EECE 310 - Homework 6

Problem 1

a) $K'_n = \mu_e \frac{\varepsilon_{ox}}{t_{ox}} = 1000 \times 10^{-4} \times \frac{3.453\times10^{-11}}{7\times10^{-9}}$

$= 4.933 \times 10^{-4}\ A/V^2.$

b) $V_{ov} = V_{GS} - V_{to} = 3 - 0.55 = 2.45\ V.\ (V_{ov} > 0)$

$V_{DS} = 3\ V$

$V_{DS} > V_{ov} \rightarrow$ Mosfet in SAT.

$I_D = \frac{1}{2} K' \frac{W}{L} V_{ov}^2$

$\frac{W}{L} = \frac{I_D}{\frac{1}{2} K'_n V_{ov}^2} = \frac{10^{-3}}{\frac{1}{2} \times 4.933\times10^{-4} \times 2.45^2}$

$= 0.675$

~~L = 0.32 µm ; W = 0.32 × 0.675 = 0.216 µm~~

W = 0.32 um, and L = 0.32/0.675 = 0.474 um (L or W cannot be less than 0.32 um)

c) • I_{D1} at $(V_{GS} = 3V,\ V_{DS1} = 3V)$.

• $0.97\, I_{D1}$ at $(V_{GS} = 3V,\ V_{DS2} = 2.5\ V)$

$(2.5 > 2.45 = V_{ov}$, we still in SAT).

Thus

$$\begin{cases} I_{D_1} = \frac{1}{2} K' \frac{W}{L} V_{ov}^2 \left(1 + \frac{V_{DS1}}{V_A}\right) \\ 0.97 I_{D_1} = \frac{1}{2} K' \frac{W}{L} V_{ov}^2 \left(1 + \frac{V_{DS2}}{V_A}\right) \end{cases}$$

$$0.97 = \frac{V_A + 2.5}{V_A + 3}$$

$$V_A = \frac{\frac{2.5}{0.97} - 3}{1 - \frac{1}{0.97}} = 13.67V.$$

$$V'_A = \frac{V_A}{L} = \frac{13.67}{\sout{0.82}} = \sout{42.71} \ V/\mu m.$$

0.474

29 V/um

Problem 2

$V_{GG} = 2.5V$, $R = 4.7K$, $V_t = 0.55V$, $K'\frac{W}{L} = 0.4 mA/V^2$

a) The mosfet is operating in the triode region.

$$\begin{cases} V_{OV} > 0 & \text{(this condition is satisfied)} \\ V_{DS} < V_{OV} \rightarrow V_{output} < V_{GG} - V_t \end{cases}$$

Thus $V_0 < 2.5 - 0.55 = 1.95V$

Current equation:

$$I_D = \frac{1}{2} K'\frac{W}{L} \left(2 V_{OV} V_{DS} - V_{DS}^2 \right)$$

Linear term $= 2 V_{OV} V_{DS}$

Square term $= V_{DS}^2$

Square term < 3% of the linear term

$$V_{DS}^2 < 0.03 \times 2 \times V_{OV} \times V_{DS}$$

Since $V_{OV} > 0$, V_{DS} is necessarily positive thus:

$$V_{DS} < 0.06\, V_{OV} = 0.117V$$

Thus $\boxed{0 < V_0 < 0.117V}$

b) $V_{ov} = V_{GS} - V_t$

$= V_{GG} - V_t$

$= 2.5 - 0.55$

$= 1.95\ V$

$g_{DS} = K' \frac{W}{L} V_{ov}$

$= 0.4 \times 1.95$

$= 0.78\ m\Omega^{-1}$

$r_{DS} = \frac{1}{g_{DS}} = 1.282\ K\Omega.$

c)

