Homework Assignment #5

ECE 0257 – Spring 2019

Name

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Collaborators

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Book Problems

Sedra & Smith 5.17

Sedra & Smith 5.18

Sedra & Smith 5.20

Sedra & Smith 5.41

Sedra & Smith 5.44

Sedra & Smith 5.50

Sedra & Smith 5.54

Sedra & Smith 5.55 (part a only)

Simulation Problems

Exercises (a) – (d)

Check-list Before Submission

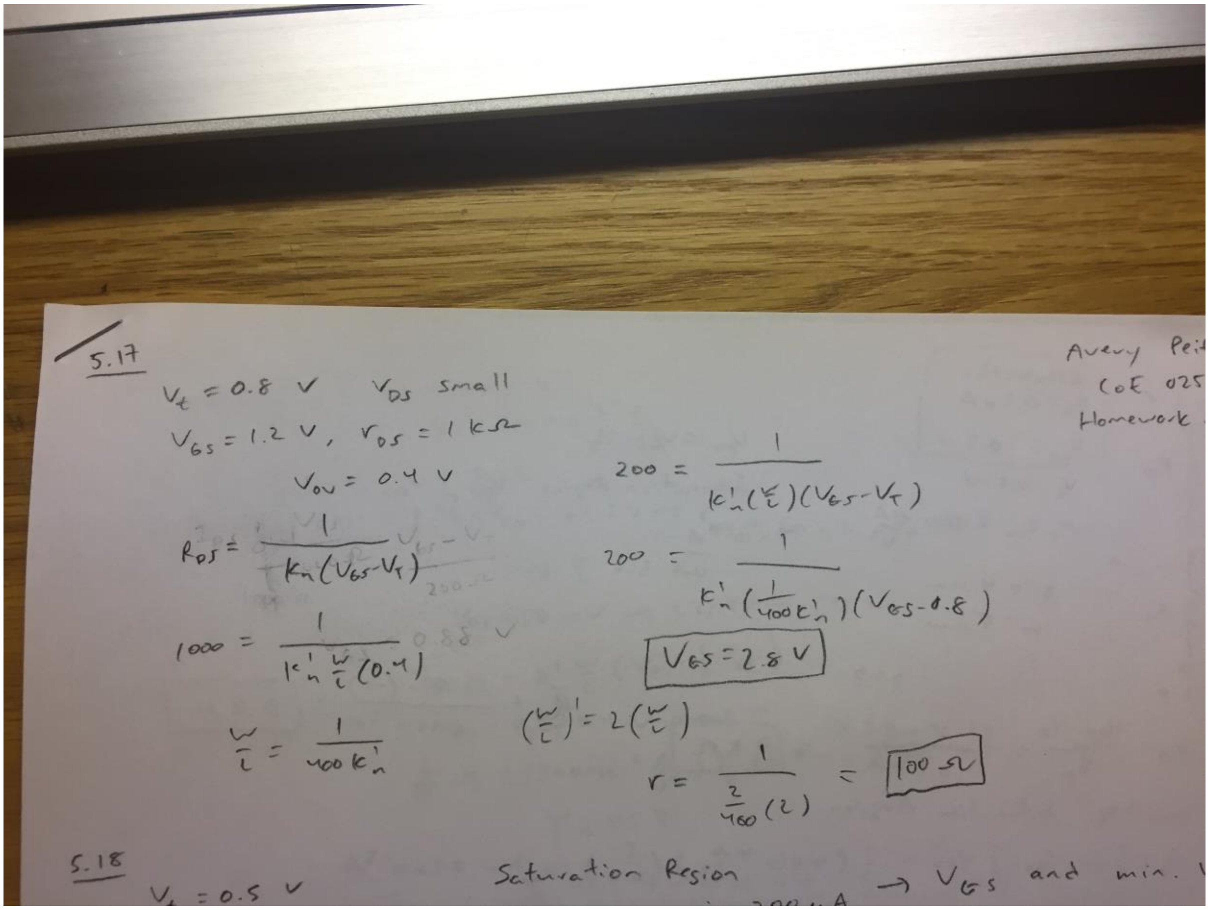
☐ Write within boxes, no boxes are moved

