CSE251

Assignment - 03

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Section : 18

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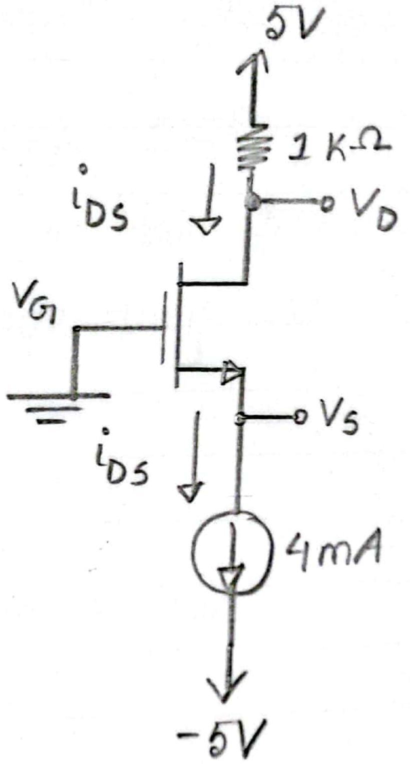
Answer to the Question NO-01 (a)

Given,



Circuit : 1

Given,

$V_T = 1\,V$

$K = K_n' \frac{W}{L}$

$= 4\,mA/V^2$

$\because V_G$ is grounded.

$\boxed{\therefore V_G = 0\,V}$ (Ans:)

And,

According to KCL,

current that in the loop always remains same.

$\therefore i_{DS}$ will be equal as the current source.

$\boxed{\therefore i_{DS} = 4\,mA}$ (Ans:)

Answer to the Q. NO – 01 (b)

$\because R_D = 1\ K\Omega$ [Given in the figure]

This current through $1K\Omega = 10^3\Omega$ resistor is equal as the drain-source ~~as~~ of current; since they are in series connection.

Here,

$V_D = 5V$

$R_D = 1\ K\Omega$
$= 1\times 10^3\ \Omega$

$i_{DS} = 4\ mA$ [from('a')]
$= 4\times 10^{-3}\ A$

Now,

Applying Ohm's Law,

$$i_{DS} = \frac{5 - V_D}{R_D}$$

$$\Rightarrow V_D = 5 - i_{DS} R_D$$

$$\Rightarrow V_D = 5 - (4\times 10^{-3} \times 1\times 10^3)$$

$$\Rightarrow V_D = 1V$$

$\boxed{\therefore V_D = 1V}$ (Ans:)

Answer to the Q. NO - 01 (c)

Let's assume,

$$V_S = x$$

Assuming that,
the MOSFET is in the Saturation Mode :-

$$\therefore \ i_D = \frac{K}{2}\left(V_{GS} - V_T\right)^2$$

Here,
$K = 4mA/V^2$
$V_T = 1V$
$V_{ov} = V_{GS} - V_T$
$= -x - 1$
$V_G = 0V$ [from ('a')]

Now,

$$V_{GS} = V_G - V_S$$
$$= 0 - x \qquad [\because V_G = 0V]$$
$$\therefore \boxed{V_{GS} = -x \ V}$$

Here,

$$V_{ov} = V_{GS} - V_T$$
$$= -x - 1$$

$$\therefore \ i_{DS} = \frac{K}{2} V_{ov}^2$$
$$\Rightarrow 4 = \frac{4}{2}(-x-1)^2$$
$$\Rightarrow (-x-1)^2 = 1$$
$$\Rightarrow x^2 + 2x + 1 = 0$$
$$\Rightarrow x^2 + 2x + 1 = 0$$

$\therefore x = 0$ or $x = 2$

$\therefore V_S = -2$ $\left[\because \text{We assumed, } V_S = x\right]$

$\therefore V_{GS} = V_G - V_S$

$= 0 - (-2)$

$= 2 > V_T$

$\therefore V_{ov} = 1V$

$\therefore V_{DS} = V_D - V_S$

$= 1 - (-2)$

$= 3\,V > V_{ov}$

$\therefore$ our ~~eo~~ assumption is correct.

