2. MI rješenja TEORIJA

(1) 2)

(2) n-kanalni, gdje ugradni granu

$U_{GS0A} < U_{GS0B}$

$I_D = K\left(U_G - U_{GS0} - \frac{U_{DS}}{2}\right)U_{DS}$ [triodno]

$I_D = \frac{K}{2}\left(U_{GS} - U_{GS0}\right)^2$ [zas.]

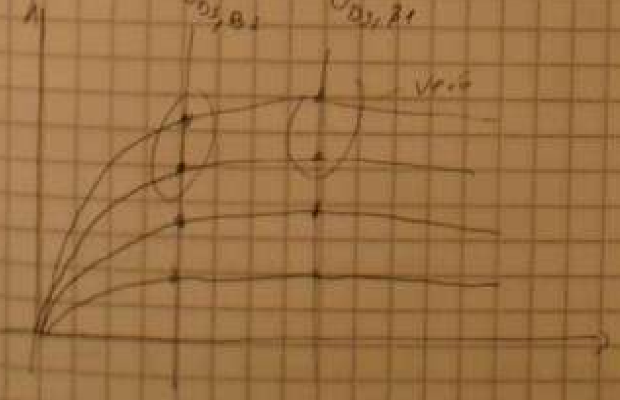
$K_A > K_B$ [C]

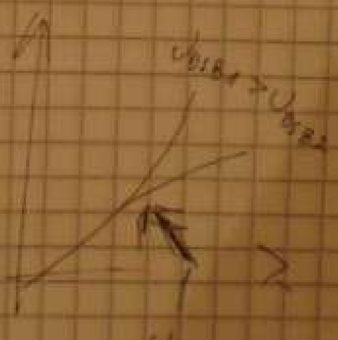
(3) $g_{mA} > g_B$ $g_m = \frac{\partial I_D}{\partial U_{GS}}$

triod. $g_m = K U_{DS}$

zas. $g_m = K(U_{GS} - U_{GS0}) = \sqrt{2KI_D}$

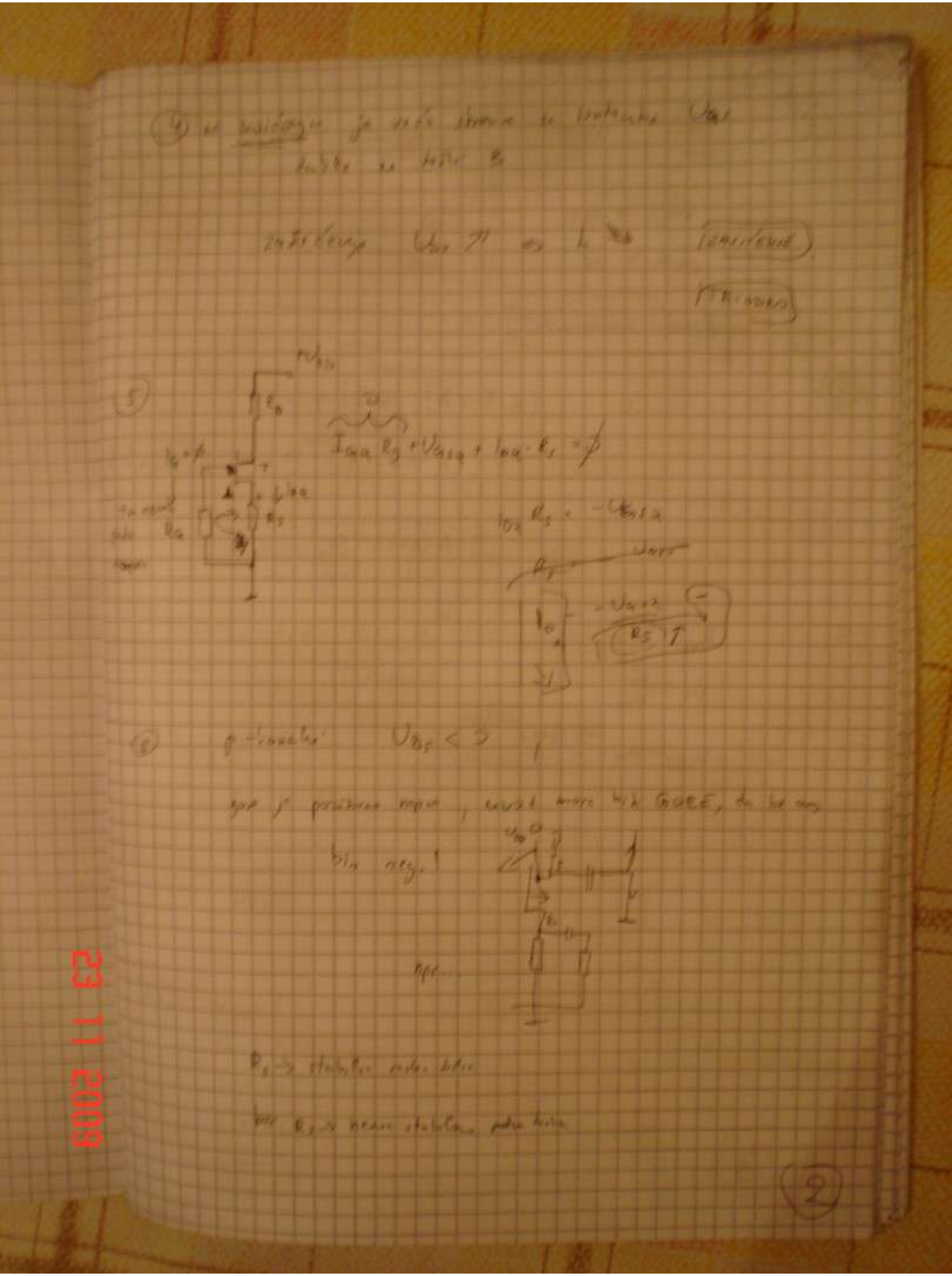
[C]





