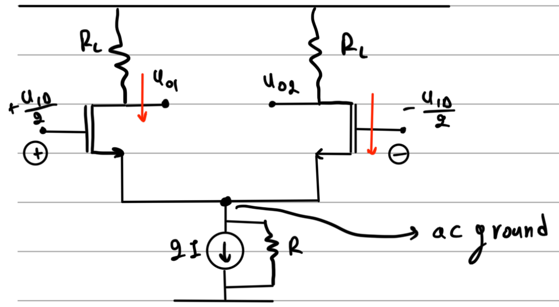
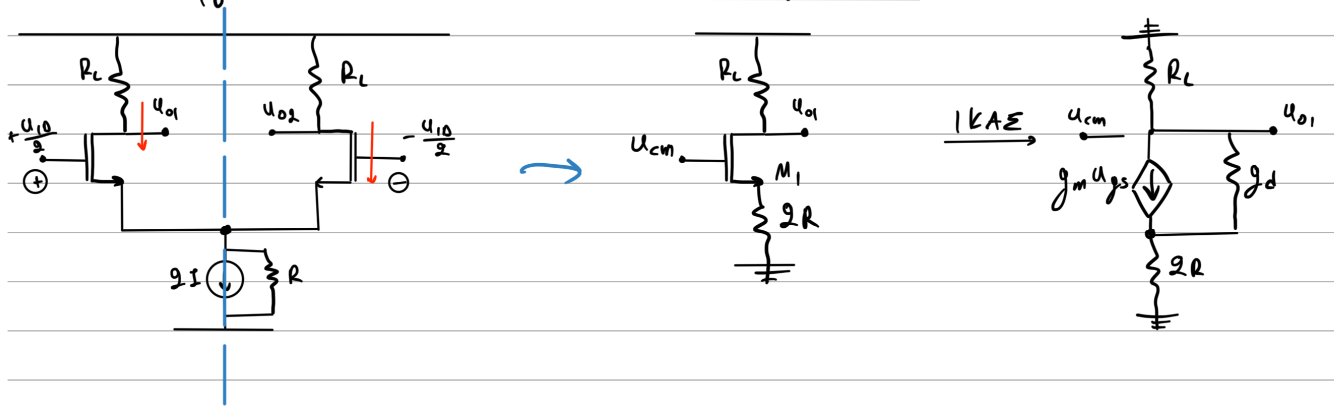
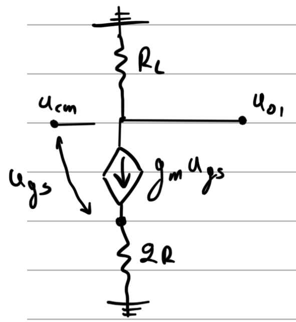


Κοινή λειτουργία (Common-Mode (CM)) διαφ. ζεύγους





$$\left.\begin{aligned} u_{o1} &= -g_m u_{gs} R_L \\ u_{gs} &= u_{cm} - u_{gs} \cdot g_m \cdot 2R \end{aligned}\right\} \Rightarrow u_{gs}(1 + g_m \cdot 2R) = u_{cm}$$

