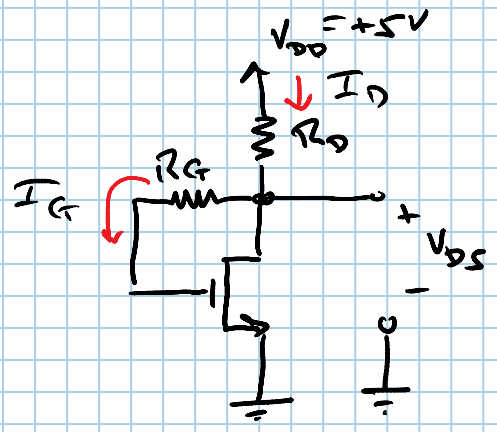
Quiz #4 Review



$V_t = 1V$

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

If $I_D = 0.5\ mA$, Find V_{DS} & R_D

$I_G = 0 \Rightarrow$ No V-drop across R_G

$\therefore V_G = V_D$

$\Rightarrow$ SATURATION

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

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

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

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

$$V_{GS} = \underline{2, 0\ V}$$

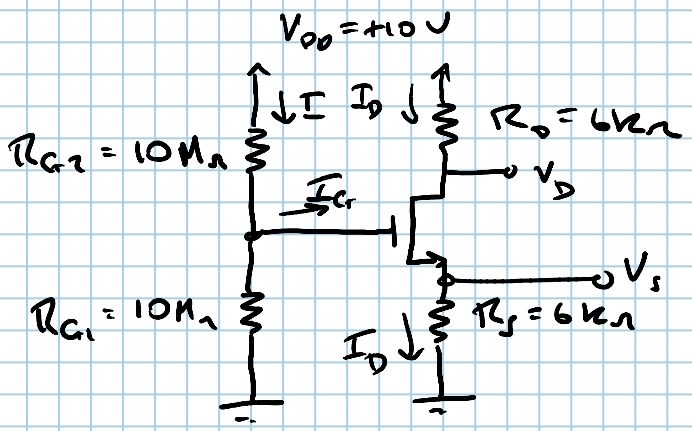
$$V_{GS} = \boxed{2V = V_{DS}}$$

$$R_D = \frac{V_{DD} - V_D}{I_D}$$

$(V_{DS} = V_D,\ V_S = 0)$

$$R_D = \frac{(5-2)\ V}{0.5\ mA} = \boxed{6\ k\Omega}$$

REWORK EXAMPLE FROM 7 JULY 2015



$V_t = 1V$

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

ASSUME TRIODE REGION

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

$V_G = 5V$

$V_S = I_D R_S = 6I_D$

$\Big\}\ V_{GS} = V_G - V_S = 5 - 6I_D$

KVL: $V_{DD} - I_D R_D - V_{DS} - I_D R_S = 0$

$10 - 6I_D - V_{DS} - 6I_D = 0$

$V_{DS} = 10 - 12I_D$ ⊗

$$I_D = \left(1\ \frac{mA}{V^2}\right)\left[\underbrace{(5 - 6I_D - 1)}_{V_{GS} - V_t}\underbrace{(10 - 12I_D)}_{V_{DS}} - \tfrac{1}{2}\underbrace{(10 - 12I_D)^2}_{V_{DS}^2}\right]$$

$I_D = (4 - 6I_D)(10 - 12I_D) - \tfrac{1}{2}(10 - 12I_D)^2$

$I_D = 40 - 48I_D - 60I_D + 72I_D^2 - \tfrac{1}{2}(100 - 120I_D - 120I_D + 144I_D^2)$

$= 40 - 108I_D + 72I_D^2 - 50 + 120I_D - 72I_D^2$

$I_D = 12I_D - 10 \Rightarrow 11I_D - 10 = 0$

$I_D = \frac{10}{11}\ mA = 0.91\,mA$

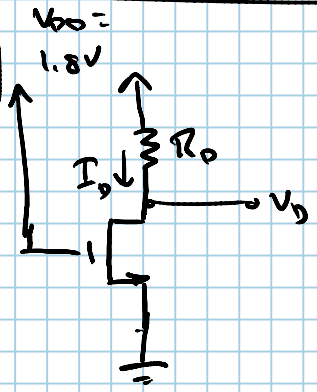
$V_{GS} = 5 - 6I_D = 5 - 6(0.91) = -0.45\,V$ NMOS: $V_{GS} \geq V_t$!!!

$V_{DS} = 10 - 12I_D = 10 - 12(0.91) = -0.92$ $V_{DS} \geq 0$ (NMOS) !!!

∴ NOT IN TRIODE

HW# 4: OMIT 5.44, REPLACE WITH 5.46

5.47



$k_n' = 0.4 \ mA/V^2$

$V_t = 0.5 \ V$

SHOW THAT OPERATION ON THE EDGE OF SATURATION IS OBTAINED WHEN $\left(\frac{W}{L}\right) R_D = 1.5 \ k\Omega$

$V_G = 1.8V \Rightarrow V_{GS} = 1.8V \quad (V_S = 0V)$

@ EDGE OF SATURATION: $V_{DS} = V_{GS} - V_t = 1.8 - 0.5 = 1.3V$

$V_{DS} = 1.3V \Rightarrow V_D = 1.3V \quad (V_S = 0V)$

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

$I_D = \frac{1}{2}\left(0.4 \ mA/V^2\right)\left(\frac{W}{L}\right)(1.8 - 0.5)^2$

