

ZBIRKA

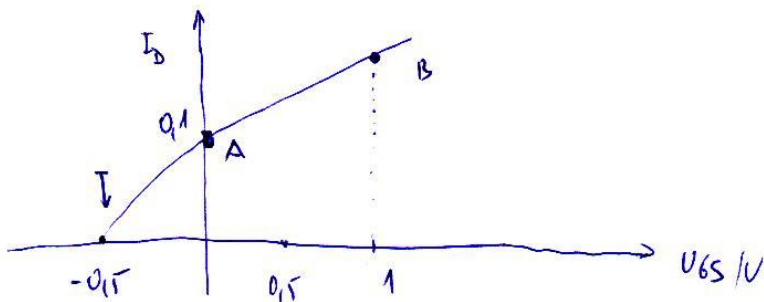
ZADACI SA PRIJEWSKOM I IZLAZOM KARAKTERISTI KOM
TEHNOLOŠKI PARAMETRI.

VJ. 17.

→ KARAKTERISTIM LA SLICI

$$\rightarrow \lambda = 5 \cdot 10^{-3} \text{ V}$$

$$V_{DS} = 1 \text{ V}$$



TO SE FORMIRA KANAL, KAPON PRAGA

$$\Rightarrow V_{GS0} = 0.5 \text{ V} \quad \text{UŽ} \quad V_{GS} = 0 \quad |I_D| > 0 \Rightarrow \text{OSI RUMAJEM TIPI}$$

→ V_{GS} - POSTAJE POZITIVNI, STRUJA I_D RASTE \Rightarrow N-MOSII

→ POGLEDATI USKRIPTI PRIJEWSKE KARAKTERISTINE !!:

TOČKA A

$$V_{GSA} = 0.5 \text{ V} \quad I_D = 0.1 \text{ mA} \quad V_{GS0} = 0.5 \text{ V}$$

KOJE PODRUČJE

$$|V_{GSA} - V_{GS0}| = |0.5 - 0.5| = 0 < |V_{DS}| = 1 \rightarrow \text{PODRUČJE ZASIĆENJA}$$

$$I_{DA} = \frac{k}{2} (V_{GSA} - V_{GS0})^2 (1 + \lambda V_{DS})$$

AKOJE λ ZADAN, U ZASIĆENJU

KORISTIMO MODEL MODULACIJE DULJINE
KANALA

→ RAČUNAMO k

$$K = \frac{2 I_{D0}}{(V_{GS0} - V_{GS0})^2 (1 + \lambda V_{DS})} = \dots = \underline{0,796 \text{ mA/V}^2}$$

TOČKA B

$$V_{GSB} = 1 \text{ V}$$

→ PROVERA TOČKE RADA B I SA APSOLUTNI VUJEH VRIJ

$$|V_{GSB} - V_{GS0}| = |1 - (-0,5)| = 1,5 \text{ V} > |V_{DS}| = 1 \text{ V}$$

⇒ TRIODNO PODRUČJE RADA

$$|V_{GS} - V_{GS0}| > |V_{DS}| \quad \text{TRIODNO} \quad ||$$

$$|V_{GS} - V_{GS0}| < |V_{DS}| \quad \text{ZASIĆENJE} \quad . .$$

$$I_{DB} = K \left[(V_{GSB} - V_{GS0}) V_{DS} - \frac{V_{DS}^2}{2} \right] = \dots = \underline{0,796 \text{ mA}}$$

$$g_m = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_Q = K \cdot V_{DS} = 0,796 \text{ mA/V}$$

$$r_{dB} = \left. \frac{1}{\frac{\partial I_D}{\partial V_{DS}}} \right|_Q = \frac{1}{K \cdot [(V_{GSB} - V_{GS0}) - V_{DS}]} = \frac{1}{0,796 \cdot 10^{-3} [1 - (-0,5) - 1]} = \underline{2,51 \text{ k}\Omega}$$

$$\mu_B = g_{mB} \cdot r_{dB} = 2 \quad (\text{TRIODNO PODRUČJE, POJAČANJE JE MALO})$$

