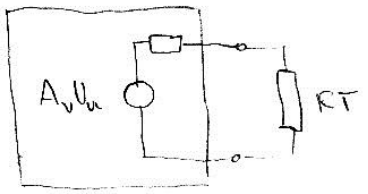
TEORIJA (21.11.2012)

1.



$A_V = 100$

$A_V = \frac{U_{iz}}{U_{ul}} = \frac{A_v = \frac{U_{ul}}{U_{ul}} \cdot \frac{R_T}{R_T + R_{iz}}}{U_{ul}}$

$$A_v = A_V \cdot \frac{R_T + R_{iz}}{R_T} = A_V\left(1 + \frac{R_{iz}}{R_T}\right) = 200$$

IDEALNO POJAČALO → $R_{iz} = 0$ d) $A_v = 200$, $R_{iz} = 0$

2. Si

VODLJIVI POJAS

- - - - - - - - - - SREDINA ZABRANJENOG PODRUČJA NA POLA KOD Si E_{Fi}

E_F - - - - $\mp 0{,}2\,E_V$ - - -

VALENTNI POJAS E_V

P-TIP, DOPIRAMO SA AKCEPTORIMA JER JE E_F ISPOD SREDINE Z.P.

NAKON TOGA Si DODATNO DOPIRAN E_F OSTAJE ISTI

⇒ TP $E_F \rightarrow E_{Fi}$ → MOŽEMO DOPIRATI DA DODAJEMO PRIMJESA E_F TEŽI E_V TJ DA E_F OSTANE ISTI BEZ OBZIRA NA POVEĆANJE TEMP DODAJEMO AKCEPTORE

a) Si P-TIP, AKCEPTORI

TEORIJA (11.11.12) Ele-1 | 18.11.13 2

③ PN - SPOJ OBJE USKE STRANE RAZLIČITO DOPIRANE $N_A = 1000\,N_D$ $N_A \gg N_D$

OSIROMAŠENO PODRUČJE $d_{DP} \ll d_{DN}$

DIFUZIJSKE STRUJE MANJINA

$p_{OP} \gg n_{ON}$

$n_{OP} \ll p_{ON}$

$I_{DP} \sim p_{OP}$ $I_{DP} \sim n_{OP}$

$\Rightarrow I_{DP} \gg I_{DN}$

a) $I_{DP} \gg I_{DN}$, $d_{DP} \ll d_{DN}$

④ LED DIODA

⇒ KORISTE REKOMBINACIJU

↳ PROPUSNA POLARIZACIJA

$\lambda = 699\,nm = 0{,}69\,\mu m$ (mora biti 0 μm)

$\lambda = \frac{1{,}24}{E_G}$ $E_G = \frac{1{,}24}{0{,}69} = 1{,}8\,eV$

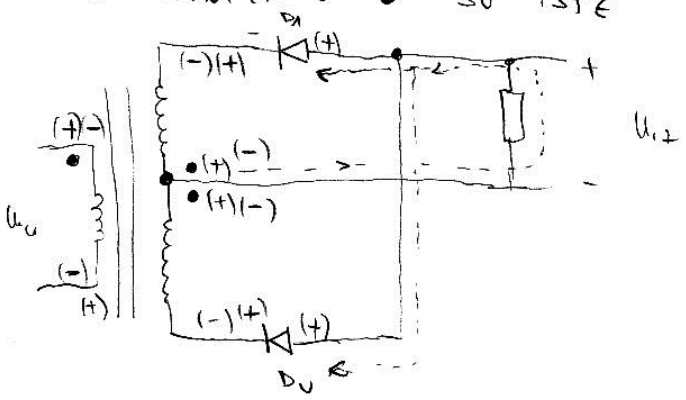
d) $E_G = 1{,}8\,eV$, PROPUSNA

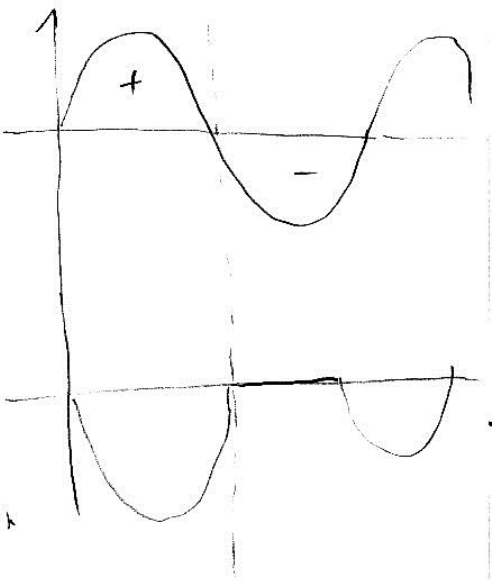
TEORIJA (21.11.12)

