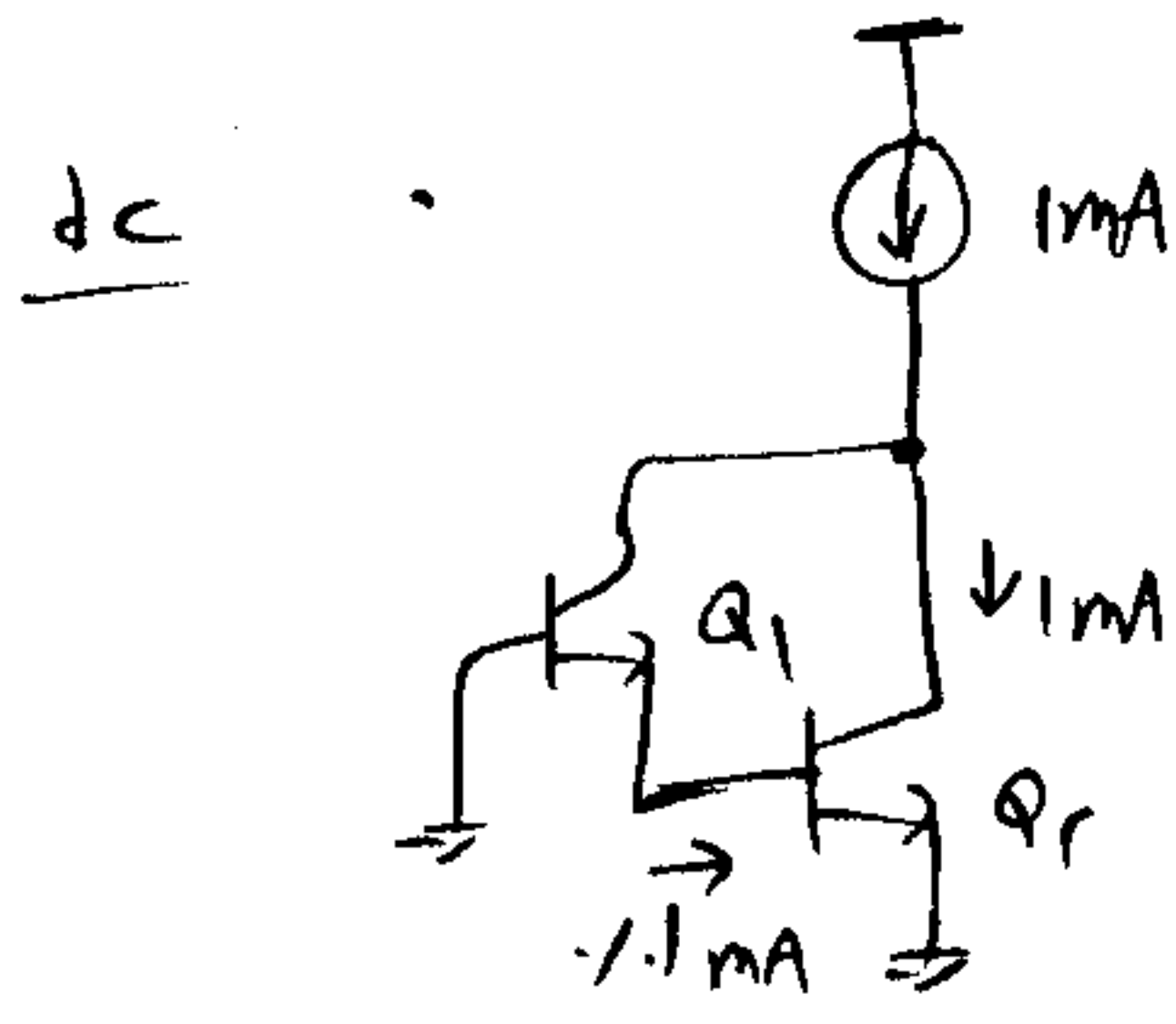


۱- ترانزیستور آمیپ است.

