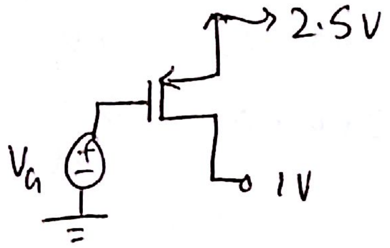
ECE 255 HW 8

5.41 $V_{tp} = -0.5\,V$

$V_G \in [0, 2.5]\,V$



$V_S = 2.5V \quad V_D = 1V$

$V_{SG} > |V_{tp}| \rightsquigarrow ON$

$2.5 - V_G > 0.5$

$\Rightarrow V_G < 2V \quad ON$

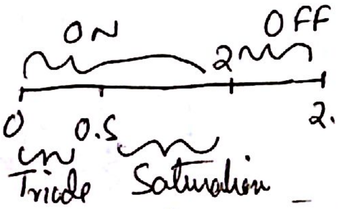
$V_{DG} \leq |V_{tp}| \rightsquigarrow$ Saturation region

$\Rightarrow 1 - V_G \leq 0.5 \Rightarrow V_G \geq 0.5 \rightsquigarrow$ Saturation

$V_G < 0.5 \rightsquigarrow$ Triode

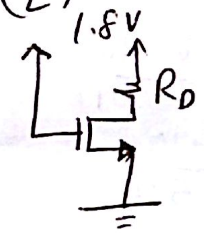
$\Rightarrow$

V_G



5.47 $k_n' = 0.4 mA V^{-2} \quad V_t = 0.5V \quad \lambda = 0$

$\left(\frac{W}{L}\right) R_D = 1.5 k\Omega$ at Edge of Saturation



$V_G = 1.8V \qquad V_S = 0V$

$V_D = 1.8 - I_D R_D$

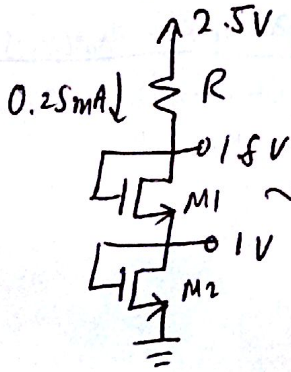
At the edge of saturation

$V_{DS} = V_{GS} - V_t \Rightarrow 1.8 - I_D R_D = 1.8 - 0.5$

$\Rightarrow I_D R_D = 0.5 \Rightarrow R_D = \frac{0.5}{I_D} = \frac{0.5}{\frac{k_n'}{2}\frac{W}{L} V_{ov}^2} = \frac{0.5 \times 2}{0.4\left(\frac{W}{L}\right)(1.3)^2}$

$\Rightarrow \frac{W}{L} R_D = \frac{5 \times 2}{24 \times 1.69} = \frac{5}{3.4} \simeq 1.5 k\Omega$ //

5.50 $V_t = 0.5V$, $\mu_n C_{ox} = 250 \mu A V^{-2}$, $\lambda = 0$ & $L_1 = L_2 = 0.25 \mu m$



$\rightsquigarrow$ Both M1, M2 in SAT as $V_D = V_G$

$R = \frac{2.5 - 1.8}{0.25m} = \frac{0.7}{0.25m} = 2.8 k\Omega$

$I_{D1} = I_{D2} = 0.25 mA$

$500\mu \rightsquigarrow 0.5m$

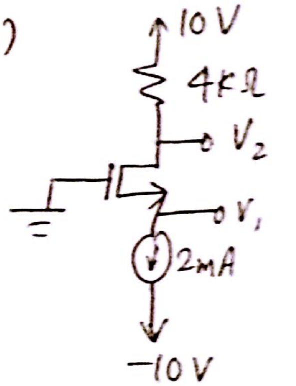
$0.25m = \frac{250\mu}{2} \frac{W}{0.25\mu} (1.8 - 1 - 0.5)^2$

$\frac{1}{2}\mu = W (0.3)^2 \Rightarrow W_1 = \frac{1}{2 \times 0.09} = \frac{1}{0.18}\mu = 5.56 \mu m$

$0.25m = 250\mu \frac{W}{0.5\mu}(1 - 0.5)^2 \Rightarrow W_2 = \frac{1}{2 \times 0.25}\mu = \frac{1}{0.5}\mu = 2\mu m$

5.55 $|V_t| = 2V$, $k'W/L = 1mAV^{-2}$ & $\lambda = 0$

I (a)



