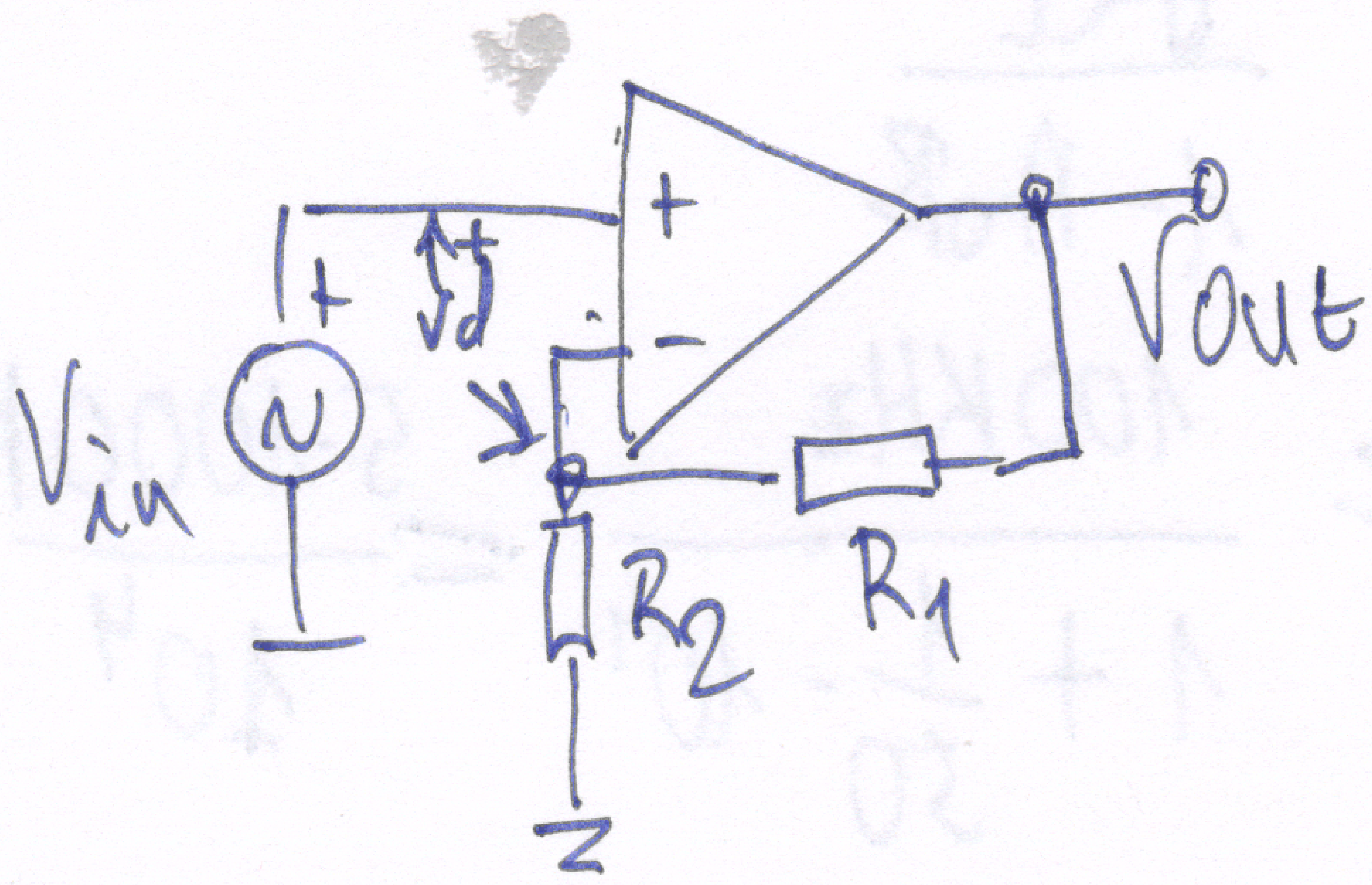
1) Isprojektovati neinvertujući pojačavač sa sledećim specifikacijama: pojačanje u zatvorenoj petlji 50, greška pojačanja 0,5%, širina propusnog opsega u zatvorenoj petlji BW=100 kHz. Odrediti pojačanje i širinu propusnog opsega operacionog pojačavača koji bi ispunio zadate zahteve?



$$V_d = V_{in} + \beta \cdot V_{out}$$

$$\beta = -\frac{R_2}{R_1 + R_2}$$

$$V_{out} = A_0 \cdot V_d$$

$$A_0 \cdot V_{in} + A_0 \beta \cdot V_{out} = V_{out}$$

$$V_{out} = \frac{A_0 V_{in}}{1 - A_0 \cdot \beta}$$

$$A_{CL} = \frac{V_{out}}{V_{in}} = \frac{A_0}{1 - A_0 \cdot \beta}$$

$$\lim_{A_0 \to \infty} A_{CL} = -\frac{1}{\beta} = \frac{R_1 + R_2}{R_1}$$

$$\delta = \frac{A_{CL} - A_{CL\,id}}{A_{CL\,id}} = \frac{\frac{A_0}{1 - A_0\beta} + \frac{1}{\beta}}{-\frac{1}{\beta}} = \frac{\frac{A_0\beta + 1 - A_0\beta}{(1 - A_0\beta)\cdot\beta}}{-\frac{1}{\beta}}$$

