Student ID:_____**Student Name:** _____

EHB222E INTRODUCTION TO ELECTRONICS (12006, 12084, 12085, 15189)

Midterm Exam 2 ✎ 6 December 2022 🕓 18.00-20.00

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1. A transistor level amplifier shown in the figure1 below utilizes an NPN transistor Q_1 that is known to have $\mathbf{V_{BE}}$- $\mathbf{I_C}$ characteristic shown in the figure2 below. (25 points)

a) Assuming transistor current gain of $\boldsymbol{\beta = 100}$ find out the optimum R_B resistor value to yield a good symmetric headroom for the $\mathbf{V_{out}}$ at the collector output of this amplifier?

b) Assuming a microphone with 100KOhm source impedance and 1mV peak AC small signal, what is the output AC small signal peak level?

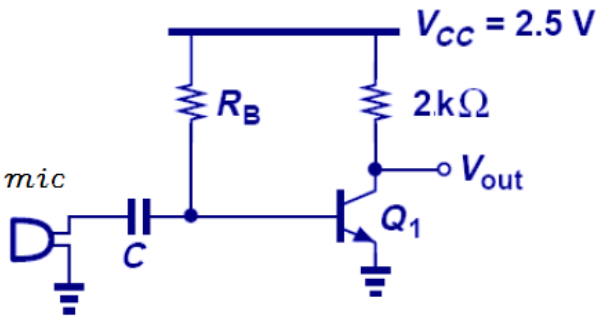


Figure 1

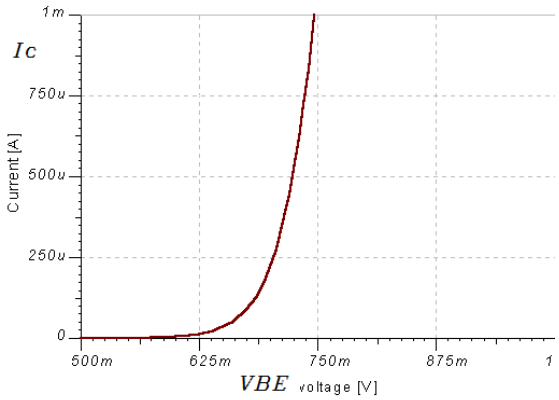


Figure 2

2. V_{CC} = 9V, V_{BE} = 0,7V, $\beta_F \rightarrow \infty$ is given for the circuit in figure3. Assume all transistors have equal bias currents. (25 points)

a) Derive the expression for I_o in terms of the resistors, V_{CC} and V_{BE}.

b) Calculate the value of R_1, R_2 and R_3 so that I_o =1mA assuming $R_1 = R_2$.

c) Calculate the minimum value of V_o so that all transistors remain in the forward active region.

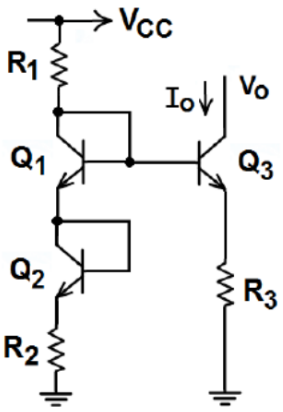


Figure 3

GOOD LUCK EVERYONE

3. For the circuit in the figure4, Zener diode with V_Z = 6,7V. NPN BJT properties are V_{BE} = 0,7V, $h_{FE} = \beta = 100$. Find operating point I_{CQ} and V_{CEQ}. Calculate I_B and I_Z. (25 points)

