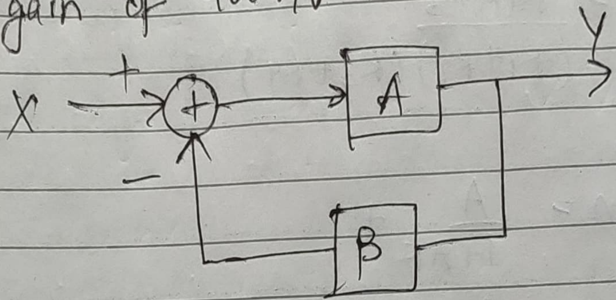
Assignment-5

Ques1 Consider a general feedback network with open loop gain of 1000 V/V and close loop gain of 100 V/V



(1) Find the tolerance in close loop gain if tolerance in open loop gain is 30%.

$\therefore$ ~~Vx= Vin-V)~~ for +30%

$$A = 1300$$

$$\frac{A}{1+Ak} = \frac{1300}{1+1300\times k} \quad \text{--- (1)}$$

$$\frac{A}{1+Ak} = 100$$

$$\frac{1000}{1+Ak} = 100$$

$$1+Ak = 10$$

$$Ak = 9$$

$$\boxed{k = 9/1000}$$

(ii) ~~[illegible]~~ from (1)

$$\frac{A'}{1+AK} = \frac{1300}{1+\frac{1300 \times 9}{1000}}$$

$$\frac{A'}{1+A'K} = 70.74$$

for -30%

$$\frac{700}{1+\frac{9}{1000} \times 700} = 95.89$$

$\therefore$ Tolerance of closed loop $= 21.26\%$.

(ii) if $\frac{A}{1+AK} = 10$

$$\frac{1000}{1+1000K} = 10$$

$$1+1000K = 100$$

$$1000K = 99$$

$$K = \frac{99}{1000}$$

$$\frac{1300}{1+\frac{1300 \times 99}{1000}} = \frac{1300}{13.15}$$

$$= 10.02$$

for $A = 700$

$$\frac{700}{1+\frac{700 \times 99}{1000}} = 9.95$$

$$\text{Tolerance} = \frac{10-9.95}{10}$$
$$= 0.005\ \%$$

(iii) When 2 stages are cascaded

$$\text{gain} = 10 \times 10 = 100\ V/V \quad — (1)$$

Tolerance

$$= 0.005 \times 0.005$$
$$= \boxed{25 \times 10^{-5}}\ \% \quad — (2)$$

Q.2 Problem 7.2 and 7.6 of Razavi's book

Problem 7.2

$$\overline{V_{n,in}^2} = 4KT\left[\frac{2}{3}\frac{1}{g_{m1}} + \frac{2}{3}\frac{g_{m2}}{g_{m1}^2}\right]$$

$$\overline{V_{n,in}} = \sqrt{4KT\,\tfrac{2}{3}}\sqrt{\frac{1}{g_{m1}} + \frac{g_{m2}}{g_{m1}^2}}$$

$$\frac{g_{m2}}{g_{m1}^2} = \left(\frac{1}{5}\right)^2 \frac{1}{g_{m1}} \Rightarrow g_{m2} = \left(\frac{1}{5}\right)^2 g_{m1}$$

$$g_m = \frac{2I_D}{V_{gs}-V_T} \Rightarrow V_{gs}-V_T = \frac{2I_D}{g_m}$$

$$\text{Output swing} = V_{DD} - (V_{gs1} - V_T) - |V_{gs2} - V_{T2}|$$
$$= V_{DD} - 2I_D\left[\frac{1}{g_{m1}} + \frac{1}{g_{m2}}\right]$$

$$V_{DD} - 2I_D\left(\frac{1}{g_{m1}}\right)(1+5^2)$$

$$g_{m1} = \sqrt{2 I_D \mu_n C_{ox}\left(\frac{W}{L}\right)}$$

$$= \sqrt{2(1\,mA)\left(134.28\,\frac{\mu A}{V^2}\right)\left(\frac{50\,\mu m}{0.54\,\mu m}\right)}$$

$$\approx 1.906\ mA/V$$

$$\therefore \text{output swing} = 3V - 2(1\,mA)\left(\frac{1}{1.906\,mA/V}\right) \times (26) = \boxed{0.30V}$$

