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!***

ELE222(E) INTRODUCTION TO ELECTRONICS (20517-20521)

Final Exam ✎ 1 June 2010 🕛 12.00-14.00

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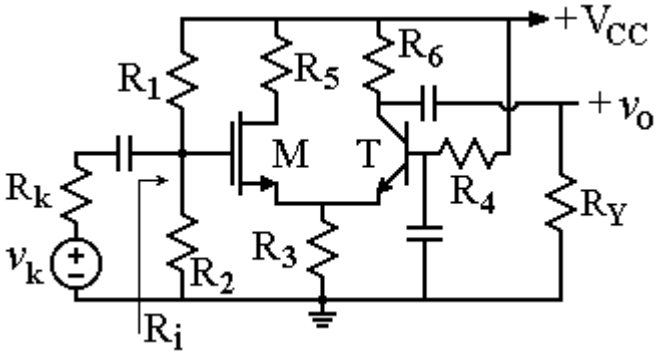


1. For the amplifier circuit shown on the left, V_{CC}=12V, R_k=20kΩ, R_Y=20kΩ, and all capacitors are ideal. Transistor parameters are $ß_n$=10mA/V^2, V_{TH}=1V, λ=0 for the MOSFET, and I_S=I_o= 2x10^{-15}A, h_{fe}=$ß_F$=50, V_A=∞ for the BJT (V_T=25.9 mV @ T=300K).

a) Determine the values of resistors R_1, R_2, R_3, R_4, R_5 and R_6 so that V_G=5V, V_{DS}=3,5V, V_{CE}=4V, V_E=3V, I_D=10·I_C and r_i=R_i=100kΩ (12 points).

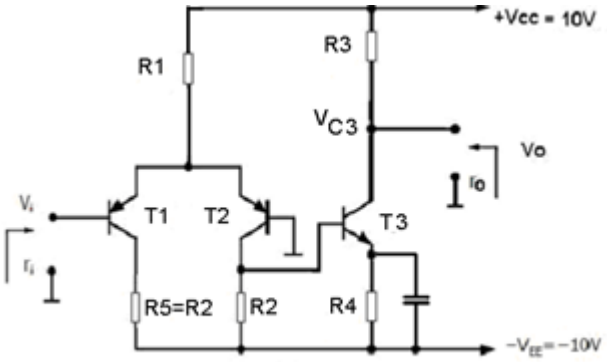
b) Calculate the AC gain of the circuit, v_o/v_k. (15 points)
HINT ::: You need to work on small signal circuit.

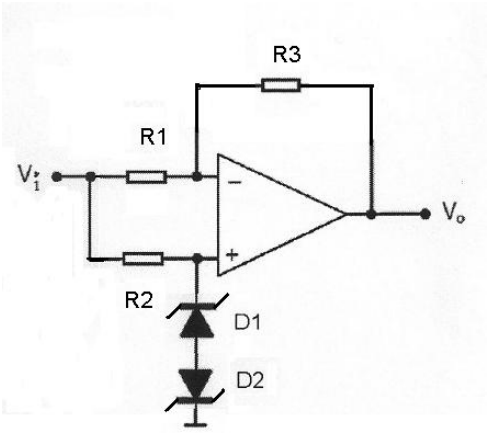
c) If AC input signal v_k's amplitude is 50mV, what is the amplitude of the AC voltage v_d on the D(rain) of the MOSFET (8 points)?

2. For the BJTs on the right h_{fe}=$ß_F$=250, $|V_{BE}|$=0,6V and V_A=∞.

a) For V_i=0V determine resistor values and CMRR such that V_{C3}=0V, r_i=62k, r_o=10k and $|v_o/v_i|$=6400. Remember R_1>>r_{e2} and V_T=25mV (25 points).

b) Using cutoff and saturation conditions for T_3 (V_{CESAT}=0V for T_3) determine the range of v_o. What is the maximum value of A to observe an undistorted output signal when a sinusoidal voltage with amplitude A is applied to the input (8 points)?





