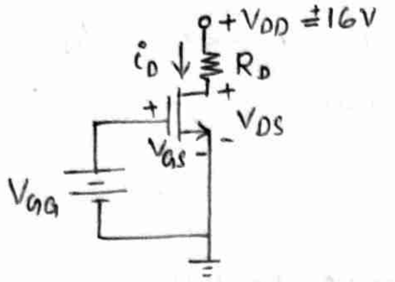
EE 101 : Tutorial 10

(22-10-2021)

Q.1)



Given $R_D = 250\Omega$ $K = 0.25\ mA/V^2$ $V_t = 2V$

and $i_D = 4mA$.

Solnⁿ : Assuming MOSFET is in saturation region,

$$i_D = K(V_{GS} - V_t)^2$$

$$4mA = 0.25 mA/V^2 (V_{GG} - 2)^2 \quad \therefore [\text{Here } V_{GS} = V_{GG}]$$

by Solving, $V_{GG} = 6V, -2V$.

for MOSFET to be turned on,

$$V_{GS} > V_t$$

ie, $\boxed{V_{GG} = 6V}$

for checking the validity of assumption,

for MOSFET to be in saturation

$$V_{DS} \geq V_{GS} - V_t$$

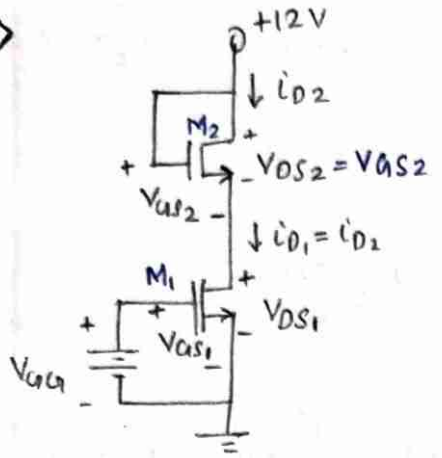
$$V_{DS} = V_{DD} - i_D R_D = 16 - 4\times10^{-3}\times250$$

$$= 15V$$

ie, $V_{DS} > V_{GS} - V_t$

So Assumption is correct.

Q.2)



Given: $K = 0.25\,mA/V^2$ $V_t = 2V$ $V_{GG} = 6V$

$M_1 \rightarrow$ active region

Solu^n: M_1 is in active region

ie, $i_{D_1} = K(V_{GS_1} - V_t)^2$

$= 0.25\times10^{-3}(6-2)^2 \quad \therefore [V_{GS_1} = V_{GG} = 6V]$

$\boxed{i_{D_1} = 4\,mA}$

$i_{D_1} = i_{D_2}$ ie, $\boxed{i_{D_2} = 4\,mA}$

here gate of M_2 connected to drain of M_2.

ie, $V_{GS_2} = V_{GS_2}$

ie, $V_{DS_2} > V_{GS_2} - V_t \Rightarrow M_2$ is in saturation region.

ie, $i_{D_2} = K(V_{GS_2} - V_t)^2$

$4\times10^{-3} = 0.25\times10^{-3}(V_{GS_2} - 2)^2$

by solving we get $V_{GS_2} = 6V, -2V$

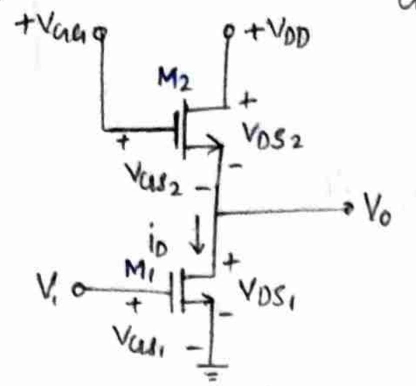
for M_2 to be ON, $V_{GS_2} > V_t$.

ie, $\boxed{V_{GS_2} = 6V = V_{DS_2}}$

$V_{DS_1} + V_{DS_2} = 12V$

ie, $\boxed{V_{DS_1} = 12 - 6 = 6V}$

Q3)



Given : $V_{GG} = 13V$ $V_{DD} = 12V$ $V_t = 2V$ $K_1 = 0.25 mA/V^2$

$V_1 = 12V$

$M_1 \rightarrow$ in ohmic region.

