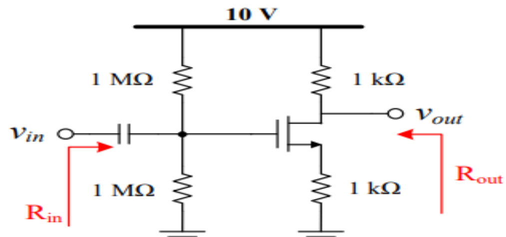
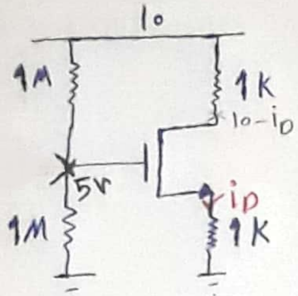


$$\begin{cases} V_{TH} = 2V \\ \mu_n C_{OX} \dfrac{W}{L} = 0.5 \dfrac{mA}{V^2} \\ \lambda = 0 V^{-1} \end{cases}$$

DC:



$v_{TH} = 2v$

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

$\lambda = 0 v^{-1}$

$v_{GS} = 5 - i_D \rightarrow$ پاسخ min، i_D ii

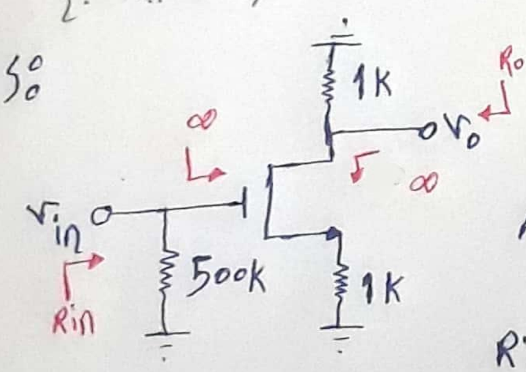
$$i_D = \frac{1}{4}(5 - i_D - 2)^2 \rightarrow 4 i_D = (3 - i_D)^2$$

$$i_D^2 - 10 i_D + 9 = 0 \rightarrow (i_D - 1)(i_D - 9) = 0 \rightarrow i_D = 1mA$$

$v_{GD} < v_{TH}$ $\rightarrow v_{GD} = 5 - 10 + i_D = -4 < 2v \rightarrow$ tr: اشباع

شرط ناحیه اشباع

s.s:

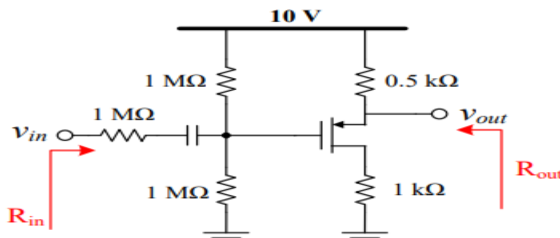


$g_m = 2\sqrt{K \times i_D} = 2\sqrt{\frac{1}{4} \times 1} = 1ms$, $K = \frac{\beta}{2}$

$$A_v = \frac{v_o}{v_{in}} = \frac{-R_D}{R_S + \frac{1}{g_m}} = \frac{-1}{1+1} = \frac{-1}{2}$$

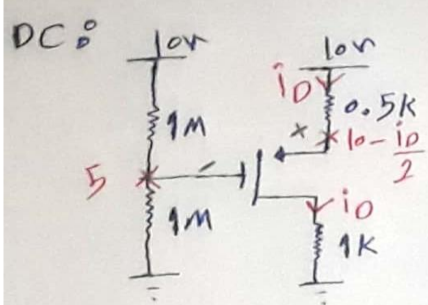
$R_{in} = 500k \| \infty = 500k\Omega$

$R_{out} = 1k \| \infty = 1k\Omega$



$$\begin{cases} V_{TH} = -1V \\ \mu_p C_{OX}\dfrac{W}{L} = 2\dfrac{mA}{V^2} \\ \lambda = 0V^{-1} \end{cases}$$

DC:



$V_{TH} = -1$

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

$\lambda = 0$

$V_{SG} = 5 - \frac{i_D}{2} \rightarrow$ یا سخ i_D min ط ق ق

$i_D = \underset{\frac{\beta}{2}}{K}\left(V_{SG} - |V_{TH}|\right)^2 \longrightarrow i_D = \left(5 - \frac{i_D}{2} - 1\right)^2$

$4 i_D = (8 - i_D)^2 \longrightarrow i_D^2 - 20 i_D + 64 = 0$

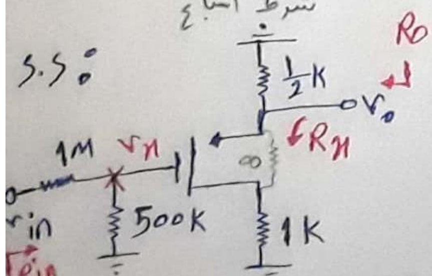
$(i_D - 4)(i_D - 16) = 0 \longrightarrow i_D = 4mA$

$V_{GD} > V_{TH} \longrightarrow V_{GD} = 5 - i_D = 1v > -1 \longrightarrow$ تر: اشباع

شرط اشباع

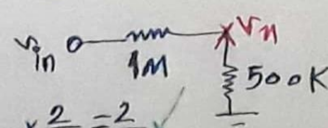
$g_m = 2\sqrt{K i_D} = 2\sqrt{1 \times 4} = 4ms$

S.S:



$\frac{v_o}{v_x} = \frac{R_S}{R_S + \frac{1}{g_m}} = \frac{\frac{1}{2}}{\frac{1}{2} + \frac{1}{4}} = \frac{\frac{1}{2}}{\frac{3}{4}} = \frac{2}{3}$

$\frac{v_x}{v_{in}} = ?$



$\frac{v_x}{v_{in}} = \frac{500}{1500} = \frac{1}{3}$

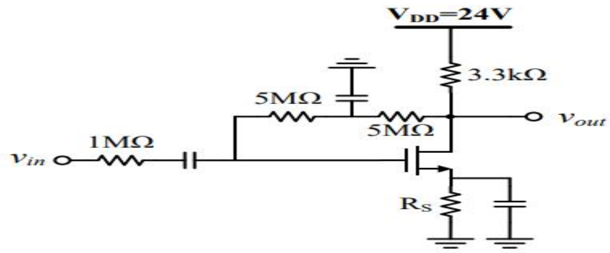
$A_v = \frac{v_o}{v_{in}} = \frac{1}{3} \times \frac{2}{3} = \frac{2}{9}$

$R_{in} = 1M + 500k = 1.5M\Omega$

$R_{out} = \frac{1}{2}k \,||\, R_x \qquad R_x = \frac{1}{g_m} = \frac{1}{4} \longrightarrow R_o = \frac{1}{2} \,||\, \frac{1}{4} = \frac{1}{6}\,k\Omega$

a) Specify the source resistance so that I_D=2.5 mA.

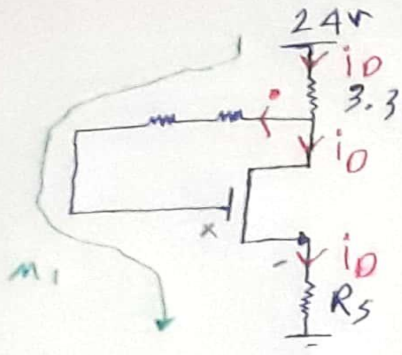
b) Calculate the voltage gain and the input and the output resistances.



$$\begin{cases} \beta = 0.25 \frac{mA}{V^2} \\ |V_{TH}| = 3V \\ \lambda = 0 \end{cases}$$

12

DC:



$? = R_s \leftarrow i_D = 2.5$ (a

$\beta = \frac{1}{4}$

$V_{TH} = 3V$

$K = \frac{\beta}{2} = \frac{1}{8}$

$KVL@M_1: -24 + 3.3 i_D + V_{GS} + R_s i_D = 0$ (I)

$V_{GS} = V_{TH} + \sqrt{\frac{i_D}{K}} = 3 + \sqrt{\frac{5 \times 8}{2}} = 7.5\ V > 3V$

tr روشن

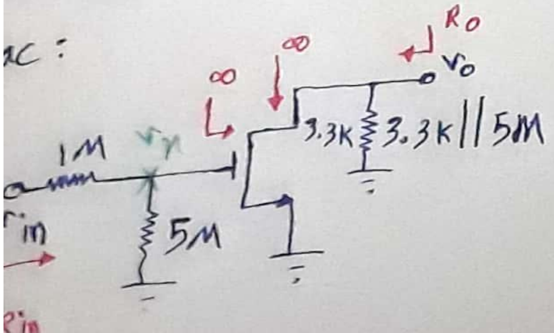
$\text{(I)} \rightarrow \frac{5}{2} R_s = 24 - V_{GS} - 3.3 \times \frac{5}{2} \rightarrow \boxed{R_s = 3.3k\Omega}$

$? = R_{out}$, R_{in} , $\frac{v_o}{v_{in}} = A_v$ (b

$r_o = r_{ds} = \infty$

$g_m = 2\sqrt{K i_D} = 2\sqrt{\frac{1}{8} \times \frac{5}{2}} = 1.1\ ms$

AC:



$\frac{v_o}{v_{in}} = \frac{v_o}{v_g} \times \frac{v_g}{v_{in}} = ?$

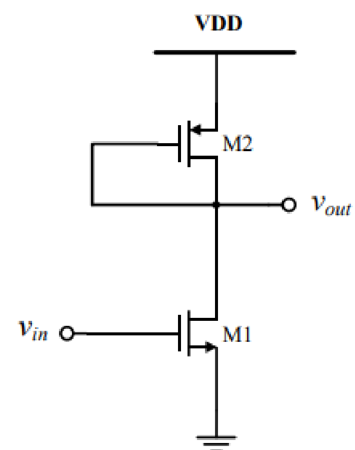
$\frac{v_o}{v_g} = -g_m R_D = -1.1 \times 3.3 = -3.63$

