یالطیف

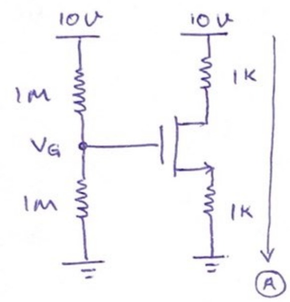
رضا ادیبی پور

۹۸۱۴۳۰۳

تمرین سری ۲ الک ۲

#1

a)



$V_{th} = 2V$

$\mu_n C_{ox} \frac{W}{L} = 0.5 \; \frac{mA}{V^2}$

$$\begin{cases} V_{DS} \geq V_{GS} - V_{th} \\ I_D = \frac{K'}{2} \frac{W}{L} (V_{GS} - V_{th})^2 \end{cases}$$

$V_G = \frac{1^M}{2^M} \times 10 = 5V \Rightarrow I_D = \frac{0.5}{2} (V_G - V_S - 2)^2 \Rightarrow I_D = \frac{1}{4} (3 - 1^K I_D)^2$

$\Rightarrow 4 I_D = (3 - 1^K I_D)^2 \Rightarrow 4 I_D = 9 + I_D^2 - 6 I_D \Rightarrow -I_D^2 + 10 I_D - 9 = 0$ $\begin{cases} \boxed{I_D = 1 \; mA} \\ I_D = 9 \; mA \end{cases}$

if $I_D = 1mA$: $V_S = 1^{mA} \times 1^K = 1V \rightarrow V_{GS} = 5 - 1 = 4V$ ✓

if $I_D = 9mA$: $V_S = 9^{mA} \times 1^K = 9V \rightarrow V_{GS} = 5 - 9 = -4V$ X

KVL @ A : $-10 + 1^K I_D + V_{DS} + 1^K I_D = 0 \Rightarrow \boxed{V_{DS} = 8V}$

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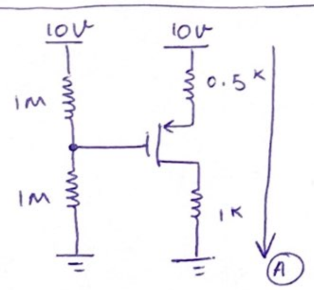
b)



$V_{th} = 1V$

$\mu_p C_{ox} \frac{W}{L} = 2 \; \frac{mA}{V^2}$

$$\begin{cases} V_{SD} > V_{SG} - |V_{th}| \\ I_D = \frac{K'}{2} \frac{W}{L} (V_{SG} - |V_{th}|)^2 \end{cases}$$

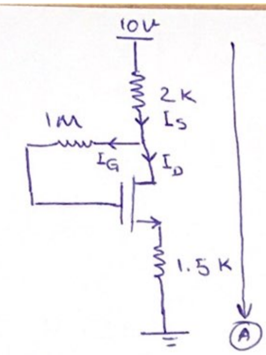
$V_G = 5V \rightarrow I_D = \frac{2}{2} (V_S - 5 - 1)^2 \Rightarrow I_D = (10 - 0.5^K I_D - 6)^2 \rightarrow I_D = \begin{cases} \boxed{4 \; mA} \\ 16 \; mA \end{cases}$

if $I_D = 4 \; mA$: $V_S = 8V \longrightarrow V_{SG} = 8 - 5 = 3V > |V_{th}|$ ✓

if $I_D = 16 \; mA$: $V_S = 2V \longrightarrow V_{SG} = 2 - 5 = -3 \not> |V_{th}|$ X

$\Rightarrow$ KVL @ A : $-10 + 0.5^K I_D + V_{SD} + 1^K I_D = 0 \Rightarrow V_{SD} = 4V \geq V_{SG} - |V_{th}|$

c)



$V_{th} = 1V$

$\mu_n C_{ox} \frac{W}{L} = 1 \frac{mA}{V^2}$

$I_S = I_D + \cancel{I_G}^{\,0}$

$$\begin{cases} V_{DS} \geqslant V_{GS} - V_{th} \\ I_D = \frac{K'}{2} \frac{W}{L} (V_{GS} - V_{th})^2 \end{cases}$$

$V_G = \cancel{I_G}^{\,0} \times 1^M = 0 \Rightarrow I_D = \frac{1}{2}(0 - 1.5^K I_D - 1)^2 \longrightarrow$ معادله جواب حقیقی ندارد. پس ترانزیستور در ناحیه Triode قرار دارد.

