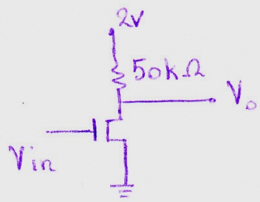
University of New Mexico
Department of Electrical and Computer Engineering

ECE 321 – Electronics I (Fall 2012) **Homework Solution # 6**

3.3



Assuming the transistor is in the saturated region,

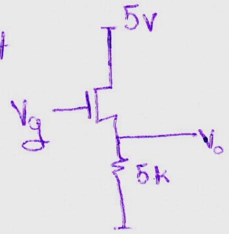
$I_D = \frac{k}{2}\left(\frac{W}{L}\right)(V_{gs} - V_{tn})^2 \longrightarrow I_D = \frac{75\mu A/V^2}{2}(4)(V_{gs} - 0.5)^2$ $\Big/ \Rightarrow$

KVL: $V_{DD} = V_o + I_D R_D \longrightarrow I_D = \frac{V_{DD} - V_o}{R_D} = \frac{2 - 1.2}{50k} \rightarrow I_D = 16\mu A$

$16\mu A = 150\mu A(V_{gs} - 0.5)^2 \longrightarrow V_{gs} = 0.827\ V$

$V_{gs} < V_{ds} + V_{tn} \longrightarrow$ Transistor is in saturated state

3.4



$$\left\{\begin{array}{l} V_{ds} = 5 - V_o \\ V_{gs} = V_g - V_o \\ V_o = 5K * I_D = 1V \end{array}\right\} \Rightarrow V_{DS} = 4V$$

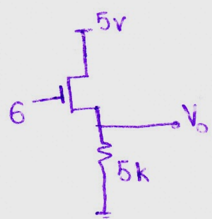
Assuming saturated state

$I_D = \frac{k}{2}\left(\frac{W}{L}\right)(V_{gs} - V_t)^2 \longrightarrow 200\mu A = \frac{100\mu A}{2}(4)(V_{gs} - 0.8)^2 \longrightarrow V_{gs} = 1.8\ V$

$V_{gs} < V_{ds} + V_{tn} \longrightarrow$ Transistor is in saturated state

$V_{gs} = V_g - V_o \longrightarrow V_g = V_{gs} + V_o \longrightarrow V_g = 2.8\ V$

3.6



$V_{gs} - V_t < V_{ds} \longrightarrow$ Linear region

$I_{ds} = \frac{V_o}{5k} = k_n'\left(\frac{W}{L}\right)\left[(V_{gs} - V_{tn})V_{DS} - \frac{V_{DS}^2}{2}\right]$

$\frac{V_o}{5K} = 200\mu A/V^2 (4)\left[(6 - V_o - 0.8)(5 - V_o) - \frac{(5 - V_o)^2}{2}\right]$

$V_o = 3.806\ V$

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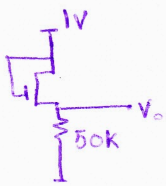
3.8



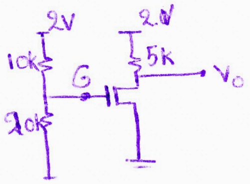
$V_{ds} > V_{gs} - V_t \longrightarrow$ Saturation

$V_{gs} = V_{ds} = 1V - V_o$

$I_{ds} = \frac{110\mu A/V^2}{2} * 5 * (1 - V_o - 0.25)^2 = \frac{V_o}{5K} \Rightarrow V_o = 0.550V$

$I_D = \frac{0.55V}{50K\Omega} = 11\mu A$

3.9



$V_g = 2 * \frac{20K}{(20+10)K} = 1.33V$

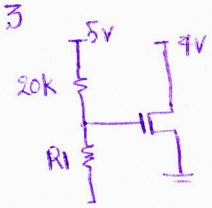
Assuming linear region:

$I_{ds} = K_n\left(\frac{W}{L}\right)\left[(V_{gs} - V_t)V_{ds} - \frac{V_{ds}^2}{2}\right]$

$120\mu A/V^2 * 20 * \left[(1.33 - 0.5)V_{ds} - \frac{V_{ds}^2}{2}\right] = \frac{2 - V_o}{5K} \longrightarrow V_{ds} = 0.204V$

$I_{ds} = \frac{2 - 0.204}{5k} = 359.2\mu A$

3.13

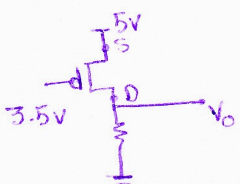


$V_{ds} = V_d - V_s = 4V$

$\frac{V_{gs} - 5}{20K} + \frac{V_{gs}}{R_1} = 0 \longrightarrow V_{gs} = \frac{5V R_1}{R_1 + 20K}$

In the boundry $V_{gs} = V_{ds} + V_{tn} \longrightarrow \frac{5R_1}{R_1 + 20K} = 4 + 0.5 \longrightarrow R_1 = 180k\Omega$

