Assignment 4

CSE251

Fall 22

Name : Shihab Muhtasim

sec : 13

ID : 21301610

Ans to Q.1
part(a)

(a) $V_G = 0V$

$I_{DS} = 4mA$

(b) $I_{DS} = \frac{5 - V_D}{R}$

$\Rightarrow V_D = 5 - (I_{DS} \times 1) = 5 - 4 = 1V$

(c) Let, the circuit 1 is in saturation region,

$I_{DS} = \frac{k(V_{GS} - V_T)^2}{2}$ | Let, $V_S = x$

$\Rightarrow 4 \times 2 = 4(V_{GS} - 1)^2$

$\Rightarrow (0 - V_S - 1)^2 = 2$

$\Rightarrow (-x - 1)^2 = 2 \Rightarrow x^2 - 2 \cdot (-x) \cdot 1 + 1 = 2$

$\Rightarrow x^2 + 2x + 1 = 0$

$x_1 = -1 + \sqrt{2}$

$x_2 = -1 - \sqrt{2}$

Validate :

① $V_{GS} \geq V_T$

$\Rightarrow (V_G - x_1) \geq 1$

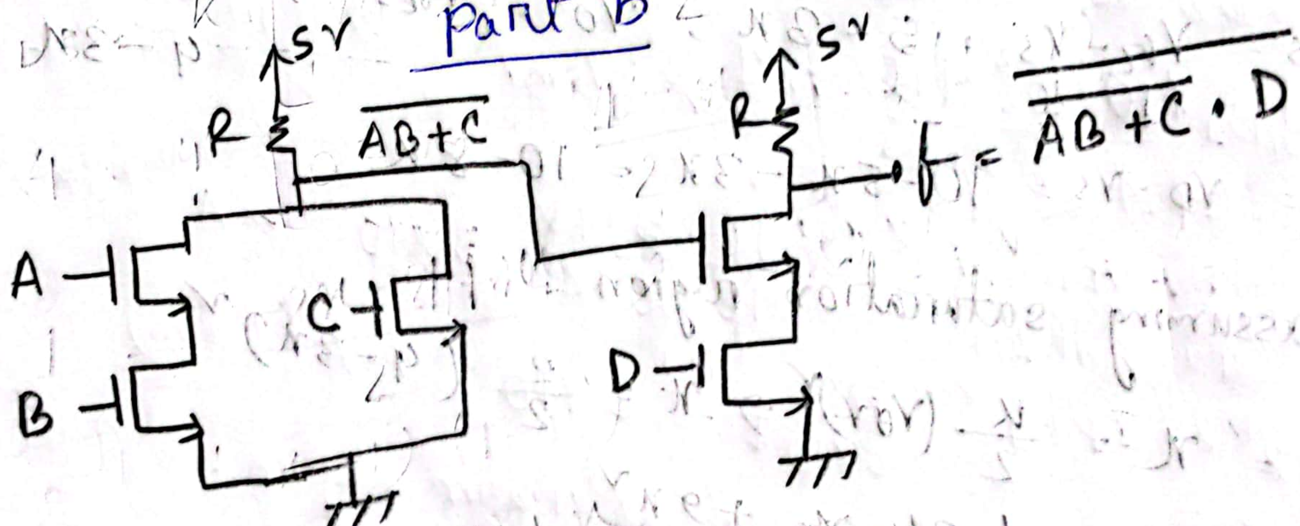
$\Rightarrow [0-(-1+\sqrt{2})] \ngeq 1 \Rightarrow 1-\sqrt{2} \ngeq 1$ $[x_1 = -1+\sqrt{2}]$

and, $[0-(-1-\sqrt{2})] \geq 1 \Rightarrow 1+\sqrt{2} \geq 1$ $[x_2 = -1-\sqrt{2}]$

$\therefore$ This assumption was correct.

