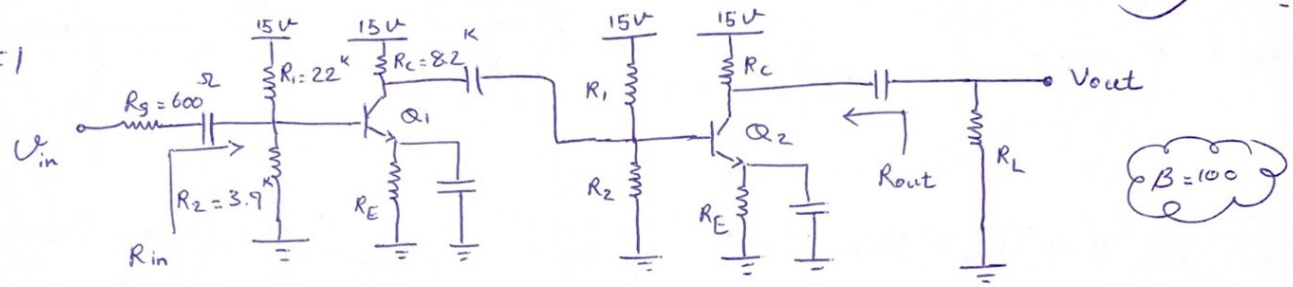
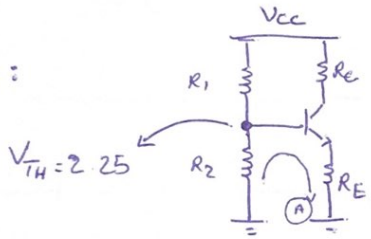
یا لطیف

رضا دبیری
۹۸۱۴۳۰۴۳
تمرین سری ۴ آنالوگ ۲

#1



DC Analysis:



$\equiv$

KVL @ A: $-V_{TH} + R_{TH} I_B + V_{BE} + R_E I_C = 0$

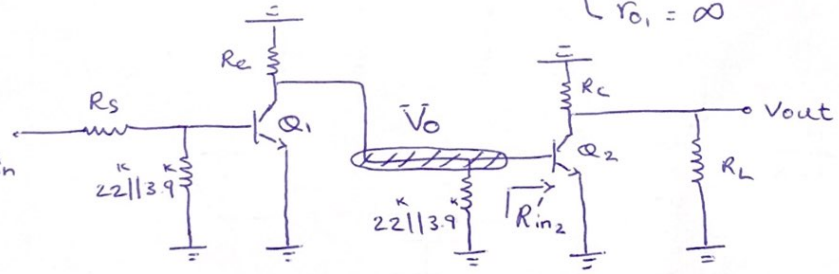
$-2.25 + 3.3^K \left(\frac{I_C}{100}\right) + 0.7 + 2^K I_C = 0$

$I_C \left(\frac{3.3^K}{100} + 2\right) = 2.25 - 0.7$

$I_{C_1} \simeq I_E = 0.76\ ^{mA} \rightarrow g_{m_1} = 30.5\ \frac{mA}{V}$

$\begin{cases} r_{\pi_1} = \frac{100}{30.5} = 3.2^{K\Omega} \\ r_{o_1} = \infty \end{cases}$

ac analysis:

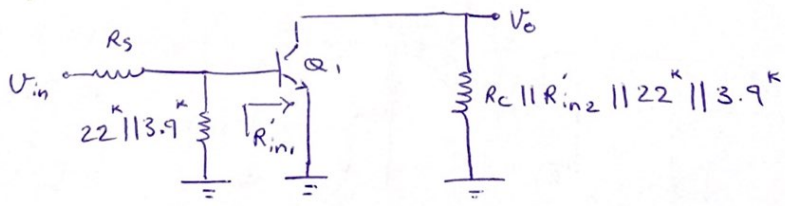


$A_v = \frac{V_{out}}{V_{in}} = \frac{V_{in}}{V_o} \times \frac{V_o}{V_{out}}$

$\frac{V_o}{V_{out}} = -g_{m_2}(R_{C_2} \| r_{o_2}) = -30.5\left(R_L \| R_{C_2}\right)$

$= -30.5\left(51^K \| 8.2^K\right) = -215.4\ \frac{V}{V}$

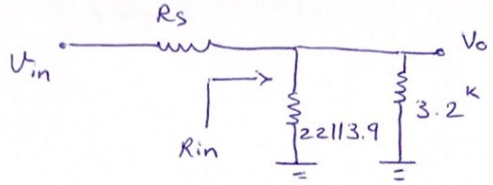
$R'_{in_2} = r_\pi = 3.2^K$



$\frac{V_{in}}{V_o} = -g_{m_1}(R_C \| r_{o_1}) = -30.5\left(3.9^K \| 22^K \| 3.2^K \| 8.2^K\right) = 1.35^K \times (-30.5) = -41$

