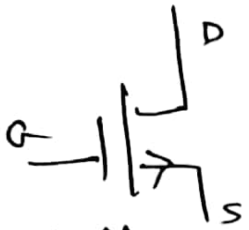
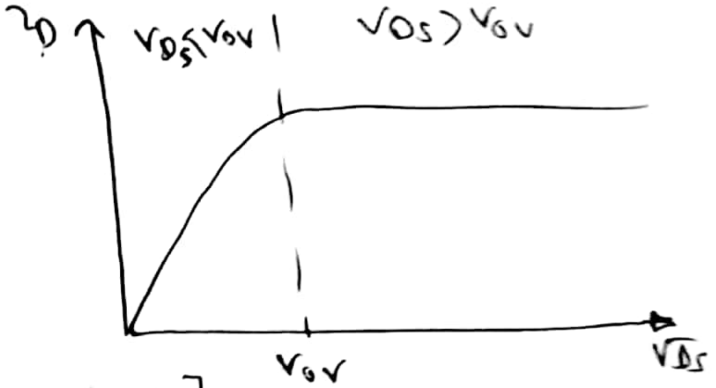
NMOS





$V_{GS} < V_T$ cutoff

$V_{GS} > V_T$ on

$V_{ov} = V_{GS} - V_T$ $[V_{GS} = V_{ov} + V_T]$

Triode

$V_{GD} > V_{tn}$

$V_{DS} < V_{ov}$

$$i_D = k_n' \frac{W}{L}\left(V_{ov} V_{DS} - \frac{V_{DS}^2}{2}\right)$$
$$= k_n' \frac{W}{L}\left[(V_{GS} - V_{tn}) V_{DS} - \frac{V_{DS}^2}{2}\right]$$

الشرط

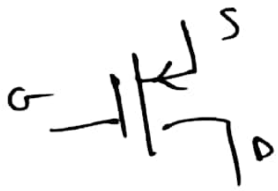
Saturation (pinch off)

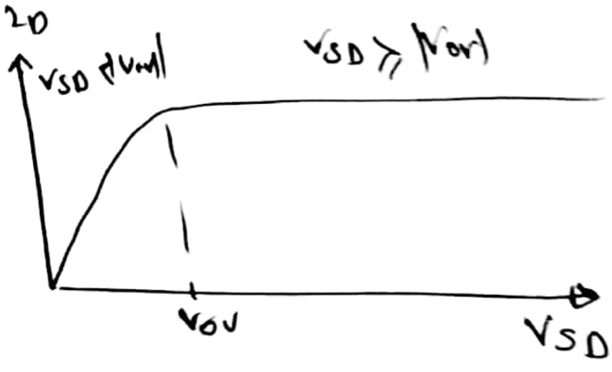
$V_{GD} \leq V_{tn}$

$V_{DS} \geq V_{ov}$

$$i_D = \frac{1}{2} k_n' \frac{W}{L} V_{ov}^2$$
$$i_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_T)^2$$

PMOS





$V_{SG} < |V_{tp}|$ cutoff

$V_{SG} > |V_{tp}|$ on

$V_{SG} = |V_{tp}| + |V_{ov}|$

Triode

$$i_D = k_p'\left(\frac{W}{L}\right)\left[|V_{ov}| - \frac{V_{SD}^2}{2}\right]$$
$$= k_p'\left(\frac{W}{L}\right)\left[(V_{SG} - |V_{tp}|) V_{SD} - \frac{V_{SD}^2}{2}\right]$$

الشرط

$V_{DG} > |V_{tp}|$

$V_{SD} < V_{ov}$

Sat

$$i_D = \frac{1}{2} k_p'\left(\frac{W}{L}\right)(V_{SG} - |V_{tp}|)^2$$
$$= \frac{1}{2} k_p' \frac{W}{L} V_{ov}^2$$

$V_{DG} \leq V_{tp}$

$V_{SD} \geq V_{ov}$

Ex) for NMOS with $\mu_n C_{ox} = 200 \frac{\mu A}{V^2}$, $V_A' = 50 \frac{V}{\mu m}$ (lec-3)

(a) if $L = 0.8\mu m$, $W = 16\mu m$ find V_A, λ

(b) find I_D when $V_{OV} = 0.5V$, $V_{DS} = 1V$. Then Calculate r_o

(c) if V_{DS} increase by 2V what is The change in I_D. what I_D at $V_{DS} = 3V$

(a) $V_A = V_A' * L = 50 \frac{V}{\mu m} * 0.8\mu m = 40V$ # ✓

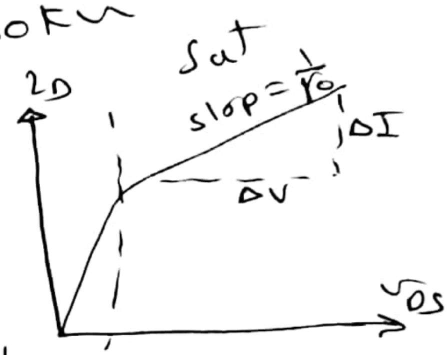
$\lambda = \frac{1}{V_A} = \frac{1}{40} = 0.025 V^{-1}$ # ✓

(b) ∵ $V_{DS} = 1V$, $V_{OV} = 0.5V$ ∴ $V_{DS} > V_{OV}$ ⇒ saturation

∴ $I_D = \frac{1}{2}\mu_n C_{ox} \frac{W}{L} V_{OV}^2 = \frac{1}{2} * 200 \frac{\mu A}{V^2} * \frac{16\mu m}{0.8\mu m} * 0.5^2 = 0.5mA$ ✓

$r_o = \frac{V_A}{I_D} = \frac{40V}{0.5mA} = 80K\Omega$

$r_o = \frac{V_A}{I_D} = \frac{1}{\lambda I_D} = \frac{1}{0.025 * 0.5mA} = 80K\Omega$



(c) $r_o = \frac{\Delta V}{\Delta I}$

∴ $\Delta I = \frac{\Delta V}{r_o} = \frac{2V}{80 * 10^3 \Omega} = 0.025mA$

∴ $I_D|_{V_{DS}=1+2V} = I_D|_{V_{DS}=1} + \Delta I|_{\text{when } V_{DS}\uparrow \text{ by } 2V}$