The MOSFET is in the saturation Mode.

$\therefore V_S = -2V$

(Ans:)

Ans. to the Q. NO - 2

Given,

$V_{SS} = 6V$

$V_T = 0.9V$

$R_L = 5K\Omega$
$= 5\times10^3\Omega$

$K'_n V_{ov} = 0.25$

We know,

$$V_{SS}\frac{R_{on}}{R_L + R_{on}} < V_T$$

$$\Rightarrow 6\times\frac{R_{on}}{5+R_{on}} < 0.9$$

$$\Rightarrow 6\times R_{on} < 0.9\,(5+R_{on})$$

$$\Rightarrow 6\times R_{on} < (4.5 + 0.9\,R_{on})$$

$$\Rightarrow 5.1\,R_{on} < 4.5$$

$$\Rightarrow R_{on} < 0.8823 \quad \text{— (i)}$$

Again,

$$R_{on} = \frac{1}{K'_n\frac{W}{L}V_{ov}}$$

$$\Rightarrow R_{on} = \frac{1}{\frac{W}{L}}\left(\frac{1}{K'_n V_{ov}}\right)$$

$$\Rightarrow R_{on} = \frac{L}{W}\times 4 \quad \text{— (ii)}$$

$\therefore$ from (i) & (ii) $\Rightarrow$

$$\frac{L}{W}\times4 < 0.8823$$

$$\Rightarrow \frac{L}{W} < \frac{0.8823}{4}$$

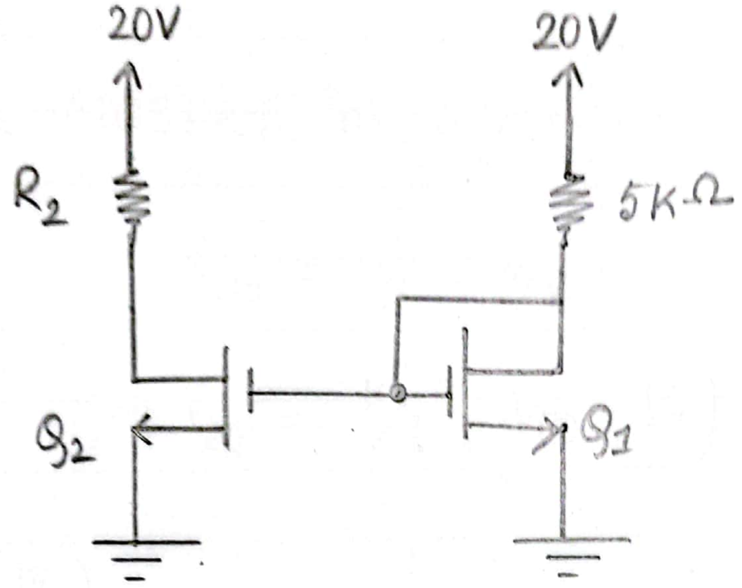
$$\Rightarrow \frac{L}{W} < 0.2205$$

$$\boxed{\therefore \frac{W}{L} < 4.535}$$

(Ans:)

Answer to the Q. NO - 03 (a)

Given figure,



Given,

$K'n = 2mA/V^2$

$\frac{W}{L} = 2.5$

$V_T = 0.5V$

As we know,

$$V_{DS} = V_D - V_S$$

$$V_{GS} = V_G - V_S$$

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

Now,

$V_G = V_D$

$V_S = 0$

$\therefore V_{GS} = V_G = V_D$

$\therefore V_{DS} = V_G$

Again,

$V_{ov} = V_G - V_T$

$V_{DS} = V_G$

$\therefore V_{DS} > V_{ov}$

$\therefore$ The MOSFET is in the saturation mode. (Ans:)

Answer to the Q. NO - 03 (b)