3. For the circuit shown on the left assume V_{CC}=10V, -V_{EE}=-10V, the OPAMP is ideal, and V_z=3,3V, V_{DO}=0,7V, I_{zmin}≈0A.

a) Find the function realized by the circuit when V_i changes in the range –15V to 15V. Analyze the circuit when the two Zener diodes are conducting and when they are not conducting (20 points).

b) For the conditions analyzed in a), draw the transfer function of the circuit (i.e., V_o as a function of V_i) for R_2=R_3=2xR_1 and indicate important values (12 points).

GOOD LUCK!!!!

ÇÖZÜMLER/SOLUTIONS:

a) $V_S = V_E = 3V \rightarrow V_{GS} = V_G - V_S = 2V$ (5V)

$V_{DS} = 3,5V > V_{GS} - V_{TH} = 1V$

$\Rightarrow$ MOSFET kisilmada

$I_D = \frac{\beta_n}{2}(V_{GS} - V_{TH})^2 = 5mA = 10\,I_C$

$\Rightarrow I_C = 0,5mA$

$V_{CC} - V_D = 5,5V = R_5 I_D \rightarrow \boxed{R_5 = 1,1k\Omega}$

(12V; $V_{DS} + V_S = 6,5V$; 5mA)

$V_{CC} - V_C = 5V = R_6 I_C \rightarrow \boxed{R_6 = 10k\Omega}$

(0,5mA; $V_C + V_{CE} = 7V$)

$V_{CC} - V_B = 8,32V = R_4 I_B \rightarrow \boxed{R_4 = 832k\Omega}$

($V_{BE} + V_E = 3,68V$; $V_T \ln \frac{I_C}{I_S} = 0,68V$; $\frac{I_C}{\beta_F} = 10\mu A$)

$V_E = (|I_E| + |I_S|)R_3 = \left(\frac{\beta_F + 1}{\beta_F} I_C + I_D\right) R_3$

$= 5,51mA \times R_3 = 3V \rightarrow \boxed{R_3 = 544,5\Omega}$

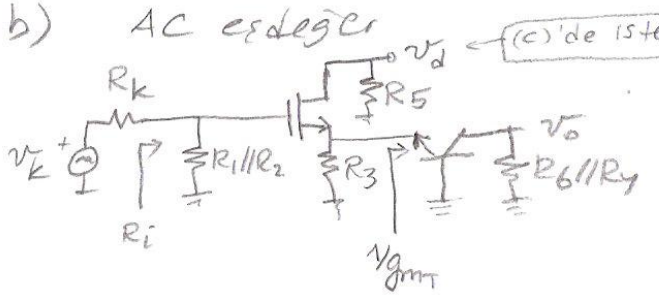
$V_G = 5V = \frac{R_2}{R_1 + R_2} V_{CC}$ (12V) $\rightarrow \frac{R_2}{R_1 + R_2} = \frac{5}{12}$ ... (*)

AC için $R_i = R_1 // R_2 = 100k\Omega$

$\Rightarrow \frac{R_1 R_2}{R_1 + R_2} \overset{(*)}{=} R_1 \frac{5}{12} = 100k\Omega \rightarrow \boxed{R_1 = 240k\Omega}$ (**)

(*) + (**) $\Rightarrow \boxed{R_2 = 171,4k\Omega}$

b) AC eşdeğeri



$g_{m_M} = \beta_n (V_{GS} - V_{TH}) = 10mS$

$g_{m_T} = \frac{I_C}{V_T} = 19,3mS$

$\frac{v_o}{v_k} = \frac{R_i}{R_i + R_k} \cdot \frac{g_{m_M}\left(R_3 // \frac{1}{g_{m_T}}\right)}{1 + g_{m_M}\left(R_3 // \frac{1}{g_{m_T}}\right)} \cdot g_{m_T}(R_6 // R_4)$

($R_3 // \frac{1}{g_{m_T}} = 47,3\Omega$; $1 + g_{m_M}(R_3 // \frac{1}{g_{m_T}}) = 47,3\Omega$)