☐ Write your full names in designated area

☐ Save this file as a PDF before uploading, keep the number of pages (**16**) unchanged

☐ Notify “TO BE CONTINUED” accordingly if you used the extra pages (page 14-16)

Sedra & Smith 5.17



Avery Pei
CoE 025
Homework

5.17

$V_t = 0.8$ V V_{DS} small

$V_{GS} = 1.2$ V, $r_{DS} = 1$ kΩ

$V_{ov} = 0.4$ V

$$R_{DS} = \frac{1}{k_n(V_{GS}-V_t)}$$

$$1000 = \frac{1}{k_n' \frac{W}{L}(0.4)}$$

$$\frac{W}{L} = \frac{1}{400 k_n'}$$

$$200 = \frac{1}{k_n'\left(\frac{W}{L}\right)(V_{GS}-V_t)}$$

$$200 = \frac{1}{k_n'\left(\frac{1}{400k_n'}\right)(V_{GS}-0.8)}$$

$$\boxed{V_{GS} = 2.8\text{ V}}$$

$$\left(\frac{W}{L}\right)' = 2\left(\frac{W}{L}\right)$$

$$r = \frac{1}{\frac{2}{400}(2)} = \boxed{100\ \Omega}$$

5.18

$V_t = 0.5$ V   Saturation Region

→ V_{GS} and min. V

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$V_{ov} = 0.4\ V$

$$R_{DS} = \frac{1}{k_n(V_{GS}-V_t)} \qquad 200 = \frac{1}{k'_n\left(\frac{W}{L}\right)(V_{GS}-V_t)}$$

$$1000 = \frac{1}{k'_n \frac{W}{L}(0.4)} \qquad 200 = \frac{1}{k'_n\left(\frac{1}{400k'_n}\right)(V_{GS}-0.8)}$$

$$\frac{W}{L} = \frac{1}{400k'_n} \qquad \boxed{V_{GS} = 2.8\ V}$$

$$\left(\frac{W}{L}\right)' = 2\left(\frac{W}{L}\right)$$

$$r = \frac{1}{\frac{2}{400}(2)} = \boxed{100\ \Omega}$$

5.18

$V_{tn} = 0.5\ V$ Saturation Region

$k'_n\left(\frac{W}{L}\right) = 1.6\ \frac{mA}{V^2}$ $i_D = 50\ \mu A$, $i_D = 200\ \mu A$ → V_{GS} and min. V_{DS}

$$50\times10^{-6}\ A = \frac{1}{2}\left(1.6\ \frac{mA}{V^2}\right)\left(\frac{1\ A}{1000\ mA}\right)(V_{GS}-0.5)^2 \Rightarrow \boxed{V_{GS} = 0.75\ V} \quad \boxed{V_{DS,min} = 0.25\ V}$$

$$200\times10^{-6}\ A = \frac{1}{2}\left(1.6\ \frac{mA}{V^2}\right)\left(\frac{1\ A}{1000\ mA}\right)(V_{GS}-0.5)^2 \Rightarrow \boxed{V_{GS} = 1\ V} \quad \boxed{V_{DS,min} = 0.5\ V}$$

5.20

$k'_n = 400\ \frac{\mu A}{V^2}$ In saturation region:

$$2\times10^{-3}\ A = \frac{1}{2}\left(400\ \frac{\mu A}{V^2}\right)\left(\frac{1\ A}{10^6\ \mu A}\right)\left(\frac{W}{0.18\times10^{-6}\ m}\right)$$

$V_t = 0.5\ V$ $(1.8-0.5)^2$

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$$r = \frac{1}{\frac{2}{400}(2)} = \boxed{100\ \Omega}$$

