

ELEKTRONIKA  
(pisni izpit: 28.11.2002)

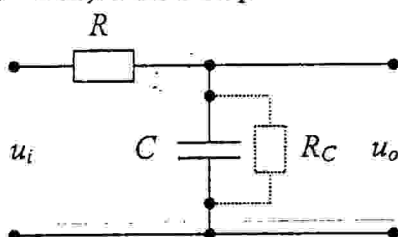
Čas reševanja: 90 minut  
Teža nalog: 25+25+25+25=100%

**1. naloga (25%)**

Za vezje nizkoprepustnega filtra izpeljite izraza za **prenosno funkcijo**  $H(j\omega)$  in za **fazni kot**  $\varphi$  za:

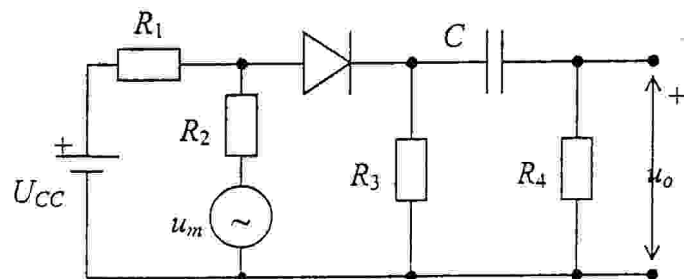
- idealni kondenzator ( $R_C = \infty$ );
- neidealni kondenzator ob upoštevanju končne vrednosti  $R_C$ .

Določite izraz za mejno frekvenco za idealni filter ( $R_C = \infty$ ) in izračunajte fazni kot  $\varphi$  pri tej frekvenci za neidealni filter ( $R_C = 10R$ ). Pazite na predznake kotov!



**2. naloga (25%)**

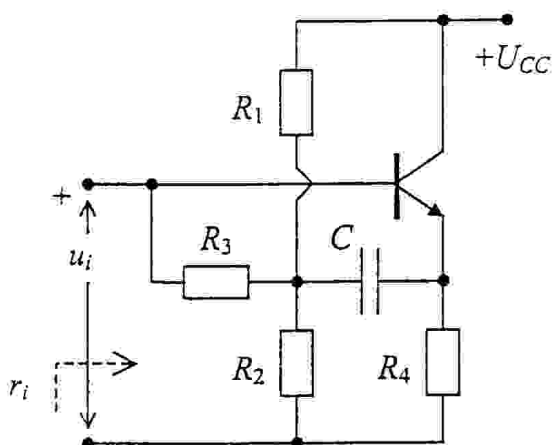
Ob uporabi podane karakteristike diode (priloga) določite delovno točko diode ( $I_{DQ}$  in  $U_{DQ}$ ) ter izračunajte amplitudo izhodne napetosti podanega vezja.



- $R_1 = 14 \Omega$
- $R_2 = 8 \Omega$
- $R_3 = 6 \Omega$
- $R_4 = 100 \Omega$
- $C = 0,1 \text{ mF}$
- $U_{CC} = 2,75 \text{ V}$
- $u_m = U_m \sin \omega t$ ;
- $U_m = 30 \text{ mV}$ ;  $\omega = 10^4 \text{ rad/s}$
- $r_D = \frac{U_T}{I_{DQ}}$ ;  $U_T = 25 \text{ mV}$

### 3. naloga (25%)

Za prikazani ojačevalnik narišite nadomestno vezje za majhne izmenične signale in izračunajte vhodno notranjo upornost.



Zunanji elementi vezja:

$$R_1 = 12 \text{ k}\Omega$$

$$R_2 = 10 \text{ k}\Omega$$

$$R_3 = 8 \text{ k}\Omega$$

$$R_4 = 6 \text{ k}\Omega$$

$$C = \infty$$

Parametri tranzistorja:

$$h_{ie}(h_{11e}) = 1,2 \text{ k}\Omega$$

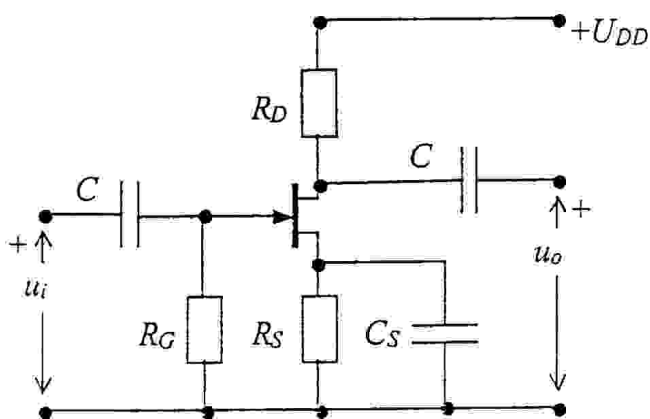
$$h_{re}(h_{12e}) = 0$$

$$h_{fe}(h_{21e}) = 120$$

$$h_{oe}(h_{22e}) = 0$$

### 4. naloga (25%)

Za ojačevalnik z JFET tranzistorjem na sliki narišite nadomestno vezje za majhne izmenične signale. Ojačevalnik 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 zahtevani delovni točki ( $I_{DQ}$ ,  $U_{DSQ}$ ) pri predpostavljenih vrednostih  $U_p$  in  $I_{DSS}$ .



Zahteve:

$$A_u = -5$$

$$I_{DQ} = 5 \text{ mA}$$

$$U_{DSQ} = 10 \text{ V}$$

Predpostavke:

$$R_G = 1 \text{ M}\Omega$$

$$C = C_S = \infty$$

$$r_D \gg R_D$$

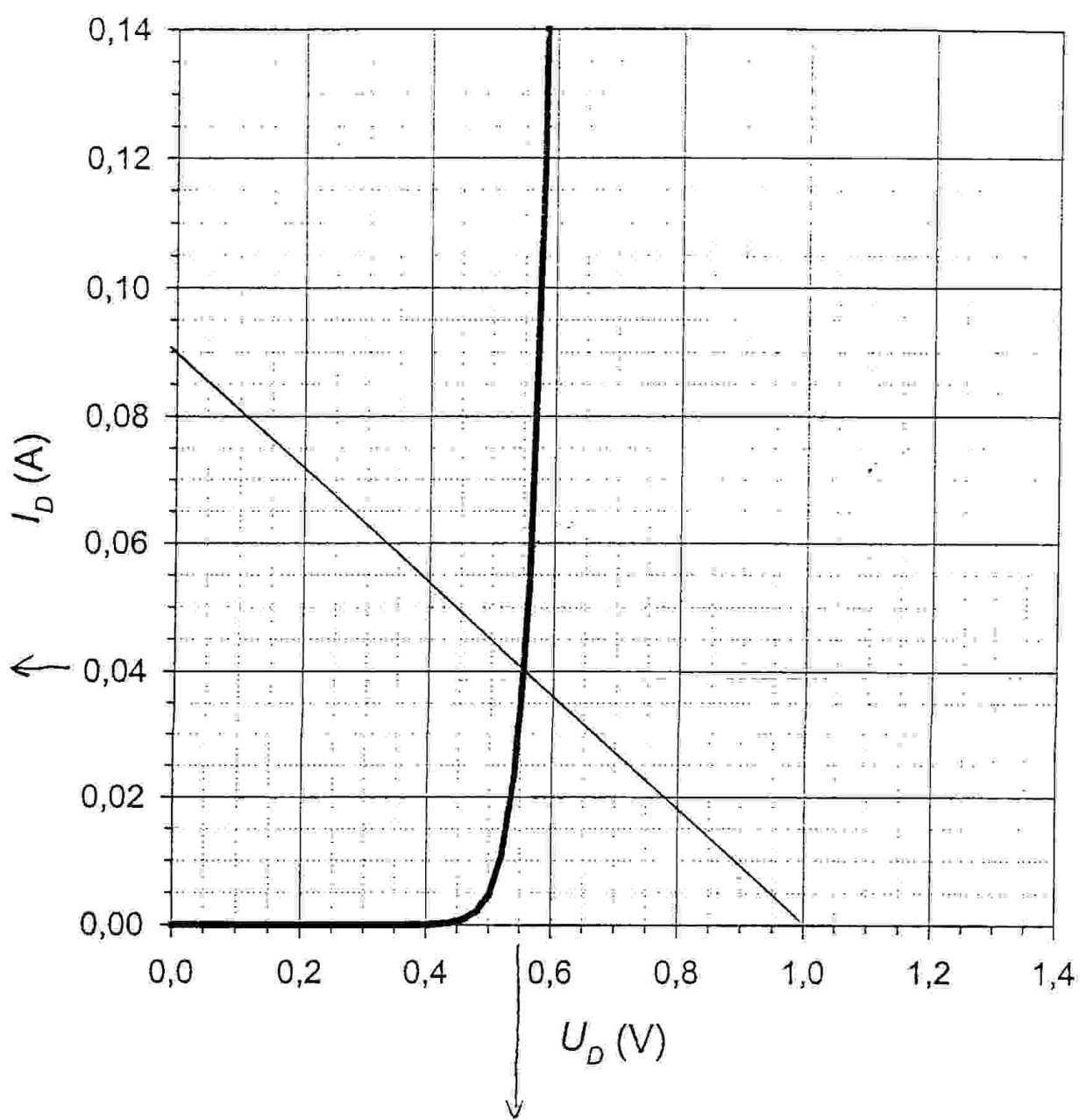
$$U_p = -5 \text{ V}$$

$$I_{DSS} = 12 \text{ mA}$$

$$i_D = I_{DSS} \left( 1 - \frac{u_{GS}}{U_p} \right)^2$$

$$g_m = \left. \frac{\partial i_D}{\partial u_{GS}} \right|_Q$$

Iščemo:  $R_D$ ,  $R_S$ ,  $U_{DD}$



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$\therefore = \text{~~5~~ } 5,111 \Omega$

# 4. naloga

- Prenosni funkciji

$$H_1(j\omega) = \frac{U_o(j\omega)}{U_i(j\omega)} = \frac{Z_c}{R + Z_c} = \frac{\frac{1}{j\omega C}}{R + \frac{1}{j\omega C}} = \frac{1}{1 + j\omega RC}$$

$$H_2(j\omega) = \frac{Z_c'}{R + Z_c'} = \frac{\frac{1}{j\omega C} \parallel R_c}{R + \frac{1}{j\omega C} \parallel R_c} = \frac{\frac{R_c}{j\omega C}}{R + \frac{R_c}{j\omega C}} = \frac{R_c}{R_c + j\omega C R}$$

$$= \frac{\frac{R_c \cdot j\omega C}{j\omega C (1 + j\omega C R_c)}}{R + \frac{R_c}{1 + j\omega C R_c}} = \frac{R_c (1 + j\omega R_c C)}{(1 + j\omega R_c C) \cdot (R_c + R + j\omega C R_c R)}$$

$$= \frac{R_c}{R + R_c + j\omega C R_c R}$$

$R_c \parallel \frac{1}{j\omega C} = \frac{\frac{R_c}{j\omega C}}{R_c + \frac{1}{j\omega C}} = \frac{R_c}{R_c + j\omega C R}$

$$H_1(j\omega) = \frac{1 - j\omega RC}{1 + \omega^2 R^2 C^2} = \frac{1}{1 + (\omega RC)^2} - j \frac{\omega RC}{1 + (\omega RC)^2}$$

$$H_2(j\omega) = \frac{R_c (R + R_c - j\omega R_c RC)}{(R + R_c)^2 + (\omega R_c RC)^2} = \frac{R_c (R + R_c)}{(R + R_c)^2 + (\omega R_c RC)^2} - j \frac{\omega R_c^2 RC}{(R + R_c)^2 + (\omega R_c RC)^2}$$

- Fazni kot ( $R_c \rightarrow \infty$ )

$$\varphi_{H_1} = \arctan \frac{\text{Im}[H_1]}{\text{Re}[H_1]} = \arctan -\omega RC = -\arctan RC\omega = -45^\circ$$

$$\Rightarrow \omega RC = \tan 45^\circ = 1 \Rightarrow \underline{f_0 = \frac{1}{2\pi RC}} \quad \text{mejna frekvenca}$$

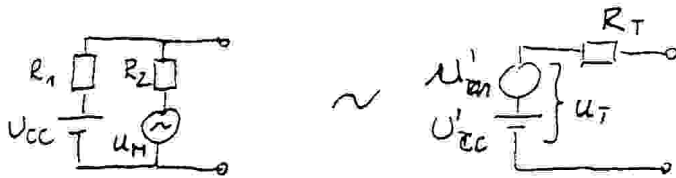
- Fazni kot pri  $f_0$  za  $R_c = 10R$

$$\varphi_{H_2} = \arctan \frac{\text{Im}[H_2]}{\text{Re}[H_2]} = \arctan - \frac{\omega R_c^2 RC}{R_c (R + R_c)} = \arctan - \frac{\omega R_c RC}{R + R_c} = -\arctan \frac{\omega R_c RC}{R + R_c}$$

$$= \arctan - \frac{\omega \cdot 10R^2 C}{R(1+10)} = \arctan - \frac{10\omega RC}{11}$$

$$\varphi|_{\text{pri } f_0} = \arctan - \frac{10}{11} \cdot 2\pi \cdot \frac{1}{2\pi RC} \cdot RC = \arctan - \frac{10}{11} = -42,27^\circ$$

