سپهر مقیسه

تمرین سری هشت

۹۸۳۱۱۰۳

$$v_0 = 4v \implies I_{D_1} = \frac{5-4}{1k} = 1mA$$

$$V_{GS_2} = 4k(1mA) = 4V \implies I_D = k\left(V_{GS_2} - V_T\right)^2 = 1mA$$

$$R_1 = \frac{5-(-5) - V_{GS_1} - V_{GS_2}}{1mA} = 2k\Omega$$
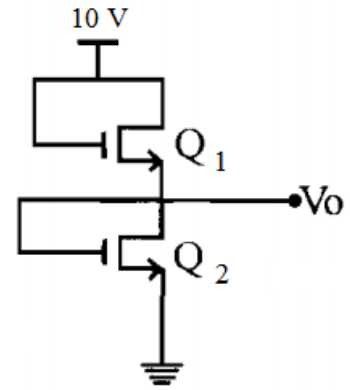
$$R_i = \frac{V_i}{I_i}$$

$$v_i = v_{gs_1} + g_m v_{gs_1}(4k) \quad , \quad g_m = k(V_{GS} - V_T) = 1\frac{mA}{V}$$

$$V_i = 5\left(V_{gs_1}\right) \quad , \quad V_{gs_2} = g_m v_{gs_1}(4k) = 4vgs_1$$

$$v_i = \frac{5}{4}\left(v_{gs_2}\right)$$

$$I_i = \frac{V_i}{R_1} + g_m v_{gs_2}$$

$$\frac{v_i}{I_i} = R_i = 0.77 \ k\Omega$$

10 V

$$Q_1$$

$$Q_2$$

•Vo

الف) $$I_{D_1} = I_{D_2} \Rightarrow \frac{K_1}{2}(V_{GS_1} - V_{T_1})^2 = \frac{K_2}{2}(V_{GS_2} - V_{T_2})^2$$

از طرفی: $$\begin{cases} K_1 = K_2 \\ V_{T_1} = V_{T_2} \end{cases} \Rightarrow \frac{K_1}{2}(V_{GS_1} - V_{T_1})^2 = \frac{K_1}{2}(V_{GS_2} - V_{T_1})^2$$

$$\Rightarrow (V_{GS_1} - V_{T_1})^2 = (V_{GS_2} - V_{T_1})^2 \Rightarrow V_{GS_1} = V_{GS_2}$$

$$I_{D_1} = I_{D_2} \Rightarrow \frac{K_1}{2}(V_{GS_1} - V_{T_1})^2 = \frac{K_2}{2}(V_{GS_2} - V_{T_2})^2$$

از طرفی: $$\begin{cases} V_{G_1} = 10^V \\ V_{S_1} = V_O \end{cases} \quad , \quad \begin{cases} V_{G_2} = V_O \\ V_{S_2} = 0^V \end{cases} \Rightarrow (10 - V_O) = (V_O - 0) \Rightarrow V_O = 5^V$$

ب)

$$I_{D_1} = I_{D_2} \Rightarrow \frac{k_1}{2}(V_{GS_1} - V_{T_1})^2 = \frac{k_2}{2}(V_{GS_2} - V_{T_2})^2$$

از طرفی: $\begin{cases} K_1 = \dfrac{K_2}{4} \\ V_{T_1} = V_{T_2} \end{cases} \Rightarrow \dfrac{K_2}{2 \times 4}(V_{GS_1} - V_{T_1})^2 = \dfrac{K_2}{2}(V_{GS_2} - V_{T_1})^2$

$$\Rightarrow V_{GS_1} - V_{T_1} = 2(V_{GS_2} - V_{T_1}) \quad , \quad \begin{cases} V_{G_1} = 10 \\ V_{S_1} = V_O \end{cases}, \quad \begin{cases} V_{G_2} = V_O \\ V_{S_2} = 0 V \end{cases}$$
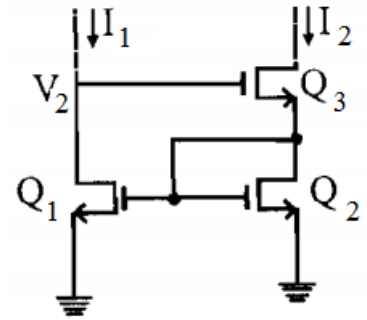
$$\Rightarrow (10 - V_O - V_{T_1}) = 2(V_O - 0 - V_{T_1}) \Rightarrow 3V_O = 10 + V_{T_1} \Rightarrow V_O = \frac{10 + V_{T_1}}{3}$$