$= 0.5mA + 0.025mA = 0.525mA$

& when $V_{DS} = 3V$ ∴ $I_D = 0.525mA$ (5V)

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when $V_{DS} = 1V$ $I_D = 0.5mA$

Ex) PMOS, $V_{tp} = -1V$, $K_p' = 60 \frac{\mu A}{V^2}$, $\frac{W}{L} = 10$

(a) find V_{GS} at which The Transistor Conduct

(b) in Term of V_{GS}, find range for V_{D_x} to be in Triod region

(c) in Term of V_G, find range To operate in Saturation

(d) neglect λ, find $|V_{OV}|$, V_G, V_D To operate in sat with $I_D = 0.75mA$

(e) if $\lambda = 0.02V^{-1}$, find r_o for case (d)

(f) if $\lambda = 0.02V$, use V_{OV} in (d), find I_D at $V_D = 3V$ & at $V_D = 0V$

(Hint) → Calculate value of r_o & Compare

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L3S2

(a) to Conduct $V_{SG} \geq |V_{tp}|$

$V_S - V_G \geq |-1|$

سم لأرى طريقة — $5 - V_G \geq 1$

$V_G \leq 4V$

$\therefore V_{GS} = V_G - V_S = \leq 4 - 5 = \leq -1V$ ⊕ ✓

(b) for operates in Triode region

$V_{DG} > |V_{tp}|$

$V_D - V_G > 1$

$V_D > V_G + 1$ ⊕ ✓

(c) for operates in saturation region

$V_{DG} \leq |V_{tp}|$

$V_D - V_G \leq 1$

$V_D \leq V_G + 1$

(d) in Sat $I_D = \frac{1}{2} K_p' \frac{W}{L} |V_{ov}|^2$

$75\mu A = \frac{1}{2} * 60 \frac{\mu A}{V^2} \cdot 10 \cdot |V_{ov}|^2$

$\therefore |V_{ov}| = 0.5$ ⊕ ✓

$\because |V_{ov}| = V_{SG} - |V_{tp}|$

$0.5 = V_{SG} - 1$

$0.5 = V_S - V_G - 1$

$0.5 = 5 - V_G - 1$

$\therefore V_G = 3.5V$ ⊕ ✓

$V_{SD} \geq V_{ov}$

$V_S - V_D \geq 0.5$

$5 - V_D \geq 0.5$

$V_D \leq 4.5V$ ⊕ ✓

(e) تظهر λ بالسالب لو V_A طالما بالسالب في (ال PMOS

$V_A = \frac{1}{\lambda} = \frac{1}{0.02} = 50V$

$r_o = \frac{V_A}{I_D} = \frac{50V}{75\mu A} = 0.666 M\Omega$

(f) $V_{ov} = 0.5$, $\lambda = 0.02 V^{-1}$, $V_G = 3.5V$

required $I_D = ?$ at $V_D = 3V$

$I_D = ?$ at $V_D = 0V$ ✓

For $V_{ov} = 0.5V$

وحسب اسم ؟ لا تطلع إلا sat لأنا نجيب بحد الترانزستور في sat

at edge of sat $V_{SD} = V_{ov} = 0.5V$

$V_S - V_D = V_{ov}$

$5 - V_D = 0.5$

$V_D = 4.5V$

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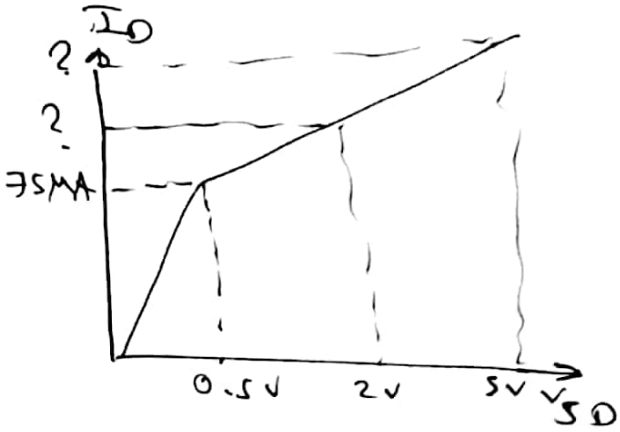
L3 S2



(i) $slop = r_o = \frac{\Delta V}{\Delta I}$

$$0.666 * 10^{6} = \frac{2 - 0.5}{I_{D_{2V}} - 75 * 10^{-6}}$$

$$\therefore I_{D_{2V}} = 77.25\ mV$$

(ii) $r_o = \frac{\Delta V}{\Delta I}$.

$$0.666 * 10^{+6} = \frac{5 - 0.5}{I_{D_{5V}} - 75 * 10^{-6}}$$

$$I_{D_{5V}} = 81.75\ \mu A$$

(EX) Given $I_D = 0.4\ mA$

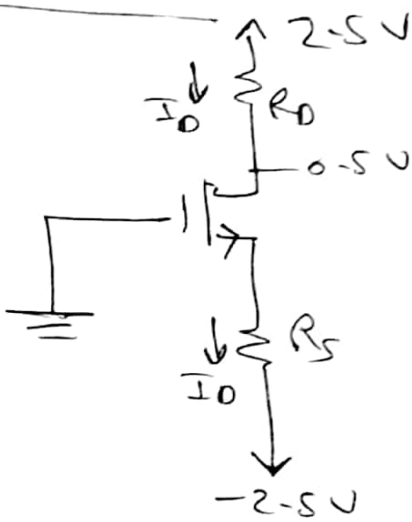
$V_D = 0.5\ V$

$V_t = 0.7\ V$

$\mu_n C_{ox} = 100\ \frac{\mu A}{V^2}$

$\frac{W}{L} = \frac{32\ \mu m}{1.0\ \mu m}$

find R_D, R_S



$$\therefore R_D = \frac{V_{DD} - V_D}{I_D} = \frac{2.5 - 0.5}{0.4\ mA}$$

$$= 5\ K\Omega$$

نفرض بأنه نفترض ان الترانزستور يعمل
في Sat region وبعدها نعمم الشرط

assume Saturation

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{tn})^2$$

$$0.4 * 10^{-3} = \frac{1}{2} * 100 * 10^{-6} * \frac{32}{1} (V_{GS} - 0.7)^2$$

$$(V_{GS} - 0.7) = \pm 0.5$$

V_{GS} < 1.2 V ; 0.2 ⇒ refuse (because $V_{GS} < V_T$ cut off)