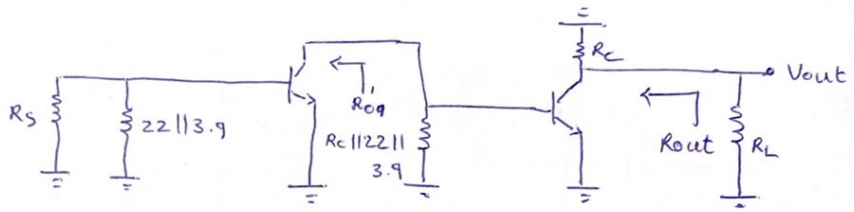
$\Rightarrow \frac{V_{out}}{V_{in}} = A_v = -41 \times (-215.4) = 8869\ \frac{V}{V}$

$\therefore r_\pi = 3.2^K$ $\Rightarrow$

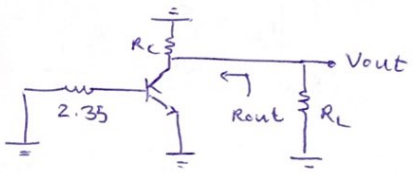


$R_{in} = 3.2^K \,||\, 22^K \,||\, 3.9^K = 1.62^{K\Omega}$

R_{out} : $R_{in} \rightarrow 0$

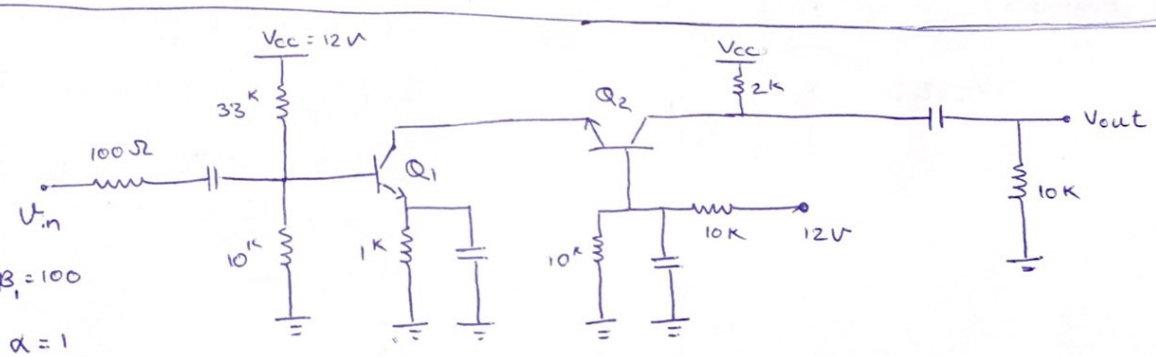


$R'_{o_1} = 8.2^K \,||\, 22^K \,||\, 3.9^K \,||\, r_o = 2.35^{K\Omega}$ $\Rightarrow$



$R_{out} = R_c \,||\, r_o = \underline{8.2^{K\Omega}}$

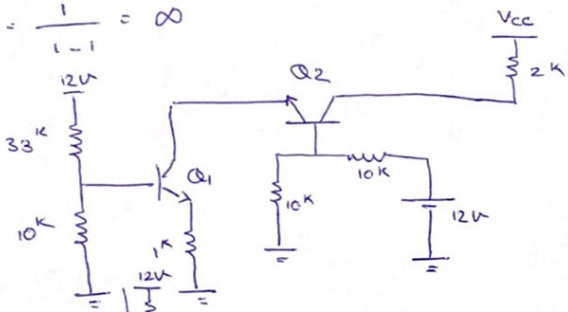
#2



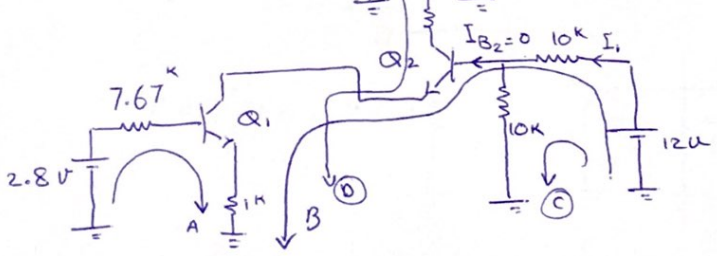
$\begin{cases} Q_1 : \beta_1 = 100 \\ Q_2 : \alpha = 1 \end{cases}$

$\alpha_2 = 1 \rightarrow \beta_2 = \frac{\alpha}{1-\alpha} = \frac{1}{1-1} = \infty$