ج)

$$I_{D_1} = I_{D_2} \Rightarrow \frac{K_1}{2}(V_{GS_1} - V_{T_1})^2 = \frac{K_2}{2}(V_{GS_2} - V_{T_2})^2 \quad , \quad \begin{cases} K_1 = K_2 \\ V_{T_1} = 4V_{T_2} \end{cases}$$

$$\Rightarrow (V_{GS_1} - 4V_{T_2})^2 = (V_{GS_2} - V_{T_2})^2 \Rightarrow V_{GS_1} - 4V_{T_2} = V_{GS_2} - V_{T_2}$$

$$\begin{cases} V_{G_1} = 10 \\ V_{S_1} = V_O \end{cases}, \quad \begin{cases} V_{G_2} = V_O \\ V_{S_2} = 0 \end{cases} \Rightarrow (10 - V_O - 4V_{T_2}) = (V_O - 0 - V_{T_2}) \Rightarrow 2V_O = 10 - 3V_{T_2}$$

$$\Rightarrow V_O = \frac{10 - 3V_{T_2}}{2}$$

$$I_{\text{۱}} = \frac{K_{\text{۱}}}{\text{۲}} (V_{GS_{\text{۱}}} - V_{T_{\text{۱}}})^{\text{۲}} \Rightarrow \text{۱mA} = \frac{\text{۲}}{\text{۲}} (V_{GS_{\text{۱}}} - \text{۲})^{\text{۲}} \Rightarrow \text{۱} = (V_{G_{\text{۱}}} - V_{S_{\text{۱}}} - \text{۲})^{\text{۲}}$$

$$V_{S_{\text{۱}}} = \text{۰ V} \Rightarrow \text{۱} = (V_{G_{\text{۱}}} - \text{۲})^{\text{۲}} \Rightarrow \begin{cases} V_{G_{\text{۱}}} - \text{۲} = \text{۱} \Rightarrow V_{G_{\text{۱}}} = \text{۳V} \\ V_{G_{\text{۱}}} - \text{۲} = -\text{۱} \Rightarrow V_{G_{\text{۱}}} = \text{۱V} \end{cases}$$

$V_{G_{\text{۱}}} = \text{۱ V}$ قابل قبول نمی‌باشد چون $V_{GS} = \text{۱V} > V_T$ نمی‌باشد.

$V_{۱} = V_{G_{\text{۱}}} = \text{۳V} \Rightarrow$ قابل قبول $V_{G_{\text{۱}}} = \text{۳V}$

$$I_{\text{۲}} = I_{D_{\text{۲}}} = I_{D_{\text{۱}}} = \frac{K_{\text{۲}}}{\text{۲}} (V_{GS_{\text{۲}}} - V_{T_{\text{۲}}})^{\text{۲}} \Rightarrow \begin{cases} V_{S_{\text{۲}}} = \text{۰} \\ V_{G_{\text{۱}}} = V_{G_{\text{۲}}} = \text{۳V} \end{cases}$$

$$\Rightarrow I_{\text{۲}} = \frac{\text{۲}}{\text{۲}} (\text{۳} - \text{۲})^{\text{۲}} = \text{۱mA}$$

$$I_{D_{\text{۳}}} = I_{D_{\text{۲}}} = \text{۱mA} \Rightarrow \text{۱mA} = \frac{K_{\text{۳}}}{\text{۲}} (V_{GS_{\text{۳}}} - V_{T_{\text{۳}}})^{\text{۲}} \Rightarrow$$

$$\text{۱mA} = \frac{\text{۲}}{\text{۲}} (V_{G_{\text{۳}}} - V_{S_{\text{۳}}} - \text{۲})^{\text{۲}}$$

