ΒΑΣΙΚΕΣ ΕΞΙΣΩΣΕΙΣ ΗΛΕΚΤΡΟΝΙΚΗΣ ΙΙΙ

Ζεύγος κοινού συλλέκτη - κοινής βάσης:

$$\frac{V_o}{V_{sig}} = \frac{1}{2}\left(\frac{R_{in}}{R_{in}+R_{sig}}\right)(g_m R_L) \qquad R_{in} = 2r_\pi$$

$$f_{P1} = \frac{1}{2\pi\left(\frac{C_\pi}{2}+C_\mu\right)(R_{sig} \parallel 2r_\pi)} \qquad f_{P2} = \frac{1}{2\pi C_\mu R_L} \qquad f_H \cong 1/\sqrt{\frac{1}{f_{P1}^2}+\frac{1}{f_{P2}^2}}$$

Ζεύγος κοινής πηγής - κοινής πύλης (κασκοδική συνδεσμολογία):

$$R_{out} = r_{o2} + [1+(g_{m2}+g_{mb2})r_{o2}]\,r_{o1} \qquad A_v = -A_0^2\frac{R_L}{R_L+A_0 r_0} \qquad f_H \cong \frac{1}{2\pi\tau_H}$$

$$R_{gd1} = (1+g_{m1}R_{d1})R_{sig} + R_{d1} \qquad \tau_H = R_{sig}\left[C_{gs1}+C_{gd1}(1+g_{m1}R_{d1})\right] + R_{d1}\left(C_{gd1}+C_{db1}+C_{gs2}\right) + (R_L \parallel R_{out})\left(C_L+C_{gd2}\right)$$

Ζεύγος κοινού εκπομπού - κοινής βάσης (κασκοδική συνδεσμολογία):

$$A_M = -\frac{r_\pi}{r_\pi+r_x+R_{sig}}g_m(\beta r_0 \parallel R_L) \qquad R_{c1} = r_{01} \parallel \left[r_{e2}\left(\frac{r_{o2}+R_L}{r_{o2}+R_L/(\beta_2+1)}\right)\right]$$

$$R'_{sig} = r_{\pi1} \parallel \left(r_{x1}+R_{sig}\right) \qquad \tau_H = C_{\pi1}R_{\pi1} + C_{\mu1}R_{\mu1} + (C_{cs1}+C_{\pi2})R_{c1} + \left(C_L+C_{cs2}+C_{\mu2}\right)(R_L \parallel R_{out})$$

$$R_{\mu1} = R'_{sig}(1+g_{m1}R_{c1}) + R_{c1} \qquad f_H \simeq \frac{1}{2\pi\tau_H}$$

Τελεστικός ενισχυτής MOS δύο βαθμίδων:

$$A_v = -g_{m1}(r_{ds2} \parallel r_{ds4}) \qquad g_{m1} = \sqrt{2\mu_p C_{ox}\left(\frac{W}{L}\right)_1 I_{D1}} = \sqrt{2\mu_p C_{ox}\left(\frac{W}{L}\right)_1 \frac{I_{bias}}{2}}$$

$$R_B = \frac{2}{\sqrt{2\mu_n C_{ox}(W/L)_{12} I_B}}\left(\sqrt{\frac{(W/L)_{12}}{(W/L)_{13}}}-1\right)$$

$$g_{m12} = \frac{2}{R_B}\left(\sqrt{\frac{(W/L)_{12}}{(W/L)_{13}}}-1\right) \qquad g_{mi} = g_{m12}\sqrt{\frac{I_{Di}(W/L)_i}{I_B(W/L)_{12}}} \qquad g_{mi} = g_{m12}\sqrt{\frac{\mu_p I_{Di}(W/L)_i}{\mu_n I_B(W/L)_{12}}}$$

$$C_1 = C_{gd4}+C_{db4}+C_{gd2}+C_{gs6} \qquad C_2 = C_{db6}+C_{db7}+C_{gd7}+C_L$$

$$\omega_Z = \frac{G_{m2}}{C_C} \qquad \omega_{P1} = \frac{1}{C_1R_1+C_2R_2+C_C(G_{m2}R_2R_1+R_1+R_2)} \cong \frac{1}{R_1C_CG_{m2}R_2}$$

$$\omega_{P2} = \frac{G_{m2}C_C}{C_1C_2+C_C(C_1+C_2)} \qquad \omega_t = (G_{m1}R_1G_{m2}R_2)\,\omega_{P1}$$