$$\delta = \frac{1}{A_0\beta - 1} < \delta_{max}$$

$$\frac{1}{\beta} = 50 \quad \delta = 5 \cdot 10^{-3}$$

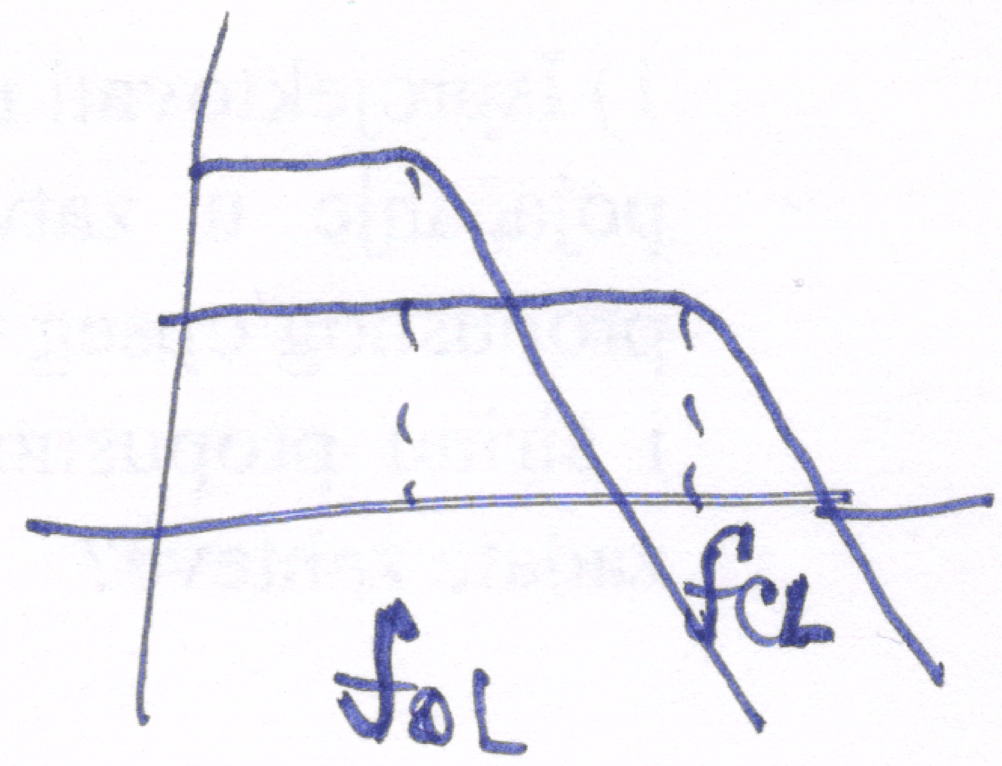
$$A_0 \cdot \beta > \frac{1}{\delta_{max}} + 1$$