$= 0,833 \times 0,321 \times 128,7 = \underline{34,4}$

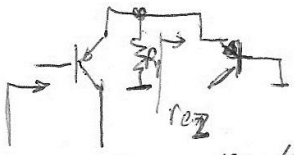
c) $\frac{v_d}{v_k} = \frac{R_i}{R_i + R_k} \cdot \frac{-g_{m_M} R_5}{1 + g_{m_M}\left(R_3 // \frac{1}{g_{m_T}}\right)}$

$= 0,833 \times (-7,468) = -6,223$

v_d'nin genliği $= 6,223 \times 50mV$

$= \underline{0,311V}$

(v_k ile ters fazda)



$r_i = \beta_F (r_{e1} + r_{e2} // R_1)$

Eştranzistorler → $r_{e1} = r_{e2}$, $R_1 >> r_{e2}$ → $r_i = \beta_F (2 r_{e2})$ → $r_{e2} = 124\,\Omega$

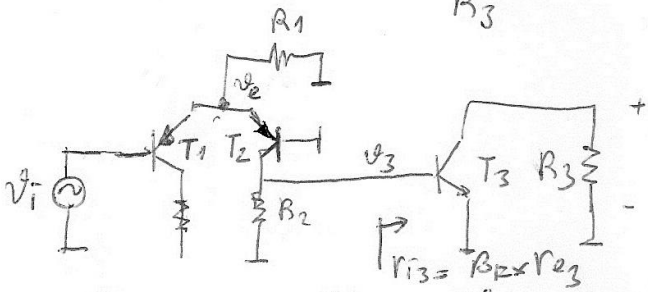
β_F ↓ 62000

$r_{e2} = \frac{V_T}{I_{E2}}$ (25mV) → $I_{E2} \cong 200\,\mu A$

$I_{R1} = 2 I_{E2} = 2 I_{B1} = 400\,\mu A$ $\quad I_{R1} = \frac{V_{CC} - V_{EB}}{R_1}$ → $R_1 \cong 23300\,\Omega$

$r_o = 10\,K$ → $R_3 = 10\,K\Omega$ $(V_A = \infty)$

$I_{E3} \cong I_{C3} = \frac{V_{CC} - V_{C3}}{R_3} = 1\,mA$ $\quad (V_{C3} < 0V)$ $\quad r_{e3} = \frac{V_T}{I_{E1}} = 25\,\Omega$



$\frac{v_o}{v_i} = \frac{v_2}{v_i} \times \frac{v_3}{v_2} \times \frac{v_o}{v_3} = \frac{R_1 // r_{e2}}{r_{e1} + R_1 // r_{e2}} \times \frac{(\beta_F \times r_{e3}) // R_2}{r_{e2}} \times (-) \frac{R_3}{r_{e3}}$

$(\beta_F \times r_{e3}) // R_2 \cong 6250\,\Omega$

$\cong \frac{1}{2} \cdot \frac{R_2 // (\beta_F \times r_{e3})}{r_{e2}} \times - \frac{R_3}{r_{e3}} = |6400|$ → $\frac{R_2 // (\beta_F \times r_{e3})}{r_{e2}} = 32$

→ $R_2 \cong 11\,K\Omega$

$I_{C2} = I_{R2} + I_{B2}$ $\quad (I_{B2} = \frac{I_{C3}}{\beta_F})$

$I_{R2} = \frac{V_{BE3} + I_{E3} \times R_4}{R_2}$ → $R_4 \cong 1550\,\Omega$

$CMRR = \frac{2 R_1 + r_{e2}}{2 r_{e2}} = 188$ yada $20 \log \left(\frac{2 R_1 + r_{e2}}{2 r_{e2}} \right) \cong 45\,dB$

b) $I_{C3} = 0 \rightarrow V_o^+ = V_{OMAX} = 10V$

Tranzistor doymada $V_o^- = V_{OMIN} = -V_{EB} + V_{E3} + V_{CE\,SAT}$ (0 V)