we choose $V_{GS} = 1.2$

$V_G - V_S = 1.2$

$0 - V_S = 1.2$ ∴ $V_S = -1.2$ V

$$R_S = \frac{V_S - (-2.5)}{I_D} = \frac{-1.2 + 2.5}{0.4} = 3.25 \text{ k}\Omega$$

check

$V_{DS} = V_D - V_S = 0.5 + 1.2 = 1.7$

$V_{GS} - V_T = 1.2 - 0.7 = 0.5$

So $V_{DS} > V_{GS} - V_T$

sat ok ✓

$V_{GD} = V_G - V_D = 0 - 0.5 = -0.5$

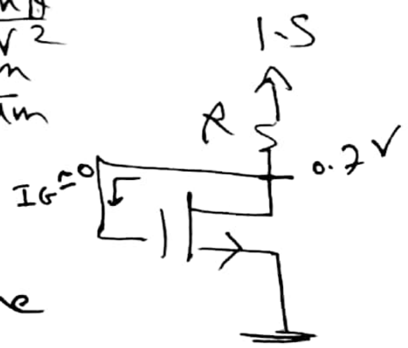
$V_t = 0.7$

Since $V_{GD} < V_T$

Sat ok ✓

EX 5.4 Given $V_{tn} = 0.5$ V, $V_D = 0.7$ V, $\mu_n C_{ox} = 0.4 \frac{mA}{V^2}$, $\frac{W}{L} = \frac{0.72 \mu m}{0.18 \mu m}$

Find R



Since G, D are connected ∴ $V_{GD} = 0$

$V_t = 0.5$

So $V_{GD} < V_T$ Sat all Time

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_t)^2$$

$$I_D = \frac{1}{2} * 0.4 * 10^{-3} * \frac{0.72}{0.18} (V_{GS} - 0.5)^2$$

$$I_D = \frac{1}{2} * 0.4 * 10^{-3} * \frac{0.72}{0.18} (0.7 - 0.5)^2$$

$= 32 \mu A$

$V_{GS} = V_{DS} = V_D - V_S = V_D - 0 = V_D = 0.7$ V

$$R = \frac{1.5 - V_D}{I_D} = \frac{1.5 - 0.7}{32 * 10^{-6}} = 39.375 \text{ k}\Omega$$

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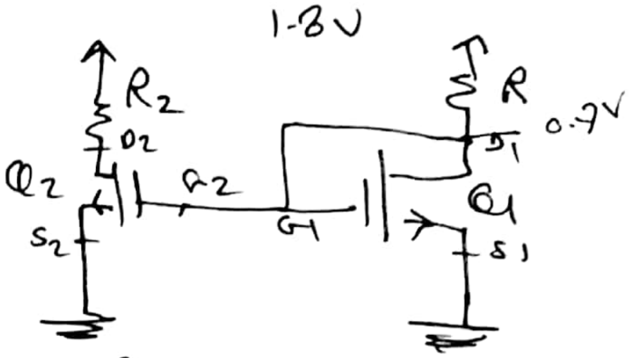
L352

D-5.10 let Q_1, Q_2 are identical
$R = 34.375\,k\Omega$
$V_{tn} = 0.5$
find R_2 To make Q_2 operate at edge of Saturation, Given



$V_D = 0.7\ V$
$\mu_n C_{ox} = 0.4\ \frac{mA}{V^2}$
$W/L = 4$

For Q_1 Since $V_{DG} = 0$ ∴ Sat becau $V_{GD} < V_t$

$$V_{DS1} = V_D - V_{S1} = 0.7 - 0 = 0.7\ V$$

$$\therefore V_{G2} = V_{G1} = V_{D1} = 0.7\ V$$

$$V_{GS2} = V_{G2} - V_{S2} = 0.7 - 0 = 0.7$$

For Q_2 at edge of Sat

$$I_{D_2} = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS_2} - V_{tn})^2$$

$$I_{D2} = \frac{1}{2} * 0.4\ \frac{mA}{V^2} * 4\,(0.7 - 0.5)^2$$

$$= 32\ \mu A$$

at edge of saturation

$$V_{DS2} = V_{OV} = V_{GS_2} - V_{T_2}$$

$$V_{D2} - V_{S2} = V_{GS_2} - V_{tn}$$

$$V_{D2} - 0 = 0.7 - 0.5$$

$$V_{D2} = 0.2\ V$$

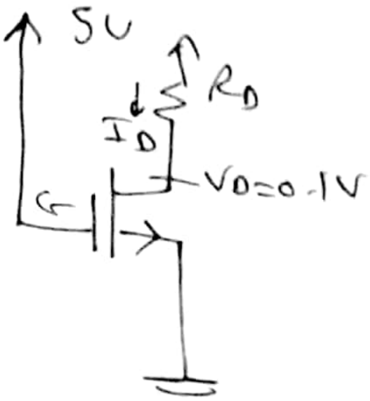
$$\therefore R_2 = \frac{1.8 - V_{D2}}{I_{D2}} = \frac{1.8 - 0.2}{32\ \mu A} = 50\ k\Omega$$

EX 5-5 Given $V_{tn} = 1V$

$K_n' \frac{W}{L} = 1 \frac{mA}{V^2}$

Design to have $V_D = 0.1V$

what is the effective r_{ds}



$\because V_{GS} = V_G - V_S = 5 - 0 = 5V$

$V_{ov} = V_{GS} - V_T = 5 - 1 = 4V$ #

$\because V_{DS} = V_D - V_S = 0.1 - 0 = 0.1$ #

Since $V_{DS} < V_{GS} - V_T$

so it is operates in Triode

$I_D = K_n' \frac{W}{L} \left[V_{ov} V_{DS} - \frac{V_{DS}^2}{2} \right]$

$= 1 \frac{mA}{V^2} \left[4 \times 0.1 - \frac{0.1^2}{2} \right] = 0.395\ mA$

$R_D = \frac{5 - V_D}{I_D} = \frac{5 - 0.1}{0.395mA} = 12.405\ K\Omega$ #

$r_{ds} \simeq \frac{V_{DS}}{I_D} \simeq \frac{0.1V}{0.395mA} \simeq 253.16\ \Omega$

use formula

$r_{ds} = \frac{1}{K_n' \frac{W}{L} (V_{GS} - V_T)} = \frac{1}{1 \frac{mA}{V^2} (5 - 1)}$

