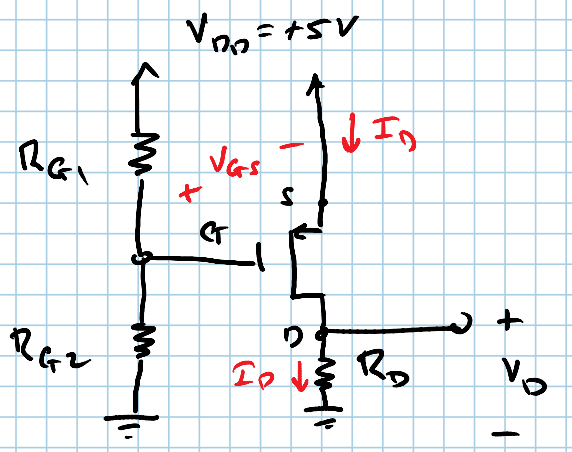
EXAMPLE: PMOS



$V_t = -1V$

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

DESIGN #: −IN SATURATION
- $I_D = 0.5\ mA$
- $V_D = +3V$

(ALSO: FIND MAX R_D & REMAIN IN SATURATION)

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

$0.5mA = \frac{1}{2}\left(1\ \frac{mA}{V^2}\right)\left[V_{GS} - (-1)\right]^2$

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

$V_{GS} + 1 = \pm 1$

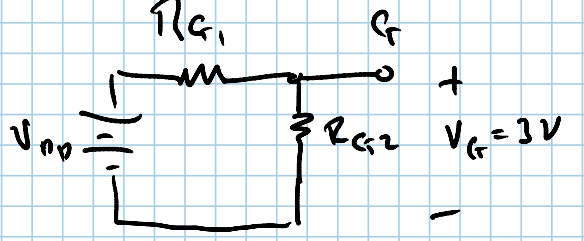
$V_{GS} = -1 \pm 1 = \cancel{0}, -2V$?

FOR PMOS

$V_{GS} \leq V_t$

$V_{GS} = -2V = V_G - V_S$, $V_S = +5V$

$V_G - 5 = -2 \Longrightarrow V_G = 3V$



$V_G = \left(\frac{R_{G2}}{R_{G1} + R_{G2}}\right)V_{DD} = 3V = \left(\frac{R_{G2}}{R_{G1} + R_{G2}}\right)5$

$\frac{R_{G2}}{R_{G1} + R_{G2}} = \frac{3}{5} = \frac{3\ M\Omega}{(2+3)\ M\Omega}$

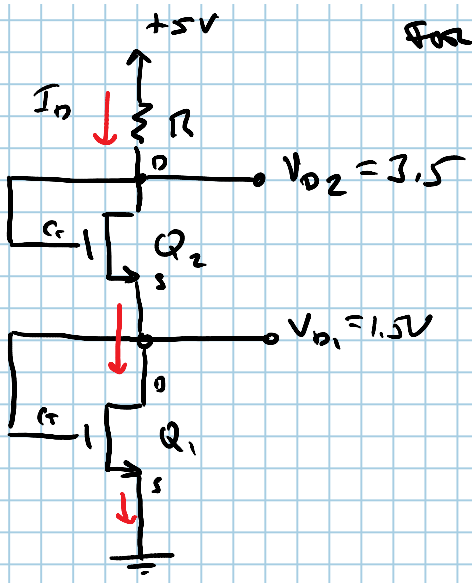
$R_{G1} = 2\ M\Omega$, $R_{G2} = 3\ M\Omega$

IF $V_D = 3V$ & $I_D = 0.5mA$: $R_D = \frac{V_D}{I_D} = \frac{3V}{0.5mA} = 6\ k\Omega$

$$R = \frac{V_{DD} - V_{D2}}{I_D}$$

$$R = \frac{5 - 3.5}{0.120\,mA}$$

$$\boxed{R = 12.5\,k\Omega}$$



FOR BOTH Q_1 & Q_2: $V_t = 1\,V$

$\mu_n C_{ox} = 120\ \frac{\mu A}{V^2}$

$\lambda = 0$

$L_1 = L_2 = 1\,\mu m$

FIND W_1 & W_2 & R & $I_D = 120\,\mu A$

$V_{D1} = 1.5V$

$V_{D2} = 3.5V$

$V_{D1} = V_{G1} \Rightarrow V_{DS1} = V_{GS1}$

$V_{DS1} > V_{GS1} - V_t \Rightarrow$ SATURATION FOR Q_1 & Q_2

Q_1

$V_{DS1} = 1.5V$

$V_{GS1} = 1.5V$

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

$$120\,\mu A = \tfrac{1}{2}\left(120\ \frac{\mu A}{V^2}\right)\left(\frac{W_1}{1}\right)(1.5 - 1)^2 \Rightarrow \boxed{W_1 = 8\,\mu m}$$

Q_2 $V_{DS2} = V_{GS2} \Rightarrow$ SATURATION

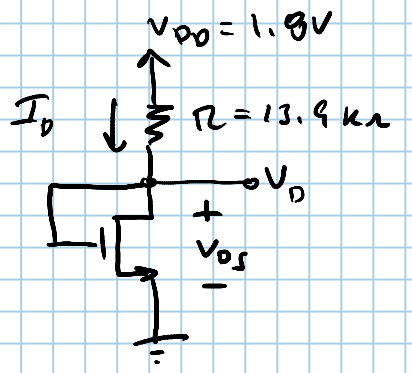
$$V_{DS2} = V_{D2} - V_{S2} = 3.5 - 1.5V \qquad (V_{S2} = V_{D1})$$

$$V_{DS2} = 2V\ (= V_{GS2})$$

$$I_D = \tfrac{1}{2} k_n' \left(\frac{W_2}{L_2}\right)(V_{GS2} - V_t)^2$$

$$120\,\mu A = \tfrac{1}{2}\left(120\ \frac{\mu A}{V^2}\right)\left(\frac{W_2}{1}\right)(2V - 1)^2 \Rightarrow \boxed{W_2 = 2\,\mu m}$$

