završni iz ele1 2007

PRVA SK. ZAD.

1. 1.1. $u_{g1} = -15 \sin \omega t$ mV

$u_{g2} = 25 \sin \omega t$ mV

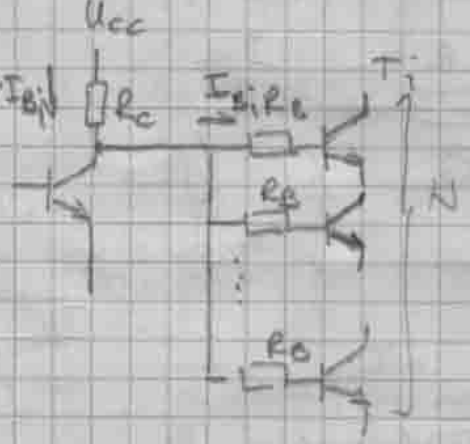
diferencijsko pojačalo

$u_z = \frac{1}{2}(u_{g1} + u_{g2}) = 5 \sin \omega t$ mV

$u_d = u_{g2} - u_{g1} = 40 \sin \omega t$ mV

1.2. veliki $|A_{vd}|$ mali $|A_{vz}|$

2. 2.1.



T_1 u zasićenju

$U_{CE1} = U_{CE\,zas} = 0{,}3V$

⇓

T_i u zapiranju

$I_{Bi} = 0$

↳ ne ulječu na nižu razinu

GS_N ostaje ista

T_1 u zapiranju

$I_{C1} = 0$ i baze ku preko R_C spojene na U_{cc}

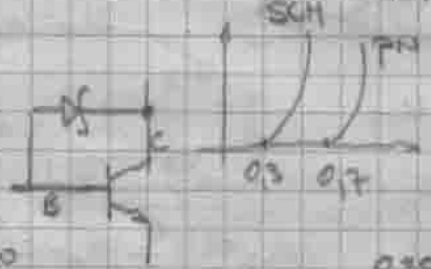
$u_1(T_1) = U_{cc} - N \cdot I_{Bi} \cdot R_C$ ↳ GS_V - ku smanjuje

$U_{cc} = N I_B \cdot R_C + I_B \cdot R_B + U_{BE}$

$I_B = \frac{U_{cc} - U_{BE}}{R_B + N \cdot R_C}$

a) GS_V pada GS_N ostaje ish

2.2.



zasićenje:

U_{BE} - propusno

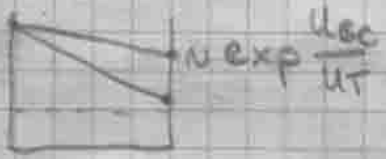
U_{BC} - propusno

0,35V SCH

0,4 SCH

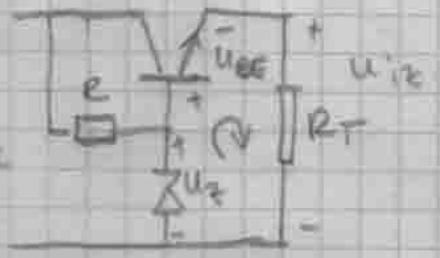
d) T2 brže isključivanje od T_1

vremena uključivanja ista



3. 3.1. stabilizator s bipolarnim tranzistorom.

$\frac{U_{iz}}{U_{ul}} << 1$ (pilasti napon se prigušuje)



napon ima polarizaciju suprotnu spoju

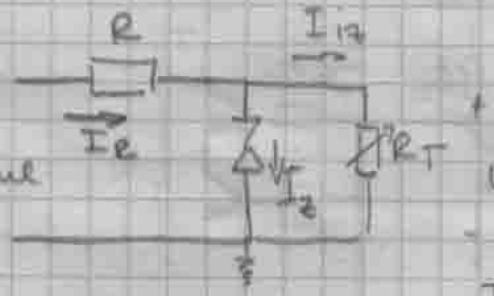
↻ → $U_{iz} = U_z - U_{BE}$

$U_z = U_{iz} + U_{BE} = 6{,}8V + 0{,}7V = 7{,}5V$

3.2. $U_{iz} = 10V$

R_T 7/200 Ω

$I_{E\,min} = 54\,mA$



$I_{R\,min} = \frac{U_{ul\,min} - U_z}{R_{max}}$

$I_{z\,min} = I_{E\,min} - I_{iz\,max}$

(ujet se postavlja na I_z, mora imati neki min struju da ode u pozitiv)

