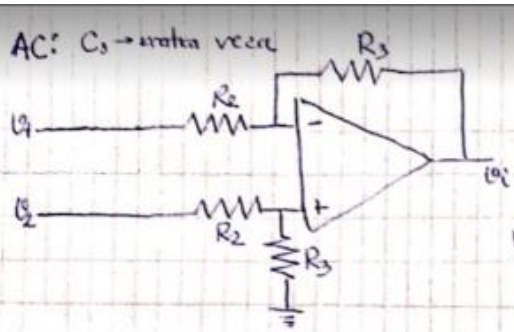
$$v_i = 6mV - 14mV\cos\omega t$$

Oktobar 2019

**3.** [20] a) Za kolo sa slike izračunati diferencijalno pojacanje $A_d$ ako je operacioni pojačavač idealan, a vrednosti otpornika $R_1 = 100\Omega$, $R_2 = 100\Omega$, $R_3 = 10k\Omega$. Pojačanja odrediti posebno za naizmeničnu i jednosmernu pobudu.
b) Ako je $v_1 = 10\text{mV} + 20\text{mV}\cdot\cos(\omega t)$, a $v_2 = 15\text{mV} - 15\text{mV}\cdot\cos(\omega t)$ izračunati i nacrtati izlazni napon.




AC: $C_s \to$ kratka veza



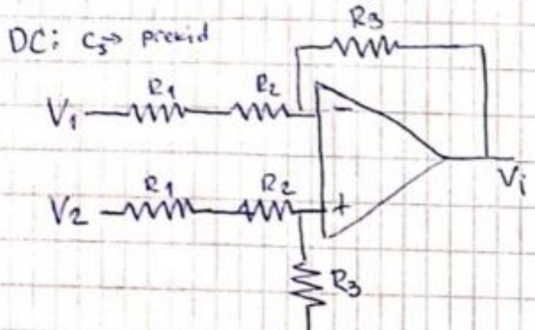

$v_i' = -\frac{R_3}{R_2} v_1 = -\frac{10k\Omega}{100\Omega} v_1 = -100 v_1$

$v_i'' = \frac{R_3}{R_3+R_2} v_2 \left(1+\frac{R_3}{R_2}\right) = v_2 \cdot \frac{R_3}{R_2} = v_2 \frac{10k\Omega}{100\Omega} = 100 v_2$

$v_i = v_i'' + v_i' = 100(v_2 - v_1)$

$A_d = \frac{v_i}{v_2 - v_1} = 100$

DC: $C_s \Rightarrow$ prekid




$V_i' = -\frac{R_3}{R_1+R_2} V_1$, $V_i'' = \frac{R_3 \cdot V_2}{R_1+R_2+R_3} \cdot \left(1 + \frac{R_3}{R_1+R_2}\right)$

$V_i'' = \frac{R_3}{R_1+R_2} V_2 \Rightarrow V_i = \frac{R_3}{R_1+R_2}(V_2 - V_1)$

$V_i = \frac{10k\Omega}{200\Omega}(V_2 - V_1)$

$A_D = 50$

b) $v_1 = 10\text{mV} + 20\text{mV}\cos\omega t$

$v_2 = 15\text{mV} - 15\text{mV}\cos\omega t$

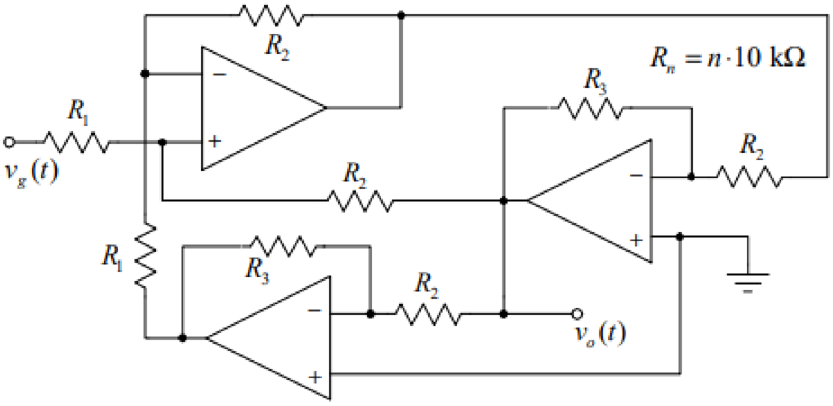
$v_2 - v_1 = 5\text{mV} - 35\text{mV}\cos\omega t$

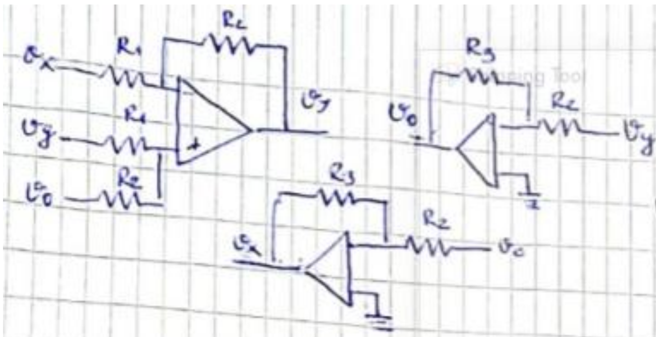
$v_i = 5\text{mV}\cdot 50 - 35\text{mV}\cdot 100\cos\omega t$