✓ $I_D = \left(\frac{W}{L}\right)(0.338 \ mA)$

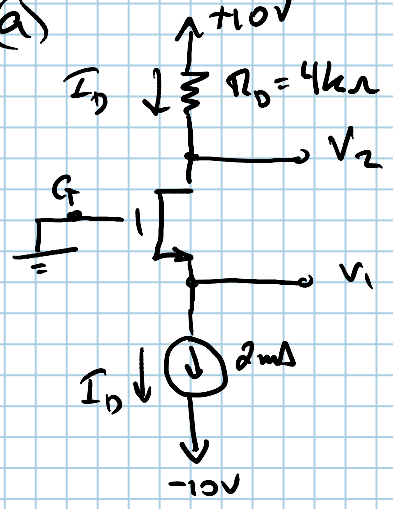
SO, FROM THE DRAIN PORTION OF THE CIRCUIT:

✓ $I_D = \frac{V_{DD} - V_D}{R_D}$

$I_D = I_D \Rightarrow \frac{W}{L}(0.338mA) = \frac{1.8 - 1.3}{R_D}$

$\left(\frac{W}{L}\right) R_D = \frac{0.5V}{0.338mA} = \underline{1.48 \ k\Omega}$

5.55 (a)



$V_t = +2V$

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

$(V_1 = V_S,\ V_2 = V_D)$

$V_G = 0V$

$V_{GS} \geq V_t$

$I_D = 2mA$

$I_D = \frac{10 - V_2}{4k\Omega} = 2mA$

$V_2 = 10 - (2mA)(4k\Omega) = \boxed{2V}\ (= V_D)$

ASSUME SATURATION: $I_D = 2mA = \frac{1}{2}\left(1\ mA/V^2\right)(V_{GS} - 2)^2$

$(V_{GS} - 2)^2 = 4V$

$V_{GS} - 2 = \pm 2V$

$V_{GS} = 2 \pm 2 = (4)\ 0V$

$V_{GS} = 4V = V_G - V_S = 4V$

$V_S = \boxed{-4V = V_1}$

CHECK ASSUMPTION: $V_{DS} = V_D - V_S = V_2 - V_1 = 2 - (-4) = 6V$

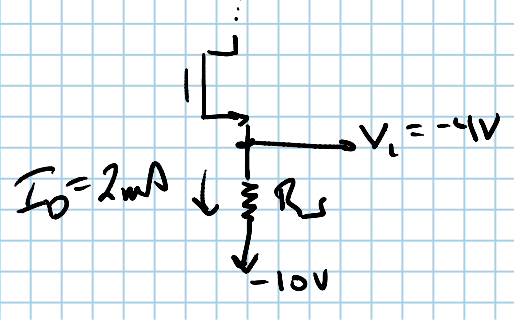
$V_{GS} = V_G - V_S = 4V$

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

$6V \geq 4 - 2 = 2$

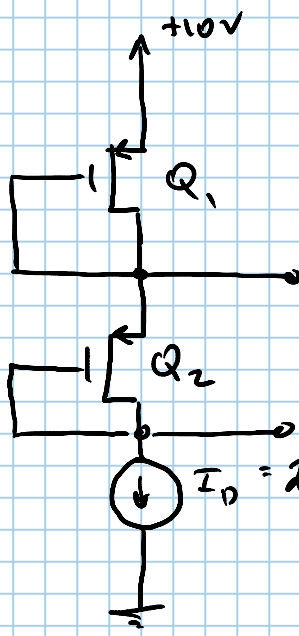
$6 \geq 2 \Rightarrow$ IN SATURATION

FIND R_S TO REPLACE CURRENT SOURCE



$R_S = \frac{-4 - (-10)}{2mA} = \boxed{3k\Omega}$

5.55 d)



$V_t = -2V$ (PMOS)

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

$V_{S1} = +10V$

$V_{D1} = V_{G1} \Rightarrow Q_1$ in SAT (if $V_{GS1} \leq V_t$) → PMOS

$2mA = \frac{1}{2}\left(1 \frac{mA}{V^2}\right)(V_{GS1} - V_t)^2$

$\Rightarrow (V_{GS1} + 2)^2 = 4V^2$

$V_{GS1} + 2 = \pm 2V$

$V_{GS1} = -2 \pm 2 = 0V, -4V$

$V_{GS1} = -4V = V_{G1} - V_{S1} = -4$ ($V_{S1} = 10V$)

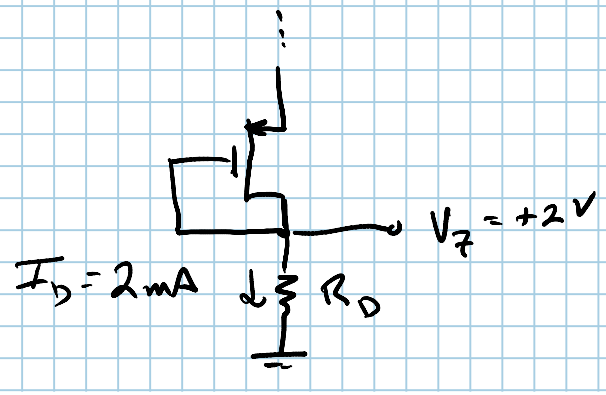
$V_{G1} = 6V = V_{D1} = V_6$

$V_6 = V_{D1} = V_{S2} = 6V$

$V_{D2} = V_{G2} \Rightarrow$ SATURATION (if $V_{GS2} \leq V_t$)

$2mA = \frac{1}{2}\left(1 \frac{mA}{V^2}\right)\left[V_{GS2} - (-2V)\right] \Rightarrow V_{GS2} = -4V$ (see above)

$V_{GS2} = V_{G2} - V_{S2} = V_{G2} - 6V = -4V \Rightarrow V_{G2} = +2V = V_{D2} = V_7 = +2V$



$R_D = \frac{V_7 - 0}{I_D} = \frac{2V}{2mA} = 1k\Omega$