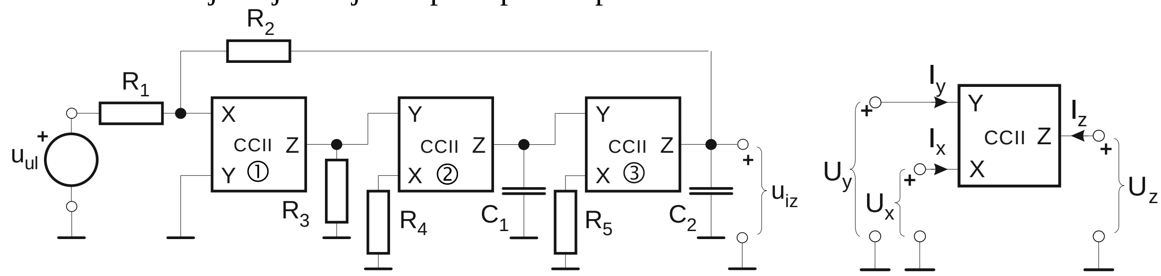
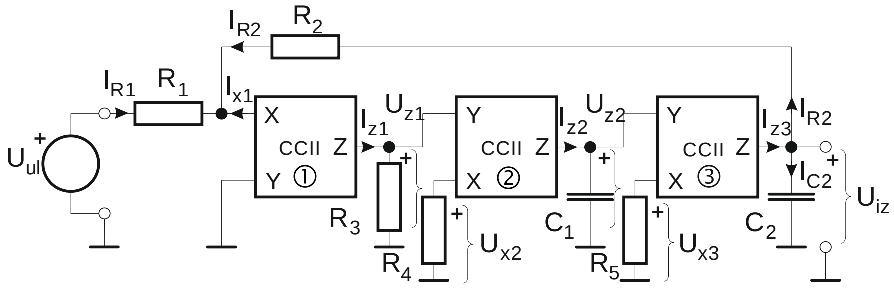
ZAVRŠNI ISPIT IZ ELEKTRIČNIH KRUGOVA 2016-2017 – Rješenja

1. Za električni krug prikazan slikom izračunati valni oblik napona $u_{iz}(t)$ za $t>0$ kao odziv, ako je zadana pobuda $u_{ul}(t)=\delta(t)$[V], a početni naponi na kapacitetima su jednaki nula. Zadane su normalizirane vrijednosti elemenata $R_1=1$, $R_2=1$, $R_3=1$, $R_4=1$, $R_5=1$, $C_1=1$, $C_2=1$. Za strujni prijenosnik druge generacije (CCII) vrijede slijedeće definicijske jednadžbe: $u_x=u_y$, $i_y=0$, $i_z=i_x$ uz referentna usmjerenja struja i napona prilaza prikazana na slici.



Rješenje:



a) Za prvi CCII vrijedi: **(1 bod)**

$$U_{z1}=I_{z1}\cdot R_3,\ I_{y1}=0,\ U_{x1}=0,\ U_{y1}=0,$$

$$I_{z1}=I_{x1}=-(I_{R1}+I_{R2})=-\left(\frac{U_{ul}}{R_1}+\frac{U_{iz}}{R_2}\right)\Rightarrow\boxed{U_{z1}=-U_{ul}\frac{R_3}{R_1}-U_{iz}\frac{R_3}{R_2}}$$

b) Za drugi CCII vrijedi: **(1 bod)**

$$U_{z2}=I_{z2}\cdot\frac{1}{sC_1},\ I_{y2}=0,\ U_{x2}=U_{y2}=U_{z1},\ I_{z2}=I_{x2}=\frac{U_{x2}}{R_4}\Rightarrow\boxed{U_{z2}=U_{z1}\frac{1}{sR_1C_1}}$$

c) Za treći CCII vrijedi: **(1 bod)**

$$I_{z3}=I_{C2}+I_{R2}=U_{iz}sC_2+\frac{U_{iz}}{R_2}=U_{iz}\left(sC_2+\frac{1}{R_2}\right)\Rightarrow U_{iz}=\frac{I_{z3}}{sC_2+1/R_2}$$

$$I_{z3}=I_{x3}=\frac{U_{x3}}{R_5}=\frac{U_{y3}}{R_5}=\frac{U_{z2}}{R_5}\Rightarrow\boxed{U_{iz}=\frac{1}{R_5}\cdot\frac{1}{sC_2+1/R_2}\cdot U_{z2}}$$

d) Nakon sređivanja do sada napisanih izraza: **(1 bod)**

$$U_{iz}=-\frac{1}{R_5}\cdot\frac{1}{sC_2+1/R_2}\cdot\frac{1}{sR_1C_1}\cdot\left(U_{ul}\frac{R_3}{R_1}+U_{iz}\frac{R_3}{R_2}\right)$$

