IMPORTANT: Besides your **calculator** and the sheets you use for calculations you are only allowed to have an A4 sized **"copy sheet"** during this exam. Notes, problems and alike are not permitted. **Please submit your "copy sheet" along with your solutions.** You may get your "copy sheet" back after your solutions have been graded. ***Do not forget to write down units and convert units carefully! Cell phones are not allowed and should be placed on the front desk before the exam.***

EHB222E INTRODUCTION TO ELECTRONICS (11394)
Final Exam 9 January 2016 9.00-11.00
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EEF 5101, 5304

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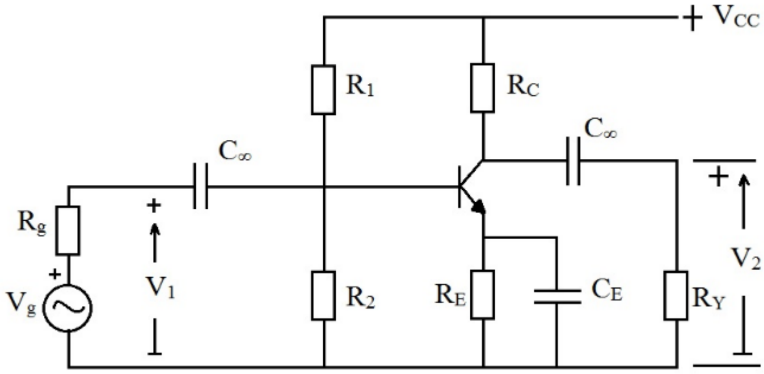
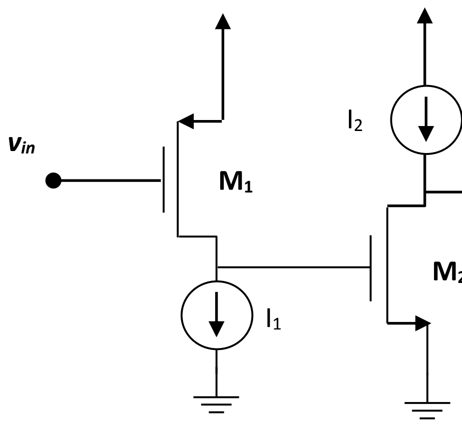
1. Analyze the transistor circuit given below. BJT parameters are $\mathbf{V_{BE}}$ = 0,6V, $\mathbf{h_{FE} = \beta_F}$ =300, $\mathbf{r_o = 1/h_{OE}}$ = 34 k and $\mathbf{V_T}$ = 25 mV. Resistor values are $\mathbf{R_g}$ = 1k, $\mathbf{R_1}$= 100 k, $\mathbf{R_2}$ = 20 k, $\mathbf{R_C}$ = 2,2 k, $\mathbf{R_E}$ = 500 Ω, $\mathbf{R_Y}$ = 10 k and $\mathbf{V_{CC}}$ = 10 V. Remember that $\mathbf{C_\infty}$ and $\mathbf{C_E}$ are short circuit at AC.
   a. Calculate $\mathbf{V_B, V_C, V_E}$ and $\mathbf{I_C}$.
   b. Find $\mathbf{v_2/v_1}$ and $\mathbf{v_2/v_g}$.
   c. Calculate **(b)** without $\mathbf{C_E}$ present.

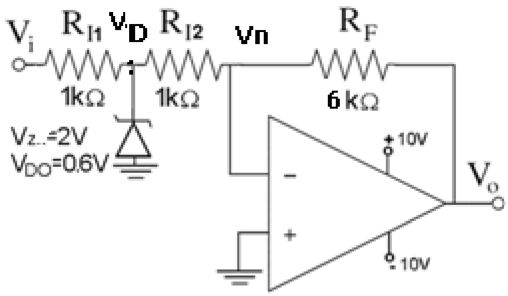


2. Assuming MOS transistors below are biased by **ideal current sources**, and **both MOS are in saturation**,



   a. Design the two ideal current sources (using BJT or MOS to your liking)
   b. Calculate voltage gain $\mathbf{v_o/v_{in}}$ as a function of MOS parameters $\mathbf{V_A}$ and $\mathbf{g_m}$.
   c. How does the gain in **(b)** change when this MOS amplifier is fed by a signal generator having a source resistance $\mathbf{R_s}$, and a load $\mathbf{R_l}$ is connected to the output.

