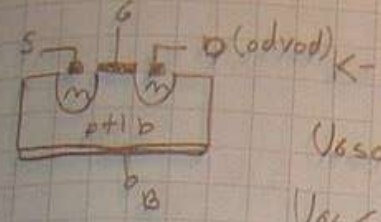
1. Mosfet

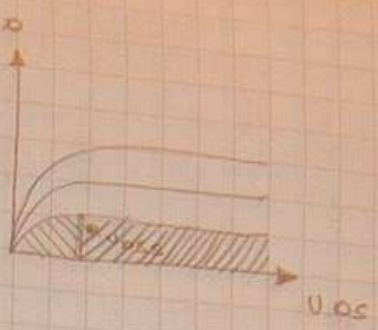


(vrata)

K - koeficijent [mA/V²]

U_{GSO} - napon praga [V]

$U_{DS} < U_{GSO}$ - nema struje



$U_{DSS} - U_{GS} - U_{GSO}$ $\quad U_{DS} > U_{GS} - U_{GSO}$ - zasićenje

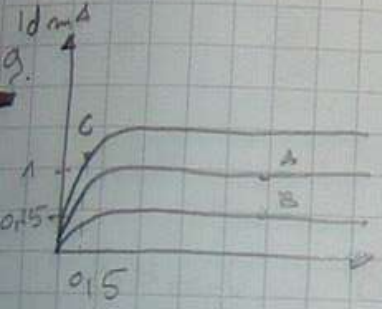
↑ dobra, tj. napon prijeloza

$$I_D = K \cdot \left[(U_{GS} - U_{GSO}) \cdot U_{DS} - \frac{U_{DS}^2}{2} \right]$$ - trioda

$$I_D = \frac{K}{2} \cdot (U_{GS} - U_{GSO})^2 \cdot (1 + \lambda U_{DS})$$ - zasićenje

$$g_m = \frac{\partial I_D}{\partial U_{GS}} \qquad g_d = \frac{\partial I_D}{\partial U_{DS}} \qquad r_d = \frac{1}{g_d}$$

$$\mu = g_m \cdot r_d$$



$\lambda = 0$ $\quad I_{DC} = ?$

$$\frac{I_{DA}}{I_{DB}} = \frac{(U_{GSA} - U_{GSO})^2}{(U_{GSB} - U_{GSO})^2} \Rightarrow \pm\sqrt{\frac{I_{DA}}{I_{DB}}} = \frac{U_{GSA} - U_{GSO}}{U_{GSB} - U_{GSO}} = \frac{1 + U_{GSA} - U_{GSB}}{U_{GSB} - U_{GSO}}$$

$$= U_{GSB} - U_{GSA} - U_{GSB}$$

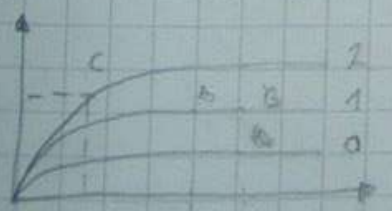
$$= \sqrt{\frac{I_{DA}}{I_{DB}}} - 1$$

$\boxed{U_{GSO} = 1\text{ V} < U_{GS}}$

~~$U_{GSO} = 1{,}66$ V~~

$mA V^2$ $\quad I_{DC} = 1{,}25$ mA

1.



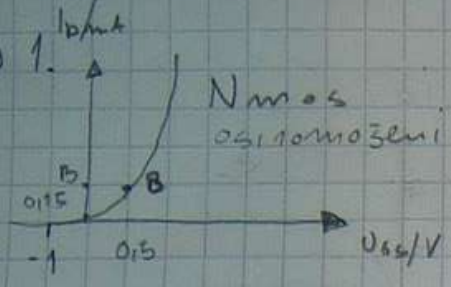
$U_{GSO} = -0{,}5$ V $\quad I_{DA} = 1$ mA $\quad I_{DB} = 1{,}01$ mA $\quad \lambda \neq 0$

$I_{DC} = ?$

$$= \frac{\frac{K}{2}(U_{GSA} - U_{GSO})^2 \cdot (1 + \lambda U_{DS_1})}{\frac{K}{2}(U_{GSB} - U_{GSO})^2 \cdot (1 + \lambda U_{DS_2})} \Rightarrow \lambda = 0{,}0102\ [V^{-1}]$$

$K = 0{,}8711\ [mA/V^2]$

VJ 1.