Triode Region: $\begin{cases} V_{GS} - V_{th} > V_{DS} \\ I_D = \beta\left[(V_{GS} - V_{th})V_{DS} - \frac{1}{2}V_{DS}^2\right] \end{cases}$

$\Rightarrow I_D = \left[(0 - 1.5^K I_D - 1)\cdot(10 - 2^K I_D - 1.5^K I_D) - \frac{1}{2}(10 - 2^K I_D - 1.5^K I_D)^2\right]$

$\Rightarrow I_D = \left[(-1.5^K I_D - 1)\cdot(10 - 3.5^K I_D) - \frac{1}{2}(10 - 3.5^K I_D)^2\right] \longrightarrow I_D = \begin{cases} 3.02 \text{ mA} \\ \boxed{22.69 \text{ mA}} \end{cases}$

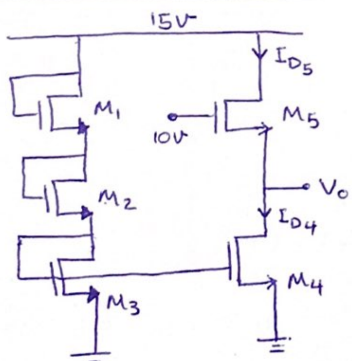
if $I_D = 3.02$ mA $\rightarrow V_{GS} = -1.5^K \times 3.02 = -4.53$, $V_{DS} = -0.57 \rightarrow V_{GS} - V_{th} \not> V_{DS}$

if $I_D = 22.69$ mA $\rightarrow V_{GS} = -34.03$, $V_{DS} = -69.41 \rightarrow \underbrace{V_{GS} - V_{th}}_{= -35.03} > V_{DS}$

KVL @ A : $-10 + 2^K I_D + V_{DS} + 1.5 I_D = 0 \Rightarrow \boxed{V_{DS} = -69.415 V}$

#2

a)



$I_{D_5} = I_{D_4}$ (I)

$I_{D_5} = \frac{K'}{2} \frac{W}{L}(10 - V_o - V_{th})^2$

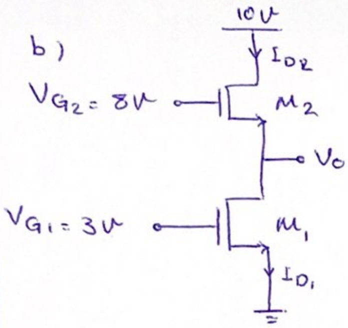
$I_{D_4} = \frac{K'}{2} \frac{W}{L}(V_{G_4} - 0 - V_{th})^2$

$\xrightarrow{(I)} \frac{K'}{2} \frac{W}{L}(10 - V_o - V_{th})^2 = \frac{K'}{2} \frac{W}{L}(V_{G_4} - V_{th})^2$

$\Rightarrow (10 - V_o - V_{th})^2 = (V_{G_4} - V_{th})^2$

$$\begin{cases} 10 - V_o - \cancel{V_{th}} = V_{G_4} - \cancel{V_{th}} \Rightarrow V_o = 10 - V_{G_4} \\ 10 - V_o - V_{th} = -V_{G_4} + V_{th} \Rightarrow V_o = 10 - 2V_{th} + V_{G_4} \end{cases}$$

b)



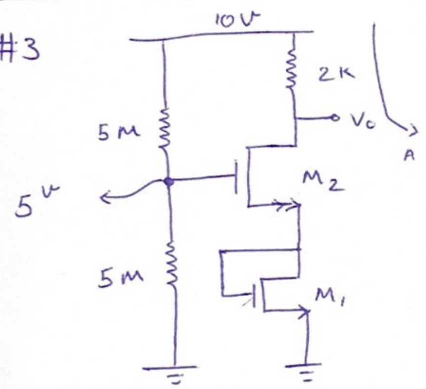
$$I_{D1} = \frac{k'}{2}\frac{W}{L}\left(3 - V_{th}\right)^2$$

$$I_{D2} = \frac{k'}{2}\frac{W}{L}\left(8 - V_o - V_{th}\right)^2$$

$$\xrightarrow{I_{D1}=I_{D2}} \frac{k'}{2}\frac{W}{L}(3-V_{th})^2 = \frac{k'}{2}\frac{W}{L}(8-V_o-V_{th})^2$$

$$\begin{cases} 3-\cancel{V_{th}} = 8 - V_o - \cancel{V_{th}} \Rightarrow \boxed{V_o = 5\,V} \\ 3 - V_{th} = -8 + V_o + V_{th} \Rightarrow \boxed{V_o = 11 - 2V_{th}} \end{cases}$$

