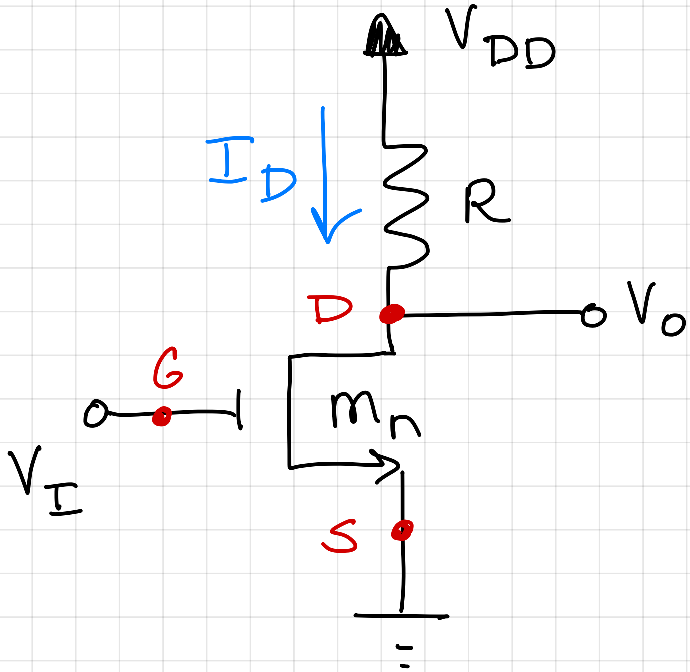


$V_t = 0.4V$

$k'_n = 0.5 \frac{mA}{V^2}$

if $V_{DD} = V_I = 1.3V$

and $V_o = 50mV$

Find $\frac{W}{L}$ and R

$V_{DS} = V_o - 0 = V_o = 0.05\,V$

$V_{GS} = V_I - 0 = V_I = 1.3\,V$

$\boxed{V_{DS} < V_{GS} - V_t}$ => triode region

$0.05 < 1.3 - 0.4$

$0.05 < 0.9$

we know $r_{ds} = 50\Omega$

$$r_{ds} = \frac{1}{k'_n \frac{W}{L}(V_{GS}-V_t)} = 50$$

$$\frac{1}{(0.5\times10^{-3})(\frac{W}{L})(1.3-0.4)} = 50$$

$$\boxed{\frac{W}{L} = 44.\overline{4}}$$

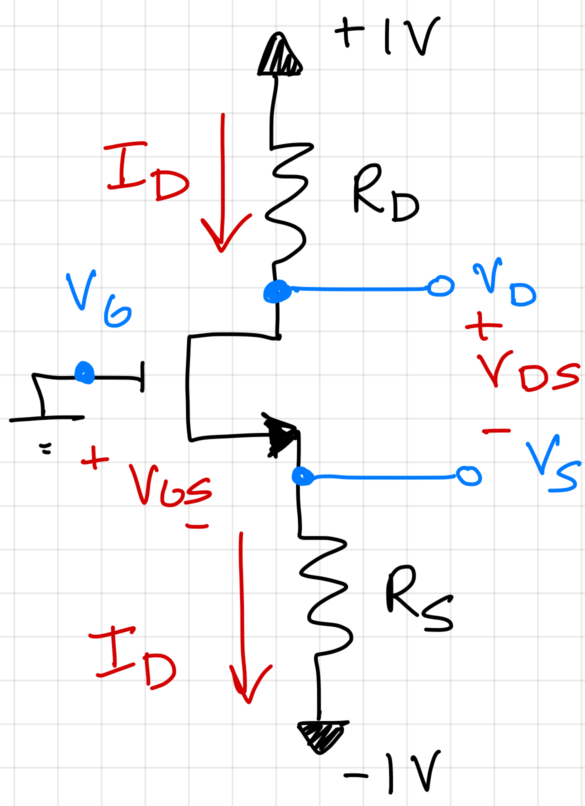
$$R = \frac{V_{DD} - V_O}{I_D}$$

$$I_D = k'_n \frac{W}{L}(V_{GS} - V_t)(V_{DS})$$

$$= 0.5\left(44.\overline{4}\right)\left(1.3 - 0.4\right)(.05)$$

$$I_D = 1mA$$

$$R = \frac{1.3 - 0.05}{1m} = 1.25\,k\Omega$$



Design R_D & R_S

$I_D = 0.1mA$

$V_D = 0.2V$

$V_t = 0.5V$

$\mu_n C_{ox} = 400\,\frac{\mu A}{V^2}$

$W = 4\mu m$

$L = 0.5\,\mu m$

$$\frac{W}{L} = \frac{4}{.5} = 8$$

Know

$V_{GS} = 0 - V_S$

$= -V_S$

$V_{DS} = 0.2 - V_S$

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

