

$$V_{GS_1} = V_{GS_Y} = V_{GS}$$

$$V_{DS_1} = V_{DS_Y} = V_{DS}$$

①

حالت أول ، اسباع

$$I_I = \frac{1}{2} \mu_n C_{ox} \frac{W_1}{L} (V_{GS} - V_t)^2 (1 + \lambda V_{DS})$$

$$I_Y = \frac{1}{2} \mu_n C_{ox} \frac{W_Y}{L} (V_{GS} - V_t)^2 (1 + \lambda V_{DS})$$

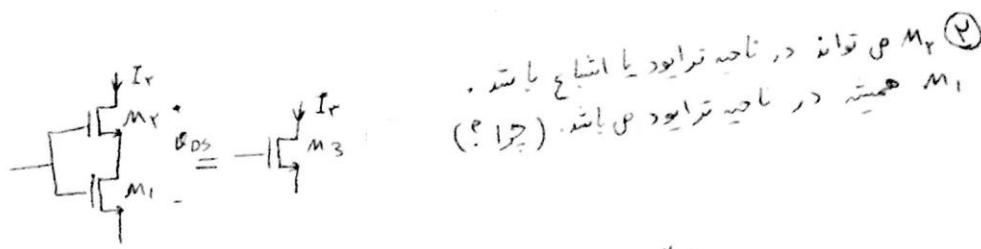
$$I_P = I_I + I_Y = \frac{1}{2} \mu_n C_{ox} \left(\frac{W_1}{L} + \frac{W_Y}{L} \right) (V_{GS} - V_t)^2 (1 + \lambda V_{DS})$$

حالت دوم : ترايدو

$$I_I = \frac{1}{2} \mu_n C_{ox} \frac{W_1}{L} (\gamma(V_{GS} - V_t) V_{DS} - V_{DS}^2)$$

$$I_Y = \frac{1}{2} \mu_n C_{ox} \frac{W_Y}{L} (\gamma(V_{GS} - V_t) V_{DS} - V_{DS}^2)$$

$$I_P = I_I + I_Y = \frac{1}{2} \mu_n C_{ox} \left(\frac{W_1}{L} + \frac{W_Y}{L} \right) (\gamma(V_{GS} - V_t) V_{DS} - V_{DS}^2)$$



$$M_1 \text{ با } M_2 \text{ میانه: } I_r = I_r = K \left(\frac{W}{L} \right)_r (V_{GS} - V_{th}) (V_{DS1} - V_{DS1}^*)$$

$$V_{DS1} = (V_{GS} - V_{th}) \pm \frac{1}{r} \sqrt{(V_{GS} - V_{th})^2 + \frac{r I_r}{K' \left(\frac{W}{L} \right)_r}}$$

نماینده جواب با ترم صدق صحیح است زیرا V_{DS1} با عکس که در $V_{GS} - V_{th}$ باشد میباشد.

$$M_2 \text{ با } M_1 \text{ میانه: } I_r = K \left(\frac{W}{L} \right)_r (V_{GS} - V_{DS1} - V_{th}) (V_{DS} - V_{DS1}) - (V_{DS} - V_{DS1})^*$$

$\therefore V_{DS} > V_{DS1}$

$$X = V_{DS} - (V_{GS} - V_{th})$$

$$Y = \sqrt{(V_{GS} - V_{th})^2 - \frac{I_r}{K' \left(\frac{W}{L} \right)_r}}$$

$$\begin{aligned} \Rightarrow I_r &= K \left(\frac{W}{L} \right)_r (Y (X+Y) - (X+Y)^*) \\ &= K \left(\frac{W}{L} \right)_r (Y^* - X^*) \\ &= K \left(\frac{W}{L} \right)_r ((V_{GS} - V_{th})^* - \frac{I_r}{K' \left(\frac{W}{L} \right)_r} - (V_{DS} - (V_{GS} - V_{th})^*)) \end{aligned}$$

$$\Rightarrow I_r \left(1 + \frac{\left(\frac{W}{L} \right)_r}{\left(\frac{W}{L} \right)_1} \right) = K \left(\frac{W}{L} \right)_r (-V_{DS}^* + Y V_{DS} (V_{GS} - V_{th}))$$

$$I_r = K \frac{W}{L_1 + L_r} (Y (V_{GS} - V_{th}) V_{DS} - V_{DS}^*) = I_r$$

$$M_2 \text{ با } M_1 \text{ میانه: } I_r = K \left(\frac{W}{L} \right)_r (V_{GS} - V_{DS1} - V_{th})$$