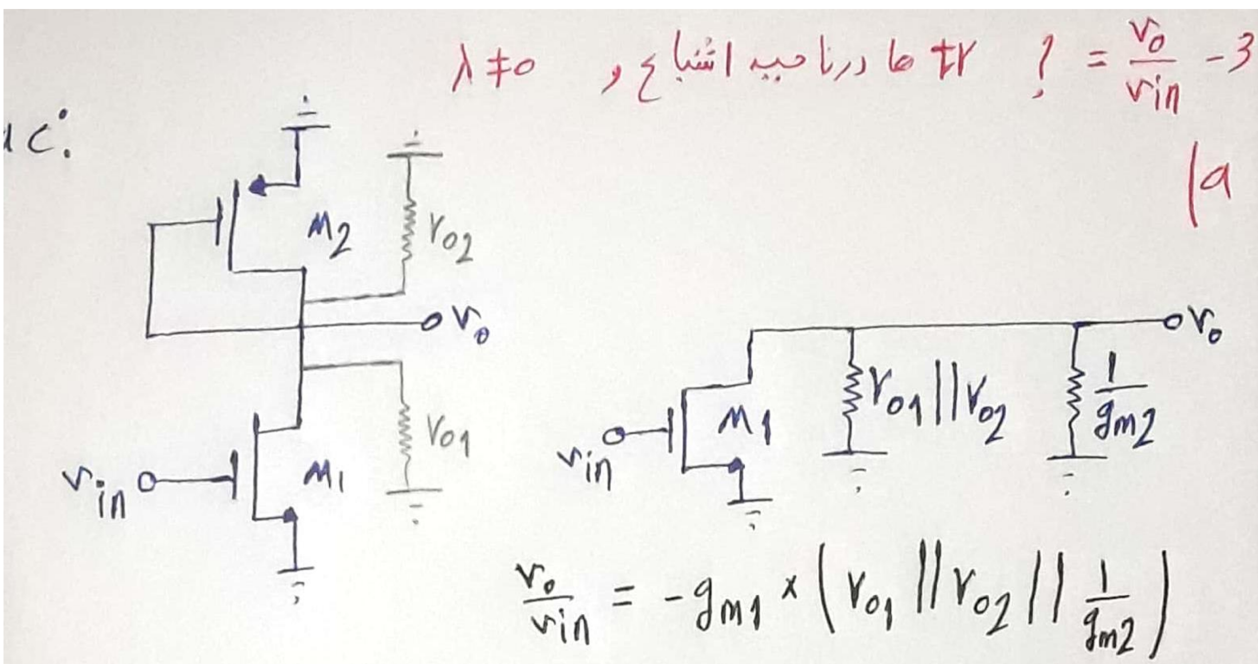
$\frac{v_g}{v_{in}} = \frac{5 || \infty}{(5 || \infty) + 1} = \frac{5}{6} \rightarrow \boxed{\frac{v_o}{v_{in}} = -3}$

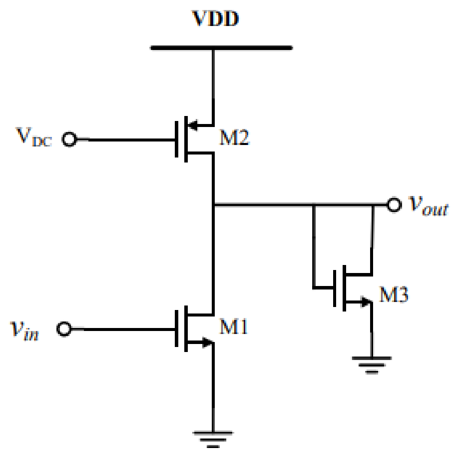
$\boxed{R_{out} = 3.3 || \infty = 3.3k\Omega = R_o}$

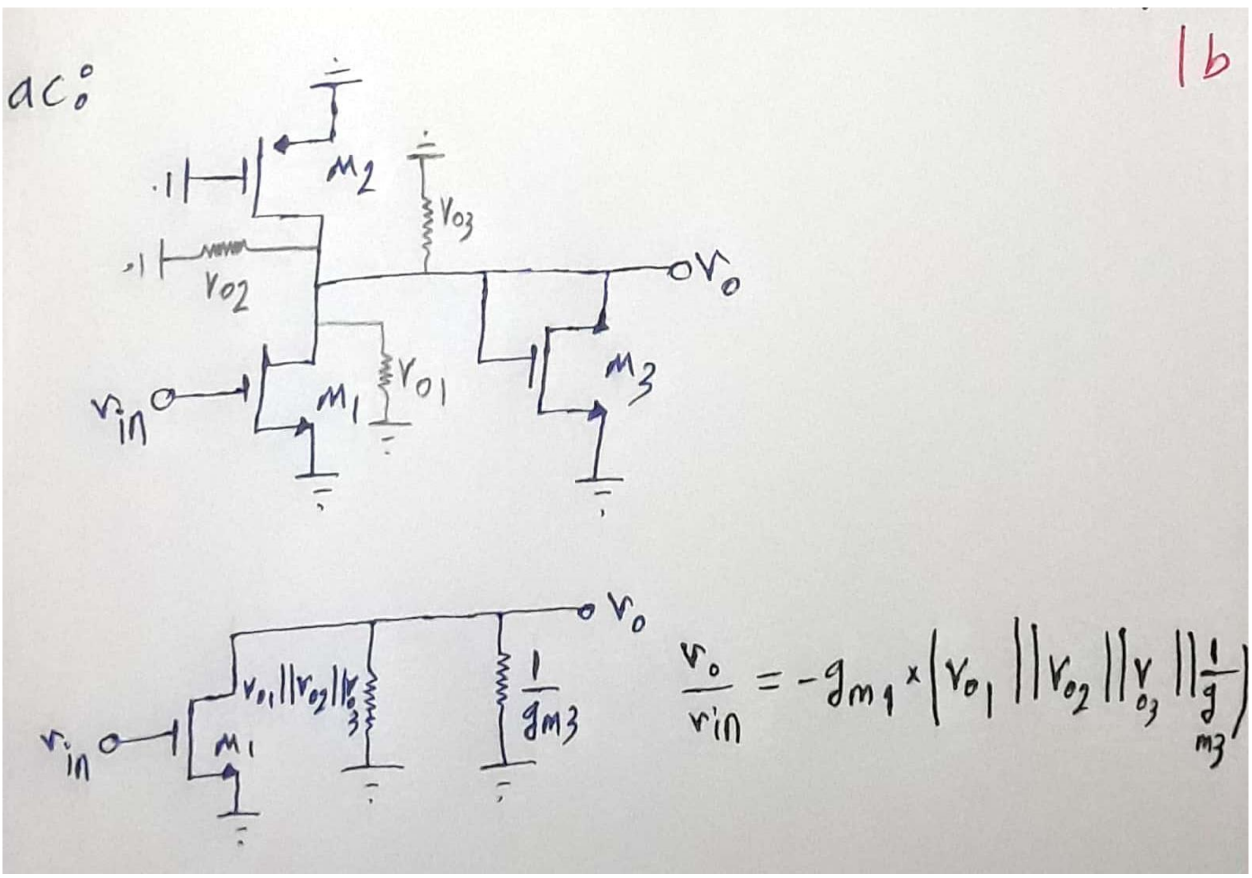
$\boxed{R_{in} = 1M + 5M = 6M\Omega = R_{in}}$