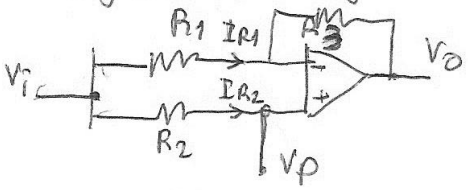
($V_{E3} = I_{E3} R_4$)

$= -10 + 1,55 + 0V = -8,45$

Bu durumda altan önce kırpılmaya başlar. $A = \left| \frac{V_{OMIN}}{V} \right| = \frac{8,45}{6400}$

$= 1,32\,mV$

a) V_i değiştirildiğinde $-V_z - V_{DO} \leq V_i \leq V_{DO} + V_z$ aralığında diyotlardan akım akmaz.



$I_{R2} = 0 \rightarrow V_+ = V_i$

$I_{R1} = \frac{V_i - V_-}{R1} = \frac{V_i - V_+}{R1} = 0$

$V_o = V_+ = V_i$

$\frac{V_o}{V_i} = 1$

D_2 normal, D_1 zener

$V_i > V_{DO} + V_z = V_p^+$ $\quad V_p^+ = 4V$

0,7V 3,3V

$V_i < -V_{DO} - V_z = V_p^-$ $\quad V_p^- = -4V$

D_1 normal, D_2 zener

(yeterince küçük)

$I_z > I_{zmin} \cong 0$ kabul edildiğinden diyotların uçlarında zener gerilimi oluşur ve $V_i > 4$ V ve $V_i < -4$ V için V_p sabit kabul edilebilir.

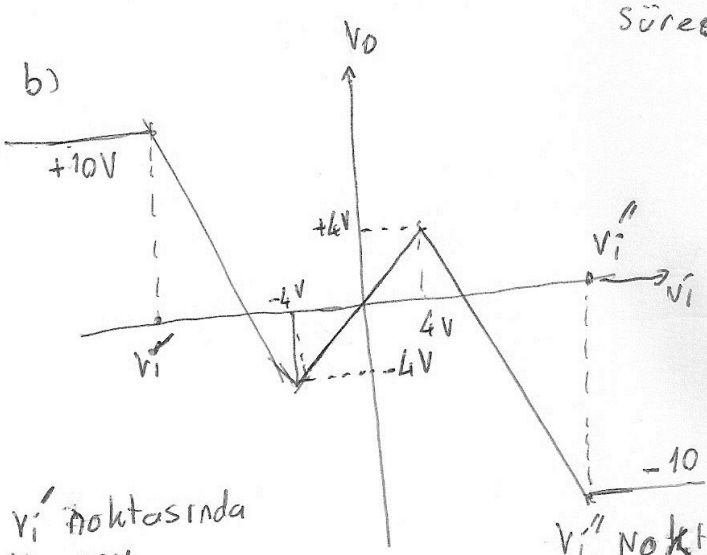
Bu durumda

$$\frac{V_i - V_p}{R_1} = \frac{V_p - V_o}{R_3} \rightarrow V_o = -V_i \frac{R_3}{R_1} + V_p\left(1 + \frac{R_3}{R_1}\right)$$

$R_3 = 2R_1 \rightarrow \boxed{V_o = -2V_i + 3 \cdot V_p}$

(Bu bağıntı $-V_{EE} < V_o < V_{cc}$ olduğu sürece geçerlidir.)

b)



① $-15 < V_i < -11$ V

$V_o = 10$ V

② $-11 \leq V_i \leq -4$ V

$V_o = -2V - 12$

③ $-4V \leq V_i \leq 4$ V

$V_o = V_i$

④ $4 \leq V_i \leq 11$ V

$V_o = -2V_i + 12$

⑤ $11 \leq V_i \leq -15$ V

$V_o = -10$ V

V_i' noktasında

$V_o = 10$ V

$10 = -2V_i - 12$

$V_i' = -11$ V

V_i'' noktasında

$V_o = -10$ V

$-10 = -2V_i + 12$

$V_i'' = +11$ V