UJ-18

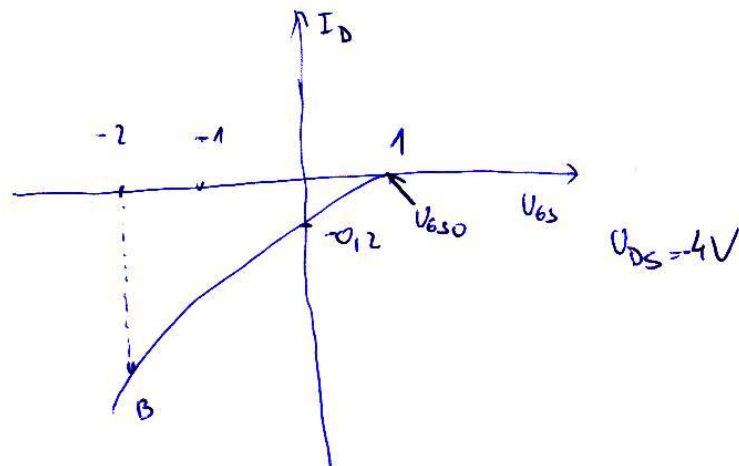
28.11. ELE 3

$$\lambda = -5 \cdot 10^{-3} \text{ V}^{-1}$$

- NIJE IDEALNI

- λ ZA PMOS < 0

$$V_{GS0} = 1 \text{ V}$$



→ TIP MOSFETA uz $V_{GS} = 0 \rightarrow |I_D| > 0 \Rightarrow$ OSIROMAŠENI

→ KAKO V_{GS} POSTAJE NEGATIVNI $|I_D|$ RASTE \Rightarrow PMOS

B) TOČKA A

$$V_{GSA} = 0 \text{ V}$$

$$I_{DA} = -0.2 \text{ mA}$$

PODPUEJE:

$$|V_{GSA} - V_{GS0}| = |0 - 1| = 1 < |V_{DS}| = 4 \Rightarrow \text{ZASICE NJI}$$

$$I_{DA} = -\frac{K}{2} (V_{GSA} - V_{GS0})^2 \cdot (1 + \lambda V_{DS}) = \dots \Rightarrow \text{RAČUNAMO } K$$

$$K = -\frac{2 I_{DA}}{(V_{GSA} - V_{GS0})^2 \cdot (1 + \lambda V_{DS})} = \dots = \underline{\underline{0.342 \text{ mA/V}^2}}$$

28.11. ECE 4

Uj 18

TOČKA B

$$U_{GSB} = -2V$$

$$\Rightarrow \text{PODRUČJE RADN} \quad |U_{GSB} - U_{GS0}| = |-2 - 1| = 3 < |U_{DS}| = 4 \Rightarrow \text{ZASIĆENJE}$$

$$I_{DB} = -\frac{K}{2} (U_{GSB} - U_{GS0})^2 (1 + \lambda U_{DS}) = \dots = -1,8 \text{ mA}$$

$$g_{mB} = \left. \frac{\partial I_D}{\partial U_{GS}} \right|_B = -K (U_{GSB} - U_{GS0}) (1 + \lambda U_{DS}) = \dots = 1,2 \text{ mA/V}$$

$$r_{dB} = \left. \frac{1}{\frac{\partial I_D}{\partial U_{DS}}} \right|_B = \frac{1}{-\frac{K}{2} (U_{GSB} - U_{GS0})^2 \cdot \lambda \cdot \frac{1 + \lambda U_{DS}}{1 + \lambda U_{DS}}} = \left. \frac{1}{I_{DB} \cdot \lambda} \right|_B$$

\downarrow r_{dB}

$$= \frac{1 + \lambda U_{DS}}{I_{DB} \cdot \lambda} = \dots = 113,3 \text{ k}\Omega$$

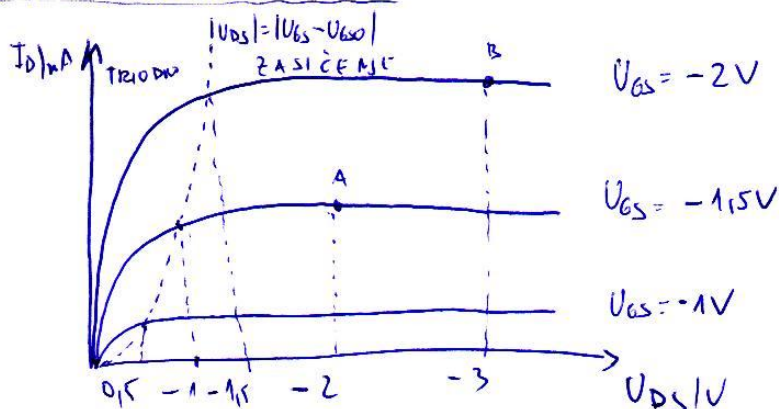
MOŠFET UTAŽIŠEN
1 VJ OČEKIVANO DES 100 kΩ

$$M_B = \beta g_{mB} r_{dB} = \dots = \underline{\underline{136}}$$

28.11. Ele. 5

UJ-25

IZAZNA KARAKTERISTIKA



$$\lambda = -0,005 \text{ V}^{-1}$$

- RADI UZ NEGATIVNI V_{DS} P-TIP
- KAKO RASTE $|V_{GS}|$ POSTAJE NEGATIVNIJ $|I_D|$ RASTE
- NAPON PRAGA $V_{GS0} = -0,5 \text{ V}$