$= 250\ \Omega$

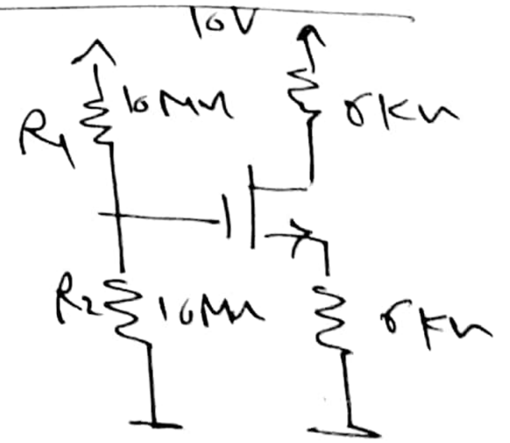
So it is nearly are equal.

EX 5-6 Find all currents and voltage

$V_t = 1V$

$K_n' \frac{W}{L} = 1 \frac{mA}{V^2}$

$\lambda = 0$



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L3S2

use Thevenin

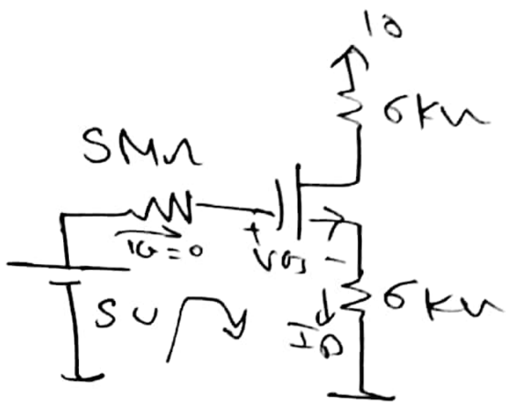
$R_G = 10 \| 10 = 5M\Omega$

$V_{th} = 10 * \frac{10}{10+10} = 5V$

use loop

$5 = V_{GS} + I_D R_D$

$5 = V_{GS} + 6 I_D \rightarrow (1)$



assume Sat

$I_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_T)^2$

$I_D = \frac{1}{2} * 1 (V_{GS} - 1)^2 \quad (2)$

sub by (1) into (2)

$\frac{5 - V_{GS}}{6} = \frac{1}{2} (V_{GS} - 1)^2$

$5 - V_{GS} = 3 (V_{GS}^2 - 2V_{GS} + 1)$

$3V_{GS}^2 - 5V_{GS} - 2 = 0$

$V_{GS} = \frac{+5 \pm \sqrt{5^2 - (4*3*(-2))}}{2*3} = \frac{5}{6} \pm \frac{7}{6}$ < 2V, −0.33V reject < V_t

$\therefore V_{GS} = 2V$ & so, $I_D = \frac{5 - V_{GS}}{6} = \frac{5-2}{6} = 0.5mA$

$V_G - V_S = 2V$

$5 - V_S = 2$

$\therefore V_S = 3V$ (#)

$V_D = V_{DD} - I_D R_D = 10 - 0.5*6 = 7V$ (#)

check $V_{GS} - V_t = 2 - 1 = 1V$ (#)

$V_{DS} = V_D - V_S = 7 - 3 = 4V$ (#)

since $V_{DS} > V_{GS} - V_T$

so it's in Sat ✓

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another check $V_{GD} = V_G - V_D = 5 - 7 = -2$

$V_t = 1$

since $V_{GD} < V_T$

Sat

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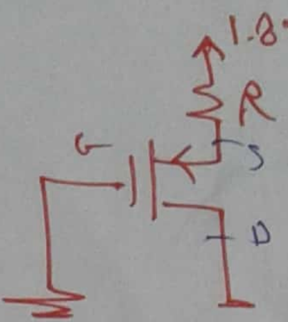
L352

(DS.19) Find R such That $|V_{ov}| = 0.6\,V$

$V_{tp} = -0.4\,V$

$k'_p = 0.1\ \frac{mA}{V^2}$

$\frac{W}{L} = \frac{10\ \mu m}{0.18\ \mu m}$



$\because V_G = 0 \quad \therefore V_{DG} = 0$ (#)

$V_D = 0$

$\because V_{tp} = -0.4\,V \quad \therefore |V_{tp}| = 0.4$ (#)

Since $V_{DG} < |V_{tp}|$, So it is in Sat.

$i_D = \frac{1}{2} k'_p \frac{W}{L} (V_{SG} - |V_{tp}|)^2$

$= \frac{1}{2} * 0.1 \frac{mA}{V^2} * \frac{10\ \mu m}{0.18\ \mu m} (V_{ov})^2$

$i_D = \frac{1}{2} * 0.1 * \frac{10}{0.18} * 0.6^2 = 1\,mA$

$\because |V_{ov}| = V_{SG} - |V_{tp}|$

$\therefore V_{SG} = |V_{ov}| + |V_{tp}| = 0.6 + 0.4 = 1.0\,V$

$V_S - V_G = 1\,V$

$V_S - 0 = 1\,V \quad \therefore V_S = 1\,V$

$\therefore R = \frac{1.8 - V_S}{I_D} = \frac{1.8 - 1}{1\,mA} = 800\,\Omega$

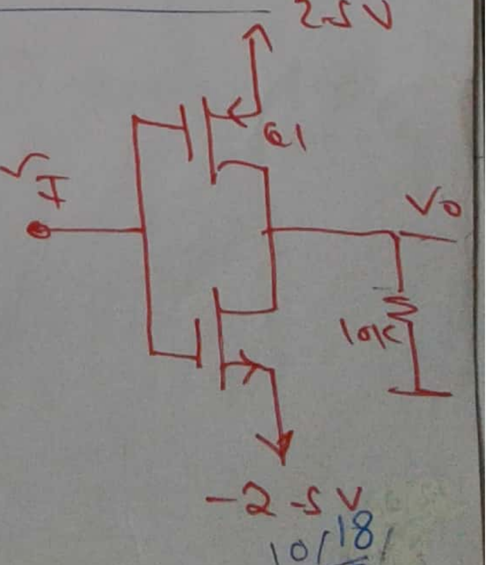
(Ex) 5.8 $k'_n \left(\frac{W_n}{L_n}\right) = k'_p \left(\frac{W_p}{L_p}\right) = 1 \frac{mA}{V^2}$