5.18

$V_{tn} = 0.5\ V$

$k'_n\left(\frac{W}{L}\right) = 1.6\ \frac{mA}{V^2}$

Saturation Region

$i_D = 50\ \mu A,\quad i_D = 200\ \mu A \rightarrow V_{GS}$ and min. V_{DS}

$$50\times10^{-6}\ A = \frac{1}{2}\left(1.6\ \frac{mA}{V^2}\right)\left(\frac{1\ A}{1000\ mA}\right)(V_{GS}-0.5)^2 \Rightarrow \boxed{V_{GS} = 0.75\ V}$$

$$\boxed{V_{DS,min} = 0.25\ V}$$

$$200\times10^{-6}\ A = \frac{1}{2}\left(1.6\ \frac{mA}{V^2}\right)\left(\frac{1\ A}{1000\ mA}\right)(V_{GS}-0.5)^2 \Rightarrow \boxed{V_{GS} = 1\ V}$$

$$\boxed{V_{DS,min} = 0.5\ V}$$

5.20

$k'_n = 400\ \frac{\mu A}{V^2}$

$V_t = 0.5\ V$

$V_{GS} = V_{DS} = V_{supply} = 1.8\ V$

$I_D = 2\ mA \quad L = 0.18\ \mu m$

In saturation region:

$$2\times10^{-3}\ A = \frac{1}{2}\left(400\ \frac{\mu A}{V^2}\right)\left(\frac{1\ A}{10^6\ \mu A}\right)\left(\frac{W}{0.18\times10^{-6}\ m}\right)(1.8-0.5)^2$$

$$\boxed{W = 1.07\ \mu m}$$

5.41

+3 V

$V_{tp} = -0.5\ V$

$V_G: +3\ V \rightarrow 0\ V$, all three modes

$2.5 < V_G \le 3$: Cutoff Region

$0.5 < V_G \le 2.5$: Linear Region

$\dots\ 0.5$: Saturation Region

Sedra & Smith 5.41

$200\times10^{-6}\,A = \frac{1}{2}\left(1.6\,\frac{mA}{V^2}\right)\left(\frac{1\,A}{1000\,mA}\right)(V_{GS}-0.5)^2 \Rightarrow \boxed{V_{GS}=1\,V}$

$\boxed{V_{DS,min}=0.5\,V}$

5.20

$k_n' = 400\,\frac{\mu A}{V^2}$

$V_t = 0.5\,V$

$V_{GS}=V_{DS}=V_{supply}=1.8\,V$

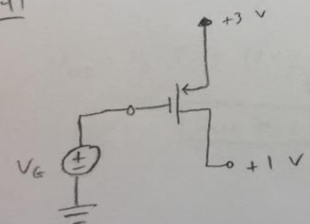
$I_D = 2\,mA$ $\quad L=0.18\,\mu m$

In saturation region:

$$2\times10^{-3}\,A = \frac{1}{2}\left(400\,\frac{\mu A}{V^2}\right)\left(\frac{1\,A}{10^6\,\mu A}\right)\left(\frac{W}{0.18\times10^{-6}\,m}\right)(1.8-0.5)^2$$

$\boxed{W=1.07\,\mu m}$

5.41



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

V_G : $+3\,V \rightarrow 0\,V$, all three modes

$2.5 < V_G \leq 3$: Cutoff Region

$0.5 < V_G \leq 2.5$: Linear Region

$0 \leq V_G \leq 0.5$: Saturation Region

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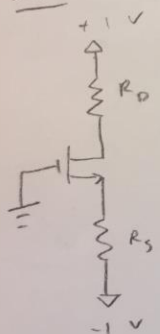
5.44



Establish:
$I_D = 0.1\ mA$
$V_{DS} = +0.3\ V$

$V_t = 0.5\ V$

$\mu_n C_{ox} = 400\ \frac{\mu A}{V^2} = 4\times10^{-4}\ \frac{A}{V^2}$

$L = 0.4\ \mu m$

$W = 5\ \mu m$

$V_{ov} = V_{GS} - V_T$

Saturation Region: $V_{DS} \geq V_{ov}$

???