$$V_{GS} = 0 \text{ ; } I_D = 0 \Rightarrow \text{OBOGAĆENJE}$$

$$\rightarrow \text{GRANICA SE } |V_{DS}| = |V_{GS} - V_{GS0}|$$

(A) \rightarrow OBJE TOČKE A I B SU U ZASIĆENJU

$$V_{GSA} = -1,5 \text{ V}$$

$$V_{GS0} = -0,5 \text{ V} \quad |V_{GSA} - V_{GS0}| = 1 \text{ V} < |V_{DS}| = 2 \text{ V} \Rightarrow \text{ZASIĆENJE}$$

$$V_{DSA} = -2 \text{ V}$$

$$I_{DA} = -\frac{K}{2} (V_{GSA} - V_{GS0})^2 (1 + \lambda V_{DS})$$

\downarrow
RADI SE O PMOS

$$\text{STRMINA U A } g_{mA} = 0,5 \frac{\text{mA}}{\text{V}} = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_A = -K \cdot (V_{GSA} - V_{GS0}) (1 + \lambda V_{DS})$$

\hookrightarrow RAČUN

$$K = \frac{-g_m}{(V_{GSA} - V_{GS0}) (1 + \lambda V_{DS})} = \frac{-0,5 \cdot 10^{-4}}{(-1,5 + 0,5) (1 + (-5 \cdot 10^{-3}) \cdot (-2))} = \dots = 0,495 \frac{\text{mA}}{\text{V}^2}$$

ELE. 28.11. 6

VJ-27.

TOČKA B

$$U_{GSB} = -2V$$

$$U_{GSO} = -0,5V$$

$$K = 0,495 \frac{mA}{V}$$

$$|U_{GSB} - U_{GSO}| = 1,5 < |U_{DS}| = 3 \Rightarrow \text{ZASICE NJE}$$

$$I_{D0} = -\frac{K}{2} (U_{GSB} - U_{GSO})^2 (1 + \lambda U_{DS}) = \dots = -0,565 \text{ mA}$$

$$g_{mB} = \left. \frac{\partial I_D}{\partial U_{GS}} \right|_B = -K (U_{GSB} - U_{GSO}) (1 + \lambda U_{DS}) = \dots = 0,754 \text{ mA/V}$$

$$r_{dB} = \left. \frac{1}{\partial I_D / \partial U_{DS}} \right|_B = \frac{1}{-\frac{K}{2} (U_{GSB} - U_{GSO})^2 \cdot \lambda} = \dots = 3593 \text{ k}\Omega$$

$$\mu_B = g_{mB} \cdot r_{dB} = \dots = \underline{\underline{271}} \quad (\text{ZASICE NJE i } \mu \text{ očekivana oko } 100 > 100)$$

MOSFET - SKLOPOVI MOSFET SKLOPOVI

28.11. 7

V3.

 R_1, R_2, R_S

- SA R_S - TEMPERATURNO STABILIZIRANO RADNO TOČKU
 - RADNA TOČKA STABILIZIRANA

 R_D → "PUTROJAC" PREMA NAPAJANJU R_T → PRAVI PUTROJAC

- C_6 } - BLOKIRAJ ISTO SMJERU KOMPONENTU
 C_D } - RADNA TOČKA ODREĐENA SA R_1, R_2, R_D, R_S
 - ULAZ IZLAZ NE ODREĐUJU RADNU TOČKU

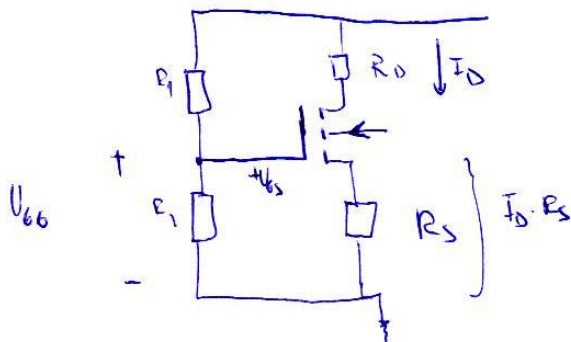
- IMPEDANCIJA JAVLJA PRI DEFINIRANOJ FREKVENCIJI
 (NAMA PREDSTAVLJA KRATKI SPOJ)

- SPOJ ZAJEDNIČKO ULODA

STATIKA

- U STATICI "IDEALNO" PA NE UZIMAMO U ČIRANJE ...

