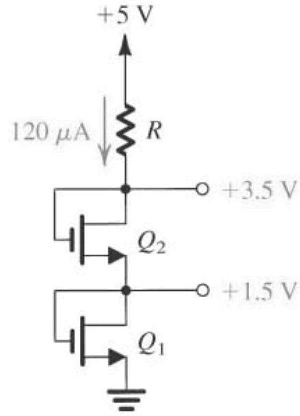
Problem Session 4

Problem 1:
The NMOS transistors in the circuit at right have V_t=1V, $\mu_n C_{ox}$=120 µA/V^2, λ=0, and L_1=L_2=1µm. Find the required values of gate width for each Q_1 and Q_2, and the value of R, to obtain the voltage and current values indicated.



Solution:

$V_{D2} = 3.5\ V$

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

$$R = \frac{5 - 3.5}{120\mu A}$$

$R = 12.5\ K\Omega$

Gate and drain Q_2 at same potential, hence Q_2 in saturation region

$V_{G2} = V_{D2} = 3.5\ V$

$V_{GS2} = V_{G2} - V_{S2} = 3.5 - 1.5\ V$

$V_{GS2} = 2\ V$

$$I_n = \frac{1}{2} \times \mu_n C_{ox} \frac{W_2}{L_2} (V_{GS2} - V_t)^2$$

$$120 = \frac{1}{2} \times 120 \times \frac{W_2}{1\ \mu m} (2 - 1)^2$$

$W_2 = 2\mu m$

Gate and drain of Q_1 01 same potential, henace Q_2 in saturation regilon

$V_{GS1} = 1.5\ V$

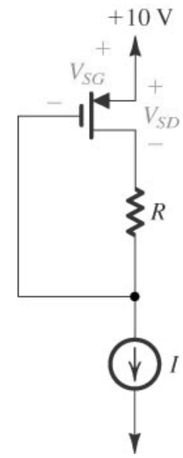
$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W_1}{L_1} (V_{GS1} - V_t)^2$$

$$120 = \frac{1}{2} \times 120 \times \frac{W_1}{1\ \mu m} (1.5 - 1)^2$$

$W_1 = 8\ \mu m$

Problem 2:

The PMOS transistor in the circuit shown at right have $k_p' = 8\mu A/V^2$, W/L = 25, and $|V_{tp}| = 1V$. For I=100mA, find the voltages V_{SD} and V_{SG} for R=0, 10kΩ, 30kΩ, and 100kΩ. What value of R is $V_{SD}=V_{SG}$?



Also, $V_{SD} + IR = V_{SG}$

$\Rightarrow V_{SD} = V_{SG} - I_R$

$\Rightarrow IR \leq |V_t|$ For PMOS to be in saturation

(A) R=0

$IR = 0 < |V_t|$

Saturation :

$$I = 100 = \frac{1}{2} \times 8 \times 25 \times \left(V_{SG} - |V_t|\right)^2$$

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

$V_{SG} = 2\ V = V_{SD}$

(B) R= 10 KΩ

$IR = 10 \times 0.1 = 1\ V$

$\Rightarrow$ Saturation

$V_{SG} = 2\ V$

$V_{SD} = 2 - 1 = 1\ V$

(C) R = 30 KΩ

$IR = 30 \times 0.1$

$= 3\ V$

$\Rightarrow$ Triode region

$$100 = 8 \times 25 \left[\left(V_{SG} - |V_t|\right) V_{SD} - \frac{1}{2} V_{SD}^2 \right]$$