$.2 - V_S \bigcirc -V_S - 0.5$

$.2 - V_S \geq -0.5 - V_S$

assume saturation operation and then check our assumption

$$R_D = \frac{1 - V_D}{I_D} = \frac{1 - 0.2}{0.1m} = 8k\Omega$$

$$I_D = \frac{1}{2} k'_n \frac{W}{L} (V_{GS} - V_t)^2$$

[mA/V]

[mA]

$$\frac{1}{2}(0.4)(8)(V_{GS} - 0.5)^2 = 0.1$$

$$(V_{GS} - 0.5)^2 = 0.0625$$

$$V_{GS} = 0.75V$$

$$V_{GS} = -V_S$$

$$-V_S = 0.75V$$

$$\boxed{V_S = -0.75V}$$

$$.2 - V_S \geq -0.5 - V_S$$

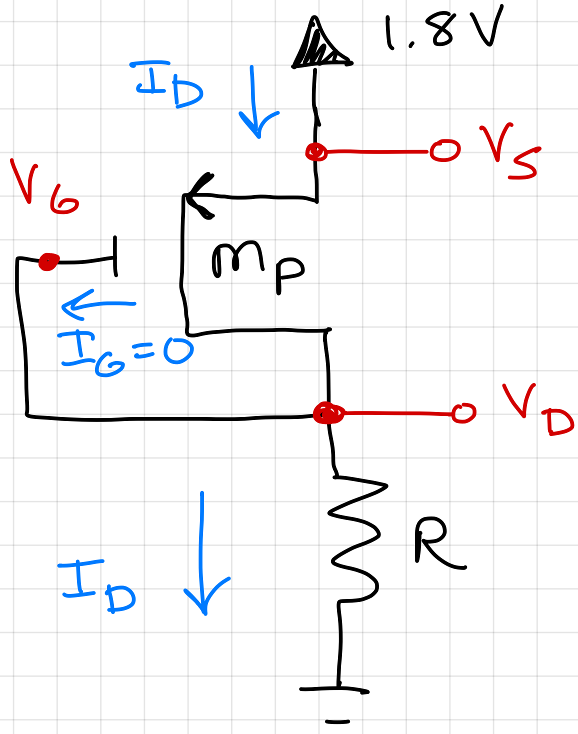
$$0.2 - (-.75) \quad \bigcirc \quad -0.5 - (-.75)$$

$$0.95 > 0.25$$

assumption was correct
device is operating in saturation

$$R_S = \frac{V_S - (-1)}{I_D} = \frac{-0.75 + 1}{0.1m} = 2.5\,k\Omega$$

$$\boxed{R_S = 2.5\,k\Omega}$$



$k'_p = \mu_p C_{ox} = 100\,\frac{\mu A}{V^2}$

$V_{tp} = -0.5V$

$L = 0.18\,\mu m$

$I_D = 160\,\mu A$

$V_D = 0.8V$

find W and R

$V_S = 1.8V$

$V_G = V_D = 0.8V$

$V_{SG} = 1.8 - 0.8$

$\boxed{V_{SG} = 1V}$

when gate & drain are tied together ($V_G = V_D$), this "diode - connected" configuration.

