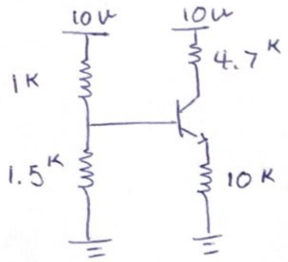
یا لطیف

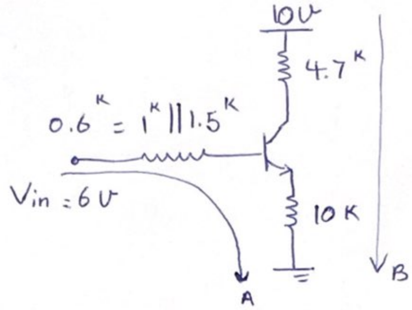
رضا ادیب پور
۹۸۱۴۳۰۳
تمرین سری ۱ الک ۲

#1

a)



$\Longrightarrow$

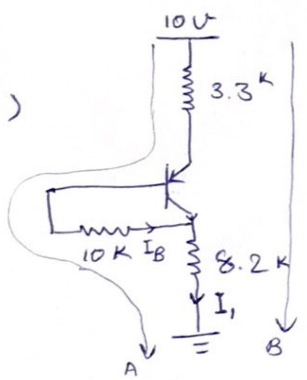


KVL @ A: $-6 + 0.6^K I_B + V_{BE} + 10^K I_c = 0 \xrightarrow{10^K \gg \frac{0.6}{100}} 10 I_c = 5.3$

$I_c = 0.53\ mA$

KVL @ B: $-10 + 4.7 I_c + V_{CE} + 10^K I_c = 0 \xrightarrow{I_c = 0.53\ mA} V_{CE} = 2.209 > V_{CE,sat}$

b)



KVL @ A: $-10 + 3.3^K I_c + V_{BE} + 10^K I_B + 8.2^K I_1 = 0$

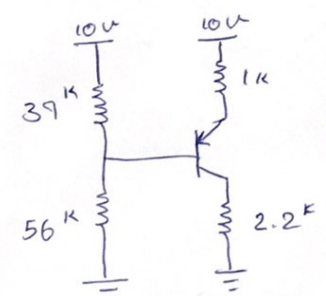
$-10 + 3.3^K I_c + 0.7 + 10^K \left(\frac{I_c}{100}\right) + 8.2^K (1.01 I_c) = 0$

$I_c (3.3^K + 0.1 + 8.282) = 9.3 \Rightarrow I_c = 0.79\ mA$

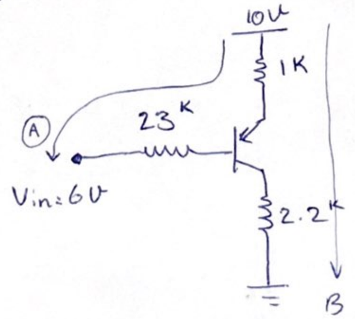
KVL @ B: $-10 + 3.3^K (0.79) + V_{CE} + 8.2^K (1.01 \times 0.79) = 0$

$V_{CE} = 0.85\ V > V_{CE,sat}$

c)



$\Longrightarrow$



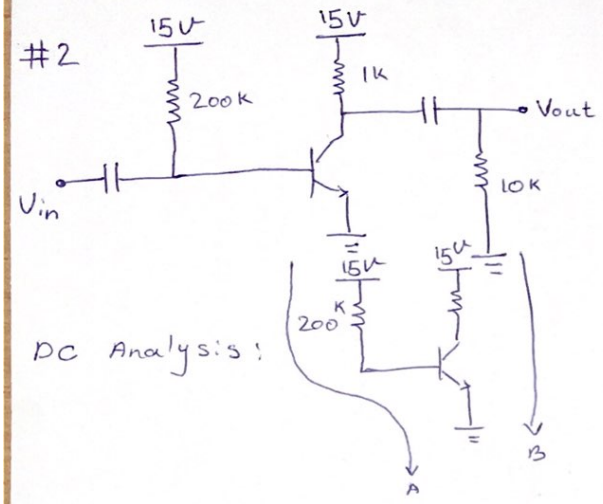
KVL @ A: $-10 + 1^K I_c + V_{BE} + 23^K I_B + 6 = 0$

