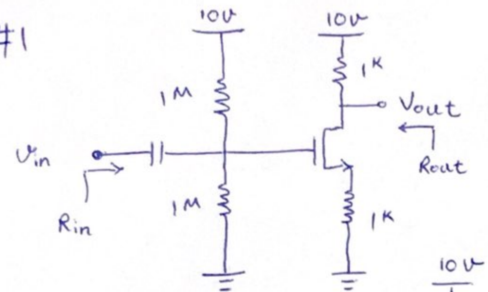
یا لطیف

رضا ادیب‌پور
۹۸۱۴۳۰۳

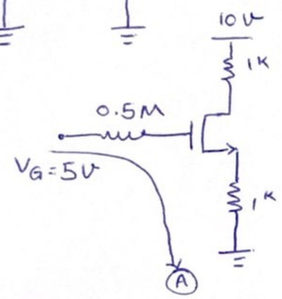
تمرین سری ۳. الک ۲

#1



$$\begin{cases} V_{th} = 2V \\ \mu_n C_{ox} \frac{W}{L} = 0.5 \ \frac{mA}{V^2} \\ \lambda = 0 \ V^{-1} \rightarrow r_{ds} = \infty \end{cases}$$

DC Analysis :



$$KVL \ @ \ A : -5^V + \cancel{0.5^M} \overset{0}{I_G} + V_{GS} + 1^K I_D = 0$$

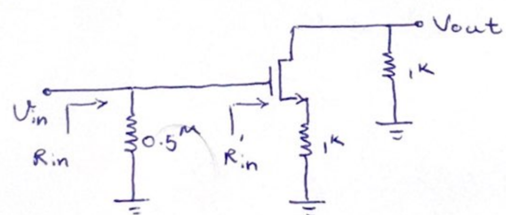
$$\Rightarrow V_{GS} = 5 - 1^K I_D \qquad (I)$$

$$I_D = \frac{K'}{2}\frac{W}{L}(V_{GS} - V_{th})^2 = \frac{1}{4}(5 - 1^K I_D - 2)^2$$

$$\Rightarrow \begin{cases} I_D = 1^{mA} \ ✓ \\ I_D = 9^{mA} \ ✗ \end{cases}$$

$$\Rightarrow g_m = \sqrt{2K'\frac{W}{L} I_D} = \sqrt{2(0.5) \times 1} = 1 \ mmho$$

AC Analysis :



$$A_v = \frac{v_{out}}{v_{in}} = -g_m (R_D \| r_{ds})$$

$$= -1(1^K \| \infty) = -1$$

$$R_{in} = 0.5^M \| R'_{in} \rightsquigarrow R'_{in} = \infty \rightarrow R_{in} = 0.5^M \| \infty = 0.5^M = 500^{K\Omega}$$

$$R_{out} = 1^K \| r_{ds}(1 + g_m R_S) = 1^K$$

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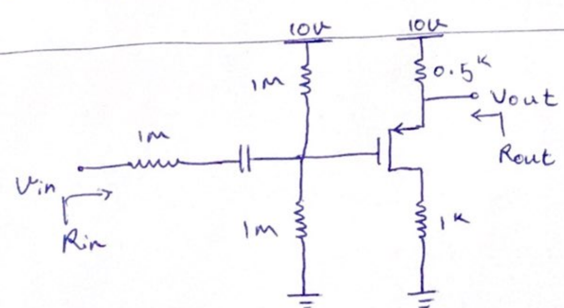
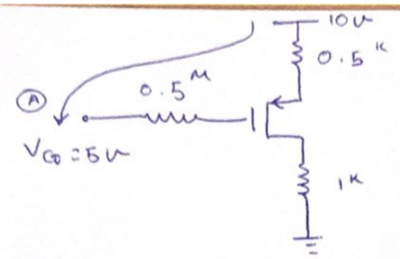
b)



$$\begin{cases} V_{th} = -1 \\ \mu_p C_{ox} \frac{W}{L} = 2 \ \frac{mA}{V^2} \\ \lambda = 0 \rightarrow r_{ds} = \infty \end{cases}$$

DC Analysis:



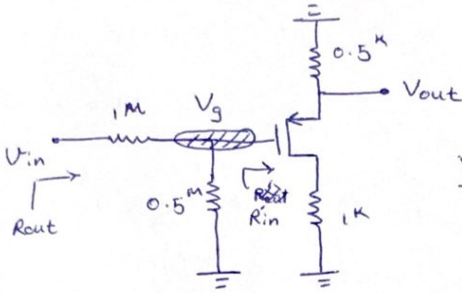
KVL @ A: $-10 + 0.5^K I_D + V_{SG} + \cancel{0.5^M I_G} + 5 = 0$

$\Rightarrow V_{SG} = 5 - 0.5^K I_D$ (I)

$I_D = \frac{K'}{2}\frac{W}{L}(V_{SG} - |V_{th}|)^2 = (5 - 0.5^K I_D - 1)^2 \rightarrow \begin{cases} I_D = 4\ mA & ✓ \\ I_D = 16\ mA & X \end{cases}$

$\rightarrow g_m = \sqrt{2K'\frac{W}{L}I_D} = \sqrt{2 \times 2 \times 4} = 4$ mmho

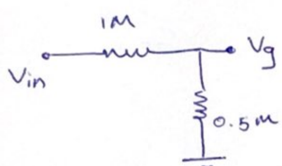
AC Analysis:



$A_v = \frac{V_{out}}{V_g} \times \frac{V_g}{V_{in}}$

$\frac{V_{out}}{V_g} = \frac{R_S}{R_S + \frac{1}{g_m}} = \frac{0.5^K}{0.5^K + \frac{1}{4}} \simeq 0.6$

$R'_{in} = \infty \Rightarrow$



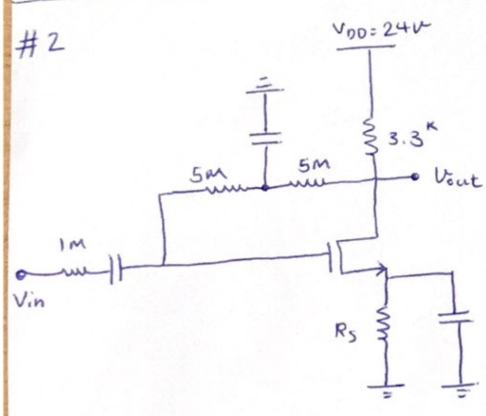
$\Rightarrow \frac{V_g}{V_{in}} = \frac{0.5^M}{1.5^M} \simeq 0.3$

$\Rightarrow A_v = \frac{V_{out}}{V_{in}} = 0.6 \times 0.3 = 0.18$

$R_{in} = 1^M + \left[0.5^M \| R'_{in}\right] = 1^M + \left(0.5^M \| \infty\right) = 1.5^{M\Omega}$

$R_{out} = 0.5^K \| \left(\frac{1}{g_m} \| \infty\right) = 0.5^K \| 0.25^K = 0.16^{K\Omega}$

#2



$\begin{cases} \beta = 0.25\ \frac{mA}{V^2} \\ |V_{th}| = 3V \\ \lambda = 0 \rightarrow r_{ds} = \infty \end{cases}$

KVL @ A: $-24 + 3.3^K I_D + \cancel{10^M I_G} + V_{GS} + R_S I_D = 0$

$V_{GS} = 24 - 3.3^K(2.5^m) - 2.5^m R_S$

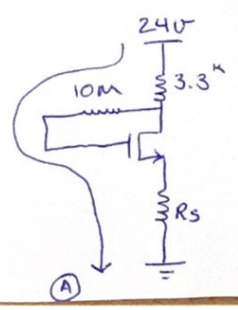
$V_{GS} = 15.75 - 2.5^m R_S$

$I_D = \frac{K'}{2}\frac{W}{L}(V_{GS} - V_{th})^2 \Rightarrow 2.5 = \frac{0.25}{2}(15.75 - 2.5R_S - 3)^2$

$\begin{cases} R_S = 3.3^K & ✓ \\ R_S = 6.8^K & X \end{cases}$

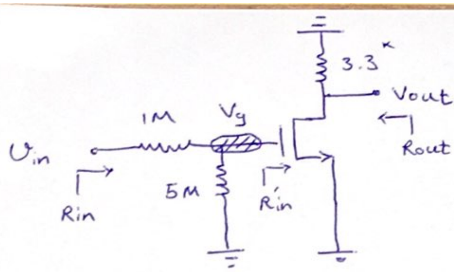
DC Analysis:

$\underline{I_D = 2.5^{mA}}$



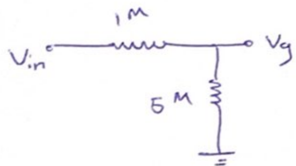
$g_m = \sqrt{2K'\frac{W}{L}I_D} = \sqrt{2(0.25) \times 2.5} = 1.1$ mmho

b) AC Analysis:



$$\frac{V_{out}}{v_{in}} = A_v = \frac{V_{out}}{V_g} \times \frac{V_g}{v_{in}} \quad \Rightarrow \quad \frac{V_{out}}{V_g} = -g_m(R_D \| r_{ds}) = -1.1(3.3 \| \infty) = -3.63$$

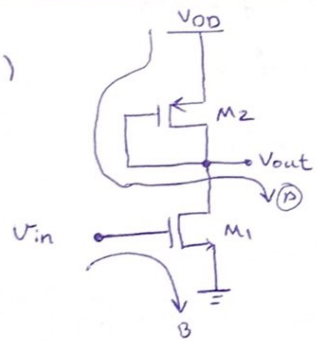
$\frac{V_g}{V_{in}}$:



$$\frac{V_g}{V_{in}} = \frac{5}{6} = 0.8 \quad \Rightarrow A_v = \frac{V_{out}}{V_{in}} = -3.63 \times 0.8 = 2.9$$

$$R_{in} = 1^M + \underbrace{(5^M \| \infty)}_{R_{in}'} = 6\,M\Omega \quad , \quad R_{out} = 3.3^K \| r_{ds}(1 + g_m R_s) = 3.3^K$$

#3 a)



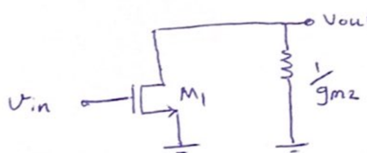
AC Analysis: KVL @ A : $0 + V_{SG} + V_{out} = 0$

$\Rightarrow V_{SG_2} = -V_{out}$

KVL @ B : $-V_{in} + V_{GS_1} = 0 \quad \Rightarrow \quad V_{in} = V_{GS_1}$

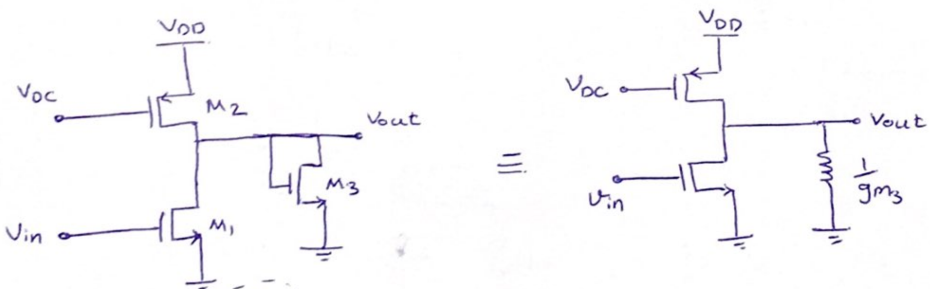
$I_{D_1} = I_{D_2} \rightarrow \frac{k'}{2}\frac{W}{L}(V_{GS_1} - V_{th})^2 = \frac{k'}{2}\frac{W}{L}(V_{GS_2} - V_{th})^2$

مقاومت ترانزیستور M_2 $\simeq \frac{1}{g_{m2}}$ $\Rightarrow$

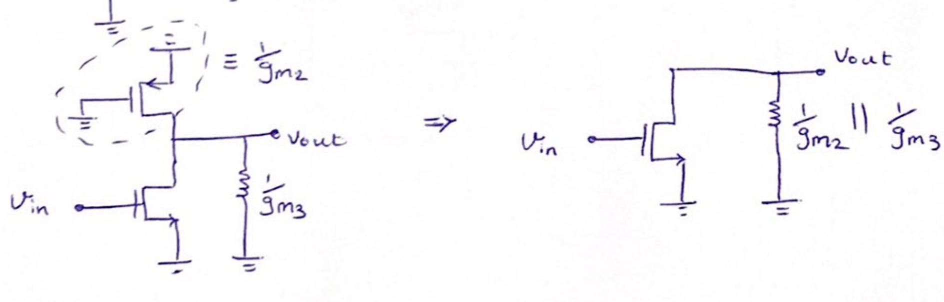


$\Rightarrow A_v = \frac{V_{out}}{V_{in}} = -g_{m_1}\left(\frac{1}{g_{m_1}} \| r_{ds_1}\right)$

b)

