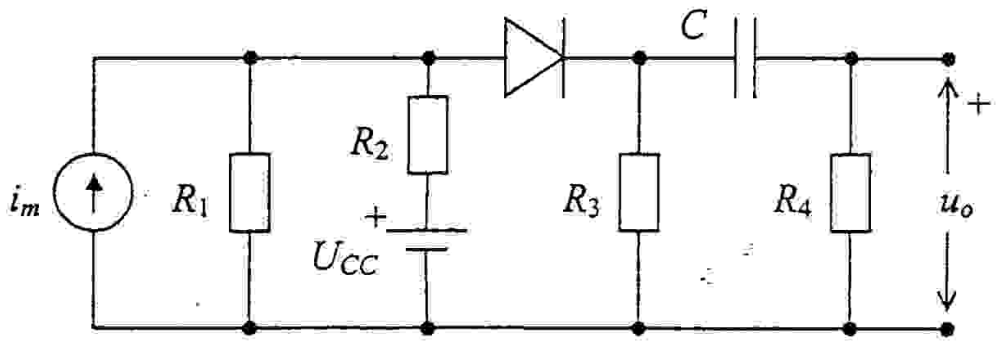
ELEKTRONIKA

(pisni izpit: 21.6.2002)

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

1. naloga (25%)

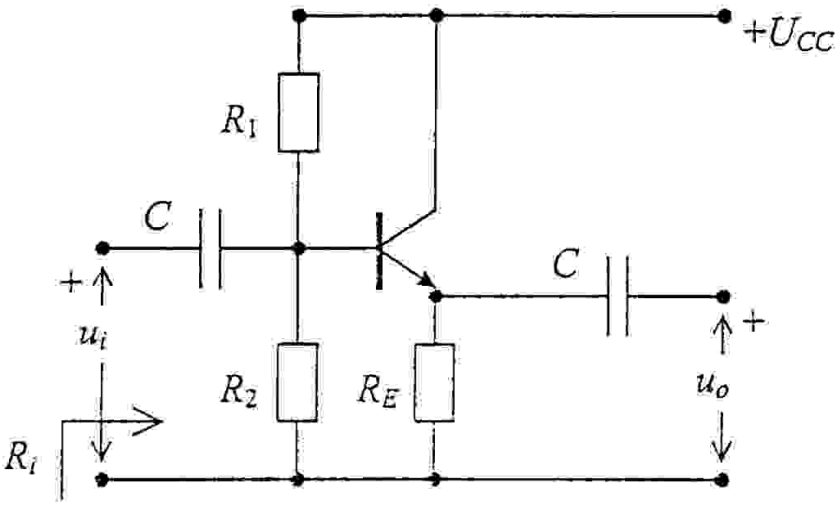
Ob uporabi podane karakteristike diode (priloga) izračunajte amplitudo izhodne napetosti podanega vezja.



$R_1 = 16\ \Omega$
$R_2 = 4\ \Omega$
$R_3 = 3{,}5\ \Omega$
$R_4 = 150\ \Omega$
$C = 1$ mF
$U_{CC} = 1$ V
$i_m = I_m \cos \omega t$;
$I_m = 7{,}5$ mA; $\omega = 10^3$ rad/s
$r_D = \dfrac{U_T}{I_{DQ}}$; $U_T = 26$ mV

2. naloga (25%)

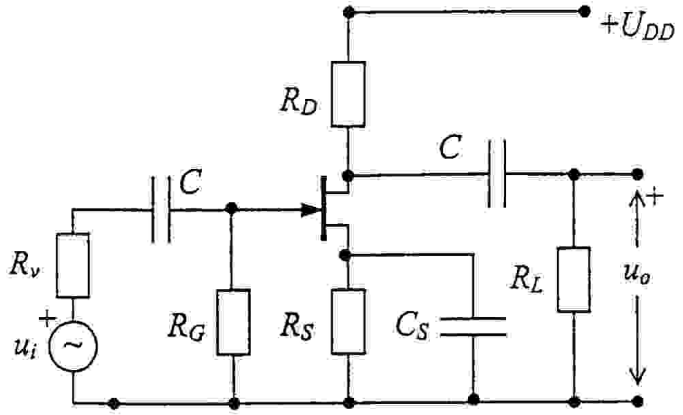
Za vezje emitorskega sledilnika narišite nadomestno shemo s hibridnimi parametri (za izmenične signale). Izračunajte napetostno ojačanje $A_u = \dfrac{u_o}{u_i}$ in vhodno notranjo upornost R_i.