3. Assuming the OPAMP on the right is ideal calculate $\mathbf{V_D}$, $\mathbf{V_n}$ and $\mathbf{V_o}$ for .($\mathbf{I_{zmin}}$ = 0 mA)
   a. $\mathbf{V_i}$ = -3 V
   b. $\mathbf{V_i}$ = 3 V
   c. $\mathbf{V_i}$ = 5 V



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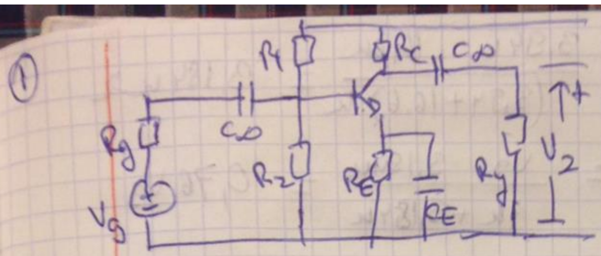
SOLUTIONS:

1



$V_{BE} = 0{,}6V$ $\beta = 300$

$r_o = 34k\Omega$ $V_T = 25mV$

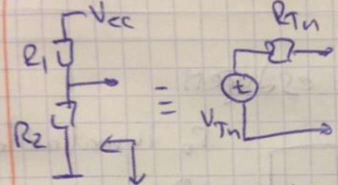
$R_g = 1k\Omega$; $R_1 = 100k\Omega$; $R_2 = 20k$

$R_C = 2k2$; $R_E = 500\Omega$; $R_y = 10k$

$V_{cc} = 10V$

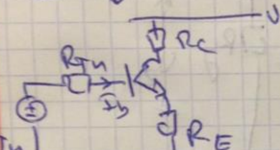
a) V_C, V_B, V_E ve I_{CQ} nedir.

Çözüm:



$R_{Th} = R_1 // R_2 = \frac{R_1 R_2}{R_1 + R_2} = 16{,}6k\Omega$

$V_{Th} = \frac{V_{cc} \cdot R_2}{R_1 + R_2} = \frac{10 \cdot 20k}{120k} = \underline{1{,}66V}$



$V_{Th} = R_{Th} I_b + \underbrace{0{,}6}_{V_{BE}} + (1+\beta) I_B \cdot R_E$

$1{,}66 = 16{,}6k I_b + 0{,}6 + 301 \cdot 500 I_b \Rightarrow$

$1{,}06 = (16{,}6 + 150{,}5) \cdot 10^3 \cdot I_b \Rightarrow$

$I_b = 1{,}06 / 167{,}6k = 6{,}34\mu A$

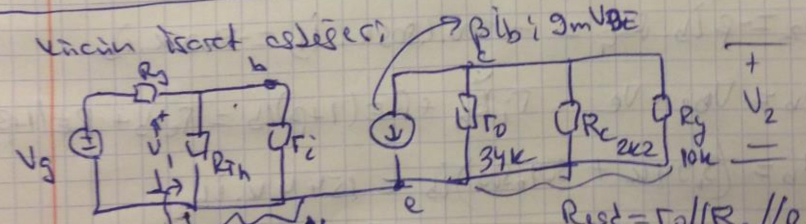
$\boxed{I_C = \beta I_b = 1{,}90mA}$

$V_B = V_{BE} + (1+\beta) R_E I_b = 0{,}6 + 301 \cdot 500 \cdot 6{,}34\mu A = \underline{1{,}554V}$