Problem 7.6

(a) $$|A_V| = \frac{g_m R_D}{1+g_m R_S}$$

$$\overline{V^2_{n,out}} = 4kTR_D + 4kT\frac{2}{3}\left(\frac{1}{g_m}\right)\left(\frac{g_m R_D}{1+g_m R_S}\right)^2 + 4kT\frac{1}{R_S}\left(\frac{R_S}{\frac{1}{g_m}+R_S}\right)^2 R_D^2$$

$$= 4kTR_D + 4kT\frac{2}{3}\frac{1}{g_m}\left(\frac{g_m R_D}{1+g_m R_S}\right)^2 + 4kTR_S\left(\frac{g_m R_D}{1+g_m R_S}\right)^2$$

$$\overline{V^2_{n,in}} = \frac{\overline{V^2_{n,out}}}{|A_V|^2} = 4kT\frac{2}{3}\frac{1}{g_m} + 4kTR_S + 4kTR_D\left(\frac{1+g_m R_S}{g_m R_D}\right)^2$$

(b) $$|A_V| = g_m\left(\frac{1}{g_m} \,||\, R_S\right)$$

$$\overline{V_{n,out}^2} = \left(4kT\,\tfrac{2}{3}g_m + 4kT\,\tfrac{1}{R_S}\right)\left(\tfrac{1}{g_m} \,||\, R_S\right)^2$$

$$\overline{V_{n,in}^2} = \frac{\overline{V_{n,out}^2}}{|A_V|} = 4kT\,\frac{2}{3}\frac{1}{g_m} + 4kT\frac{1}{g_m^2 R_S}$$

(c) $$|A_V| = \frac{g_m}{1+\left(g_m + 1/R_F\right)R_S} \cdot R_{out}$$

$$R_{out} = R_S + (1+g_m R_S)R_F$$

$$\overline{V_{n,out}^2} = \left(\frac{4kT\,\frac{2}{3}g_m}{\left(\left(1+g_m\frac{1}{R_F}\right)R_S\right)^2} + \frac{4kT\,\frac{1}{R_F}}{\left(1+\left(g_m+\frac{1}{R_F}\right)R_S\right)^2} + \frac{4kT\,\frac{1}{R_S}\times R_S^2}{R_S + \frac{1}{g_m \,||\, R_F}^2}\right) R_{out}^2$$

$$\overline{V_{n,in}^2} = \frac{\overline{V_{n,out}^2}}{|A_V|^2} = 4kT\left(\frac{2}{3}\frac{1}{g_m} + \frac{1}{g_m^2 R_F} + R_S\left(1+\frac{1}{g_m R_F}\right)^2\right)$$

(d) $$|A_V| = \frac{g_{m_1}}{1+g_{m_1}R_S}\cdot R_{out}$$

$$R_{out} = \frac{1}{g_{m_2}}$$

$$\overline{V_{n,out}^2} = 4kT\,\tfrac{2}{3}g_{m_2}R_{out}^2 + 4kT\,\tfrac{2}{3}\frac{1}{g_{m_1}}|A_V|^2 + 4kT\frac{1}{R_S}\left(\frac{R_S}{\frac{1}{g_{m_1}}+R_S}\right)^2 R_{out}^2$$

$\overline{V_{n,in}^2} =$

(e) $|A_V|$

$\overline{V_{n,ou}^2}$

$\overline{V_{n,in}^2}$

(f) $|A$

note

$\overline{V_n}$

$$\overline{V_{n\,in}^2} = \frac{\overline{V_{n\,out}^2}}{|A_V|^2} = 4kT\left[\frac{2}{3}\frac{1}{g_{m1}} + R_S + \frac{2}{3}g_{m2}\left(\frac{1+g_{m1}R_S}{g_{m1}}\right)^2\right]$$

(e) $|A_V| = g_{m1}R_D$

$$\overline{V_{n\,out}^2} = \left(4kT\,\tfrac{2}{3}g_{m1} + 4kT\,\tfrac{1}{R_D}\right)R_D^2$$

$$\overline{V_{n\,in}^2} = \frac{\overline{V_{n\,out}^2}}{|A_V|^2} = 4kT\left[\frac{2}{3}\frac{1}{g_{m1}} + \frac{1}{g_{m1}^2R_D}\right]$$