$I_D = 2mA \Rightarrow 10 - V_2 = 8 \Rightarrow V_2 = 2V$

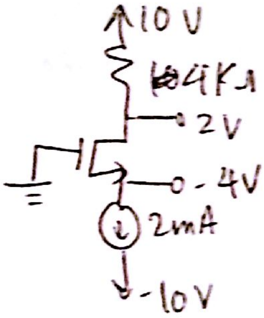
Assume MOSFET in SAT ($V_{DS} = V_2 - V_1 = 6V > V_{OV}$, $0-(-4)-2 = 2V$)

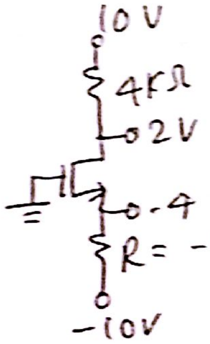
$\Rightarrow 2m = \frac{1mA}{2}(0 - V_1 - 2)^2 \Rightarrow \pm 2 = 2 + V_1$

as $V_{OV} > 0 \Rightarrow -V_1 - 2 > 0 \Rightarrow 2 + V_1 < 0 \Rightarrow 2 + V_1 = -2$

$\Rightarrow V_1 = -4V$

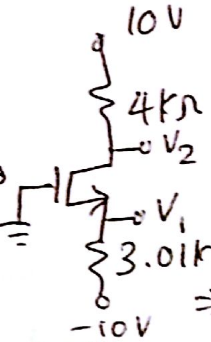
(b)





$R = \frac{-4+10}{2m} = 3k\Omega$

actual



~~$V_1 + 10 = I_D R$~~

~~$\Delta V_1 = (\Delta R) I_D'$~~

~~$\Rightarrow I_D' R' = I_D R$~~

? ~~3.01k 2m 3k~~

~~$\Rightarrow \Delta V_1 = \frac{6}{3.01} \times 0.01$~~

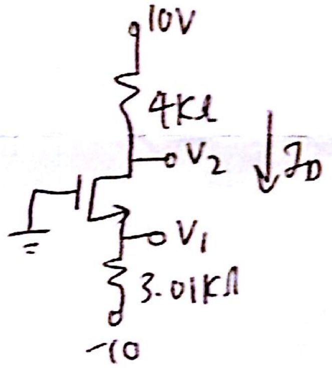
~~$= 1.9934 \times 0.01$~~

~~$= 0.0199$~~

~~$V_1 = -4 + \Delta V_1$~~

~~$= -3.980 + V$~~

EXACT ANALYSIS



$V_2 = 10 - 4I_D$

$V_1 = I_D(3.01) - 10$

$I_D = \frac{k'W}{2L} V_{OV}^2$

$= \frac{1m}{2}(0 - V_1 - 2)^2$

$\Rightarrow 0.5m(V_1 + 2)^2 = \frac{V_1 + 10}{3.01K}$

$(V_1 + 2)^2 = \frac{V_1 + 10}{1.505}$

$V_1^2 + 4 + 4V_1 - \frac{V_1}{1.505} - \frac{10}{1.505} = 0$

$V_1^2 + 3.3355V_1 - 2.645 = 0$

$V_1 = \frac{-3.3355 \pm \sqrt{11.1256 + 10.58}}{2}$

$= \frac{-3.3355 \pm 4.6589}{2}$ → +ve ✗, → −ve ✓ as $V_1 < -2$

$= -3.9972 V$ ← The SAME

$I_D = \frac{1m}{2}(3.9972 - 2)^2$

$= 1.9944$

$V_2 = 10 - 4I_D$

$= 2.0223 V$ → Slight difference

- V_1 remain almost the same (increase by a small %) $V_1 = -4V$ | APPROXIMATE ANALYSIS
- But as $I_D \downarrow$ (as $I_D R = I_D' R'$, $I_D' = 1.9934 mA$) $V_2 \uparrow$ considerably as compared to V_1

  2m, 3k, ?, 3.01k

$\Delta V_2 = 4K \Delta I_D = 0.0264 \Rightarrow V_2 = 2.0264 V$

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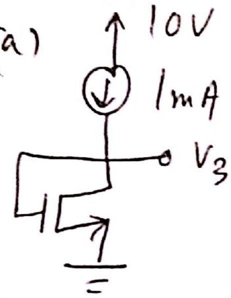
II (a)