$I_{iz\,max} = \frac{U_{iz}}{R_{T\,min}}$

$= \frac{10V}{0{,}2k\Omega}$

$= 50\,mA$

$I_{z\,min} = 54\,mA - 50\,mA$

$= 4\,mA$

točan odgovor c) ⇒ 4 mA ili više struje treba dovest na Zener diodu

4. 4.1 $U_{ul_1} = 2{,}0V$

$U_{ul_2} = 2{,}5V$

$R_1 = 10k\Omega$

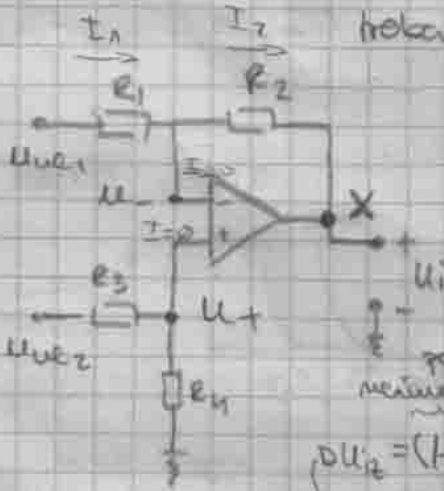
$R_2 = 40k\Omega$

$R_3 = 10k\Omega$

$R_4 = 40k\Omega$

$Z_{iz} << \{R_{iz} = 0\}$

↳ za X mi pišemo jednadžbu



$U_{iz} = A_{VOP}(U_+ - U_-)$

$U_+ - U_- = \frac{U_{iz}}{A_{VOP}} = \{A_{VOP} \to \infty\}$

$U_+ - U_- = 0 \Rightarrow \boxed{U_+ = U_-}$ virtualni kratki spoj

$\Delta U_{iz} = (1 + \frac{R_2}{R_1})U_+ - \frac{R_2}{R_1} \cdot U_{ul_1}$

pojačanje neinvertirajućeg

pojačanje nikirul.

$I_1 = I_2$

$\frac{U_{ul_1} - U_-}{R_1} = \frac{U_- - U_{iz}}{R_2}$

↳ $\Delta U_{iz} = (1 + \frac{R_2}{R_1}) \cdot U_- - \frac{R_2}{R_1} \cdot U_{ul_1}$

$I_3 = I_4$

$U_+ = (\frac{R_4}{R_3 + R_4}) \cdot U_{ul_2}$

$U_{iz} = \frac{R_1 + R_2}{R_1} \cdot \frac{R_4}{R_3 + R_4} \cdot U_{ul_2} + \frac{R_2}{R_1} U_{ul_1}$

$$u_{iz} = \frac{R_1+R_2}{R_1} \cdot \frac{R_4}{R_3+R_4} u_{ul_1} + \frac{R_2}{R_1} u_{ul_2}$$

$R_3 = R_1$, $R_2 = R_4$ $\quad \Big\rfloor_D = \frac{R_2}{R_1}(u_{ul_2} - u_{ul_1})$

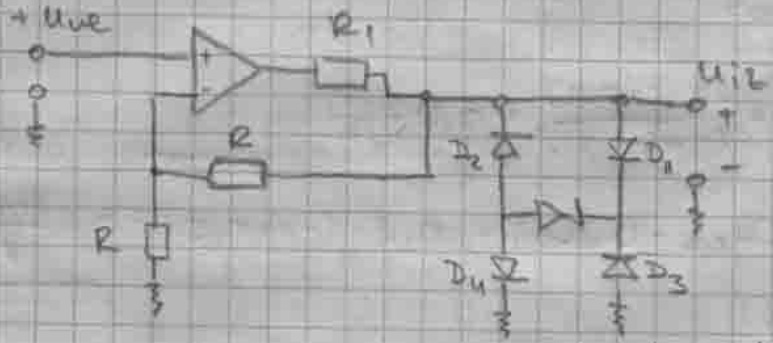
$$u_{iz} = \frac{40}{10}(2{,}5-2) = 2V$$

4.2 $\qquad R_1 = R_3 \qquad R_2 + R_4$

$$u_{iz} = \frac{\left(1+\frac{R_2}{R_3}\right)}{\left(1+\frac{R_2}{R_4}\right)} u_{ul_2} - \frac{R_2}{R_1} u_{ul_1}$$

$$= \frac{1+\frac{40}{10}}{1+\frac{10}{30}} u_{ul_2} - \frac{40}{10} u_{ul_1} = \frac{5 \cdot 3}{4} \cdot 2{,}5 - 4{,}2 = 1{,}375V$$