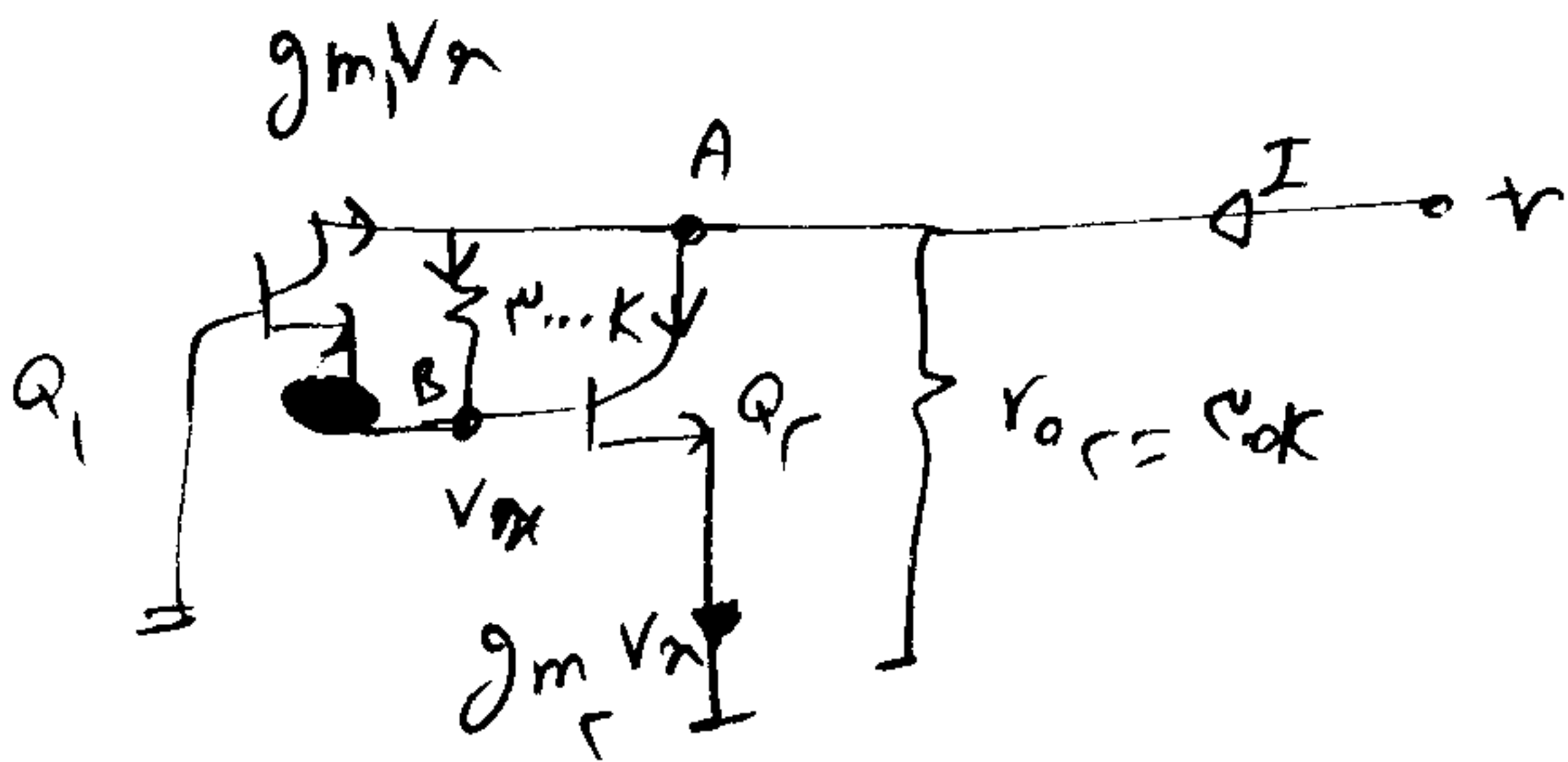


$I_{C1} = 1mA, I_{C2} = 1mA$

$g_{m1} = 7.5ms, g_{m2} = 5ms$

$r_{o1} = \frac{VA}{I_{C1}} = \frac{10}{0.1} = 100k\Omega, r_{o2} = \frac{10}{1} = 10k\Omega$