We know,

For a MOSFET in Saturation Mode,

$$i_{DS} = \frac{1}{2} K V_{ov}^2$$

$$\Rightarrow i_{DS} = K/2 \left(V_{DS} - V_T\right)^2$$

Given,
$K'n = 2mA/V^2$
$\frac{W}{L} = 2.5$
$V_T = 0.5\,V$

Here,

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

$$= 2 \times 2.5$$

$$\therefore K = 5$$

And, $V_{ov} = V_{DS}$ (Which is at saturation edge)

Now, By applying KVL,

we get,

$$20 - 0 = 5 I_{D_I} + V_{DS}$$

$$\Rightarrow 20 = 5 I_{D_I} + V_D$$

$$\Rightarrow V_D = 20 - 5 I_{D_I} \quad \text{--- (1)}$$

Now, $I_{D_I} = \frac{5}{2} \left(20 - 5 I_{D_I} - 0.5\right)^2$

$$\Rightarrow I_{D_I} = 5/2 \left(19.5 - 5 I_{D_I}\right)$$

$$\Rightarrow 2I_{D_1} = 5\left\{(19.5)^2 - 2\times 19.5\times 5I_{D_1} + (5I_{D_1})^2\right\}$$

$$\Rightarrow 125I_{D_1}^2 - 977I_1 - 5\times(19.5)^2 = 0$$

$$\therefore I_{D_1} = 3.658 \text{ mA} \quad \text{or}$$

$$I_{D_1} = 4.157 \text{ mA}$$

$\therefore$ Now, $V_D = 20 - 5(3.658)$

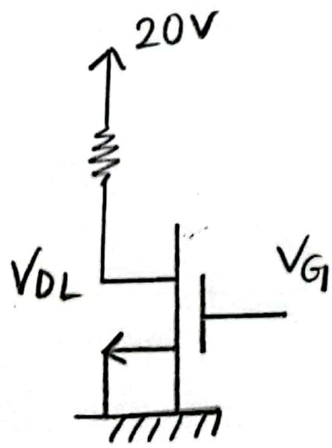
$$= 1.71 \text{ V}$$

$$\because V_{GS_1} = V_{GS_2} = V_G$$

$$\therefore I_{D_1} = I_{D_2}$$

And if we change V_{GS},

it will be like :-



$\therefore I_{D_1} = I_{D_2} = 3 \cdot 658 \text{ mA}$

$V_{DS_L} = 20 - I_{D_2} \times R_2$

$\Rightarrow 1 \cdot 21 = 20 - 3 \cdot 658 \times R_2$

$\Rightarrow R_2 = \dfrac{10 - 1 \cdot 21}{3 \cdot 658}$

$\boxed{\therefore R_2 = 5 \cdot 136 \text{ K}\Omega}$

(Ans:)

Here,

$\because V_{DS_L} = V_{GS} - V_T$

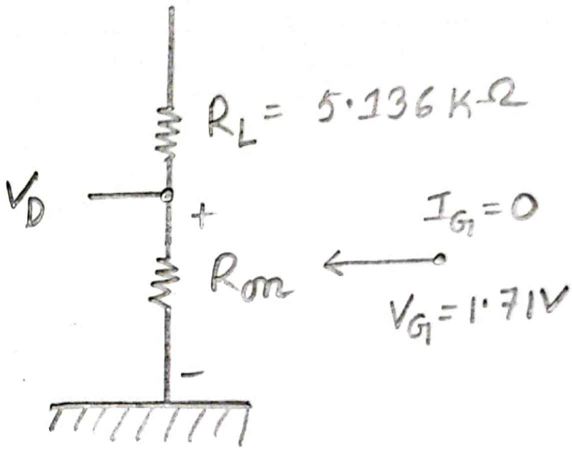
$\Rightarrow V_{DS_L} = (1 \cdot 71 - 0 \cdot 5) V$

$= 1 \cdot 21 V$

Answer to the Q. NO- 03(c)

Calculating the on-state resistance, R_{on} :- (for Q_2)