$V_E = (1+\beta) R_E \cdot I_B = 0{,}954V$

$V_C = V_{cc} - R_C I_C = 10 - 2k2 \cdot 1{,}9mA = \underline{5{,}81V}$

b) küçük işaret eşdeğeri



$R_{gir} = R_{Th} // r_i$

$R_{eşd} = r_o // R_C // R_y = 1{,}712k\Omega$

$V_2 = -g_m V_{be} \cdot R_{eşd} = -76 \cdot 1{,}712 V_{be}$

$g_m = \frac{I_{CQ}}{V_T} = \frac{1{,}9mA}{25mV}$

$g_m = 0{,}076 = 76mS$

$\boxed{\frac{V_2}{V_{be}} = -130{,}14}$ $V_{be} = V_1 \Rightarrow \boxed{\frac{V_2}{V_1} = -130{,}14}$

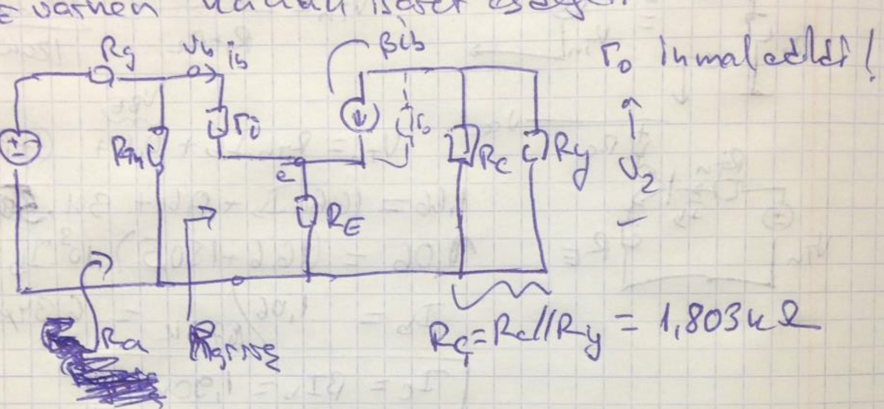
$r_i = \frac{\beta_F}{g_m} = \frac{300}{76mS} = 3{,}94k\Omega$

$R_{giriş} = R_{Th} // r_i = \frac{3,94k \cdot 16,6k}{(3,94+16,6).k} = 3,184k\Omega$

$V_1 = \frac{V_g}{R_g + R_{giriş}} \cdot R_{giriş} = \frac{V_g \; 3,184k}{1k+3,184k} = 0,76\, V_g$

$\frac{V_1}{V_g} = 0,76 \Rightarrow$ $\boxed{\frac{V_2}{V_g} = \frac{V_2}{V_1} \cdot \frac{V_1}{V_g} = -130,14 \cdot 0,76 = -99,93}$

