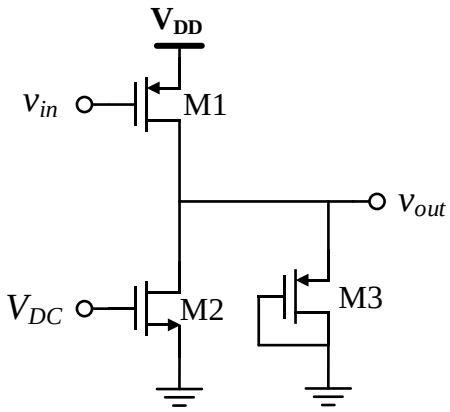
Electronics2, Quiz #1	Shahrood University of Technology	**1401/08/19**
Name:		**90 min**

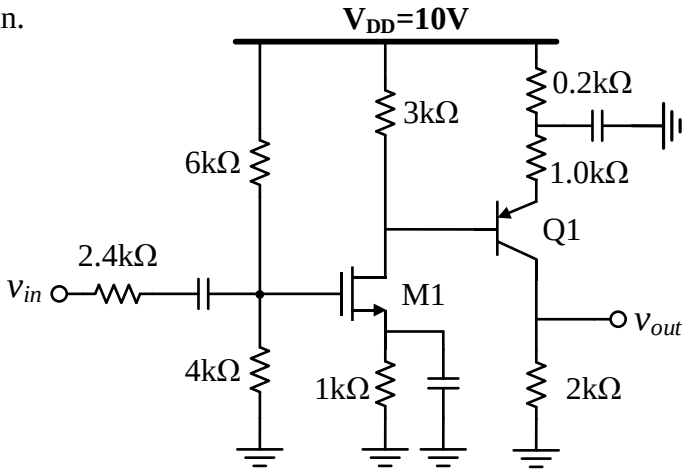
1- a) Using the small-signal **model**, determine a relation for the voltage gain ($A_v = V_{out} / V_{in}$) of the following circuit. Assume that the transistors operate in saturation and $\lambda \neq 0$.

b) Determine R_{out}.



2- a) Determine the bias points of the transistors.

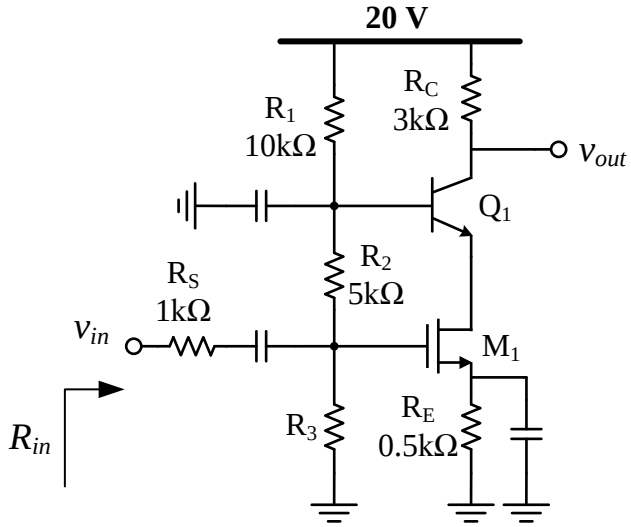
b) Calculate the voltage gain.



$$\begin{cases} V_{EB,on} = 0.6\,\text{V} \\ V_{EC,sat} = 0.2\text{V} \\ V_{TH} = 1\text{V} \\ \beta_{nmos} = 0.5\,\text{mA/V}^2 \\ \beta_{pnp} = 100 \\ V_A = 100V \\ \lambda = 0 \end{cases}$$

3- a) Specify R_3 so that the bias current of the transistors will be equal to 2 mA. Prove that Q1 operates in forward active region.

b) Calculate the voltage gain ($A_v = V_{out} / V_{in}$) and the input resistance (R_{in}). Neglect the base current in DC analysis.



$$BJT: \begin{cases} V_{BE} = 0.7V \\ V_{CEsat} = 0.2V \\ V_A = \infty \\ V_T = 25mV \\ \beta = 100 \end{cases}$$

$$MOS: \begin{cases} V_{TH} = 2V \\ \mu_n C_{ox} = 0.5\,mA/V^2 \\ \lambda = \infty \\ \left(\frac{W}{L}\right) = \frac{2\mu m}{1\mu m} \end{cases}$$

