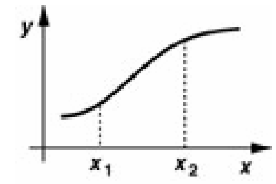
ΕΝΙΣΧΥΤΕΣ ΜΙΑΣ ΒΑΘΜΙΔΑΣ

Βασικές Έννοιες

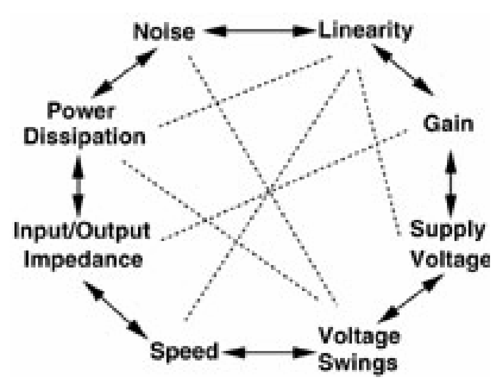
$$y(t) \approx \alpha_0 + \alpha_1 x(t) + \alpha_2 x^2(t) + \ldots + \alpha_n x^n(t) \qquad x_1 \le x \le x_2$$



$$y(t) \approx \alpha_0 + \alpha_1 x(t)$$

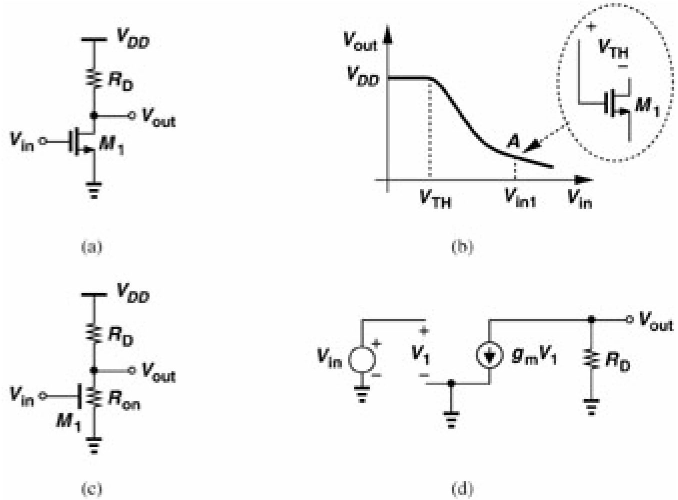
$$\alpha_1 \, x(t) << \alpha_0 \qquad \Delta y = \alpha_1 \Delta x$$

Το οκτάγωνο της αναλογικής σχεδίασης



Βαθμίδα κοινής πηγής

Βαθμίδα κοινής πηγής με φόρτο ωμική αντίσταση



Για $V_{in}=0 \Rightarrow V_{out}=V_{DD}$

Για $V_{in}>V_{TH}$, $$V_{out} = V_{DD} - R_D \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{in}-V_{TH})^2$$

Για $V_{out}=V_{in1}-V_{TH}$, $$V_{in1}-V_{TH} = V_{DD} - R_D \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{in1}-V_{TH})^2,$$

Για $V_{in}>V_{in1}$, $$V_{out} = V_{DD} - R_D \frac{1}{2}\mu_n C_{ox}\frac{W}{L}[2(V_{in}-V_{TH})V_{out}-V_{out}^2].$$

Για $V_{in}>>$, $Vout<<2(Vin-V_{TH})$,

$$V_{out} = V_{DD}\frac{R_{on}}{R_{on}+R_D} = \frac{V_{DD}}{1+\mu_n C_{ox} R_D \frac{W}{L}(V_{in}-V_{TH})}$$

$$A_\upsilon = \frac{\partial V_{out}}{\partial V_{in}} = -R_D \mu_n C_{ox}\frac{W}{L}(V_{in}-V_{TH}) = -g_m R_D$$

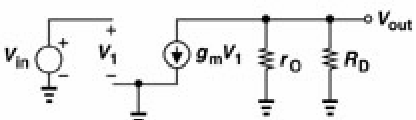
$$A_\upsilon = -\sqrt{2\mu_n C_{ox}\frac{W}{L}I_D}\,\frac{V_{RD}}{I_D}. \quad = -\sqrt{2\mu_n C_{ox}\frac{W}{L}}\,\frac{V_{RD}}{\sqrt{I_D}}.$$

Για $R_D>>$ $$V_{out} = V_{DD} - R_D \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{in}-V_{TH})^2(1+\lambda V_{out}),$$

$$\frac{\partial V_{out}}{\partial V_{in}} = -R_D \mu_n C_{ox}\frac{W}{L}(V_{in}-V_{TH})(1+\lambda V_{out}) - R_D \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{in}-V_{TH})^2 \lambda \frac{\partial V_{out}}{\partial V_{in}}$$