DC Analysis:



$\Rightarrow$



$I_{C1} = I_{C2} = 1.96^{mA}$

KVL @ B : $-12 + 10^K (I_1 + \cancel{I_B}) + 0.7 + V_{CE_1} + 1^K I_{C_1} = 0$

$-12 + 10^K (0.6^m) + 0.7 + V_{CE_1} + 1^K (1.96^m) = 0 \Rightarrow \underline{V_{CE_1} = 3.34}$

KVL @ A : $-2.8 + 7.67 \left(\frac{I_{C_1}}{100}\right) + 0.7 + 1^K I_{C_1} = 0$

$I_c \left(1^K + \frac{7.67}{100}\right) = 2.8 - 0.7$

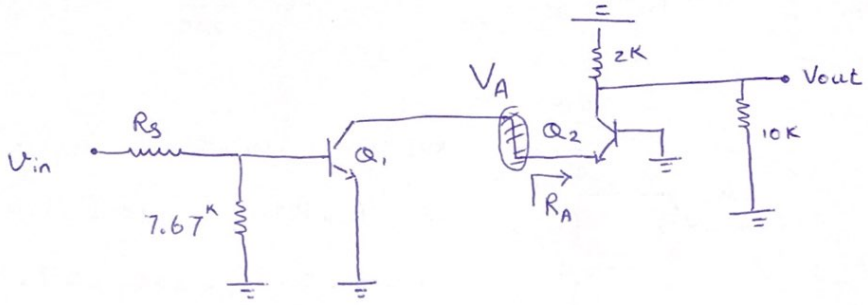
$I_{C_1} = 1.96^{mA} \rightarrow \begin{cases} g_{m_1} = 78.4 \text{ mmho} \\ r_{\pi_1} = 1.27^{K\Omega} \\ r_{o_1} = \infty \end{cases}$

KVL @ C : $-12 + 10^K I_1 + 10^K I_1 = 0$

$I_1 = 0.6 \text{ mA}$

KVL @ D: $-12 + 2^{K}(1.96^{m}) + V_{CE_2} + V_{CE_1} + 1^{K}(1.96^{m}) = 0 \Rightarrow V_{CE_2} = 2.78$

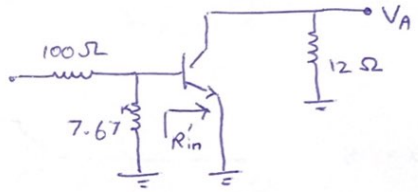
ac analysis:



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

$$\frac{V_A}{V_{out}} = g_m R_C = 78.4 \times (2^{K} \| 10^{K}) = 125.44 \ \frac{V}{V}$$

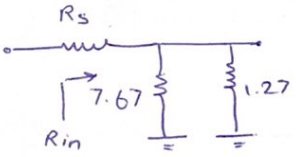
$$R_A = \frac{1}{g_m} = \frac{1}{78.4} = 0.012^{K\Omega} = 12\,\Omega \quad \Rightarrow$$



$$\frac{V_{in}}{V_A} = -g_m R_C = -78.4\,(0.012) = 0.94 \ \frac{V}{V}$$

$$\Rightarrow A_v = \frac{V_{out}}{V_{in}} = 0.94 \times 125.44 = 118 \ \frac{V}{V}$$

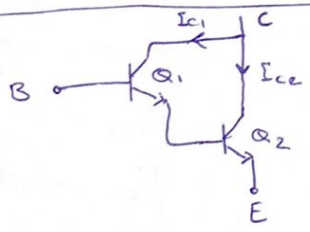
$$R'_{in} = r_\pi = 1.27^{K} \quad \Rightarrow$$



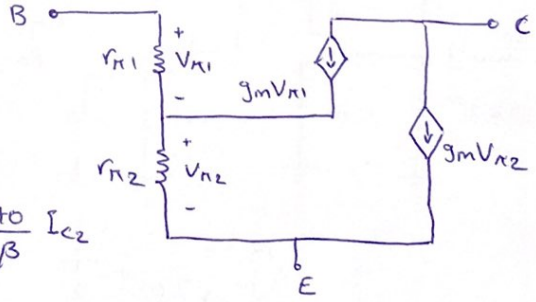
$$R_{in} = 7.67^{K} \| 1.27^{K\Omega}$$

:

#3



S.S →

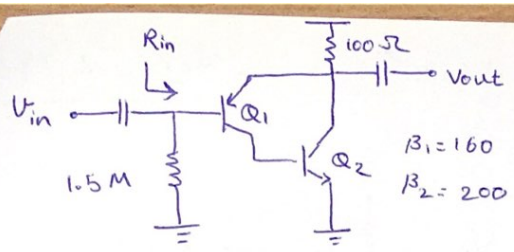


$$I_{C_1} = \frac{I_{C_2}}{\beta} \rightarrow g_{m_1} = 40 I_C \ , \quad g_{m_2} = \frac{40}{\beta} I_{C_2}$$

$$\beta_1 = \frac{I_{C_1}}{I_{B_1}} \ , \quad \beta_2 = \frac{I_{C_2}}{I_{C_1}}$$

$$r_{\pi 1} = \frac{\beta_1}{g_{m_1}} = \frac{\frac{I_{C_1}}{I_{B_1}}}{40 I_{C_1}} = \frac{1}{40 I_{C_1} I_{B_1}}$$

$$r_{\pi 2} = \frac{\beta_2}{g_{m2}} = \frac{\frac{I_{C_2}}{I_{C_1}}}{\frac{40}{\beta} I_{C_2}} = \frac{\beta}{40 I_{C_1}}$$



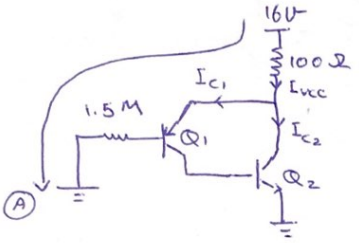
$\beta_1 = 160$

$\beta_2 = 200$

$I_{Vcc} = I_{C1} + I_{C2}$

$I_{C1} = \frac{I_{C2}}{200}$

DC Analysis:



KVL @ A: $-16 + 100(I_{C1} + I_{C2}) + V_{BE} + 1.5^{M} I_{B1} = 0$

$\Rightarrow -16 + 100^{\Omega}\left(I_{C1} + 200 I_{C1}\right) + 0.7 + 1500^{K}\left(\frac{I_{C1}}{160}\right) = 0$

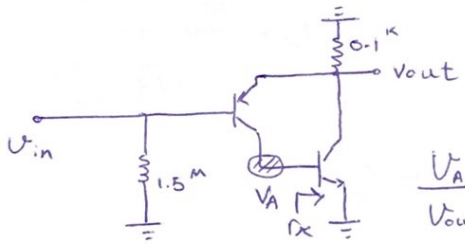
$\Rightarrow -16 + 0.1\, I_{C1} + 20 I_{C1} + 0.7 + 9.375\, I_{C1} = 0$

$I_{C1}\left(0.1 + 20 + 9.375\right) = 16 - 0.7$

$I_{C1} = 0.5^{mA} \rightarrow \begin{cases} g_{m1} = 20 \text{ mmho} \\ r_{\pi 1} = 8\ K\Omega \\ r_{o1} = \infty \end{cases}$

$\Rightarrow I_{C2} = 104^{mA} \rightarrow \begin{cases} g_{m2} = 4160 \text{ mmho} \\ r_{\pi 2} = 0.04\ K\Omega = 40\ \Omega \\ r_{o2} = \infty \end{cases}$

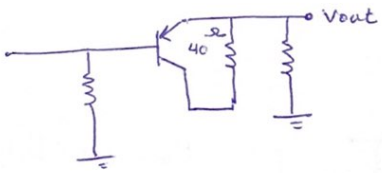
ac Analysis:



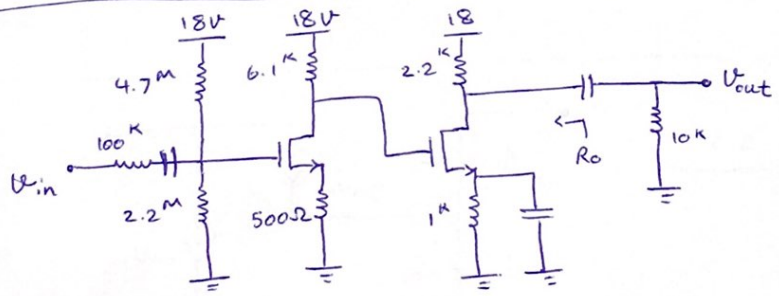
$A_v = \frac{V_{out}}{V_{in}} = \frac{V_{in}}{V_A} \times \frac{V_A}{V_{out}}$