5. 5.1. komparator $\quad U_z = 5{,}6V$, $U_D = 0{,}7V$; $u_{ul} = -4V$



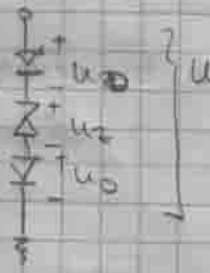
$$u_{iz} = \pm(U_z \pm 2U_D) = \pm(5{,}6+0{,}7)$$
$$= \pm 7V$$

napon okidanja niske razine:

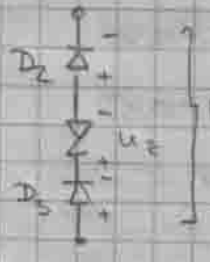
$$u_{PN} = -u_{iz}\frac{R}{R+R} = -7 \cdot \frac{1}{2} = -3{,}5V$$

$u_{PV} = 3{,}5V$

$u_{iz} > 0$ $\qquad$ $u_{iz} < 0$



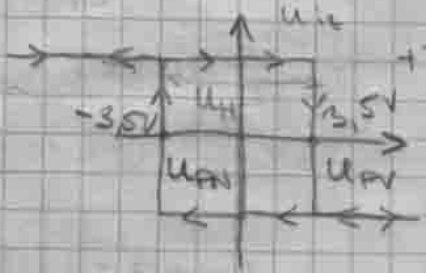
$u_{iz} = U_z + 2U_D$



$u_{iz} = -(U_z + 2U_D)$

D_3, D_4 - reverzno polarizirano

prijenosna karakteristika



za ulaz $u_{ul} = -4V$ → izlaz e) +7V

5.2

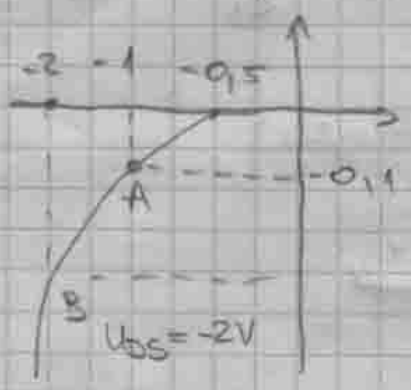
napon u_{ul} se povećava na +3V → izlaz d) +7V

(ova prijenosna k.)

DRUGA SK. ZAD.

1. $\lambda = 0$

1.1



u_{GS} postaje negativniji $|I_D| \uparrow$
↳ OPHOS

$u_{GSO} = -0,5\,V$

tranzistor vodi iz zadno 1 predznak u_{GS}
↳ OBOGAĆENJE

1.2. A: $u_{GS} = -1V$

$u_{DS} = -2V$

$I_D = -0,1$ mA

$|u_{DS}| > |u_{GS} - u_{GSO}|$

$2V > 0,5V$ zasićenje

$$I_D = \frac{k}{2}(u_{GS} - u_{GSO})^2$$

$$k = \frac{-2I_D}{(u_{GS} - u_{GSO})^2} = \frac{-2 \cdot (-0,1)}{(-1-(-0,5))^2} = 0,8 \frac{mA}{V^2}$$

$$g_m = \frac{\partial I_D}{\partial u_{GS}} = -k \cdot (u_{GS} - u_{GSO}) = -0,8 \cdot (-1+0,5) = 0,4 \frac{mA}{V}$$

1.3. B: $u_{GS} = -2V$

$u_{DS} = -2V$

$|u_{DS}| \geq |u_{GS} - u_{GSO}|$

$|-2| > |-2-(-0,5)|$ još uvijek zasićenje

$2V > 1,5V$

$$I_D = \frac{-k}{2}(u_{GS} - u_{GSO})^2$$

$$I_D = \frac{-0,8}{2}(-2+0,5)^2 = -0,9\,mA$$

$$g_{mB} = -k(u_{GS} - u_{GSO}) = -0,8 \cdot (-2+0,5) = 1,2 \frac{mA}{V}$$

2. $\mu_n = 500 cm^2/Vs$ n-strana uska

$\mu_p = 300 cm^2/Vs$ p-strana široka

$\tau_n = \tau_p = 0{,}5 \mu s$

$S = 2 mm^2$

$T = 300K$

2.1. $p_{no} = p_{on} \cdot \exp\left(\frac{U_D}{U_T}\right)$

$U_D = U_T \ln\left(\frac{p_{no}}{p_{on}}\right) = \frac{300}{11600} \cdot \ln\left(\frac{9{,}51 \cdot 10^{11}}{2{,}1 \cdot 10^2}\right)$

