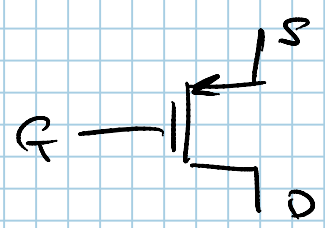
EXAM #2 REVIEW

(1)



$|V_{GS}| = 3V$

$|V_{DS}| = 4V$

$|V_t| = 1V$

$i_D = 3mA$

Find: V_{DS}

V_{GS}

V_t

$k_p'\left(\frac{W}{L}\right)$

$V_{GS} = -3V$

$V_D = -4V$

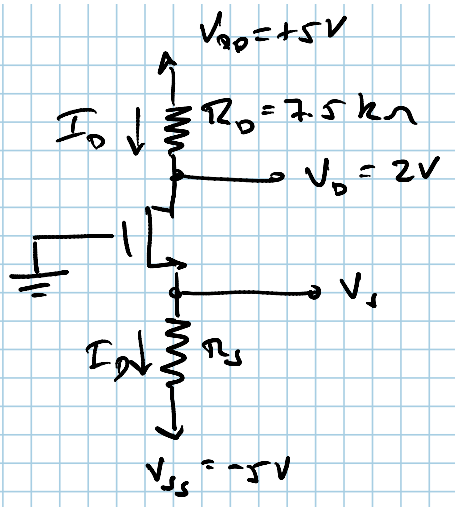
$V_t = -1V$

IN SATURATION

$$i_D = \frac{1}{2} k_p'\left(\frac{W}{L}\right)(V_{GS} - V_t)^2$$

$$k_p'\left(\frac{W}{L}\right) = \frac{2 i_D}{(V_{GS} - V_t)^2} = 1.5 \frac{mA}{V^2}$$

(2)



$V_t = 1V$

$\mu_n C_{ox} = 20 \frac{mA}{V^2}$ $(= k_n')$

$W = 40L$ $\left(\frac{W}{L} = 40\right)$

Find I_D, V_S, R_S

$I_D = \frac{V_{DD} - V_D}{R_D} = \frac{5-2}{7.5k\Omega} = \boxed{400\mu A}$

Assume Saturation

$I_D = \frac{1}{2} k_n' \left(\frac{W}{L}\right)(V_{GS} - V_t)^2 = \frac{1}{2}\left(20 \frac{mA}{V^2}\right)(40)(V_{GS}-1)^2 = 400\mu A$

$400 (V_{GS}-1)^2 = 400$

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

$V_{GS} - 1 = \pm 1 \Rightarrow V_{GS} = \boxed{2V}, \cancel{0V}$

$V_{GS} = \cancel{V_G}^{0} - V_S = 2V \Rightarrow V_S = -2V$

$V_{RS} = V_D - V_S = 2V - (-2V) = 4V$

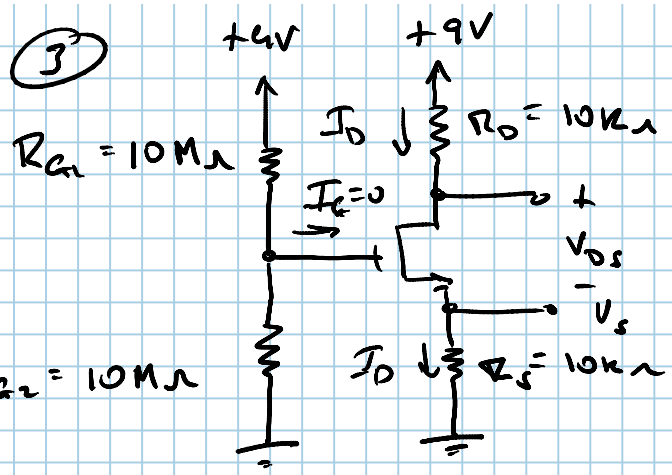
TEST FOR SATURATION: $V_{DS} \geq V_{GS} - V_t$

$4 \geq 2 - 1$ ✓ (IN SAT)