- ODPRAJANO GRANE SA KONDEZATORIMA

SA V_{GS} ODREĐIMO STROJ I_D

$$V_{GS} = \frac{R_2}{R_1 + R_2} \cdot V_{GG} = 3,75 \text{ V}$$

$$(1) \quad V_{GSQ} = V_{GS} - I_{DQ} \cdot R_S$$

$$(2) \quad I_{DQ} = \frac{K}{2} (V_{GSQ} - V_{GS0})^2$$

$$(2 \rightarrow 1) \quad V_{GSQ} = V_{GS} - \frac{K R_S}{2} (V_{GSQ}^2 - 2 V_{GSQ} V_{GS0} + V_{GS0}^2)$$

$$V_{GSQ}^2 - \left[\frac{2}{K R_S} - 2 V_{GS0} \right] V_{GSQ} + V_{GS0}^2 - \frac{2}{K \cdot R_S} V_{GS} = 0$$

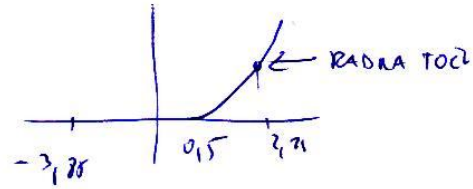
MOSFET - SKLOPOVI - VJ3.

28.11. ELE 8

$$U_{GSQ}^2 + 1.564 U_{GSQ} - 7.8 = 0$$

$$U_{GSQ} = \left\{ -3.85V ; \underline{\underline{2.29V}} \right\}$$

, DOBAR FIZIKALNO PRIHVATLJIV



$$I_{DQ} = \frac{U_{GG} - U_{GSQ}}{R_S} = 4.13 \text{ mA}$$

$$U_{DSQ} = U_{DD} - I_{DQ} (R_D + R_S) = \dots = \underline{\underline{5.23V}}$$

$$g_m = \frac{\partial I_D}{\partial U_{GS}} = K (U_{GSQ} - U_{GS0}) (1 + \lambda U_{DSQ}) = \dots = 3.65 \frac{\text{mA}}{\text{V}}$$

$$r_d = \left. \frac{1}{\frac{\partial I_D}{\partial U_{DS}}} \right|_Q = \frac{1}{\lambda I_{DQ}} = \underline{\underline{63.72 \text{ k}\Omega}}$$

SAMO ZA DYNAMIČKE PARAMETRE !!!

$$M = g_m \cdot r_d = \underline{\underline{233}}$$

MOSFET SKLOPOVI VJ.3

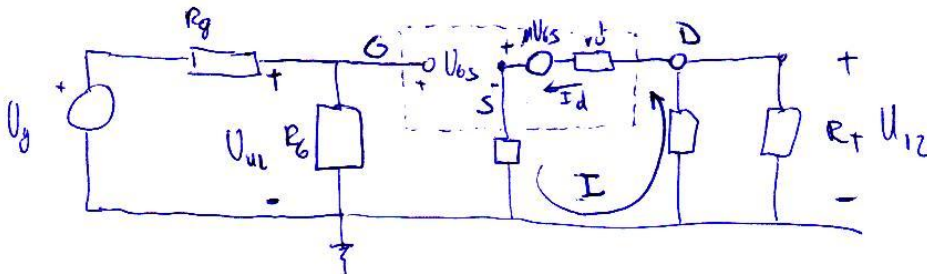
28.11. ELE

(9)

DINAMIČKA NAPONJESU

- SOURCE, DRAIN PREKO OTPORNIKA SPOLJEI MU, VISU DIREKTAU

→ IZVORISU R PO THEVENINU (SA NAPONSKIM IZVOROM)



$$R_G = R_1 \parallel R_2$$

- METODOM SUPERPOZICIJE

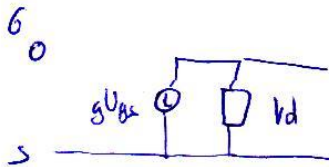
→ DINAMIČKI MALI SIGNALI PA C PREDSTAVLJA KRATKI SPOJ

- KRATKO SPOJITI ~~IZVORISU~~ ~~IZVORISU~~ - ISTOSMJERNI IZVOR

→ UDD SE SPAJA NA MASU

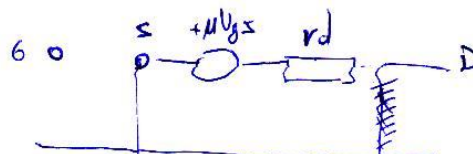
→ MALO SE "PRESLOŽI" RADI PREGLEDNOSTI

I R1 "SPOJIMO" PARALELNO S R2 JER SU OBA SPOJENA NA MASU



STROJNI

(ili)



NAPONSKI

MOSFET - SKLOPOVI VJ.3

28.11. E1F

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$$① \quad U_{12} = -i_d (R_D \parallel R_T)$$

$$② \quad i_d [(R_D \parallel R_T) + r_d + R_S] - \mu U_{gs} = 0 \quad \text{ZA KRUG I}$$

$$③ \quad U_{gs} = U_{in} - i_d \cdot R_S$$

$$U_{12}, U_{in}, \textcircled{i_d, U_{gs}} = ?$$

ELIMINIRATI

- SVE PREMA U_{12} I U_{in} .