$\underline{U_D = 0{,}575 V}$ //

2.2. n strana

$p_{on} = 2{,}1 \cdot 10^2 cm^{-3}$

$p_{on} \cdot n_{on} = n_i^2$

$n_{on} = \frac{n_i^2}{p_{on}} = \frac{(1{,}45 \cdot 10^{10})^2}{2{,}1 \cdot 10^2} = 10^{18} cm^{-3}$

$n_{on} >> 2n_i$ $n_{on} \approx N_D = \underline{10^{18} cm^{-3}}$ //

2.3. struja koja teče preko pn spoja je zbroj šupljinskih i elektronskih struja

$I_{dp} = -q \cdot S \cdot D \cdot \frac{dp}{dx}$ (uska n strana) $\frac{dp}{dx} \approx \frac{p_{no}}{}$

$= -q \cdot S \cdot \mu_p \cdot U_T \frac{p_{no} - p_{on}}{W_n}$

$= -1{,}6 \cdot 10^{-19} \cdot 2 \cdot 10^{-2} \cdot 300 \cdot \frac{300}{11600} \cdot \frac{9{,}51 \cdot 10^{11}}{10^{-4}} = -0{,}236 mA$ [cm]

$I_{dn} = q \cdot S \cdot D_n \cdot \frac{dn}{dx}$ $\frac{dn}{dx} \approx -n_{po}$

$= q \cdot S \cdot D_n \cdot \frac{n_{op} - n_{po}}{L_n}$ $L_n = \sqrt{D_n \cdot \tau_n}$

$= -q \cdot S \cdot D_n \cdot \frac{n_{po}}{\sqrt{D_n \tau_n}}$ $\rightarrow n_{po} = n_{op} \cdot \exp\left(\frac{U_D}{U_T}\right)$

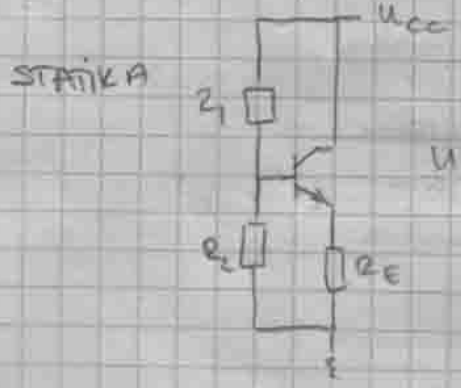
$= -q \cdot S \cdot n_{po} \cdot \sqrt{\frac{D_n}{\tau_n}} = -q \cdot S \cdot n_o \cdot \sqrt{\frac{\mu_n \cdot U_T}{\tau_n}}$

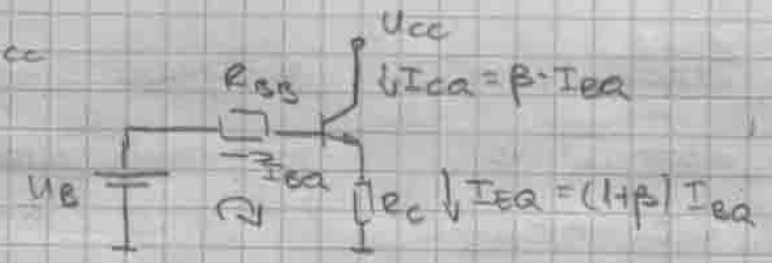
$= -1{,}6 \cdot 10^{-19} \cdot 2 \cdot 10^{-2} \cdot 9{,}51 \cdot 10^{12} \cdot \sqrt{\frac{300 \cdot 300}{11600 \cdot 0{,}5 \cdot 10^{-6}}} = -0{,}155 mA$

$|I_D| = |I_{dp} + I_{dn}|$

$\underline{= 0{,}39 mA}$ //

3.





THEVENIN

3.1.