$R_1 = R_2 = 18\ \text{k}\Omega$
$R_E = 1\ \text{k}\Omega$
$h_{11e} = 1\ \text{k}\Omega$
$h_{12e} = 0$
$h_{21e} = 150$
$h_{22e} = 10^{-4}$ S
$C = \infty$

3. naloga (25%)

Za ojačevalnik z na sliki narišite nadomestno shemo za majhne izmenične signale in izračunajte napetostno ojačanje $A_u = \frac{u_o}{u_i}$.

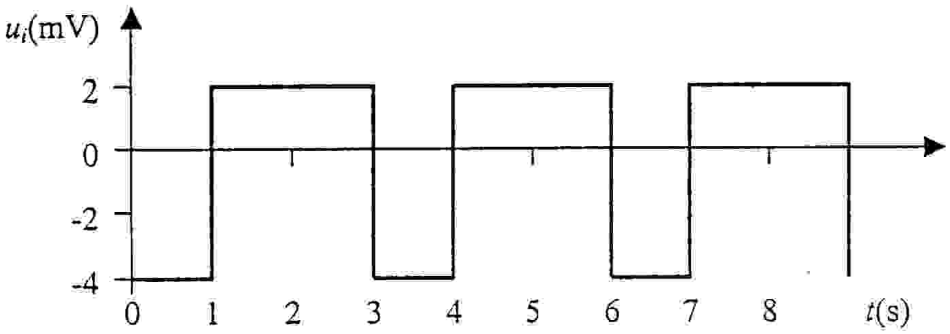


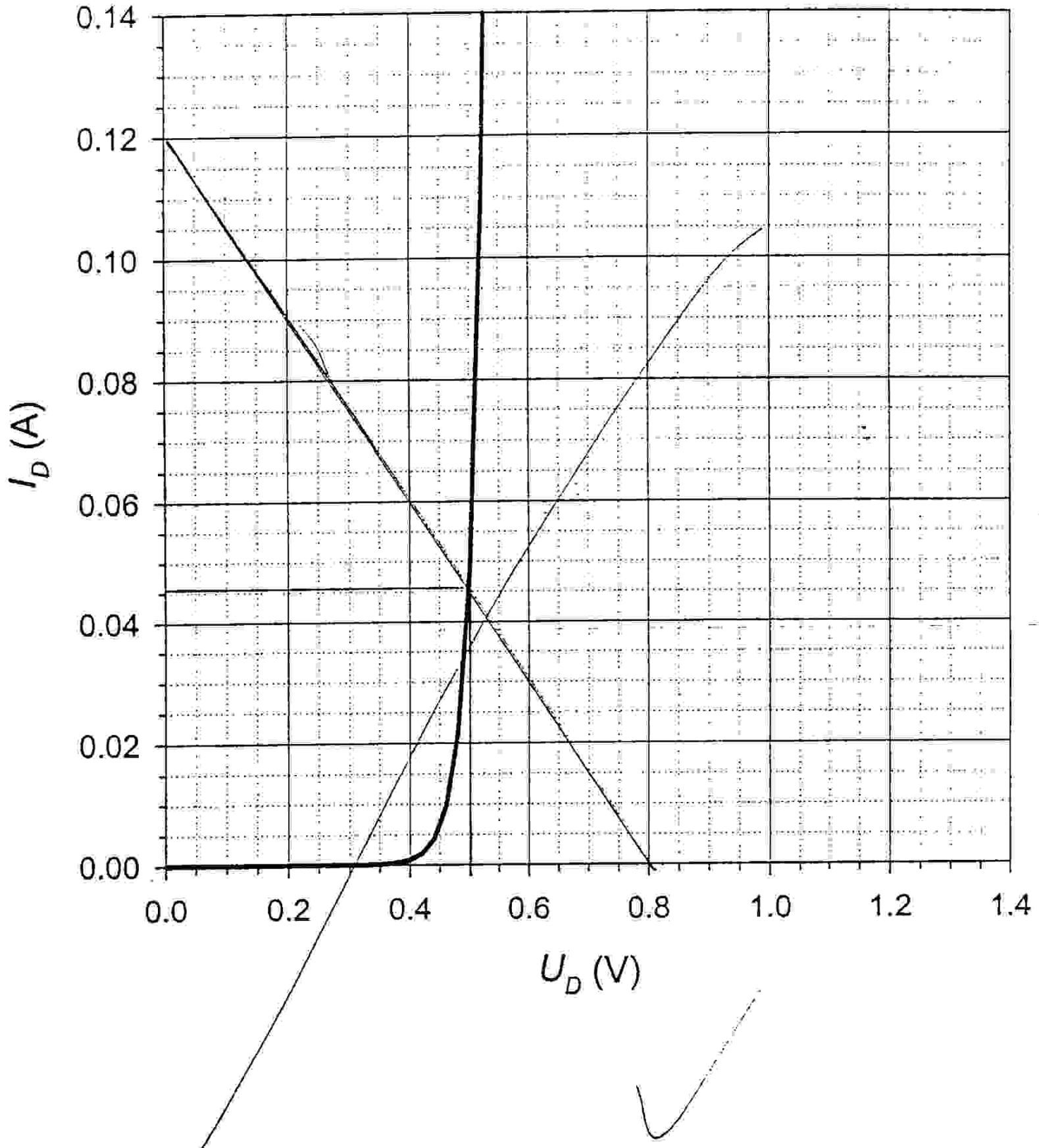
$R_L = R_D = 10\ \text{k}\Omega$
$R_S = 200\ \Omega$
