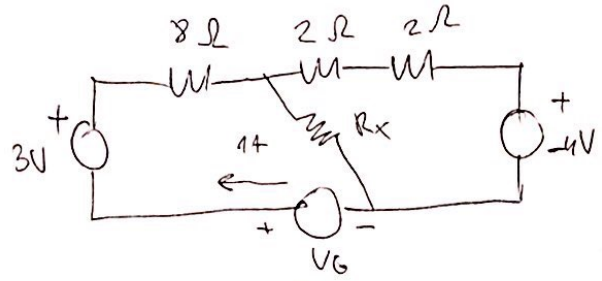
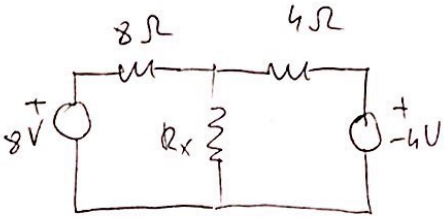
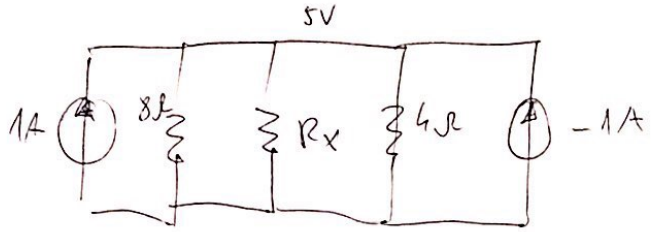
① a) $U_{AB} = 3V = U_1$ b) $R_T = \frac{3 \cdot 6}{9} = 2\,\Omega$ c) $V_G = 5V$

$R_T = 8\,\Omega$ $U_1 = -4V$

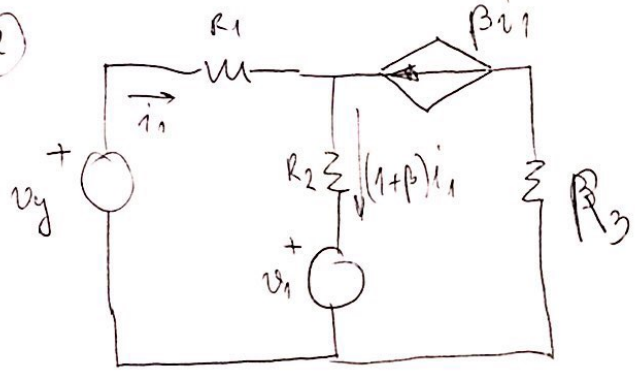






$U_{AD} = 0V$

$P_{R_p} = 0W$ za svaki R_p

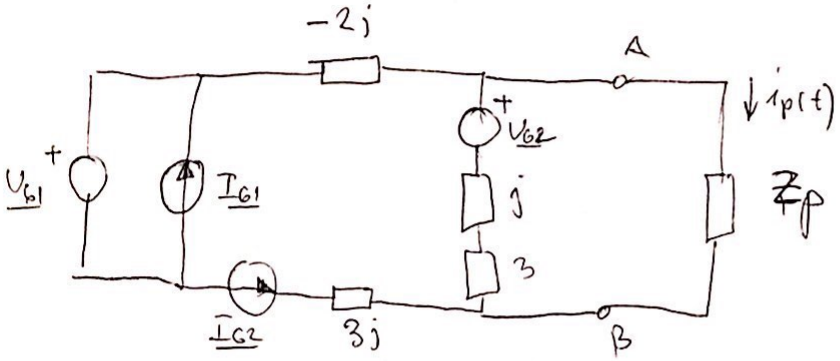
② 

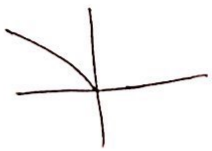
$$v_1 + (1+\beta) i_1 R_2 + i_1 R_1 = v_g$$

$$\frac{v_g}{R_1 + (1+\beta) R_2} = i_1$$

$$R_{EKV} = R_1 + (1+\beta) R_2$$

$\underline{U_{G1}} = 1+j \quad \underline{U_{G2}} = 2j \quad \underline{I_{G1}} = 1-j \quad \underline{I_{G2}} = j$