$v_i = 250\text{mV} - 3{,}5\text{V}\cos\omega t$

Jul 2019

**3.** [20] Smatrajući da su svi operacioni pojačavači idealni i da rade u linearnom režimu, za kolo sa slike odrediti naponsko pojačanje $a = v_o / v_g$.




$$v_o = -\frac{R_3}{R_2} v_y = -\frac{3}{2} v_y$$

$$v_x = -\frac{R_3}{R_2} v_o = -\frac{3}{2} v_o$$

$$v_y' = \frac{R_1}{R_1+R_2}\left(1+\frac{R_2}{R_1}\right) v_o = \frac{R_1}{R_1+R_2} \cdot \frac{R_1+R_2}{R_1} = v_o$$

$$v_y'' = \frac{R_2}{R_1+R_2}\left(\frac{R_1+R_2}{R_1}\right) v_g = \frac{R_2}{R_1} v_g = 2 v_g$$

$$v_y''' = -\frac{R_2}{R_1} v_x = -2 v_x$$

$$v_y = v_o + 2v_g + 3v_o = 2v_g + 4v_o$$

$$-\frac{2}{3} v_o = 2v_g + 4v_o$$

$$-\frac{12}{3} v_o - \frac{2}{3} v_o = 2 v_g$$

$$-\frac{6}{3} - \frac{1}{3} v_o = v_g$$

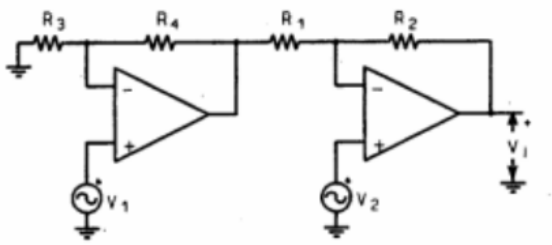
$$-\frac{7}{3} v_o = v_g$$

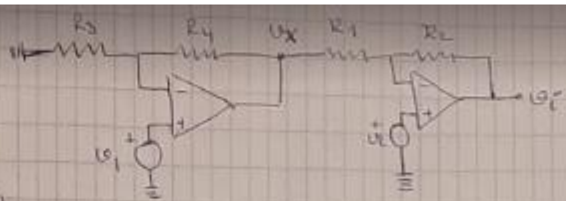
$$\boxed{a_v = \frac{v_o}{v_g} = -\frac{3}{7}}$$

7. U kolu sa slike 7. odrediti:

a) odnos otpornosti tako da se kolo ponaša kao idealni diferencijalni pojačavač

b) pojačanje Ad i As i faktor potiskivanja srednje vrednosti ρ ako je $R4/R1 = R1(1-\varepsilon)/R2$ za $R2/R1 = 99$ i $\varepsilon = 0.01$.




a)

$$v_x = \left(1 + \frac{R_4}{R_3}\right) v_1$$

$$v_i = \left(1 + \frac{R_2}{R_1}\right) v_2 + \left(-\frac{R_2}{R_1}\right) \cdot v_x$$

$$v_i = \left(1 + \frac{R_2}{R_1}\right) v_2 - \left(1 + \frac{R_4}{R_3}\right) \cdot \frac{R_2}{R_1} \cdot v_1$$

$$v_i = \left(1 + \frac{R_2}{R_1}\right) v_2 - \left(\frac{R_4 R_2}{R_3 R_1} + \frac{R_2}{R_1}\right) v_1$$

$$\frac{R_4 R_2}{R_3 R_1} + \frac{R_2}{R_1} = 1 + \frac{R_2}{R_1} \Rightarrow v_i = \left(1 + \frac{R_2}{R_1}\right)(v_2 - v_1)$$

$$\frac{R_4 R_2}{R_3 R_1} = 1 \Rightarrow \frac{R_4}{R_3} = \frac{R_1}{R_2}$$

b)

$$\frac{R_4}{R_3} = \frac{R_1(1-\varepsilon)}{R_2} \Rightarrow v_i = \left(1 + \frac{R_2}{R_1}\right) v_2 - \left(\frac{R_1(1-\varepsilon)}{R_2} \cdot \frac{R_2}{R_1} + \frac{R_2}{R_1}\right)$$

$$v_i = \left(1 + \frac{R_2}{R_1}\right) v_2 - \left((1-\varepsilon) + \frac{R_2}{R_1}\right) v_1$$

$$v_i = A_D (v_2 - v_1) + A_S \frac{v_1 + v_2}{2}$$

$$v_i = A_D v_2 - A_D v_1 + A_S \frac{v_1}{2} + A_S \frac{v_2}{2}$$

$$v_i = \left(A_D + \frac{A_S}{2}\right) v_2 - \left(A_D - \frac{A_S}{2}\right) v_1$$

$$\text{I)}\ A_D + \frac{A_S}{2} = 1 + \frac{R_2}{R_1}$$

$$\text{II)}\ A_D - \frac{A_S}{2} = \left(1 - \varepsilon + \frac{R_2}{R_1}\right)$$

$A_S = \varepsilon$ (od prve oduzmemo drugu)

$2A_D = 2 + 2\frac{R_2}{R_1} - \varepsilon$ (saberemo I i II

$$\boxed{A_D = 1 + \frac{R_2}{R_1} - \frac{\varepsilon}{2}} \Rightarrow v_i = \left(1 + \frac{R_2}{R_1} - \frac{\varepsilon}{2}\right)(v_2 - v_1) + \varepsilon \cdot \frac{v_2 + v_1}{2}$$

Resenja: Merisa Harcinovic