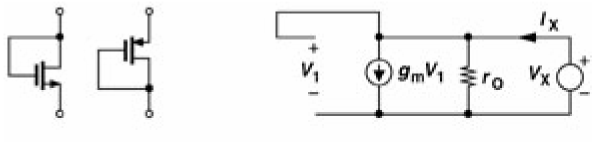
$$A_\upsilon = -R_D g_m - R_D I_D \lambda A_\upsilon \Rightarrow \qquad A_\upsilon = -\frac{g_m R_D}{1+R_D \lambda I_D}$$

$$A_\upsilon = -g_m \frac{r_D R_D}{r_D + R_D}$$



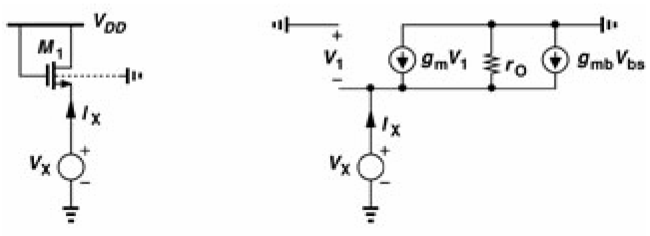
Ενδογενής απολαβή $$A_{\upsilon\max} = -g_m r_D$$

Βαθμίδα κοινής πηγής με φόρτο MOSFET σε συνδεσμολογία διόδου



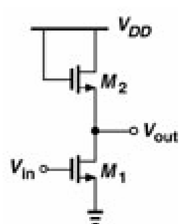
(a) (b)

$$\frac{V_\chi}{I_\chi} = \frac{1}{g_m} // r_D \approx \frac{1}{g_m}$$



(a) (b)

$$(g_m + g_{mb})V_\chi + \frac{V_\chi}{r_D} = I_\chi \qquad \frac{V_\chi}{I_\chi} = \frac{1}{g_m + g_{mb} + r_D^{-1}} = \frac{1}{g_m + g_{mb}} // r_D \approx \frac{1}{g_m + g_{mb}}.$$



$$A_\upsilon = -g_{m1} \frac{1}{g_{m2} + g_{mb2}} = -\frac{g_{m1}}{g_{m2}} \frac{1}{1+\eta}. \qquad \eta = \frac{g_{mb}}{g_m}$$

$$A_\upsilon = -\frac{\sqrt{2\mu_n C_{ox}(W/L)_1 I_{D1}}}{\sqrt{2\mu_n C_{ox}(W/L)_2 I_{D2}}} \frac{1}{1+\eta} = -\frac{\sqrt{(W/L)_1}}{\sqrt{(W/L)_2}} \frac{1}{1+\eta}$$

Γραμμική απόκριση όσο το M1 είναι στον κόρο.

Ανάλυση μεγάλου σήματος

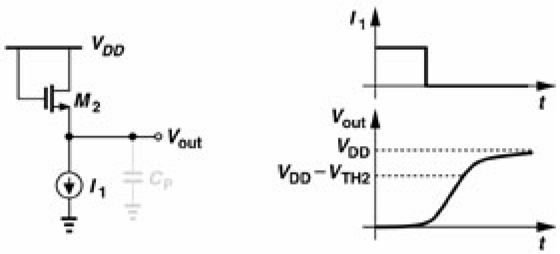
$$\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_1 (V_{in} - V_{TH1})^2 = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2 (V_{DD} - V_{out} - V_{TH2})^2,$$

$$\sqrt{\left(\frac{W}{L}\right)_1}(V_{in} - V_{TH1}) = \sqrt{\left(\frac{W}{L}\right)_2}(V_{DD} - V_{out} - V_{TH2}).$$

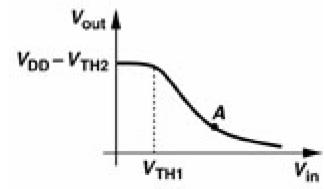
$$\sqrt{\left(\frac{W}{L}\right)_1} = \sqrt{\left(\frac{W}{L}\right)_2}\left(-\frac{\partial V_{out}}{\partial V_{in}} - \frac{\partial V_{TH2}}{\partial V_{in}}\right),$$

όπου $\frac{\partial V_{TH2}}{\partial V_{in}} = \frac{\partial V_{TH2}}{\partial V_{out}} \cdot \frac{\partial V_{out}}{\partial V_{in}} = \eta \cdot \frac{\partial V_{out}}{\partial V_{in}} \Rightarrow$

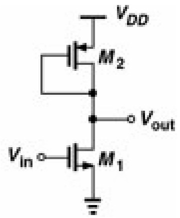
$$\frac{\partial V_{out}}{\partial V_{in}} = -\sqrt{\frac{(W/L)_1}{(W/L)_2}} \frac{1}{1+\eta}.$$