⑤ ISPRAVLJAČ

⇒ NA ULAZU SINUS, AKA CIJELO + i − FAZU

⇒ FAZE SIGNALA U ● SU ISTE





- POLARIZACIJA DIODA, PROPUSNA
  ZA POZITIVNI DIO ULAZ (LIJEVA OZNAKA)
- DIODA, ZAPORNA
  ZA NEGATIVNI DIO ULAZA (DESNA OZNAKA)

e)

TEORIJA (21.11.12) Ele-1 | 18.11.13 4

6.

SLIKA POPREČNOG PRESJEKA

→ S → ⊥ , KANAL FORMIRAN I SUŽAVA SE

ALI NIJE PREKINUT PA JE U TRIODNOM

MOGUĆE A, B, C ... TE TOČKE SU U TRIODNOM

$U_{DS} > 0$ pa nije a jer $U_{DSA} = 0$

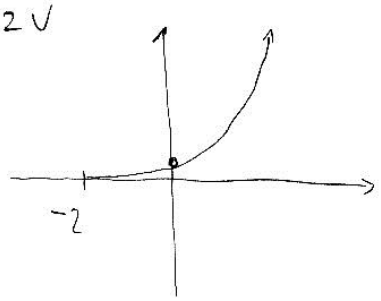
nije C jer kanal nije prekinut

TOČKA B $U_{DS} > 0$, TRIODNO PODRUČJE, KANAL NIJE PREKINUT

7. KOJI TIP MOSSFET

KAKO U_{GS} POSTAJE POZITIVAN I_D ↑ → N MOS

$U_{GSO} = -2V$



↳ $U_{GS} = 0V$, $I_D > 0$

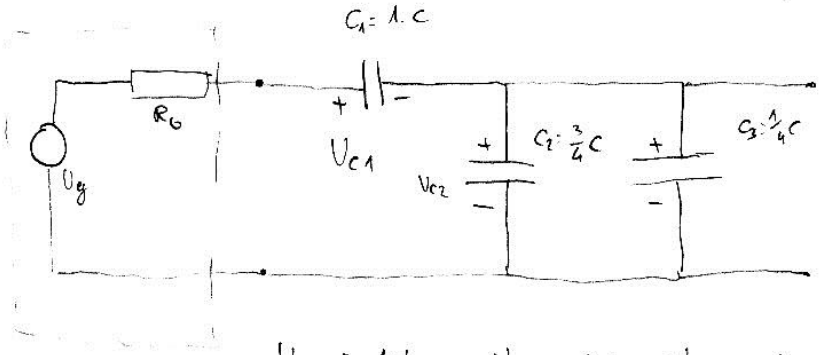
→ OSIROMAŠENI

(C)