$R_S = \frac{V_S - V_{SS}}{I_D} = \frac{-2-(-5)}{0.4mA} = \frac{3V}{0.4mA}$

$\boxed{R_S = 7.5k\Omega}$

(3)



a) Find I_D & V_{DS}

$V_t = 2V$, $k_n'\left(\frac{W}{L}\right) = 1\ \frac{mA}{V^2}$

Assume saturation

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

$V_{DD} = I_D R_D + V_{DS} + I_D R_S$

$V_{DS} = V_{DD} - I_D R_D - I_D R_S$

$$V_G = \left(\frac{R_{G2}}{R_{G1} + R_{G2}}\right) V_{DD} = \left(\frac{10M}{20M}\right) 9V = 4.5V.$$

$$V_{GS} = V_G - V_S = 4.5 - V_S$$

$$I_D = \frac{V_S}{R_S} = \frac{V_S}{10}$$

$$\frac{V_S}{10} = \frac{1}{2}\left(1\ \frac{mA}{V^2}\right)(4.5 - V_S - 2)^2$$

$$\frac{V_S}{5} = (2.5 - V_S)^2$$

$$\frac{V_S}{5} = V_S^2 - 5V_S + 6.25$$

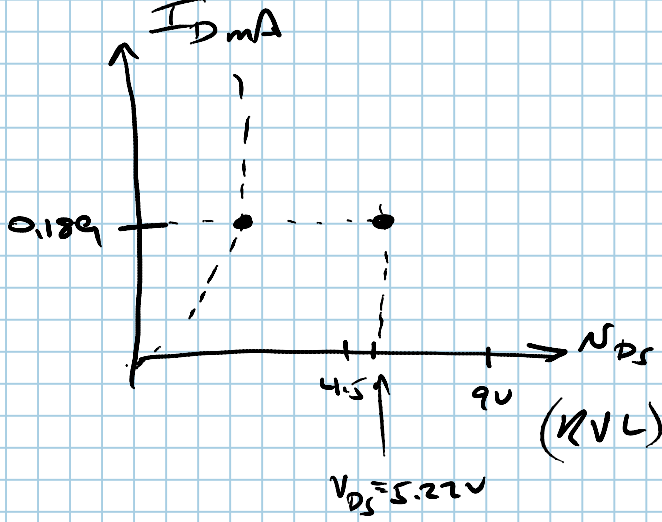
$$5V_S^2 - 26V_S + 31.25 = 0$$

$$\Rightarrow V_S = 3.31V,\ 1.89V$$

$V_{GS} = V_G - V_S = 4.5 - 3.31 = 1.186V$

$= 4.5 - 1.89 = 2.614V$ ←

$V_S = 1.89V \Rightarrow I_D = \frac{V_S}{R_S} = \frac{1.89V}{10k\Omega} = \boxed{0.189mA}$ ⊛



(KVL) $V_{DS} = V_{DD} - I_D R_D - I_D R_S$

$= 9 - (0.189mA)(10k) - (0.189mA)(10k)$

⊛ $\boxed{V_{DS} = 5.22V}$

$V_{DS} \geq V_{GS} - V_t$?

$5.22 \geq 2.614 - 2$ ✓ (in saturation)

3 (b) IF $V_{DS} \equiv$ ON BOUNDARY & SAME I_D, FIND R_S

@ EDGE OF SATURATION, $V_{DS} = V_{GS} - V_t = 2.614\,V - 2V$

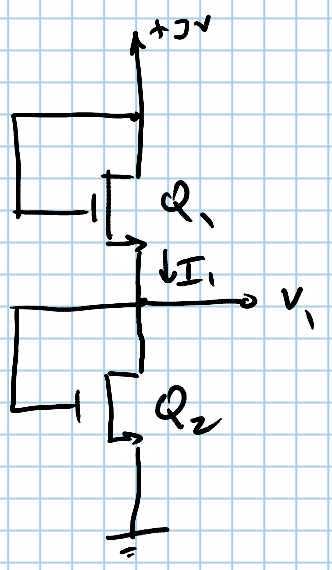
$V_{DS} = 0.614\,V$

KVL: $V_D = V_{DD} - I_D R_D = 9 - 10 I_D = 7.11\,V$ $\left(I_D = 0.189\,mA\right)$

$V_{DS} = V_D - V_S = 7.11 - V_S \quad .614\,V \Rightarrow V_S = 6.5\,V$

$$R_S = \frac{V_S}{I_D} = \frac{6.5\,V}{0.189\,mA} = \boxed{34.39\,k\Omega}$$

(4) a)



$|V_t| = 1V$, $\mu_n C_{ox} = 50 \frac{mA}{V^2}$

$\mu_p C_{ox} = 20 \frac{mA}{V^2}$

$\frac{W}{L} = \frac{30}{10} = 3$

Q_1: $V_t = +1V$ $k_n' = 50 \frac{mA}{V^2}$, $\frac{W}{L} = 3$

$V_{D_1} = V_{G_1} \Rightarrow$ SAT.