با عکس از V_{DS1} و ساده سازی داریم:

$$I_r = K \left(\frac{W}{L} \right)_r (V_{GS} - V_{th}) - \left(\frac{W}{L} \right)_r \frac{I_r}{\left(\frac{W}{L} \right)_1}$$

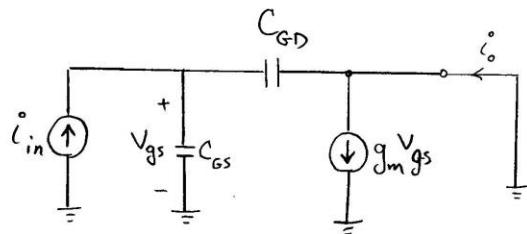
$$I_r \left(1 + \frac{\left(\frac{W}{L} \right)_r}{\left(\frac{W}{L} \right)_1} \right) = K \left(\frac{W}{L} \right)_r (V_{GS} - V_{th})^*$$

$$I_r = K \left(\frac{\left(\frac{W}{L} \right)_r}{1 + \frac{\left(\frac{W}{L} \right)_r}{\left(\frac{W}{L} \right)_1}} \right) (V_{GS} - V_{th})^*$$

$$I_r = K \left(\frac{W}{L_1 + L_r} \right) (V_{GS} - V_{th})^* = I_r$$

حل سوال ۳

قسمت اول:



$$i_o \approx g_m V_{gs}$$

$$i_{in} = s(C_{GD} + C_{GS}) V_{gs}$$

$$\frac{i_o}{i_{in}} = \left| \frac{g_m}{s(C_{GD} + C_{GS})} \right| = 1 \quad \rightarrow \quad \omega_T = \frac{g_m}{C_{GD} + C_{GS}}$$

$s = j\omega_T$

$$f_T \approx \frac{g_m}{2\pi(C_{GD} + C_{GS})}$$

قسمت ب:

$$\text{معادله جوابی: } I_D = I_{D_0} \frac{W}{L} e^{\frac{V_{GS} - V_T}{2V_{TH}}} \left(1 - e^{-\frac{V_{DS}}{V_{TH}}} \right)$$

$$g_m = \frac{I_D}{2V_{TH}} \quad , \quad C_{GD} = C_{GS} = W \cdot C_{ov}$$

$$f_T = \frac{g_m}{2\pi(C_{GD} + C_{GS})} = \frac{I_D}{2\pi \frac{W}{L} V_{TH} W \cdot C_{ov}}$$

: $\int \int$

$$V_G = 1.4 \text{ V}$$

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = \frac{1.9 \times 1.1 \times 1.0 \times 1.0 \frac{F}{cm}}{4 \times 1.0 \frac{V}{cm}} = 0.01 \frac{nF}{cm^2}$$

$$V_S = -0.8 \text{ V}$$

$$L_{eff} = L - 2L_{ov} = 1 - 2 \times (0.8) = -0.9 \mu m$$

$$V_D = 1.1 \text{ V}$$

$$V_{DS} = 1.1 - 0.8 = 0.3 \text{ V}$$

$$V_{GS} = 1.4 - 0.8 = 0.6 \text{ V}$$

$$V_{SB} = V_S - V_B = 0.8 \text{ V}$$

$$\begin{aligned} V_{TH} &= V_{TH_0} + \gamma \left(\sqrt{V_{SB} + |V_{PF}|} - \sqrt{|V_{PF}|} \right) \\ &= 0.4 + 0.8 \left(\sqrt{0.8 + 0.4} - \sqrt{0.4} \right) = 0.8 \text{ V} \end{aligned}$$

$$\left. \begin{aligned} V_{eff} &= V_{GS} - V_{TH} = 0.6 - 0.8 \text{ V} = -0.2 \text{ V} \\ V_{DS} &= 0.3 \text{ V} \end{aligned} \right\} \rightarrow \text{متغير T}$$

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L_{eff}} \left[V_{eff} \right]^2 = \frac{1}{2} \times 0.4 \times \frac{0.8}{0.9} \times (0.8)^2 = 0.128 \text{ mA}$$

$$g_m = \frac{V_{eff}}{I_D} = \frac{0.8}{0.128} = 6.25 \frac{\text{mA}}{\text{V}}$$

$$r_o = \frac{1}{\lambda I_D} = \frac{1}{0.1 \times 0.128} \approx 11 \text{ k}\Omega$$

$$g_{mb} = \frac{\gamma}{\sqrt{V_{PF} + V_{SB}}} \cdot g_m = \frac{0.8}{\sqrt{0.4 + 0.8}} \times 6.25 \approx 1.1 \frac{\text{mA}}{\text{V}}$$

