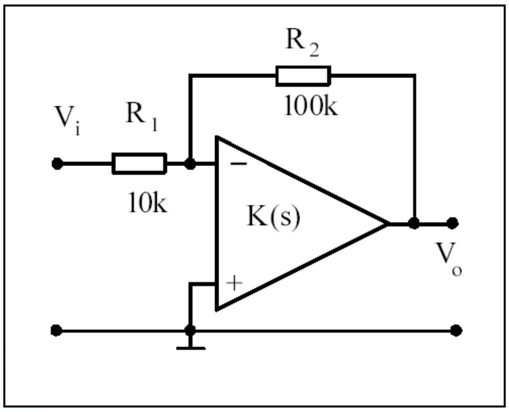
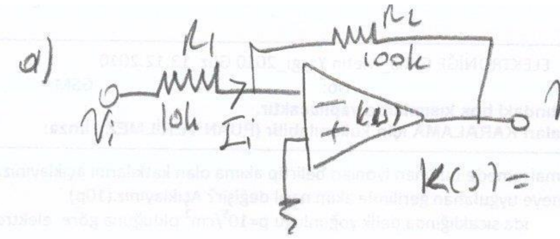
For the amplifier in the circuit;
$r_{Ki}=100k\Omega$, $C_{Ki}=100pF$, $r_{Ko}\approx 0$, $C_{Ko}\approx 0$,
$K(s)=\pi^2 10^{15}/(s+\pi 10^5)(s+\pi 10^7)$



a)Find vo/vi in s domain ($A_F(s)=?$).

b) Investigate the stability of the circuit and find the gain margin.

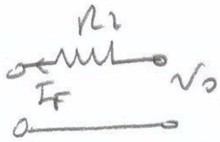
a)



$$K(s)=\frac{\pi^2\cdot 10^{15}}{(s+\pi\cdot 10^5)(s+\pi\cdot 10^7)}$$

Feedback type: input current, output voltage

β network:



$$I_F=\frac{V_o}{R_2}\rightarrow\beta=\frac{1}{R_2}$$

open loop case including, the loading effect of β

$(V_o=-I_t\cdot Z_i\cdot K(s))$

$$Z_M=\frac{V_o}{I_t}=-K(s)\,Z_i(s)$$

$$Z_i(s)=\frac{50k}{s\cdot 10^{-10}\cdot 5\cdot 10^4+1}=\frac{10^{10}}{s+200k}$$

$50k \rightarrow (R_L \parallel r_{iK})$, C_{iK}; C_{iK} 100pF

Feedback

$$Z_{MF}=\frac{Z_M}{1-\beta Z_M}=\frac{-K(s)\,Z_i(s)}{1+\beta K(s)\,Z_i(s)} = V_o/I_i$$

$$I_i=\frac{V_i}{R_1+Z_{iF}} \qquad Z_{iF}=\frac{Z_i}{1-\beta Z_M}$$

feedback type input current

$$\frac{V_o}{I_i}=\frac{V_o}{\frac{V_i}{R_1+Z_{iF}}}\rightarrow\frac{V_o}{V_i}=\frac{1}{R_1+Z_{iF}}\cdot\frac{Z_M}{1-\beta Z_M}$$

$$=\frac{1}{R_1+\frac{Z_i(s)}{1+\beta K(s)\,Z_i(s)}}\cdot\frac{-K(s)\cdot Z_i(s)}{1+\beta K(s)\,Z_i(s)}$$