$U_{AB} = -I_{G2}(3+j) + U_{G2} = -3j + 1 + 2j = 1 - j$

Rg $Z_T = 3+j$

$I_N = \frac{1-j}{3+j} \cdot \frac{3-j}{3-j} = \frac{3-3j-j-1}{10} = \frac{2-4j}{10} = \frac{1}{5} - \frac{2}{5}j$

$\underline{I_N} = \frac{1}{5} - \frac{2}{5}j \quad Z_N = 3+j$

$Z_p = 3-j \quad R_p = 3\,\Omega \quad C_p = 3{,}18\,\mu F$

$(3+j)(1-2j) = 3+j-6j+2 = 5-5j$

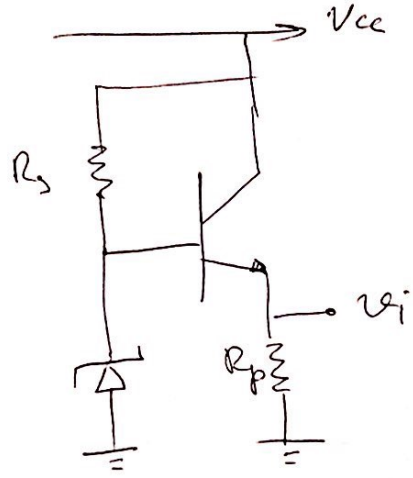
$I_p = \frac{Z_N}{Z_N + Z_p} \cdot I_N = \frac{3+j}{6} \cdot \frac{1}{5}(1-2j) = \frac{1-j}{6}$

$\underline{I_p} = \frac{1}{6} - \frac{1}{6}j$ $\quad \frac{\sqrt{2}}{6}\left(\frac{\sqrt{2}}{2} - \frac{\sqrt{2}}{2}j\right) = \frac{\sqrt{2}}{6} e^{-45°j}$

$\frac{2}{36} = \frac{1}{18}$

$i_p(t) = \frac{1}{3}\cos(\omega t - 45°)$

$\underline{S} = \frac{3}{18} - \frac{j}{18} = \frac{1}{6} - \frac{1}{18}j \quad P = \frac{1}{6}W \quad Q = -\frac{1}{18}\,VAr$