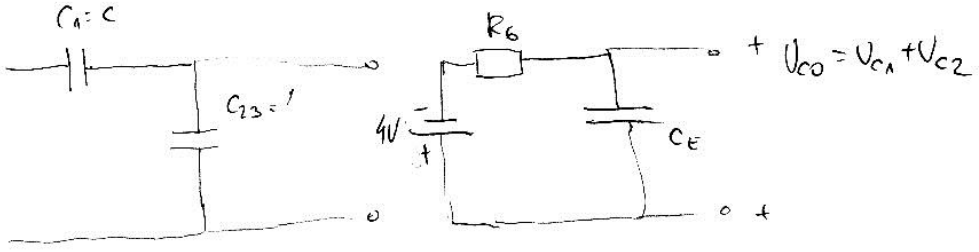
ZADACI 21.11.12 EL-1/18-11.13 5

① RC - mreža

- OTPOR "SKRIVEN" U NAPONSKOM IZVORU $C = 1\,\mu F$



$U_{C1} = 1V \quad U_{C2} = 1V = U_{C3}$ → POČETNI NAPON ZA $\| C$



$C_{23} = C_2 + C_3 = \frac{3}{4} + \frac{1}{4} = C$

$C_E = C_1 \| C_{23} = \frac{C}{2}$

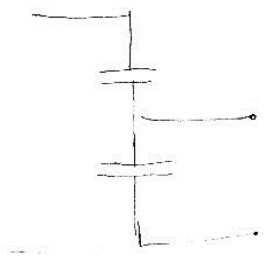
$U_{CO} = 2V$

→ PAZI NA POLARITETE KONDENZATORA

$U_{CP} = 2V \quad U_{CK} = -4V \quad 0 \le t \le \infty$

$\tau = R_6 \cdot C_{EK} = 1ms$

$$U_C(t) = U_{CP} + (U_{CK} - U_{CP})\left(1 - \exp\frac{-t}{\tau}\right)$$
$$= 2 + (-4 - 2)\left(1 - \exp\frac{-t}{\tau}\right)$$
$$= -4 + 6\exp\frac{-t}{\tau}$$



$$U_{17} = \frac{\frac{1}{C}}{\frac{1}{C} + \frac{1}{C}} U_C = \frac{1}{2} U_C$$

$$U_{12}(t) = \frac{1}{2} U_C(t) = -2 + 3\exp\frac{-t}{\tau}$$

1 b)

$$U_{12}(t) = -2 + 3\exp\frac{-t}{\tau}$$

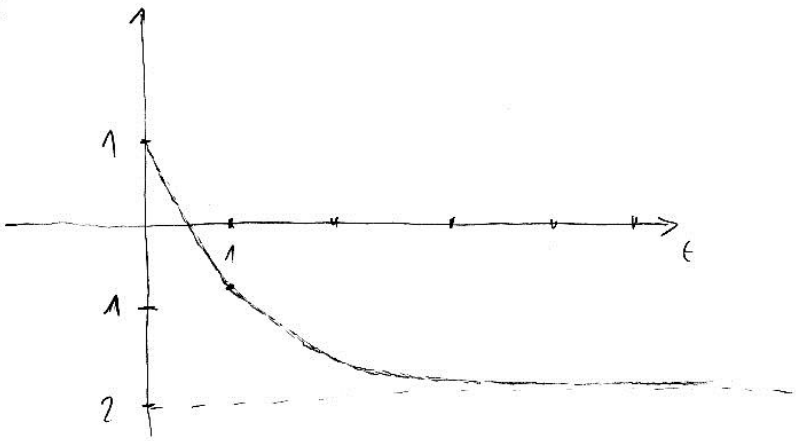
$$U_{12}(0) = -2 + 3 = 1\,V$$

$$U_{12}(1_{ms}) = -2 + 3\exp\left(\frac{-1}{1}\right) = -0{,}896\,V$$

$$U_{12}(\infty) = -2 + 3\exp\frac{-t}{\tau} = -2\,V$$

$t \to \infty$

c)



ZADACI (21.11.12 Ele-1 | 18.11.13 7

(2) Si DOPIRAN 1. PRIMJESOM

VODLJIVI

$E_{Fi} - E_F = 0{,}34$ eV

0,34V

E_{Fi}

E_F

VALENTNI

$\mu_e = 1400\ cm^2/Vs$

$\mu_p = 420\ cm^2/Vs$

P-TIP, $E_F < E_{Fi}$

→ DOPIRAN AKCEPTORIMA

$T = 300\ K \Rightarrow n_i = 1{,}45 \cdot 10^{10}\ cm^{-3}$

$$p_0 = n_i \exp\frac{E_{Fi} - E_F}{kT} = 1{,}45 \cdot 10^{10} \cdot \exp\frac{0{,}34\ eV}{\frac{300}{11600}} = 7{,}43 \cdot 10^{15}\ cm^{-3}$$

(Većinski nosioci šupljine / N_A)

manjinski nosioci u P-TIPU su elektroni.

$$n_0 = \frac{n_i}{p_0} = \frac{1{,}45 \cdot 10^{10}}{7{,}43\,10^{15}} = 2{,}83 \cdot 10^4\ cm^{-3}$$ (elektroni)

$p_0 \gg n_i \Rightarrow p_0 \approx N_A$ (DOPIRAMO AKCEPTORIMA)

$p_0 \gg n_0 \Rightarrow \sigma \approx \sigma_p = (\text{koncentr. šupljs.}) = e\,\mu_p \cdot p_0 = 0{,}5\ Si/cm$

ZADACI (21.11.12) ELE-1 | 18.11.13 8

2 b)