$(0_{S_1} = V_{GS_1})$

$V_{S_1} = V_1 = V_{D_2}$, $V_{D_1} = V_{G_1} = 3V$

$I_1 = \frac{1}{2} k_n' \left(\frac{W}{L}\right) \left(V_{GS_1} - V_t\right)^2$, $V_{GS_1} = V_{G_1} - V_{S_1} = 3 - V_1$

$I_1 = \frac{1}{2}(50)(3)\left(3 - V_1 - 1\right)^2 = 75\left(2 - V_1\right)^2$ ⊛

Q_2: $V_{D_2} = V_1 = V_{G_2} \Rightarrow$ SAT.

$V_{S_2} = 0V \Rightarrow V_{GS_2} = V_{G_2} - V_{S_2} = V_1$

$I_1 = \frac{1}{2} k_n' \left(\frac{W}{L}\right)\left(V_{GS_2} - V_t\right)^2 = \frac{1}{2}(50)(3)\left(V_1 - 1\right)^2$

$I_1 = 75\left(V_1 - 1\right)^2$ ⊛

$I_1 = I_1 \Rightarrow$ ~~75~~ $\left(2 - V_1\right)^2 =$ ~~75~~ $\left(V_1 - 1\right)^2$

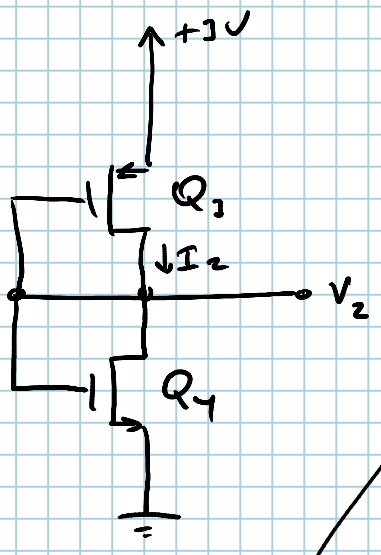
$\vdots$

$\boxed{V_1 = 1.5V}$

$I_1 = 75\left(V_1 - 1\right)^2$

$\boxed{I_1 = 18.75 mA}$

4(b)



Q_3: PMOS: $V_t = -1V$

$k_p' = 20 \frac{mA}{V^2}$

IN SAT. $V_{D3} = V_{G3} \Rightarrow V_{DS3} = V_{GS3}$

$I_D = \frac{1}{2} k_p' \left(\frac{W}{L}\right)(V_{GS3} - V_t)^2$

$I_D = \frac{1}{2}(20)(3)(V_{GS3} + 1)^2$

$V_{GS3} = V_{G3} - V_{S3} = V_2 - 3$

$V_{G3} = V_2$, $V_{S3} = +3V$

$I_D = 30(V_2 - 3 + 1)^2 = \underline{30(V_2 - 2)^2 = I_D}$

Q_4: NMOS $V_t = +1V$, $k_n' = 50 \frac{mA}{V^2}$

IN SAT: $(V_{D4} = V_{G4} \Rightarrow V_{DS4} = V_{GS4})$

$V_{D4} = V_2 = V_{G4}$, $V_{S4} = 0 \Rightarrow V_{GS4} = V_2$

$I_2 = \frac{1}{2} k_n' \left(\frac{W}{L}\right)(V_{GS4} - V_t)^2 = \frac{1}{2}(50)(3)(V_2 - 1)^2$

$\underline{I_2 = 75(V_2 - 1)^2}$

$I_2 = I_D \Rightarrow 30(V_2 - 2)^2 = 75(V_2 - 1)^2$

$V_2 = 1.39V$

$I_2 = 75(V_2 - 1)^2 = 30(V_2 - 2)^2 = \boxed{11.4 mA}$