$$V_{SD} \geq V_{SG} - |V_{tp}|$$

$$V_G = V_D$$

$$V_S - \cancel{V_D} \quad V_S - \cancel{V_G} - |V_{tp}|$$

$$V_S > V_S - |V_{tp}|$$

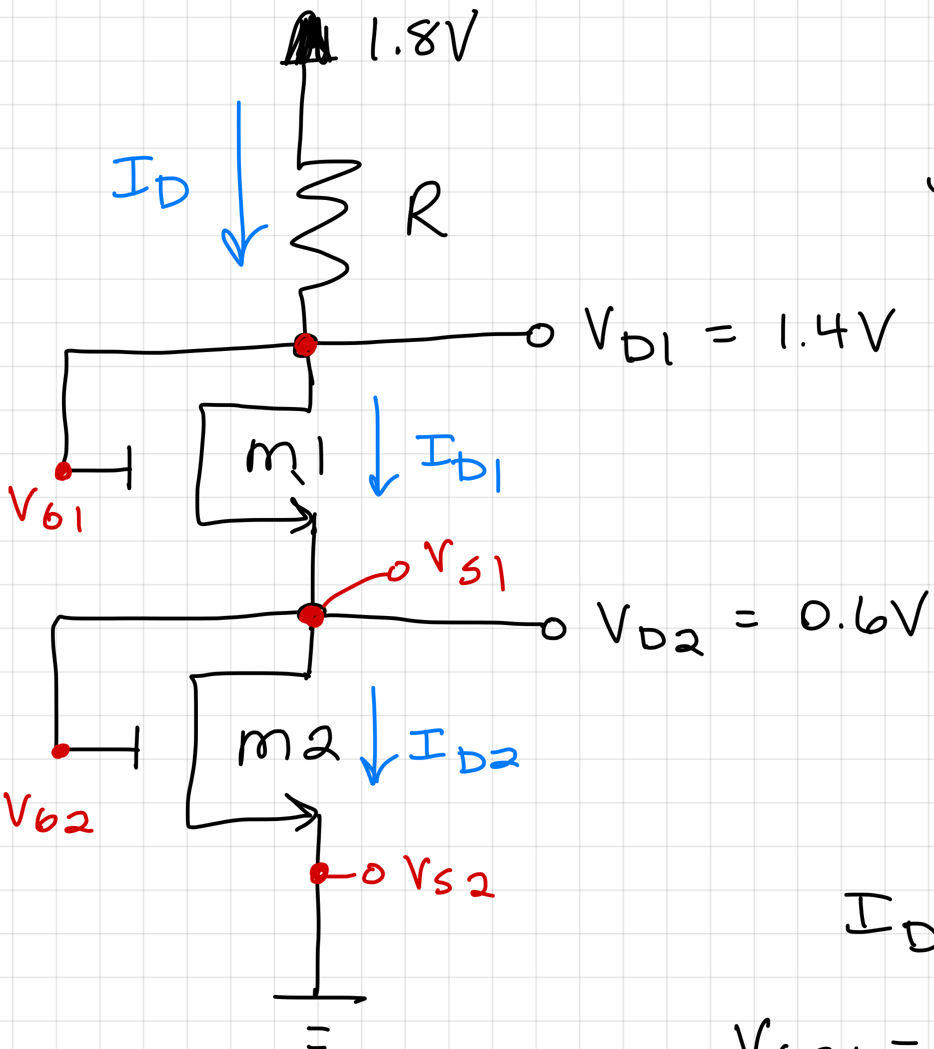
under diode connected conditions the MOSFET operates in saturation.

$$\boxed{R = \frac{V_D}{I_D} = \frac{0.8}{160 \times 10^{-6}} = 11.25\,k\Omega}$$

$$I_D = \frac{1}{2} k'_p \left(\frac{W}{L}\right)\left(V_{SG} - |V_{tp}|\right)^2 = 160\,\mu A$$

$$\frac{1}{2}(100)\left(\frac{W}{.18}\right)\left(1 - |-.5|\right)^2 = 160$$

$$\boxed{W = 2.3\,\mu m}$$



$I_D = 0.1mA$

$V_t = 0.4V$ (both m_1 & m_2)