U_{DS} raste u točci saturacije, pomak gore

(1)



(2) Poarta NAND | IZVOR:

Serija → AND | DC

paralel → OR | AND

Aparici komplement !!!

(3)

U $(B \cdot \bar{D} + \bar{A}) \cdot (\bar{E} + \bar{C}) = Y$

$Y = \overline{(\bar{A} + \bar{B}\bar{D})} + \overline{(\bar{C} + \bar{E})} = \bar{A} \cdot \overline{\bar{B}\cdot\bar{D}} + \bar{C} \cdot \bar{E}$

$\rightarrow \overline{A(B+D)} + C_E$

(8)

N_{DG}

$P_{DE} = \frac{P_E}{P_{DG}}$

$N_{DG2} \rightarrow N_{DG1} \Rightarrow P_{DB2} < P_{DB1}$

(3)

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1.4

ZADACI!!!

1.1) $\mu = 1$ } bude podvoje
$\mu = \infty$

$L = 2\mu m$
$C_{ox} = 0,5\ pF$
$\mu_n = 400\ cm^2/Vs$

1.2) $K = \mu_n \frac{\varepsilon_{ox}}{d_{ox}} \cdot \frac{W}{L}$

$C_{ox} = \varepsilon_0 \cdot \frac{S}{d_{ox}} = \frac{\varepsilon_{ox}}{d_{ox}} \cdot W \cdot L \Rightarrow W = \frac{C_{ox}}{L} \cdot \frac{d_{ox}}{\varepsilon_{ox}}$

za pločasti kondenzator

$K = \mu_n \frac{\varepsilon_{ox}}{d_{ox}} \cdot \frac{1}{L} \cdot \frac{C_{ox}}{L} \cdot \frac{d_{ox}}{\varepsilon_{ox}} = \mu_n \frac{C_{ox}}{L^2}$

$= 400 \cdot \frac{0,5 \cdot 10^{-12}}{(2 \cdot 10^{-4})^2} = \ldots = 5\ mA/V^2$

1.3) $\mu = 1$

$g_m = 6\ mA/V$
$K = 4\ mA/V^2$
$U_{GS} = ?$

triodno: $I_D = K\left[(U_{GS} - U_{GS0})U_{DS} - \frac{U_{DS}^2}{2}\right]$

$g_m = \frac{\partial I_D}{\partial U_{GS}} = \ldots = K \cdot U_{DS} =$

$\Rightarrow U_{DS} = \frac{g_m}{K} = \frac{6 \cdot 10^{-3}}{4 \cdot 10^{-3}} = 1,5\ V$