$R_S = \frac{-0.7-(-1)}{0.1\times10^{-3}\ A} = \boxed{3\ k\Omega}$

$R_D = \frac{V_{DD}-V_D}{I_D} = \frac{+1\ V - 0.3\ V}{0.1\ mA} = \boxed{7\ k\Omega}$

$V_{DS} > V_t$: Saturation Region

$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}V_{ov}^2 = \frac{1}{2}\left(4\times10^{-4}\ \frac{A}{V^2}\right)\left(\frac{5}{0.4}\right)V_{ov}^2 = 0.1\times10^{-3}\ A$

$V_{ov} = 0.2\ V \qquad V_{GS} = V_t + V_{ov} = 0.7\ V$

50 $\quad +2.5\ V$

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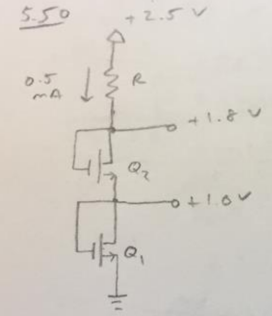
$V_{DS} > V_t$: Saturation Region

$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}V_{ov}^2 = \frac{1}{2}(4\times10^{-4}\,\frac{A}{V^2})(\frac{5}{0.4})\,V_{ov}^2 = 0.1\times10^{-3}\,A$

$V_{ov} = 0.2\,V \qquad V_{GS} = V_t + V_{ov} = 0.7\,V$

5.50



NMOS:

$V_t = 0.5\,V$

$\mu_n C_{ox} = 250\,\frac{\mu A}{V^2} = 250\times10^{-6}\,\frac{A}{V^2}$

$\lambda = 0$

$L_1 = L_2 = 0.25\,\mu m$

Find W_{Q_1}, W_{Q_2}, R to obtain indicated voltage, current values

$$R = \frac{2.5\,V - 1.8\,V}{0.5\,mA} = \boxed{1.4\,k\Omega}$$

Q_2: $V_{DS} = 1.8\,V - 1.0\,V = 0.8\,V > $ Saturation

$V_{GS} = 1.8\,V - 1.0\,V = 0.8\,V$

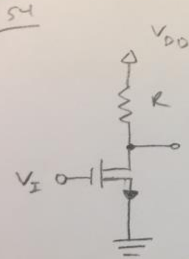
$$0.5\times10^{-3}\,A = \frac{1}{2}(250\times10^{-6}\,\frac{A}{V^2})(\frac{W}{0.25\,\mu m})(0.8\,V - 0.5\,V)^2 \qquad \boxed{W_2 = 11.1\,\mu m}$$

Q_1 : Also saturation

$$0.5\times10^{-3}\,A = \frac{1}{2}(250\times10^{-6}\,\frac{A}{V^2})(\frac{W}{0.25\,\mu m})(1.0\,V - 0.5\,V)^2 \qquad \boxed{W_1 = 4\,\mu m}$$

Sedra & Smith 5.54

5.54



$V_t = 0.4\ V$

$k'_n = 500 \times 10^{-6}\ \frac{A}{V^2}$

$\lambda = 0$

$V_I = V_{DD} = +1.3\ V \rightarrow r_{DS} = 50\ \Omega,\ V_o = 50\ mV$

Find $\frac{W}{L}$ and R

$V_{DS} = 50\ mV \rightarrow$ LINEAR region

$50\ \Omega = k'_n \frac{W}{L}\left(V_{ov} - \frac{1}{2}V_{DS}\right)$

$V_{ov} = V_I - 0.4\ V = 0.9\ V$

$\frac{1}{50}\ \Omega = \left(500 \times 10^{-6}\ \frac{A}{V^2}\right)\frac{W}{L}(0.9\ V - 0.025\ V)$

$\frac{W}{L} = 45.71$

$\frac{V_{DD} - V_o}{R} = I_D \longrightarrow \frac{(1.3\ V - 0.05\ V)}{R} = \left(500 \times 10^{-6}\ \frac{A}{V^2}\right)(45.71)(0.9 - 0.025)(0.05)$