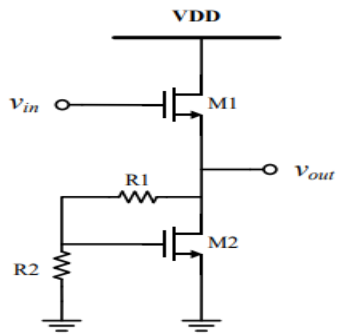
3- Determine a relation for the voltage gain ($A_V = \frac{v_{out}}{v_{in}}$) of the following circuits. Assume that the transistors operate in saturation and $\lambda \neq 0$.



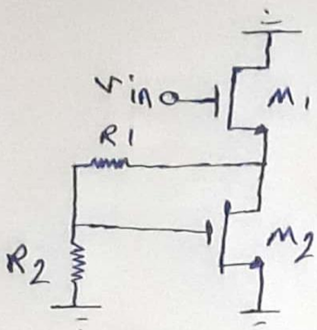



VDD
VDC
M2
vout
M3
vin
M1


1b
ac:
M2
ro3
ro2
vo
vin
M1
ro1
M3
vo
ro1||ro2||ro3
1/gm3
vin
M1
$\frac{v_o}{v_{in}} = -g_{m1} \times \left(r_{o1} \,||\, r_{o2} \,||\, r_{o3} \,||\, \frac{1}{g_{m3}}\right)$

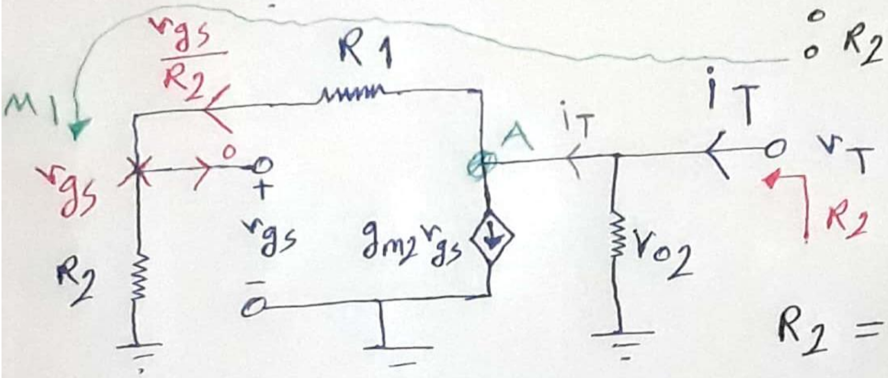


1c



$R_2 = ?$

روش اول محاسبه R_2:



$$R_2 = r_{o2} \,||\, \frac{v_T}{i_T}$$

KCL @ A: $g_{m2} v_{gs} - i_T + \frac{v_{gs}}{R_2} = 0 \rightarrow$

$$\left(g_{m2} + \frac{1}{R_2}\right) v_{gs} = i_T \quad (\mathrm{I})$$

KVL @ M_1: $-v_T + \frac{R_1}{R_2} v_{gs} + v_{gs} = 0 \rightarrow$

$$\frac{R_1+R_2}{R_2} v_{gs} = v_T \rightarrow v_{gs} = \frac{R_2 v_T}{R_1+R_2} \quad (\mathrm{II})$$

$$v_T \left(\frac{R_2 g_{m2}}{R_1+R_2} + \frac{1}{R_1+R_2} \right) = i_T \rightarrow \frac{v_T}{i_T} = \frac{R_1+R_2}{R_2 g_{m2}+1}$$

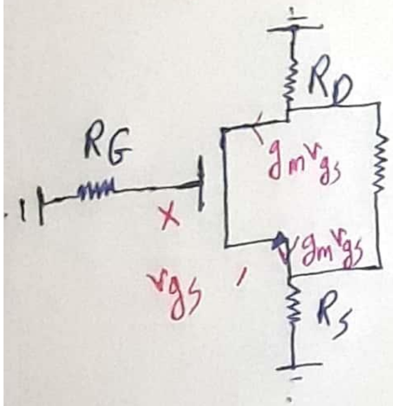
ادامه حل ص بعد

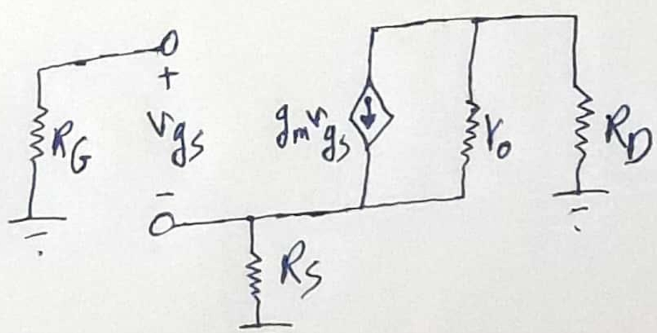
$$\frac{v_T}{i_T} = \frac{R_1+R_2}{R_2 g_{m2}+1} \times \frac{R_2}{R_2} = \frac{R_1+R_2}{R_2} \times \left(R_2 \,\|\, \frac{1}{g_{m2}}\right)$$

$$R_2 = r_{o2} \,\|\, \left(\frac{R_1+R_2}{R_2}\left(R_2 \,\|\, \frac{1}{g_{m2}}\right)\right)$$

