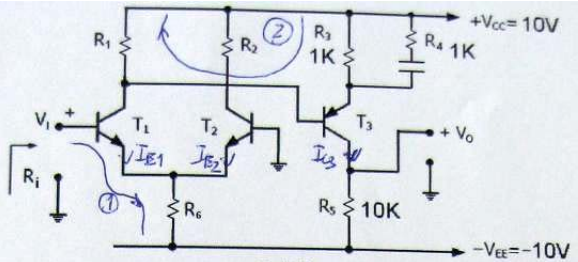
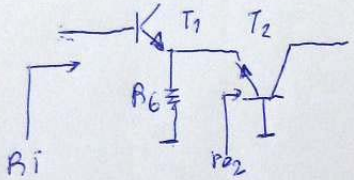
SORU 1



Şekil 1

a)



$R_i = \beta_F (r_{e1} + r_{e2} // R_b)$

$R_{E_2} \gg r_{e2} \rightarrow R_i = \beta_F (r_{e1} + r_{e2})$

Tranzistorlar eş olduklarından $V_i = 0$ için $r_{e1} = r_{e2} = r_e$

$R_i = 125K = \beta_F (2 \times r_e) \rightarrow r_e = 250\Omega$

$r_e = \frac{V_T}{I_{E1}} \rightarrow I_{E1} = I_{E2} = 104\mu A$

① Çevre yardımıyla $0 - (-V_{EE}) - V_{BE1} = 2 I_{E1} R_b \rightarrow R_b = 45K\Omega$

$I_{C1} = \frac{\beta_F}{\beta_F + 1} \times I_{B1} = 103\mu A$

Diğer yandan $I_{E_3} \cong I_{C_3} = \frac{V_o - (-V_{EE})}{R_5}$ (V_o ↓ 0V) $\rightarrow I_{E_3} = 1mA$

$r_{e_3} = \frac{V_T}{I_{E_3}} = 26\Omega$

② Çevre yardımıyla

$R_3 I_{E3} + V_{EB3} + \left(\frac{I_{E3}}{\beta_F} - I_{C1} \right) R_1 = 0 \rightarrow R_1 = \frac{R_3 I_{E3} + V_{EB3}}{I_{C1} - \frac{I_{E3}}{\beta_F}} = 16K\Omega$

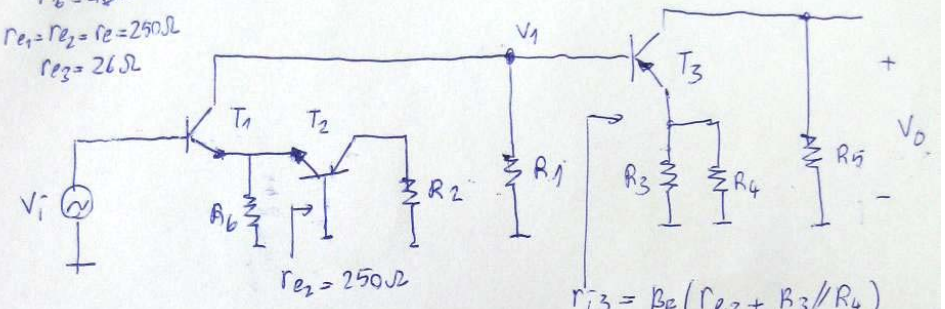
b) Devrenin Küçük İşaret Eşdeğeri

$R_2 = R_1 = 16K$

$R_b = 45K$

$r_{e1} = r_{e2} = r_e = 250\Omega$

$r_{e3} = 26\Omega$



$r_{i3} = \beta_F (r_{e3} + R_3 // R_4)$

$= 131K\Omega$

$\frac{V_o}{V_i} = \frac{V_1}{V_i} \times \frac{V_o}{V_i}$

$= \frac{-R_1 // r_{i3}}{r_{e1} + R_b // r_{e2}} \times - \frac{R_5}{R_3 // R_4 + r_{e3}}$

Değerler yerine konursa

$= (-28,6) \times (-19) = 543$ bulunur

$CMRR = \left| \frac{2 R_b + r_e}{2 r_e} \right| = 180,5$

yada $20 \log \left| \frac{2 R_b + r_e}{2 r_e} \right| = 45dB$

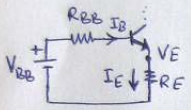
SORU 2

DC Analiz

(a) $R_B = R_1 // R_2 = 100k // 47k \cong 32k\Omega$

$V_{BB} = \frac{R_2}{R_1+R_2} \cdot V_{CC} = \frac{47k \cdot 12}{100k+47k} \cong 3,84\,V$

$I_C = 2\,mA$; $I_B = I_C/\beta_F = \frac{2.10^{-3}}{100} = 20\mu A$



$V_{BB} = R_{BB} \cdot I_B + V_{BE} + V_E$

$V_E = V_{BB} - V_{BE} - R_{BB} \cdot I_B$

$V_E = 3,84 - 0,6 - 32.10^3 . 20.10^{-6}$

$V_E = 2,6\,V$

$R_E = V_E/I_E = \frac{V_E}{(\beta_F+1)I_B} = \frac{2,6}{2,02.10^{-3}} \cong 1287\,\Omega$

(veya $I_E \simeq I_C$ alınarak $R_E = 1300\,\Omega$ alınabilir!)