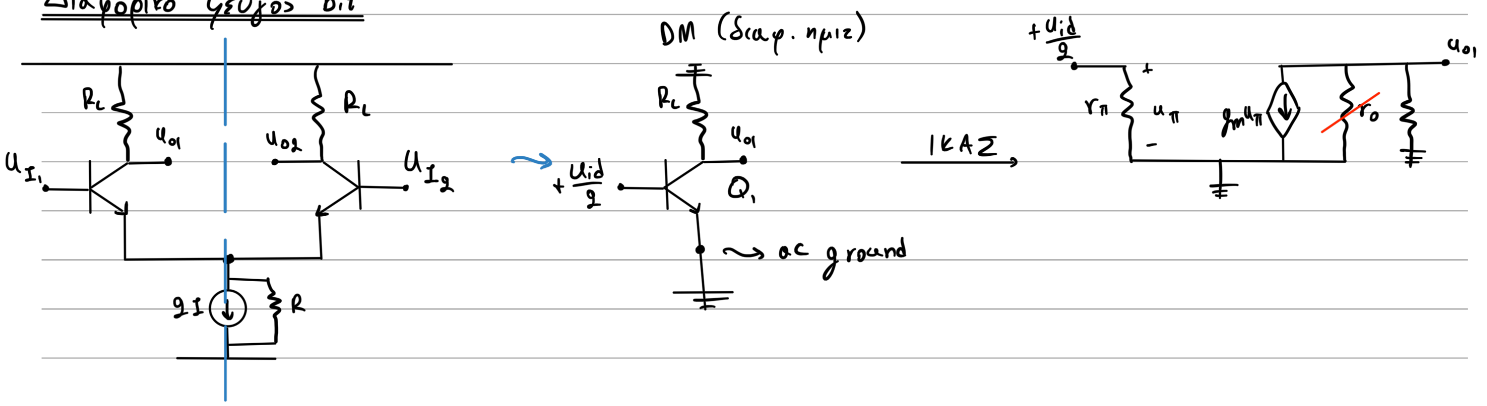
$$u_{o1} = -g_m \frac{u_{cm}}{1+g_m \cdot 2R} R_L \rightarrow A_{cm} \equiv \frac{u_{o1}}{u_{cm}} = -\frac{g_m R_L}{1+g_m 2R} = -\frac{R_L}{\frac{1}{g_m}+2R} \simeq \boxed{\frac{-R_L}{2R}}$$

↳ εάν R ↑ → A_{cm} ↑

$$CMRR \equiv \frac{A_{dm}}{A_{cm}} = \frac{-g_m \cdot R_L}{\frac{-R_L}{2R}} = \boxed{g_m \cdot 2R}$$

↳ common-mode regection ratio

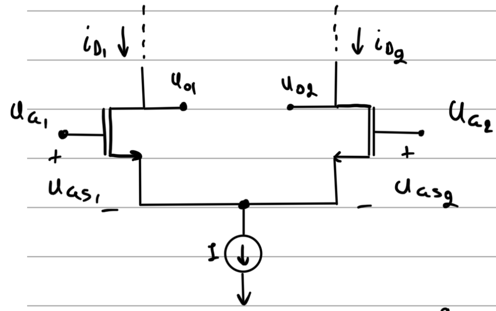
Διαφορικό ζεύγος bjt



$$u_{o1} = -g_m u_\pi R_L = -g_m \frac{u_{id}}{2} R_L \quad \text{αντίστοιχα:} \quad u_{o2} = g_m \frac{u_{id}}{2} R_L$$

$$u_{od} = u_{o1} - u_{o2} = -g_m R_L \cdot u_{id} \rightarrow A_{DM} \equiv \frac{u_{od}}{u_{id}} = \boxed{-g_m R_L}$$

Λειτουργία Μεγάλου Σήματος - MOS



$i_{D1} = \underset{dc}{I_{D1}} + \underset{ac}{i_{d1}}$

$$i_{D1} = \frac{1}{2}\mu C_{ox}' \frac{W}{L}(V_{GS1} - V_T)^2 \rightarrow \sqrt{i_{D1}} = \sqrt{\frac{1}{2}\mu C_{ox}'\frac{W}{L}}\,(V_{GS1} - V_T)$$

$$i_{D2} = \frac{1}{2}\mu C_{ox}' \frac{W}{L}(V_{GS2} - V_T)^2 \rightarrow \sqrt{i_{D2}} = \sqrt{\frac{1}{2}\mu C_{ox}'\frac{W}{L}}\,(V_{GS2} - V_T)$$

$$\rightarrow \sqrt{i_{D1}} - \sqrt{i_{D2}} = \sqrt{\frac{1}{2}\mu C_{ox}'\frac{W}{L}}\; v_{ID} \xrightarrow{(\cdot)^2} 2\sqrt{i_{D1}\cdot i_{D2}} = I\,\frac{1}{2}\mu C_{ox}'\frac{W}{L}\, v_{ID}^2$$