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

$L_1 = L_2 = 0.18 \mu m$

Find R and W_1, W_2

m_1 & m_2 are diode connected => saturation

$I_D = I_{D1} = I_{D2} = 0.1mA$

$$V_{GS1} = V_{G1} - V_{S1}$$
$$= V_{D1} - V_{D2}$$
$$= 1.4 - 0.6$$
$$\boxed{V_{GS1} = 0.8V}$$

$$R = \frac{1.8 - V_{D1}}{I_D}$$
$$= \frac{1.8 - 1.4}{.1m}$$
$$\boxed{R = 4k\Omega}$$

$$V_{GS2} = V_{G2} - V_{S2}$$
$$= V_{D2} - 0$$
$$V_{GS2} = 0.6 - 0$$
$$\boxed{V_{GS2} = 0.6V}$$

for M1

$$I_{D1} = \frac{1}{2} k'_n \left(\frac{W_1}{L_1}\right)\left(V_{GS1} - V_t\right)^2$$

$$\frac{1}{2}(0.4)\left(\frac{W_1}{.18}\right)(0.8 - 0.4)^2 = 0.1$$

$$\left(\frac{W_1}{.18}\right) = 3.125$$

$$W_1 = 0.56\ \mu m$$

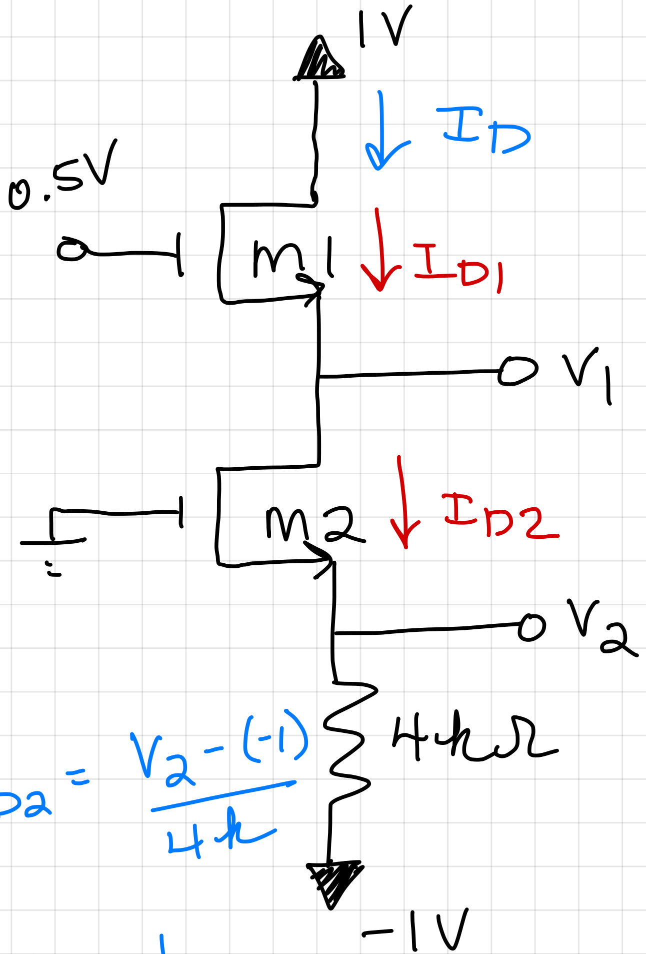
for M2

$$I_{D2} = \frac{1}{2} k'_n \left(\frac{W_2}{L_2}\right)\left(V_{GS2} - V_t\right)^2$$