Nmos osiromašeni

$U_{GSO} = -1\,V$ ~~$U_{DS} =$~~

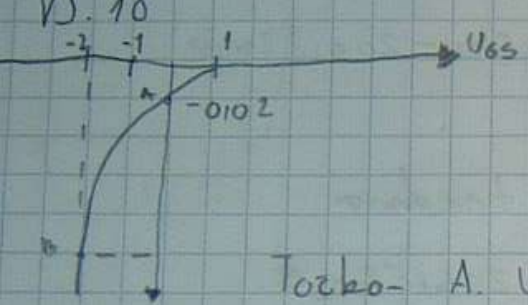
$\lambda = 0$ zbog toga jer nema U_{DS}.

$i_{DB} = ?$

$K = 0,3\ mA/V^2$

$I_{DB} = 0,3375\ mA$

VJ. 18



Pmos osiromašeni

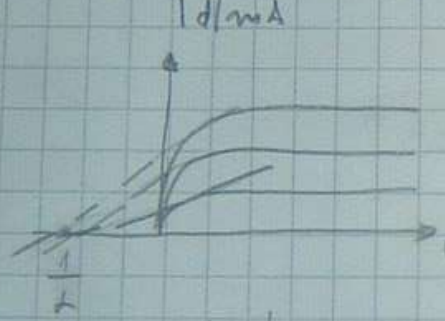
$U_{DS} = -4V$ $\lambda = 5 \cdot 10^{-3}$.

Točka A. $U_{DS} \geq U_{GS} - U_{GSO} = -1$ $\quad -4 < -1$ zasićenje

$I_{DA} = \frac{K}{2} \cdot (U_{GSA} - U_{GSO})^2 (1 + \lambda U_{DS})$ $\quad K = -0,39\ mA/V^2$

$^{-4}$

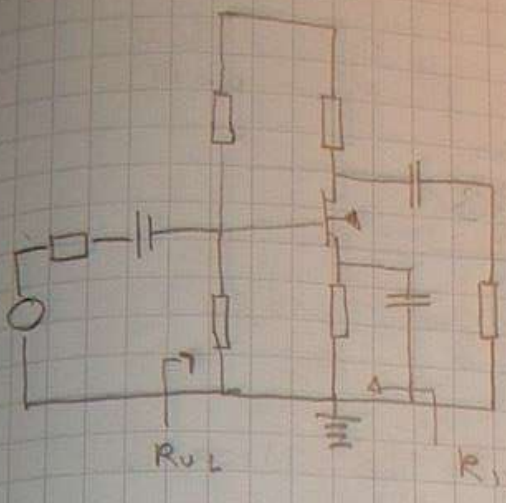
B točka $\quad -4 < -3$ $\quad$ B - zasićenje $\quad I_{DB} = -1,8\ mA$



	Struja I_D	Uvjet vođenja	K	$U_{GSO} > 0$	$U_{GSO} < 0$
N MOS	$I_D > 0$	$U_{GS} > U_{GSO}$	$K > 0$	obogaćen	osiromašen
P MOS	$I_D < 0$	$U_{GS} < U_{GSO}$	$K < 0$	osiromašen	obogaćen

	$U_{DS} \geq U_{DSS}$	$U_{DS} < U_{DSS}$	$r_d \to \infty$
N MOS	ZASIĆENJE	TRIODNO	100 kΩ zasićenje
P MOS	TRIODNO	ZASIĆENJE	$r_d \to 0$ 500 Ω triodno