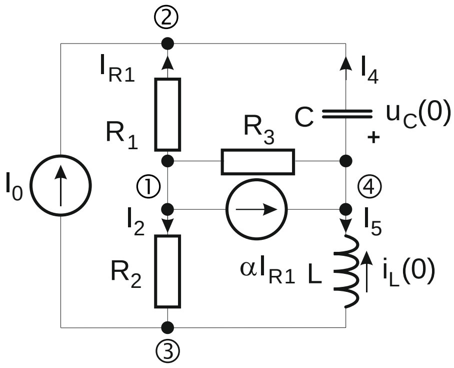
e) Uz uvrštene vrijednosti elemenata: **(1 bod)**

$$U_{iz}=-\frac{1}{s+1}\cdot\frac{1}{s}\cdot(U_{ul}+U_{iz})\Rightarrow U_{iz}\left(1+\frac{1}{s+1}\cdot\frac{1}{s}\right)=-\frac{1}{s+1}\cdot\frac{1}{s}\cdot U_{ul}\Rightarrow$$

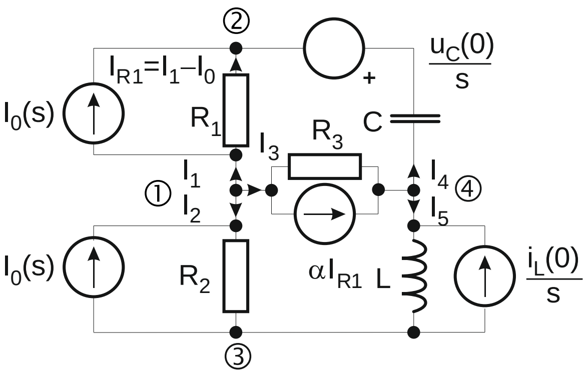
$$U_{iz}\frac{s^2+s+1}{s(s+1)}=-\frac{1}{s(s+1)}U_{ul}\Rightarrow U_{iz}(s)=-\frac{1}{s^2+s+1}U_{ul}(s);\ U_{ul}(s)=1\Rightarrow$$

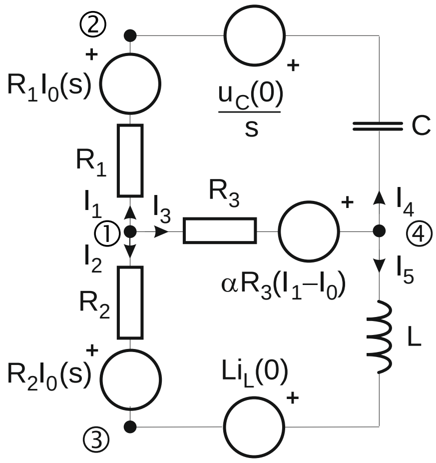
$$U_{iz}(s)=-\frac{1}{s^2+s+1}=-\frac{2}{\sqrt{3}}\cdot\frac{\sqrt{3}/2}{(s+1/2)^2+\left(\sqrt{3}/2\right)^2}\Rightarrow \underline{u_{iz}(t)=-\frac{2\sqrt{3}}{3}\cdot e^{-\frac{t}{2}}\cdot\sin\left(\frac{\sqrt{3}}{2}t\right)\cdot S(t)}$$

2. Zadan je električni krug prema slici. Poštujući oznake čvorišta i grana nacrtati pripadni orijentirani graf i napisati spojnu matricu **S**. Napisati naponsko-strujne jednadžbe grana u matričnom obliku te ispisati matricu impedancija grana $\mathbf{Z}_b$ i vektor početnih uvjeta i nezavisnih izvora grana $\mathbf{U}_{0b}$. Matrica $\mathbf{Z}_b$ mora biti regularna. Napisati temeljni sustav jednadžbi petlji, odnosno odrediti matrice impedancija petlji $\mathbf{Z}_p$ i vektor početnih uvjeta i nezavisnih izvora petlji $\mathbf{U}_{0p}$.