3.16



for pMos $\Rightarrow$ Higher voltage $\rightarrow$ Source

Lower voltage $\rightarrow$ Drain

$|V_{DS}| \overset{?}{} |V_{gs}| - |V_t|$

$|V_o - 5| \overset{?}{} |3.5 - 5| - |0.8|$

$|V_o - 5| \overset{?}{} 0.7$

Assuming Sat. $\longrightarrow$ $|I_{ds}| = \frac{|k_p|}{2}(|V_{gs}| - |V_t|)^2 * 2 = \frac{V_o}{100K} \rightarrow V_o = 1.47V$

$|I_{ds}| = 14.7\mu A$

$|1.47 - 5| > 0.7$

Saturation ✓

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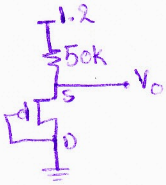
3.21



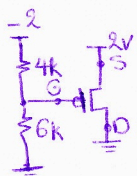
$|V_{gs}| - |V_t| \overset{?}{} |V_{ds}|$

$V_o - |V_t| < V_o \longrightarrow$ Saturation

$$|I_{ds}| = \frac{|K_p'|}{2}\left(\frac{W}{L}\right)\left[(|V_{gs}| - |V_t|)\right]^2 \longrightarrow \frac{|40\,\mu A/V^2|}{2} * 6 * (+V_o - 0.3)^2 = \frac{V_o - 1.2v}{50k}$$

$|I_{ds}| = 11.743\,\mu A$ & $V_o = 0.61283\,v$

3.22



$V_G = -2 * \frac{4k}{10k} = -1.2v$ $\quad |V_{gs}| - |V_t| \overset{?}{} |V_{ds}|$

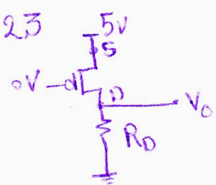
$|-1.2-2| - |-0.4| > |0-2|$

$2.8 > 2 \longrightarrow$ Linear

$$|I_{ds}| = |K_p'|\left(\frac{W}{L}\right)\left[(|V_{gs}| - |V_{tp}|)|V_{ds}| - \frac{|V_{ds}|^2}{2}\right]$$

$$|I_{ds}| = (100\,\mu A/V^2) * 4 * \left[(3.2 - 0.4)2 - \frac{2^2}{2}\right] \longrightarrow |I_{ds}| = 1.44\,mA$$

3.23



$|V_{gs}| - |V_{tp}| \overset{?}{} |V_{ds}|$

$|-5| - |-0.8| > |-0.2|$

$4.2 > 0.2 \longrightarrow$ Linear

$$|I_{ds}| = |K_p'|\left(\frac{W}{L}\right)\left[(|V_{gs}| - |V_{tp}|)|V_{ds}| - \frac{|V_{ds}|^2}{2}\right]$$

$$0.25A = 75\,\mu A/V^2 * \left(\frac{W}{L}\right)\left[(5 - 0.8) * 0.2 - \frac{0.2^2}{2}\right]$$

$$\frac{W}{L} = 4.065 \times 10^3$$

$I_D = \frac{V_o}{R_D} = \frac{4.8v}{R_D} \longrightarrow R_D = 19.2\,\Omega$

for $V_{SD} < 0.2 \Rightarrow V_o > 4.8v \longrightarrow 0.25 R_D > 4.8v$

$R_D > 19.2\,\Omega$

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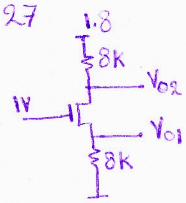
3.27



Assuming Saturation

$$I_{ds} = \frac{K_n'}{2}\left(\frac{W}{L}\right)(V_{gs}-V_{tn})^2$$

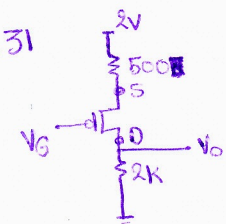
$$I_{ds} = \frac{95\mu A/V^2}{2} * 4 * [(1-V_{o1})-0.4]^2$$

$$I_{ds} = \frac{V_{o1}}{8K}$$

$\Rightarrow V_{o1} = 0.2148\,V \Rightarrow I_{ds} = 24.475\,\mu A$

$V_{o2} = 1.8V - I_{ds} * 8K \Rightarrow V_{o2} = 1.5802\,V$

3.31



$V_o = 0.3$

$|I_{ds}| = \frac{V_o}{2K} \rightarrow |I_{ds}| = 150\mu A$

$V_o = V_D$

$V_S = 2v - 500 * |I_{ds}| = 1.925\,V$

Assuming Saturation

$$|I_{ds}| = \frac{|150\mu A/V^2|}{2} * 5 * [|V_{gs}| - 0.5]^2 = 150\mu A \Rightarrow |V_{gs}| = 1.595V \Rightarrow V_G = 0.33V$$

$$|-1.595| - |-0.5| < |0.3 - 1.925|$$

$$1.095 < 1.625 \quad \text{Saturation} \checkmark$$