از طرفی: $V_{S_{\text{۳}}} = V_{۱} = \text{۳V} \Rightarrow \text{۱} = (V_{G_{\text{۳}}} - \text{۳} - \text{۲})^{\text{۲}} \Rightarrow$

$$V_{G_3} - \Delta = \pm 1 \Rightarrow \begin{cases} V_{G_3} = 6 V \\ V_{G_3} = 4 V \Rightarrow \end{cases}$$ قابل قبول نمی‌باشد

$V_{G_3} = 4 V$ باشد در این صورت $V_{GS_3} = 4 - 3 = 1V$ می‌شود که از V_T کمتر می‌باشد پس

$V_{G_3} = 4 V$ قابل قبول نمی‌باشد پس داریم:

$$V_{G_3} = 6 V \Rightarrow V_3 = V_{G_3} = 6 V$$

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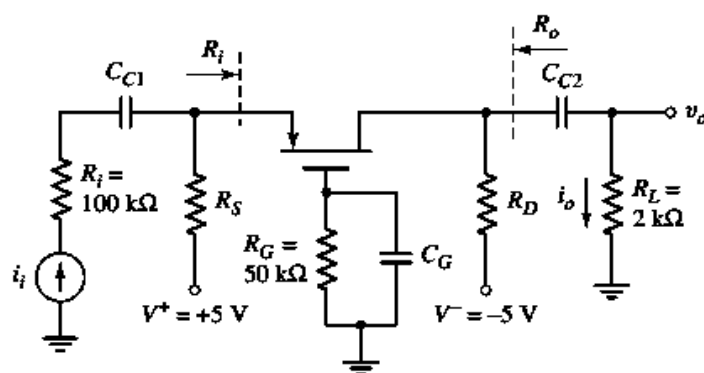
a.

$$I_{DQ} = K_p \left(V_{SG} + V_{TP} \right)^2$$
$$0.75 = (0.5)(V_{SG} - 1)^2 \Rightarrow V_{SG} = 2.225 \text{ V}$$
$$5 = I_{DQ} R_S + V_{SG} \Rightarrow R_S = \frac{5 - 2.225}{0.75} \Rightarrow \underline{R_S = 3.70 \text{ k}\Omega}$$
$$V_{SDQ} = 10 - I_{DQ} \left(R_S + R_D \right)$$
$$6 = 10 - (0.75)(3.70 + R_D) \Rightarrow \underline{R_D = 1.63 \text{ k}\Omega}$$

b.

$$R_i = \frac{1}{g_m}$$
$$g_m = 2\sqrt{K_p I_{DQ}} = 2\sqrt{(0.5)(0.75)} = 1.225 \ mA/V$$
$$R_i = \frac{1}{1.225} \Rightarrow \underline{R_i = 0.816 \text{ k}\Omega}$$
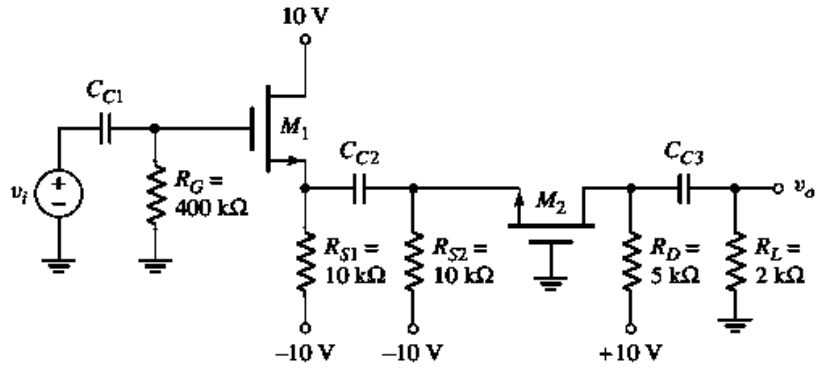$$R_o = R_D \Rightarrow \underline{R_o = 1.63 \text{ k}\Omega}$$

c.

$$i_0 = \left(\frac{R_D}{R_D + R_L} \right) \left(\frac{R_S}{R_S + \left[1/g_m \right]} \right) \cdot i_i$$

$$i_0 = \left(\frac{1.63}{1.63 + 2} \right) \left(\frac{3.70}{3.70 + 0.816} \right) i_i$$

$$i_0 = 0.368 i_i = \underline{i_0 = 1.84 \sin \omega t \, (\mu A)}$$

$$v_0 = i_0 R_L = (1.84)(2) \sin \omega t \Rightarrow \underline{v_0 = 3.68 \sin \omega t \, (mV)}$$