EXERCISE DS.9 (pg 261)



FIND R if $V_D = 0.8V$

$V_t = 0.5\,V$

$\mu_n C_{ox} = k_n' = 0.4\ \frac{mA}{V^2}$

$\frac{W}{L} = \frac{0.72\,\mu m}{0.18\,\mu m}$

$V_D = V_G = 0.8V$, $V_{GS} = V_G - V_S = 0.8\,V$, $V_{GS} - V_t = 0.8 - 0.5 = 0.3\,V$

$V_{DS} = 0.8V > V_{GS} - V_t = 0.3\,V \Rightarrow$ in SATURATION

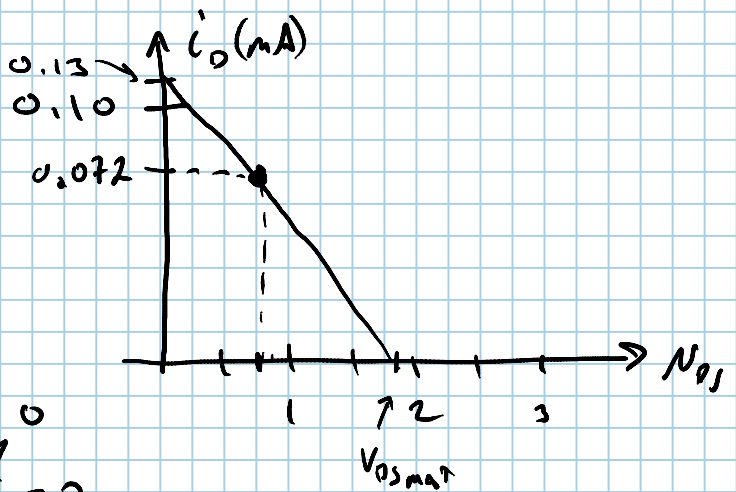
$$I_D = \tfrac{1}{2} k_n' \left(\frac{W}{L}\right)(V_{GS} - V_t)^2 = \tfrac{1}{2}\left(0.4\ \tfrac{mA}{V^2}\right)\left(\frac{0.72}{0.18}\right)(0.3V)^2$$

$$I_D = 72\,\mu A = 0.072\,mA$$

$$R = \frac{V_{DD} - V_D}{0.072\,mA} = \frac{1.8 - 0.8}{0.072\,mA} = 13.9\,k\Omega$$

OPERATING POINT (Q-POINT)

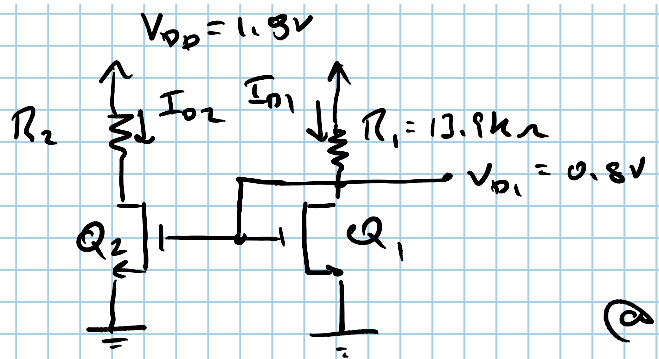
(V_{DS}, I_D)



KVL

$$V_{DD} - I_D R_D - V_{DS} = 0$$ (0)

$I_D\big|_{I_{D\,MAX}} = \frac{V_{DD}}{R_D} = \frac{1.8\,V}{13.9\,k\Omega} = 0.13\,mA$, $V_{DS}\big|_{MAX,\,I_D=0} =$



$Q_2 \equiv Q_1$

FIND R_2 IF Q_2 OPERATES @ THE EDGE OF SATURATION

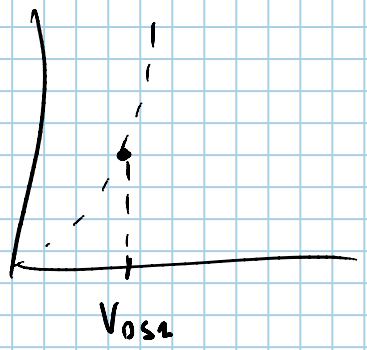
@ THE EDGE OF SAT. & TRIODE:

$$V_{DS2} = V_{GS2} - V_t$$

$$V_{G2} = V_{D1} = 0.8V$$

$$V_{GS2} = V_{D1} = 0.8V$$

$$V_{DS2} = V_{GS2} - V_t = 0.8V - 0.5V = 0.3V$$



$$I_{D2} = \tfrac{1}{2} k_n' \left(\frac{W}{L}\right)\left(V_{GS2} - V_t\right)^2 = \frac{1}{2}\left(0.4\,\frac{mA}{V^2}\right)\left(\frac{0.72}{0.18}\right)(0.3V)^2 = 0.072\,mA \left(= I_{D1}\right)$$

$$R_2 = \frac{V_{DD} - V_{D2}}{I_{D2}} = \frac{1.8V - 0.3V}{0.072\,mA} = \boxed{20.83\,k\Omega}$$