για $V_{cc} \in (0, 0,6V)$ Q je zack, DZ : OFF

$V_{cc} > 0,2V$ Q je zack DZ : OFF go V_{cc}

$V_{CE} = V_{CES}$

$V_{BE} = V_{BES}$

$i_c < \beta i_b$

$v_i = 0V$ P

$V_{cc} - R_S i_b - V_{BE} - i_E R_p = 0$

$V_{cc} - R_S i_b - V_{BE} - V_{cc} + V_{CES} = 0$

$i_b = \frac{V_{CES} - V_{BE}}{R_S}$

$v_i = V_{CES}$

$i_E = \frac{V_{cc} - V_{CES}}{R_p}$

$\frac{V_{cc} - V_B}{R_S} = i_b$

$V_B = V_{cc} - R_S i_B$

$V_{cc} - R_S i_b - V_{BE} - i_E R_p = 0$

$v_i = V_{cc} - V_{CES}$

$i_b = \frac{V_{cc} - V_{BE} - i_E R_p}{R_S} = \frac{V_{CES} - V_{BE}}{R_S} < 0$

$V_X - V_{cc} = i_B R_S$

$V_{cc} - R_S i_b - V_{BE} - (1+\beta) i_b \cdot R_p$

$i_b = \frac{V_{cc} - V_{BE}}{R_S + (1+\beta) R_p} < 0$

$v_i = \frac{V_{cc} - V_{BE}}{R_S + (1+\beta) R_p} \cdot (1+\beta) R_p$

για $v_g > 0,6V$ Q → gap DZ : OFF

$v_i = \frac{V_{cc}}{2} - 0,3\,V$ 2°

$i_{CE} = V_{cc} - \frac{V_{cc}}{2} + 0,3\,V = \frac{V_{cc}}{2} + 0,3V$

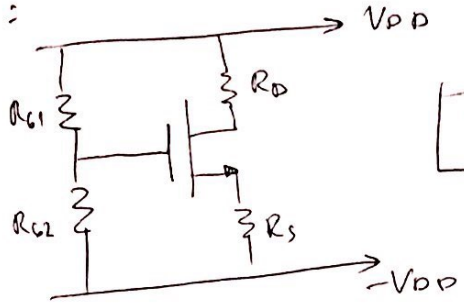
$v_B = i_b R_S - V_{cc} = \frac{V_{cc} - V_{BE}}{R_S + (1+\beta) R_p} \cdot R_S - V_{cc} = \frac{1}{2} V_{cc} - \frac{1}{2} V_{BE} + V_{cc} = \frac{1}{2} V_{cc} - \frac{1}{2} V_{BE}$

για $v_B = V_Z = \frac{1}{2} V_{cc} - 0,3$ $v_B = \frac{1}{2} V_{cc} + 0,3V$

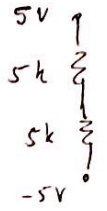
για $v_g = 9,4V$ DZ → περάσει $v_i = 9,4V$ 3°

(5)

DC :



$V_G = 0V$



$5V - 5k \cdot 1mA = 0$

$I = \frac{10V}{10k\Omega} = 1mA$

$I_D = \frac{B}{2}(-V_S - V_t)^2$

$\frac{V_S - V_{DD}}{R_S} = I_D \qquad V_S = R_S I_D + V_- = R_S I_T - 5V$

$I_D = \frac{B}{2}(-R_S I_D + 5V - 3V)^2$

$1000 I_D = (2 - 2000 I_D)^2$

$2000^2 I_D^2 - 9000 I_D + 4 = 0$

$I_{D1/2} = \frac{9000 \pm 8062{,}25}{2 \cdot 2000^2}$

$I_{D1} = 2{,}13mA \qquad I_{D2} =$

$I_D = \frac{B}{2}(-V_S - V_t)^2$

$-5 + R_S I_D = V_S$

$I_D = \frac{B}{2}(5 - R_S I_D - V_t)^2$

$2000^2 I_D^2 - 8000 I_D + 4 = 1000 I_D$

$1000 I_D = (2 - 2000 I_D)^2$

$2000^2 I_D^2 - 9000 I_D + 4 = 0 \qquad I_{D1/2} = \frac{9000 \pm 4123}{2 \cdot 2000^2}$

