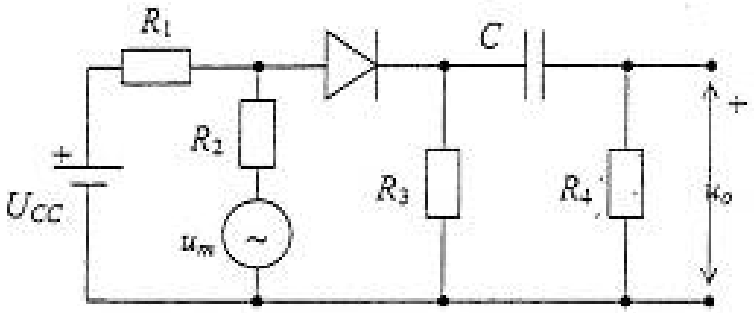
ELEKTRONIKA
(pisni izpit: 22.4.2003)

Čas reševanja: 90 minut
Teža nalog: 25+30+25+20=100%

1. naloga (25%)

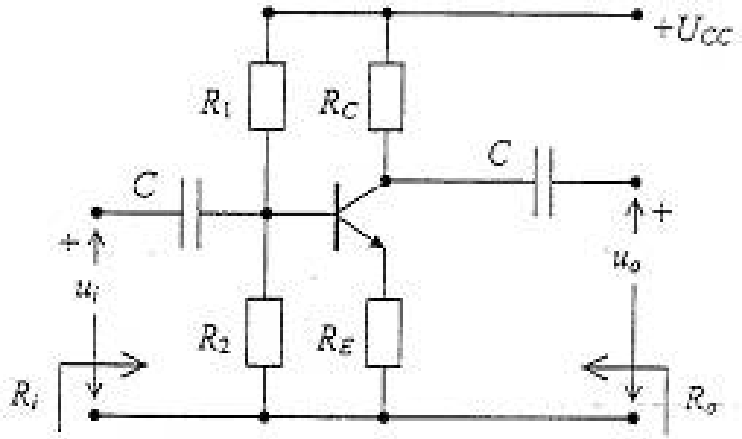
Ob uporabi podane karakteristike diode (priloga) izračunajte amplitudo izhodne napetosti podanega vezja.



$R_1 = R_2 = 10\ \Omega$
$R_3 = 5\ \Omega$
$R_4 = 200\ \Omega$
$C = 1$ mF
$U_{CC} = 2$ V
$u_m = U_m \sin \omega t$;
$U_m = 100$ mV; $\omega = 10^3$ rad/s
$r_D = \frac{U_T}{I_{DQ}}$; $U_T = 25$ mV

2. naloga (30%)

Za vezje tranzistorskega ojačevalnika s skupnim emitorjem izračunajte napetostno ojačanje $A_v = \frac{u_o}{u_i}$ ter vhodno in izhodno notranjo upornost R_i in R_o.

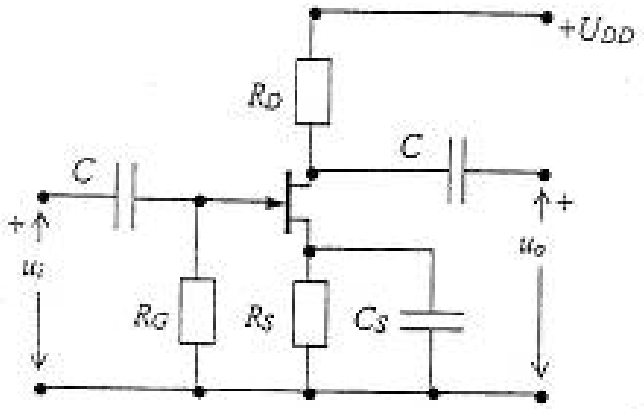


$R_1 = R_2 = 25\ \text{k}\Omega$
$R_C = 3\ \text{k}\Omega$
$R_E = 600\ \Omega$
$h_{11e} = 1\ \text{k}\Omega$
$h_{21e} = 120$
$h_{12e} = h_{22e} = 0$
$C = \infty$