$$\frac{1}{2}(.4)\left(\frac{W_2}{.18}\right)(0.6 - 0.4)^2 = 0.1$$

$$\frac{W_2}{.18} = 12.5$$

$$\boxed{W_2 = 2.25\ \mu m}$$



$$I_{D2} = \frac{V_2 - (-1)}{4k}$$

$$= \frac{V_2 + 1}{4k}$$

Find I_D, V_1 & V_2 for both m_1 & m_2

$V_t = 0.4V$

$$\left(k_n' \frac{W}{L}\right) = \frac{5mA}{V^2}$$

$$\boxed{V_{GS1} = 0.5 - V_1}$$

$$\boxed{V_{GS2} = 0 - V_2}$$

$$\boxed{V_{DS1} = 1 - V_1}$$

$$\boxed{V_{DS2} = V_1 - V_2}$$

for m1

V_{DS1} ◯ $V_{GS1} - V_t$

$1 - V_1$ ◯ $0.5 - V_1 - 0.4$

$1 - V_1 \geq 0.1 - V_1$

assume m1 is in saturation

for m2

$V_1 - V_2$ ◯ $-V_2 - 0.4$

assume m2 in saturation

$I_D = I_{D1} = I_{D2}$ & devices are matched

$\left(k'_n \frac{W}{L} \,,\, V_t \text{ are same} \right)$

$$I_{D1} = I_{D2}$$

$$\cancel{\frac{1}{2} k'_n \frac{W}{L}} (V_{GS1} - V_t)^2 = \cancel{\frac{1}{2} k'_n \frac{W}{L}} (V_{GS2} - V_t)^2$$

$$(V_{GS1} - V_t)^2 = (V_{GS2} - V_t)^2$$

$$V_{GS1} = V_{GS2}$$

$$0.5 - V_1 = 0 - V_2$$

$$\boxed{V_1 - V_2 = 0.5V}$$

$$I_{D2} = \frac{V_2 + 1}{4k}$$

$$\frac{1}{2} k'_n \frac{W}{L} (V_{GS2} - V_t)^2 = \frac{V_2 + 1}{4k}$$

$$\frac{1}{2} (5m)(-V_2 - 0.4)^2 = \frac{V_2 + 1}{4k}$$

$$10(-V_2 - 0.4)^2 = V_2 + 1$$

$$10(0.16 + 0.8V_2 + V_2^2) = V_2 + 1$$

$$1.6 + 8V_2 + 10V_2^2 = V_2 + 1$$

$$10V_2^2 + 7V_2 + 0.6 = 0$$

$$V_2 = -0.1V \qquad V_2 = -0.6V$$

$V_1 = 0.4V$
$V_2 = -0.1V$

$V_{GS2} = 0.1V$

$V_{DS2} = 0.5V$

$V_{DS1} = 0.6V$

$V_{GS1} = 0.1V$

$V_{GS1} < V_t$

$.1 < 0.4$

$V_{GS2} < V_t$

$.1 < 0.4$

Both devices are off.

$\boxed{V_{GS1} = 0.5 - V_1}$

$\boxed{V_{GS2} = 0 - V_2}$

$\boxed{V_{DS1} = 1 - V_1}$

$\boxed{V_{DS2} = V_1 - V_2}$

$\boxed{V_1 - V_2 = 0.5V}$

$$\boxed{V_{GS1} = 0.5 - V_1}$$

$$\boxed{V_{GS2} = 0 - V_2}$$

$$\boxed{V_{DS1} = 1 - V_1}$$

$$\boxed{V_{DS2} = V_1 - V_2}$$

$$\boxed{V_1 - V_2 = 0.5V}$$

$$\boxed{\begin{aligned} V_2 &= -0.6V \\ V_1 &= -0.1V \end{aligned}}$$

$$\boxed{\begin{aligned} V_{GS1} &= 0.6V \\ V_{GS2} &= 0.6V \end{aligned}}$$

greater than V_t

$V_{DS1} = 1.1V$

$V_{DS2} = 0.5V$

V_{DS1} ◯ $V_{GS1} - V_t$

$1.1 \geq 0.6 - 0.4$

V_{DS2} ◯ $V_{GS2} - V_t$

$0.5 \geq 0.6 - 0.4$

confirmed saturation for both!

$$I_D = \frac{V_2 + 1}{4k} = \frac{-0.6 + 1}{4k}$$

$$\boxed{I_D = 0.1mA}$$