$\frac{V_A}{V_{out}} = -g_{m2} R_e = 4160\left(0.1^{K}\right) = 416$

$\frac{V_{in}}{V_A} = ???$



#5



$\beta_1 = 0.5\ \frac{mA}{V^2}$

$\beta_2 = 0.3\ \frac{mA}{V^2}$

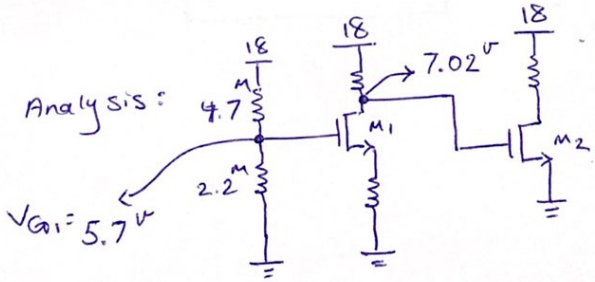
$V_{th1} = 2\ V$

$V_{th2} = 2.6\ V$

$r_{ds1} = 75^{K}$

$r_{ds2} = 100^{K}$

DC Analysis:



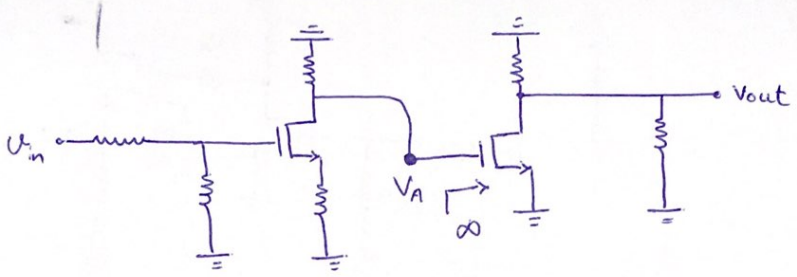
$I_{D1} = \frac{\beta_1}{2}\left(V_{GS1} - V_{th1}\right)^2$

$= \frac{0.5}{2}\left(5.7 - 0.5^{K} I_{D1} - 2\right)^2$

$\rightarrow \begin{cases} I_{D1} = 28.9 \text{ mA} \times \\ I_{D1} = 1.8 \text{ mA} \checkmark \rightarrow g_{m1} = 1.8 \text{ mmho} \end{cases}$

$V_{GS2} = 7.02^{V} \rightarrow I_{D2} = 0.15\left(7.02 - 2.6\right)^2 = 2.9 \text{ mA} \rightarrow g_{m2} = \sqrt{2\beta_2 I_D} = 1.31 \text{ mmho}$

ac Analysis:



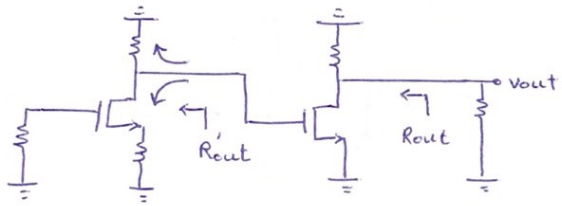
$$A_v = \frac{V_{out}}{V_{in}} = \frac{V_{in}}{V_A} \times \frac{V_A}{V_{out}}$$

$$\frac{V_A}{V_{out}} = -g_{m_2}(R_D \| r_{ds}) = -1.31\left(2.2^K \| 10^K \| 100^K\right)$$

$$= -2.31 \ V/V$$

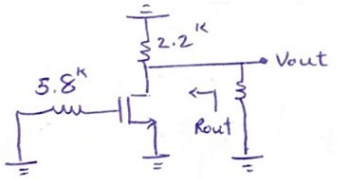
$$\frac{V_{in}}{V_A} = \frac{-R_D}{\frac{1}{g_m} + R_S} = \frac{-6.1^K}{\frac{1}{1.3} + 0.5^K} = -4.8 \quad \rightarrow \quad A_v = \frac{V_{out}}{V_{in}} = -2.31 \times (-4.8) = \underline{11.18}$$

Rout :



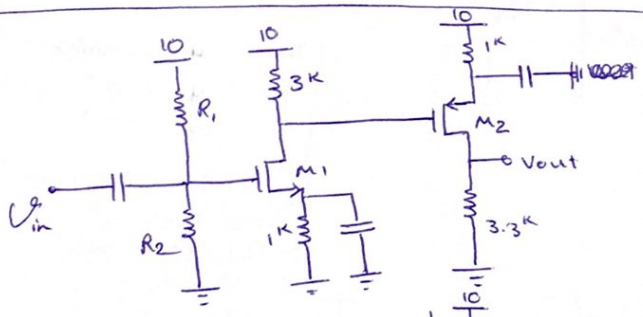
$$R'_{out} = 6.1^K \| r_{ds_1}(1+g_{m_1}R_S) = 6.1^K \| 75^K(1+0.65) = 5.8^{K\Omega}$$

$\Rightarrow$



$$R_{out} = 2.2^K \| r_{ds_2} = 2.2^K \| 100^K = \underline{1.96 \ K\Omega}$$

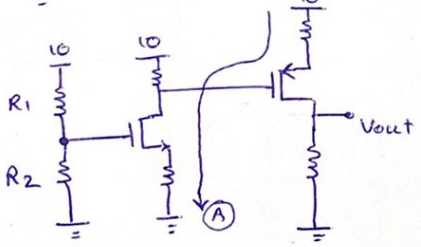
#6



a) R_1 & R_2 = ? $\rightarrow$ $I_{D_1} = 1mA$

b) $A_v = \frac{V_{out}}{V_{in}}$ = ?