SPEC. VODLJIVOST NA $T = 500\,K$, ISTI MATERIJAL, $T \uparrow$

$$n_i(500K) = C_1 T^{\frac{3}{2}} \exp\frac{(-E_{G0})}{2KT} = 3{,}24 \cdot 10^{14}\ cm^{-3}$$

$n_i \ll N_A$ ekstrinzično TEMP PODRUČ

$p_0 \doteq N_A = 7{,}43 \cdot 10^{15}$

→ KAKO $T \uparrow \rightarrow \mu \downarrow$ (TEMP RASTE, POKRETLJIVOST PADA)

$\sigma \doteq \sigma_p = q\,\mu_p(500K) \cdot p_0 = 1{,}6 \cdot 10^{-19}\ 0{,}45 \cdot 470 \cdot 7{,}43 \cdot 10^{15} = 0{,}45 \cdot \sigma(300K)$

$= \underline{0{,}225\ S/cm}$

ZADACI (21. 11. 12)

③

KONCENTRACIJA n i p DIODE

⇒ n dopiran $N_D = 2 \cdot 10^{15}\ cm^{-3}$, manjinski su šupljine

GLEDAJU SE MANJINSKI NOSIOCI na N STRANI

$\mu_p = 370\ cm^2/Vs$, $\tau_p = 0{,}8\ \mu s$ $W_n = 0{,}5\ \mu m = 0{,}5 \cdot 10^{-4}\ cm$

⇒ P STRANA, AKCEPTOR $N_A = 8 \cdot 10^{17}\ cm^{-3}$

→ manjinski nosioci $\mu_n = 700\ cm^2/Vs$ $\tau_p = 0{,}5\ \mu s$ $W_p = 100\ \mu m = 100 \cdot 10^{-4}\ cm$

n

$n_{on} \approx N_D = 2 \cdot 10^{15}\ cm^{-3}$

$p_{on} \approx \frac{n_i^2}{n_{on}} = 1{,}05 \cdot 10^5\ cm^{-3}$

P

$p_{op} \approx N_A = 8 \cdot 10^{17}\ cm^{-3}$

$n_{op} = \frac{n_i^2}{p_{op}} = 2{,}63 \cdot 10^2\ cm^{-3}$

DIFUZIJSKA DUŽINA NU P STRANI

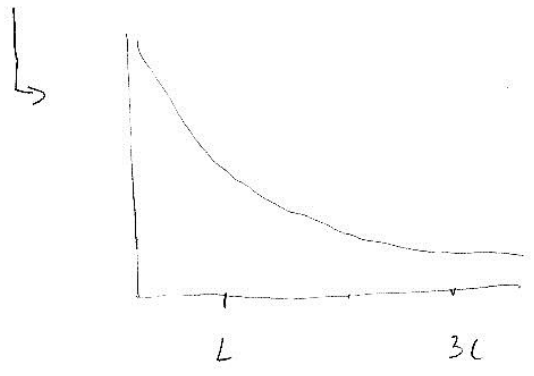
$$L_p = \sqrt{D_n \cdot \tau_n} = \sqrt{\mu_n \frac{T}{11600} \cdot \tau_n} = 30{,}09 \cdot 10^{-4}\ cm = 30{,}09\ \mu m$$

→ USPOREDIMO SA $W_p = 100\ \mu m$ $L_p \ll W_p$ (3x jače exp. ovisnost)

$-\frac{x}{L}$	0	-1	-2	-3	-4	-5
$exp-\frac{x}{L}$	1	0,368	0,135	0,05	0,018	0,0067

OPSEGNIJE PA MOŽEMO ZAKLJUČITI GORE

ŠIROKA STRANA



$W > 3L$
$W \gtrsim 5L$
} ŠIROKA STRANA

Elo-1 | 18.11.13 10

3)

n STRAN

$$L_p = \sqrt{D_p \tau_p} = \sqrt{\mu_p \frac{T}{11600} \tau_p} = 25{,}75\,\mu m \gg W_n = 0{,}5\,\mu m$$

USKA STRANA (n)

na SLABAHITEN manjinski nosioci ($S = 0{,}5\,mm^2 = 0{,}5 \cdot 10^{-2}\,cm^2$)

a) $$I_S = I_{Sn} + I_{Sp} = q S \left[D_n \frac{n_{op}}{L_n} + D_p \frac{p_{on}}{W_n} \right] = q S \frac{T}{11600} \left[\mu_n \frac{n_{op}}{L_n} + \mu_p \frac{p_{on}}{W_n} \right] = 13{,}92\,pA$$