OBRNITE

3. naloga (25%)

Ojačevalnik z JFET tranzistorjem na sliki naj ima napetostno ojačanje A_u. Določite potrebne vrednosti uporov R_D in R_S ter napajalno napetost U_{DD}, da bo ojačevalnik deloval v delovni točki (I_{DQ}, U_{DSQ}) pri predpostavljenih vrednostih U_p in I_{DSS}.



$$i_D = I_{DSS}\left(1-\frac{u_{GS}}{U_p}\right)^2 \qquad g_m = \left.\frac{\partial i_D}{\partial u_{GS}}\right|_Q$$

Zahteve:
- $A_u = -4$
- $I_{DQ} = 3.9$ mA
- $U_{DSQ} = 12$ V

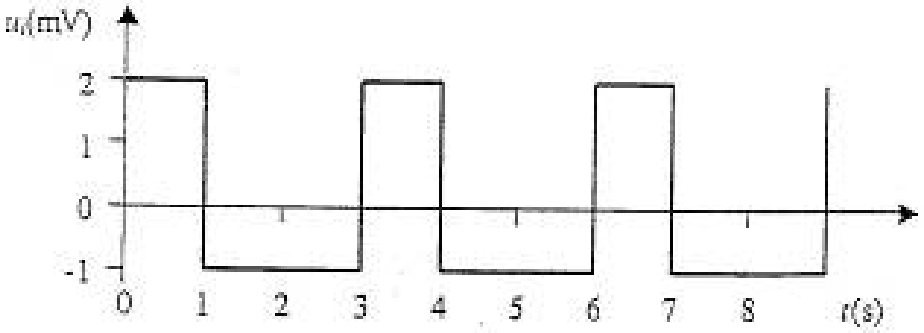
Predpostavke:
- $R_G = 1$ MΩ
- $C = C_S = \infty$
- $r_D >> R_D$
- $U_p = -4$ V
- $I_{DSS} = 10$ mA.