فجوات

$$C_{GS} = \frac{\gamma}{r} w \cdot L \cdot C_{ox} + W L_{ov} C_{ox} = \frac{\gamma}{r} x \frac{\mu m}{\delta o} \times \frac{\mu m}{\delta V} \frac{nF}{cm^2} + \frac{\mu m}{\delta o} \times \frac{\mu m}{\delta x} \frac{\mu m}{\delta V} \frac{nF}{cm^2}$$
$$= 1V \cdot \delta FF + 1F \cdot r V \delta FF = 1A \cdot 1V \delta FF$$

$$C_{GD} = w L_{ov} C_{ox} = \delta o \times \delta x \times \delta V \delta = 1F \cdot r V \delta FF$$

ویرایش
جواب نهاد
ویرایش

$$A_s = A_d = \delta o \times \delta x = 1 \delta \times 1 \delta = 1 \delta (\mu m)^2$$

$$P_s = P_d = \gamma (\delta o + w) = \gamma \times [1 \delta + 1 \delta] = 1.1 \mu m$$

$$A_{CH} = w L_{eff} = \delta o \times 19 = 1 \delta \mu m^2$$

$$C_{js} = \frac{C_{jo}}{\sqrt{1 + \frac{V_{SB}}{\Psi_0}}} = \frac{1}{\sqrt{1 + \frac{1/\delta}{1/40}}} = 1/V \delta \frac{mF}{m^2}$$

$$C_{jds} = \frac{C_{jo}}{\sqrt{1 + \frac{V_{DB}}{\Psi_0}}} = \frac{1}{\sqrt{1 + \frac{1/\Lambda}{1/40}}} = 1/\delta \delta \frac{mF}{m^2}$$

$$C_{js-sw} = \frac{C_{js-sw}}{\sqrt{1 + \frac{V_{SB}}{\Psi_0}}} = \frac{1/\gamma}{\sqrt{1 + \frac{1/\delta}{1/40}}} = 1/\delta \frac{nF}{m^2}$$

$$C_{jds-sw} = \frac{C_{jds-sw}}{\sqrt{1 + \frac{V_{DB}}{\Psi_0}}} = \frac{1/\gamma}{\sqrt{1 + \frac{1/\Lambda}{1/40}}} = 1/\delta \gamma \frac{nF}{m^2}$$

$$C_{SB} = (A_S + A_{ch}) C_{j_S} + P_s C_{j_{S-SW}} \approx 100 \text{ pF}$$

$$= (10 + 1) \times 10^{-12} + 10 \times 10^{-12} \approx 100 \text{ pF}$$

Fjmls

$$C_{DB} = A_d \times C_{j_d} + P_d \times C_{j_{d-SW}} =$$

$$= 10 \times 10^{-12} + 10 \times 10^{-12} = 20 \text{ pF}$$

$$\theta = \frac{1}{L E_c} = \frac{1}{10 \times 10^{-4} \times 10^6} = 0.1 \text{ V/A}$$

(*)

$$I_D = \frac{I_{D,sat}}{1 + \theta V_{eff}} = \frac{0.1 \text{ A}}{1 + 0.1 \text{ V/A} \times 0.1 \text{ V}} \approx 0.1 \text{ mA}$$

$$g_m' = \frac{\partial I_D}{\partial V_{eff}} = \frac{\partial}{\partial V_{eff}} \left[\frac{I_{D,sat}}{1 + \theta V_{eff}} \right]$$

$$= \frac{\frac{\partial I_{D,sat}}{\partial V_{eff}} \times [1 + \theta V_{eff}] - \theta \cdot I_{D,sat}}{(1 + \theta V_{eff})^2}$$

$$= \frac{g_m}{1 + \theta V_{eff}} - \theta \frac{I_{D,sat}}{(1 + \theta V_{eff})^2}$$

$$= \frac{1}{1 + \theta V_{eff}} [g_m - \theta I_D]$$

$$g_m' = \frac{1}{1 + 0.1 \text{ V/A} \times 0.1 \text{ V}} \left[0.1 \text{ V/A} \times 0.1 \text{ V} \right] \approx 1 \text{ mS} \approx \frac{mA}{V}$$

$$R_{sw} = \left[E_c \mu_n C_{on} \cdot W \right]^{-1} = \left[10^6 \times 10^{-12} \times 10^{-9} \times 10^{-12} \right]^{-1} = 10^{14} \Omega$$

$$K = \sqrt{\frac{r k_b \Sigma}{q N_A}} = \sqrt{\frac{r \times 11.8 \times 8.6 \times 10^{-19}}{1.4 \times 10^{-19} \times 10^{23}}} = 1.412 \times 10^{-19} \frac{m}{\sqrt{A}}$$