$\hookrightarrow i_{D1} + i_{D2} = I \rightarrow i_{D2} = I - i_{D1}$

$$\rightarrow i_{D1,2} = \frac{I}{2} \pm \sqrt{\frac{1}{2}\mu C_{ox}'\frac{W}{L}}\;\frac{v_{ID}}{2}\cdot\sqrt{1 - \frac{(v_{ID}/2)^2}{I/\mu C_{ox}'\frac{W}{L}}}$$

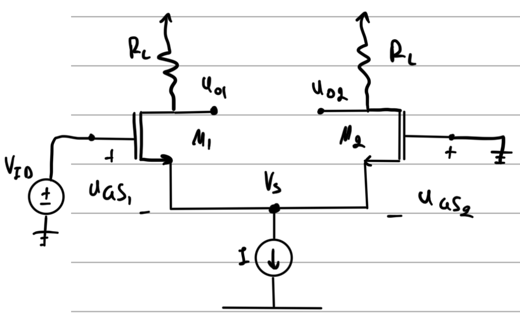
Σε συνθήκες ηρεμίας: $v_{ID} = 0$

- $i_{D1} = i_{D2} = \frac{I}{2}$
- $v_{GS1} = v_{GS2} = V_{GS}$
- $\frac{I}{2} = \frac{1}{2}\mu C_{ox}'\frac{W}{L}(V_{GS} - V_T)^2 = \frac{1}{2}\mu C_{ox}'\frac{W}{L}V_{ov}^2 \rightarrow \boxed{V_{ov} = \sqrt{\frac{I}{\mu C_{ox}' W/L}}}$

- $i_{D1} = \frac{I}{2} + \frac{I}{V_{ov}}\cdot\frac{v_{ID}}{2}\cdot\sqrt{1 - \left(\frac{v_{ID}/2}{V_{ov}}\right)^2}$

- $i_{D2} = \frac{I}{2} - \frac{I}{V_{ov}}\cdot\frac{v_{ID}}{2}\cdot\sqrt{1 - \left(\frac{v_{ID}/2}{V_{ov}}\right)^2}$

- $V_{ID} = V_{GS1} - V_{GS2} > 0 \rightarrow V_{GS1} > V_{GS2} \rightarrow I_{D1} > I_{D2} \rightarrow V_{D2} - V_{D1} > 0$ $\boxed{\text{στο όριο?}}$

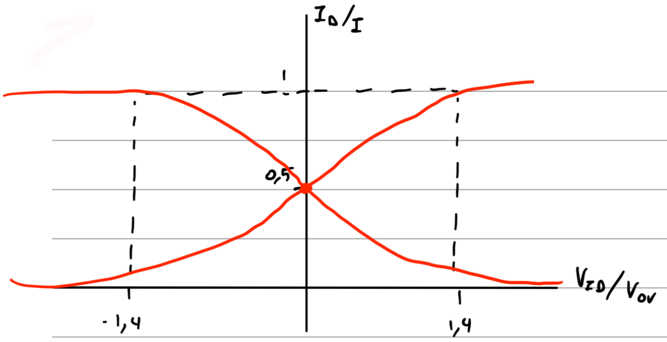


$I_{D1} = I$ (M_2 off, $I_{D2} = 0$)

$I = \frac{1}{2}\mu C_{ox}'\frac{W}{L}(V_{GS1} - V_T)^2$

$V_{GS1} = V_T + \sqrt{\frac{2I}{\mu C_{ox}'\frac{W}{L}}} = V_T + \sqrt{2}\cdot V_{ov}$