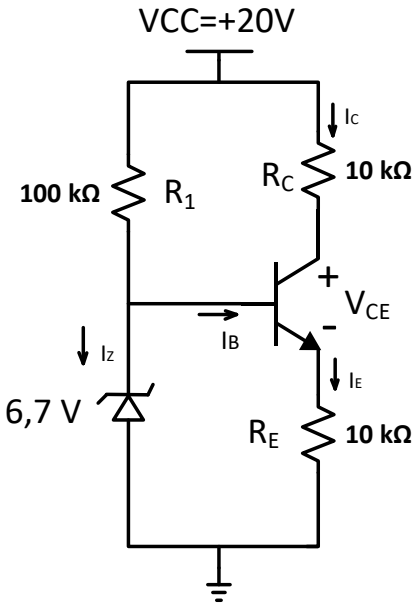


Figure 4

4. Analyze the 3-stage amplifier circuit in the figure5. For all transistors $h_{FE} = h_{fe} = 200$, $|V_{BE}| = 0.6V$, $h_{re} \cong 0$, $h_{oe} \cong 0$ and $V_T = 25mV$. (25 points)

a. Find the collector currents of all 4 transistors.
b. Calculate the total voltage gain.
c. Calculate input resistance (r_i) and output resistance (r_o).

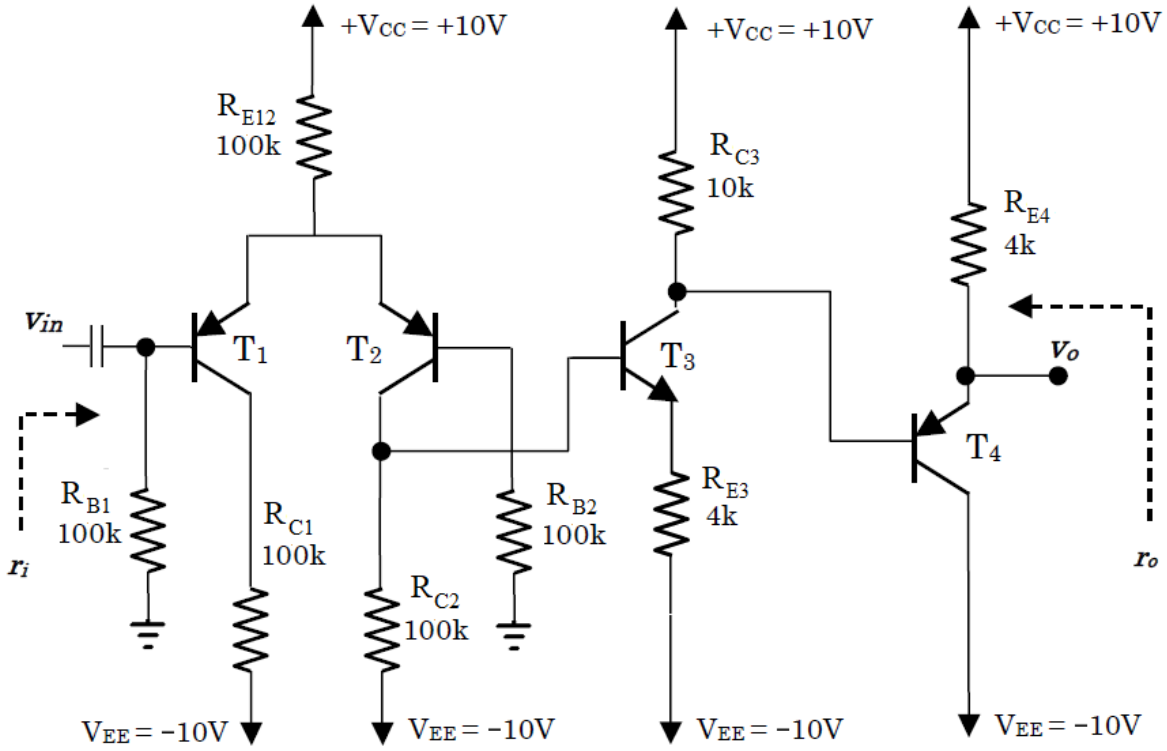
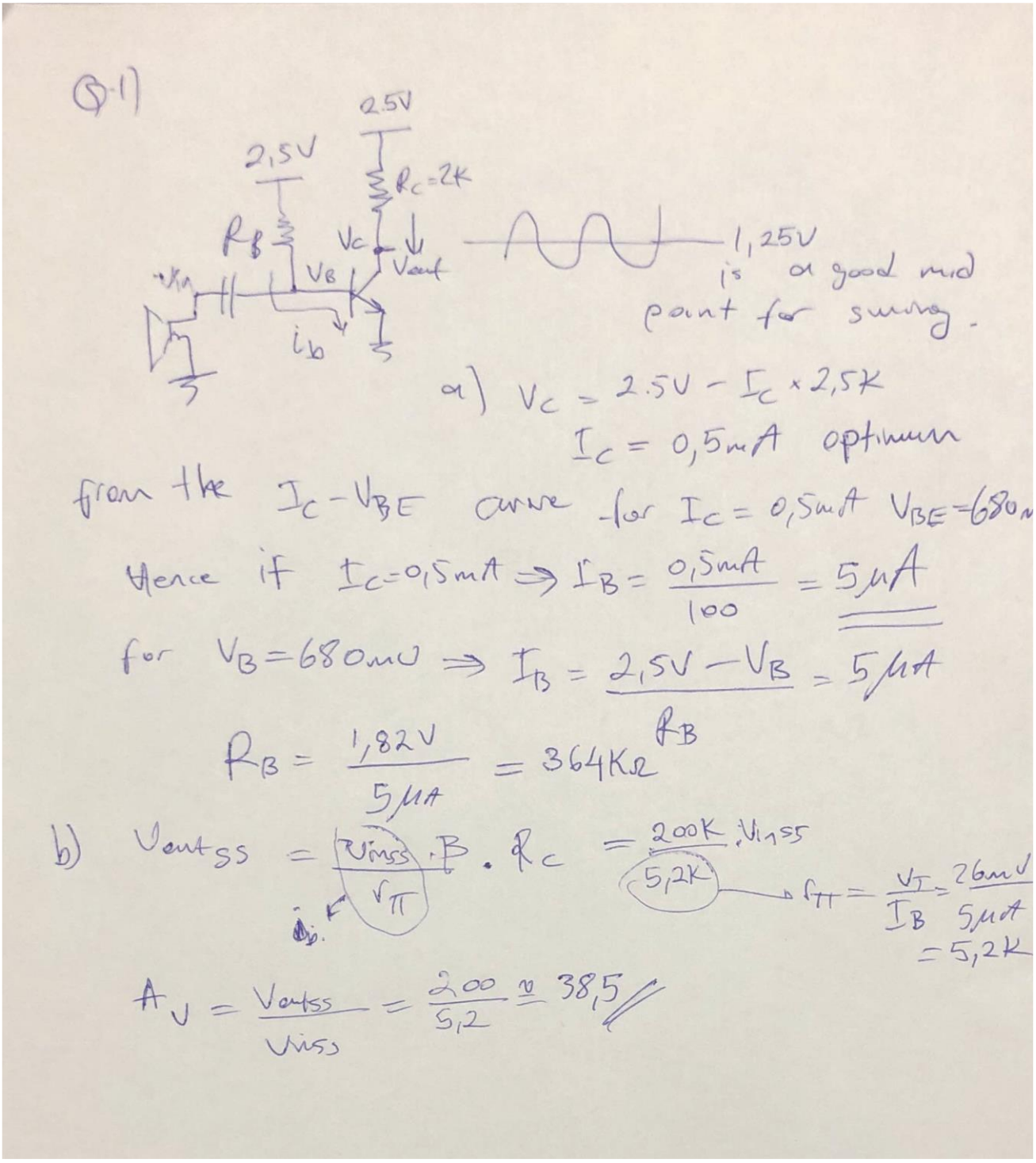