روش دوم برای محاسبه R_2 :

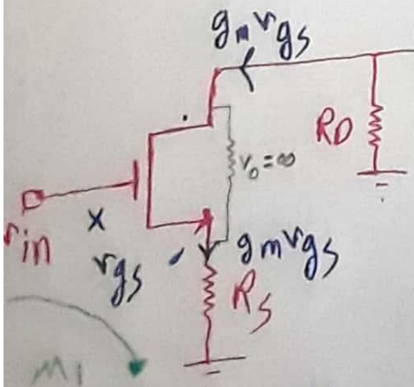
روش پخش جریان جهت محاسبه بهره و R_{in} و R_{out} :





مثال : بهره تقویت کننده زیر از روش پخش جریان بدست آورید :

$(\lambda=0)$ $r_o=\infty$



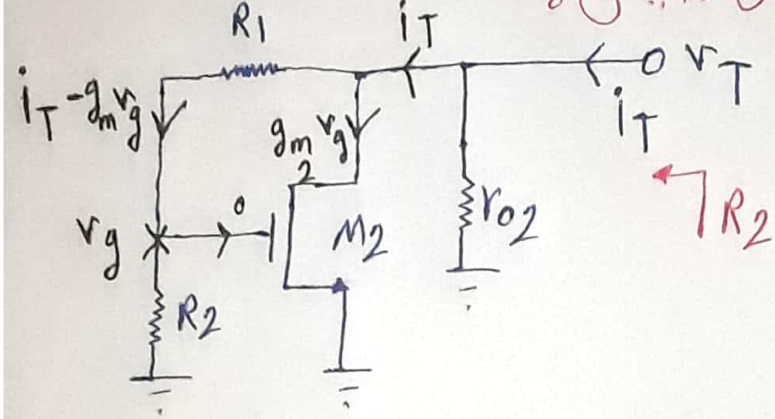
KVL @ M_1 : $-v_{in} + v_{gs} + g_m R_s v_{gs} = 0$

$$v_{gs} = \frac{v_{in}}{g_m R_s + 1}$$

KCL @ v_o : $v_o = -g_m v_{gs} R_D = \dfrac{-g_m R_D v_{in}}{g_m R_s + 1}$

$$\frac{v_o}{v_{in}} = \frac{-g_m R_D}{g_m R_s + 1} \times \frac{\frac{1}{g_m}}{\frac{1}{g_m}} = \frac{-R_D}{R_s + \frac{1}{g_m}} = A_v$$

محاسبه R_2 از روش بخش جریان :



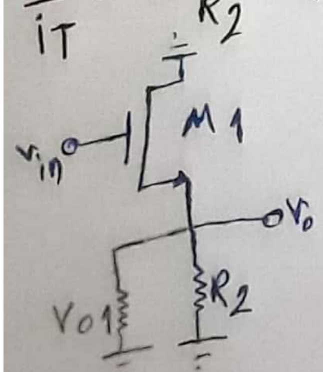
$$R_2 = r_{o2} \,||\, \frac{v_T}{i_T} \qquad v_g = \frac{R_2 v_T}{R_1+R_2}$$

$$v_{gs2} = v_g$$

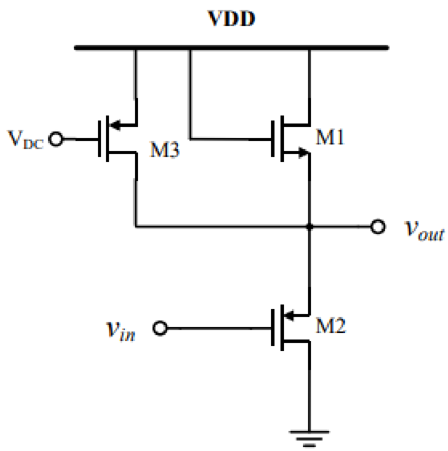
$$KCL\ @\ v_g : \frac{v_g}{R_2} = i_T - g_{m2} v_g \rightarrow \left(\frac{1}{R_2} + g_{m2}\right) v_g = i_T$$

$$\left[\frac{1}{R_1+R_2} + \frac{R_2 g_{m2}}{R_1+R_2}\right] v_T = i_T \rightarrow \frac{v_T}{i_T} = \frac{R_1+R_2}{R_2 g_{m2}+1} \times \frac{R_2}{R_2}$$