$V_{ID\,max} = V_{GS1} + V_S = V_T + \sqrt{2}V_{ov} - V_T = \boxed{\sqrt{2}\cdot V_{ov}}$



• $g_m = \mu C_{ox}' \dfrac{W}{L} V_{ov}$ (κορεσμός)

• $g_m = \dfrac{2I_D}{V_{ov}}$, $I_D = \dfrac{I}{2}$ $\rightarrow$ $\boxed{g_m = \dfrac{I}{V_{ov}}}$

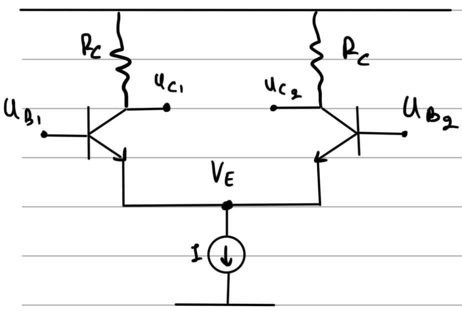
• $i_{OD} = i_{D_1} - i_{D_2} = \dfrac{I}{V_{ov}} u_{ID} \sqrt{1-\left(\dfrac{u_{ID}}{2V_{ov}}\right)^2} \rightarrow$

$\rightarrow \boxed{i_{OD} = g_m u_{ID} \sqrt{1-\left(\dfrac{u_{ID}}{2V_{ov}}\right)^2}} \rightarrow \boxed{i_{OD} \simeq g_m u_{ID}}$

• $x \equiv \dfrac{u_{ID}}{2V_{ov}} << 1 \rightarrow \sqrt{1-x^2} \simeq 1 - \dfrac{x^2}{2} \rightarrow i_{OD} \simeq g_m u_{ID} - \dfrac{g_m}{8V_{ov}^2} \cdot u_{ID}^3$

το δ.ζ. MOS παρουσιάζει ασθενή κυβική μη γραμμικότητα

BJT



• $V_{B_1} = V_B + \Delta V_B \rightarrow \dfrac{I}{2} + \Delta I$

• $V_{B_2} = V_B - \Delta V_B \rightarrow \dfrac{I}{2} - \Delta I$

• $i_{E_1} = \dfrac{I_s}{a} e^{(u_{B_1} - u_E)/V_T}$

• $i_{E_2} = \dfrac{I_s}{a} e^{(u_{B_2} - u_E)/V_T}$

$\rightarrow \dfrac{i_{E_1}}{i_{E_2}} = e^{(u_{B_1} - u_{B_2})/V_T}$

$\hookrightarrow i_{E_1} + i_{E_2} = I$

• $\dfrac{i_{E_1} + i_{E_2}}{i_{E_1}} = 1 + \dfrac{i_{E_2}}{i_{E_1}} \rightarrow \dfrac{i_{E_1}}{i_{E_1} + i_{E_2}} = \dfrac{1}{1 + e^{(u_{B_2} - u_{B_1})/V_T}}$

• $\dfrac{i_{E_2}}{i_{E_1} + i_{E_2}} = \dfrac{1}{1 + e^{(u_{B_2} - u_{B_1})/V_T}}$

$\xrightarrow{u_{B_1} - u_{B_2} = u_{ID}}$

$\rightarrow i_{E_1} = \dfrac{I}{1 + e^{-u_{ID}/V_T}}$, $i_{E_2} = \dfrac{I}{1 + e^{u_{ID}/V_T}}$

• $U_{OD} = u_{C_2} - u_{C_1} = V_{CC} - i_{C_2} R_C - V_{CC} + i_{C_1} R_C \rightarrow u_{OD} = R_C (i_{C_1} - i_{C_2}) = R_C \cdot a \cdot (i_{E_1} - i_{E_2}) =$

$= a I R_C \left(\dfrac{1}{1 + e^{-u_{ID}/V_T}} - \dfrac{1}{1 + e^{u_{ID}/V_T}} \right)$