$$A_v = \frac{U_{12}}{U_{in}} = \frac{-\mu (R_D \parallel R_T)}{\underbrace{(1 + \mu) R_S}_{\text{ULOVSKA DEGENERACIJA}} + r_d + (R_D \parallel R_T)} = \dots = \underline{\underline{-2,21}}$$

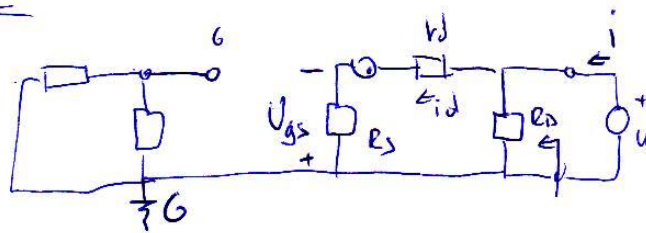
→ RUSI POJAČAN.

$A_v < 0 \rightarrow$ SPOJ ZAJEDNIŠKO SOURCE / U_{gs}

U_{in} I U_{12} SU U PROTU FAZI, OKREĆ FAZU SIGNALA.

$$\Rightarrow R_{in} = R_6 = \frac{U_{in}}{U_{in}} = \dots = \underline{\underline{1,61 \text{ M}\Omega}}$$

$\Rightarrow R_{12} =$ IKRATKO SPOJITI POROD



MOSFET SKLOPOVI VJ-3.

22M.ELE (11)

RJEŠ. PREKO „PRESUKAVAN“

U IZVORU-KRUGU D OTPORI IZ KRUGA S VIDE SE $(1+M)$ PUTA VEĆE
 R_d JE OTPOR IZ KRUGA D

$$R_{12} = R_D \parallel [R_d + (1+M)R_S] = \dots = \underline{\underline{2,65 \text{ k}\Omega}}$$

iii) PREKO PETICE I IZVOR D

$$(1) \quad i = \frac{U}{R_d} + i_d$$

$$(2) \quad i_d \cdot R_d - (1+M)U_{GS} = U$$

$$(3) \quad -U_{GS} = i_d \cdot R_S$$

SPOJENI

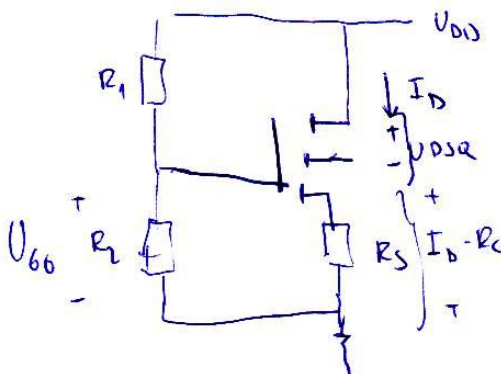
- * — ULAZ NA GATE
 — IZLAZ NA DRAIN ODVOD
 — ZAJEDNIČKA SOURCE UVOD

- * — ULAZ NA SOURCE/UVOD
 — IZLAZ NA DRAIN/ODVOD
 — ZAJEDNIČKA UPRAVLJAJE GATE

- * — ULAZ UPRAVLJAJE GATE
 — IZLAZ NA SOURCE/UVOD
 — ZAJEDNIČKA NA DRAIN/ODVOD

VJ 5. MOSFET SA SKLOPOVIMA

- V_{G2} JE NA GATE
- I_{DQ} SE NA SOURCE
- ZAJEDNICI DRAIN

STATIKA

- ODSPOJIMO OVAJ SA C

 R_1, R_2, R_3 ODREĐUJU RADNU TOČKU

$$V_{GG} = \frac{R_2}{R_1 + R_2} V_{DD} = \underline{10V}$$

$$V_{GSQ} = V_{GG} - I_{DQ} R_S$$

$$I_{DQ} = \frac{K}{2} (V_{GSQ} - V_{GS0})^2$$

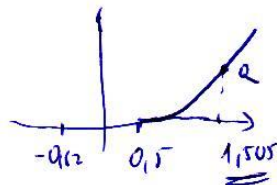
VIDI PRETHODI ZADATAK

$$V_{GSQ}^2 - 0,88 V_{GSQ} - 0,04 = 0$$

$$V_{GSQ1,2} = \left\{ -0,88 \pm \sqrt{0,88^2 + 0,16} \right\}$$

$$V_{GS0} = 0,5V$$

N KAKVO MOSFET



$$I_{DQ} = \frac{V_{GG} - V_{GSQ}}{R_S} = \dots = \underline{1,517 mA}$$

$$V_{DSQ} = V_{DD} - I_{DQ} R_D = \underline{11,505V}$$

MOSFET SASKLOPOVIMA UJ.5

28.11. ELE

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DINAMICKI PARAMETRI

$$g_m = \frac{\partial I}{\partial U_{gs}} = k (U_{gsQ} - U_{gs0}) (1 + \lambda U_{dsQ}) = 3.171 \text{ mA/V}$$