$U_{BB} = \frac{R_2}{R_1+R_2} \cdot U_{CC} = 7,2V$ (gornjo U_{CC})

$R_{BB} = R_1 \| R_2 = 60k\Omega$

I: $U_{BB} = I_{BA} \cdot R_{BB} + I_{EA} \cdot R_E$

$I_{BA} = \frac{U_{BB} - U_{BEA}}{R_{BB} + (1+\beta) R_E}$

$= 6,47\mu A$

$I_{CA} = \beta \cdot I_{BA} = 200 \cdot 6,47\mu A = 1,294mA$

$U_{CEA} = U_{CC} - I_{CA} \cdot R_E = 5,92V$

3.2.

$I_{CA} = 1,54mA$

$U_{CEA} = 5,96V$

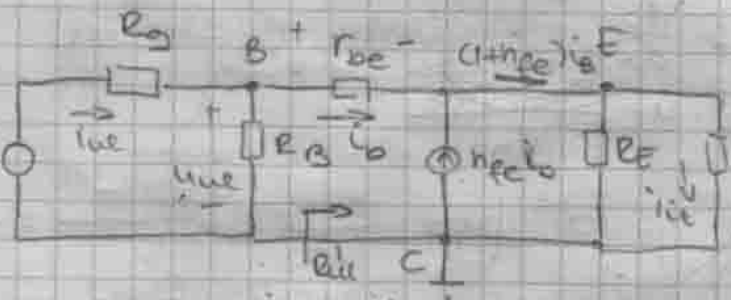
$R_E = 3,9k\Omega$

$g_m = \frac{I_{CA}}{U_T} = \frac{1,54\ (mA)}{25 \cdot 10^{-3}\ V} = 61,6 \frac{mA}{V}$

$r_{be} = \frac{U_T}{I_{BA}} = \frac{U_T}{\frac{I_{CA}}{\beta}} = h_{fe} \cdot \frac{U_T}{I_{CA}} = h_{fe} \cdot \frac{1}{g_m}$

$r_{be} = \frac{U_T}{I_{BA}} = \frac{U_T}{\frac{I_{CA}}{\beta}} = \frac{\beta U_T}{I_{CA}} = \frac{200 \cdot 25 \cdot 10^{-3}}{1,54 \cdot 10^{-3}} = 3246\Omega$

3.3.



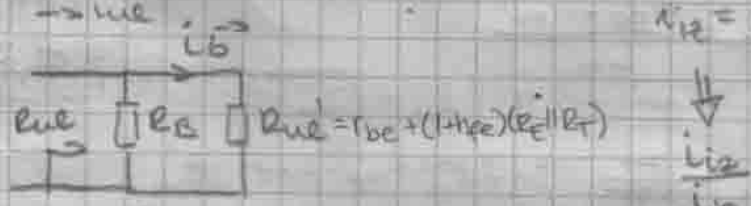
$A_I = \frac{i_{iz}}{i_{ul}} = \frac{i_{iz}}{i_b} \cdot \frac{i_b}{i_{ul}}$

$u_{iz} = i_{iz} \cdot R_T = (1+h_{fe})(R_E \| R_T) \cdot i_b$

$i_{iz} = (1+h_{fe}) i_b \cdot \frac{R_E}{R_E + R_T}$

$\Downarrow$

$\frac{i_{iz}}{i_b}$



$R_{ul}' = \frac{u_{ul}}{i_b} = \frac{i_b \cdot r_{be} + (1+h_{fe}) \cdot i_b (R_E \| R_T)}{i_b}$

$R_{ul}' = r_{be} + (1+h_{fe})(R_E \| R_T)$ otpon E→B je vide $(1+h_{fe})$ puta veći

$= 334k\Omega$

$$i_b = \frac{R_B}{R_B + R_{ul}'} \cdot i_{ul}$$

$$A_I = \frac{i_{iz}}{i_{ul}} \cdot \frac{i_b}{i_b} = \frac{R_B}{R_B + R_{ul}'} \cdot (1 + h_{fe}) \cdot \frac{R_E}{R_E + R_T}$$