$R_G = 100\ \text{k}\Omega$
$R_v = 5\ \text{k}\Omega$
$g_m = 5\ \text{mS}$
$r_d = 5\ \text{k}\Omega$
$C = C_S = \infty$

4. naloga (25%)

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

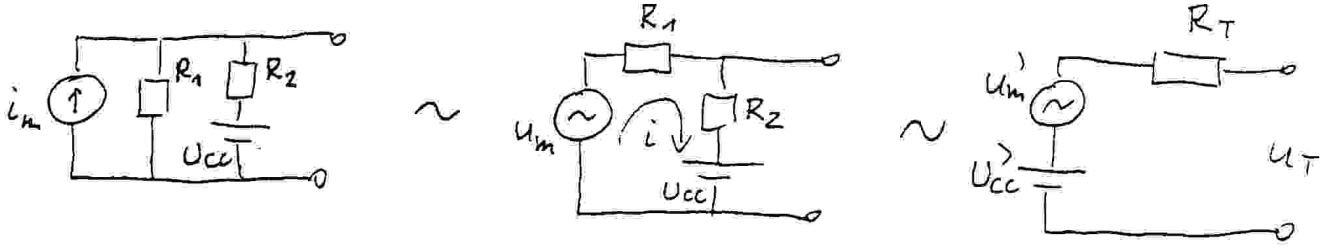
Kakšen signal dobimo na izhodu integratorja pri vhodnem signalu, kot ga prikazuje spodnja slika, če sta vrednosti elementov C = 4 nF ($u_C(0)$ = 0 V) in R = 200 kΩ in je napetost na kondenzatorju ob začetku opazovanja $u_C(0)$ = -2 V?