Rješenje: Posmicanje strujnog izvora i primjena Laplaceove transformacije **(1 bod)**
Da bismo na ispravan način postavili naponsko strujne jednadžbe grana, moramo paziti da nakon transformacije (posmicanja strujnog izvora) mreža ostane ista i da naponsko strujni odnosi unutar mreže ostanu nepromijenjeni. Odnosno, moramo paziti kako ćemo označiti pojedine struje grana.





(1 bod)

Naponsko-strujne jednadžbe grana:

$$U_1 = I_1 \cdot R_1 - I_0 \cdot R_1$$

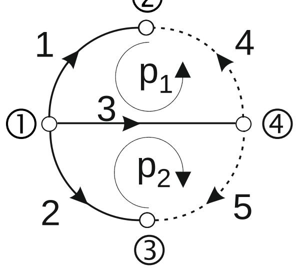
$$U_2 = I_2 \cdot R_2 + I_0 \cdot R_2$$

$$U_3 = -I_1 \cdot \alpha R_3 + I_3 \cdot R_3 + I_0 \cdot \alpha R_3$$

$$U_4 = I_4 \cdot \frac{1}{sC} + \frac{u_C(0)}{s}$$

$$U_5 = I_5 \cdot sL + Li_L(0)$$

Orijentirani graf i temeljne petlje:



Spojna matrica:

$$\mathbf{S} = \begin{array}{c} \\ (p_1) \\ (p_2) \end{array} \begin{array}{c} \begin{array}{ccccc} 1 & 2 & 3 & 4 & 5 \end{array} \\ \begin{bmatrix} -1 & 0 & 1 & 1 & 0 \\ 0 & -1 & 1 & 0 & 1 \end{bmatrix} \end{array}$$

Naponsko-strujne relacije grana u matričnom obliku: $\mathbf{U}_b = \mathbf{Z}_b \cdot \mathbf{I}_b + \mathbf{U}_{0b}$

$$\underbrace{\begin{bmatrix} U_1 \\ U_2 \\ U_3 \\ U_4 \\ U_5 \end{bmatrix}}_{\mathbf{U}_b} = \underbrace{\begin{bmatrix} R_1 & 0 & 0 & 0 & 0 \\ 0 & R_2 & 0 & 0 & 0 \\ -\alpha R_3 & 0 & R_3 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{sC} & 0 \\ 0 & 0 & 0 & 0 & sL \end{bmatrix}}_{\mathbf{Z}_b} \cdot \underbrace{\begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{bmatrix}}_{\mathbf{I}_b} + \underbrace{\begin{bmatrix} -I_0 R_1 \\ I_0 R_2 \\ \alpha R_3 I_0 \\ \frac{u_C(0)}{s} \\ Li_L(0) \end{bmatrix}}_{\mathbf{U}_{0b}}$$ **(1 bod)**

Matrica $\mathbf{Z}_b$ je regularna, jer nema niti jedan stupac niti redak jednak nuli. Temeljni sustav jednadžbi petlji u matričnom obliku: $\mathbf{Z}_p \cdot \mathbf{I}_p = \mathbf{U}_{0p}$, gdje su (matrice $\mathbf{Z}_p$ i $\mathbf{U}_{0p}$):

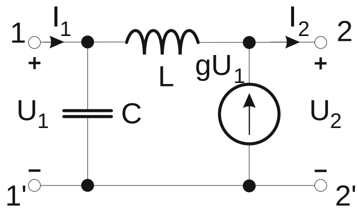
$$\mathbf{Z}_p = \mathbf{S} \cdot \mathbf{Z}_b \cdot \mathbf{S}^T = \begin{bmatrix} -1 & 0 & 1 & 1 & 0 \\ 0 & -1 & 1 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} R_1 & 0 & 0 & 0 & 0 \\ 0 & R_2 & 0 & 0 & 0 \\ -\alpha R_3 & 0 & R_3 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{sC} & 0 \\ 0 & 0 & 0 & 0 & sL \end{bmatrix} \cdot \mathbf{S}^T =$$

$$= \begin{bmatrix} -R_1 - \alpha R_3 & 0 & R_3 & \frac{1}{sC} & 0 \\ -\alpha R_3 & -R_2 & R_3 & 0 & sL \end{bmatrix} \cdot \begin{bmatrix} -1 & 0 \\ 0 & -1 \\ 1 & 1 \\ 1 & 0 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} R_1 + \alpha R_3 + R_3 + \frac{1}{sC} & R_3 \\ \alpha R_3 + R_3 & R_2 + R_3 + sL \end{bmatrix}$$ **(1 bod)**

$$\mathbf{U}_{0p} = -\mathbf{S} \cdot \mathbf{U}_{0b} = -\begin{bmatrix} -1 & 0 & 1 & 1 & 0 \\ 0 & -1 & 1 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} -I_0 R_1 \\ I_0 R_2 \\ \alpha R_3 I_0 \\ \frac{u_C(0)}{s} \\ Li_L(0) \end{bmatrix} = -\begin{bmatrix} I_0 R_1 + \alpha R_3 I_0 + \frac{u_C(0)}{s} \\ -I_0 R_2 + \alpha R_3 I_0 + Li_L(0) \end{bmatrix}$$ **(1 bod)**