transimpedance

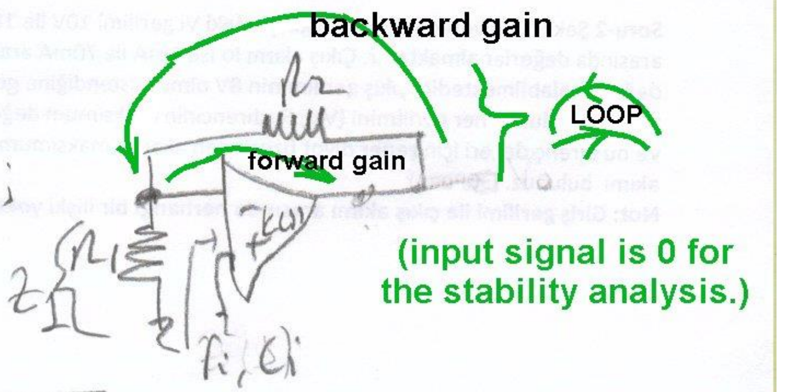
voltage gain

$$\frac{V_o}{V_i} = \frac{-K(s)\cdot Z_i(s)}{R_1\left[1+\beta K(s)\, Z(s)\right] + Z_i(s)}$$

$$= \frac{\dfrac{-\pi^2\cdot 10^{15}}{(s+\pi\cdot 10^5)(s+\pi\cdot 10^7)}\cdot\dfrac{10^{10}}{s+200k}}{10k + \dfrac{10k}{100k}\cdot\dfrac{+\pi^2\cdot 10^{15}}{(s+\pi\cdot 10^5)(s+\pi\cdot 10^7)}\cdot\dfrac{10^{10}}{s+200k} + \dfrac{10^{10}}{s+200k}}$$

$$\frac{V_o}{V_i} = \frac{-\pi^2\cdot 10^{21}}{(s+\pi\cdot 10^5)(s+\pi\cdot 10^7)(s+200k) + \pi^2\cdot 10^{20} + 10^{6}(s+\pi\cdot 10^5)(s+\pi\cdot 10^7)}$$

b) **For stability analysis ;**



$$R_1 \| r_i \cong 9k$$

$$Z_1 = \frac{9k}{s\cdot 10^{-10}\cdot 9k+1} \cong \frac{10^{10}}{s+1,1\cdot 10^6}$$

$$\beta(s) = \frac{Z_1}{R_2+Z_1} = \frac{10^{10}}{(s+1,1\cdot 10^6)\cdot 100k + 10^{10}} \cong \frac{10^5}{s+1,2\cdot 10^6}$$

$$A(s) = K(s) \quad (r_o = 0,\ A_v = \infty)$$

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$$\beta(s)A(s) = \frac{10^5}{s+1{,}2\cdot10^6} \cdot \frac{-\pi^2\cdot10^{15}}{(s+\pi\cdot10^5)(s+\pi\cdot10^7)}$$

$$= \frac{-\pi^2\cdot10^{20}}{(s+1{,}2\cdot10^6)(s+\pi\cdot10^5)(s+\pi\cdot10^7)}$$

denominator $\cong s^3 + s^2\cdot 33\cdot10^6 + s\cdot 479\cdot10^{11} + 1{,}2\cdot10^{19}$

$s \to j\omega \quad = -j\omega^3 - \omega^2\cdot 33\cdot10^6 + j\omega\cdot 479\cdot10^{11} + 1{,}2\cdot10^{19}$

If the imaginal part of the denominator is zero, the phase of the loop gain is zero. Since, for this condition, denominator becomes real and negative, the loop gain becomes real and positive.

$-\omega^3 + \omega\, 479\cdot10^{11} = 0 \to \omega_o = 6{,}9\cdot10^6$

the phase is zero

at $\omega_o = 6{,}9\cdot10^6$

$$\beta\cdot A = \frac{-\pi^2\cdot10^{20}}{-479\cdot10^{11}\cdot 33\cdot10^6 + 1{,}2\cdot10^{19}} \cong \frac{-9{,}9\cdot10^{20}}{-1{,}57\cdot10^{21}} = 0{,}63$$

$$\beta\cdot A\Big|_{\omega_o=6{,}9\cdot10^6} = 0{,}63 < 1$$

loop gain is less than 1 when the loop phase becomes 0. Thus, the circuit is stable.

Gain Margin $= 4\,dB = -20\log 0{,}63$

Note that in this analysis, ω_o is not the natural frequency.