در خروجی ac = 0



KCL A: $I = \frac{V}{r_o} + g_{m2} v_n + \frac{V - v_n}{r_{o1}} - g_{m1} v_n$

$I = \frac{V}{r_o} + 5 v_n + \frac{V - v_n}{100} - 7.5 v_n$

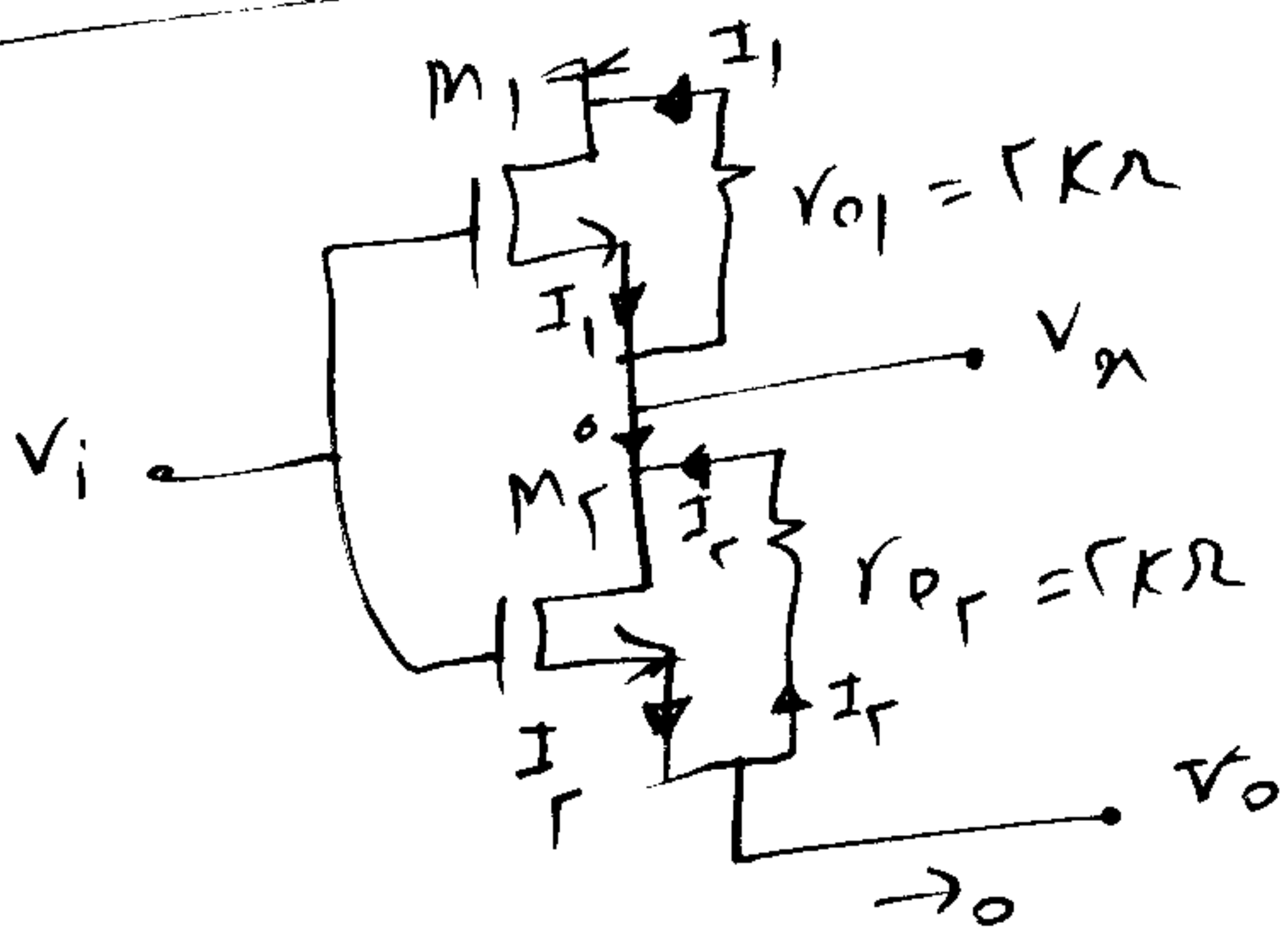
KCL (B): $\frac{V - v_n}{100} = 7.5 v_n + \frac{g_{m2}}{100} v_n$

$\frac{V - v_n}{100} = 7.5 v_n + \frac{5}{100} v_n \Rightarrow V - v_n = 750 v_n \Rightarrow v_n = \frac{V}{751}$

$I = \frac{V}{r_o} + \frac{V}{r_{o1}} + (5 v_n - 7.5 v_n - \frac{v_n}{100}) \approx \frac{V}{r_o} + 5 \frac{V}{751} = \frac{V}{r_o}$

$R_{out} = \frac{V}{I} = 10k\Omega$

۲- ترانزیستور آمیپ است.