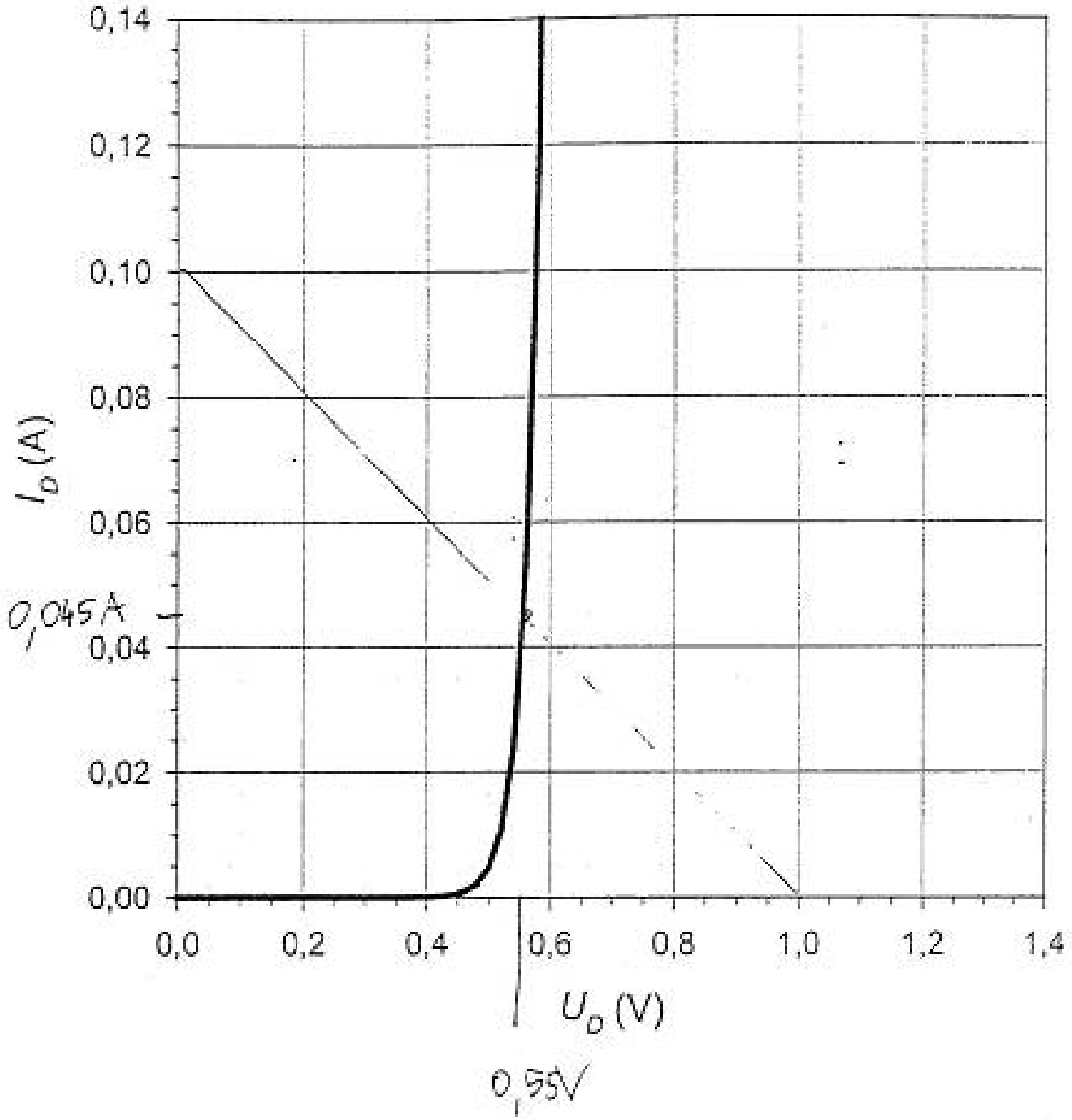
Iščemo: R_D, R_S, U_{DD}

4. naloga (20%)

Narišite shemo preprostega integratorja z operacijskim ojačevalnikom in izpeljite izraz za izhodno napetost kot funkcijo vhodne napetosti. Predpostavite, da je operacijski ojačevalnik idealen ($R_i = \infty$, $R_o = 0$, $A = \infty$).

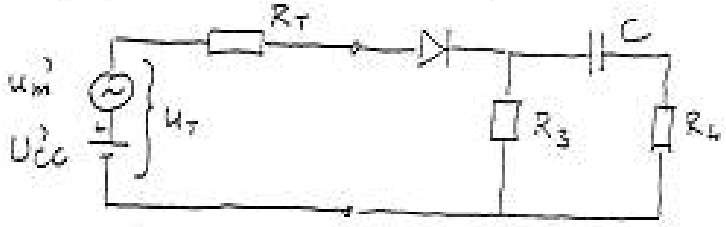
Kakšen signal dobimo na izhodu integratorja pri vhodnem signalu, kot ga prikazuje spodnja slika, če sta vrednosti elementov $C = 2$ nF ($u_C(0) = 0$ V) in $R = 500$ kΩ?

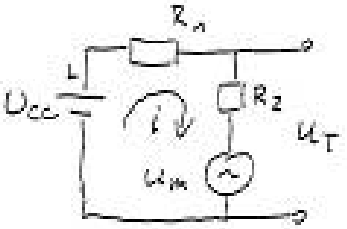



0,14
0,12
0,10
0,08
0,06
0,04
0,02
0,00
I_D (A)
0,045 A
0,0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
U_D (V)
0,55V

Rešitve 1 (13.6.2002)