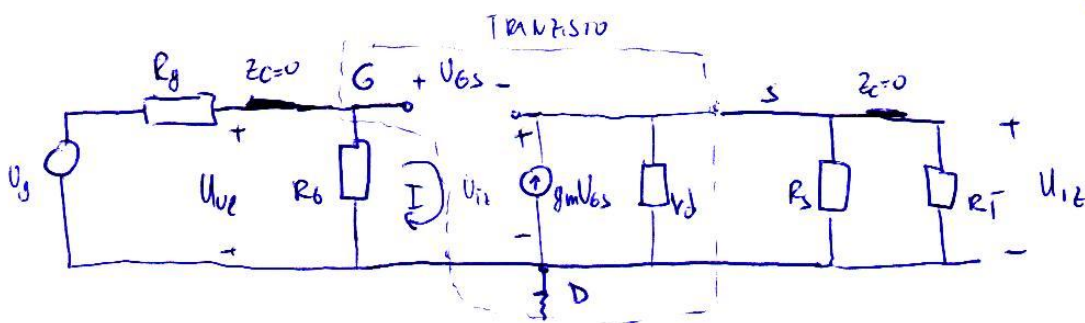
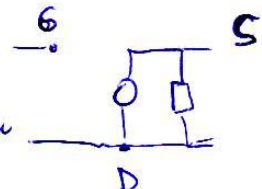
U DINAMICKI
FA PARAMETRI

$$V_d = \frac{1}{\frac{\partial I_D}{\partial U_{ds}}} = \frac{1}{\lambda I_{DQ}} = \underline{146.5 \text{ k}\Omega}$$

$$M = g_m \cdot V_d = \dots = 465$$

DINAMIKA

- U_{DD} SPAJAMO NA MASU
- KRATKO SPOJIMO SVE C
- ① JE U DINAMICI DIREKTNO SPOJEN NA MASU
→ KORISTIĆEMO KADUJESMI PO KORTON



$$R_0 = R_1 \parallel R_2$$

$$U_{iz} = g_m U_{gs} [R_d \parallel R_s \parallel R_L]$$

$$(I) \quad U_{ul} = U_{gs} + U_{iz}$$

MOSFET SA SKLOPOVIMA VJ.5.

28.11. EKF 14

$$A_v = \frac{u_{i2}}{u_{i1}} = \frac{g_m V_{gs} [r_d \parallel R_s \parallel R_T]}{V_{gs} + g_m V_{gs} [r_d \parallel R_s \parallel R_T]} = \frac{g_m [r_d \parallel R_s \parallel R_T]}{1 + g_m [r_d \parallel R_s \parallel R_T]}$$

(očekivano < 1)

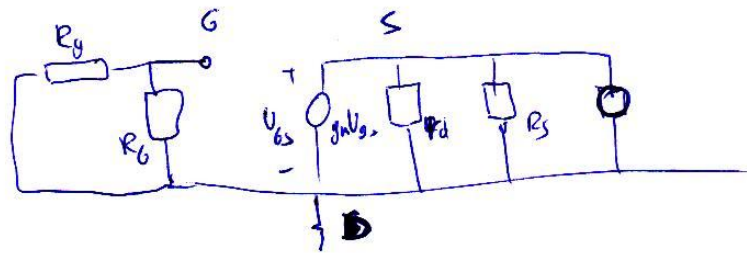
$$= \dots = 0,88$$

- $A_v < 1$; $A_v > 0$ - u_{i1} i u_{i2} su u fazi

- ne invertira signal

→ VODSKO SLJEDEĆE

$$R_{u1} = \frac{u_{i1}}{i_{u1}} = R_0 = R_1 \parallel R_2 = \underline{\underline{1,35 \text{ M}\Omega}}$$

 R_{i2} - krak spoja U_6 

PREKO PRESLIKALA, - IZLAZ NAM JE NA (S)

- otpori iz D se u S preslikaju (1-M) puta manje

- r_d je iz kruga D

$$R_{i2} = R_s \parallel \frac{r_d}{1-M} = \underline{\underline{298 \Omega}}$$

MOJFET SA SKLOPOVIMA UJ.5

28.11. EEF 15

~~i~~

$$g_m V_{gs} + i = \frac{V}{r_d \parallel R_s}$$

$$V_{gs} = -u$$

$$-g_m u + i = \frac{V}{r_d \parallel R_s}$$

$$u \left[\frac{1}{r_d \parallel R_s} + g_m \right] = i \quad \frac{u}{i} = \frac{r_d \parallel R_s}{1 + g_m r_d \parallel R_s} = R_{iz}$$

$$= \dots \quad \frac{u}{i} = \frac{r_d \parallel R_s}{1 + g_m r_d \parallel R_s} = \underline{\underline{R_{iz}}} \quad \dots$$

BIPOLARNI TRANZISTORIBIPOLARNI TRANZISTOR

V2.