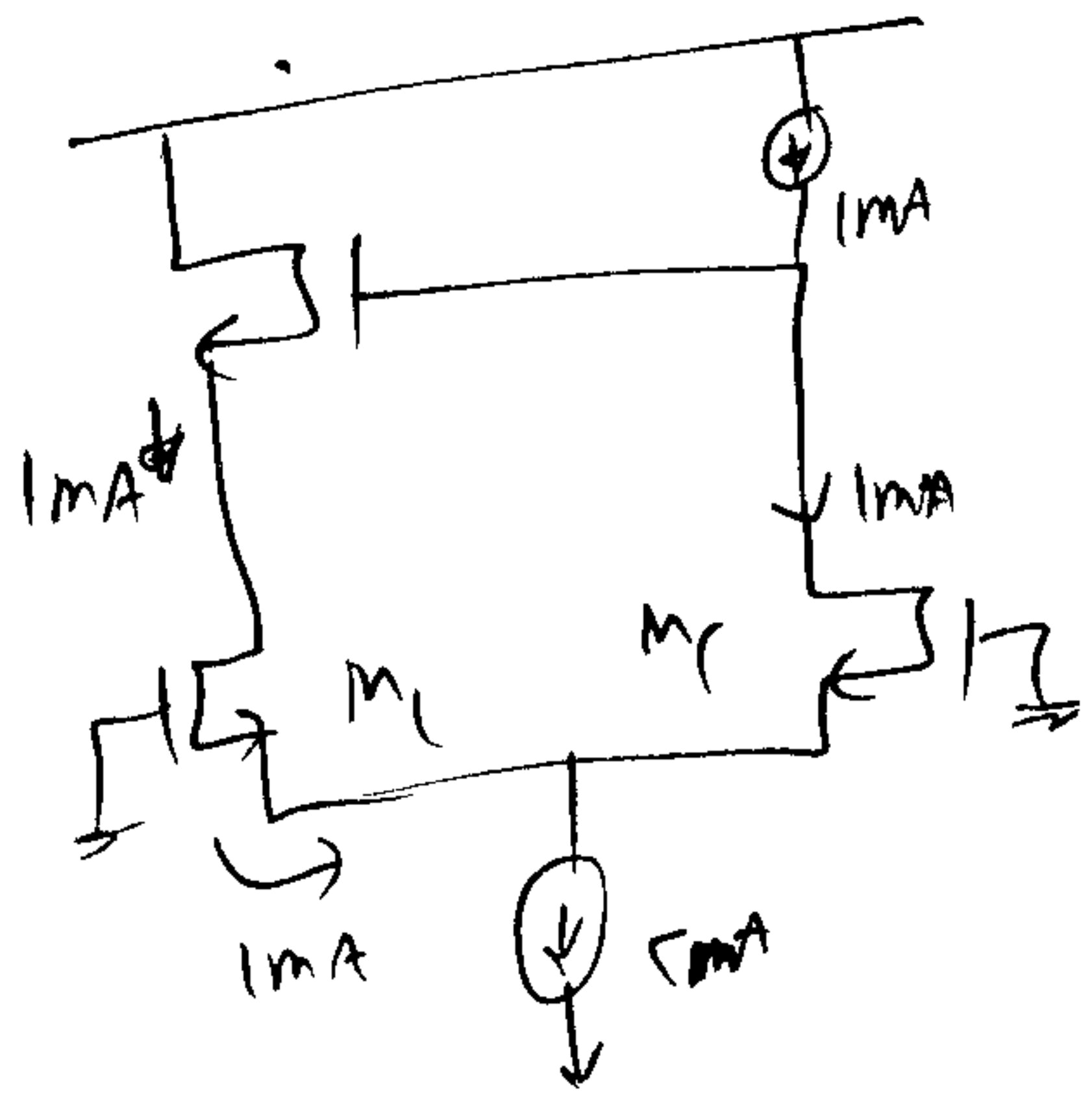


$I_1 = g_{m1} (v_i - v_n) = v_i - v_n$
 $I_2 = g_{m2} (v_i - v_o) = v_i - v_o$

$v_n = r I_1 = r (v_i - v_n) \Rightarrow 2v_n = r v_i \Rightarrow v_n = \frac{r}{2} v_i$

$v_o = r I_2 + r I_1 = r (I_1 + I_2) = r (2v_i - v_o - v_n)$

$v_o = 2v_i - v_o - r (\frac{r}{2} v_i) \Rightarrow 2v_o = \frac{1}{2} v_i \Rightarrow \frac{v_o}{v_i} = \frac{1}{4} = 0.25$