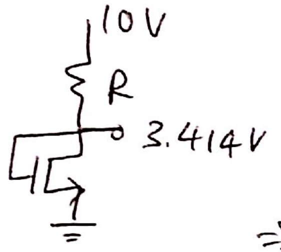
$V_D = V_G \Rightarrow SAT^n$

$V_3 - 2 > 0 \rightarrow ON$

$I_D = \frac{1m}{2}(V_3 - 2)^2 = 1mA$

$\Rightarrow 2 = (V_3 - 2)^2 \Rightarrow V_3 = +\sqrt{2} + 2 = 3.414V$

(b)



$R = \frac{10 - 3.414}{1m} = 6.586 K\Omega$ 6.65KΩ (approximation)

$I_D' = \frac{6.586}{6.65} = 0.9904mA$

$\Rightarrow \Delta V_3 = -(\Delta I_D R + \Delta R I_D')$ ($\Delta I_D \to 0$) $\Rightarrow$ V_3 should approximately be the same

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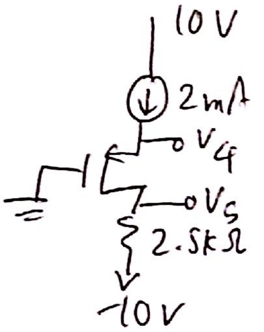
III



$|V_{tp}| = 2V$

$V_S + 10 = 2.5k \, 2m$

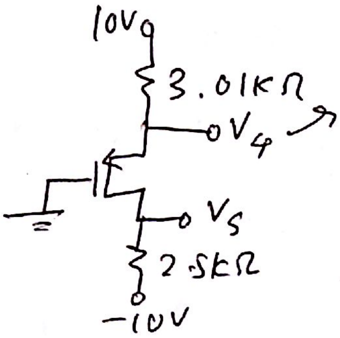
$\Rightarrow V_S = -10 + 5 = -5V$

$V_{GD} = 5V \Rightarrow SAT^n$

$\Rightarrow 2mA = \frac{1m}{2}(V_4 - 2)^2 \rightarrow V_4 - 2 > 0 \rightarrow ON$

$\Rightarrow 4 = (V_4 - 2)^2 \Rightarrow V_4 - 2 = 2 \Rightarrow V_4 = 4V$

$\hookrightarrow R = \frac{10-4}{2m} = 3k\Omega \Rightarrow$



we know that $I_D' < I_D$ i.e drain current decreases

$V_4 \sim 4V$

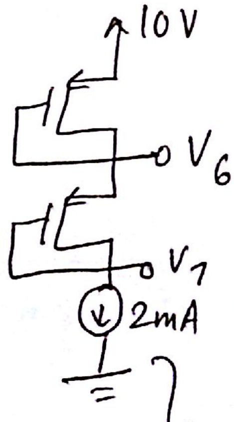
$\Delta V_S = \Delta I_D \, 2.5k$

$I_D' = \frac{2 \times 3}{3.01} \simeq 1.9934 mA$

$\Delta V_S \simeq -0.0165V$

$V_S = -5 + \Delta V_S = -5.0165V$

IV



$V_D = V_G$ both MOSFETs $\Rightarrow SAT^n$

$8 - V_6 > 0 \rightarrow ON$

$I_D = 2mA = \frac{1m}{2}(10 - V_6 - 2)^2$

$\Rightarrow 4 = (8 - V_6)^2 \Rightarrow 8 - V_6 = 2 \Rightarrow V_6 = 6V$

$I_D = 2mA = \frac{1m}{2}(V_6 - V_7 - 2)^2 \rightarrow 4 - V_6 > 0$ ($V_6 \to 6V$)

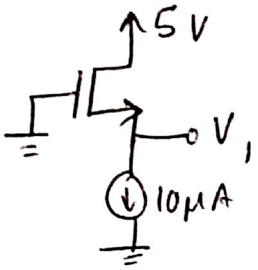
$\Rightarrow 2 = 4 - V_7 \Rightarrow V_7 = 2V$

$\hookrightarrow R = \frac{V_7 - 0}{2m} = 1k\Omega = 1k\Omega$ (1% tolerance value)

$\Rightarrow V_7 = 2V \;\&\; V_6 = 6V$!