$I_{D1} = 1{,}64mA$

$V_{S1} = -1{,}72V$

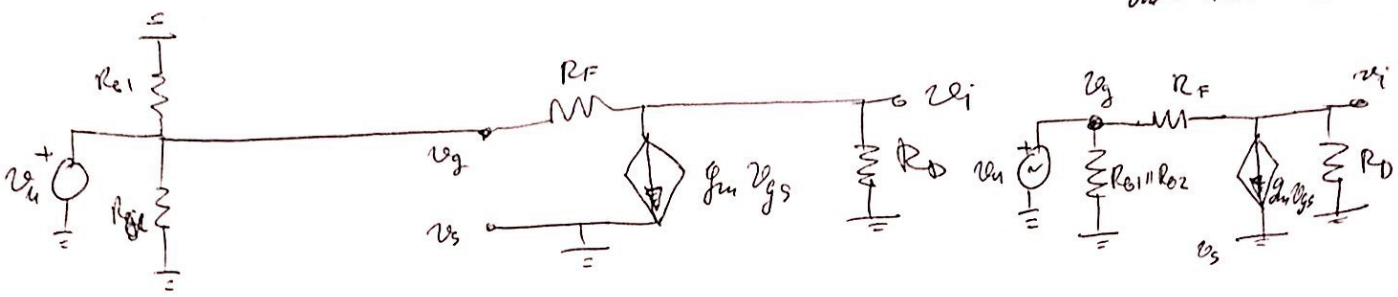
$I_{D2} = 0{,}61mA$

$V_{S2} = -3{,}78V \Rightarrow V_{GS} > V_T$

$V_D = 1{,}95V \Rightarrow V_{GD} < V_T$

$g_m = 1{,}562mS$

$g_m = 9{,}562\ mS$



$v_{gs} = v_u$

$$\frac{v_g - v_i}{R_F} + \frac{0 - v_i}{R_D} = g_m v_g \quad / \cdot R_D R_F$$

$$v_g \cdot R_D - v_i \cdot R_D - v_i \cdot R_F = g_m R_D R_F \cdot v_g$$

$$v_g \cdot R_D (1 - g_m R_F) = v_i (R_D + R_F)$$

$$v_i = \underbrace{\frac{R_D (1 - g_m R_F)}{R_D + R_F}}_{a} v_g$$

$$v_g - v_i = v_g \left(1 - \frac{R_D (1 - g_m R_F)}{R_D + R_F}\right) = v_g (1 - a_v)$$

$$= v_g \left(\frac{R_D + R_F - R_D (1 - g_m R_F)}{R_D + R_F}\right) \cdot \frac{i_u}{i_u}$$

$$i_1 = \frac{v_g (1 - a_v)}{R_F} \qquad i_2 = \frac{v_g}{R_{g1} \| R_{g2}}$$

$$i_u = v_g \left(\frac{1 - a_v}{R_F} + \frac{1}{R_{g1} \| R_{g2}}\right)$$

$$R_{UL} = \frac{R_F}{1 - a_v} \| R_{g1} \| R_{g2} = \frac{R_F}{1 - a_v} \| 2{,}5\,k\Omega =$$

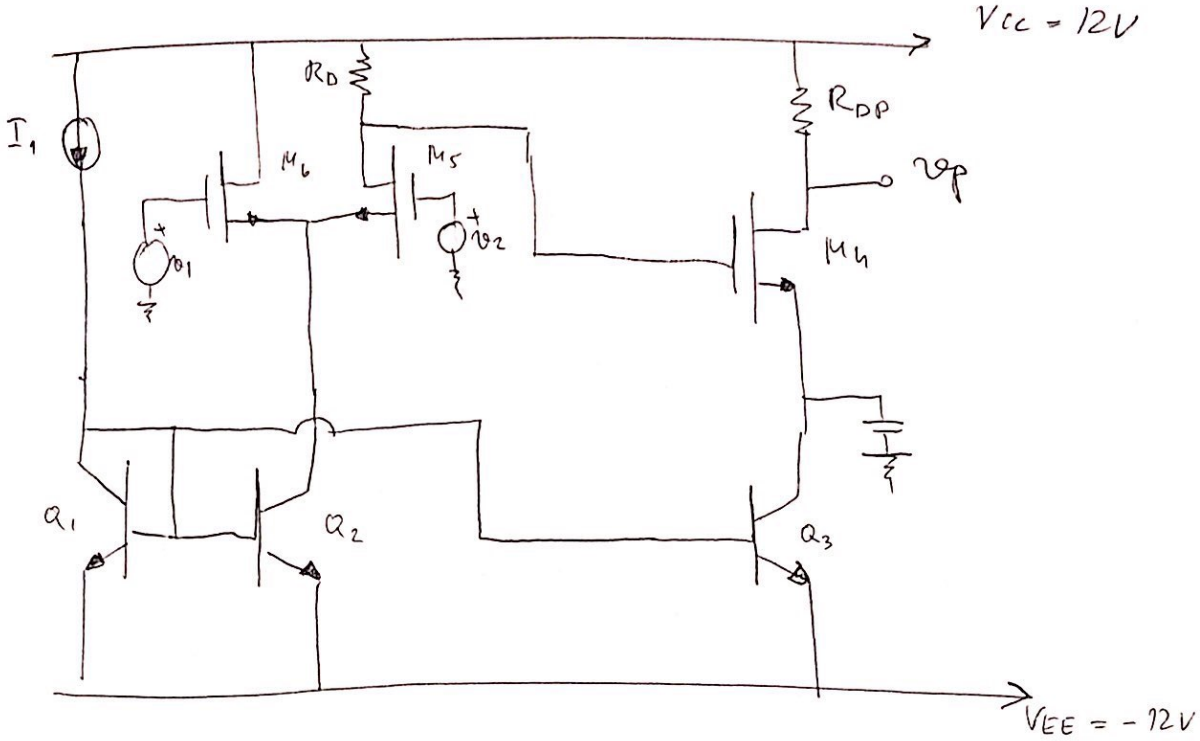
$$\frac{R_D (1 - g_m R_F)}{R_D + R_F} = -4$$