Solnⁿ : case (a) $K_2 = 0.25 mA/V^2$

from the circuit, $i_{D_1} = i_{D_2}$ & $V_{GS_1} = 12V$

$$i_{D_1} = K_1 \left[2(V_{GS_1} - V_t) V_{DS_1} - V_{DS_1}^2\right]$$

for MOSFET M_2 : $V_{DS_2} = V_{DD} - V_o$ and $V_{GS_2} = V_{GG} - V_o$

$= 12 - V_o$ $= 13 - V_o$

$$V_{GS_2} - V_t = 11 - V_o < V_{DS_2}$$

ie, M_2 is in saturation.

ie, $i_{D_1} = i_{D_2}$ (∴ from circuit)

$$K_1 \left[2(V_{GS_1} - V_t) V_{DS_1} - V_{DS_1}^2\right] = K_2 \left[V_{GS_2} - V_t\right]^2 \quad \text{—} ①$$

Substituting values for $K_1, K_2, V_t, V_{GS_1}, V_{GS_2}$

we get $2(12-2) V_{DS_1} - V_{DS_1}^2 = [11 - V_o]^2$

$V_{DS_1} = V_o$ $\Rightarrow$ $20 V_o - V_o^2 = 121 - 22 V_o + V_o^2$

$$2V_o^2 - 42 V_o + 121 = 0 \quad \text{—} ②$$

Solving this equation, we get

$V_o = 17.55V, 3.446V$

for M_1 to be in ohmic region : $V_{DS_1} < V_{GS_1} - V_t = 10V$

ie, $\boxed{V_o = 3.446V}$

Case (b) : $K_2 = \underline{0.05\,mA/V^2}$

$i_{D_1} = i_{D_2}$

$K_1 \left[2(V_{GS_1} - V_t)V_{DS_1} - V_{DS_1}^2\right] = K_2 \left[V_{GS_2} - V_t\right]^2$

as $V_{DS_1} = V_0$.

$$0.25\left[2[12-2]V_0 - V_0^2\right] = 0.05\left[11 - V_0\right]^2$$

$$5[20V_0 - V_0^2] = 121 - 22V_0 + V_0^2$$

rearranging : $6V_0^2 - 122V_0 + 121 = 0$ — ③

by solving the above equation we get

$V_0 = \underline{\underline{19.28V}}, 1.045V$

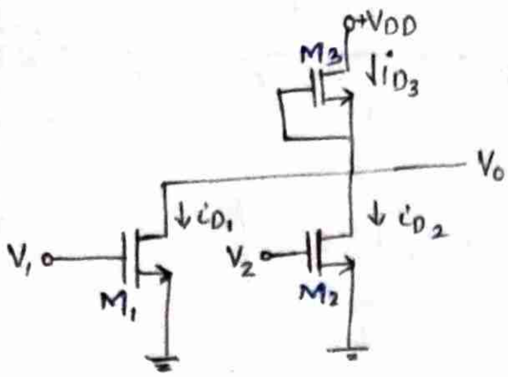
for M_1 to be in ohmic region,

$V_{DS_1} < V_{GS_1} - V_t$ ie, $V_{DS_1} < 12 - 2$

$V_{DS_1} < 10V$

$\Rightarrow$ $\boxed{V_0 = 1.045\,V}$ (here $V_{DS_1} = V_0$)

Q4>



given: $V_{DD} = 12V$, $V_t = 2V$ [enhancement MOSFET]

$k = 0.25 mA/V^2$

for depletion MOSFET: $I_{DSS} = 4mA$ and $V_p = -4V$

$V_1 = V_2 = 12V$

M_1, M_2 are in ohmic region and M_3 is active

Solution: as $V_1 = V_2$ $\Rightarrow$ M_1 and M_2 will carry same current.

ie, $i_{D1} = i_{D2} = K[2[V_{GS1} - V_t] V_{DS1} - V_{DS1}^2]$

$= 0.25[2[12-2]V_o - V_o^2]$

$= 0.25[20V_o - V_o^2]$

From the circuit, by applying KCL at output node,

$i_{D3} = i_{D1} + i_{D2} = 2i_{D1}$

$\Rightarrow$ $I_{DSS}\left[1 - \frac{V_{GS3}}{V_p}\right]^2 = 2i_{D1}$ [here $V_{GS3} = 0V$]

ie, $4 = 2 \times 0.25[20V_o - V_o^2]$ — (4)

rearranging the above equation

$V_o^2 - 20V_o + 8 = 0$

Solving this equation, we get

$V_o = 19.59V, 0.408V$

for M_1 and M_2 to be in ohmic region, $V_{DS1} = V_o < V_{GS1} - V_t$

ie, $V_o < 10 V$.

$\Rightarrow$ $\boxed{V_o = 0.4084V}$