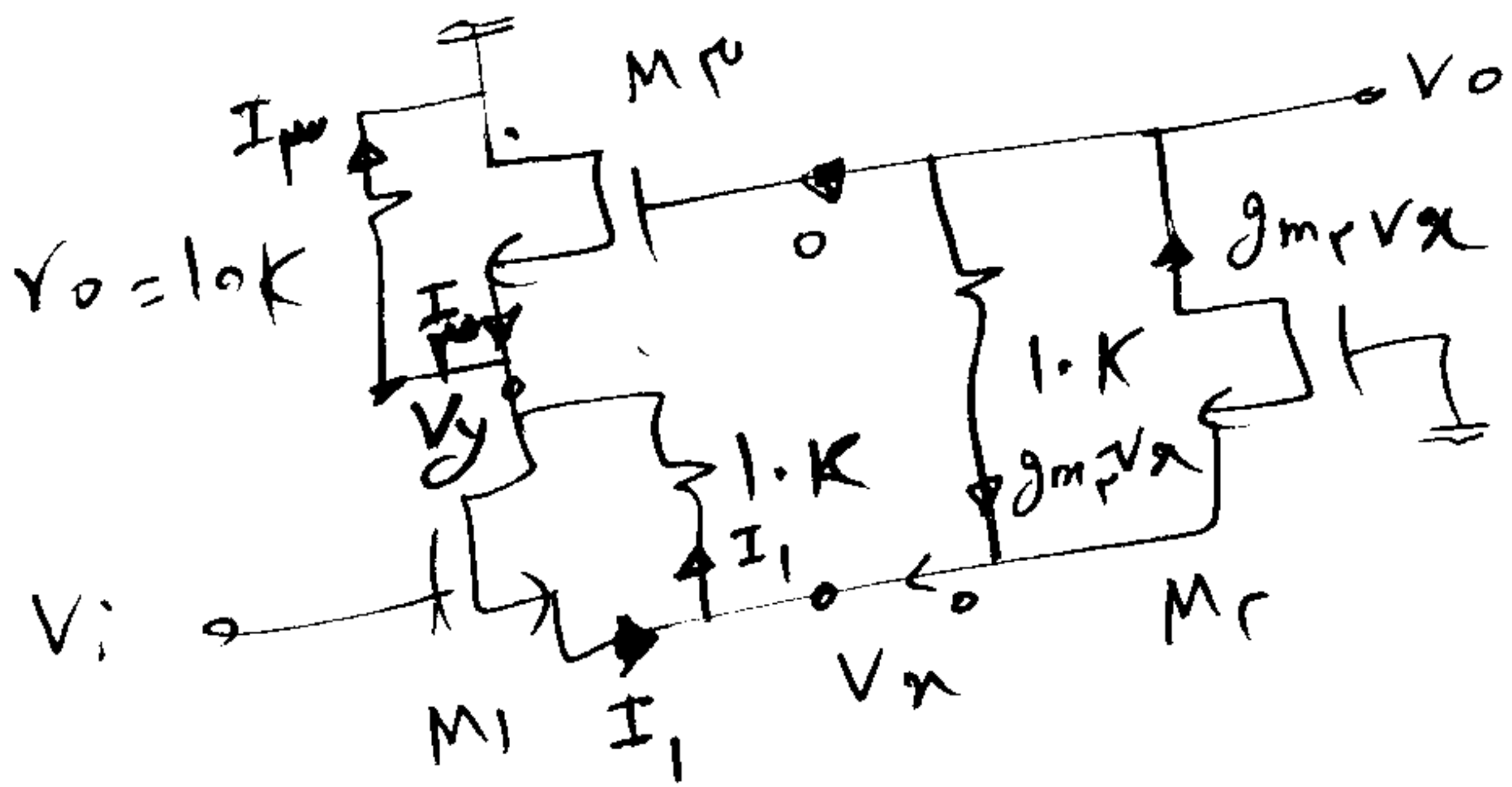


۳- ترانسپزیور صحیح است.