As we know,



$$V_{GS} = V_G - V_S$$

$$V_{OV} = V_{GS} - V_T$$
$$= (1.71 - 0.5)\ V$$
$$= 1.21\ V$$

Again,

$$R_{on} = \frac{1}{K_n' \left(\frac{W}{L}\right) V_{OV}}$$

$$= \frac{1}{2 \times 2.5 \times 1.21}$$

$$\boxed{\therefore R_{on} = 0.16529\ K\Omega}$$

(Ans:)

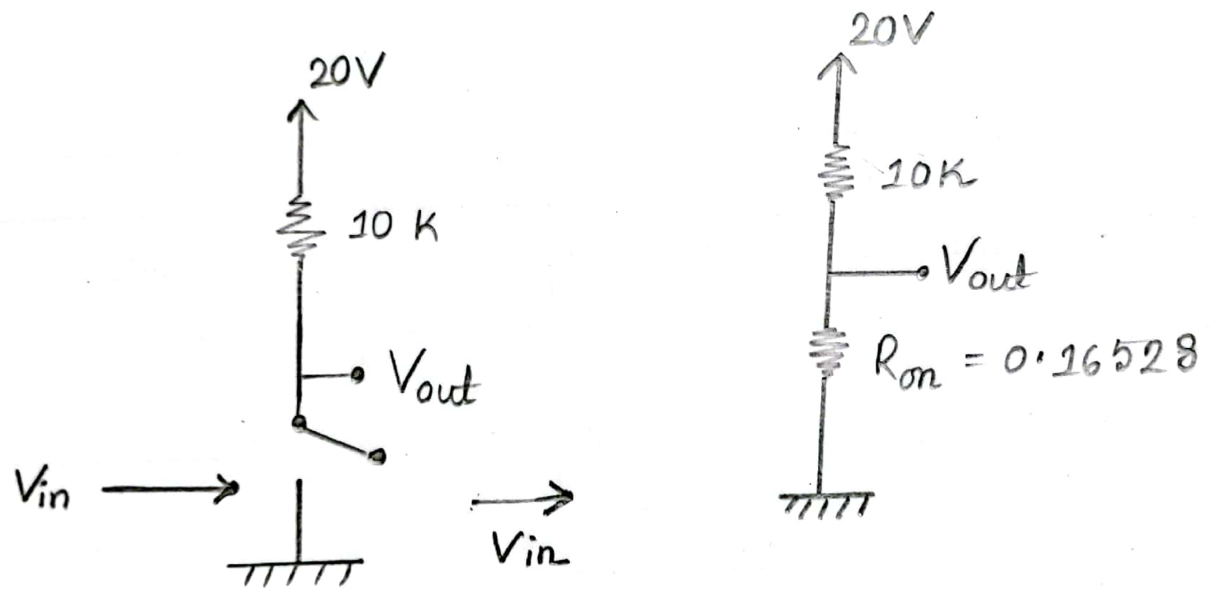
Answer to the Q. NO- 03(d)

Given,

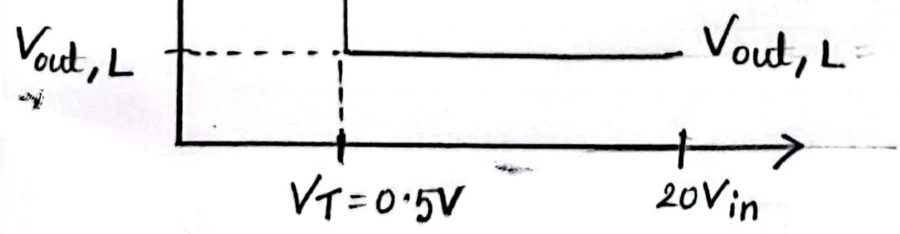
an inverter is designed using Q2 and a 10K resistor

Now,

drawing the circuits for better visualization;



∴ VTC graph for the inverter:



Now,

$V_{out,H} = 20V$

$$V_{out,L} = 20 \times \frac{0.1658}{0.16528+10}$$

$$= 0.3251V < V_T$$

Given function,

$$F = \overline{A\overline{B}+C}$$

Applying Morgan's Law:-

$$\overline{A\overline{B}+C} = \overline{A} \cdot \overline{\overline{B} \cdot C}$$