(a)

$$I_{DQ1} = \frac{10 - V_{GS1}}{R_{S2}} = K_{n1}\left(V_{GS1} - V_{TN1}\right)^2$$

$$10 - V_{GS1} = (4)(10)\left(V_{GS1}^2 - 4V_{GS1} + 4\right)$$

$$40V_{GS1}^2 - 159V_{GS1} + 150 = 0$$

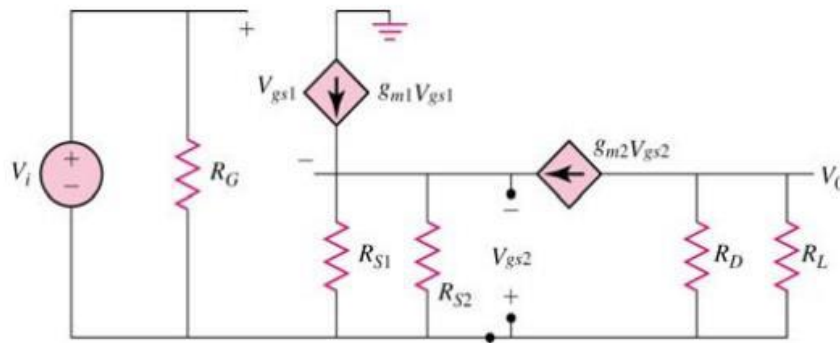$$V_{GS1} = \frac{159 \pm \sqrt{(159)^2 - 4(40)(150)}}{2(40)} \Rightarrow V_{GS1} = 2.435 \text{ V}$$

$$I_{DQ1} = (4)(2.435 - 2)^2 \Rightarrow \underline{I_{DQ1} = 0.757 \text{ mA}}$$

$$V_{DSQ1} = 20 - (0.757)(10) \Rightarrow \underline{V_{DSQ1} = 12.4 \text{ V}}$$

Also $\underline{I_{DQ2} = 0.757 \text{ mA}}$

$$V_{DSQ2} = 20 - (0.757)(10 + 5) \Rightarrow \underline{V_{DSQ2} = 8.65 \text{ V}}$$

(b)

$$g_{m1} = g_{m2} = 2\sqrt{KI_{DQ}} = 2\sqrt{(4)(0.757)} \Rightarrow \underline{g_{m1} = g_{m2} = 3.48 \; mA/V}$$

$$V_0 = -\left(g_{m2}V_{gs2}\right)\left(R_D \| R_L\right)$$

$$V_{gs2} = \left(-g_{m1}V_{gs1} - g_{m2}V_{gs2}\right)\left(R_{S1} \| R_{S2}\right)$$

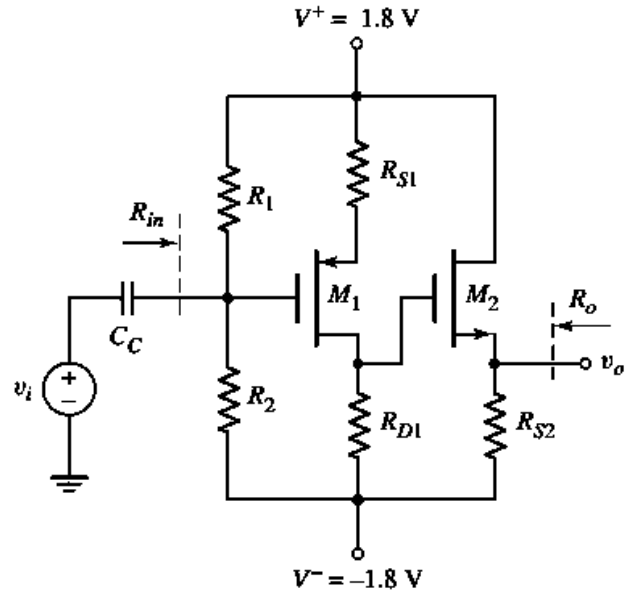$$V_i = V_{gs1} - V_{gs2} \Rightarrow V_{gs1} = V_i + V_{gs2}$$