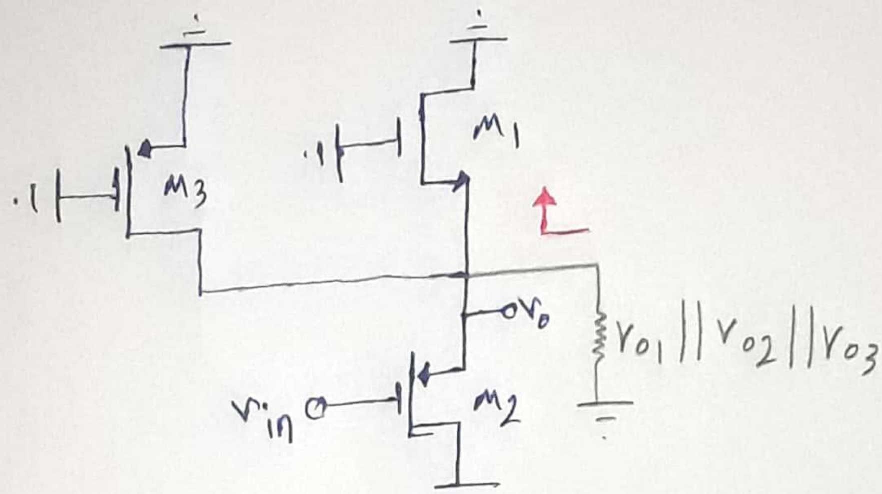
$$\frac{v_T}{i_T} = \frac{R_1+R_2}{R_2}\left(R_2 \,||\, \frac{1}{g_{m2}}\right) \rightarrow R_2 = r_{o2} \,||\, \left[\frac{R_1+R_2}{R_2}\left(R_2 \,||\, \frac{1}{g_{m2}}\right)\right]$$

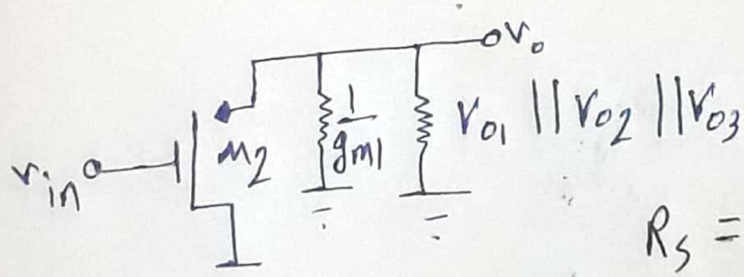


$$\frac{v_o}{v_{in}} = \frac{R_2 \,||\, r_{o1}}{R_2 \,||\, r_{o1} + \frac{1}{g_{m1}}}$$ ✓



1d

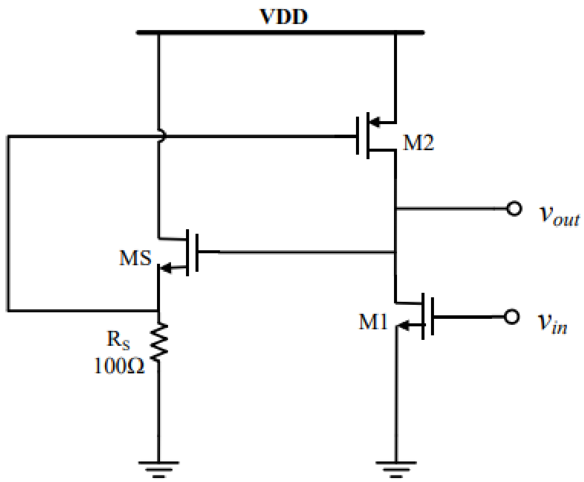




$$R_s = \frac{1}{g_{m1}} \| r_{o1} \| r_{o2} \| r_{o3}$$

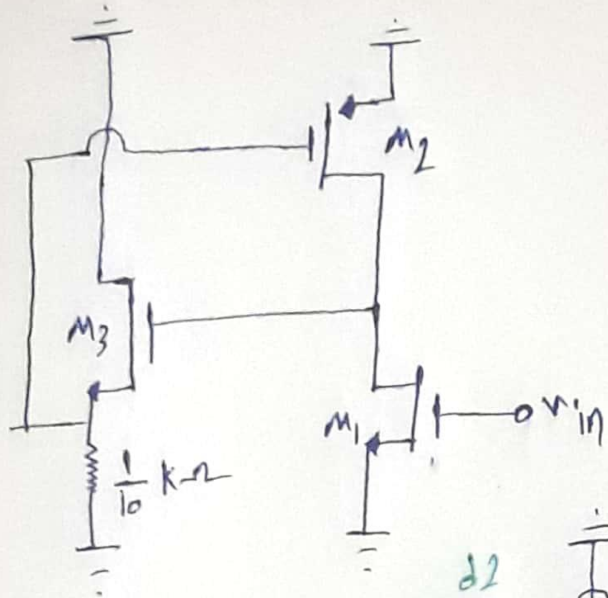
$$\frac{v_o}{v_{in}} = \frac{R_s}{R_s + \frac{1}{g_{m2}}}$$

4- Draw the small-signal model of the following circuit and calculate the voltage gain. Assume that all of the transistors are in saturation.