(a) (b)



PMOS



$$A_\upsilon = -\frac{\sqrt{\mu_n (W/L)_1}}{\sqrt{\mu_p (W/L)_2}}$$ Απαλλαγμένο από το φαινόμενο σώματος

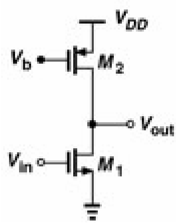
$$\mu_n (\frac{W}{L})_1 (V_{GS1} - V_{TH1})^2 \approx \mu_p (\frac{W}{L})_2 (V_{GS2} - V_{TH2})^2,$$

$$\frac{|V_{GS2} - V_{TH2}|}{V_{GS1} - V_{TH1}} \approx A_\upsilon.$$

Με τη διαμόρφωση μήκους καναλιού

$$A_\upsilon = -g_{m1}(\frac{1}{g_{m2}} // r_{D1} // r_{D2}),$$

Βαθμίδα κοινής πηγής με φόρτο πηγή ρεύματος



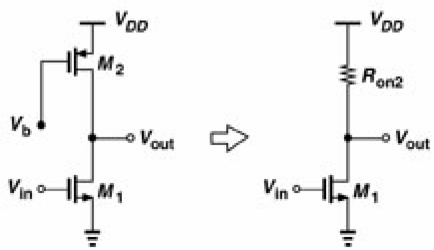
$$A_\upsilon = -g_{m1}(r_{D1} // r_{D2}).$$

Ενδογενής απολαβή

$$g_{m1} r_{D1} = \sqrt{2(\frac{W}{L})_1 \mu_n C_{ox} I_D} \, \frac{1}{\lambda I_D}$$

Η γραμμική περιοχή μπορεί να αυξηθεί με αύξηση του (W/L)2

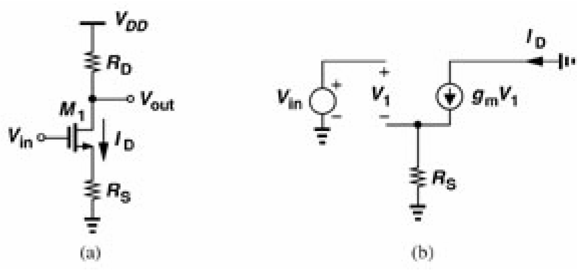
Βαθμίδα κοινής πηγής με φόρτο στην περιοχή τριόδου



$$R_{on2} = \frac{1}{\mu_p C_{ox} (\frac{W}{L})_2 (V_{DD} - V_b - |V_{THP}|)}$$

Μειονέκτημα: εξάρτηση από τις παραμέτρους.

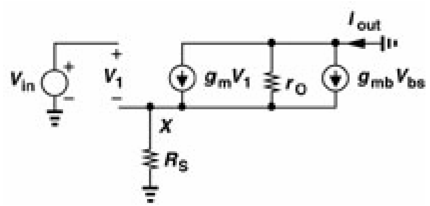
Βαθμίδα κοινής πηγής με ανασύζευξη (εκφυλισμό) πηγής



$$I_D = f(V_{GS})$$

$$G_m = \partial I_D / \partial V_{in} = \frac{\partial f}{\partial V_{GS}} \frac{\partial V_{GS}}{\partial V_{in}} = (1 - R_S \frac{\partial I_D}{\partial V_{in}}) \frac{\partial f}{\partial V_{GS}} \Rightarrow \quad G_m = \frac{g_m}{1 + g_m R_S}$$

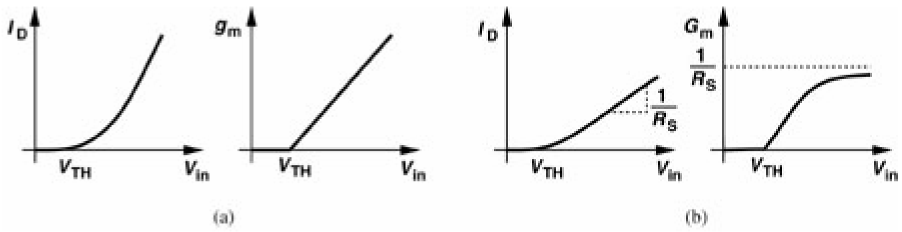
$$A_\upsilon = -G_m R_D = \frac{-g_m R_D}{1 + g_m R_S}$$



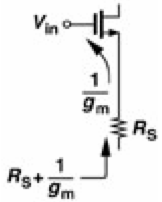
Υπολογισμός της διαγωγιμότητας αν συμπεριλάβουμε το φαινόμενο σώματος και τη διαμόρφωση μήκους καναλιού:

$$I_{out} = g_m V_1 - g_{mb} V_X - \frac{I_{out} R_S}{r_D} \qquad = g_m (V_{in} - I_{out} R_S) + g_{mb}(-I_{out} R_S) - \frac{I_{out} R_S}{r_D}$$