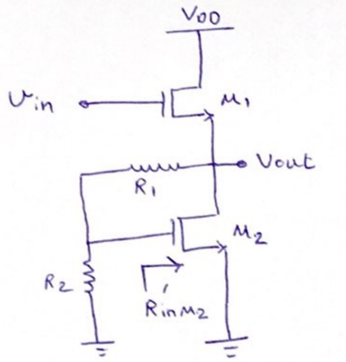


AC Analysis:



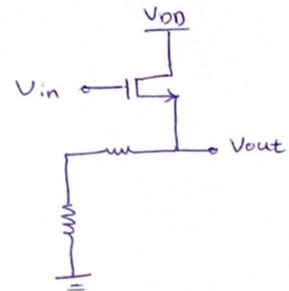
$$\Rightarrow A_v = \frac{V_{out}}{v_{in}} = -g_{m_1}\left(\frac{1}{g_{m2}} \| \frac{1}{g_{m3}} \| r_{ds_1}\right)$$

c)

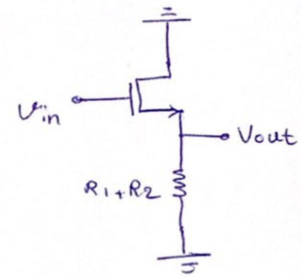


$R'_{in(M_2)} = \infty$

$\Rightarrow$



$\equiv$



$$A_v = \frac{R_1 + R_2}{(R_1 + R_2) + \frac{1}{g_{m_1}}}$$

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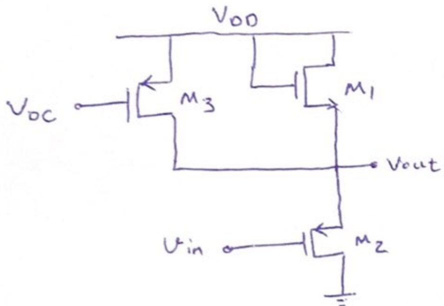
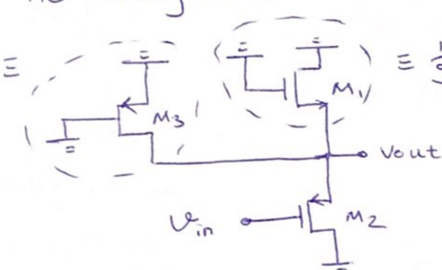
d)



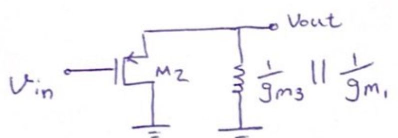
AC Analysis :

$\frac{1}{g_{m3}} \equiv$



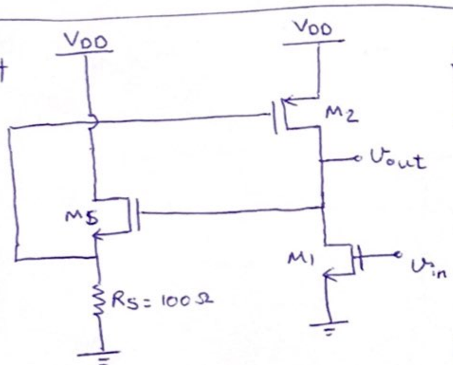
$\equiv \frac{1}{g_{m_1}}$

$\Rightarrow$



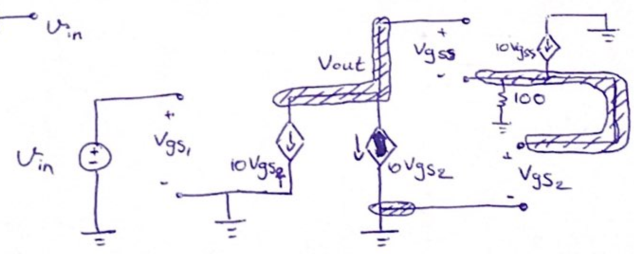
$$\Rightarrow A_v = \frac{v_{out}}{v_{in}} = \frac{\frac{1}{g_{m3}} \| \frac{1}{g_{m_1}}}{\left(\frac{1}{g_{m3}} \| \frac{1}{g_{m_1}}\right) + \frac{1}{g_{m2}}}$$

#4



$$\begin{cases} g_m = 10\ \frac{mA}{V^2} \\ \lambda = 0 \rightarrow r_{ds} = \infty \end{cases}$$