$$R_D - 6{,}24 R_F = -4 R_D - 4 R_F$$

$$5 R_D = 2{,}24 R_F$$

$$R_F = 8{,}928\,k\Omega$$

$$R_{UL} = 1042\,\Omega$$



$3I_B + I_C = I_1$

$(\beta+3) I_B = I_1$

$I_1 = \frac{\beta+3}{\beta} \cdot 1mA = 1,03mA$

$I_6 = I_5 = \frac{I_C}{2} = 0,5mA \Rightarrow g_{m5} = g_{m6} = \sqrt{2I_D \cdot \beta} = 1mS$

$I_4 = I_C \Rightarrow g_{m4} = \sqrt{2I_C \beta} = 1,4mS$

$I_4 = 1mA \quad V_{GS4} = \sqrt{\frac{2I_4}{\beta}} + V_t \quad V_{G4} = \sqrt{\frac{2I_4}{\beta}} + V_t + V_S = -1,59V$

$R_{DP} = 12k\Omega$

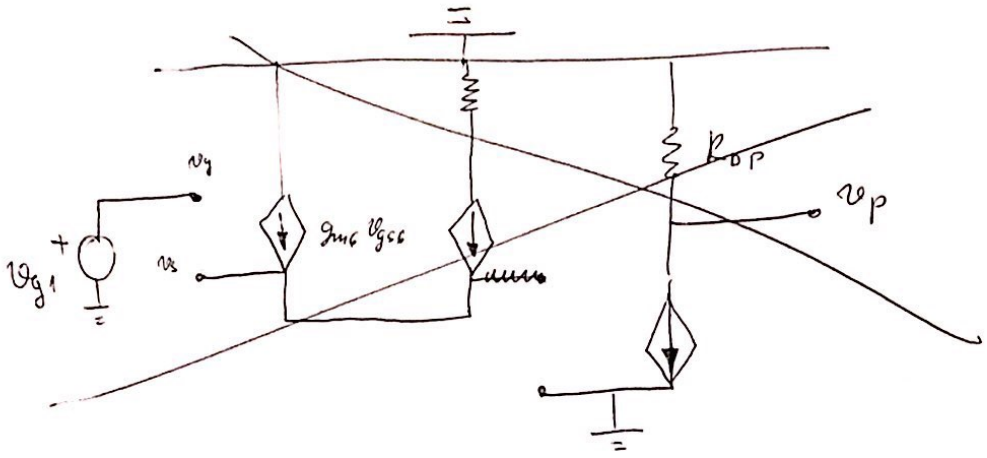
$\frac{V_{CC} - V_{G4}}{\frac{I_C}{2}} = R_D = 27,18k\Omega$