$$\frac{V_o}{V_s} = \frac{r_{DS}}{r_{DS} + R} = \frac{1}{1 + R\, g_{DS}}$$

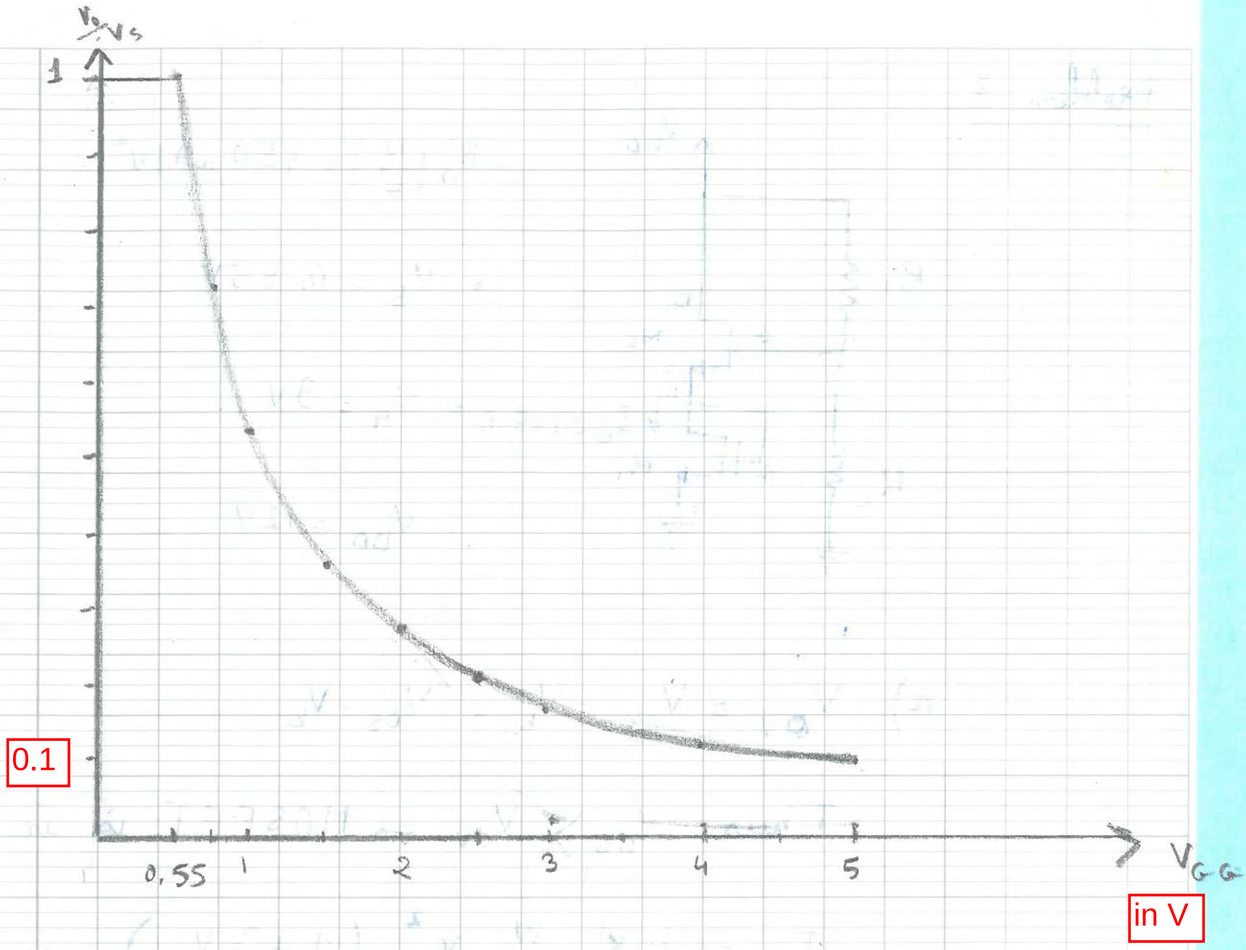
$$= \frac{1}{1 + 4.7 \times 0.4 \times (V_{GG} - 0.55)}$$

$$\frac{V_o}{V_s} = \frac{1}{1.88\, V_{GG} - 0.034} \rightarrow \text{\#/ans}$$

The above equation is always satisfied when $V_{ov} > 0 \rightarrow V_{GG} > V_t \rightarrow V_{GG} > 0.55V$