$\therefore V_S = x_2 = (-1-\sqrt{2})\,V$

part b

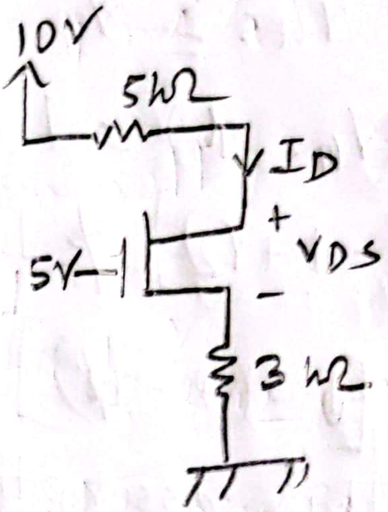


$f = \overline{\overline{AB+C} \cdot D}$

Ans to Q 2

Let,
$I_D = x$

$V_T = 1V$
$k = 2\ mA/V^2$



For $5k\Omega$:

$I_D = \frac{10 - V_D}{5} \Rightarrow V_D = 10 - 5I_D$

$\therefore V_D = 10 - 5x$

For $3k\Omega$,

$I_D = \frac{V_S}{3} \Rightarrow V_S = 3x$

$\therefore V_{GS} = V_G - V_S = 5 - 3x$, $V_{OV} = V_{GS} - V_T = 5 - 3x - 1$
$= 4 - 3x$

$V_{DS} = V_D - V_S = 10 - 5x - 3x = 10 - 8x$

Now, assuming saturation region.

$I_D = x = \frac{k}{2}(V_{OV})^2 \Rightarrow x = \frac{2}{2}(4-3x)^2$

$\Rightarrow x = 16 - 24x + 9x^2$

$\Rightarrow 9x^2 - 25x + 16 = 0$

$x_1 = \frac{16}{9}$, $x_2 = 1$

varify: if $x_1 = \frac{16}{9}$ mA,

$V_{GS} = 5 - \frac{3 \times 16}{9} = -\frac{1}{3} \ngtr V_T$

Taking $x_2 = 1\,mA$,

① $V_{GS} = 5 - 3 = 2 \geq V_T = 1$

② $V_{DS} = 10 - 8 = 2 \geq V_{OV} = 4 - 3 = 1$

$\therefore I_D = 1\,mA$

$V_{DS} = 2\,V$

Ans to qr 3

Given, $L = 0.18\,\mu m$, $W = 24\,m$, $k_n' = \underline{387 \times 10^{-3}}\, mA/V^2$

$V_t = 0.5\,V$, $I_{DS} = 150 \times 10^{-3}\, mA$

In saturation region,

$I_{DS} = \frac{k}{2} (V_{GS} - V_T)^2$

$\Rightarrow 150 \times 10^{-3} = \frac{4.3}{2} (V_{GS} - 0.5)^2$

$k = k_n' \frac{W}{L} = 387 \times 10^{-3} \times \frac{24}{0.18} = 4.3$

Let, $V_{GS} = x$

$\Rightarrow \frac{3}{43} = x^2 - x + \frac{1}{4}$

$\Rightarrow x^2 - x + \frac{31}{172} = 0$

$x_1 = 0.764 \geq V_t$, $x_2 = 0.235 \ngeq V_t$

$\therefore V_{GS} = 0.764\,V$ [Ans]

At the edge of saturation,

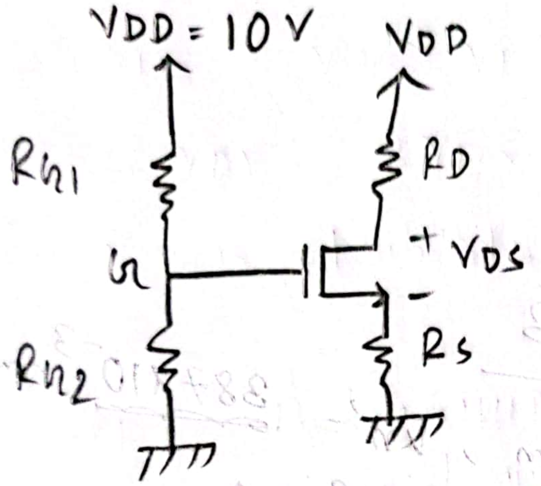
$V_{DS} = V_{OV} = V_{GS} - V_t = 0.764 - 0.5 = 0.264\,V$

$\therefore V_{DS} = 0.264\,V$ [Ans]