$R_E = 1287\,\Omega$ veya $1300\,\Omega$

$R_C \cdot (I_C + I_G) = V_{CC} - V_C$; $I_G = 0$

$\Rightarrow R_C = \frac{V_{CC}-V_C}{I_C} = \frac{12-6}{2.10^{-3}} = 3k\Omega$

$R_C = 3k\Omega$

MOSFET doyma bölgesinde çalışmaktadır $\Rightarrow$

$\Rightarrow I_D = \frac{\beta_n}{2}(V_{GS}-V_{Th})^2$

$2.10^{-3} = \frac{4.10^{-3}}{2}(V_{GS}-1)^2 \Rightarrow V_{GS} = 2V$

$V_C = V_G = 6\,V$ verilmiş.

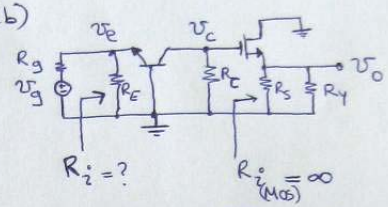
$V_G - V_{GS} = V_S \Rightarrow V_S = 6-2 = 4V$

$R_S = \frac{V_S}{I_D} = \frac{4}{2.10^{-3}} = 2k\Omega$

$R_S = 2k\Omega$

AC Analiz

(b)



$R_i = R_E // (r_e + \frac{0}{\beta_F})$ → Baz ucuna bağlı direnç yok.

$R_i = R_E // r_e$; $r_e = \frac{1}{g_{m_{(BJT)}}} = \frac{V_T}{I_{CQ}} = \frac{26}{2} = 13\,\Omega$

$R_i = 1287 // 13 \Rightarrow \boxed{R_i \cong 12,87\,\Omega}$

$K_V = \frac{v_o}{v_c} \times \frac{v_c}{v_e} \times \frac{v_e}{v_g} = \frac{v_o}{v_g}$

$\frac{v_o}{v_c} = \frac{R_S // R_L}{\frac{1}{g_{m_{(MOS)}}} + R_S // R_L}$; $g_{m_{(mos)}} = \beta_n (V_{GS}-V_{Th})$

$g_{m_{(mos)}} = 4.10^{-3}\,Siemens$

$R_S // R_L \cong 1918\,\Omega$

$\frac{v_o}{v_c} = \frac{1918}{250+1918} = 0,885$

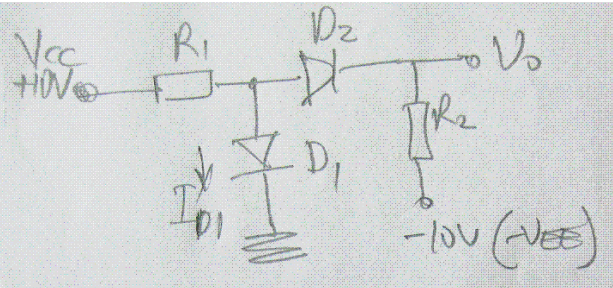
$\frac{v_c}{v_e} = \frac{R_C // R_{i_{(MOS)}}}{r_e + \frac{0}{\beta_F}} = \frac{R_C}{r_e} = \frac{3000}{13} \cong 230,77$ ($R_{i_{(MOS)}} \to \infty$)

$\frac{v_e}{v_g} = \frac{R_i}{R_i+R_g} = \frac{12,87}{12,87+500} \cong 0,025$

$K_V = +(0,885).(230,77).(0,025)$

$\boxed{K_V = +5,1}$

SORU 4



a) D_1 ve D_2 iletimde $\Rightarrow V_0 = 0$ dır

$I_{D_1} = \frac{V_{CC}-V_0}{R_1} - \frac{0-(-10V)}{R_2} = \frac{10-0,7}{5K} - \frac{0-(-10)}{10K} = 1,86 - 1,0 = 0,86mA$

b) D_1 kesimde, D_2 iletimde

$I_{D_1} = 0$ $I = \frac{V_{CC}-V_0-(-V_{EE})}{R_1+R_2} = \frac{10-0,7-(-10)}{15K} = 1,287\,mA$