$$I_{D1} = I_{D2} = I_D = 1mA$$

$$r_o = \frac{1}{\lambda I_D} = \frac{1}{0.01(1)} = 10k\Omega$$

$$g_m = \frac{2 I_D}{|V_{GS} - V_{TH}|} = \frac{2(1)}{1} = 2mS$$



KVL $V_o = 10 g_m v_x + v_n = 10 v_n + v_n = 11 v_n$

KVL $v_n = 10 I_1 + v_y = 10 (g_m (V_i - v_n)) + v_y = 10 V_i - 10 v_n + v_y$

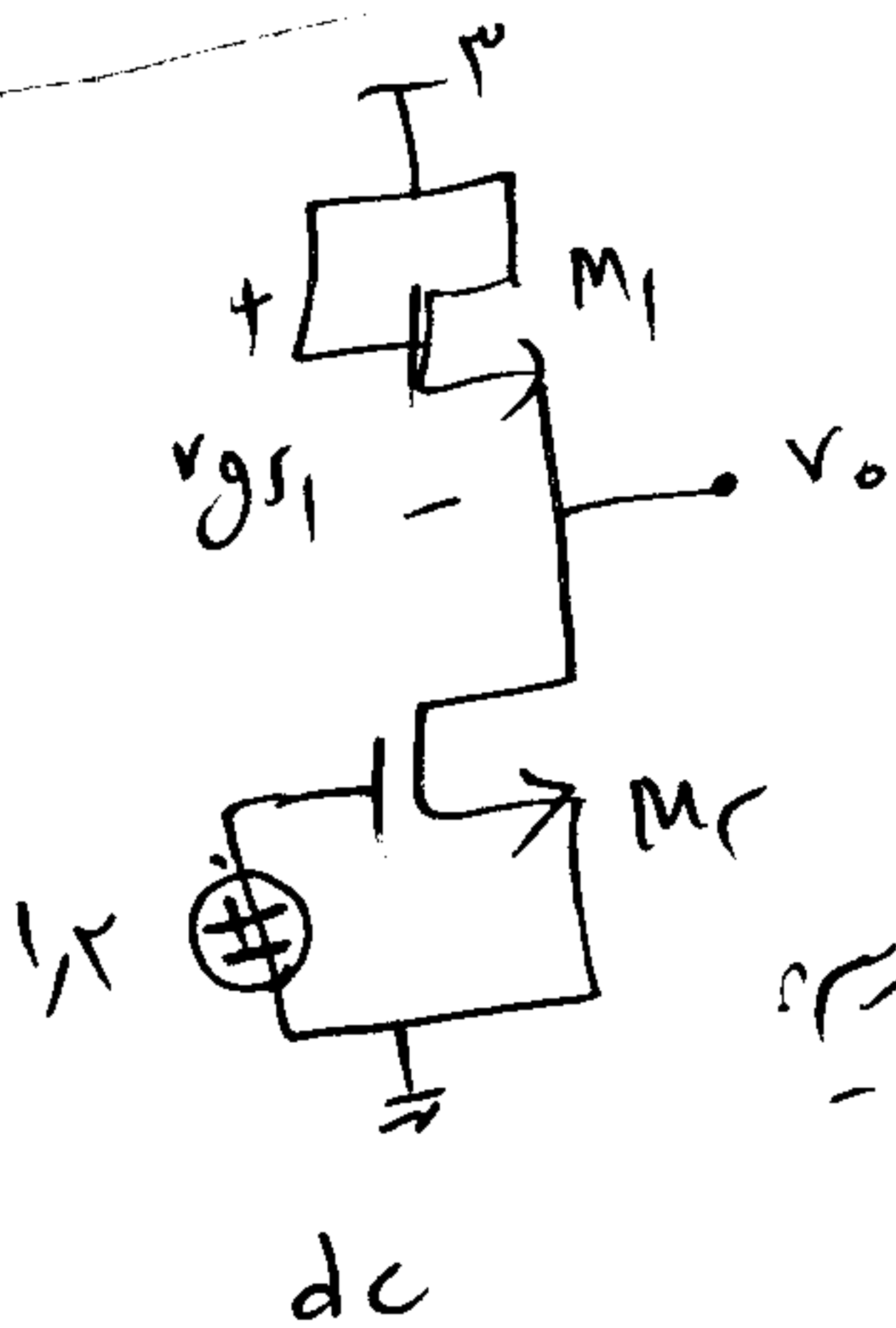
$$v_y = \frac{10}{11} V_o$$

$\Rightarrow 11 v_n = 10 V_i + v_y \Rightarrow V_o = 10 V_i + v_y$ (1)

KVL $v_y = 10 I_2 = 10 (g_m (V_o - v_y)) = 10 (V_o - v_y) \Rightarrow$

$V_o = 10 V_i + v_y = 10 V_i + \frac{10}{11} V_o \Rightarrow \frac{V_o}{11} = 10 V_i \Rightarrow \frac{V_o}{V_i} = 110$

۴- ترانسپزیور صحیح است.