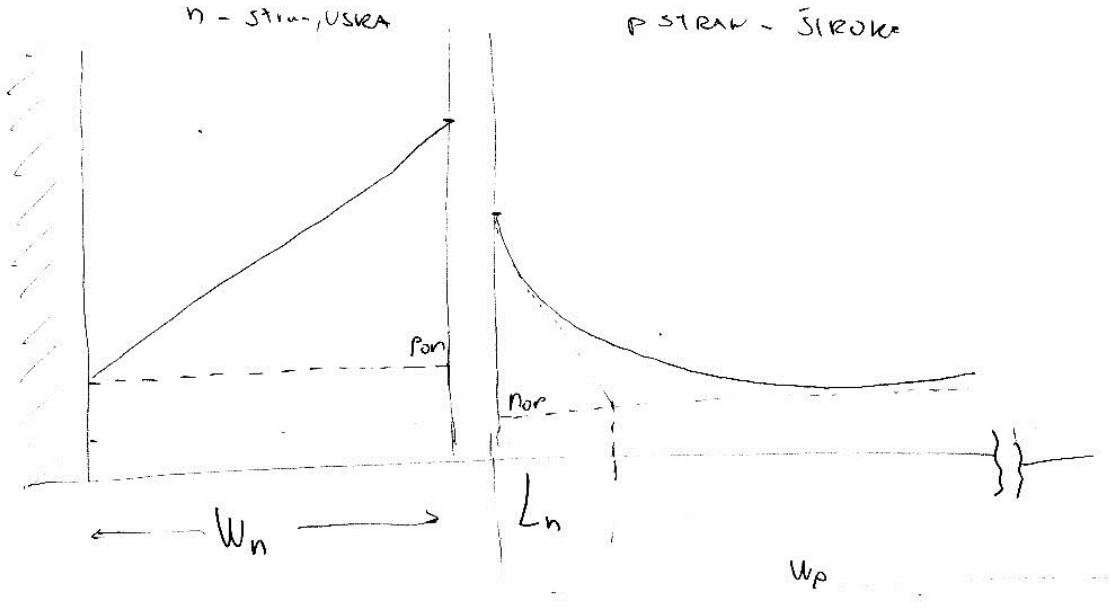
($D_n = \mu_n U_T$, $D_p = \mu_p U_T$)

→ GLEDAMO MANJINSKE NOSIOCE NA STRANI

3b) $$I_D = I_S \left(\exp \frac{U_D}{m U_T} - 1 \right) \approx I_S \exp \frac{U_D}{U_T} = 24\,mA$$

3c) $p_{on} = 1{,}05 \cdot 10^5\,cm^{-3} \Rightarrow p_{no} = p_{on} \exp \frac{U_D}{m U_T} = 1{,}91 \cdot 10^4\,cm^{-3}$

$n_{op} = 2{,}63 \cdot 10^7\,cm^{-3} \Rightarrow n_{po} = n_{op} \exp \frac{U_D}{m U_T} = 4{,}53 \cdot 10^{11}\,cm^{-3}$



3 d) DINAMIČKI OTPOR

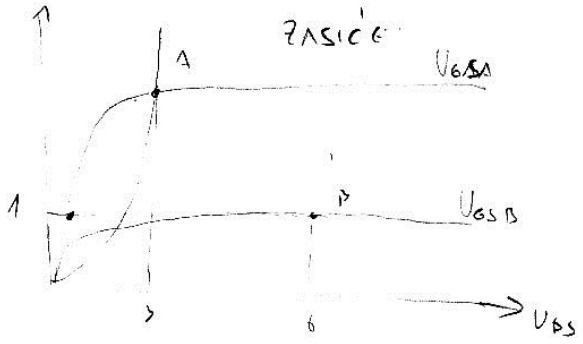
→ nagib tangete u radnoj točki, odreden izvorom

$$r_d = \frac{1}{g_d} = \frac{1}{\frac{\partial I_D}{\partial U_D}\Big|_Q} = \frac{1}{I_S \exp\frac{U_D}{mU_T} \cdot \frac{1}{mU_T}} = \frac{mU_T}{\left(I_S \exp\frac{U_D}{mU_T} - I_S\right) + I_S}$$

$$= \frac{mU_T}{I_{DQ} + I_S} \approx \frac{mU_T}{I_{DQ}} = \frac{1 \cdot \frac{300}{11600}}{24} \approx 1{,}08\,\Omega$$