$$\frac{i_b}{i_{ul}}$$

$$\underline{A_I = 15,29}$$

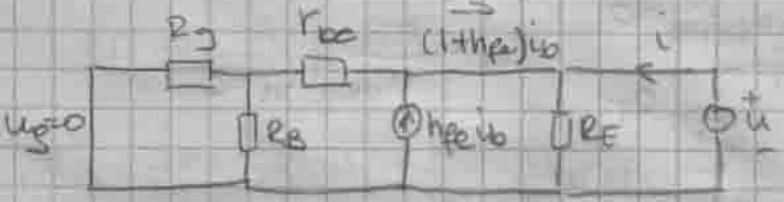
3.4. Ish parametri

$$R_{ul} = R_B \| R_{ul}'$$

$$= R_{BE} \| (r_{be} + (1 + h_{fe}) R_E \| R_T)$$

$$\underline{R_{ul} = 50,9\ k\Omega}$$

3.5. R_{iz} → izvor zrcalno spajamo potrošač odspajamo

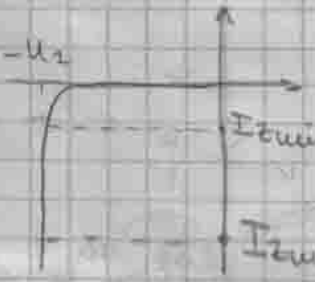


$$i = \frac{u}{R_E} - (1 + h_{fe}) i_b$$

$$u = -i_b (r_{be} + R_g \| R_B)$$

$$R_{iz} = \frac{u}{i} = R_E \| \frac{r_{be} + R_g \| R_B}{(1 + h_{fe})} = \ldots = \underline{16,22\ \Omega}$$

4.



$P_z = U_z I_z$ (disipacija) $\quad U_0 > R_T > 7,47\Omega$

(uzeto iz $P_{Z\max}$)

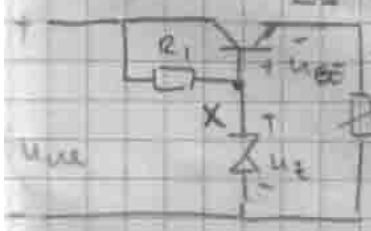
4.2. u zoni X

$$I_{Z\max} = I_{R\max} - I_{B\min}$$

$$I_{B\min} = \frac{I_{iz\min}}{(1+\beta)} = \frac{U_{iz}}{R_{T\max}} \cdot \frac{1}{(1+\beta)} = 0$$

$$I_{Z\max} = I_{R\max} = \frac{U_{ul\max} - U_z}{R_{1\min}}$$

$$R_{1\min} = \left(\frac{U_{ul\max} - U_z}{I_{Z\max}} \right) = \frac{U_{ul\max} - U_z}{P_{Z\max}/U_z}$$



$$U_{iz} = U_z - U_{BE}$$

$$= 9,7 - 0,7 = 9V$$

4.1

$$R_1 = 336\ \Omega$$

4.3 u obru x:

$$I_{z\,min} = I_{R\,min} - I_{B\,max}$$ VELO BITAN UVJET !!

$$I_{R_1\,min} = \frac{U_{ue\,min} - U_z}{R_{1\,max}}$$

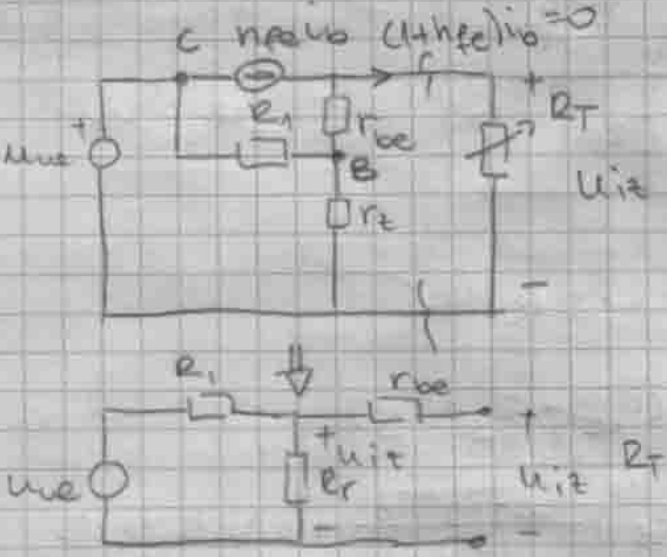
$$I_{B\,max} = \frac{U_{iz}}{(1+\beta)\cdot R_{T\,min}}$$

$$I_{z\,min} = \frac{U_{ue\,min} - U_z}{R_{1\,max}} - \frac{U_{iz}}{(1+\beta)\cdot R_{T\,min}}$$

$$R_{1\,max} = \frac{U_{ue\,min} - U_z}{I_{z\,min} + \frac{U_z - U_{BE}}{(1+\beta) R_{T\,min}}}$$

$$R_{1\,max} = 1{,}77\,k\Omega$$

4.4.