1.4) $U_{GS} = 1\ V$
$U_{DS} = 1,5\ V$
$g_d = 6\ mS$
$K = 4\ mA/V^2$
$U_{GS0} = ?$

$r_d = \frac{1}{g_d} = 167\ \Omega$

za idealni $r_d = \infty$ u zasićenju, ali ovaj u triodnom je

$I_D = K\left((U_{GS} - U_{GS0})U_{DS} - \frac{U_{DS}^2}{2}\right)$

$g_d = \frac{\partial I_D}{\partial U_{DS}} = K\left[(U_{GS} - U_{GS0}) - U_{DS}\right]$

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$U_{GS0} = \ldots = U_{GS} - U_{DS} - \frac{g_d}{K} = 1 - 1{,}5 - \frac{6 \cdot 10^{-1}}{4 \cdot 10^{-1}} =$

$= -2V$

$|U_{GS} - U_{GS0}|$ $|U_{DS}|$ triodno područje

$3 > 1{,}5$

1.5) (= 1.4a)

$U_{GS0} = -2V$

$U_{GS} = 1V$

$U_{DS} = 5V$

$K = 4mA/V^2$

$|U_{GS} - U_{GS0}|$ $|U_{DS}|$ zasićenje

$|3| < |5|$

$g_m = \frac{\partial I_D}{\partial U_{GS}} = \ldots K(U_{GS} - U_{GS0})$

$= 4 \cdot 10^{-3}(1-(-2)) = \ldots$

$= 12\ mA/V$

(2) $U_{DD} = 12V$

$R_G = 500\ \Omega$

$R_1 = 7{,}8\ M\Omega$

$R_2 = 1{,}8\ M\Omega$

$R_D = 1{,}2\ k\Omega$

$R_T = 3{,}3\ k\Omega$

$K = 1{,}5\ mA/V^2$

$U_{GS0} = -1{,}7V$

$\lambda = 0{,}0075V^{-1}$

$R_S = ?$

1. čvor → source (uvod)

2. čvor → drain

zajednički → gate

(5)

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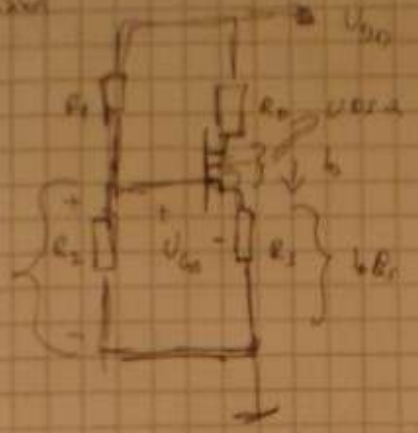
2.1) $R_S = 560\ \Omega$



$$U_{GG} = \frac{R_2}{R_1+R_2} U_{DD} = \frac{4{,}18}{4{,}18+18} \cdot 12 = 2{,}25\ V$$

$$U_{GS\,a} = U_{GG} - I_{D\,a} R_S \qquad (1)$$

$$I_{D\,a} = \frac{k}{2}\left(U_{GS\,a} - U_{GS\,th}\right)^2 \qquad (2)$$

$$U_{GS\,a} = U_{GG} - R_S\left[\frac{k}{2} U_{GS\,a}^2 - k\, U_{GS\,th}\, U_{GS\,a} + \frac{k}{2} U_{GS\,th}^2\right]$$