Good luck – M.R. Ashraf

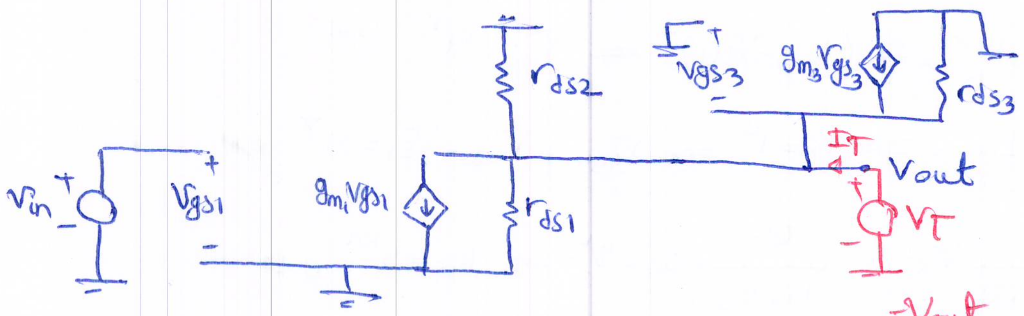
روابط قابل استفاده:

$$R_{seen-base} = r_\pi + (\beta + 1)R_E$$
$$R_{seen-collector} = r_O(1 + g_m(R_E \parallel r_\pi))$$
$$R_{seen-emitter} = \frac{r_O + R_C}{1 + g_m r_O} \qquad if\ (R_B = 0)$$
$$R_{seen-emitter} = \frac{r_\pi + R_B}{\beta} \qquad if\ (R_B \neq 0)$$

$$A_{V,CE} = -g_m(R_C \parallel r_O)$$
$$A_{V,ED} = \frac{-R_C}{R_E + 1/g_m}$$
$$A_{V,CC} = \frac{R_E}{R_E + 1/g_m}$$
$$A_{V,CB} = g_m(R_C \parallel r_O)$$

حل سوالات کوئیز اول الکترونیک ۲، نیم سال اول تحصیلی ۱۴۰۱-۰۲

۱۶ نمره — حل سوال اول:



۸ نمره — مقاومت خروجی ←

منابع ورودی صفر

$$KCL @ V_{out}: \frac{V_{out}}{r_{ds1}} + \frac{V_{out}}{r_{ds2}} + \frac{V_{out}}{r_{ds3}} - g_{m3}V_{gs3} + g_{m1}V_{gs1} - I_T = 0$$

($V_{gs3} \to -V_{out}$, $V_{gs1} = V_{in} \to 0$)

$$V_{out} = V_T \Rightarrow \frac{V_T}{I_T} = r_{ds1} \| r_{ds2} \| r_{ds3} \| 1/g_{m3}$$

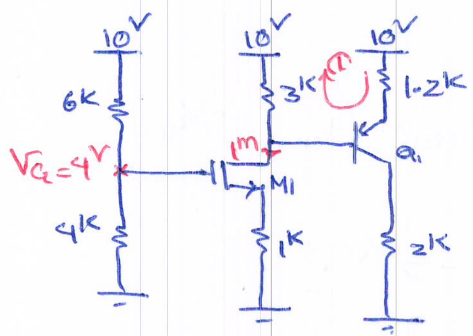
بهره ولتاژ ← ۸ نمره

$$\frac{V_{out}}{r_{ds1}} + \frac{V_{out}}{r_{ds2}} + \frac{V_{out}}{r_{ds3}} - g_{m3}V_{gs3} + g_{m1}V_{gs1} = 0$$

($V_{gs3} \to -V_{out}$, $V_{gs1} \to V_{in}$)

$$\Rightarrow A_V = \frac{V_{out}}{V_{in}} = -g_{m1}(r_{ds1} \| r_{ds2} \| r_{ds3} \| 1/g_{m3}) \cong -g_{m1}/g_{m3}$$

۲۰ نمره — حل سوال دوم:



حل DC:
۱۰ نمره

$$I_{M1} = \tfrac{1}{2}\beta_{nmos}(V_{GS} - V_{TH})^2$$

$$= \tfrac{1}{2} \times \tfrac{1}{2}^{m} \times (4 - 1^{k} I_{M1} - 1)^2 \Rightarrow I_{M1} = 1^{mA}$$