0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
I_D (A)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
U_D (V)

Naloga 1 (21.6.2002)

- Pretvorba levega dela vezja v Thevninov ekvivalent.



$$u_m = R_1 \cdot i_m = R_1 \cdot I_m \overset{\cos}{\sin}\omega t = U_m \overset{\cos}{\sin}\omega t$$

$$U_m = R_1 \cdot I_m = 16 \cdot \cancel{0{,}075}\ 0{,}0075 = 120\,mV$$

$$u_T = i \cdot R_2 + U_{cc}$$

$$u_m = i \cdot R_1 + i \cdot R_2 + U_{cc} \rightarrow i = \frac{u_m - U_{cc}}{R_1 + R_2}$$

$$u_T = \frac{u_m - U_{cc}}{R_1 + R_2} R_2 + U_{cc} = \underbrace{\frac{R_2}{R_1 + R_2} u_m}_{u_m'} + \underbrace{\frac{R_1}{R_1 + R_2} U_{cc}}_{U_{cc}'}$$

$$U_{cc}' = \frac{R_1}{R_1 + R_2} U_{cc} = 0{,}8 \cdot U_{cc} = \cancel{\quad\quad} = 0{,}8\,V$$

$$U_m' = \frac{R_2}{R_1 + R_2} U_m = 0{,}2 \cdot U_m = 24\,mV \qquad (u_m' = U_m' \overset{\cos}{\sin}\omega t)$$

$$R^T = R_1 \| R_2 = \frac{\cancel{32} \cdot \cancel{20}}{\cancel{52}} \overset{16 \cdot 4}{\underset{20}{\ }} = \cancel{3{,}4}\ 3.2\,\Omega$$

$U_{cc}' = 1{,}15\,V$

- Delovna točka diode (princip superpozicije, $u_m' \ll U_{CC}$), linearizacija v okolici delovne točke

$$U_{CC}' = U_D + I_D(R_T + R_3) \qquad 2$$

$$U_D(I_D = 0) = U_{CC}' = \underline{0{,}8\,V}$$

$$I_D(U_D = 0) = \frac{U_{CC}'}{R_T + R_3} = \underline{119 \doteq 120\,mA}$$

Odčitana delovna točka: $U_{DQ} = \underline{0{,}5\,V}$

$I_{DQ} = \underline{45\,mA}$ 2

- Dinamična upornost diode v D.T.

$$r_D = \frac{U_T}{I_{DQ}} = \frac{26 \cdot 10^{-3}}{45 \cdot 10^{-3}} = \underline{0{,}58\,\Omega} \qquad 2$$

- Izmenične razmere (odziv na u_m')

$$U_0 = U_{R_3} \cdot \frac{R_4}{R_4 + \frac{1}{j\omega C}} = \frac{150}{150 + \frac{1}{j}1} \doteq U_{R_3}$$