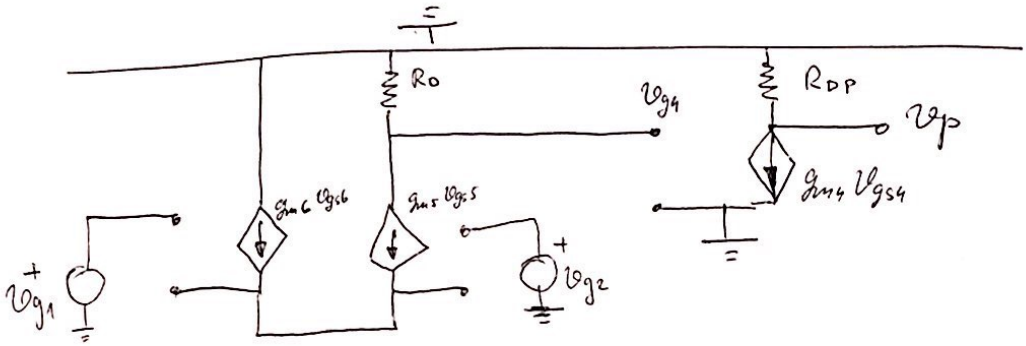
$v_{g1} = 0,1mV \cos \omega t \quad v_{g2} = -0,2mV \cos(\omega t + \frac{\pi}{6})$

$\underline{V_{G1}} = \frac{0,1}{\sqrt{2}} \quad \underline{V_{G2}} = -\frac{0,2}{\sqrt{2}} \cdot \left(\frac{\sqrt{3}}{2} + \frac{1}{2}j\right)$

$\frac{0,1}{\sqrt{2}} + \frac{0,2}{\sqrt{2}}\left(\frac{\sqrt{3}}{2} + \frac{1}{2}j\right) = \frac{0,1}{\sqrt{2}}(1 + \sqrt{3} + j)$

$\underline{V_{G1}} - \underline{V_{G2}} = \frac{0,1}{\sqrt{2}}(1 + \sqrt{3} + j) \quad V_{Deff} = 0,1 \cdot$





$v_{gs5} = v_{gs5}$

$g_m v_{gs6} = - g_m v_{gs5}$

$v_{G6} = - v_{G5}$

$v_{g1} = - v_{g2}$

$g_m v_{g1} - g_m v_{S1} + g_m v_{g2} - g_m v_{S2} = 0$

$$v_{S1} = \frac{v_{g2} + v_{g1}}{2}$$

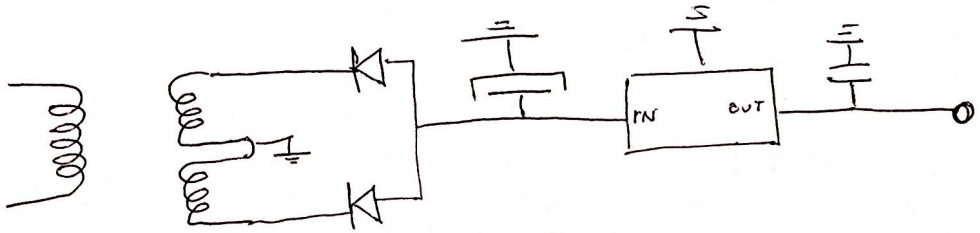
$$v_{g4} = - g_m \left(v_{G2} - \frac{v_{g2} + v_{g1}}{2} \right) R_D$$

$$v_{g4} = - g_m \cdot \frac{v_{g2} - v_{g1}}{2} R_D$$

$$v_p = \frac{+ g_{m4} \cdot g_m \cdot R_D \cdot R_p}{2} \cdot (v_{g2} - v_{g1})$$

$$v_f = \underbrace{- \frac{g_m g_{m4} R_D R_p}{2}}_{a \approx -230} (v_{g1} - v_{g2})$$

(7)



$-V_u + V_z$

$\frac{20}{3}$ mA $=$ R

$i \cdot V_z = 20mV$

$i = \frac{20}{3}$ mA

$i = \frac{20}{3}$ mA

$\frac{V_z - V_u}{\frac{20}{3}mA} = 1050\Omega$

$R_2 = 2k\Omega$ 1mA

$i_{max} = 10mA$

$\frac{-3 - V_{umax}}{1050} = 10mA$ $\quad V_{umin} = -13,5V$

$V_i - V_u < 0,2$

$V_{umax} = -5,2V$