Επιλογή C_C ώστε $\omega_t < \omega_Z < \omega_{P2}$

$$\mathrm{PSRR} = g_{mN}(r_{oP} \parallel r_{oN}) \qquad \mathrm{SR} \equiv \left.\frac{\mathrm{d}V_{out}}{\mathrm{d}t}\right|_{\max} = \frac{I_{SS}}{C_L}$$

$$\mathrm{GB} = A_v(0)\cdot|p_1| = (g_{m1}g_{m2}R_IR_{II})\cdot\left(\frac{1}{g_{m2}R_IR_{II}C_C}\right) = \frac{g_{m1}}{C_C}$$

$$\mathrm{PM} = \mathrm{Arg}\,[AB] = \pm180^\circ - \arctan\left(\frac{\omega}{|p_1|}\right) - \arctan\left(\frac{\omega}{|p_2|}\right) - \arctan\left(\frac{\omega}{Z}\right)$$

Για περιθώριο φάσης (PM) 45° και $Z \geqslant 10\cdot\mathrm{GB}$: $|p_2| \geqslant 1.22\cdot\mathrm{GB}$

Για περιθώριο φάσης (PM) 60° και $Z \geqslant 10\cdot\mathrm{GB}$: $|p_2| \geqslant 2.22\cdot\mathrm{GB}$

$$Z = \frac{1}{C_C\left(\frac{1}{g_{m2}}-R_Z\right)}$$

Τελεστικός ενισχυτής με είσοδο n-MOS

$$\max(V_{in}) = V_{DD} - \sqrt{\frac{I_5}{\beta_3}} - \max(|V_{T03}|) + \min(V_{T01}) \qquad \min(V_{in}) = V_{SS} + \sqrt{\frac{I_5}{\beta_1}} + \max(V_{T01}) + V_{DS5_{sat}} \qquad V_{DS_{sat}} = \sqrt{\frac{2I_{DS}}{\beta}}$$

Τελεστικός ενισχυτής με είσοδο p-MOS

$$\max(V_{in}) = V_{DD} - \sqrt{\frac{I_5}{\beta_1}} - V_{DS5_{sat}} - \max(|V_{T01}|) \qquad \min(V_{in}) = V_{SS} + \sqrt{\frac{I_5}{\beta_3}} + \max(V_{T03}) - \min(|V_{T01}|)$$

Σχεδίαση τελεστικού ενισχυτή με είσοδο n-MOS

$$\mathrm{SR} = \frac{I_5}{C_C} \qquad A_{v1} = \frac{-g_{m1}}{g_{ds2} + g_{ds4}} = \frac{-2g_{m1}}{I_5 \cdot (\lambda_2 + \lambda_4)} \qquad A_{v2} = \frac{-g_{m6}}{g_{ds6} + g_{ds7}} = \frac{-g_{m6}}{I_6 \cdot (\lambda_6 + \lambda_7)}$$

$$\mathrm{GB} = \frac{g_{m1}}{C_C} \qquad p_2 = \frac{-g_{m6}}{C_L} \qquad Z = \frac{g_{m6}}{C_C} \qquad \beta = k' \frac{W}{L} \cong \mu_0 C_{ox} \frac{W}{L} \ \left(\mathrm{A/V^2}\right)$$

$$C_C > 0.22 C_L \qquad I_5 = \mathrm{SR} \cdot C_C \qquad S_3 = \left(\frac{W}{L}\right)_3 = \frac{I_5}{k'_3 \left[V_{DD} - \max\left(V_{in}\right) - \max\left(|V_{T03}|\right) + \min\left(V_{T01}\right)\right]^2}$$

$$\frac{g_{m3}}{2C_{gs3}} > 10 \cdot \mathrm{GB} \qquad g_{m1} = \mathrm{GB} \cdot C_C \Longrightarrow S_1 = S_2 = \frac{g_{m2}^2}{k'_2 I_5}$$

$$V_{DS5_{sat}} = \min\left(V_{in}\right) - V_{SS} - \sqrt{\frac{I_5}{\beta_1}} - \max\left(V_{T01}\right) \geqslant 100\mathrm{mV} \qquad S_5 = \frac{2I_5}{k'_5 V_{DS5_{sat}}^2}$$

$$g_{m6} = 2.2 g_{m2} \left(C_L/C_C\right) \qquad S_6 = S_4 \frac{g_{m6}}{g_{m4}} \qquad I_6 = \frac{g_{m6}^2}{2k'_6 S_6}$$

$$S_6 = \frac{g_{m6}}{k'_6 V_{DS6_{sat}}} \qquad V_{DS6} = \min\left(V_{DS6}\right) = V_{DS6_{sat}} = V_{DD} - \max\left(V_{out}\right) \qquad S_7 = S_5 \frac{I_6}{I_5}$$

$$A_v = \frac{2 g_{m2} g_{m6}}{I_5 \left(\lambda_2 + \lambda_4\right) I_6 \left(\lambda_6 + \lambda_7\right)} \qquad P_{diss} = \left(I_5 + I_6\right) \cdot \left(V_{DD} + |V_{SS}|\right)$$