3

$$Z_C = \frac{1}{j\omega C} = -j \cdot \frac{1}{10^3 \cdot 10^{-3}} = -j1$$

$$|Z_C| = 1\,\Omega \ll R_4$$

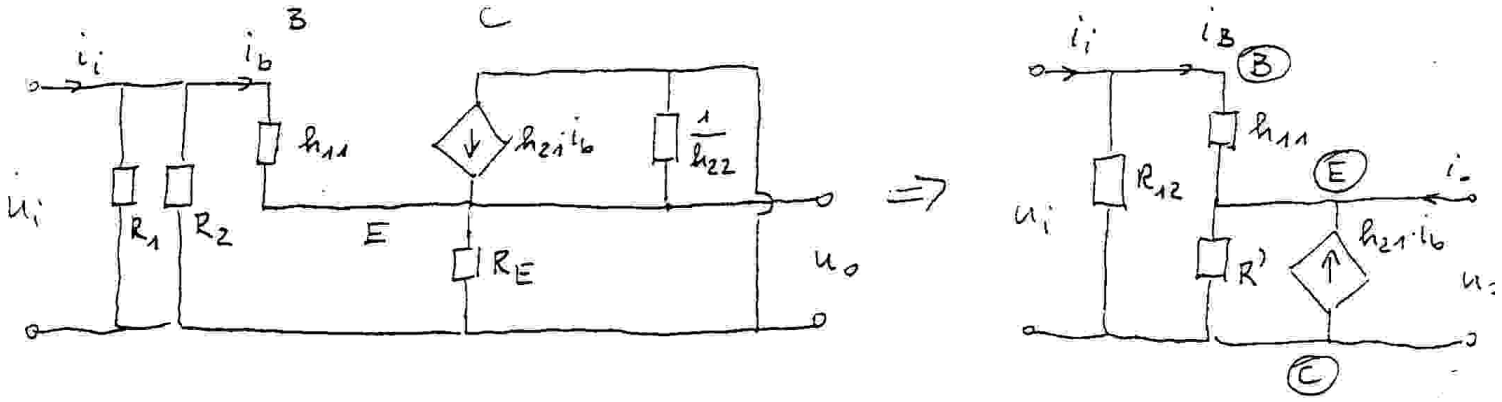
$$U_{R_3} = I \cdot R_3 \| R_4 = \frac{U_m'}{R_T + r_D + R_3 \| R_4} \cdot R_3 \| R_4$$

$$= U_m' \cdot \frac{\frac{3{,}5 \cdot 150}{153{,}5}}{3{,}2 + 0{,}58 + \frac{3{,}5 \cdot 150}{153{,}5}} = \frac{3{,}42}{3{,}2 + 0{,}58 + 3{,}42} \cdot U_m'$$

$$= 0{,}475 \cdot U_m' = \underline{11{,}4\,mV} = \underline{U_0}$$

naloga 2 (21.6.2002)

- Nadomestna shema



- Nove upornosti:

$$\underline{R_{12}} = R_1 \| R_2 = \frac{18k \cdot 18k}{36k} = \underline{9k\Omega}$$

$$\underline{R'} = R_E \| \frac{1}{h_{22}} = \frac{1k \cdot 10k}{11k} = \underline{909\Omega} \quad [\text{brez } h_{22}: R' = R_E = 1k\Omega]$$

- Nap. ojačanje:

$$\underline{u_i} = u_{h11} + u_{R'} = i_B \cdot h_{11} + (i_B + h_{21} i_b) \cdot R' =$$

$$= i_B \cdot (h_{11} + R'(1 + h_{21})) = \underline{i_B \cdot R}$$

[brez h_{22}: 152kΩ]

$$\underline{R} = h_{11} + R'(1 + h_{21}) = 1k + 909(1 + 150) = \underline{138{,}26k\Omega}$$

$$\underline{u_o} = u_{R'} = (i_b + h_{21} i_b) \cdot R' = i_b \cdot R'(1 + h_{21}) = \underline{i_b \cdot R''}$$

$$\underline{R''} = R'(1 + h_{21}) = 909(1 + 150) = \underline{137{,}26k\Omega}$$

[brez h_{22}: 151kΩ]

$$\underline{A_u} = \frac{u_o}{u_i} = \frac{i_B R''}{i_B R} = \frac{137{,}26k}{138{,}26k} = \underline{0{,}9928} \quad [\text{brez } h_{22}: 0{,}9934]$$

- Vhodna notranja up.:

2 $\underline{u_i} = i_b \cdot R$; $R = 138{,}26k\Omega$

3 $\underline{i_i} = i_{R12} + i_b = \frac{u_{R12}}{R_{12}} + i_b = \frac{u_{h11} + u_{R'}}{R_{12}} + i_b =$

$$= \frac{i_b \cdot R}{R_{12}} + i_b = i_b \left(\frac{R}{R_{12}} + 1\right) = \underline{i_b \cdot 16{,}36}$$