- Najprej celotni levi del vezja nadomestimo s Thevenineovim ekvivalentom:





$$\boxed{u_T = U_{cc}' + u_m' = \ldots}$$

$$U_{cc} = i(R_1 + R_2) + u_m \Rightarrow i = \frac{U_{cc} - u_m}{R_1 + R_2}$$

1

$$\boxed{u_T} = u_m + i \cdot R_2 = u_m + \frac{R_2}{R_1+R_2}(U_{cc} - u_m)$$

$$= u_m\left(1 - \frac{R_2}{R_1+R_2}\right) + U_{cc}\frac{R_2}{R_1+R_2} = \underbrace{U_{cc}\frac{R_2}{R_1+R_2}}_{U_{cc}'} + \underbrace{u_m\frac{R_1}{R_1+R_2}}_{u_m'}$$

$$\boxed{U_{cc}'} = U_{cc}\frac{R_2}{R_1+R_2} = 2 \cdot \frac{1}{2} = \underline{\underline{1V}}$$

1/2

$$\boxed{U_m'} = U_m \cdot \frac{R_1}{R_1+R_2} = 0{,}1 \cdot \frac{1}{2} = \underline{\underline{50mV}} \quad (u_m' = U_m' \cdot \sin\omega t)$$

1/2

$$\boxed{R_T} = R_1 \| R_2 = \frac{R_1 R_2}{R_1+R_2} = \frac{10 \cdot 10}{20} = \underline{\underline{5\Omega}}$$

(10)

1/2

- Določimo delovno točko diode. Upoštevamo princip superpozicije, ker je $U_m' \ll U_{cc}'$ (linearizacija diodne karakteristike okoli delovne točke)

Delovna premica (C je odprte sponke 8)

DC: $$\boxed{U_{cc}' = U_D + I_D(R_T + R_3)}$$

1

$$\boxed{U_D(I_D = 0)} = \boxed{U_{cc}'} = \underline{\underline{1V}}$$

$$\boxed{I_D(U_D = 0)} = \frac{U_{cc}'}{R_T + R_3} = \frac{1}{5+5} = \underline{\underline{100mA}}$$

2

0,55V

Odčitamo iz karakteristike: $U_{DQ} = \underline{\underline{0{,}5V}}$ 0,645...Ω

(7)

$I_{DQ} = \underline{\underline{50mA}}$

- Dinamična upornost diode v delovni točki:

$$\boxed{r_D} = \frac{U_T}{I_{DQ}} = \frac{25 \cdot 10^{-3}}{50 \cdot 10^{-3}} = \underline{\underline{0{,}5\Omega}}$$

0,56

2

Jemenčne nazmere (odziv na u_m')

amplitude:

$$U_0 = U_{R_3} \cdot \frac{R_4}{R_4 + \frac{1}{j\omega C}} \doteq U_{R_3}$$

3

$$Z_C = \frac{1}{\omega C} = \frac{1}{10^3 \cdot 10^{-3}} = 1\,\Omega \ll R_4 = 200\,\Omega$$

$$U_{R_3} = I \cdot R_3 \| R_4 = U_m' \cdot \frac{R_3 \| R_4}{R_T + r_D + R_3 \| R_4} =$$

(8)