$$\lambda = \frac{K}{Y L \sqrt{V_{DS} - V_{eff} + \Phi_0}} = \frac{1.412 \times 10^{-19}}{Y \times 1.8 \times 10^{-4} \sqrt{0.9}} = 0.12V^{-1}$$

$$I = \frac{1}{Y} \mu_n C_0 \times \frac{W}{L} (V_{GS} - V_{th})^2 (1 + \lambda (V_{DS} - V_{eff}))$$

$$V_{DS} = V_{eff} \Rightarrow I_D = \frac{1}{Y} \times 9.2 \times 10^{-12} \times \frac{10}{1.8} \times (1, 1 - 0, 1) = 1.2 \times 10^{-12} A$$

$$V_{DS} = V_{eff} + 0.1 \Rightarrow I_D = \frac{1}{Y} \times 9.2 \times 10^{-12} \times \frac{10}{1.8} \times (1, 1 - 0, 1) (1 + 0, 12 \times 0.1)$$

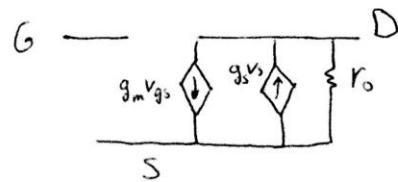
$$I_D = 1.44 \times 10^{-12} A$$

(C)

$$R_o = \frac{1}{\lambda I_D} = \frac{1}{0.12 \times 10^{-12}} = 8.33 \times 10^{13} \Omega$$

$$g_m = \sqrt{Y \mu_n C_0 \times \frac{W}{L} I_D} = \sqrt{Y \times 9.2 \times \frac{10}{1.8} \times 1.44 \times 10^{-12}} = 9.2 \times 10^{-12} A/V$$

$$g_s = \frac{g_m}{Y \sqrt{V_{sb} + V_{eff}}} = \frac{0.12 \times 9.2 \times 10^{-12}}{Y \sqrt{1 + 0.1}} = 1.44 \times 10^{-12} A/V$$



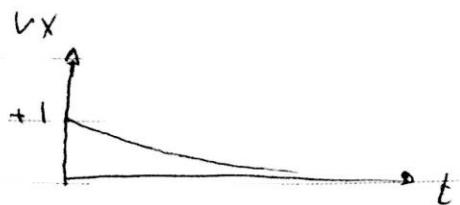
۳۶ (a) ترانزیستور، روش شده و جازن (۴)
 تخلیه می شود. ترانزیستور در ناحیه خطی می باشد.

$$I_D = \frac{1}{\mu} M_n C_{ox} \frac{W}{L} \left(2(V - V_{th}) V_x - V_x^2 \right) = -C_1 \frac{dV_x}{dt}$$

$$\Rightarrow \underbrace{\frac{1}{C_1}}_{\alpha} (f_{t,4} V_x - V_x^2) = - \frac{dV_x}{dt} \Rightarrow -\alpha dt = \frac{dV_x}{V_x(f_{t,4} - V_x)}$$

$$\Rightarrow -\alpha t = \left(\frac{1}{V_x} + \frac{1}{f_{t,4} V_x} \right) \frac{1}{f_{t,4}} + K \quad \left\{ \begin{array}{l} t=0 \\ V_x=1 \end{array} \right. : \text{شرط اولیه}$$

$$\Rightarrow \frac{1}{f_{t,4}} e^{-\alpha t} = \frac{V_x}{f_{t,4} - V_x} \rightarrow V_x = \frac{f_{t,4}}{1 + f_{t,4} e^{f_{t,4} \alpha t}}$$



۴) ابتدا وارد ناحیه استیاغ مشویم و زمانی که $V_x < V - \alpha_1 V$ شود وارد

$$i_D = -i_C \rightarrow V_{C(t)} = \frac{1}{C_1} \int_0^t i_C(t) dt \quad \text{نمایه تراوود مشویم.}$$