DC Analysis:



$$I_{D_1} = \frac{0.25}{2}\left(V_G - 1^K(1^m) - 0.5\right)^2 \xrightarrow{I_D=1}$$

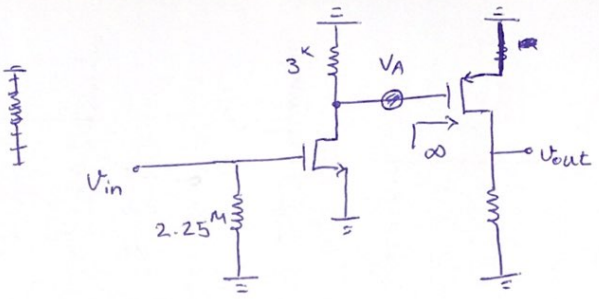
$$\begin{cases} V_G = 2.5 \ \checkmark \\ V_G = 0.5 \ \times \end{cases} \Rightarrow V_G = \frac{R_2}{R_1+R_2} \times 10$$

$$\Rightarrow 2.5 = \frac{10R_2}{R_1+R_2} \Rightarrow R_1 = 3R_2 \xrightarrow{V_{to}} \begin{cases} R_1 = 3 \ M\Omega \\ R_2 = 9 \ M\Omega \end{cases} \qquad g_{m_1} = \sqrt{2\beta I_D} = 0.7 \ mmho \qquad V_{OS_1} = 6V$$

KVL @ A: $-10 + 1^K I_{D_2} + V_{SG} + 6^V + 1 = 0$

$\Rightarrow V_{SG} = 3 - 1^K I_{D_2} \quad \Rightarrow I_{D_2} = \frac{13}{2}\left(3 - 1^K I_{D_2} - 0.5\right)^2$ $\begin{cases} I_D = 12.5^{mA} \times \\ I_D = 0.5 \ mA \ \checkmark \rightarrow g_{m_2} = 0.5 \ mmho \end{cases}$

alysis :

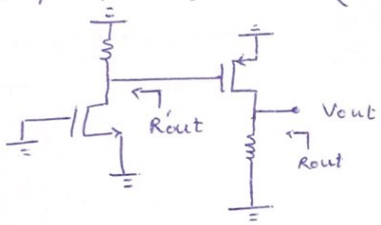


$$A_v = \frac{V_{out}}{V_{in}} = \frac{V_{in}}{V_A} \times \frac{V_A}{V_{out}}$$

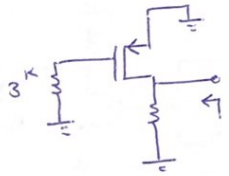
$$\frac{V_A}{V_{out}} = -g_{m2}(R_D \,||\, \underbrace{r_{ds2}}_{=\infty}) = -0.5(3.3^K) = -1.65$$

$$\frac{V_{in}}{V_A} = -g_{m1}(R_D \,||\, r_{ds1}) = -0.7\,(3^K) = -2.1 \quad \Rightarrow \quad A_v = \frac{V_{out}}{V_{in}} = -1.65\,(-2.1) = 3.465$$

Rout :