Small signal model :

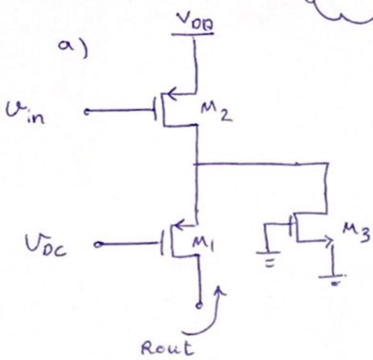


KCL @ V_{out} : $10V_{gs_2} + 10V_{gs_1} = 0 \longrightarrow$

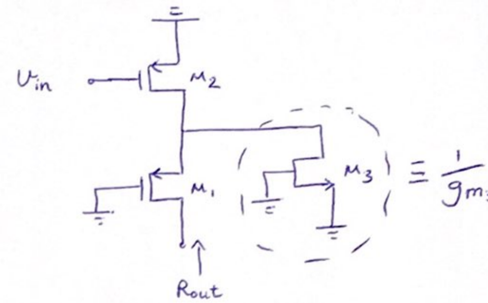
#5

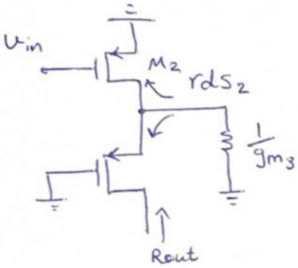
$\lambda \neq 0$

a)

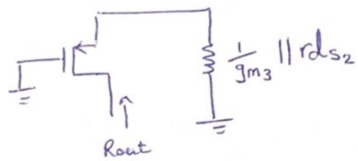


AC Analysis:



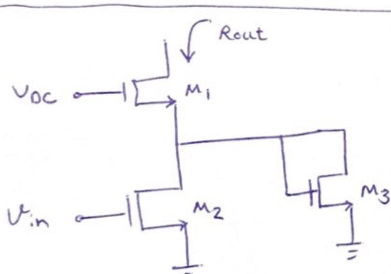


$\Rightarrow$

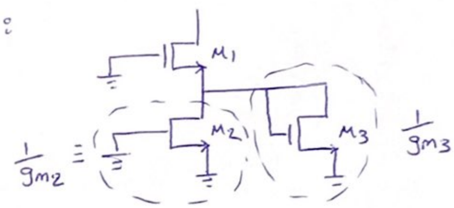


$$R_{out} = rds_1\left(1 + g_{m1}\left(\frac{1}{g_{m3}} \| rds_2\right) \| rds_1\right)$$

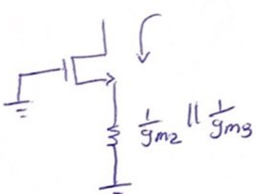
b)



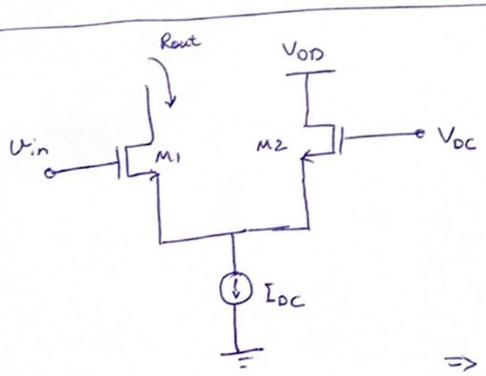
AC Analysis:



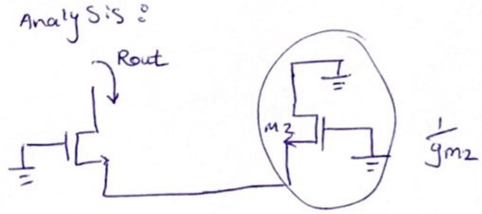
$\Rightarrow$



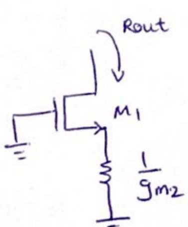
$$rds_1\left(1 + g_{m1}\left(\frac{1}{g_{m2}} \| \frac{1}{g_{m3}} \| \infty\right)\right) = R_{out}$$



AC Analysis:



$\Rightarrow$



$$rds_1\left(1 + g_{m1}\left(\frac{1}{g_{m2}}\right)\right) = R_{out}$$