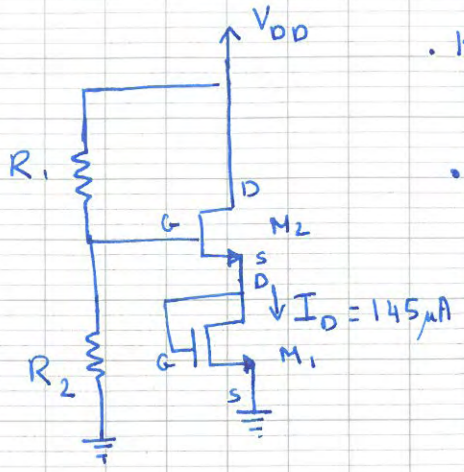
For $0 < V_{GG} \leq 0.55V$, Mosfet → Cutoff region.

$\frac{V_o}{V_s} = 1$ in this case.



Vo/Vs
1
0.1
0,55
1
2
3
4
5
VGG
in V

Problem 3



- $K'_n \left(\frac{W}{L}\right) = 450\, \mu A / V^2$
- $V_t = 0.55V$
- $V_A = 9V$
- $V_{DD} = 12V$

a) $V_{OV} = V_{GS} - V_t = V_{DS} - V_t$

Thus $V_{DS} > V_{OV} \rightarrow$ MOSFET is in SAT.

$I_D = \frac{1}{2} K'_n \frac{W}{L} V_{OV}^2 (1 + \lambda V_{DS})$

$(V_{GS} > V_t = 0.55V)$.

$$I_D = \frac{1}{2} K'_n \frac{W}{L} (V_{GS} - V_t)^2 (1 + \lambda V_{GS})$$

$$(V_{GS}^2 - 2 V_{GS} V_t + V_t^2)(1 + \lambda V_{GS}) = \frac{2 I_D}{K'_n \frac{W}{L}}$$

$$V_{GS}^2 + \lambda V_{GS}^3 - 2V_t V_{GS} - 2V_t \lambda V_{GS}^2 + V_t^2 + \lambda V_t^2 V_{GS} = \frac{2 I_D}{K'_n \frac{W}{L}}$$

$$\frac{1}{9} V_{GS}^3 + \frac{79}{90} V_{GS}^2 - 1.066 V_{GS} + 0.55^2 - \frac{2 \times 145}{450} = 0$$

$$V_{GS2} = 1.3 \text{ V}$$

b) Assume M_1 in SAT $\rightarrow \begin{cases} v_{OV1} > 0 \\ V_{DS1} > v_{OV1} \end{cases}$

$$I_D = \frac{1}{2} K' \frac{W}{L}_n (V_{GS1} - V_t)^2 \left(1 + \frac{V_{DS1}}{V_A}\right)$$

$$V_{GS1} = V_t + \sqrt{\frac{2 I_D}{K' \frac{W}{L} \left(1 + \frac{V_{DS1}}{V_A}\right)}}$$

$$V_{G1} = \underset{\overset{\parallel}{V_{G2}}}{V_{S1}} + V_t + \sqrt{\frac{2 I_D}{K' \frac{W}{L} \left(1 + \frac{V_{DS1}}{V_A}\right)}}$$

$$= 1.3 + 0.55 + \sqrt{\frac{2 \times 145}{450 \left(1 + \frac{12 - 1.3}{9}\right)}}$$

$$= 2.39 \text{ V}$$

$$v_{OV1} = 2.39 - 0.55 = 1.84 < V_{DS1} = 12 - 1.3 = 10.7 \text{ V}$$

Thus M1 : SAT.

c) $I_{Gate} = 0$

Thus $I_{R1} = I_{R2}$

$$\frac{V_{DD} - V_{G1}}{R_1} = \frac{V_{G1}}{R_2}$$

$$R_1 = \frac{R_2 (V_{DD} - V_{G1})}{V_{G1}}$$

$$= \frac{120(12 - 2.39)}{2.39}$$

$$= 482.51 \text{ k}\Omega$$

~~≈ 637.98 kΩ~~

d) $P = V_{DD} (I_{R2} + I_D)$

$$= 12 \times \left(\frac{2.39}{120} + 0.145 \right)$$

~~2.78 mA~~

$$= 1.979 \text{ mW}$$