$\boxed{R = 1.25\ k\Omega}$

$\boxed{\text{Let } L = 10\ \mu m \quad \text{Then } W = 457.1\ \mu m}$

$\frac{W}{L} = 4\ mA = 4 \times 10^{-3}\ A$, $\lambda = 0$

Sedra & Smith 5.55 (part a only)

5.55 $|V_t| = 1\text{ V}$, $k'\frac{W}{L} = 4\ \frac{mA}{V^2}$, $\lambda = 0$

(a) Assume Saturation:

$I_D = \frac{1}{2} k_n V_{ov}^2$ $\qquad V_{GS} = |V_t| + V_{ov} = 1+1 = 2\text{ V}$

$2 = \frac{1}{2}(4) V_{ov}^2$ $\qquad V_1 = 0 - V_{GS} = \boxed{-2\text{ V}}$

$V_{ov} = 1\text{ V}$ $\qquad V_2 = 5 - 2(2) = \boxed{1\text{ V}}$

$V_{DG} = +1\text{ V}$ → Saturation is correct

(b) Assume Saturation:

$I_D = \frac{1}{2} k_n V_{ov}^2$ $\qquad V_{GS} = |V_t| + V_{ov} = 1+1 = 2\text{ V}$

$2 = \frac{1}{2}(4) V_{ov}^2$ $\qquad \boxed{V_3 = 2\text{ V}}$

$V_{ov} = 1\text{ V}$

→ Saturation is correct

(c) Assume Saturation:

$I_D = \frac{1}{2} k_n V_{ov}^2$ $\qquad V_{SG} = |V_t| + V_{ov} = \boxed{2\text{ V} = V_4}$

$2 = \frac{1}{2}(4) V_{ov}^2$ $\qquad \frac{V_{DG} - -5}{1.5\text{ k}\Omega} = 2 \qquad V_{DG} = \boxed{-2\text{ V} = V_5}$

$V_{ov} = 1\text{ V}$

→ Saturation is correct

(d) Assume Saturation:

$I_D = \frac{1}{2} k_n V_{ov}^2$ $\qquad V_{SG} = 1+1 = 2\text{ V}$

$2 = \frac{1}{2}(4) V_{ov}^2$ $\qquad V_S - V_G = 2$

$V_{ov} = 1\text{ V}$ $\qquad 5 - V_6 = 2$

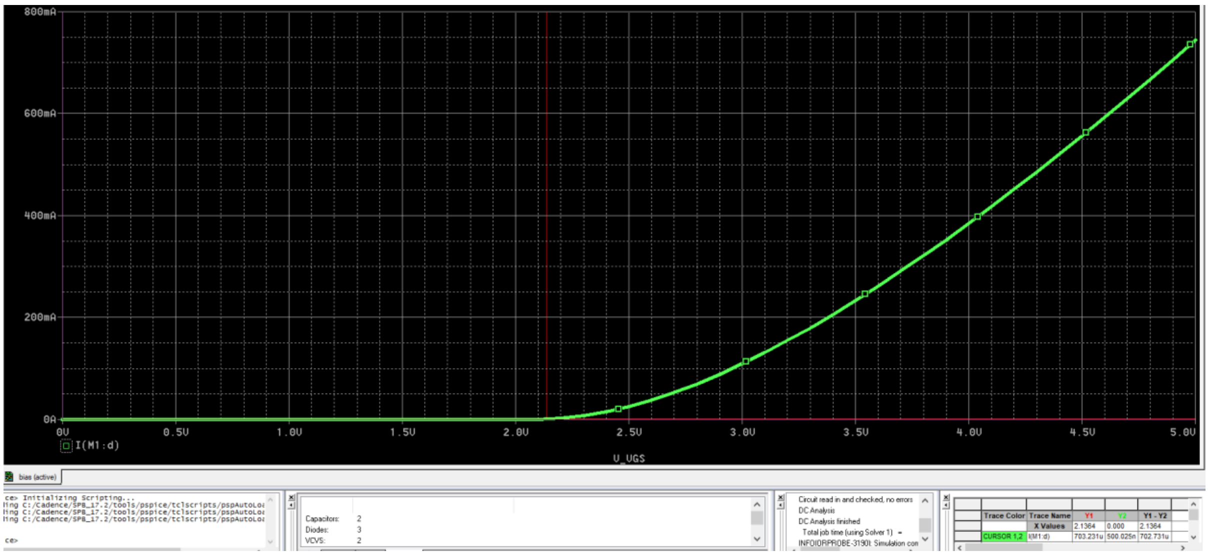
$\boxed{V_6 = 3\text{ V}}$

$V_6 - V_7 = 2$

$3 - V_7 = 2$

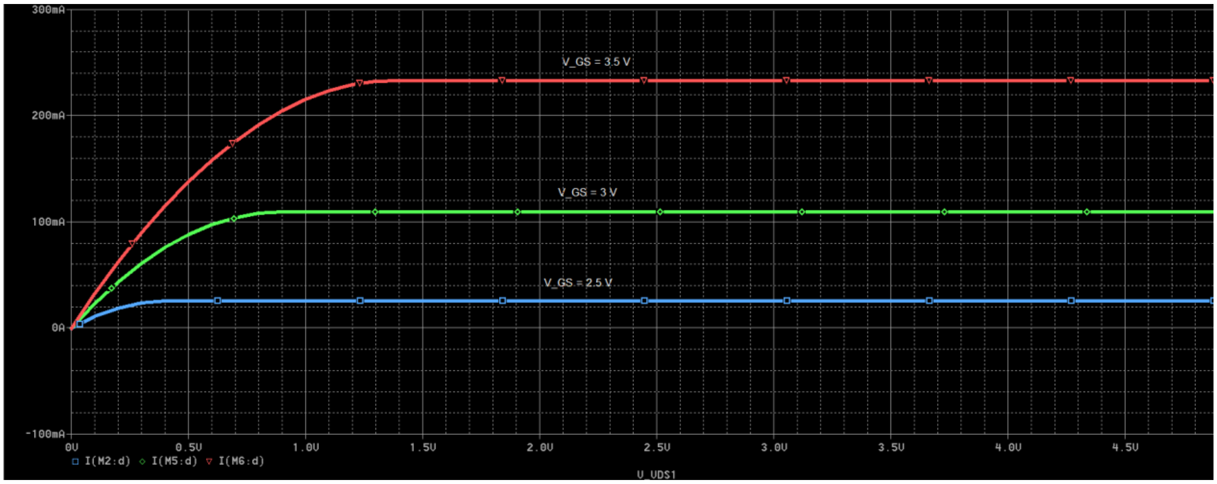
$\boxed{V_7 = 1\text{ V}}$

Simulation Exercise (a)