c) R_E varken küçük işaret eşdeğeri



$R_C' = R_c // R_y = 1,803k\Omega$

$R_{giriş} = \frac{v_b}{i_b} = r_i + (1+\beta)R_E = 154,4k\Omega$

$R_a = R_{giriş} // R_{Th} = 154,4k\Omega // 16,6k \cong 15k\Omega$

$v_2 = -\beta i_b . R_C' = -300 . 1,803k . i_b = -540.k.i_b$

$v_b = v_{be} + v_e = r_i . i_b + R_E(1+\beta) i_b = r_e i_b + R_E(1+\beta) i_b$

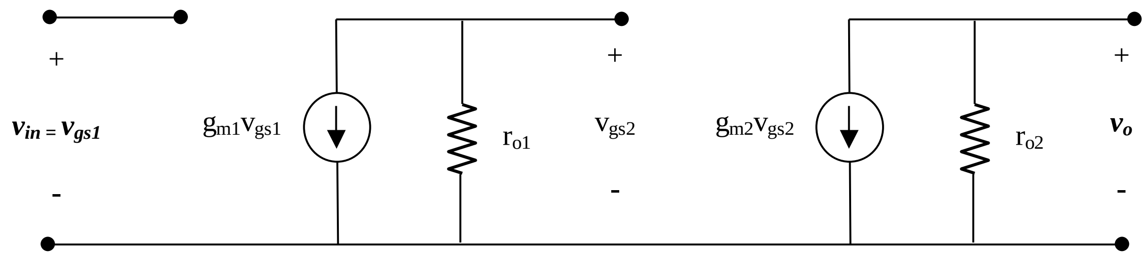
$v_b = (3,94k + 301 . 500) i_b = 154,4k . i_b$

$\boxed{\frac{v_2}{v_b} = \frac{-540k}{154,4k} = -3,49}$

$v_b = \frac{v_g}{R_g + R_a} \cdot R_a = \frac{v_g . 15k}{(1+15)k} = 0,93\, v_g \Rightarrow$

$\boxed{\frac{v_o}{v_g} = \frac{v_o}{v_b} \frac{v_b}{v_g} = -3,49 . 0,93 = -3,24}$

2. Small signal circuit:



$$r_{o1} = \frac{V_{A1}}{I_{D1}}; r_{o2} = \frac{V_{A2}}{I_{D2}}$$

$$A_v = \frac{v_o}{v_{in}} = \frac{v_o}{v_{gs2}} \cdot \frac{v_{gs2}}{v_{in}} = (-g_{m2}r_{o2}) \cdot (-g_{m1}r_{o1}) = \underline{\underline{g_{m1}g_{m2}r_{o1}r_{o2}}} .$$

The gain in **(b) does NOT** change when this MOS amplifier is fed by a signal generator having a source resistance $\mathbf{R_s}$, because no current flows into the G(ate).

However, when a load $\mathbf{R_l}$ is connected to the output, $\mathbf{R_l}$ is connected in parallel to r_{o2}. Thus

$$A_v^* = \frac{v_o^*}{v_{in}} = \frac{v_o^*}{v_{gs2}} \cdot \frac{v_{gs2}}{v_{in}} = [-g_{m2}(r_{o2} \parallel R_l)] \cdot (-g_{m1}r_{o1}) = \underline{\underline{g_{m1}g_{m2}r_{o1}(r_{o2} \parallel R_l)}}$$

3. <u>Analyze how the Zener diode works:</u>

a. The Zener diode is forward biased. $V_D = -V_{DO} = -0{,}6$ V. Assuming $V_n = 0$ V (negative feedback over the OPAMP) $V_o = -R_F/R_{l2}*V_D = 3{,}6$ V
Because $-10 \text{ V} < V_o < 10$ V $V_n = 0$ V assumption IS CORRECT.

b. The Zener diode is reverse biased. Assuming $I_D = 0$ mA and $V_n = 0$ V, $V_D = 1{,}5$ V.
Since $V_D < V_Z$ $I_D = 0$ mA assumption IS CORRECT.
$V_o = -R_F/R_{l2}*V_D = -9$ V.
Because $-10 \text{ V} < V_o < 10$ V $V_n = 0$ V assumption IS CORRECT.

c. The Zener diode is reverse biased. Assuming $I_D = 0$ mA and $V_n = 0$ V, $V_D = 2{,}5$ V.
Since $V_D > V_Z$, $I_D = 0$ mA assumption IS <u>NOT</u> CORRECT.
If $I_{zmin} = 0$ mA then $V_D = V_Z = 2$ V. Assuming $V_n = 0$ V (negative feedback over the OPAMP) $V_o = -R_F/R_{l2}*V_D = -12$V. However, because $-10 \text{ V} < V_o < 10$ V, $V_o = -10$ V.
THUS $V_n = 0$ V assumption IS <u>NOT</u> CORRECT. And $V_n = 0{,}28$ V