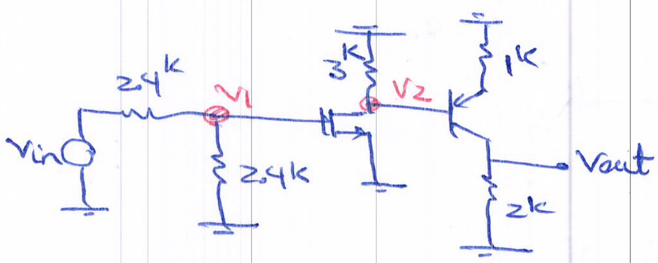
۲ نمره → $V_{GD1} = 3^V > 1^V$ ✓

$$KVL @: -10 + 1.2^{k} I_{E1} + 0.6 - 3^{k}(1^{m} - I_{B1}) + 10 = 0$$

$$\Rightarrow I_{E1} = I_{C1} = 2^{mA}$$ ۲ نمره

$\Rightarrow V_{DS1} = 6^V > V_{GS1} - V_{TH} = 2^V$ ✓ ۲ نمره , $V_{EC1} = 3.6^V > 0.2^V$ ✓ ۲ نمره

$$\begin{cases} g_{m1(M)} = 1^{mA/V} \\ g_{mQ1} = 80^{mA/V} \end{cases}$$



حل S.S:
۱۰ نمره

$$\frac{V_{out}}{V_{in}} = \frac{V_{out}}{V_2} \cdot \frac{V_2}{V_1} \cdot \frac{V_1}{V_{in}}$$

$$\frac{V_{out}}{V_2} = \frac{-2^k}{1^k + 1/80^m} \cong -2^{V/V}$$ ۳ نمره

$$\frac{V_2}{V_1} = -g_{m1}(3^k \| r_{\pi} + (\beta+1)1^k) \cong -3^{V/V}$$ ۳ نمره

$$\frac{V_1}{V_{in}} = \frac{2.4^k}{2.4^k + 2.4^k} = 1/2$$ ۲ نمره

$$\Rightarrow \frac{V_{out}}{V_{in}} = +3^{V/V}$$ ۲ نمره

حل سؤال سوم :

$$I_{M1} = 2^{mA} = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{TH})^2 \Rightarrow V_{GS} = 4^V$$

$$\Rightarrow V_{S1} = R_E \times I_{M1} = 2\times 0.5 = 1^V \Rightarrow V_{GM1} = V_{GS} + V_{S1} = 5^V$$

$$V_{GM1} = \frac{R_3}{R_1+R_2+R_3}V_{CC} = \frac{R_3}{15+R_3}\times 20 = 5^V \Rightarrow R_3 = 5^{k\Omega}$$

$$V_{B1} = \frac{R_2+R_3}{R_2+R_3+R_1}V_{CC} = 10^V \Rightarrow V_{E1} = 10-0.7 = 9.3^V \rightarrow V_{DS1} = 8.3$$

$$V_{C1} = V_{CC} - R_C I_{RC} = 20 - 3^k \times 2^m = 14^V \Rightarrow V_{CEQ1} = 14-9.3 = \underline{4.7^V}$$

$$g_{mQ1} = 80^{mA/V}, \quad g_{mM1} = \frac{2I}{V_{GS}-V_{TH}} = 2^{mA/V}$$

$$A_V = \frac{V_{out}}{V_{in}} = \frac{V_{out}}{V_{e1}} \times \frac{V_{e1}}{V_{g1}} \times \frac{V_{g1}}{V_{in}}$$

$$\Rightarrow \frac{V_{out}}{V_{e1}} = +g_{mQ1} \times R_C = 80^m \times 3^k = 240^{V/V}$$

$$\Rightarrow \frac{V_{e1}}{V_{g1}} = -g_{mM1} \times R_{DM1} = -g_{mM1} \times R_{inQ1} = -g_{mM1} \times 1/g_{mQ1} = -1/40$$

$$\frac{V_{g1}}{V_{in}} = \frac{R_2 \| R_3}{R_2 \| R_3 + R_S} = \frac{2.5}{3.5} \Rightarrow A_V = -5^{V/V}$$

$$R_{in} = R_S + R_2 \| R_3 = 1^k + 5^k \| 5^k = 3.5^{k\Omega}$$