Ans to Q 4

Given, $V_T = 1V$, $k = \mu_n \left(\frac{W}{L}\right) = 1\ mA/V^2$,

$I_G = 0$



Finding thevenin voltage:

$$\frac{V_{DD} - V_G}{R_{G1}} = I_G + \frac{V_G}{R_{G2}}$$

$$\Rightarrow R_{G2}V_{DD} - R_{G2}V_G = V_G R_{G1} + 0$$

$$\Rightarrow V_G = \frac{R_{G2} \times V_{DD}}{R_{G1} + R_{G2}}$$

$$\therefore V_G = \frac{10\times10^3 \times 10}{2\times10 \times 10^3} = 5V \text{ (ans)}$$

$$I_{RG1} = \frac{V_{DD} - V_G}{R_{G1}} = \frac{10-5}{10\times10^3} = 5\times10^{-4}\ mA \text{ (ans)}$$

$$I_{RG2} = I_{RG1} = \frac{5}{10\times10^3} = 5\times10^{-4}\ mA \text{ (ans)}$$

Now, $V_G = 5V$; Assuming saturation region.

$$I_{DS} = \frac{k}{2}(V_{GS} - V_T)^2 \Rightarrow I_{DS} = \frac{(5 - V_S - 1)^2}{2} = \frac{(4 - V_S)^2}{2} \quad \text{—— (1)}$$

$$I_{DS} = \frac{V_S}{R_S} \Rightarrow I_{DS} = \frac{V_S}{6} \quad \text{—— (2)}$$

From ① and ②,

$\frac{V_S \times 2}{6} = (4-V_S)^2 \Rightarrow \frac{V_S}{3} = 16 + (V_S)^2 - 8V_S$

$\Rightarrow V_S = 48 + 3V_S^2 - 24V_S$

$\Rightarrow 3V_S^2 - 25V_S + 48 = 0$

$V_{S1} = \frac{16}{3}V, \quad V_{S2} = 3V$

if $V_{S1} = \frac{16}{3}V$, $V_{GS} = 5 - \frac{16}{3} = -\frac{1}{3} \ngeq V_T$

$\therefore V_S = 3V$ (ans)

Now, V_D:

$\frac{10 - V_D}{6} = \frac{(4-V_S)^2}{2} \Rightarrow \frac{10 - V_D}{3} = 16 + V_S^2 - 8V_S$

$\Rightarrow -V_D = 38 + 3V_S^2 - 24V_S$

$\Rightarrow V_D = -3V_S^2 + 24V_S - 38$ (ans)

$\Rightarrow V_D = 7V \quad [V_S = 3V]$

$\therefore$ varify: ① $V_{GS} = 5 - 3 = 2V \geq V_T = 1$

② $V_{DS} = 7 - 3 = 4 \geq (V_{GS} - V_T) = (2-1) = 1$

$V_{DD} = 10V$ (ans)

$I_{DS} = \frac{V_S}{6} = \frac{3}{6} = 0.5\ mA$ [ans]

BONUS

(i) In saturation, $V_{DS} \geq V_{GS} - V_T$

At the edge of saturation,

$$V_{DS} = V_{GS} - V_T = V_{OV}$$

$$\Rightarrow 2V_{OV} = 2V_{DS}$$

$\therefore$ If V_{OV} is doubled V_{DS} should be doubled too.

(ii) I_{D1} = Before current

I_{D2} = changed current.

$$I_{D1} = \frac{k}{2} \times (V_{OV})^2 \Rightarrow (V_{OV})^2 = \frac{2 I_{D1}}{k} \quad \text{--- (1)}$$

Now, $I_{D2} = \frac{k}{2} (2V_{OV})^2 \Rightarrow \frac{4k}{2} (V_{OV})^2$

$\therefore I_{D2} = 2k \times \frac{2 I_{D1}}{k}$ [from 1]

$\Rightarrow I_{D2} = 4 I_{D1}$

Drain current will be multiplied by 4.

(iii) Changing V_{OV} doesn't change process parameter k_n'. $k_n' = \mu_0 C_{ox}$ which depends on how the mosfet is made. However, In $k = k_n' \frac{W}{L}$, k will change if V_{OV} is changed as the W and L depends on V_{OV}.