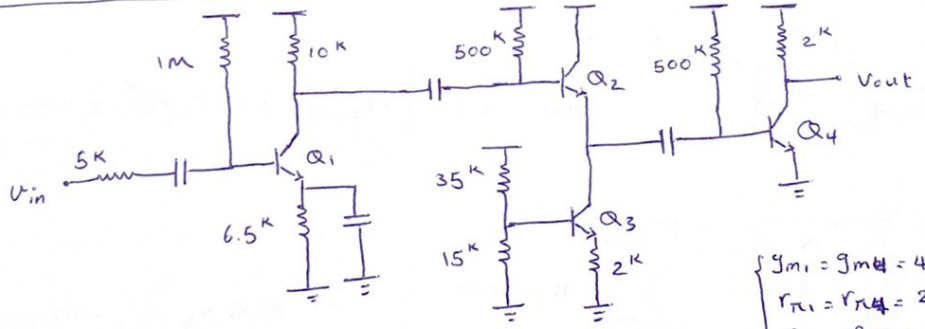


$R_{out} = 3^K \,||\, r_{ds} = 3^K$



$R_{out} = 3.3^K \,||\, r_{ds2} = \underline{3.3^K}$

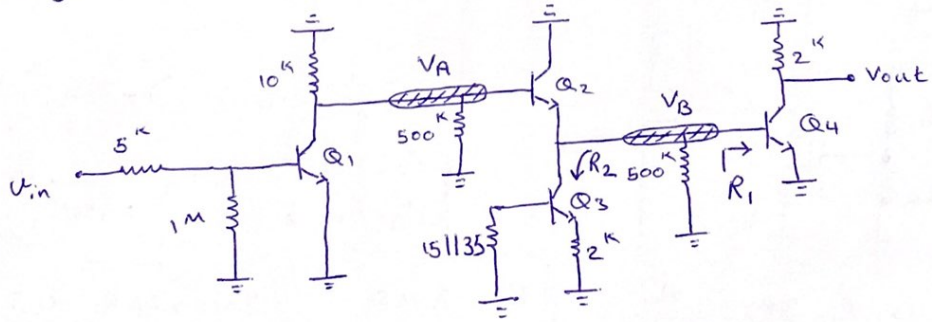
#7



$V_A = 100\,V$
$V_T = 25\,mV$
$\beta = 100$
$I_{C1} = I_{C4} = 1^m$
$I_{C2} = 0.5^m = I_{C3}$

$g_{m1} = g_{m4} = 40$ mmho
$r_{\pi 1} = r_{\pi 4} = 2.5^K$
$r_{o1} = r_{o4} = 100^K$
$g_{m2} = g_{m3} = 20$ mmho
$r_{\pi 2} = r_{\pi 3} = 5^K$
$r_{o2} = r_{o3} = 200^K$

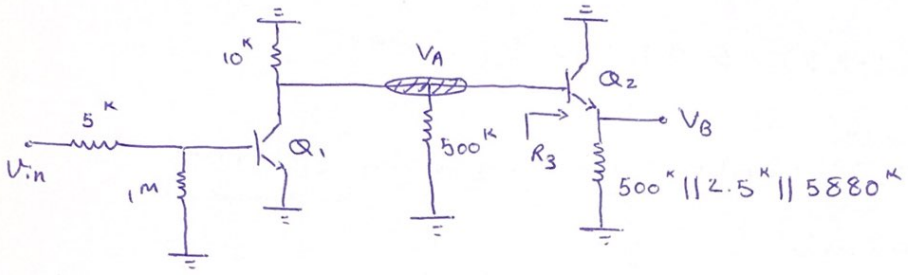
ac Analysis :



$$A_v = \frac{V_{out}}{V_{in}} = \frac{V_{out}}{V_B} \times \frac{V_B}{V_A} \times \frac{V_A}{V_{in}}$$

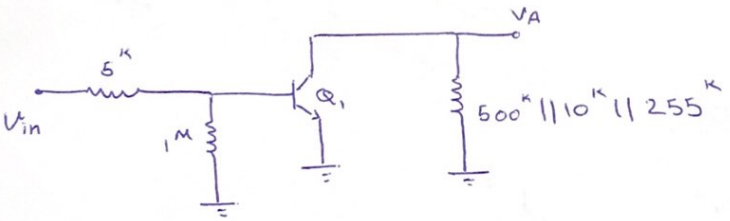
$$\frac{V_{out}}{V_B} = -g_m (R_C \| r_o) = -40 (2^K \| 100^K) = -80 \ \frac{V}{V}$$

$R_1 = r_\pi = 2.5^K$, $R_2 = r_o (1 + g_m (R_E \| r_\pi)) = 200^K (1 + 20^m (2^K \| 5^K)) = 588$



$$\frac{V_B}{V_A} = \frac{R_E}{R_E + \frac{1}{g_m}} = \frac{(500^K \| 2.5^K \| 5880^K)}{(500^K \| 2.5^K \| 5880^K) + \frac{1}{20}} = \frac{2.5}{2.55} = 0.98$$

$R_3 = r_\pi + (\beta + 1) R_E = 5^K + (100)\, 2.5^K = 255^K$

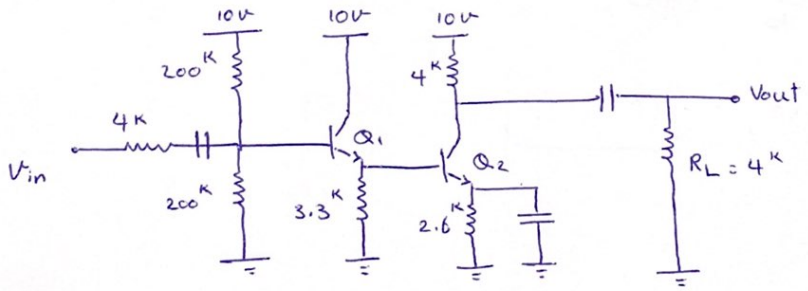


$$\frac{V_A}{V_{in}} = -g_m (R_C \| r_o)$$

$$= -40 (500 \| 10 \| 255 \| 100) \approx -345$$

$$\Rightarrow A_V = \frac{V_{out}}{V_{in}} = -345 \times 0.98 \times (-80) = 27048 \ \frac{V}{V}$$