$$0.5 = \left[(V_{SG} - 1)(V_{SG} - 3) - \frac{1}{2}(V_{SG} - 3)^2 \right]$$

$0.5 = 0.5\ V_{SG}^2 - V_{SG} - 1.5$

$V_{SG}^2 - 2\ V_{SG} - 4 = 0$

$V_{SG} = 3.24\ V, \quad -1.2\ V$

$V_{SD} = 3.24 - 3 = 024\ V$

(D) $R = 100\ K\Omega$

$IR = 100\times0.1$
$= 10\ V$

$\Rightarrow$ Triode region

$$100 = 8\times25\left[(V_{SG}-1)(V_{SG}-10) - \frac{1}{2}(V_{SG}-10)^2\right]$$

$$0.5 = 0.5\ V_{SG}^2 - V_{SG} - 40$$

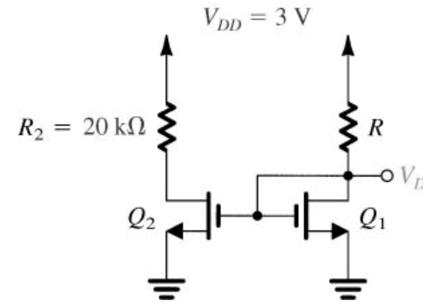
$$V_{SG}^2 - 2V_{SG} - 81 = 0$$

$$V_{SG} = 10.1\ V$$

$$V_{SD} = 0.1\ V$$

$V_{SD}=V_{SG}$ when R=0

Problem 3:



Let Q1 and Q2 have V_t=0.6V, $\mu_n C_{ox}$=200 $\mu A/V^2$, λ=0, L_1=L_2=0.8μm, and W_1=8μm.

(a) Establish a current 0.2mA in Q_1. Find R.

(b) Find W_2 and a new value for R_2 so that Q_2 operates in the saturation region with a current of 0.5mA and drain voltage of 1V.

(a)

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

We know that $i_{D1} = 0.2$mA

$$0.2\times10^{-3} = \frac{1}{2}\times200\times10^{-6}\times\frac{8}{0.8}(V_{GS1}-0.6)^2$$

$$V_{GS1} - 0.6 = \sqrt{0.2}$$

$$V_{GS1} = 1.047V$$

$$V_{GS1} = 1.05V$$

From the circuit the value of R is

$$R = \frac{3-1.05}{0.2\times10^{-3}}$$

$$R = 9750\Omega$$

$$\boxed{R = 9.75k\Omega}$$

(b)

For Q_2 to conduct with 0.5 mA

$$R_2 = \frac{3-1}{0.5\times10^{-3}}$$

$$R_2 = 4000\Omega$$

$$R_2 = 4\,k\Omega$$

Since the gates are connected together, both transistors have the same V_{GS} and hence same i_D. In order to conduct 0.5mA or multiply i_D by 2.5.

$$\frac{W_2}{W_1} = 2.5$$

$$W_2 = 2.5\times 8\times10^{-6}$$

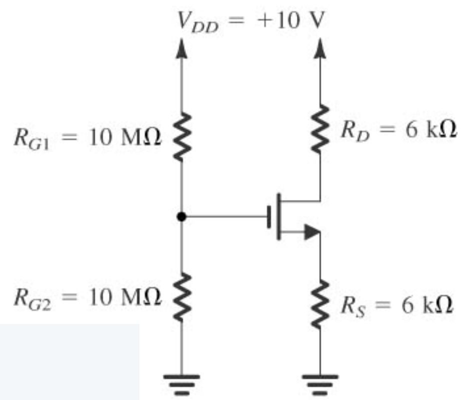
$$\boxed{W_2 = 20\,\mu m}$$

Problem 4:

Let V_t=2V, $\mu_n C_{ox}$(W/L)=2mA/V^2, and λ=0

(a) Find I_D and V_D.

(b) Compare these answers to the solution (Example 4.5) was found when V_t=1V, $\mu_n C_{ox}$(W/L)=2mA/V^2, and λ=0 that I_D=0.5mA and V_D=7V. Comment on how tolerant (or intolerant) the circuit is to changes in device parameters.



(a)

Since the gate current is zero, the voltage at the gate is

$$V_G = V_{DD}\frac{R_{G2}}{R_{G1}+R_{G2}}$$

$$V_G = 10\times\frac{10}{10+10}$$

$$V_G = +5\ \text{V}$$

$$V_S = 6I_D\ \ \text{V}$$

$$V_{GS} = V_G - V_S = (5 - 6I_D)\ \ \text{V}$$

Thus I_D, when transistor rreplace with another transistor

having $V_t = 2$ V and $K_n'\frac{W}{L} = 2$ mA/V^2. Then I_D

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

$$I_D = \frac{1}{2}\times 2\times(5 - 6I_D - 2)^2$$

$$36I_D^2 - 37I_D + 9 = 0$$

I_D have two values $I_D = 0.632$ not possible

Then

$$I_D = 0.4\ \text{mA}$$

$$V_D = V_{DD} - 6I_D$$

$$V_D = 10 - 6\times 0.4$$

$$V_D = 7.6\ \text{V}$$