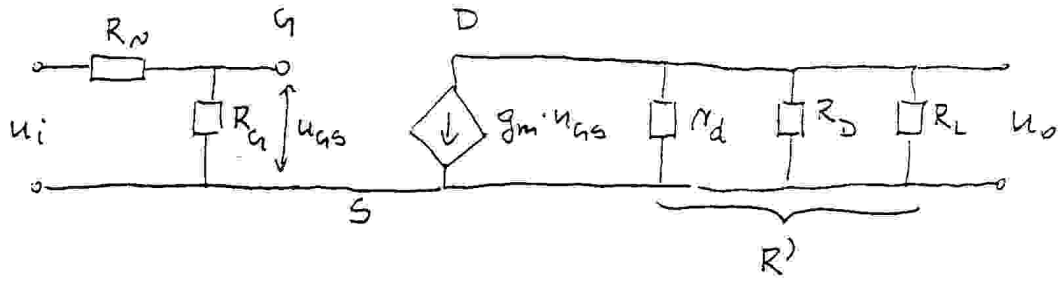
[brez h_{22}: $i_b \cdot 1$]

2 $\underline{R_i} = \frac{u_i}{i_i} = \frac{R \cdot i_b}{\left(\frac{R}{R_{12}} + 1\right) i_b} = R \| R_{12} = \frac{138{,}26k \cdot 9k}{147{,}26k} = \underline{8{,}45k\Omega}$

[brez h_{22}:

Naloga 3 (21.6.2002)

$C_S = \infty$



$$R' = r_d \parallel R_D \parallel R_L = \frac{1}{\frac{1}{5000} + \frac{1}{10000} + \frac{1}{10000}} = 2{,}5\ k\Omega$$

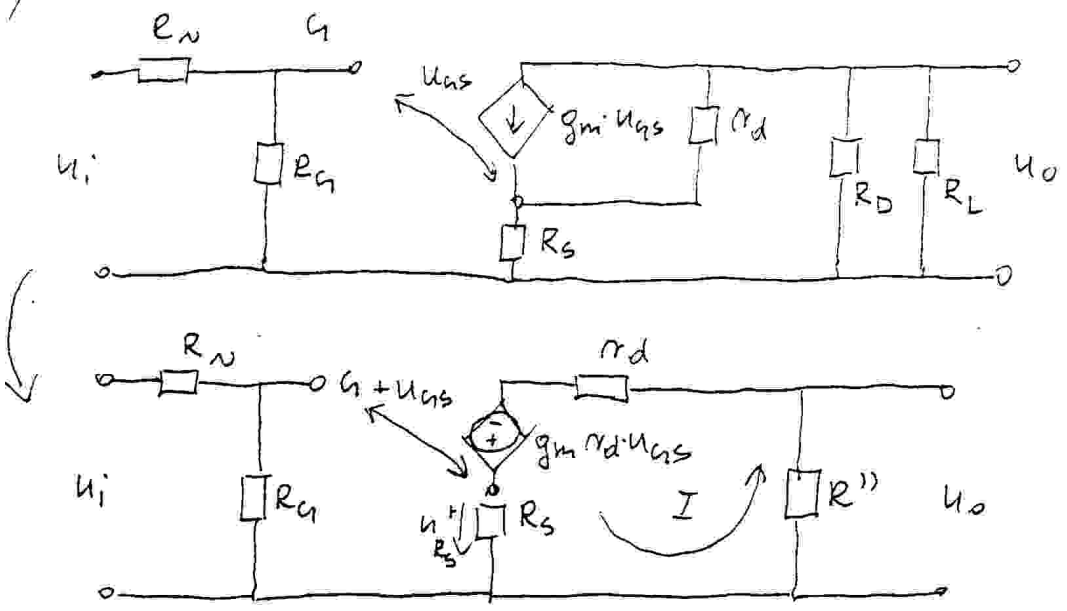
$$u_{GS} = \frac{R_G}{R_N + R_G} u_i = \frac{100k}{105k} u_i = 0{,}9524\, u_i$$

$$u_o = -g_m \cdot u_{GS} \cdot R' \Rightarrow -5 \cdot 10^{-3} \cdot 0{,}9524\, u_i \cdot 2{,}5 \cdot 10^{3} = -11{,}905\, u_i$$

$$A_u = \frac{u_o}{u_i} = \frac{-g_m \cdot R' \cdot R_G \cdot u_i}{(R_N + R_G)\, u_i} = -\frac{g_m \cdot R' \cdot R_G}{R_N + R_G} = -11{,}905$$