$V_0 = IR_2 - 10 \Rightarrow V_0 = -3,57\,V$

SORU 3

a) $\frac{v_{I1}-v_N}{R_1} = \frac{v_N - v_O}{R_F}$ ... (*)

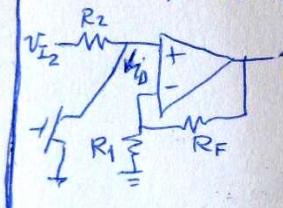
$v_N = v_P = v_{I2} - i_D R_2$ ... (**)

(*) ve (**) yardımıyla,

$v_O = -\frac{R_F}{R_1} v_{I1} + \left(1+\frac{R_F}{R_1}\right)\left(v_{I2} - i_D R_2\right)$

Alternatif çözüm (süperpozisyon)

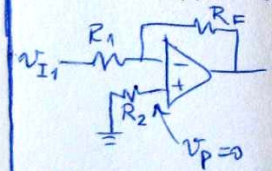
1°) $v_{I1}=0$, $v_{I2}\neq 0$, $i_D \neq 0$



$v_O^{(1)} = \left(1+\frac{R_F}{R_1}\right) v_P$

$= \left(1+\frac{R_F}{R_1}\right)\left(v_{I2} - i_D R_2\right)$

2°) $v_{I1}\neq 0$, $v_{I2}=0$, $i_D=0$



$v_O^{(2)} = -\frac{R_F}{R_1} v_{I1}$

(1°) ve (2°) birleştirilirse

$v_O = -\frac{R_F}{R_1} v_{I1} + \left(1+\frac{R_F}{R_1}\right)\left(v_{I2} - i_D R_2\right)$

b) $R_1 = R_2 = R_F = 1k\Omega$

$\Rightarrow v_O = -v_{I1} + 2\left(v_{I2} - 1k\Omega\, i_D\right)$

i) $v_{GS} = v_{I3} = 0{,}5V < V_{TH} \Rightarrow$ MOSFET tıkamada ($i_D = 0$)

$\Rightarrow v_O = -v_{I1} + 2v_{I2}$

$= -1{,}5V + 2V = \underline{0{,}5V}$

ii) $v_{GS} = v_{I3} = 2V > V_{TH} \Rightarrow$ MOSFET iletimde

$v_{DS} = v_{I2} - i_D R_2 = 3{,}5V - 1k\Omega\, i_D$

MOSFET'i kısılmada (doyma) varsayalım. (sonra sağlaması yapılabilir).

$i_D = \frac{\beta_n}{2}(v_{I3} - V_{TH})^2 = 250\mu A$

$\Rightarrow v_{DS} = 3{,}5 - 1k\Omega \times 250\mu A = 3{,}25V$

$v_{DS} > v_{GS} - V_{TH} = 1V$ olduğuna göre, yaklaşım tutarlı ve doğru ✓.

$\Rightarrow v_O = -0{,}5 + 2\times(3{,}5 - 1k\Omega \times 250\mu A)$

$= 6V$? Ancak bu değer V_O^+'dan büyük!

O zaman, $v_O = V_O^+ = \underline{5V}$ (sınırlanır)

iii) $v_{GS} = v_{I3} = 2{,}5V > V_{TH} \Rightarrow$ MOSFET iletimde

$v_{DS} = v_{I2} - i_D R_2 = 1{,}5V - 1k\Omega \times i_D$

$v_{DS} < v_{GS} - V_{TH} = 1{,}5V$

(çünkü $i_D > 0$ olacağı kesin)

(MOSFET triyot bölgede çalışıyor.)

$i_D = \beta_n\left[(v_{GS} - V_{TH})v_{DS} - \frac{1}{2}v_{DS}^2\right]$ ... (***)

$v_{DS} = v_{I2} - i_D R_2$

$\Rightarrow i_D = \frac{v_{I2} - v_{DS}}{R_2}$ ... (****)

(***) ve (****) eşitlenirse, sonuçta

$v_{DS}^2 - 7v_{DS} - 8 = 0$ elde edilir.

$\Rightarrow v_{DS_{1,2}} = \frac{+7 \pm \sqrt{7^2 - 4\times 8}}{2} = \begin{cases} \underline{1{,}438V} \checkmark \\ 5{,}562V \times \end{cases}$

($> v_{GS} - V_{TH}$ olduğundan uygun değil)

$v_O = -v_{I1} + 2(v_{I2} - 1k\Omega\, i_D)$

(bu v_{DS} olduğundan, i_D'nin hesaplanmasına gerek de yok.)

$v_O = -(-1V) + 2\times 1{,}438V = \underline{3{,}876\,V}$