$\Rightarrow I_c (1 + 0.23) = 3.3$

$I_c = 2.68\ mA$

KVL @ B: $-10 + 1^K I_c + V_{CE} + 2.2^K I_c = 0 \xrightarrow{I_c = 2.68} V_{CE} = 1.424\ V > V_{CE,sat}$

#2



$\begin{cases} V_A = \infty \\ V_T = 25\ mV \\ \beta = 100 \end{cases}$

DC Analysis:

KVL @ A: $-15 + 200^K I_B + V_{BE} = 0$

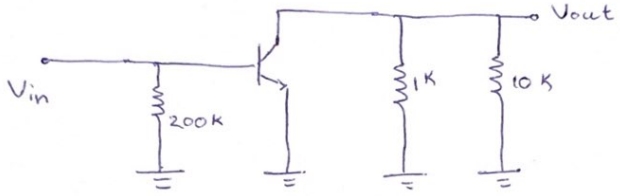
$-15 + 200^K \left(\frac{I_C}{100}\right) + 0.7 = 0$

$2 I_C = 14.3 \Rightarrow I_C = 7.15\ mA$

KVL @ B: $-15 + 1^K I_C + V_{CE} = 0 \Rightarrow V_{CE} = 7.85 > V_{CE,sat}$

$\begin{cases} g_m = 286\ \frac{mA}{V} \\ r_\pi = 0.34\ K\Omega \\ r_o = \infty \end{cases}$

ac Analysis:

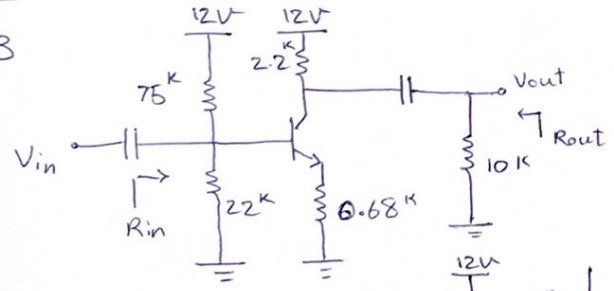


$A_v = \frac{V_{out}}{V_{in}} = -g_m (R_C \| r_o) \simeq -g_m R_C = -286 \left(1^K \| 10^K\right) \simeq -286$

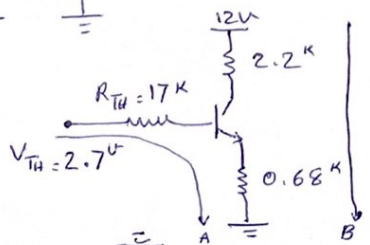
$R_{in} = 200^K \| r_\pi = 200^K \| 0.34^K \simeq 0.34^K$

$R_{out}: r_o \| 1^K \| 10^K \simeq 1^K$

#3



DC Analysis:



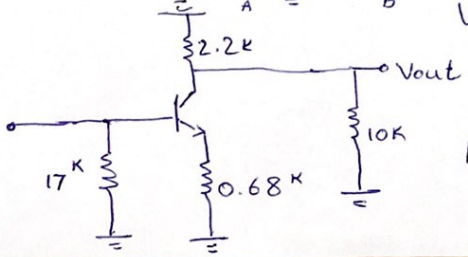
KVL @ A: $-2.7 + 17^K I_B + V_{BE} + 0.68^K I_C = 0$

$0.85 I_C = 2 \rightarrow I_C = 2.35\ mA$

KVL @ B: $-12 + 2.2^K I_C + V_{CE} + 0.68^K I_C = 0$

$V_{CE} = 5.23 > V_{CE,sat} \Rightarrow \begin{cases} g_m = 94\ \frac{mA}{V} \\ r_\pi = 1.06\ K\Omega \\ r_o = 42.5\ K \end{cases}$

ac Analysis:

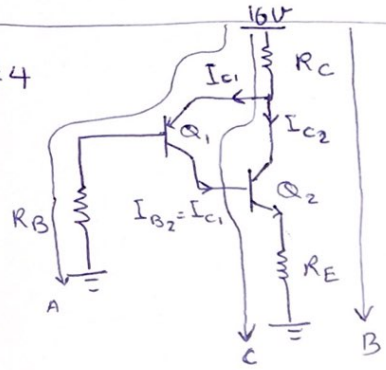


$A_u = \frac{V_{out}}{V_{in}} = \frac{-R_C}{R_E + \frac{1}{g_m}} = \frac{10^K \| 2.2^K}{0.68^K + 0.01} \simeq 2.6$

$R_{in}: \quad 17^K \,||\, r_\pi + (\beta+1) R_E = 17^K \,||\, 1^K + (101) \times 0.68^K \simeq \underline{13^K \Omega}$

$R_{out}: \quad 10^K \,||\, 2.2^K \,||\, r_o(1+g_m(R_E \,||\, r_\pi)) = 1.8 \,||\, 42.5^K \left(1+94\left(0.68^K \,||\, 1^K\right)\right) \simeq \underline{1.8K}$

#4



$V_{CC}=16V$
$R_C=0.1K$
$R_B=1.5M\Omega$
$|V_{CE,sat}|=0.2$
$|V_{BE,sat}|=0.7$
$\beta_1=160, \ \beta_2=200$

a) assume $R_E=0$: KVL @ A : $-16 + 0.1^K(I_{C1}+I_{C2}) + 0.7 + 1.5^M I_{B1} = 0$

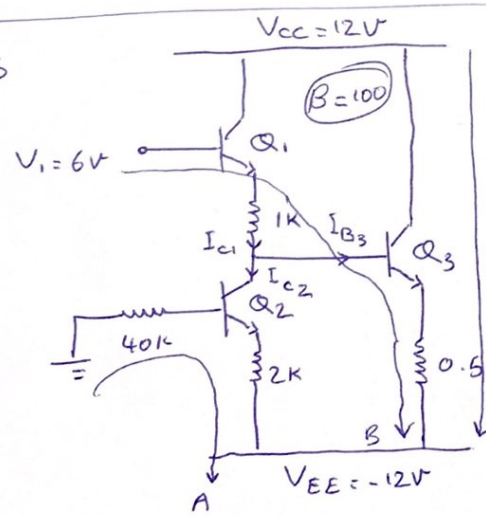
$9.475\, I_{C1} + 0.1\, I_{C2} = 15.3$ (I) $\xrightarrow{I_{C2}=\beta_2 I_{C1}}$ $9.475\, I_{C1} + 0.1(200 I_{C1}) = 15.3$

$I_{C1}(29.475) = 15.3 \Rightarrow \underline{I_{C1} = 0.51\,mA}$, $\underline{I_{C2} = 200 \times 0.51 \simeq 103\,mA}$

KVL @ B : $-16 + 0.1^K(I_{C1}+I_{C2}) + V_{CE_2} = 0 \Rightarrow \underline{V_{CE_2} = 5.6 > V_{CE,sat}}$

KVL @ C : $-16 + 0.1^K(I_{C1}+I_{C2}) + V_{CE_1} + 0.7 = 0 \Rightarrow \underline{V_{CE_1} = 5 > V_{CE,sat}}$

#5



$V_{B,ON}=0.6$

KVL @ A : $40^K I_{B_2} + 0.6 + 2^K(I_{C_2}) - 12 = 0$

$I_{C_2}(2+0.4) = 11.4$

$\underline{I_{C_2} = 4.75\,mA}$

$I_{C_1} = I_{C_2} + I_{B_3} = \underline{I_{C_2} + 0.01\, I_{C_3}}$ (I)

KVL @ B : $-6 + 0.6 + 1^K(I_{C_1}) + 0.6 + 0.5^K(I_{C_3}) = 12 = 0$

(I) $\rightarrow$ $-6 + 0.6 + 1^K I_{C_1} + 0.6 + 0.5^K\left(100(I_{C_1} - 4.75^{mA})\right) - 12 = 0 \Rightarrow \underline{I_{C_1} = 4.98mA}$