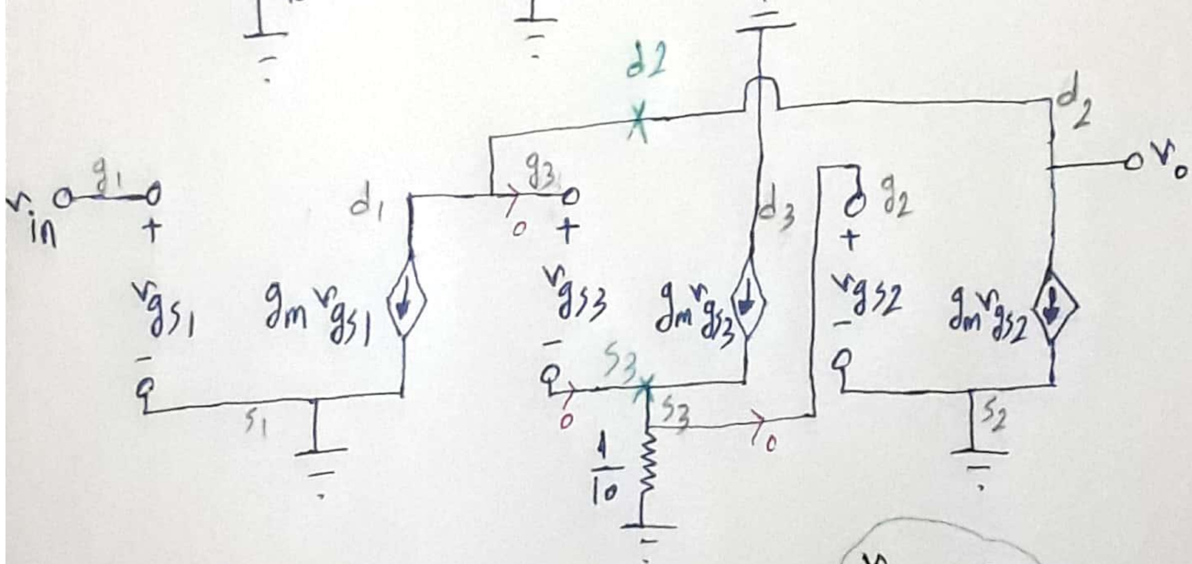
$$\begin{cases} g_m = 10\dfrac{mA}{V} \\ \lambda = 0 \end{cases}$$

4| FETها در ناحیه اشباع بایاس شده اند با رسم مدل s.s بهره ولتاژ را بدست آورید



$r_o = \infty$

$g_m = 10\,mS$



$$\frac{v_o}{v_{in}} = -2$$

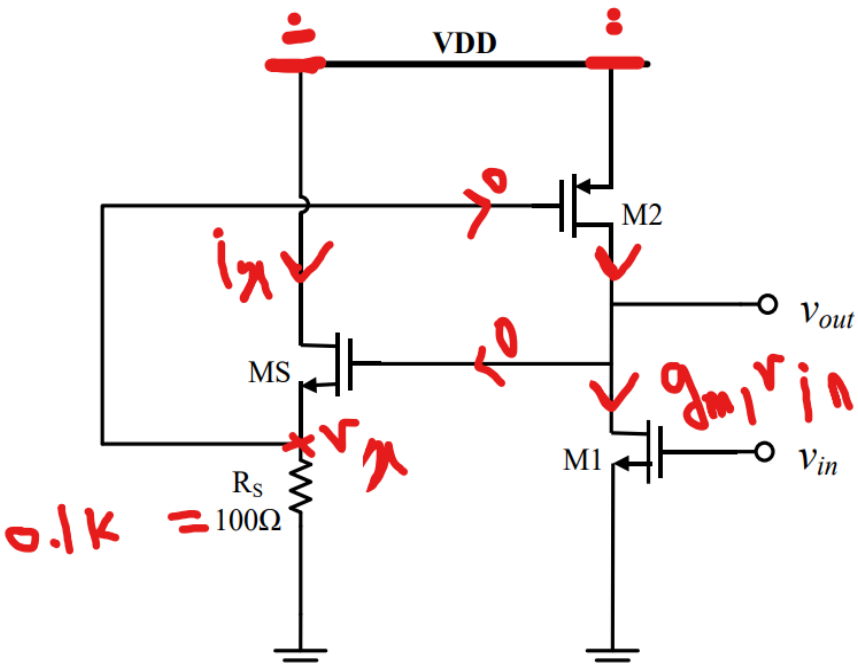
$v_{gs1} = v_{in}$ (I)

KCl @ d2: $g_m v_{gs1} = -g_m v_{gs2} \xrightarrow{(I)} v_{gs2} = -v_{in}$

KCl @ s_3: $v_{s3} = \frac{1}{10} g_m v_{gs3} = v_{gs3}$ (II) $\quad v_{s3} = v_{gs2} = -v_{in}$

$v_{gs3} = -v_{in} \qquad v_{gs3} = v_o - v_{s3} \rightarrow v_o = v_{gs3} + v_{s3} = -2v_{in}$

حل با استفاده از پخش جریان



$$\begin{cases} g_m = 10\dfrac{mA}{V} \\ \lambda = 0 \end{cases}$$

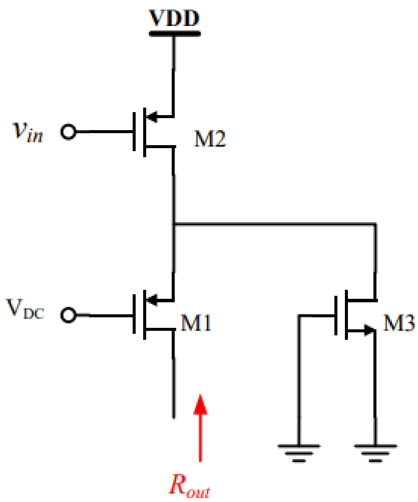
$v_{gs2} = v_x$

$i_{d2} = g_m v_x = -g_m v_{in} \rightarrow v_x = -v_{in}$ (I)