$$V_{gs2} + g_{m2}V_{gs2}\left(R_{S1} \| R_{S2}\right) = -g_{m1}\left(V_i + V_{gs2}\right)\left(R_{S1} \| R_{S2}\right)$$

$$V_{gs2} + g_{m2}V_{gs2}\left(R_{S1} \| R_{S2}\right) + g_{m1}V_{gs2}\left(R_{S1} \| R_{s2}\right) = -g_{m1}V_i\left(R_{S1} \| R_{S2}\right)$$

$$V_{gs2} = \frac{-g_{m1}V_i\left(R_{S1} \| R_{S2}\right)}{1 + g_{m2}\left(R_{S1} \| R_{S2}\right) + g_{m1}\left(R_{S1} \| R_{S2}\right)}$$

$$A_v = \frac{V_0}{V_i} = \frac{g_{m1}g_{m2}\left(R_{S1} \| R_{S2}\right)\left(R_D \| R_L\right)}{1 + \left(g_{m1} + g_{m2}\right)\left(R_{S1} \| R_{S2}\right)}$$

$$A_v = \frac{(3.48)^2\left(10 \| 10\right)\left(5 \| 2\right)}{1 + \left(3.48 + 3.48\right)\left(10 \| 10\right)} \Rightarrow \underline{A_v = 2.42}$$

$V^+ = 1.8$ V

R_{S1}

R_1

R_{in}

M_1 M_2 R_o

C_C

v_o

v_i

R_2 R_{D1} R_{S2}

$V^- = -1.8$ V

(a) $R_{S1} = \dfrac{0.6}{0.1} = 6\,\text{k}\Omega$

$V_{D1} = 1.8 - 0.6 - 1 = 0.2$ V

$R_{D1} = \dfrac{0.2 - (-1.8)}{0.1} = 20\,\text{k}\Omega$

$I_{DQ1} = K_{p1}\left(V_{SGQ1} + V_{TP}\right)^2$

$0.1 = 0.4\left(V_{SGQ1} - 0.4\right)^2 \Rightarrow V_{SGQ1} = 0.90$ V

$I_{DQ2} = K_{n2}\left(V_{GSQ2} - V_{TN}\right)^2$

$0.3 = 4\left(V_{GSQ2} - 0.4\right)^2 \Rightarrow V_{GSQ2} = 0.6739$ V

$V_{G1} = 1.8 - 0.6 - V_{SGQ1} = 1.8 - 0.6 - 0.9 = 0.3$ V

$V_{G1} = \left(\dfrac{R_2}{R_1 + R_2}\right)(3.6) - 1.8$

$0.3 = \dfrac{1}{R_1}(200)(3.6) - 1.8 \Rightarrow R_1 = 343\,\text{k}\Omega$

$$R_1 \| R_2 = 200\,\text{k}\Omega \Rightarrow R_2 = 480\,\text{k}\Omega$$

$$V_{D1} = 1.8 - 0.6 - 1.0 = 0.2\,\text{V}$$

$$V_{S2} = V_{D1} - V_{GSQ2} = 0.2 - 0.6739 = -0.4739\,\text{V}$$

$$R_{S2} = \frac{-0.4739 - (-1.8)}{0.3} = 4.42\,\text{k}\Omega$$

(b) $A_v = \left(\dfrac{-g_{m1}R_{D1}}{1 + g_{m1}R_{S1}}\right)\left(\dfrac{g_{m2}R_{S2}}{1 + g_{m2}R_{S2}}\right)$

$$g_{m1} = 2\sqrt{K_{p1}I_{DQ1}} = 2\sqrt{(0.4)(0.1)} = 0.4\,\text{mA/V}$$

$$g_{m2} = 2\sqrt{K_{n2}I_{DQ2}} = 2\sqrt{(4)(0.3)} = 2.191\,\text{mA/V}$$

$$A_v = \frac{-(0.4)(20)}{1 + (0.4)(6)} \cdot \frac{(2.191)(4.42)}{1 + (2.191)(4.42)} = -2.13$$

(c) $R_o = \dfrac{1}{g_{m2}} \| R_{S2} = \dfrac{1}{2.191} \| 4.42 = 0.4564 \| 4.42 \Rightarrow R_o = 414\,\Omega$