5.56. $k_n'(W/L) = 0.5 mA V^{-2}$, $V_t = 0.8V$, $\lambda = 0$

(a)



Assume SAT^n (✓)

$I_D = 10\mu A = \frac{k_n' W}{2L} V_{ov}^2 = \frac{0.5m}{2}(0 - V_1 - 0.8)^2$ ↳ $V_1 + 0.8 < 0$ → ON

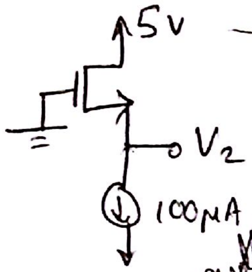
$\Rightarrow 40\mu = (V_1 + 0.8)^2 m$

$\Rightarrow 40 m = (V_1 + 0.8)^2 \Rightarrow (V_1 + 0.8)^2 = 40 \times 10^{-3}$

$\Rightarrow V_1 + 0.8 = \pm(2 \times 10^{-1}) = \pm 0.2$

$\Rightarrow V_1 = -1V$ // $V_{DS} = 5+1$, $V_{ov} = 0+1-0.8$ ⇒ $V_{DS} > V_{ov}$

(b)



Assume SAT^n (✓) — regardless as $V_{DG} > V_t$

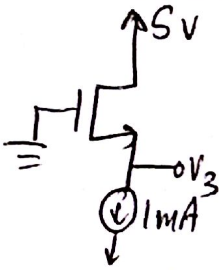
$I_D = 100\mu A = \frac{0.5m}{2}(0 - V_2 - 0.8)^2$ ↳ $V_2 + 0.8 < 0$ → ON

$\frac{200\mu}{0.5m} = (V_2 + 0.8)^2 \Rightarrow 400m = (V_2 + 0.8)^2$; 400×10^{-3} → 0.4

$\Rightarrow V_2 = -\sqrt{0.4} - 0.8 = -1.43V$ //

$V_{DS} > V_{ov}$ as $5 + V_2 > 0 - V_2 - 0.8$

(c)

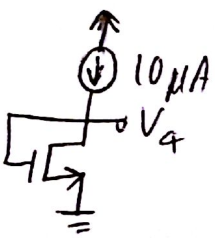


$V_{DG} = 5V > -V_t$, -0.8 ⇒ SAT^n

$I_D = 1m = \frac{0.5m}{2}(-V_3 - 0.8)^3$ ↳ $V_3 + 0.8 < 0$ → ON

$\Rightarrow 4 = (V_3 + 0.8)^2 \Rightarrow V_3 + 0.8 = -2 \Rightarrow V_3 = -2.8V$ //

(d)



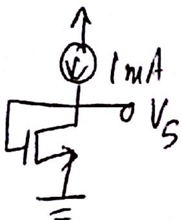
$V_{DG} = 0 > -V_t$, 0.8 ⇒ SAT^n

$I_D = 10\mu A = \frac{0.5m}{2}(V_4 - 0 - 0.8)^2$; $V_4 - 0.8 > 0$ (ON)

$\Rightarrow \frac{20\mu}{0.5m} = (V_4 - 0.8)^2 \Rightarrow (V_4 - 0.8)^2 = 40m$ ↳ $40 \times 10^{-3} = 4 \times 10^{-2}$

$\Rightarrow V_4 - 0.8 = 2 \times 10^{-1} = 0.2$ (+ve) $\Rightarrow V_4 = 1V$ //

(e)



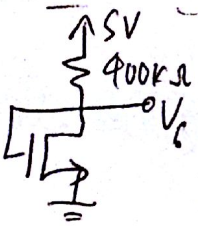
$V_{DG} = 0 > -V_t$, -0.8 ⇒ SAT^n

$I_D = 1mA = \frac{0.5m}{2}(V_5 - 0 - 0.8)^2$; $V_5 - 0.8 > 0$ (ON)

$\Rightarrow \frac{2m}{0.5m} = (V_5 - 0.8)^2 \Rightarrow 4 = (V_5 - 0.8)^2$

$\Rightarrow V_5 = 0.8 + \sqrt{4} = 2.8V$ //

(f)



$V_{DG} = 0 > -V_t$, -0.8 ⇒ SAT^n

$I_D = \frac{5 - V_6}{400k} = \frac{0.5m}{2}(V_6 - 0.8)^2 \Rightarrow 10 - 2V_6 = 200k\,m\,(V_6 - 0.8)^2$

$\Rightarrow 1/20 - 1/100\, V_6 = (V_6 - 0.8)^2 \simeq V_6 = 0.8\,V$ (MAKES SENSE AS I_D is very low)

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