Figure 5

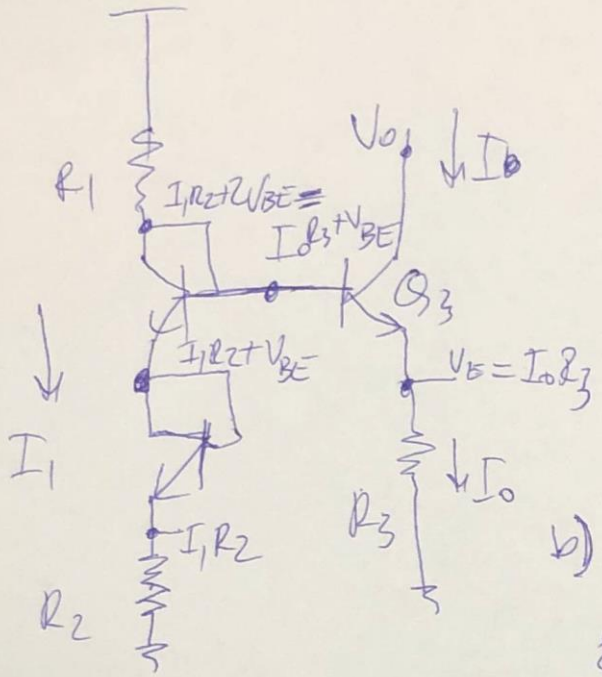
Solutions:

1.


Q-1)
2.5V
2,5V
R_C=2K
R_B
V_C
V_{out}
V_B
i_b
1,25V is a good mid point for swing.
a) $V_C = 2.5V - I_C \times 2,5K$
$I_C = 0,5mA$ optimum
from the $I_C - V_{BE}$ curve for $I_C = 0,5mA$ V_{BE}=680m
Hence if I_C=0,5mA $\Rightarrow I_B = \frac{0,5mA}{100} = 5\mu A$
for V_B=680mV $\Rightarrow I_B = \frac{2,5V - V_B}{R_B} = 5\mu A$
$R_B = \frac{1,82V}{5\mu A} = 364K\Omega$
b) $V_{outss} = \frac{V_{inss} \cdot \beta \cdot R_C}{r_\pi} = \frac{200K \cdot V_{inss}}{5,2K}$
$r_\pi = \frac{V_T}{I_B} = \frac{26mV}{5\mu A} = 5,2K$
$A_V = \frac{V_{outss}}{V_{inss}} = \frac{200}{5,2} \approx 38,5$

2.

(Q-2)



a) $I_1R_2+2V_{BE}=I_oR_3+V_{BE}$

$I_oR_3=V_{BE}+I_1R_2$

$I_o=\dfrac{V_{BE}+I_1R_2}{R_3}$

$I_1=\dfrac{V_{CC}-2V_{BE}}{R_1+R_2}$

$I_o=\dfrac{V_{BE}+\left(\frac{V_{CC}-2V_{BE}}{R_1+R_2}\right)\cdot R_2}{R_3}$

b) $1mA=\dfrac{0,7V+\frac{I_o}{2}}{R_3}$

$R_3=\dfrac{4,5V}{1mA}=4,5K\Omega$

c) for Q_3 $V_E=I_oR_3=4,5V$.

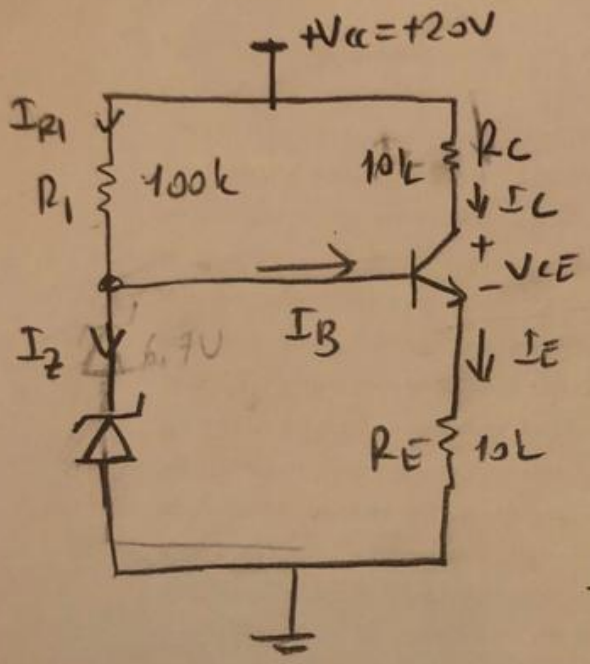
Hence for Q_3 to be in active region,

$V_o-V_E\geq V_{CE_{sat}}$

hence $V_o\geq 4,8V$

3.