ELE -1 | 18.11.13 12

4) MOSFET, STATIKA



→ TIP MOSFETA

$U_{DS} > 0$
$I_D > 0$ } N-mos

$U_{GSA} = -U_{GSB} \Rightarrow$ $U_{GSA} > 0$, $U_{GSB} < 0$ } radi iz oba predznaka → OSIROMAŠENI TIP N mos !!

b) $I_{DB} = 1mA$, ZASIĆENJE (IZ GRAFA)

(1) $I_{DB} = \frac{k}{2}\left(U_{GSB} - U_{GSO}\right)^2$

A - točka na granici TRIODNOG ZAĆ

$U_{DS} = U_{GS} - U_{GSO}$

$U_{DSA} = 3V$ (IZ GRAFA)

(2) $U_{GSO} = U_{GSA} - 3$

(3) $U_{GSA} = -U_{GSB}$ } → (1)

$I_{DB} = \frac{k}{2}\left(-U_{GSA} - U_{GSA} + 3\right)^2 = \frac{k}{2}\left(2U_{GSA} - 3\right)^2 \quad \left|\frac{2}{k}\sqrt{}\right.$

$2U_{GSA} - 3 = \pm\sqrt{\frac{2I_{DB}}{k}}$

$U_{GSA} = 1{,}5 \pm 0{,}5\sqrt{\frac{2I_{DB}}{k}} = 1{,}5 \pm 0{,}5\sqrt{\frac{2\cdot 1}{2}}$

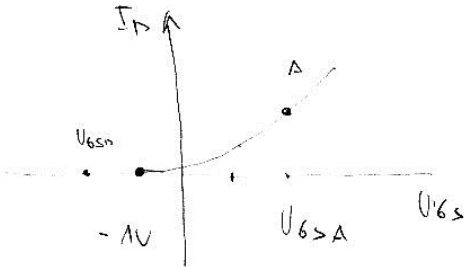
$U_{GSA1} = 2V$
$U_{GSA2} = 1V$ } 2 r. 1. SAMO PRIHVAĆA

ELE-1 | 18.11.13 13

$U_{GSA1} = 2V$

$U_{GSO1} = U_{GSA1} - 3 = 2 - 3 = -1V$

$U_{GSB1} = -U_{GSA1} = -2V$



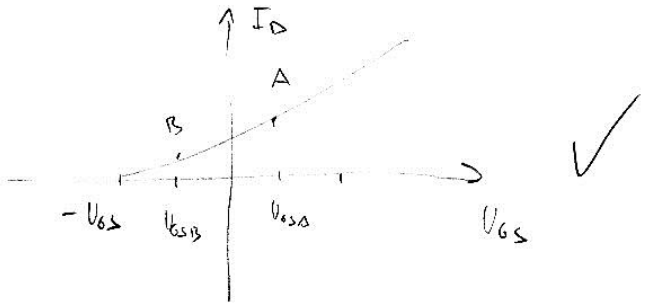
DOBIJEM DA JE U1 $U_{GSB1} = 2V$ $I_D = 0$

PA NE ODGOVARAJ ZADANOJ KARAKTERISTICI ⇒ NIJE PRIHVATLJIVO

$U_{GSA2} = 1V$

$U_{GSO2} = U_{GSA2} - 3 = 1 - 3 = -2V$

$U_{GSB2} = -U_{GSA2} = -1$



✓

c) $U_{GSC} = U_{GSA} = 1V$ $I_D = 1mA$

C-> TRIODNO PODRUČJE

$$I_{DC} = K\left[(U_{GSC} - U_{GSO})U_{DSC} - \frac{U_{DSC}^2}{2}\right]$$

$$\frac{2I_{DC}}{K} = 2(U_{GSC} - U_{GSO})U_{DSC} - U_{DSC}^2$$

$$U_{DSC}^2 - 2(U_{GSC} - U_{GSO})U_{DSC} + \frac{2I_{DC}}{K} = 0$$

$$U_{DSC}^2 - 6U_{DSC} + 1$$

$$U_{DSC1,2} = \frac{6 \pm \sqrt{62-4}}{2} = \begin{cases} U_{DSC1} = 5,83V - \text{ZASIĆEN} \\ U_{DSC2} = \boxed{0,17V - \text{TRIODNO}} \end{cases}$$ ✓