- emiter 2mm, prema vremenu života u emiter → uski emiter

$$N_{DE} = 1,5 \cdot 10^{18} \text{ cm}^{-3}$$

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

$$N_{AB} = 2,5 \cdot 10^{16} \text{ cm}^{-3}$$

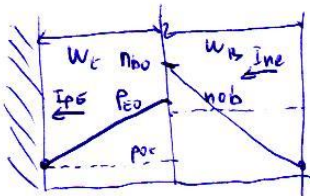
$$\mu = 280 \text{ cm}^2/\text{Vs}$$

$$W_B = 1 \mu\text{m} = 10^{-4} \text{ cm}$$

$$W_E = 2 \text{ mm} = 2 \cdot 10^{-4} \text{ cm}$$

$$n_{0E} \rightarrow N_{DE} = 1,5 \cdot 10^{18} \text{ cm}^{-3} \quad p_{0E} = \frac{n_i^2}{N_{DE}} = \frac{(1,45 \cdot 10^{10})^2}{1,5 \cdot 10^{18}} = 1,4 \cdot 10^2 \text{ cm}^{-3}$$

$$p_{0B} = N_{AB} = 2,5 \cdot 10^{16} \text{ cm}^{-3} \rightarrow n_{0B} = \frac{n_i^2}{N_{AB}} = \dots = 8,41 \cdot 10^3 \text{ cm}^{-3}$$



$$\begin{array}{l} \text{ZADANO} \\ U_{BE} = 0,525 \text{ V} \rightarrow \text{PROPUŠNO} \\ U_{CB} = 5 \text{ V} \rightarrow \text{ZAPORNO} \end{array} \quad \left. \vphantom{\begin{array}{l} U_{BE} = 0,525 \text{ V} \\ U_{CB} = 5 \text{ V} \end{array}} \right\} \text{NAP}$$

BOLTZMAN

$$n_{B0} = n_{0B} \cdot \exp\left(\frac{U_{BE}}{U_T}\right) = \dots = 1,11 \cdot 10^{13} \text{ cm}^{-3}$$

$$p_{E0} = p_{0E} \cdot \exp\left(\frac{U_{BE}}{U_T}\right) = \dots = 1,85 \cdot 10^{11} \text{ cm}^{-3}$$

$$I_{nE} = q \cdot S \cdot D_{nB} \cdot \frac{n_{B0}}{W_B} = q \cdot S \cdot \mu_{nB} \cdot U_T \cdot \frac{n_{B0}}{W_B} =$$

$$= 1,6 \cdot 10^{-19} \cdot 10^{-2} \cdot 520 \cdot \frac{1,11 \cdot 10^{13}}{10^{-4}} \cdot 25 \cdot 10^{-3} = \dots = \underline{\underline{2,3088 \text{ mA}}}$$

BIPOLARNI TRANZISTORI VJ.2.

28.11. ELE 17

$$I_{PE} = q \cdot S \cdot D_{PE} \cdot \frac{P_{oc}}{w_c} = q \cdot S \cdot \mu_n \cdot V_T \cdot \frac{P_{oc}}{w_c} = 10,36 \mu A$$

$$\gamma = \frac{I_{ne}}{I_{ne} + I_{PE}} = \frac{1}{1 + \frac{I_{PE}}{I_{ne}}} = 0,9955$$

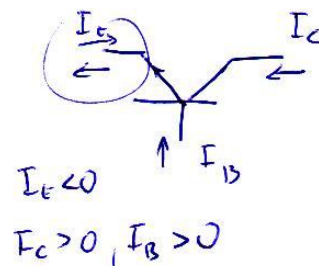
(na 4 decimale više decimala)

$$\beta^* = 1 - \frac{1}{2} \left(\frac{W_B}{L_{nB}} \right)^2 = 1 - \frac{1}{2} \cdot \frac{W_B^2}{L_{nB}^2} = 1 - \frac{1}{2} \cdot \frac{W_B^2}{\mu_{nB} V_T \cdot \tau_{nB}} = \dots = 0,99915$$