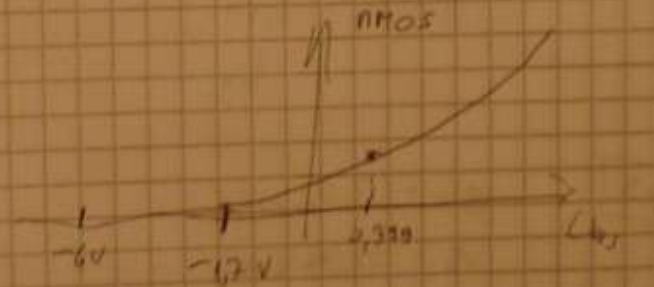
$$U_{GS\,a}^2 + \left[\frac{2}{kR_S} - 2U_{GS\,th}\right] U_{GS\,a} + U_{GS\,th}^2 - \frac{2}{kR_S} U_{GG} = 0$$

$$U_{GS\,a}^2 + 5{,}78\, U_{GS\,a} - 2{,}465 = 0$$

$$U_{GS\,a\,1,2} = \frac{-5{,}78 \pm \sqrt{5{,}78^2 + 4 \cdot 2{,}465}}{2}$$

$0{,}359\ V$

$-6{,}18\ V$



$$I_{D\,a} = \frac{k}{2}\left(U_{GS\,a} - U_{GS\,th}\right)^2 = \frac{1{,}5 \cdot 10^{-3}}{2}\left(0{,}359 - (-1{,}71)\right)^2 = 3{,}31\ mA$$

$$U_{DS\,a} = U_{DD} - I_{D\,a}\left(R_1 + R_2\right) = 12 - \frac{3{,}31}{mA}\left(0{,}56 + \frac{1}{k}\right) = 6{,}12\ V$$

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2.2

$I_{DQ} = 3{,}69\ mA$

$U_{DSQ} = 5{,}84\ V$

$U_{GSQ} = 2{,}52\ V$

$R_S = 470\ \Omega$

$g_m,\ r_d = ?$

$I_D = \frac{k}{2}(U_{GS} - U_{GSo})^2(1 + \lambda U_{DS})$

↑ u dinamici ...

$g_m = \frac{\partial I_D}{\partial U_{GS}}\Big|_Q = k(U_{GS_Q} - U_{GSo})(1 + \lambda U_{DS_Q}) =$

$= 1{,}5 \cdot 10^{-3}(2{,}52 - (-1{,}77)) \cdot (1 + 0{,}0035 \cdot 5{,}84)$

$= 3{,}398\ mA/V$

$r_d = \frac{1}{g_d} = \frac{1}{\frac{\partial I_D}{\partial U_{DS}}\Big|_Q} = \frac{1}{\underbrace{\frac{k}{2}(U_{GS_Q} - U_{GSo})^2}_{I_{DQ}}\lambda} = \frac{1}{\lambda I_{DQ}}$

$= \frac{1}{0{,}0035 \cdot 3{,}69} = 77{,}43\ k\Omega$

1/mA

2.3

$g_m = 3{,}02\ mA/V$

$r_d = 98{,}14\ k\Omega$

$R_S = 680\ \Omega$

$A_V = \frac{u_{iz}}{u_{ul}}$

7

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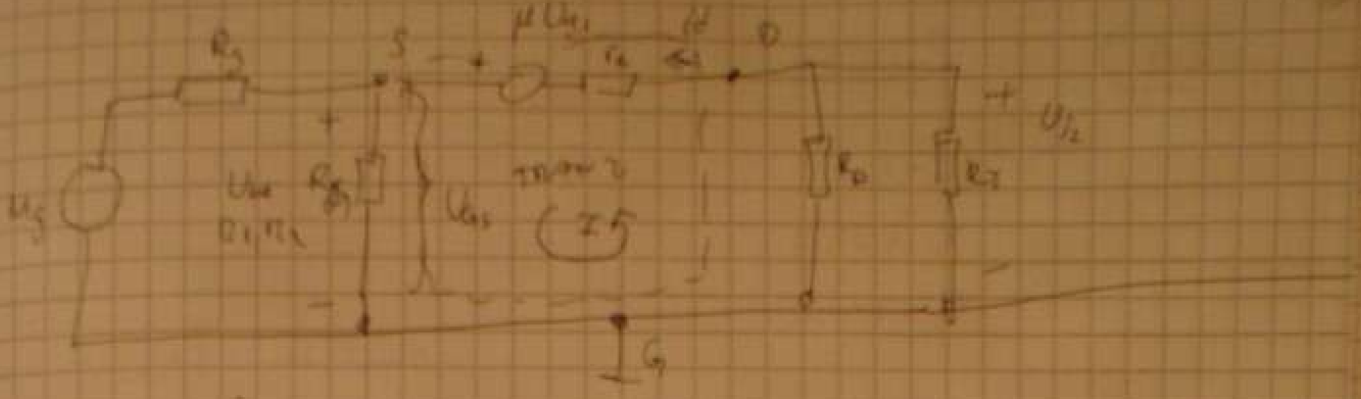