$$S_u = \frac{U_{iz}}{U_{ue}}\Big|_{U_{iz}=0}$$

$$S_u = \frac{U_{iz}}{U_{ue}} = \frac{r_z}{R_z + R_1}$$

$$S_u = 0{,}009$$

4.5. $$I_{iz} = \frac{U_{iz}}{R_T} = \frac{U_z - U_{BE}}{R_T} = 8{,}24\,\mu A$$

$$I_B = \frac{I_{iz}}{1+\beta} = 87{,}65\,\mu A$$

$$r_{be} = \frac{U_T}{I_B} = 285\,\Omega$$

$$R_{iz} = \frac{r_{be} + R_z \| R_1}{(1+h_{fe})}$$

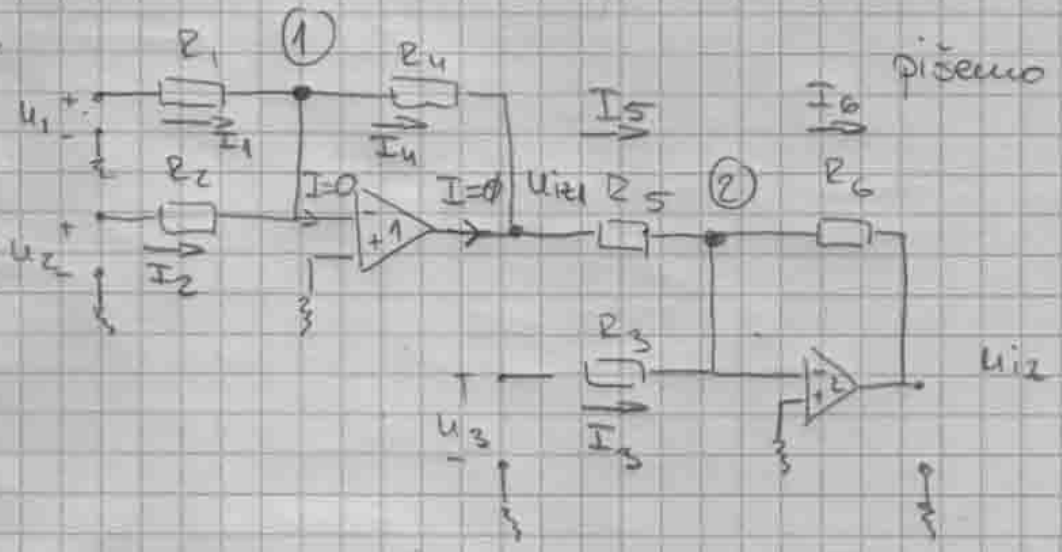
izlaz na emiter, otpor iz baze vidi se $(1+h_{fe})$ puta manje

$$R_{iz} = 1{,}95\,\Omega$$

(odspajamo R_T i spajamo naponski izvor u koji bira struju i, odspajam U_{ue})

$R_4 = 10k$ $R_5 = 10k$ $R_6 = 10k$

5.



pišemo jednadžbe za ① i ②

za čvor U_{iz1} NE pišemo jednadžbu

① $I_1 + I_2 = I_4$

$$\frac{U_1 - 0}{R_1} - \frac{U_2 - 0}{R_2} = \frac{0 - U_{iz1}}{R_4}$$

(1) $$U_{iz1} = -\frac{R_4}{R_1} \cdot U_1 - \frac{R_4}{R_2} \cdot U_2$$

② $I_5 + I_3 = I_6$

$$\frac{U_{iz1} - 0}{R_5} + \frac{U_3 - 0}{R_3} = \frac{0 - U_{iz}}{R_6}$$

(2) $$U_{iz} = \frac{-R_6}{R_5} \cdot U_{iz1} - \frac{R_6}{R_3} \cdot U_3$$

(1) → (2)

$$U_{iz} = \frac{R_6}{R_5} \cdot \frac{R_4}{R_1} \cdot U_1 + \frac{R_6}{R_6} \cdot \frac{R_4}{R_2} \cdot U_2 - \frac{R_6}{R_3} \cdot U_3$$

$$U_{iz} = \frac{10}{R_1} \cdot U_1 + \frac{10}{R_2} U_2 - \frac{10}{R_3} \cdot U_3$$