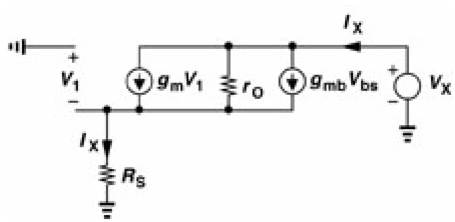
$$G_m = \frac{I_{out}}{V_{in}} = \frac{g_m r_D}{R_S + [1 + (g_m + g_{mb}) R_S] r_D}$$



$$A_\upsilon = -\frac{R_D}{(1/g_m) + R_S}$$



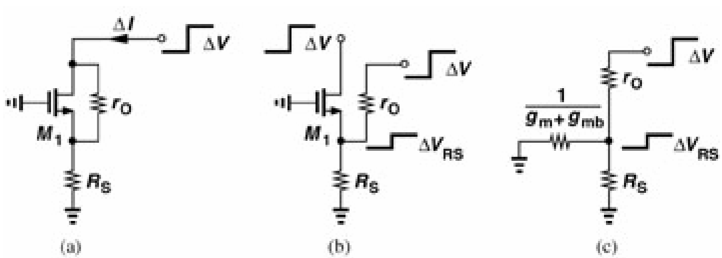
Υπολογισμός της αντίστασης εξόδου



$$r_D[I_X + (g_m + g_{mb})R_S I_X] + I_X R_S = V_X$$

$$R_{out} = [1 + (g_m + g_{mb})R_S]r_D + R_S = [1 + (g_m + g_{mb})r_D]R_S + r_D$$

$$R_{out} \approx (g_m + g_{mb})r_D R_S + r_D = [1 + (g_m + g_{mb})R_S]r_D \Rightarrow R_{out} >> r_D$$



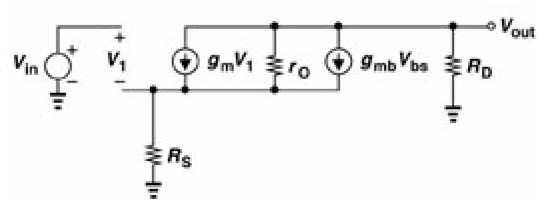
$$\Delta V_{RS} = \Delta V \frac{\frac{1}{g_m + g_{mb}} // R_S}{\frac{1}{g_m + g_{mb}} // R_S + r_D}$$

$$\Delta I = \frac{\Delta V_{RS}}{R_S} = \Delta V \frac{1}{[1 + (g_m + g_{mb})R_S]r_D + R_S}$$

$$\frac{\Delta V}{\Delta I} = [1 + (g_m + g_{mb})R_S]r_D + R_S$$

Υπολογισμός της απολαβής

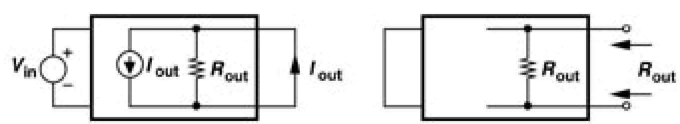
$$I_{r0} = -\frac{V_{out}}{R_D} - (g_m V_1 + g_{mb} V_{bs}) = -\frac{V_{out}}{R_D} - [g_m (V_{in} + V_{out}\frac{R_S}{R_D}) + g_{mb} V_{out}\frac{R_S}{R_D}]$$



$$V_{out} = I_{r0} r_D - \frac{V_{out}}{R_D} R_S = -\frac{V_{out}}{R_D} r_D - [g_m (V_{in} + V_{out}\frac{R_S}{R_D}) + g_{mb} V_{out}\frac{R_S}{R_D}] r_D - V_{out}\frac{R_S}{R_D}$$

$$\frac{V_{out}}{V_{in}} = \frac{-g_m r_D R_D}{R_D + R_S + r_D + (g_m + g_{mb}) R_S r_D}$$

$$A_\upsilon = \frac{-g_m r_D R_D [R_S + r_D + (g_m + g_{mb}) R_S r_D]}{R_D + R_S + r_D + (g_m + g_{mb}) R_S r_D} \cdot \frac{1}{R_S + r_D + (g_m + g_{mb}) R_S r_D} = -\frac{g_m r_D}{R_S + r_D + (g_m + g_{mb}) R_S r_D} \cdot \frac{R_D [R_S + r_D + (g_m + g_{mb}) R_S r_D]}{R_D + R_S + r_D + (g_m + g_{mb}) R_S r_D}$$



$$V_{out} = -I_{out} R_{out}, G_m = I_{out} / V_{in} \Rightarrow V_{out} = -G_m V_{in} R_{out} \Rightarrow A_\upsilon = -G_m R_{out}$$