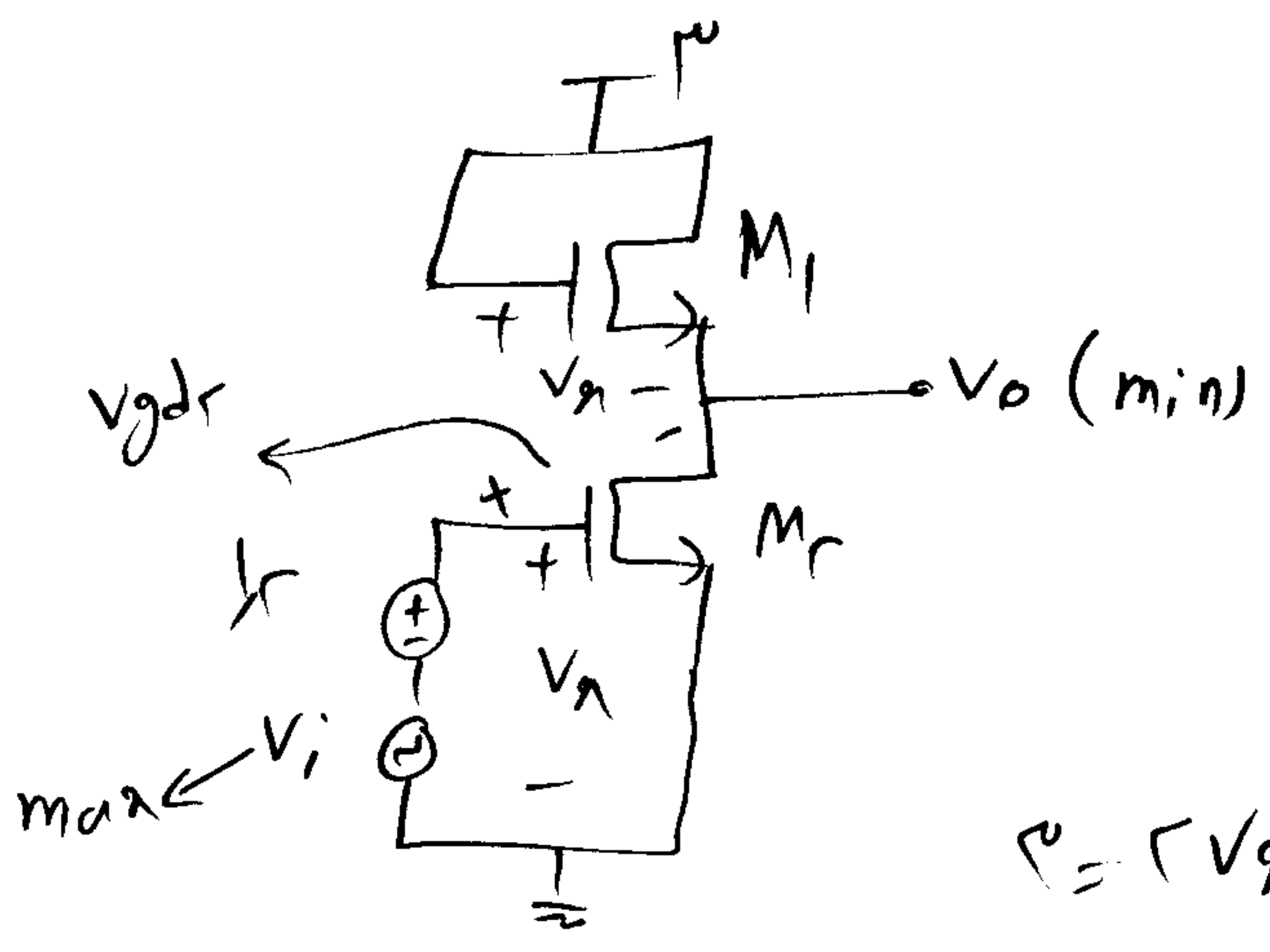


dc $\Rightarrow I_{D1} = I_{D2} \Rightarrow v_{gs1} = v_{gs2} = 1.2$

ولت $V_o(dc) = 1.2 - v_{gs1} = 1.2 - 1.2 = 0$

حد با افزایش V_i تغییر M_2 بیشتر شده و لذا M_2 در ترانسپزیور نزدیک شود.