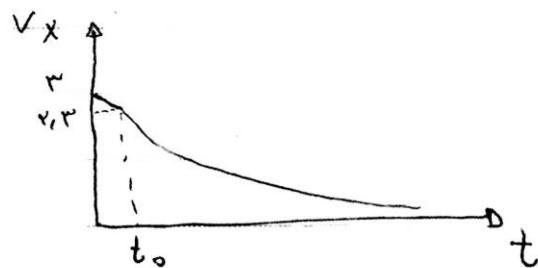
$$\Rightarrow V_C = -\frac{i_D \times t}{C_1}$$

$$t < t_0 \rightarrow V_x = V - \underbrace{\frac{1}{C_1} M_n C_{ox} \frac{W}{L}}_{\gamma} (V - \alpha_1 V)^2 \frac{t}{C_1} \quad \gamma, \alpha_1 \ll V_x \ll V$$

$$t > t_0 \rightarrow I_D = -C_1 \frac{dV_x}{dt} = \frac{1}{C_1} M_n C_{ox} \frac{W}{L} (\gamma(V - \alpha_1 V) V_x - V_x^2)$$

$$\frac{dV_x}{V_x(t, V - V_x)} = -\frac{1}{C_1} M_n C_{ox} \frac{W}{L} \frac{dt}{C_1} \quad \left\{ \begin{array}{l} t = t_0 \\ V_x = V, V - \frac{V}{C_1} = \alpha \end{array} \right.$$

$$-\alpha(t - t_0) = \frac{1}{\epsilon_1 q} \ln \frac{V_x}{V - V_x} \rightarrow V_x = \frac{\epsilon_1 q}{1 + e^{\epsilon_1 q \alpha t}}$$



$$V_{TH_0} = 0 \text{ V} \quad \& \quad \gamma = 1/2\delta, \quad \Phi_F = 1.9 \quad \& \quad V_{DD} = 5 \text{ V}$$

(a) (V)

$$V_{SG} = 1 - V_{in}$$

$$V_{GS} = 1$$

$$V_{TH_0} = V_{TH_0} + \gamma \left[\sqrt{\Phi_F + V_{SB}} - \sqrt{\Phi_F} \right]$$

$$= 0 \text{ V} + 0.5 \left[\sqrt{1.9 - V_{in}} - \sqrt{1.9} \right]$$

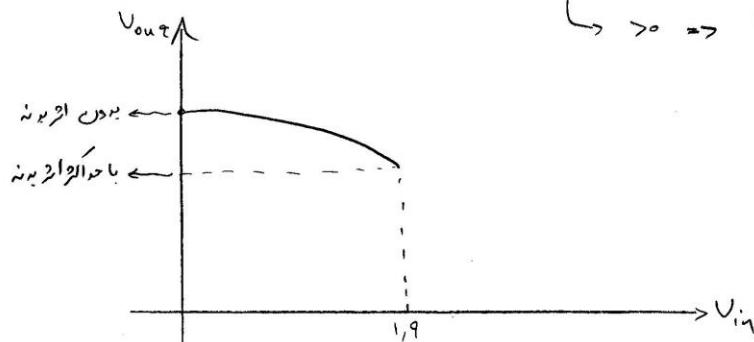
آخر مرحله لش R_1 متغير درجه کوئی سیم رنجی مغایل مان

$$V_{out} = V_{DD} - R_1 \times I_D$$

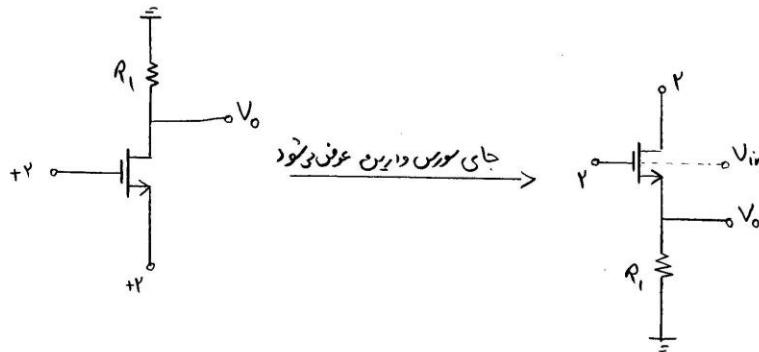
$$= V_{DD} - R_1 \times \frac{1}{\gamma} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})^2$$

$$= 5 - R_1 \times k \left(0.5 - 0.5 \left(\underbrace{\sqrt{1.9 - V_{in}} - \sqrt{1.9}} \right) \right)^2$$

$$> 0 \Rightarrow V_{in} < 1.9$$



: b = صفر (V)



$$V_{TH} = V_{TH_0} + \gamma \left[\sqrt{V_F + V_{SB}} - \sqrt{V_F} \right]$$

$$= 0.1V + 0.180 \left[\sqrt{0.1V + V_o - V_{in}} - \sqrt{0.1V} \right]$$

$$V_{GS} = V - V_o$$

$$I_D = \frac{1}{r} \mu_n C_{on} \frac{W}{L} \left[V - V_o - 0.1V - 0.180 \left(\sqrt{0.1V + V_o - V_{in}} - \sqrt{0.1V} \right) \right]^{\gamma}$$

$$V_o = R_L \times I_{D1}$$

