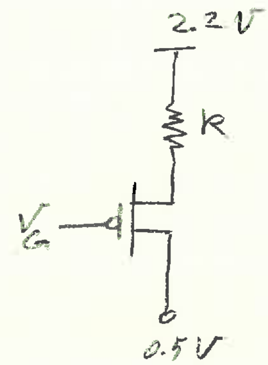
HW #8

3.25 $\quad V_{tp} = -0.4 \qquad k_p' = 50\ \mu A/V^2$

$\frac{W}{L} = 8 \qquad P_R = 10\ \mu W$



$$P_R = \frac{\Delta V^2}{R} = \frac{(2.2 - V_S)^2}{R} = 10\ \mu W$$

$$\Rightarrow R = \frac{(2.2 - V_S)^2}{10\ \mu W} \qquad ①$$

Transistor is biased at the boundary.

$$V_{DS} = V_{GS} - V_{tp} \Rightarrow V_D - V_S = V_G - V_S - V_{tp}$$

$$V_G = V_{tp} + V_D = 0.5 - 0.4 = 0.1$$

$$|I_D| = \frac{k_p'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{tp})^2 = \frac{k_p'}{2}\left(\frac{W}{L}\right)(V_G - V_S - V_{tp})^2$$

$$= \frac{50}{2}(8)(0.1 - V_S - (-0.4))^2 = \frac{50}{2} \times 8 \times (0.5 - V_S)^2 \qquad ②$$

Also $|I_D| = \frac{2.2 - V_S}{R}$ combine ① $\Rightarrow \frac{2.2 - V_S}{\frac{(2.2 - V_S)^2}{10\ \mu W}} = \frac{10\ \mu W}{2.2 - V_S}$ ③

② = ③

$$\frac{50}{2} \times 8 \times (0.5 - V_S)^2 = \frac{10\ \mu W}{2.2 - V_S}$$

$V_S = 0.6815 \qquad V_S > V_D \quad \therefore V_S \neq 0.336\ V$

from ① $\Rightarrow \quad R = \frac{(2.2 - 0.6815)^2}{10\ \mu W} = \boxed{230.6\ k\Omega}$

3.26

(a) $V_{GS} = V_G - V_S = 0 - V_S$

Assume Saturation

$$|I_{DS}| = \frac{75}{2}(5)(-V_S + 0.6)^2 = \frac{3 - V_S}{4k\Omega} = I_{DS}$$

$$\frac{3 - V_S}{4k\Omega} = \frac{75}{2} \times 5 \times (V_S^2 - 1.2V_S + 0.36)$$

$$\boxed{V_S = 1.842\,V} \quad \text{for PMOS } V_S > V_G$$

b) $I_{DS} = \frac{3 - V_S}{4k\Omega} = \frac{3 - 1.842}{4k\Omega} = 289.5 \times 10^{-4}$

$I_{DS} = \frac{V_D}{2k\Omega} \Rightarrow V_D = (2k\Omega) \times (289.5 \times 10^{-4}) = 0.579\,V$

$|V_{DS}| > |V_{GS}| - |V_{Tp}|$

$1.263 > 1.242$, So Saturation is true

Thus, $\boxed{V_D = 0.579\,V}$

3.30)

$V_{GS} = V_G - V_S = 0 - (-1) = 1\,V$

Since $V_{DS} > V_{GS} - V_{Tn}$ i.e. $(2 > 1 - 0.6)$

NMOS is in Saturation

$$I_{DS} = \frac{k_n}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{Tn})^2 = \frac{200\ \mu A/V^2}{2} \times 3 \times (1-0.6)^2$$

$$I_{DS} = 48\ \mu A$$

$$R_1 = \frac{3 - V_D}{I_{DS}} = \frac{3-1}{48\mu A} = 41.67\ k\Omega$$

$$R_1 = R_2 = 41.67\ k\Omega$$

3.35.

$$V_G = V_D = V_o \Rightarrow V_{DS} = V_{GS}$$

Transistor is saturated because drain and gate are connected

$$I_{DS} = \frac{k_n'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{Tn})^2 = \frac{90}{2}(10)(V_{DS} - 0.5)^2$$

$$I_{DS} = \frac{2.5 - V_D}{5k\Omega} = \frac{V_S}{2k} \Rightarrow V_D - V_S = V_{DS} = 2.5V - (5k)I_{DS} - (2k)I_{DS}$$

$$I_{DS} = \frac{90}{2}(10)(2.5 - 5I_{DS} - 2I_{DS} - 0.5)^2$$

$$I_D = 192.32\ \mu A \quad \text{or} \quad I_D = 424.46\ \mu A$$

Saturation $\Rightarrow$ $I_D = 192.32\ \mu A$

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For V_o, $I_D = \dfrac{2.5V - V_o}{5k\Omega} \Rightarrow V_o = 2.5V - (5k\Omega) \times I_D$

$$V_o = 2.5 - (5k\Omega)(192.32\ \mu A) = 1.54\ V$$

3.37.

$$V_T = V_{T0} + \gamma\left(\sqrt{|2\phi_F + V_{SB}|} - \sqrt{|2\phi_F|}\right)$$

$$\sqrt{|2\phi_F - V_{SB}|} = \sqrt{|2\phi_F|} + \frac{V_T - V_{T0}}{\gamma}$$

$$\Rightarrow V_{SB} = \left(\sqrt{|2\phi_F|} + \frac{V_T - V_{T0}}{\gamma}\right)^2 - |2\phi_F| = 86.17\ mV$$

$$V_{BS} = -V_{SB} = -86.17\ mV$$

3.38.

$$V_T = V_{T0} + \gamma\left(\sqrt{2\phi_F + V_{SB}} - \sqrt{2\phi_F}\right)$$

$$V_T = 0.6V + 0.25\left(\sqrt{0.7 + V_o} - \sqrt{0.7}\right)$$

maximum $V_o = V_{dd} - V_T \rightarrow V_T = 2 - V_o$

$$\Rightarrow V_o = 1.26\ V$$

$$V_T = 0.74\ V$$