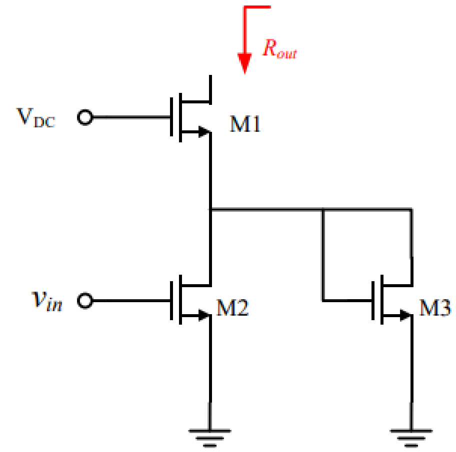
$i_x = g_m(v_o - v_x) = 10 v_x \rightarrow \quad 2v_x = v_o \rightarrow v_o = -2v_{in}$

$A_v = \dfrac{v_o}{v_{in}} = \boxed{-2 = \dfrac{v_o}{v_{in}}}$

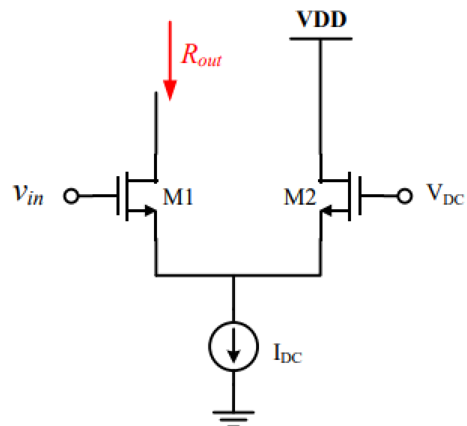
5- Specify a relation for the output resistance of the following circuits. Assume $\lambda \neq 0$.



(a)

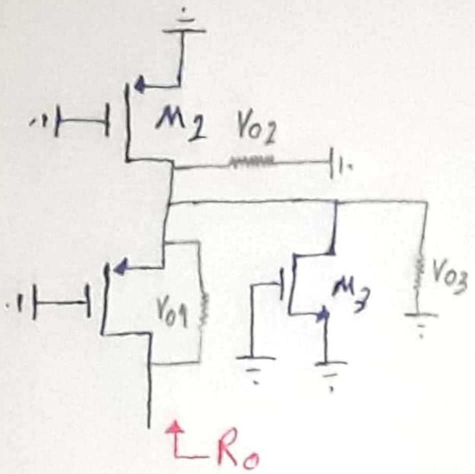


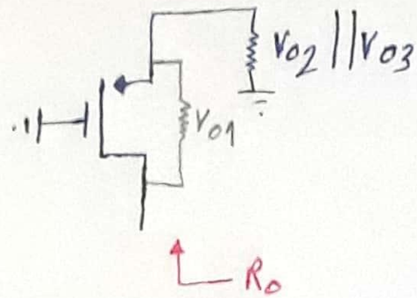
(b)



ac:

? = R_{out} | 5

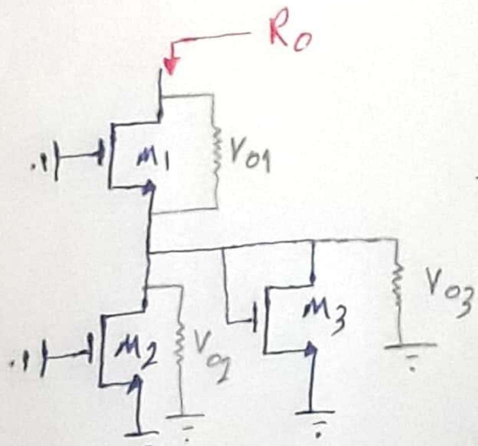


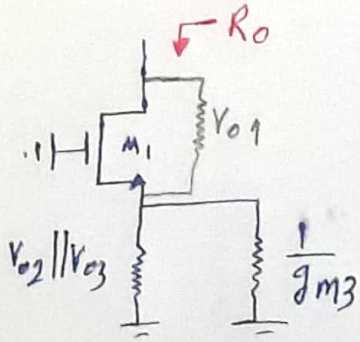


$$R_o \simeq r_{o1}\left(1 + g_{m1}\left(r_{o2} \| r_{o3}\right)\right)$$

| b

ac)

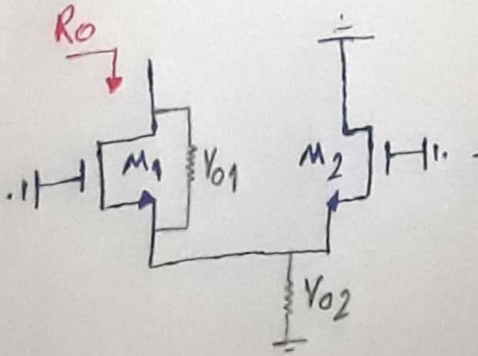


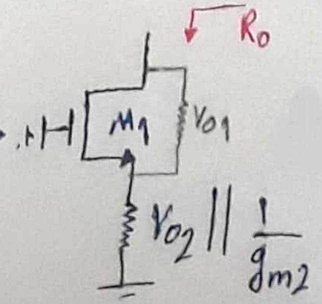


$$R_o \simeq r_{o1}\left(1 + g_{m1}\left(r_{o2} \| r_{o3} \| \frac{1}{g_{m3}}\right)\right)$$

| c

S.S)





$$R_o = r_{o1}\left(1 + g_{m1}\left(r_{o2} \| \frac{1}{g_{m2}}\right)\right)$$