- Napajalni del vezja transformiramo v Théveninovo ekvivalent



$$\boxed{R_T = R_1 \parallel R_2 = \frac{R_1 R_2}{R_1 + R_2} = \frac{14 \cdot 8}{22} = \underline{\underline{5,091 \Omega}}$$

$$\boxed{U'_{cc} = i_{R_2}^{DC} \cdot R_2 = \frac{U_{cc}}{R_1 + R_2} R_2 = \frac{R_2}{R_1 + R_2} U_{cc} = \frac{8}{22} \cdot 2,75 = \underline{\underline{1V}}$$

$$u'_m = \cancel{u_m} \cdot i_{R_1}^{AC} \cdot R_1 = \frac{u_m}{R_1 + R_2} R_1 = \frac{R_1}{R_1 + R_2} u_m = \frac{14}{22} \cdot u_m =$$

$$\boxed{U'_m = U_m \cdot \frac{R_1}{R_1 + R_2} = 30mV \cdot \frac{14}{22} = \underline{\underline{19,091mV}}$$

- Določite delovne točke diode:

$$U'_{cc} = U_D + I_D (R_T + R_3)$$

$$\boxed{U_D (I_D = 0) \rightarrow U_D = U'_{cc} = \underline{\underline{1V}} \quad 2$$

$$\boxed{I_D (U_D = 0) \rightarrow I_D = U'_{cc} \cdot \frac{1}{R_T + R_3} = \underline{\underline{90mA}} \quad 2$$

Iz karakteristike sledi:

$$\boxed{I_{DQ} = \underline{\underline{40mA}} \quad 2$$

$$\boxed{U_{DQ} = \underline{\underline{0,55V}} \quad 2$$

- Dinamična upornost diode v delovni točki:

$$\boxed{r_D = \frac{U_T}{I_{DQ}} = \frac{0,025V}{0,040A} = \underline{\underline{0,625 \Omega}} \quad 2$$

- Odziv na  $u'_m$

$$Z_C = \frac{1}{\omega C} = \frac{1}{10^4 \cdot 10^{-4}} = 1 \Omega \ll R_4 = 100 \Omega \Rightarrow C \text{ zanedajamo}$$

$$\boxed{U_D} = U_{R4} = U_{R3}$$

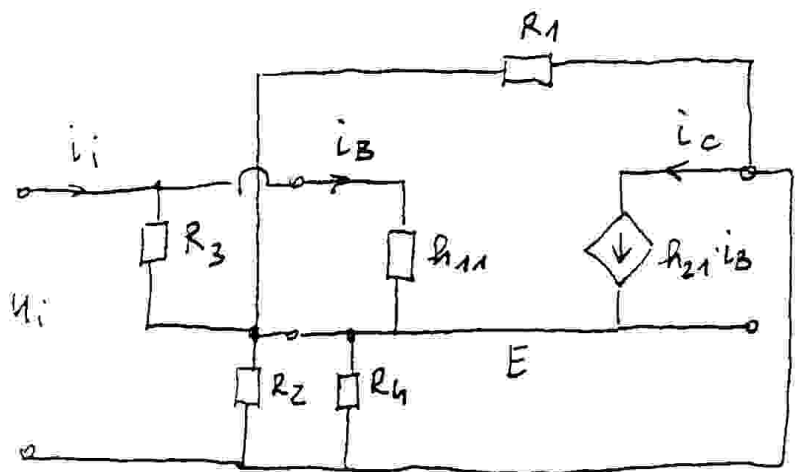
$$U_{R3} = I \cdot R_3 \parallel R_4 = \frac{U'_m}{R_T + r_D + R_3 \parallel R_4} \cdot R_3 \parallel R_4 = U'_m \cdot \frac{6 \cdot 100}{5,091 + 0,625 + 106}$$

$$= 19,091mV \cdot \frac{5,660}{5,091 + 0,625 + 5,660} = 19,091 \cdot 0,496$$

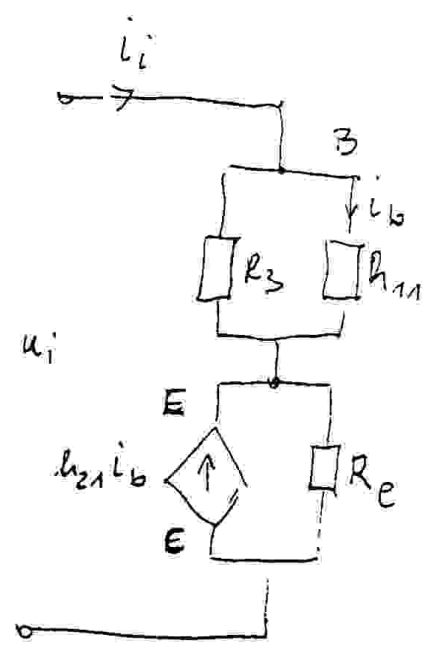
$$= \underline{\underline{9,499mV}}$$

5. naloga

Nadomestno vezje



⇒



$$R_e = R_1 \parallel R_2 \parallel R_4 = \frac{R_1 R_2 R_4}{R_1 R_2 + R_2 R_4 + R_1 R_4} = \frac{12 \cdot 10 \cdot 6}{12 \cdot 10 + 10 \cdot 6 + 12 \cdot 6} = \underline{\underline{2,857 \text{ k}\Omega}}$$