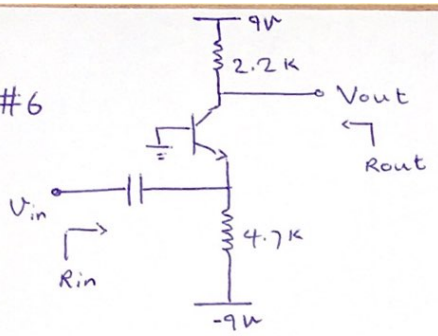
$\rightarrow$ $I_{C_3} = 100(I_{C_1} - I_{C_2}) = 100(4.98 - 4.75) = \underline{23\,mA}$

KVL @ D : $-12 + V_{CE_3} + 0.5^K(I_{C_3}) - 12 = 0 \Rightarrow V_{CE_3} = 12.5V > V_{CE,sat}$

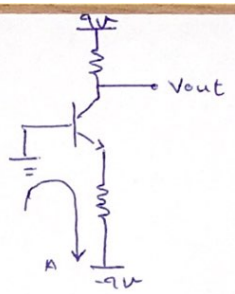
KVL @ E : $-12 + V_{CE_1} + 1^K I_{C_1} + 0.6 + 0.5^K I_{C_3} - 12 = 0 \Rightarrow V_{CE_1} = 6.92 > V_{CE,sat}$

KVL @ F : $-6 + 0.6 + 1^K I_{C_1} + V_{CE_2} + 2^K I_{C_2} - 12 = 0 \Rightarrow V_{CE_2} = 2.92 > V_{CE,sat}$

#6

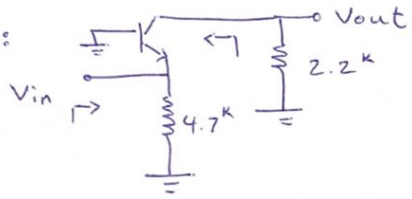


DC analysis:



KVL @ A: $0.7 + 4.7^{K} I_C - 9 = 0 \Rightarrow I_C = 1.76\ mA$ → $\begin{cases} g_m = 70.4\ mA/V \\ r_\pi = 1.4\ K\Omega \end{cases}$

ac Analysis:



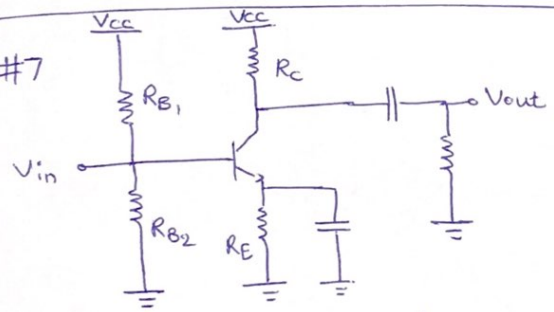
$A_v = \frac{V_{out}}{V_{in}} = g_m (R_C \| r_o) \approx 70.4 \times 2.2^{K}$

$= 154.88\ V/V$

$R_{in}: R_E \| \frac{1}{g_m} = 4.7^{K} \| \frac{1}{70.4} \approx 0.014\ K\Omega = 14\ \Omega$

$R_{out}: R_C \| r_o = R_C = 2.2\ K\Omega$

#7

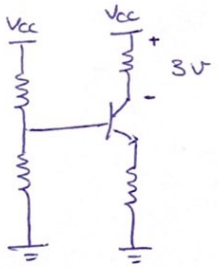


$V_{CE,sat} = 0V$

$V_T = 25\ mV$

$R_L = 1K\Omega$

DC Analysis:

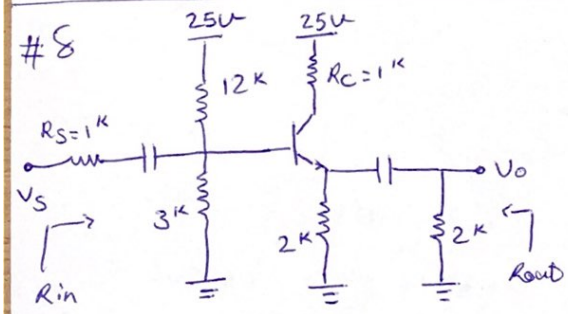


$A_v = \frac{V_{out}}{V_{in}} \approx -g_m R_C = -48$

$\Rightarrow R_C = \frac{48}{g_m} = \frac{48}{40} \times \frac{1}{I_C}$

$= \frac{1.2}{I_C} = R_C$

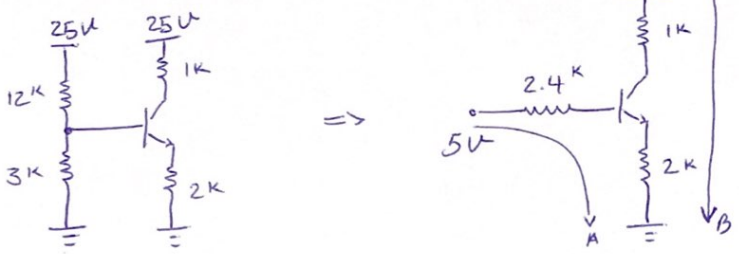
#8



$\begin{cases} V_{BE} = 0.6 \\ V_{CE,sat} = 0.2 \\ V_A = \infty \\ V_T = 25mV \\ \beta = 80 \end{cases}$

a) $V_{BE,on} = 0.7$

dc analysis:



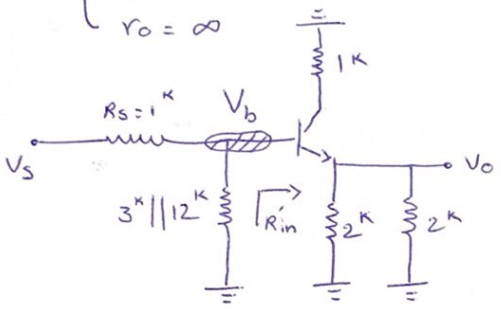
KVL @ A: $-5 + 2.4^K I_B + 0.7 + 2^K I_C = 0 \Rightarrow I_C(2+0.03) = 4.3$

$\Rightarrow I_C \cong 2.1\,mA \longrightarrow \begin{cases} g_m = 84\ \frac{mA}{V} \\ r_\pi = 0.95\,K \\ r_o = \infty \end{cases}$

KVL @ B: $-25 + 1^K(2.1^m) + V_{CE} + 2^K(2.1) = 0$

$\Rightarrow V_{CE} = 18.7\,V$

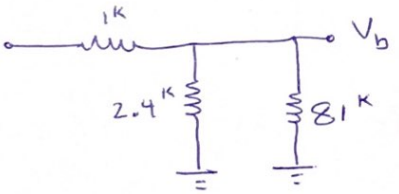
ac Analysis:



$$A_v = \frac{V_o}{V_S} = \frac{V_o}{V_b} \times \frac{V_b}{V_S} \Rightarrow \frac{V_o}{V_b} = \frac{R_E}{R_E + \frac{1}{g_m}} = \frac{2^K \| 2^K}{(2^K \| 2^K) + \frac{1}{84}} \cong 0.99\ \frac{V}{V}$$

$$R'_{in} = r_\pi + (\beta+1) R_E = 0.95^K + 80(2^K \| 2^K) \cong 81^K$$

$\Rightarrow$



$$\Rightarrow \frac{V_b}{V_S} = \frac{(81^K \| 2.4^K)}{(81^K \| 2.4^K) + 1} \cong 0.6\ \frac{V}{V}$$

$$\Rightarrow \frac{V_o}{V_S} = A_v = 0.99 \times 0.6 = 0.594\ \frac{V}{V}$$

b) $Swing_{V_o} = ?$ $\quad \min\left\{ V_{CE,Q} - V_{CE,sat},\ R_{ac} I_{CQ} \right\}$

($V_{CE,Q} = 18.7$ ✓)

$R_{ac} = (2^K \| 2^K) + 1^K = 2^K \Rightarrow \min\left\{ 18.7 - 0.2,\ 2^K \times 2.1^m \right\} = \min\left\{ 18.5, 4.2 \right\}$

$= 4.2\,V$

$$\Rightarrow Swing_{V_o} = \frac{R_C}{R_C + R_E} \times Swing_{V_{CE}} = \frac{1^K}{1^K + (2^K \| 2^K)} \times 4.2 = 2.1\,V$$