• MOSFET SKLOPOVI

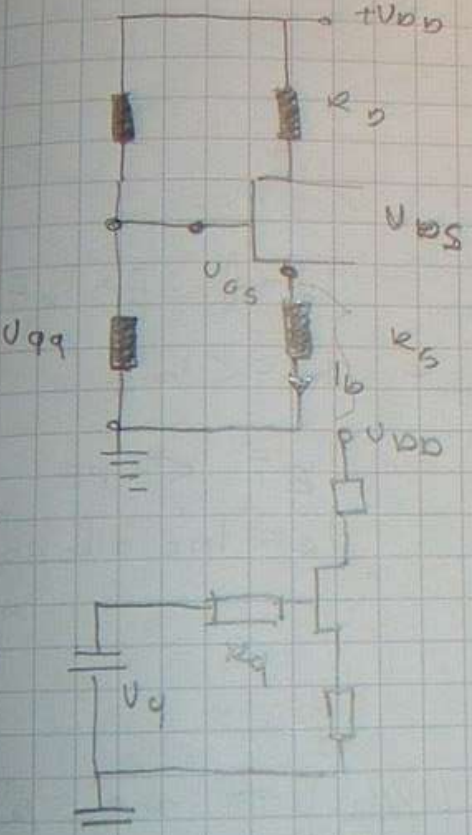


SRT - tipično

$$U_{gg1} = \frac{U_{bb}}{R_1 + R_2} \cdot R_2$$

$$R_g = R_1 \parallel R_2$$

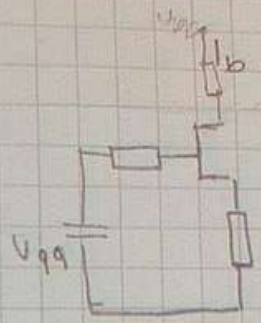
$$U_{DS} = U_{bb} - I_d \cdot (R_D + R_S)$$



$$U_{GG} = U_{GS} + I_D \cdot R_S$$

$I_G = 0$

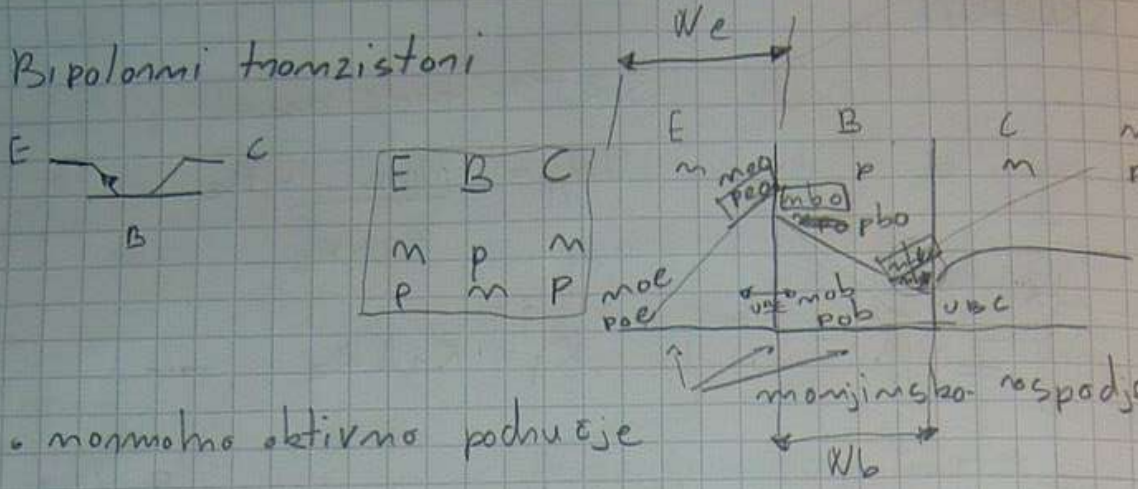
$$I_D = \frac{K}{2}(U_{GS} - U_{GS0})^2$$



$$U_{GG} = I_G \cdot R_G + U_{GS} + I_D \cdot R_S =$$

$$U_{bb} = I_b \cdot R_b + U_{bs} + I_b \cdot R_s$$

• Bipolarni tranzistori



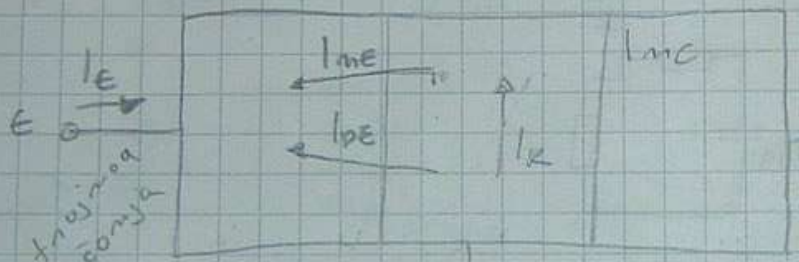
• neravnotežna aktivna područja

noe } raspodjele u dubini
poe }

neo } raspodjela na granicama
peo }

$n_{oe} = N_D \quad N_D \gg N_A$
$p_{ob} = N_A$

peo } manjinski nosioci
nbo }
nbW }



$I_E = -(I_{nE} + I_{pE})$

$I_{nC} < I_{nE}$

$I_B = I_K + I_{pE}$

$I_C \approx I_{NC} + I_{CBO}$ (≈0)

$\alpha = \frac{I_C}{-I_E} = \frac{I_{NC}}{I_{nE} + I_{pE}}$ (0.998 → 0.995)

$\alpha^* = 1 - \frac{1}{2}\left(\frac{W_b}{L_{nb}}\right)^2 \rightarrow I_{nC} = \alpha^* I_{nE}$

$\beta = \frac{I_C}{I_B} = \frac{\alpha}{1-\alpha}$

$I_B = I_{nE} - I_{nC} = (1-\alpha^*) I_{nE}$

$\gamma = \frac{I_{nE}}{-I_E} = \frac{I_{nE}}{(I_{nE} + I_{pE})}$

ZADATAK 1.