#3



$\beta = 0.5\ \frac{mA}{V^2}$

$V_{th} = 0.5V$

$$V_{G2} = \frac{5^M}{10^M} \times 10 = 5V$$

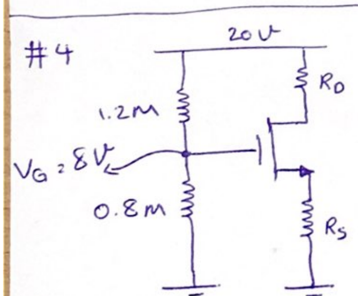
$$V_{DS} > V_{GS} - V_{th} \xrightarrow{M_2} 10 - 2^k I_{D2} - \cancel{V_s} > 5 - \cancel{V_s} - 0.5$$

$$10 - 2^k I_{D2} > 4.5 \rightarrow \boxed{I_{D2} < 2.75\ mA}$$

if $I_D = 2 \rightarrow$ KVL @ A : $-10 + 2^k I_D + V_o = 0$

$\Rightarrow \boxed{V_o = 6V}$

#4



$V_{th} = 2V$

$\mu_n C_{ox}\frac{W}{L} = 0.5\ \frac{mA}{V^2}$

$R_D, R_S = ? \rightarrow I_D = 1mA$, saturation Region

$$I_D = \frac{\beta}{2}\left(V_{GS} - V_{th}\right)^2 \Rightarrow 1^{mA} = \frac{1}{4}\left(8 - V_s - 2\right)^2 \rightarrow \begin{cases} V_s = 4V \\ V_s = 8V \end{cases}$$

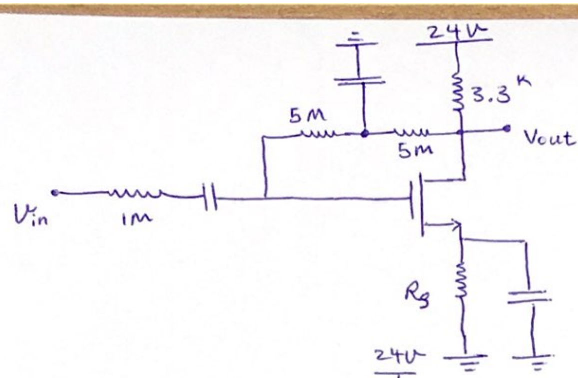
$$V_{GS} > V_{th} > 0 \Rightarrow 8 - V_s > 2 > 0 \Rightarrow 0 < V_s < 6 \longrightarrow \boxed{V_s = 4V}$$

$$\Rightarrow R_s = \frac{V_s}{I_D} = \frac{4V}{1^m} = \boxed{4K\Omega}$$

$$V_{DS} > V_{GS} - V_{th} \rightarrow V_D - 4 > 8 - 4 - 2 \Rightarrow \boxed{V_D > 6V}$$

$$20 - V_D = R_D I_D \xrightarrow{I_D = 1} V_D = 20 - 1^m R_D \Rightarrow 20 - 1^m R_D > 6 \Rightarrow \boxed{R_D < 14^K}$$

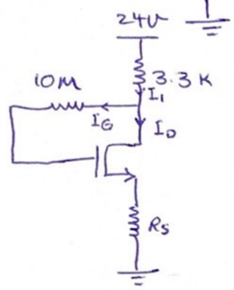
#5



$\beta = 0.25 \ \frac{mA}{V^2}$

$|V_{th}| = 3V$

DC Analysis :



$I_1 = I_D + \cancel{I_G}^{\,0} \Rightarrow I_D = \frac{0.25}{2}\left(-R_S I_D - 3\right)^2$