$V_{tn} = -V_{tp} = 1\,V$

$\lambda = 0$

find i_{DN}, i_{DP}, V_o

when $v_I = 0, 2.5, -2.5\,V$



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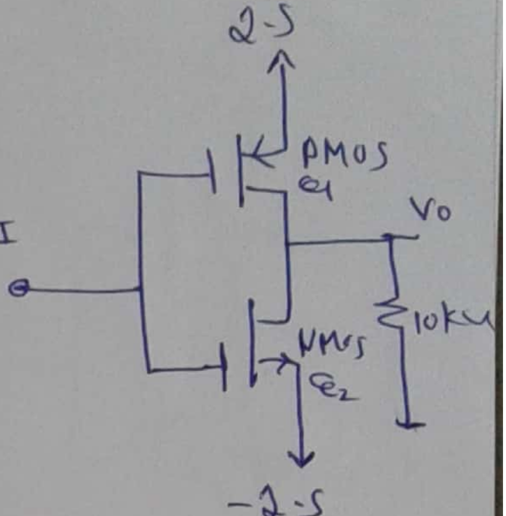
L353

(a) when $V_I = 0$



for NMOS

$V_{GS} = V_G - V_S = 0 - (-2.5) = 2.5$

$V_{GS} - V_{tn} = 2.5 - 1 = 1.5$

$\therefore V_{GS} > V_{tn}$ on state

To make NMOS on, So

since $V_{D1} = V_{D2} = < 2.5$

بعمل NEP Q_2 عوف احسب تيار يمر لغاية 2.5

$\therefore V_{DS} = V_D - V_S = < 2.5 - (-2.5) = > 2.5$ } Saturation

NMOS $V_{GS} - V_T = 1$

$\therefore V_{DS} > V_{GS} - V_T$

for PMOS

$V_{SG} = V_S - V_G = 2.5 - 0 = 2.5V$

$|V_{tp}| = 1$

since $V_{SG} > |V_{TP}|$ on state also

To work so $V_{D2} = V_{D1} = > -2.5$

$\therefore V_{SD} = 2.5 - > -2.5 > +2.5V$ } sat

PMOS $V_{SG} - |V_{tp}| = 2.5 - 1 = 1.5$

$\therefore V_{SD} > V_{SG} - |V_{TP}|$

$\therefore i_{D1} = i_{D2} = \frac{1}{2} k'_{n,p} \left(\frac{W}{L}\right) (V_{GS_n} - V_{t_n})^2$

$= \frac{1}{2} * 1 \frac{mA}{V^2} * (2.5 - 1)^2 = 1.125 mA$

since $i_{D1} = i_{D2} = 1.125 mA$

So no current flow through 10kΩ

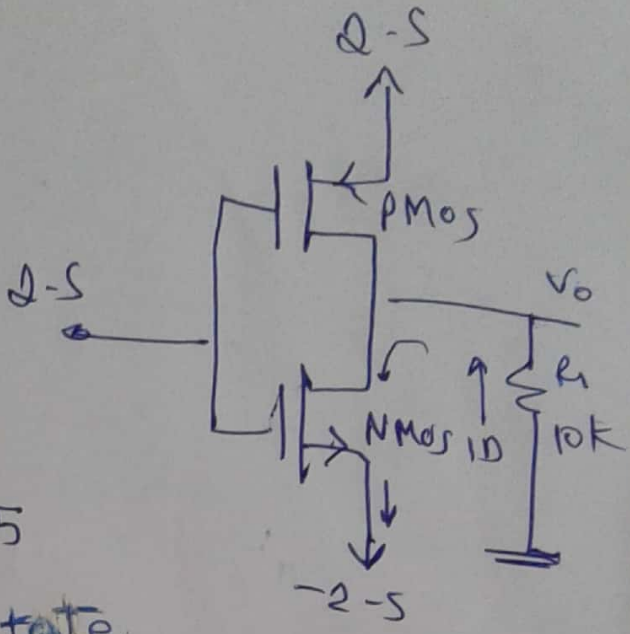
$\therefore V_O = V_{O1} = V_{D2} = 0$

check NMOS	check PMOS
$V_{DS} = 0 - (-2.5) = 2.5$	$V_{SD} = 2.5 - 0 = 2.5$
$V_{GS} - V_T = 1.5$	$V_{SG} - |V_{TP}| = 2.5 - 1 = 1.5$
$V_{DS} > 2.5$	$V_{SD} \geq V_{SG} - |V_{TP}|$
Sat ✓	Sat ✓

$V_I = 0$, $V_O = 0$ as buffer + Delay

11/18 — L2 S3

(b) When $v_I = 2.5$



For PMOS

$V_{SG} = V_S - V_G = 2.5 - 2.5 = 0$

$|V_{tp}| = 1$

$\therefore V_{SG} < |V_{tp}|$ cutoff

for NMOS

$V_{GS} = V_G - V_S = 2.5 - (-2.5) = 5$

$V_{tn} = 1$

$\therefore V_{GS} > V_{tn}$ on, state

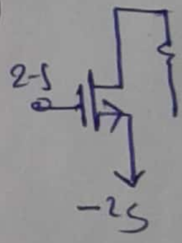
For NMOS be on, So current go from ⏚ thought R_L to Drain

$\therefore V_{D_{NMOS}} = -ve$

$V_{GD} = V_G - V_D = 2.5 - (-ve) > 2.5$

$V_{tn} = 1$

$\therefore V_{GD} > V_{tn}$ Triode



$\therefore i_{D_{NMOS}} = k_n' \frac{W}{L} \left[(V_{GS} - V_t) V_{DS} - \frac{V_{DS}^2}{2} \right]$ → ≈ 0