S, D → u čvorovi nije spojen na masu, onda tranzistor nadomještamo po TEVENINU!!!

$$A_V = \frac{u_{iz}}{u_{ul}}$$

I $\quad i_d \left[R_D \| R_T + r_d \right] - \mu U_{gs} - U_{gs} = 0$

$$U_{gs} = -u_{ul}$$

$$U_{iz} = -i_d (R_D \| R_T) \Rightarrow i_d = -\frac{U_{iz}}{R_D \| R_T}$$

$$i_d \left[(R_D \| R_T) + r_d \right] = -(1+\mu) U_{ul}$$

$$\frac{-U_{iz}}{R_D \| R_T} \left[\quad \right] = -(1+\mu) u_{ul}$$

$$A_V = \frac{u_{iz}}{u_{ul}} = \frac{(1+\mu) R_D \| R_T}{R_D \| R_T + r_d} = 2{,}76$$

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2.)

R_{ul} :

$R_G = 100\,k\Omega$

$r_d = 95\,\Omega$

$R_S = 470\,\Omega$

$$R_{ul} = R_G \,||\, \frac{r_d + R_S \| R_L}{1-\mu}$$

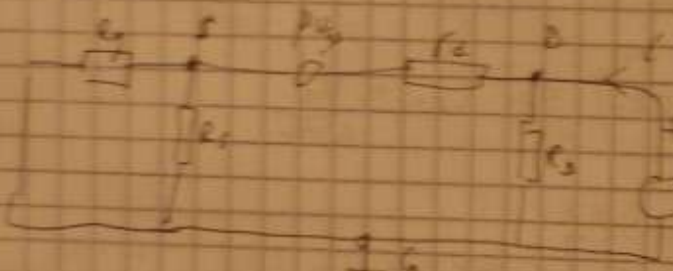
$$R_{ul} = \frac{u_{ul}}{i}$$

$$i_R = \frac{u_{ul}}{R_S} - i_d$$

$$i_d = \frac{-u_{ul}(1-\mu)}{r_d + (R_S \| R_L)}$$

$$= 227\,\Omega$$

3.)



$$R_{ul} = \frac{u}{i}$$

$$R_{ul} = R_G \,||\, \left[r_d + (1-\mu)(R_S \| R_L \| \ldots) \right] = 1{,}3\,k\Omega$$

$\approx R_D$

r_d ... DRAIN

...

preklopa

3

$N_{BE} = 1{,}5 \cdot 10^{16}\ cm^{-3}$

PNP

$N_{BB} = 6 \cdot 10^{16}\ cm^{-3}$

$n_{i0} = 1{,}4 \cdot 10^{10}\ cm^{-3}$

$S = 2{,}5\ mm^2$

$W_B = 1{,}5\ \mu m$

$\mu_n = 1350\ cm^2/Vs$

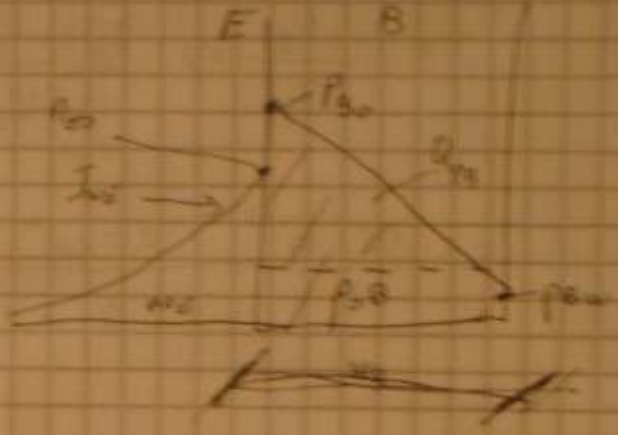
$\mu_p = 300\ cm^2/Vs$

$I_E = 2\ mA$

$U_T = 25\ mV$

$T = 300\ K$

$\gamma^* = 0{,}9926$



$$\rho_B = \frac{R_B^2}{\rho_B} = \frac{R_B^2}{N_{BB}} = \frac{(1{,}5 \cdot 10^{-4})^2}{6 \cdot 10^{16}} =$$