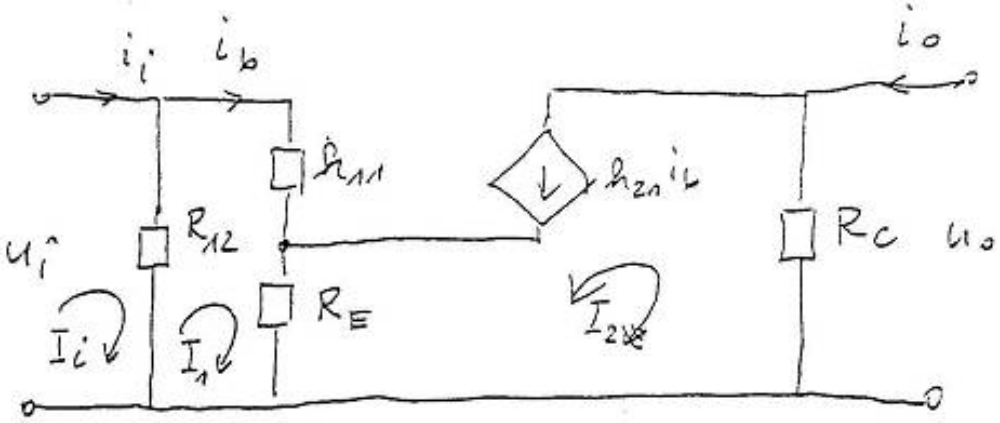
3

$$I = \frac{U_m'}{R_T + r_D + R_3 \| R_4}$$

$$= 0{,}05 \cdot \frac{4{,}878}{5 + 0{,}5 + 4{,}878} = \underline{23{,}5\ mV}$$

2

$U_0 = \underline{23{,}5\ mV}$; $u_0 = U_0 \cdot \sin \omega t$



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$$u_i = i_b h_{11} + R_E (i_b + h_{21} i_b) = i_b (h_{11} + R_E (1 + h_{21}))$$

$$u_i = i_b \cdot R$$

$$R = h_{11} + R_E (1 + h_{21}) = 1000 + 600 \cdot 121 = \underline{73{,}6\,k\Omega}$$

5

$$u_o = - I_2 \cdot R_C = - h_{21} i_b R_C$$

5

$$\Rightarrow A_u = \frac{u_o}{u_i} = - \frac{h_{21} R_C}{R} = - \frac{120 \cdot 3k}{73{,}6k} = \underline{- 4{,}891}$$

5

5

$$R_i = \frac{u_i}{i_i} = \frac{i_b \cdot R}{i_b + \frac{i_b R}{R_{12}}} = R \,//\, R_{12} = \frac{73{,}6k \cdot 12{,}5k}{86{,}1k} = \underline{10{,}69k\Omega}$$

$$R_o = \frac{u_o}{i_o} = \frac{R_C i_o}{i_o} = R_C = \underline{3k\Omega} \quad (\text{kein } i_b \hat{=} 0)$$

5

1

Izpit 3 (13.6.2002)

- U_{GSQ}:

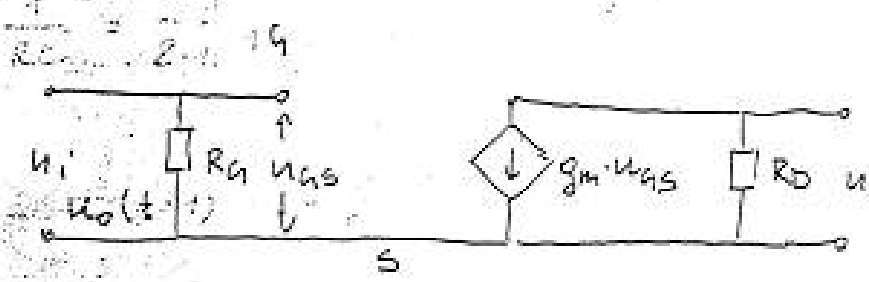
$$I_{DQ} = I_{DSS}\left(1 - \frac{U_{GSQ}}{U_P}\right)^2 \Rightarrow \sqrt{\frac{I_{DQ}}{I_{DSS}}} = 1 - \frac{U_{GSQ}}{U_P}$$

$$\boxed{U_{GSQ} = U_P\left(1 - \sqrt{\frac{I_{DQ}}{I_{DSS}}}\right) = -4\left(1 - \sqrt{\frac{3,9}{10}}\right) = -1,5\,V} \quad 4$$

- R_S (sledi iz $-U_{GSQ} \doteq U_{RSQ}$)

$$\boxed{R_S = \frac{-U_{GSQ}}{I_{DQ}} = 385\,\Omega} \quad 4$$

- R_D načrtamo v izmeničnih razmerah, ki določa ojačenje:



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$$\left.\begin{aligned} u_i &= u_{GS} \\ u_o &= -g_m u_{GS} R_D \end{aligned}\right\} \boxed{A_u = -g_m R_D} \Rightarrow \boxed{R_D = -\frac{A_u}{g_m} = -\frac{-4\cdot 10^{-3}}{3,125} = 1,28\,k\Omega} \quad 4$$

$$\boxed{g_m = \frac{\partial i_D}{\partial u_{GS}}\Big|_Q = -\frac{2\,I_{DSS}}{U_P}\left(1 - \frac{U_{GSQ}}{U_P}\right) = \frac{-0,02}{-4}\left(1 - \frac{-1,5}{-4}\right) = 3,125\,mS} \quad 4$$

- U_{DD} -1

$$\boxed{U_{DD}} = I_{DQ}\cdot R_D + U_{DSQ} + I_{DQ}\cdot R_S =$$

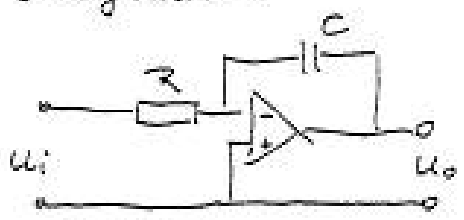
$$= I_{DQ}(R_D + R_S) + U_{DSQ} = \quad 4$$

-2V +

$$= 3,9\cdot 10^{-3}(1280 + 385) + 12 = 18,49\,V$$

Naloga 4 (13. 6. 2002)

- Integrator:



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$$\sum i = 0 \Big|_{\text{inv. vhod}} \Rightarrow \frac{u_i}{R} + C\frac{du_o}{dt} = 0$$

$$\frac{du_o}{dt} = -\frac{1}{RC}u_i \Rightarrow u_o = -\frac{1}{RC}\int_0^T u_i\,dt \;, \quad u_o(0) = 0\,V$$

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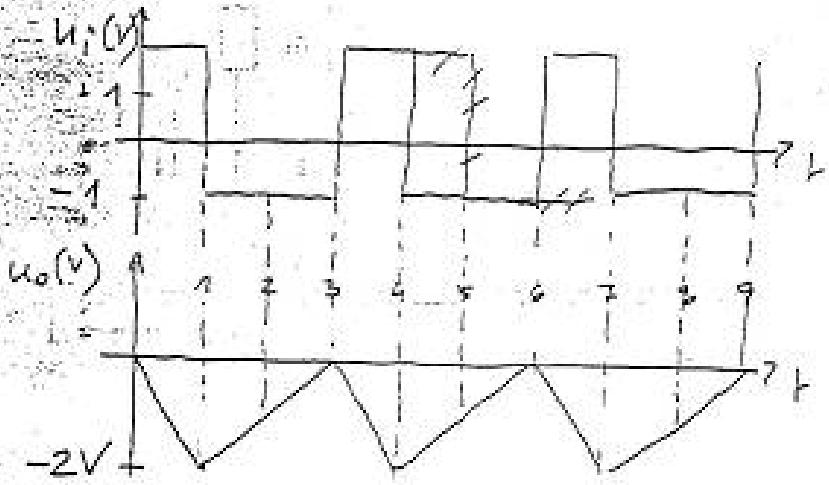
$$\frac{1}{RC} = \frac{1}{2\cdot10^{-9}\cdot0{,}5\cdot10^{6}} = 1000\,s^{-1}$$

$$u_o(t=1) = -\frac{1}{RC}\int_0^1 u_i\,dt + u_o(0) = -1000\cdot2\cdot10^{-3}\,t\Big|_0^1 + 0$$

$$= -2\,V \quad \text{(lin. padanje)}$$

$$u_o(t=3) = -\frac{1}{RC}\int_1^3 u_i\,dt + u_o(t=1) = -1000(-10^{-3})\,t\Big|_1^3 - 2V$$

$$= +1\cdot2 - 2 = 0\,V \quad \text{(lin. naraščanje)}$$



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