$i_D \simeq k_n' \frac{W}{L} \left[(V_{GS} - V_T) V_{DS} \right]$

$\simeq 1 \frac{mA}{V^2} \left[(5-1) V_{DS} \right] = 4 V_{DS}$

$i_D \simeq 4 (V_D - V_S) = 4(V_D + 2.5) = 4V_D + 10$ — ①

$\therefore V_D = -10 i_D$ — ②

sub into ① $\therefore i_D = 4(-10 i_D) + 10$

$i_D = \frac{10}{41} = 0.24390$ mA

check $\left\{ \begin{array}{l} V_D = -10 i_D = -2.439V \\ V_{DS} = -2.439 + 2.5 = 0.061V \\ V_{GS} - V_T = 5 \\ \therefore V_{DS} < V_{GS} - V_T \quad \text{Triode} \end{array} \right.$

$v_I = 2.5$, $V_O = -ve \simeq -2.439V$ inverter —▷o— inverter

12/18
L3 S2

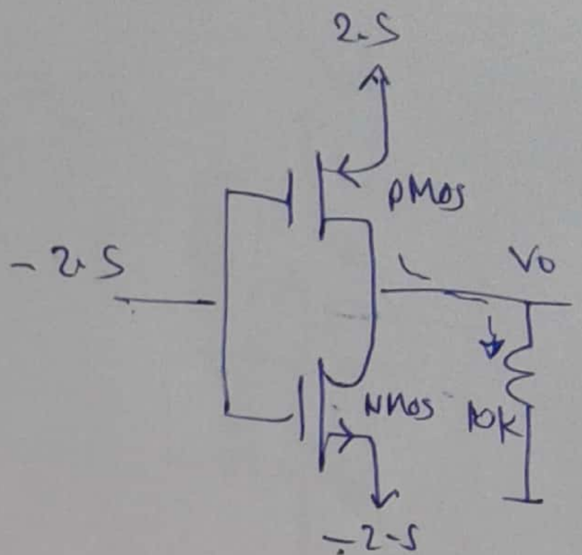
(c) when $V_I = -2.5\,V$

For NMOS

$V_{GS} = V_G - V_S = -2.5 + 2.5 = 0$

$V_{tn} = 1$

$\therefore V_{GS} < V_t$ cutoff-state



For PMOS

$V_{SG} = V_S - V_G = 2.5 - (-2.5) = 5$

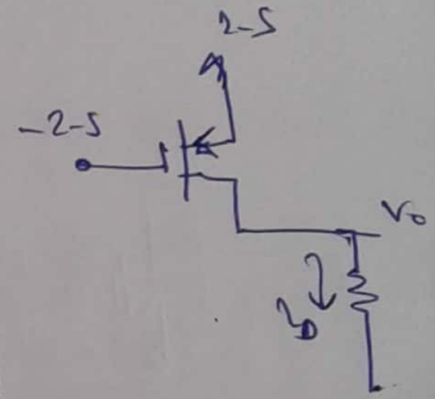
$|V_{tp}| = 1$

$\therefore V_{SG} > |V_{TP}|$ on state

$\therefore V_D = V_O = i_D R_D = +ve$

$V_{DG} = V_D - V_G = +ve - (2.5) > 2.5$

$|V_{TP}| = 1.0 = 1.0\,V$



$\therefore V_{DG} > |V_{TP}|$ Triode

$\therefore i_D = K'_p \frac{W}{L}\left[(V_{SG} - |V_{TP}|)V_{SD} - \frac{V_{SD}^2}{2}\right]$ ($\frac{V_{SD}^2}{2} \to 0$)

$\simeq K'_p \frac{W}{L}\left[(V_{SG} - |V_{TP}|)V_{SD}\right]$

$\simeq \frac{1\,mA}{V^2}\left[(5-1)V_{SD}\right] = 4\,V_{SD} = 4(V_S - V_O)$

$i_D \simeq 4(2.5 - V_O) \simeq 10 - 4V_D \Rightarrow (1)$

$V_D = 10\,i_D$ — (2)

sub by (2) into (1)

$i_D \simeq 10 - 4(10 i_D)$

$\therefore 41 i_D = 10$ $\quad i_D = \frac{10}{41} = 0.2439\,mA$, $V_O = 2.439\,V$

check $\begin{cases} V_{SD} = V_S - V_D = 2.5 - 10 i_D = 2.5 - 2.439 = 0.061 \\ V_{SG} - |V_{TP}| = 5 - 1 = 4 \\ \therefore V_{SD} < V_{SG} - |V_{TP}| \quad \text{Triode} \checkmark \end{cases}$

$V_I = -ve$ ($= -2.5\,V$) $\quad V_O = +ve$ ($\simeq 2.439$) inverter

13/18

L252

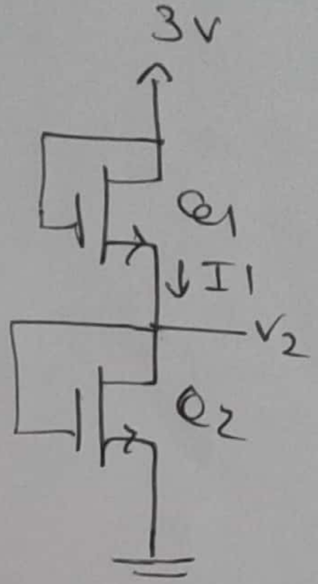
Ex 22

$\mu_n C_{ox} = 270 \frac{\mu A}{V^2}$

$\frac{W}{L} = 3$

$V_t = 0.5$

find I_1, V_2



For both Transistor

$V_{GD} = V_G - V_D = 0$

$\therefore V_{GD} < V_T$ sat

$\therefore i_{D1} = i_{D2}$

$\frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS1}-V_T)^2 = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS2}-V_T)^2$

$(V_{G1}-V_{S1}-V_T)^2 = (V_{G2}-V_{S2}-V_T)^2$

$(3-V_2-0.5)^2 = (V_2-0-0.5)^2$

negative:

$2.5-V_2 = -(V_2-0.5)$

$2.5-V_2 = -V_2+0.5$

XX

positive:

$2.5-V_2 = V_2-0.5$

$2.5+0.5 = 2V_2$

$V_2 = 1.5\ V$ #

$I_1 = i_{D2} = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS2}-V_T)^2$

$= \frac{1}{2} * 270*10^{-3}\frac{mA}{V^2} * 3\ (V_{G2}-V_{S2}-0.5)^2$

$= \frac{1}{2} * 270 * 3\ (V_2-0-0.5)^2$

$= \frac{1}{2} * 270 * 3\ (1.5-0.5)^2$

$= 0.405\ mA$ #

quick answer

from sym $V_2 = 3/2 = 1.5$

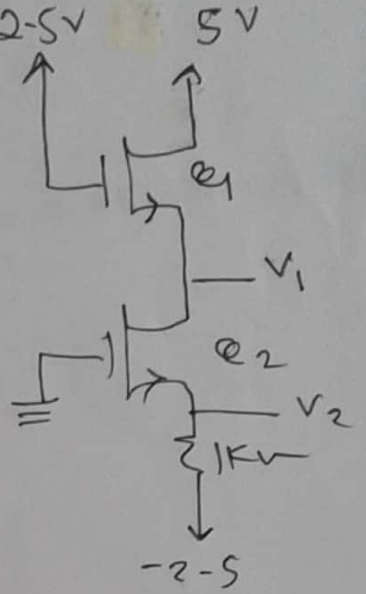
M/18
L352

2o sheet-2

ex $V_t = 0.9V$

$K_n \frac{W}{L} = 1.5 \frac{mA}{V^2}$

find V_1, V_2



For Q1

$V_{GD} = V_G - V_D = 2.5 - 5 = -2.5$

$\because V_t = 0.9$

So $V_{GD} < V_t$ saturation

$i_{D1} = \frac{1}{2} K_n \frac{W}{L} (V_{GS1} - V_T)^2 = \frac{1}{2} K_n \frac{W}{L} (V_{G1} - V_{S1} - V_T)^2$

$i_{D1} = \frac{1}{2} * 1.5 \left[2.5 - V_1 - 0.9\right]^2 \rightarrow \boxed{1}$

for Q2

assume sat

$i_{D2} = \frac{1}{2} K_n \frac{W}{L} (V_{GS2} - V_T)^2 = \frac{1}{2} K_n \frac{W}{L} (V_{G2} - V_{S2} - V_T)^2$

$i_{D2} = \frac{1}{2} * 1.5 (0 - V_2 - 0.9)^2$ — $\boxed{2}$

مراجعة also $i_{D2} = \frac{V_2 - (-2.5)}{1K\Omega} = V_2 + 2.5$ — $\boxed{3}$

sub by eq ③ into eq ②

$V_2 + 2.5 = 0.75 \left[-V_2 - 0.9\right]^2$

$V_2 + 2.5 = 0.75 V_2^2 + 1.35 V_2 + 0.6075$

$0.75 V_2^2 + 0.35 V_2 - 1.8925 = 0$

$\therefore V_2 = \frac{-0.35 \pm \sqrt{(0.35)^2 - 4 * 0.75 * (-1.8925)}}{2 * 0.75}$

$= -0.2333 \pm 1.6055$ < -1.8388 / 1.3722

كيف احنا , الاثنين , المحصل

let $V_2 = 1.3722$

$\therefore V_{GS2} = V_{G2} - V_{S2} = 0 - V_2 = -1.3722V$

$\because V_T = 0.9$

$\therefore V_{GS2} < V_{tn} \Rightarrow$ So This condition make Q2 off

XX 15/18

L352

$\therefore$ when $V_2 = -1.8388$ ✓✓

sub into eq [2]

$$i_{D2} = 0.75\,(0+1.8388-0.9)^2 = 0.660101\,mA$$ ✓

sub by $i_{D2} = i_{D1}$ into eq [1]

$$0.660101 = 0.75\,[2.5 - V_1 - 0.9]^2$$

$$0.660101 = 0.75\,[1.6 - V_1]^2$$

$\therefore V_1$ = 0.6612 V or 2.5388 V

نعوض هنا، الحل الصح

let $V_1 = 2.5388$

$\therefore V_{GS1} = V_{G1} - V_{S1} = V_{G1} - V_1 = 2.5 - 2.5388 = -0.0388V$

since $V_T = 0.9$ $\quad\therefore V_{GS} < V_T$ cutoff

مرفوض XX

let $V_1 = 0.6612V$

$\therefore V_{GS1} = V_{G1} - V_{S1} = V_{G1} - V_1 = 2.5 - 0.6612 = 1.8388V$ on ✓

$\therefore V_{GS1} > V_T$

Summary

$$V_2 = -1.8388V$$
$$V_1 = 0.6612V$$
$$i_{D1} = i_{D2} = 0.660101\,mA$$

check for Q_2

$V_{G2} = 0$ $\quad V_{S2} = V_2 = -1.8388$

$\therefore V_{GS2} = V_{G2} - V_{S2} = 0 + 1.8388\,V$, $V_{GS2} - V_T = 0.9388$

$\therefore V_{DS2} = V_{D2} - V_{S2} = V_1 - V_2 = 0.6612 + 1.8388V$
$= 2.5V$

since $V_{DS2} > V_{GS} - V_T$

so sat ✓

as assumed ✓

16/18

L3S2

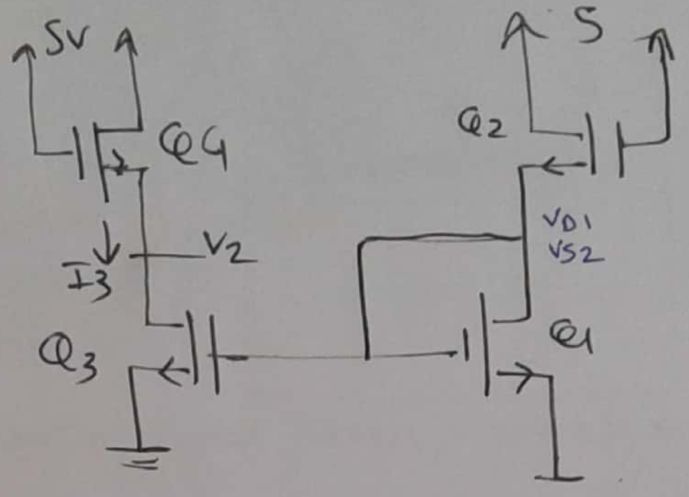
(ex)