$$R_i = \frac{u_i}{i_i}$$

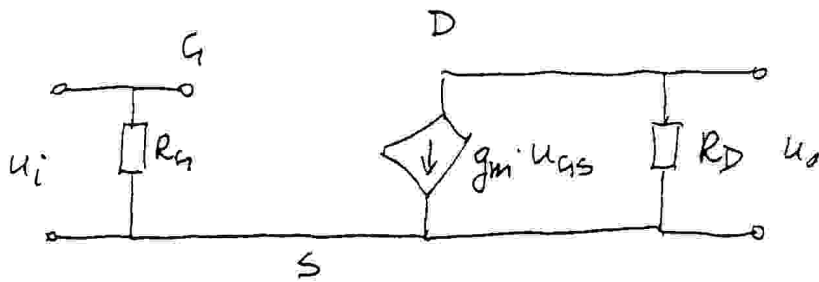
$$i_b = i_i \cdot \frac{R_3}{R_3 + h_{11}} \quad (\text{tokovni delilnik})$$

$$u_i = R_e \cdot (i_i + h_{21} \cdot i_b) + h_{11} \cdot i_b = i_i \cdot R_e + i_i \cdot \frac{R_3 R_e h_{21}}{R_3 + h_{11}} + i_i \cdot \frac{h_{11} \cdot R_3}{R_3 + h_{11}}$$

$$R_i = \frac{u_i}{i_i} = R_e + \frac{R_3 R_e h_{21}}{R_3 + h_{11}} + \frac{h_{11} R_3}{R_3 + h_{11}} = 2,857 \text{ k} + \frac{8 \text{ k} \cdot 2,857 \text{ k} \cdot 120}{8 \text{ k} + 1,2 \text{ k}} + \frac{1,2 \text{ k} \cdot 8 \text{ k}}{9,2 \text{ k}} =$$

$$= 2,857 \text{ k} + 298,122 \text{ k} + 1,043 \text{ k} = \underline{\underline{302,022 \text{ k}\Omega}}$$

#### 4. naloga



relativna točka:

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

$$\Rightarrow \boxed{U_{GSQ}} = U_P \left(1 - \sqrt{\frac{I_{DQ}}{I_{DSS}}}\right) = -5 \left(1 - \sqrt{\frac{0,005}{0,012}}\right) = \underline{\underline{-1,773V}}$$

$$U_{RSQ} = -U_{GSQ} \Rightarrow U_{RSQ} = I_{DQ} \cdot R_S$$

$$\Rightarrow R_S = \frac{-U_{GSQ}}{I_{DQ}} = \frac{1,773}{0,005} = \underline{\underline{354,5\Omega}}$$

napajanje:

$$\begin{aligned} \boxed{U_{DD}} &= I_{DQ} (R_D + R_S) + U_{DSQ} = \\ &= 0,005 \cdot (1614 + 354,5) + 10 = \underline{\underline{19,84V}} \end{aligned}$$

rečanje:

$$\left. \begin{aligned} u_i &= u_{GS} \\ u_o &= -g_m \cdot R_D \cdot u_{GS} \end{aligned} \right\} \Rightarrow A_u = \frac{u_o}{u_i} = -g_m \cdot R_D = -5$$

$$\Rightarrow \boxed{R_D} = \frac{A_u}{-g_m} = \frac{-5}{-3,098 \text{ mS}} = \underline{\underline{1,614 \text{ k}\Omega}}$$

transk.

$$\begin{aligned} \boxed{g_m} &= \left. \frac{\partial I_D}{\partial u_{GS}} \right|_{I_{DQ}} = -2 \cdot I_{DSS} \left(1 - \frac{U_{GSQ}}{U_P}\right) \frac{1}{U_P} = \frac{2 \cdot 0,012}{-5} \left(1 - \frac{-1,773}{-5}\right) \\ &= \underline{\underline{3,098 \text{ mS}}} \end{aligned}$$