VALENTINE

PAGE NO.:

DATE:

HW 7 sol^n ECE 255

5.5 V_{DS} is kept small, $r_{DS} = \frac{1}{\mu_n C_{ox}(W/L)(V_{GS}-V_t)}$

$k_n' = \mu_n C_{ox} = 400\ \mu A/V^2$

max allowed voltage $1.8\,V = V_{GS}$, $r_{DS} \to$ min.

so $200 = \frac{1 \cdot 0.18 \times \cancel{10^{-6}}}{400 \times \cancel{10^{-6}} \times W \times (1.8-0.4)} \Rightarrow W = 1.6\times10^{-6}\,m = 1.6\,\mu m$

$1\,k\Omega = \frac{1}{400\times10^{-6} \times \frac{1.6}{0.18} \times (V_{GS}-0.4)} \Rightarrow V_{GS}-0.4 = 0.28 \Rightarrow V_{GS} = 0.12\,V$

range of V_{GS} $(0.12, 1.8)V$, $W = 1.6\,\mu m$

5.9 $V_{GS} > V_t$ (on), $V_{OV} = V_{GS}-V_t = 2.5-1 = 1.5\,V$

when $V_{OV} = V_{DS} \Rightarrow$ sat^n (entered into)

$I_D = \frac{1}{2}k_n V_{OV}^2 = \frac{1}{2}(1)(1.5)^2 = 1.125\,mA$

5.14 $t_{ox} = 9\,nm$, $\mu_n = 500\,cm^2/V\cdot s$, $V_t = 0.7\,V$, $W/L = 10$

(a) $V_{GS} = 5V$, $V_{DS} = 1V$

$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{3.45\times10^{-11}}{9\times10^{-9}} = 3.8\,mF/m^2$

$V_{GS} > V_t$ $V_{OV} = 5-0.7 = 4.3\,V$

$V_{DS} < V_{OV} \Rightarrow$ linear reg^n

$\mu_n C_{ox}\frac{W}{L} = 500\times10^{-4} \times 3.8\times10^{-3} \times 10$

$k_n = 19\times10^{-4} = 1.9\,mA/V^2$

$I_D = k_n[V_{OV} - \frac{1}{2}V_{DS}]V_{DS}$

$= 1.9(4.3 - \frac{1}{2}(1)) = 7.22\,mA$

(b) $V_{GS} = 2V$, $V_{DS} = 1.3V$, $V_{GS} > V_t$, $V_{OV} = 1.3V = V_{DS} \Rightarrow$ sat^n

$I_D = \frac{1}{2}k_n V_{OV}^2 = \frac{1}{2}(1.9)(1.3)^2 = 1.6\,mA$

(c) $V_{GS} = 5V$, $V_{DS} = 0.2V$, $V_{GS} > V_t$, $V_{OV} = 4.3V > V_{DS} \Rightarrow$ linear

$I_D = k_n[V_{OV} - \frac{1}{2}V_{DS}]V_{DS}$

$= 1.9(4.3 - 0.1)0.2 \approx 1.6\,mA$

(d) $V_{GS} = V_{DS} = 5V$, $V_{OV} = 4.3V < V_{DS} \Rightarrow$ sat^n

$I_D = \frac{1}{2}k_n V_{OV}^2 = \frac{1}{2}(1.9)(4.3)^2 = 17.56\,mA$

5.21 $I_D = k_n\left[V_{OV} - \frac{1}{2}V_{DS}\right]V_{DS}$

$\frac{I_{D1}}{I_{D2}} = \frac{\left(V_{OV1} - \frac{1}{2}V_{DS1}\right)\cancel{V_{DS1}}}{\left(V_{OV2} - \frac{1}{2}V_{DS2}\right)\cancel{V_{DS2}}} \Rightarrow \frac{60}{160} = \frac{V_{OV1} - 0.05}{V_{OV2} - 0.05}$

$\frac{6}{16} = \frac{V_{GS1} - V_t - 0.05}{V_{GS2} - V_t - 0.05} = \frac{1.95 - V_t}{3.95 - V_t}$

$1.48 - 0.375V_t = 1.95 - V_t \Rightarrow V_t(0.625) = 0.47$

$\Rightarrow \underline{V_t = 0.752\,V}$

$k_n' = 50\,\mu A/V^2$

$60\,\cancel{\mu A} = 50\frac{W}{L}[1.198]\,0.1 \Rightarrow \frac{W}{L} \approx 10$

$V_{GS} = 3V > V_t$. $V_{OV} = 2.248V > V_{DS} \Rightarrow$ linear regn

$I_D = 500\,[2.248 - 0.075]\,0.15 \Rightarrow I_D = \underline{0.16\,mA}$ (162.97 μA)

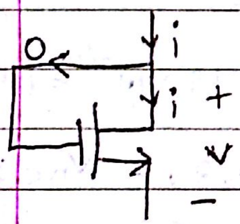
$V_{GS} = 3V$, drain: pinch off, $\Rightarrow$ edge of satn $\Rightarrow V_{DS} = V_{OV}$

$V_{OV} = 2.248 = V_{DS}$ $I_D = \frac{1}{2}k_n(V_{OV})^2 = \frac{1}{2}500\,(2.248)^2$

$= \underline{1.26\,mA}$

5.24 (a) $V_{GS} = V_{DS}$ since $V_G = V_D$ now, $V_{GS} - V_t = V_{OV} < V_{DS}$

$\Rightarrow$ always satn regn



$i = \frac{1}{2}k_n'\frac{W}{L}V_{OV}^2$

$V_{OV} = V_{GS} - V_t$

$= V_{DS} - V_t = V - V_t$

if PMOS, $V_{GS} = V_{DS}$ (−ve) and $V_{DS} < V_{OV}$

$V_{OV} = V_{SD} - |V_{tp}|$

so ultimately, $i = \frac{1}{2}k_n'\frac{W}{L}(V - |V_t|)^2$

(b) $v = |V_t| + V_{OV}$ (satn) differentiate the equation in part (a)

$\frac{\partial i}{\partial v} = \frac{1}{2}k_n'\frac{W}{L}2(V - |V_t|) = k_n'\frac{W}{L}V_{OV}$

$\Rightarrow r = 1/\left[\frac{\partial i}{\partial v}\right] = 1/k_n'\frac{W}{L}V_{OV}$

5.26 $v_{DS} = v_{GS}$ (satn) $i_D = \frac{1}{2}k_n(V_{OV})^2$

quadratic dependence on $V_{GS} = V_{DS}$