$V_t = 1V$

$\mu_n C_{ox} = 50 \frac{\mu A}{V^2}$

$\frac{W}{L} = 10$

find V_2, I_3



For Q1, Q2, Q4 $V_{GD} = 0$, $V_T = 1$

$\therefore V_{GD} < V_T$

all in saturation

For Q1, Q2 & Due To symmetry

$V_{D1} = V_{S2} = \frac{5}{2} = 2.5$

$\therefore V_{G3} = V_{G1} = V_{D1} = 2.5V$

assume Q3 in saturation

$\therefore I_{D4} = I_{D3}$

$\frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS4} - V_T)^2 = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS3} - V_T)^2$

$(V_{G4} - V_{S4} - V_T)^2 = (V_{G3} - V_{S3} - V_T)^2$

$(5 - V_2 - 1)^2 = (2.5 - 0 - 1)^2$

$(4 - V_2)^2 = (1.5)^2$

$4 - V_2 = \pm 1.5$

V_2 < $4 + 1.5 = 5.5$ × $> V_{DD}$; $4 - 1.5 = 2.5$ ✓

$V_2 = 2.5V$ #

$I_{D3} = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{G3} - V_{S3} - V_T)^2$

$I_{D3} = \frac{1}{2} * 50 * 10^{-3} * 10 (2.5 - 0 - 1)^2 = 0.5625 mA$

check for Q3 $\begin{cases} V_{DS3} = V_{D3} - V_{S3} = V_2 - 0 = 2.5V \\ V_{GS3} - V_T = V_{G3} - V_{S3} - V_T = 2.5 - 0 - 1 = 1.5 \\ \therefore V_{DS} > V_{GS} - V_T \quad \text{sat ✓} \end{cases}$

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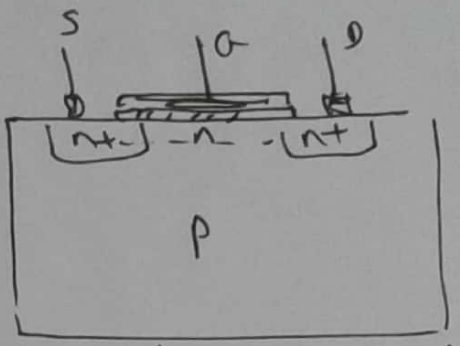
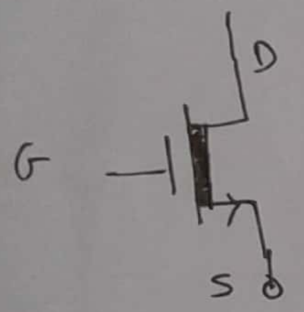
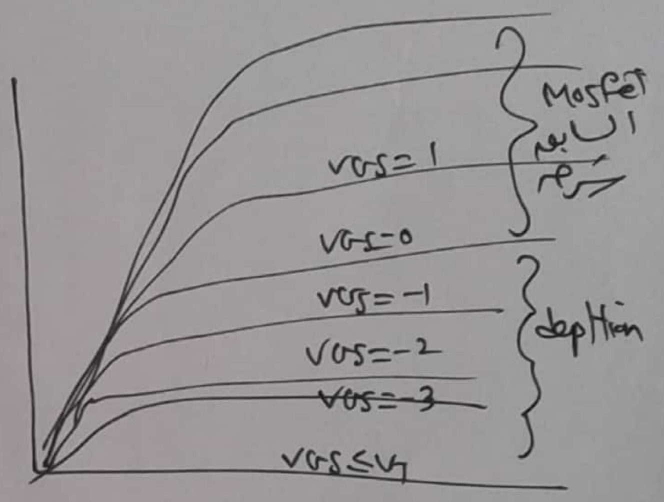
Depltion Type MosFET

هذا النوع متواجد به channel من البداية
ولا تحتاج لتطبيق جهد ع gate لعمل channel

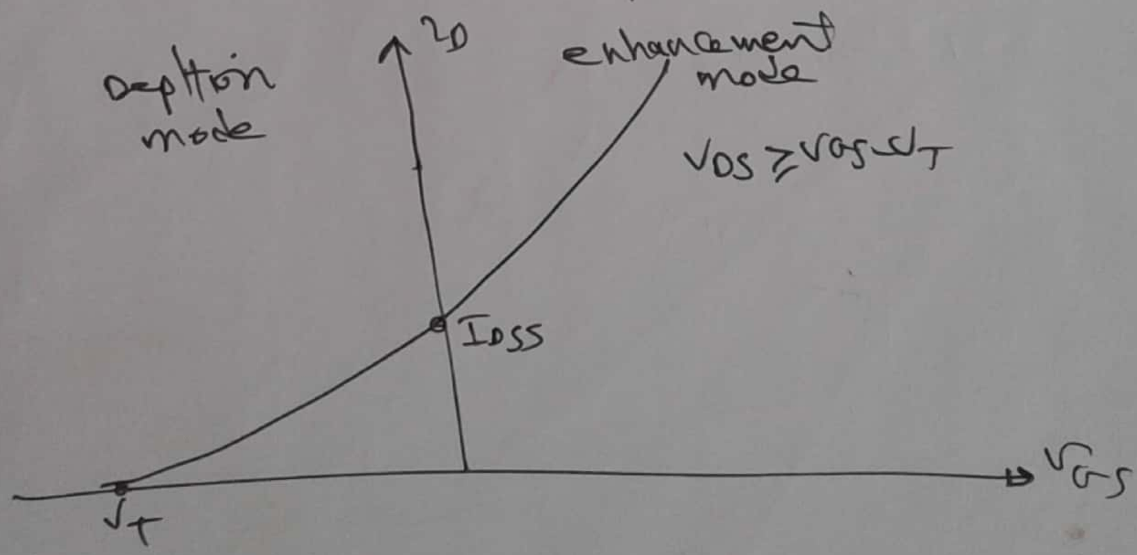


Not commonly used because just Touch, channel discharge





عندما نطبق الجهد ع gate سالبة فإن n الموجودة في channel تقل وبالتالي يقل التيار



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L3.52