Do th

) $u_S = 0$



$$\underline{\underline{R''}} = R_D \| R_L = \frac{10k \cdot 10k}{20k} = \underline{\underline{5k\Omega}}$$

$$\underline{\underline{u_{GS}}}: \quad u_{R_G} = u_{GS} + u_{R_S} \Rightarrow$$

$$u_{GS} = u_{R_G} - u_{R_S} = \frac{R_G}{R_N + R_G} u_i - I \cdot R_S =$$

$$= \frac{R_G}{R_G + R_N} u_i - \frac{g_m r_d u_{GS}}{R_S + R'' + r_d} \cdot R_S \Rightarrow$$

$$u_{GS} \left(1 + \frac{g_m r_d R_S}{R_S + R'' + r_d} \right) = \frac{R_G}{R_G + R_N} u_i$$

$$u_{GS} = u_i \cdot \frac{R_G (R_S + R'' + r_d)}{(R_G + R_N)(R_S + R'' + r_d + g_m r_d R_S)} =$$

$$= u_i \cdot \frac{100k (200 + 5k + 5k)}{(100k + 5k)(200 + 5k + 5k + 5 \cdot 5 \cdot 200)} = 0{,}6391 \cdot u$$

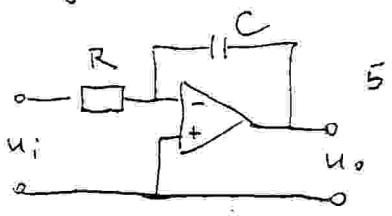
$$\underline{\underline{u_o}} = -I \cdot R'' = -\frac{g_m r_d}{R_S + R'' + r_d} \cdot u_{GS} \cdot R'' = -\frac{g_m r_d R''}{R_S + R'' + r_d} u_{GS}$$

$$= -0{,}6391 \cdot \frac{g_m r_d R''}{R_S + R'' + r_d} u_i = \frac{-R_G}{(R_G + R_N)} \cdot \frac{g_m r_d R''}{(R_S + R'' + r_d + g_m r_d R_S)}$$

$$\underline{\underline{A_u}} = -\frac{R_G g_m r_d R''}{(R_G + R_N)(R_S + R'' + r_d + g_m r_d R_S)} = \underline{\underline{-7{,}832}}$$

Naloga 4 (21.6.2002)

- Integrator



$$\sum i = 0 \Rightarrow$$

$$\frac{u_i}{R} + C\frac{du_o}{dt} = 0$$

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

$$\frac{1}{RC} = \frac{1}{2\cdot 10^5 \cdot \cancel{5}\cdot 10^{-9}} = \frac{1}{8\cdot 10^{5}\cdot 10^{-9}} = \cancel{1000}\,1250\ s^{-1} \qquad 2$$
4

$$u_o(t=1) = -\frac{1}{RC}\int_0^1 u_i\,dt + u_o(0) = -\cancel{1000}\,1250\,(-4\cdot 10^{-3})\cdot t\Big|_0^1 + u_o(0) =$$

$$= \underline{\underline{4V}} \quad (\text{lin. naraščanje}) \qquad (= 4V - 2V = \underline{\underline{2V}})$$
5V

$$u_o(t=3) = -\frac{1}{RC}\int_1^3 u_i\,dt + u_o(1) = -\cancel{1000}\,1250\,(2\cdot 10^{-3})\cdot t\Big|_1^3 + 4V =$$

$$= -4V + 4V = \underline{\underline{0V}} \quad (\text{lin. padanje})$$
$$(-5V + 3V = -2V)$$