$$A_0 > \frac{1}{\beta}\left(\frac{1}{\delta_{max}} + 1\right)$$

$$A_0 > \frac{50}{5 \cdot 10^{-3}}$$

$$A_0 > 10^4$$

$$f_{CL} = BW > 100\,KHz$$



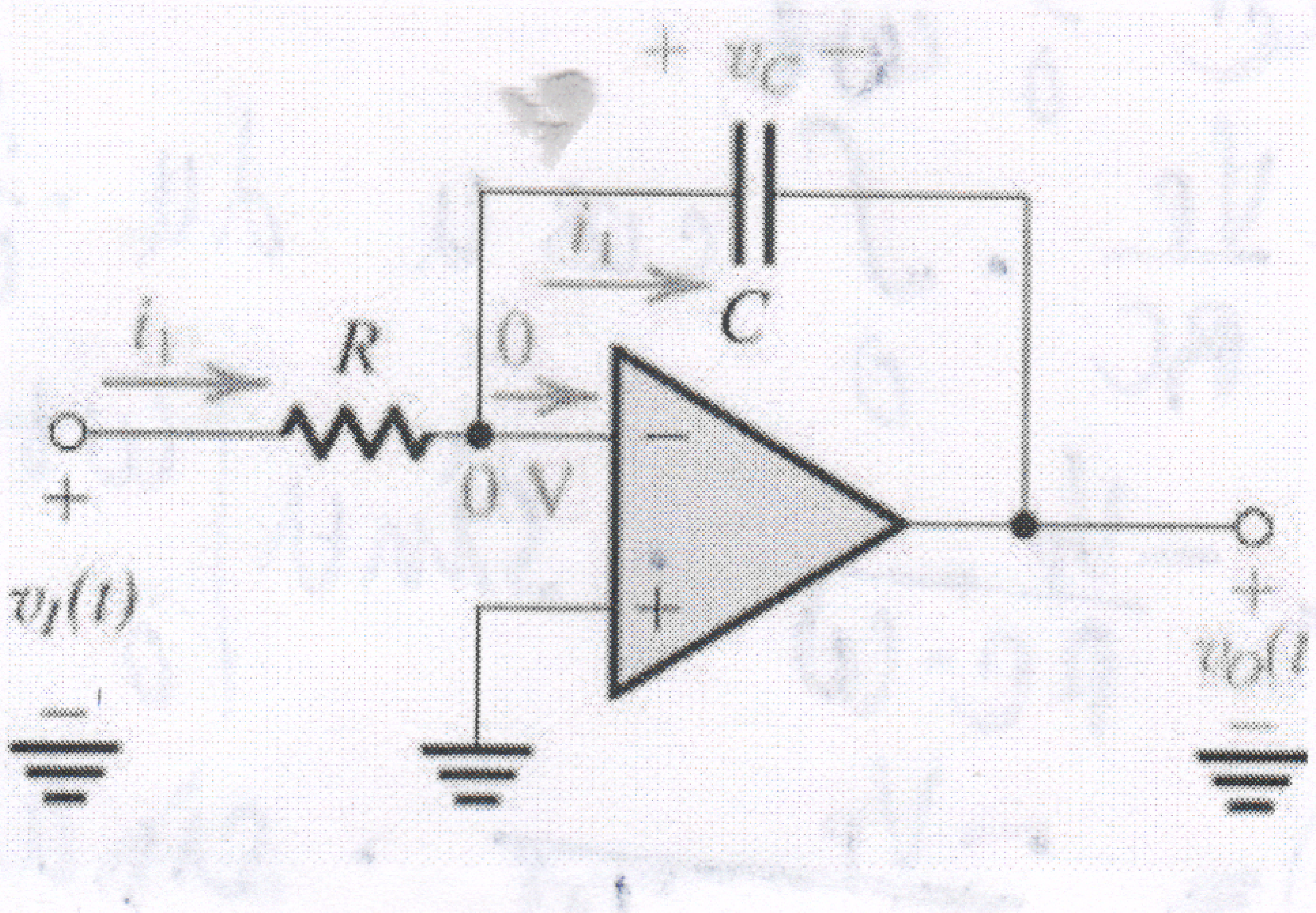
$$f_{CL} = f_{OL}(1 - A_0 B)$$

$$f_{OL} \geq \frac{f_{CL}}{1 - A_0 B}$$

$$f_{OL} \geq \frac{100\,KHz}{1 + \frac{1}{50} \cdot 10^4} = \frac{5 \cdot 1000\,KHz}{10^4}$$

$$f_{OL} \geq 500\,Hz$$

2) Isprojektovati integrator čija frekvencija jediničnog pojačanja iznosi 10 kHz i ulazna impedansa 20 kΩ. Operacioni pojačavač ima slew-rate od 0,1 V/μs. Kolo se pobuđuje sinusoidalnim signalom frekvencije 5 kHz. Koliki je najveći opseg promene (peak-to-peak) sinusoidalnog signala na ulazu koji ne prouzrokuje nelinearna izobličenja.



$$\frac{V_{out}}{V_{in}} = \frac{1}{R}\left(-\frac{1}{sC}\right) = \frac{-1}{sCR}$$

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{1}{\omega CR}$$

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{1}{\omega_T C \cdot R} = 1$$

$$C \cdot R = \frac{1}{2\pi \cdot f_T}$$

$$R_{in} = R = 20\,k\Omega$$

$$C = \frac{1}{2\pi \cdot f_T \cdot R_{in}}$$

$$C = \frac{1}{6{,}28 \cdot 10^4\,Hz \cdot 2 \cdot 10^4\,\Omega}$$

$$C = \frac{10^{-8}}{12{,}56}\,F = 796\,pF$$

$$V_{in}(t) = V_p \cdot \cos \omega t$$

$$V_{out}(t) = \frac{-1}{C}\int_0^t i_C(\tau)\,d\tau = \frac{-1}{C}\int_0^t \frac{V_{in}(\tau)}{R}\,d\tau$$

$$V_{out}(t) = -\frac{1}{RC}\int_0^t V_p \cdot \cos \omega\tau \,d\tau$$

$$V_{out}(t) = -\frac{V_p}{RC} \cdot \int_0^{\omega t} \cos u \,du \cdot \frac{1}{\omega}$$

$$V_{out}(t) = \frac{-V_p}{RC \cdot \omega} \cdot \sin u \Big|_0^{\omega t}$$

$$V_{out}(t) = \frac{-V_p}{R \cdot C \cdot \omega} \cdot \sin \omega t$$

$$\frac{dV_{out}(t)}{dt} = \frac{-V_p}{R \cdot C \cancel{\omega}} \cancel{\omega} \cdot \cos \omega t$$

$$\frac{dV_{out}(t)}{dt} = \frac{-V_p}{RC} \cdot \cos \omega t$$

$$\frac{dV_{out}}{dt}\Big|_{max} = \frac{V_p}{R \cdot C} < SR$$

$$V_p < SR \cdot R \cdot C$$

$$V_p < 0{,}1 \frac{V}{\mu s} \cdot 20k\Omega \cdot 796pF$$

$$V_p < 1{,}59\ V$$