(f) $|A_V| \simeq g_{m1}\left(\frac{g_{m2}R_S}{1+g_{m2}R_S}\right)R_D$

note: $\frac{R_S}{\frac{1}{g_{m1}}+R_S} = \frac{g_{m2}R_S}{1+g_{m2}R_S}$

$$\overline{V_{n\,in}^2} = \frac{\overline{V_{n\,out}^2}}{|A_V|^2} = 4kT\left[\frac{2}{3}\frac{1}{g_{m1}} + \frac{2}{3}\frac{1}{g_{m1}}\left(\frac{1}{g_{m1}R_S}\right)^2 + \frac{1}{g_{m1}^2R_S} + \frac{1}{g_{m1}^2R_D}\left[\frac{1+g_{m2}R_S}{g_{m2}R_S}\right)^2\right]$$

Ques 3) Short note on non-Linearity in differential circuit

Ans 3) Non Linearity

It is used to measure performance in Digital to analog converter (DAC) Analog to Digital converter (ADC).

It refers to constant relation between the change in output & input

$$\boxed{DNL(i) = \frac{V_{out}(i+1) - V_{out}(i)}{\text{ideal LSB step width}} - 1}$$

Ques 4 Problem 9.4 of Razavi's book

$\left(\frac{W}{L}\right)_{1-8} = \frac{100}{0.5}$,

$I_{SS} = 1mA$

$V_{b1} = 1.2V$

$r = 0$

(a) $V_{in,CM\,min} = V_{ISS} + V_{GS_1}$

$= V_{ISS} + V_{thn} + V_{OD_1}$

$V_{in,CM\,max} = V_X + V_{th_1}$

$$V_r = V_{b1} - V_{GS_3}$$
$$= V_{b1} - V_{th_3} - V_{OD_3}$$

$$\boxed{V_{in,cm\,max} = V_{b1} - V_{OD_3}}$$

$$V_{in\,cm\,max} = 1.7 - 0.159$$
$$= \boxed{1.541\,V}$$

(b) $V_x = ?$

$$V_{GS_7} - V_{thp} = \left[\frac{2 I_{D7}}{\mu_p C_{ox} \left(\frac{W}{L}\right)_7}\right]^{1/2}$$

$$= \left[\frac{2\,(0.5\,mA)}{100 \times (1 \times 3.6 \times 10^{-9}) \left(\frac{100}{0.32}\right)}\right]^{1/2} = 0.289$$

$$V_{GS_7} = 0.289 + V_{thp} = 1.089\,V$$

$$V_x = V_{DD} - V_{GS_7} = 3 - 1.089\,V$$

$$\boxed{V_x = 1.911\,V}$$

(c) $V_{GS_3} = V_{th}$

$$V_{GS_4} = 0.7 + 0.159 = 0.859\,V$$

max o/p swing $= 0.7 - (0.859 - 0.7)$

$$\boxed{\text{max o/p swing} = 0.541\,V}$$

(d) we know $V_x = 1.911V$

$V_{GS5} = V_{GS7} = 1.089V$

$V_t < V_x + V_{thp}$ M_7 in sat.

$V_{b2} = V_t - |V_{GS}|$

$V_{b2} < V_x + V_{thp} - |V_{GS5}|$

$= 1.911V + 0.8 - 1.089$

$V_{b2} < 1.622V$

$V_{b2} > V_x - V_{thn} = 1.911 - 0.8$

$= V_{b2} > 1.111V$

$$\boxed{1.11V < V_{b2} < 1.62V}$$

(e) $\overline{V_n^2}_{input} = 4kT\gamma \frac{1}{g_{m1}}$

$\overline{V_n^2}_{input} M_8 = 4kT\gamma \frac{g_{m}}{g_{m1}^2}$

$= \left[4kT\gamma \left[\frac{1}{g_{m1,2}} + \frac{g_{m7,8}}{g_{m}^2{}_{1,2}}\right]\right] \times 2$

$g_{m7,8} = \left[2(100)(3183.6 \times 10^{-9})\left(\frac{100}{0.32}\right)(0.5mA)\right]^{1/2}$

$= 3.46\ m\Omega^{-1}$

~~Input refer~~ noise voltage $= \boxed{5.45 \times 10^{-18}\ V^2/Hz}$

or $\boxed{2.34 \times 10^{-9}\ V/\sqrt{Hz}}$