NPN - tranzistor $N_b = 2 \cdot 10^{18} \Rightarrow n_{oe} = 2 \cdot 10^{18}$

$N_A = 5 \cdot 10^{16} \Rightarrow p_{ob} = 5 \cdot 10^{16}$

$n_{bo} = n_{ob} \cdot \exp\left(\frac{U_{BE}}{U_T}\right) = 1{,}506 \cdot 10^{13}$ $\quad U_T = \frac{T}{11600} = 26\,mV$

$n_{ob} = \frac{n_i^2}{p_{ob}} = 4205$ $\quad p_{eo} = p_{oe} \cdot \exp\left(\frac{U_{BE}}{U_T}\right)$ $\quad T = 300\,K$

$p_{oe} = \frac{n_i^2}{n_{oe}} = 3{,}764$

$U_{BC} = -V_{CB}$

$n_{bW} = n_{ob} \cdot \exp\left(\frac{U_{BC}}{U_T}\right)$

$p_{co} = p_{oc} \cdot \exp\left(\frac{U_{BC}}{U_T}\right)$

STRUJE:

$1\,mm^2 = 10^{-2}\,cm^2$

$I_{pE} = Q \cdot S \cdot D_{pE} \cdot \frac{p_{nb}}{W_E}$ $\quad D_{pE} = \mu_{pE} \cdot U_T$

$I_{bE} = Q \cdot S \cdot D_{nE} \cdot \frac{n_{bo}}{W_b}$ $\quad N_{nE} = \mu_{nE} \cdot U_T$

$I_E = -(I_{nE} + I_{pE})$

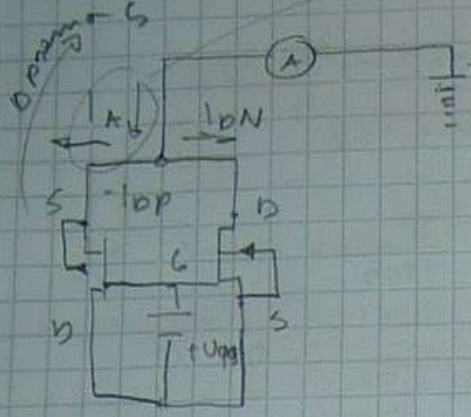
$I_{nC} = ?$ $\quad \beta^* = \frac{I_{nC}}{I_{nE}}$ $\quad \beta^* = 1 - \frac{1}{2}\left(\frac{W_b}{L_{nb}}\right)^2$ $\quad L_{nb} = \sqrt{D_{nb} \cdot \tau_b}$

$\beta = 0{,}9992$ $\quad I_{nC} = 6\,mA$ $\quad I_R = I_{nE} - I_{nC} = 4.8\,\mu A$

$D_{nb} = \mu_{nb} \cdot U_T$

$\mu_{nE} = \mu_n$

ZADATAK 19)



→ Obrnuto jer ide od D prema S, a mi nekli obrnuto.

$U_{DD} = 3V \quad U_{GG} = -1,5\,V$

$U_{GSDN} = -U_{GSDP} = 1V$

$K_n = -K_p = 0.5\,mA/V^2$

n-MOS $\quad U_g = 1.5V \quad U_S = 0 \quad U_D = 3V$

$U_{GS} = 1,5V \quad U_{DS} = 3V$

$3V > 1.5 - 0.5 = 1 = 0,5 \Rightarrow$ zasićenje

$I_{DN} = \frac{K_n}{2}(U_{GN} - U_{GS0})^2 = 625\,\mu A$

P MOS

$U_G = 1,5\,V \quad U_S = 3V \quad U_D = 0V$

$U_{GS} = -1.5V = -1.5V \quad U_{DS} = -3V$

$I_{DP} = -62.5\mu A \quad -3 < -0.5$ zasićenje