$$= 3{,}75 \cdot 10^{-5}\ cm^2$$

$$\rho_{B0} = 1{,}4 \cdot 10^{4}\ \frac{\Omega}{cm}$$

$$\rho_{B0} = \rho_{B0} \cdot \exp\left(\frac{-U_{BE}}{U_T}\right)$$

$$-U_{BE} = U_T \ln \frac{\rho_{B0}}{\rho_{B0}} = 25 \cdot 10^{-3} \ln \frac{1{,}4 \cdot 10^{4}}{\ldots} = -9{,}01\ V$$

$$U_{BE} = -9{,}01\ V$$

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3-2.7] $I_R = 2\mu A$ SVE u cm i cm² ?

mora biti 11:

$$I_R = \frac{Q_{pB}}{\tau_p} \Rightarrow \tau_p = \frac{Q_{pB}}{I_R} = \frac{q \cdot S \cdot \frac{p_{B0} \cdot W_B}{2}}{I_R} =$$

$$= \frac{1{,}6 \cdot 10^{-19} \cdot 2{,}5 \cdot 10^{-2} \cdot 1{,}4 \cdot 10^{14} \cdot 1{,}5 \cdot 10^{-4}}{2 \cdot 2 \cdot 10^{-6}} = 21\mu s$$

$2{,}1 \cdot 10^{-5} s$

3.3] $I_{nE} = ?$

$$\gamma = \frac{I_{pE}}{I_{pE} + I_{nE}} \qquad \gamma = \frac{1}{1 + \frac{I_{nE}}{I_{pE}}}$$

$$I_{pE} = q \cdot S \cdot D_p \cdot \frac{p_{B0}}{W_B} = q \cdot S \cdot \mu_p \cdot U_T \cdot \frac{p_{B0}}{W_B}$$

$$= \frac{1{,}6 \cdot 10^{-19} \cdot 2{,}5 \cdot 10^{-2} \cdot 300 \cdot 25 \cdot 10^{-3} \cdot 1{,}4 \cdot 10^{14}}{1{,}5 \cdot 10^{-4}} = \dots = 28\mu A$$

$$I_{nE} = I_{pE}\left(\frac{1}{\gamma} - 1\right) = \dots = 209\mu A$$

3.4] $\tau_{tr} = ?$

$$I_{pE} = q \cdot S \cdot D_{pB} \cdot \frac{p_{B0}}{W_B} = \left(q \cdot S \cdot \frac{p_{B0} \cdot W_B}{2}\right) \cdot \frac{D_{pB}}{W_B^2} \cdot 2$$

Q_{pB}

~~$\tau_{tr} = \frac{I_{pE}}{Q_{pB}}$~~

$$\frac{I_{fE}}{Q_{fB}} = \frac{2D_n}{W_B^2} \qquad \gamma_E = \frac{Q_{fB}}{t_{tr}}$$

$$t_{tr} = \frac{Q_{fB}}{I_{fE}} = \frac{W_B^2}{2D_n} = \underbrace{\frac{W_B^2}{\mu_n U_T}}_{\mu_n U_T} = \ldots = 1{,}5\ \text{ns}$$

3.5 $\alpha = \gamma \cdot \beta^*$

$\gamma = 99525$

$$\beta^* = \frac{I_{fC}}{I_{fE}} = \frac{I_{fE} - I_B}{I_{fE}} = 1 - \frac{I_B}{I_{fE}} \overset{3.2}{=} 1 - \frac{2 \cdot 10^{-6}}{2 \cdot 10^{-3}} =$$

$$\boxed{\text{tyr } \beta = \frac{\alpha}{1-\alpha}}$$

$= 0{,}99995$

$\alpha = 0{,}9995 \quad = 0{,}9995$

$\gamma \cdot \beta^* =$

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