SORUNUN ÇÖZÜMÜ 2. VİZE



$V_{BE} = 0,7V$

$V_B = 6,7V$

$V_E = 6V$

$I_E = \frac{V_E}{R_E} = 0,6mA$

$I_B = \frac{0,6mA}{(1+\beta)} = \frac{0,6mA}{101} = 6\mu A$

$I_{R1} = \frac{20-6,7}{100k\Omega} = \frac{13,3}{100k\Omega} = 133\mu A$

$I_Z = I_{R1} - I_B = 133\mu A - 6\mu A = 127\mu A$

$I_{CQ} \cong I_E = 0,6mA \rightarrow V_{CQ} = 20 - \underbrace{10k\Omega \cdot 0,6mA}_{6V}$

$\Leftarrow V_{CQ} = 14V$

$V_{CEQ} = 14V - 6V$

$V_{CEQ} = 8V$

4. **a.**

$V_{cc} = 2I_{E1} .100k + V_{EB1} + I_{B1}.100k = 2\frac{(\beta+1)}{\beta} I_{C1} .100k + 0,6V + \frac{I_{C1}}{\beta}.100k$

$I_{C1} = I_{C2} = \frac{\beta.(Vcc - 0,6V)}{2(\beta+1).100k+100k} =$ 0,0467mA

$-100k . (I_{C2} - I_{B3}) + V_{BE3} + 4k . I_{E3} = 0$

$-100k . (0,0467mA - \frac{I_{C3}}{\beta}) + 0,6V + 4k . \frac{(\beta+1)}{\beta} I_{C3} = 0$

$I_{C3} = \frac{\beta.(100k.0,0467mA-0,6V)}{4k.(\beta+1)+100k} =$ 0,9mA

$10k . (I_{C3} - I_{B4}) - V_{EB4} - 4k . I_{E4} = 0$

$10k . (0,9mA - \frac{I_{C4}}{\beta}) - 0,6V - 4k . \frac{(\beta+1)}{\beta} I_{C4} = 0$

$I_{C4} = \frac{\beta.(10k.0,9mA-0,6V)}{10k+4k.(\beta+1)} =$ 2,064mA

b.

$r_{e1} = r_{e2} = \frac{V_T}{I_{C2}} = \frac{25mV}{0,0467mA} = 536\Omega$ $r_{e3} = \frac{25mV}{0,9mA} = 27,8\Omega$ $r_{e4} = \frac{25mV}{2,064mA} = 12,11\Omega$

$A_{v4} = \frac{R_{e4}}{R_{e4}+r_{e4}} = \frac{4k}{4k+12,11} =$ 0,997 $r_{i4} = hfe(R_{e4}+r_{e4}) = 200(4k+12,11) = 802,4k$

$A_{v3} = -\frac{R_{C3}//r_{i4}}{R_{e3}+r_{e3}} = -\frac{10k//802,4k}{4k+27,8} =$ −2,452 $r_{i3} = h_{fe}(R_{e3}+r_{e3}) = 200(4k+27,8) = 805,56k$

$A_{vd} = \frac{R_4//r_{i3}}{2r_{e2}+\frac{100k}{h_{fe}}} =$ 56,6

$A_v = A_{vd} . A_{v3} . A_{v4} = 56,6 . (-2,452) . 0,997 =$ −138

c.

$r_i' = 2h_{fe}r_{e1}+100k = 314,4k$

$r_i = 100k//r_i' =$ 75,87k

$r_o = r_{e4} + \frac{10k}{h_{fe}} =$ 62,11Ω