$\xrightarrow{I_D = 2.5^{mA}} \quad 2.5 = 0.125\left(-2.5R_S - 3\right)^2$

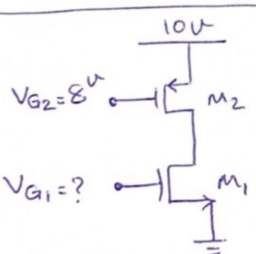
$\begin{cases} \boxed{R_S = -2.98 \ K\Omega} \\ R_S = 0.58 \ K\Omega \end{cases}$

if $R_S = -2.98^{K\Omega} \rightarrow V_S = -2.98^K \times 2.5 = -7.45V \rightarrow \underbrace{V_{GS}}_{7.45} > V_{th} > 0$ ✓

if $R_S = 0.58^{K\Omega} \rightarrow V_S = 0.58 \times 2.5 = 1.45V \rightarrow V_{GS} \not> V_{th} > 0$ ✗

#6

a)



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

$\mu_p C_{ox} = 100 \ \mu A / V^2$

$\frac{W}{L} = \frac{1 \mu m}{0.1 \mu m}$

$|V_{th}| = 1V$

$\beta_n = \mu_n C_{ox} \frac{W}{L} = 4000 \ \frac{\mu A}{V^2} = 4 \ \frac{mA}{V^2}$

$\beta_p = \mu_p C_o \frac{W}{L} = 1000 \ \frac{\mu A}{V^2} = 1 \ \frac{mA}{V^2}$

$M_1: \ V_{DS} \geq V_{GS} - V_{th} \rightarrow V_D - \cancel{V_S} \geq V_G - \cancel{V_S} - 1 \Rightarrow \boxed{V_G \leq V_D + 1}$

$I_{D_1} = \frac{\beta_n}{2}\left(V_{GS} - V_{th}\right)^2 = 2\left(V_G - 1\right)^2 \Rightarrow \boxed{I_{D_1} = 2\left(V_{G_1} - 1\right)^2}$ *

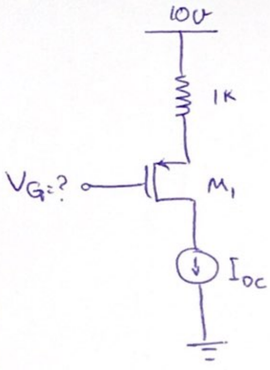
$M_2: \ V_{SD} > V_{SG} - |V_{th}| \Rightarrow V_S - V_D > V_S - V_G - 1 \Rightarrow \boxed{V_{D_{1,2}} < 9V}$

$I_{D2} = \frac{\beta_p}{2}\left(V_{SG} - |V_{th}|\right)^2 = \frac{1}{2}\left(2-1\right)^2 = \underline{0.5 \ mA} = I_{D_1}$

$\xrightarrow{*} \quad \frac{1}{2} = 2\left(V_{G_1} - 1\right)^2 \rightarrow \begin{cases} \boxed{V_{G_1} = 1.5V} \\ V_{G_1} = 0.5V \end{cases}$

if $V_{G_1} = 1.5 \rightarrow V_{GS} > V_{th}$ ✓

if $V_{G_1} = 0.5 \rightarrow V_{GS} \not> V_{th}$ ✗



$I_{DC} = 1mA$

$\mu_p C_{ox} = 400 \ \frac{\mu A}{V^2}$

$\frac{W}{L} = \frac{2\mu m}{0.1\mu m}$

$V_{th} = 0.5V$

$\beta_p = \mu_p C_{ox} \frac{W}{L} = 400 \times \frac{2}{0.1} = 8000 \ \frac{\mu A}{V^2}$

$= 8 \ \frac{mA}{V^2}$

$I_D = \frac{\beta}{2}\left(V_{SG} - |V_{th}|^2\right) \Rightarrow 4\left(10 - 1^K I_D - V_G - 0.5\right)^2 = I_D^m$

$\xrightarrow{I_D = 1mA} 1^m = 4\left(9 - V_G - 0.5\right)^2 \longrightarrow \begin{cases} \boxed{V_G = 8} \\ V_G = 9 \end{cases}$

if $V_G = 8$: $V_{SG} = 9 - 8 = 1 > 0$ ✓

if $V_G = 9$: $V_{SG} = 9 - 9 = 0 \not> 0$ X