M_2 در آستانه ترانسپزیور است. در این حالت داریم $V_i(max) = 0$



$$I_{D1} = I_{D2} \Rightarrow v_{gs1} = v_{gs2} = V_{gs}$$

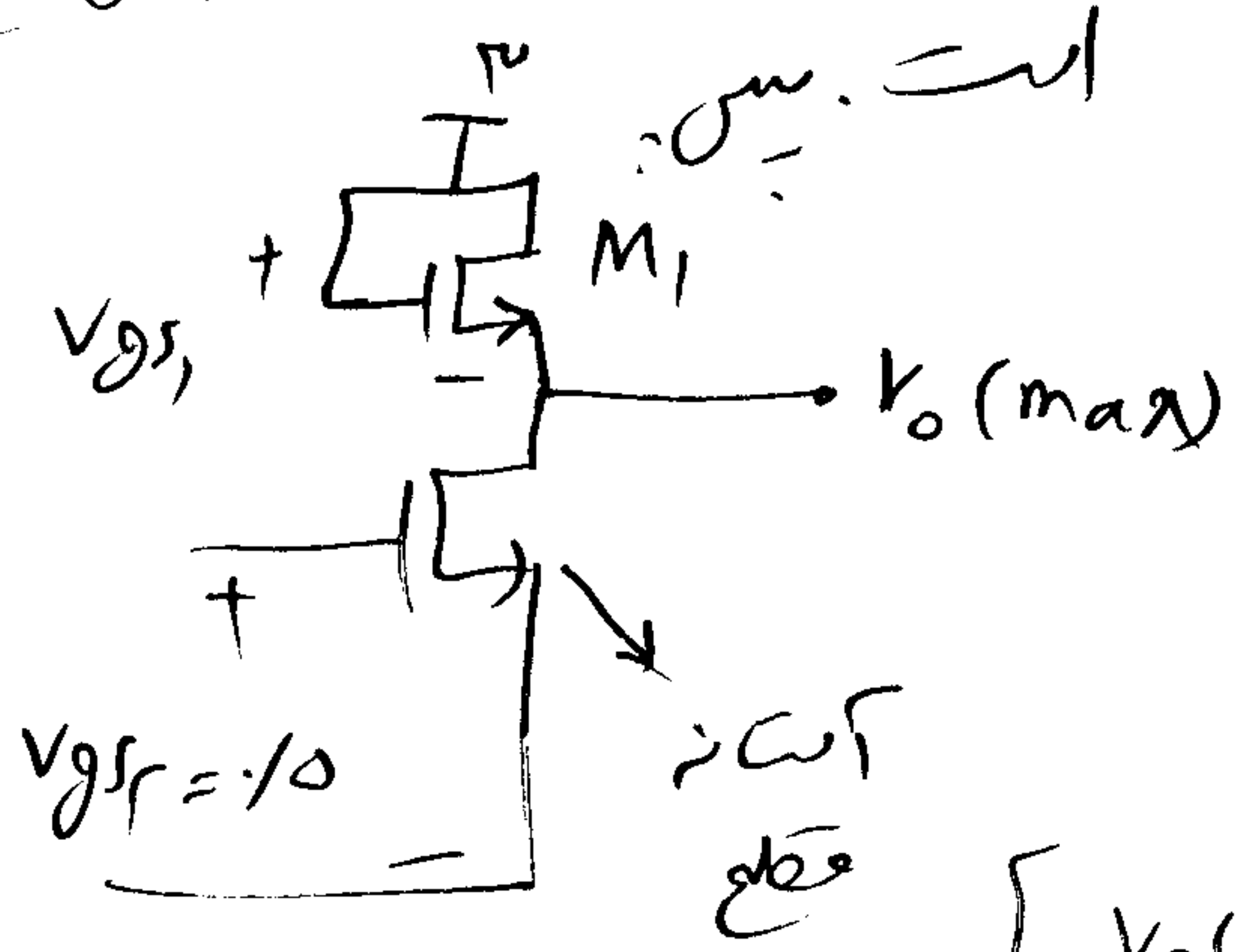
$$v_{gdr} = V_{TH} = 0.5V$$

KVL $V_{gs} = V_{gs} - v_{gdr} + V_{gs}$

$$V_{gs} = 2V_{gs} - 0.5 \Rightarrow V_{gs} = 0.5V$$

$$V_o(\min) = V_{gs} - V_{gs} = 0.5V - 0.5V = 0V$$

با کاهش v_i تقریباً M_2 کمتر شده تا M_2 را آستانه‌ی مقطع قرار می‌گیریم. در آن مقطع M_2 $v_{gs} = V_{TH} = 0.5V$



$$v_{gs1} = v_{gs2} = 0.5V$$

$$V_o(\max) = V_{gs1} = 0.5V = 0.5V$$

$$\begin{cases} V_o(\max) = 0.5V \\ V_o(\text{dc}) = 0.25V \\ V_o(\min) = 0V \end{cases} \begin{cases} V_{om}^+ = 0.5V \\ V_{om}^- = 0.25V \end{cases}$$

$$V_{om} = \min(V_{om}^+, V_{om}^-) = \min(0.5V, 0.25V) = 0.25V$$

موفقاً به شد. $0.25V$