$$\beta^* = \frac{I_{nc}}{I_{ne}} \quad I_{nc} = \beta^* \cdot I_{ne} = 2,3068 \mu A$$

$$I_E = I_{ne} - I_{nc} = \dots = 2 \mu A$$

$$I_E = -(I_{ne} + I_{pe}) = -2,319 \mu A$$



$$I_B = I_E + I_{pe} = 12,36 \mu A$$

$$\alpha = \gamma \cdot \beta^* = 0,9947$$

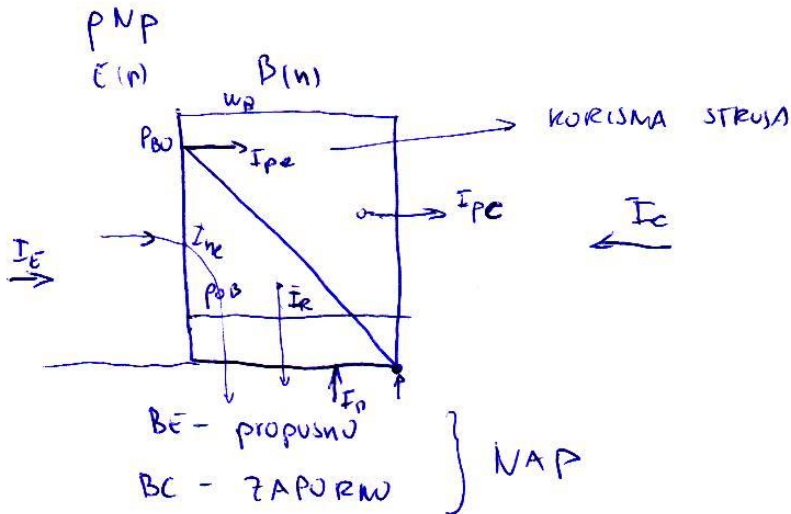
$$\beta = \frac{\alpha}{1 - \alpha} = \dots = 188$$

$$\alpha = \frac{I_C}{-I_E} \quad \rightarrow \text{ta vjeru}$$

$$\beta = \frac{I_C}{I_B} = \dots \quad \rightarrow \text{ta vjeru}$$

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$$I_{CE} = g S D_{PB} = \frac{P_{B0}}{w_B} = g \cdot S \cdot \mu_p V_T \frac{P_{B0}}{w_B} = \underline{\underline{4,9 \text{ mA}}}$$

$$S = 2,5 \text{ mm} = 2,5 \cdot 10^{-2} \text{ cm}^2$$

$$w_B = 1 \text{ mm} = 10^{-4} \text{ cm}$$

$$\gamma = 99,1 = 0,99$$

$$\gamma = \frac{I_{CE}}{I_{CE} + I_{BE}} \Rightarrow I_{BE} = I_{CE} \left(\frac{1}{\gamma} - 1 \right) = \dots = \underline{\underline{49,5 \text{ }\mu\text{A}}}$$

$$\tau_{PB} = 0,5 \text{ ns} \quad (\text{ZADANO} \dots \tau_n \text{ kn.})$$

$$I_R = \frac{Q_{PB}}{\tau_{PB}} \quad \left| \quad Q_{PB} = g \cdot S \cdot \frac{P_{B0} \cdot w_B}{2} \Rightarrow g \cdot S \cdot \frac{P_{B0} \cdot w_B}{2 \tau_{PB}} = \frac{16 \cdot 10^{-13} \cdot 2,5 \cdot 10^{-2} \cdot 1,1 \cdot 10^{-4}}{2 \cdot 0,5 \cdot 10^{-6} \text{ s}} \right.$$

$$I_R = \dots = \underline{\underline{7 \text{ }\mu\text{A}}}$$

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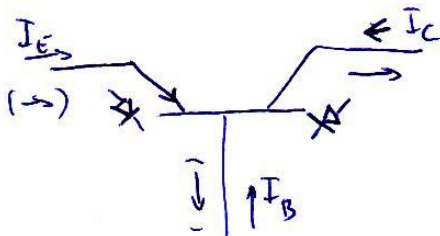
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$$I_{pc} = I_E - I_R = \dots = \underline{\underline{4,893 \text{ mA}}}$$

$$I_E = I_{ne} + I_{pe} = \dots = 4,9495 \text{ mA} \quad I_E > 0$$

$$I_C = -I_{pc} = \dots = \underline{\underline{-4,893 \text{ mA}}} \quad I_C < 0$$

$$I_B = -I_R - I_{ne} = \dots = \underline{\underline{-56,5 \text{ }\mu\text{A}}} \quad I_B < 0$$



- Uvek se pretpostavlja da struje ulaze u tranzistor
- Ali ~~to~~ je u stvarnosti drugačije

$$I_E + I_B + I_C = 0$$