#8

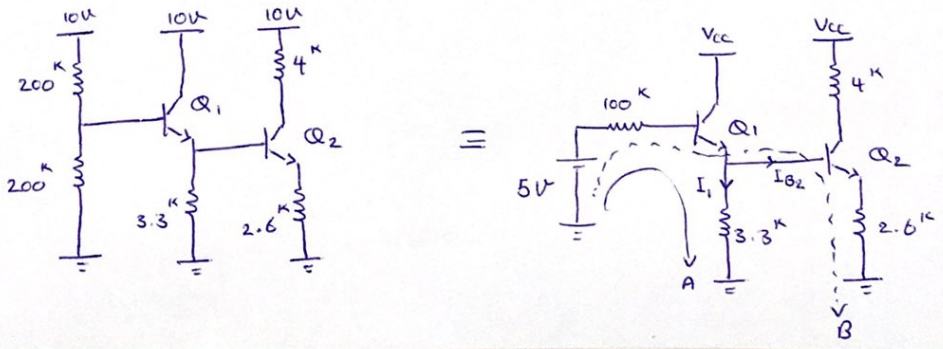


$V_{CE,sat} = 0.2$

$V_{BE,ON} = 0.7$

$\beta_1 = \beta_2 = 100$

DC Analysis:



KVL @ A: $-5 + 100^{K}\left(\frac{I_{C_1}}{100}\right) + 0.7 + 3.3^{K}\left(I_1 + I_{B_2}\right) = 0$ (I)

KVL @ B: $-5 + 100^{K}\left(\frac{I_{C_1}}{100}\right) + 0.7 + 0.7 + 2.6^{K} I_{C_2} = 0$ (II)

$I_1 = I_{C_1} = \frac{I_{C_2}}{100}$ →

$I_{C_1}\left(1 + 3.3^{K}\right) = 5 - 0.7 \Rightarrow \underline{I_{C_1} = 1\ mA}$

(I) in (II) → $-5 + 1 + 1.4 + 2.6^{K} I_{C_2} = 0 \Rightarrow \underline{I_{C_2} = 1\ mA}$

$I_{C_1} = I_{C_2} = 1\ mA$ →

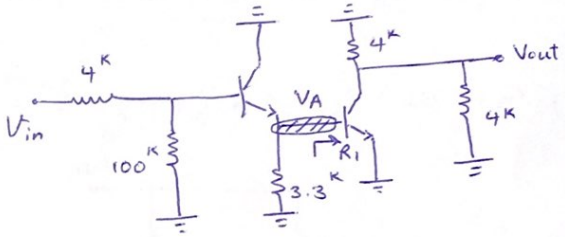
$g_m = 40$ mmho

$r_\pi = 2.5^{K}$

$r_o = \infty$

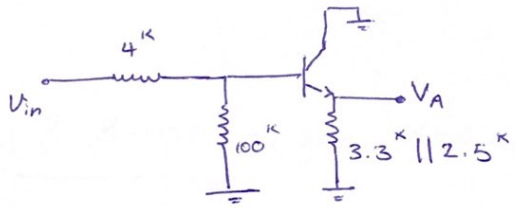
$A_v = \frac{V_{out}}{V_{in}} = \frac{V_{out}}{V_A} \times \frac{V_A}{V_{in}}$

$\frac{V_{out}}{V_A}$:



$\frac{V_{out}}{V_{in}} = -g_m R_C = -40\left(4^{K} \| 4^{K}\right) = -80\ \frac{V}{V}$

$R_1 = r_\pi = 2.5^{K} \Rightarrow$



$\frac{V_A}{V_{in}} = \frac{R_E}{R_E + \frac{1}{g_m}} = \frac{\left(3.3^{K} \| 2.5^{K}\right)}{\left(3.3^{K} \| 2.5^{K}\right) + \frac{1}{40}} = \frac{1.42}{1.445} \simeq 0.98$

$\Rightarrow A_v = \frac{V_{out}}{V_{in}} = 0.98(-80) = \underline{-78.4\ \frac{V}{V}}$