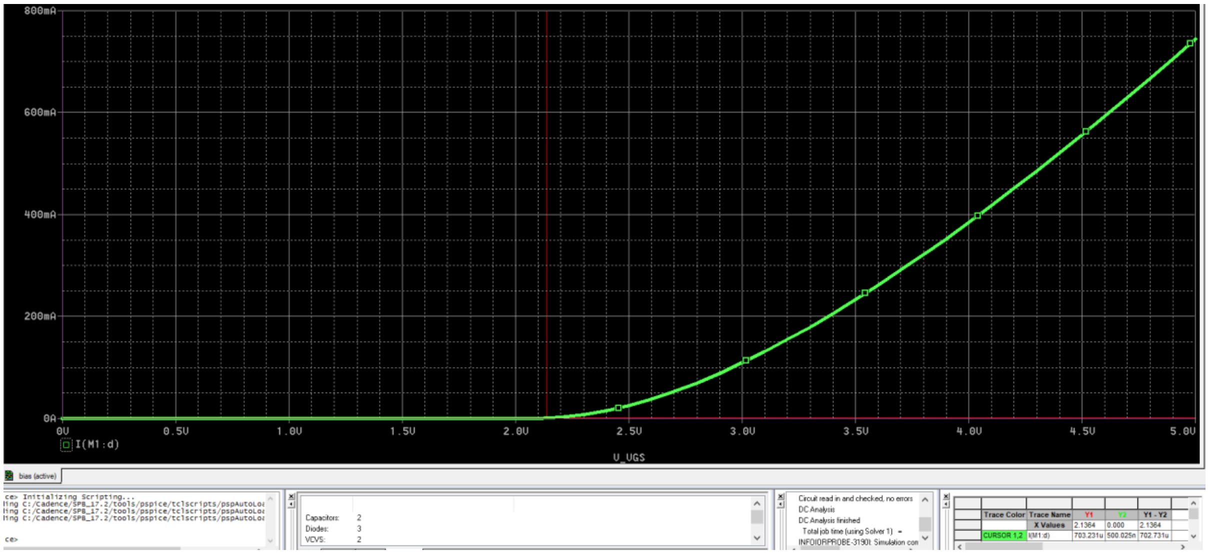
The current turns on at a value of 2.13 V.

Simulation Exercise (b)



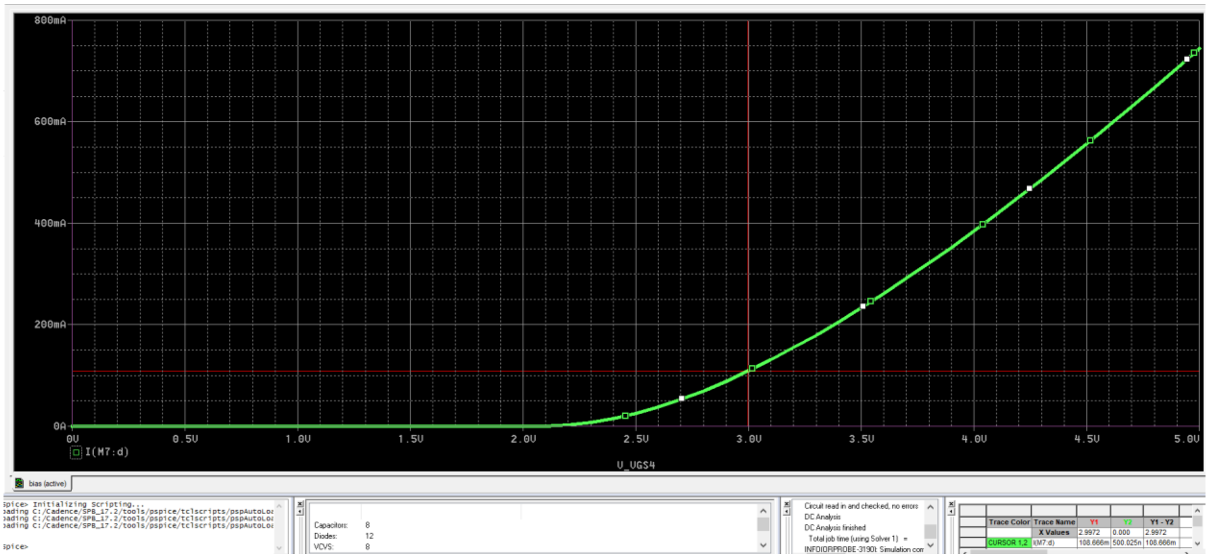
In case it is tough to see, the bottom line is V_GS = 2.5 V (blue), the middle is V_GS = 3 V (green), and the top line is V_GS = 3.5 V (red).

Simulation Exercise (c)



The NMOS turns on at a value of 2.13 V.

Simulation Exercise (d)



At V_{GS}= 3.0 V, i_D= 108.67 mA.

108.67 = $(1/2)k_n(V_{GS} – V_T)^2$ = $(1/2)\ k_n(3.0\ V – 2.13\ V)^2$

K_n = 287 mS

EXTRA PAGES

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