Rješenje: $\mathbf{Z}_p \cdot \mathbf{I}_p = \mathbf{U}_{0p} \Rightarrow \mathbf{I}_p = \begin{bmatrix} I_{p1} \\ I_{p2} \end{bmatrix}$

3. Za četveropol prikazan slikom izračunati prijenosne [*a*]-parametre i napisati matricu [*a*]-parametara. Pomoću poznatih [*a*]-parametara izračunati naponsku prijenosnu funkciju četveropola $T(s)=U_2(s)/U_1(s)$ te ulaznu impedanciju $Z_{ul1}(s)=U_1(s)/I_1(s)$ ako je na izlaznom prilazu (2–2') spojen otpor *R*. Da li je četveropol: *a*) recipročan, *b*) simetričan ? Obrazložiti odgovor. Zadane su normalizirane vrijednosti elemenata R=1, L=1, C=1 i parametar g=1.



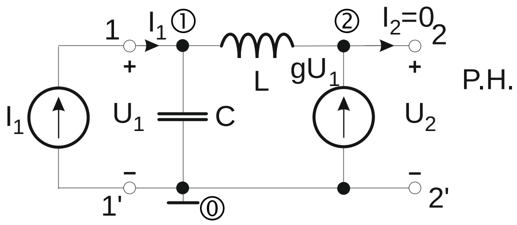
Rješenje:

[*a*]-parametri:

$$U_1 = A\cdot U_2 + B\cdot I_2$$

$$I_1 = C\cdot U_2 + D\cdot I_2$$

$$\underline{I_2 = 0} \quad A = \left.\frac{U_1}{U_2}\right|_{I_2=0} \qquad C = \left.\frac{I_1}{U_2}\right|_{I_2=0}$$



$$(1)\ U_1\left(\frac{1}{sL}+sC\right)-U_2\frac{1}{sL}=I_1$$

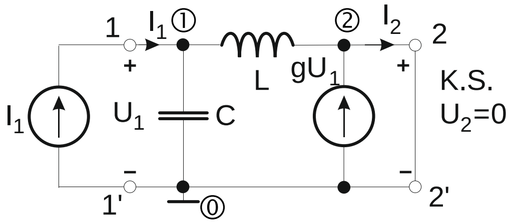
$$(2)\ -U_1\frac{1}{sL}+U_2\frac{1}{sL}=gU_1$$

$$(2)\Rightarrow \left(g+\frac{1}{sL}\right)U_1=\frac{1}{sL}U_2 \Rightarrow U_1=\frac{1}{gsL+1}U_2 \Rightarrow A=\frac{U_1}{U_2}=\frac{1}{gsL+1}$$

$$(2)\rightarrow(1)\Rightarrow U_2\frac{1}{gsL+1}\left(\frac{1}{sL}+sC\right)-U_2\frac{1}{sL}=I_1 \Rightarrow C=\frac{I_1}{U_2}=\frac{1}{gsL+1}\left(\frac{1}{sL}+sC\right)-\frac{1}{sL}$$

$$C=\frac{\left(\frac{1}{sL}+sC\right)-\frac{1}{sL}(gsL+1)}{gsL+1}=\frac{sC-g}{gsL+1}$$

$$\underline{U_2 = 0} \quad B = \left.\frac{U_1}{I_2}\right|_{U_2=0} \qquad D = \left.\frac{I_1}{I_2}\right|_{U_2=0}$$



$$(1)\ U_1\left(\frac{1}{sL}+sC\right)-U_2\frac{1}{sL}=I_1$$

$$(2)\ \underline{-U_1\frac{1}{sL}+U_2\frac{1}{sL}=gU_1-I_2}$$

$$U_2=0\ \ (1)\ \Rightarrow\ U_1\left(\frac{1}{sL}+sC\right)=I_1$$

$$(2)\Rightarrow\ -U_1\frac{1}{sL}=gU_1-I_2\ \Rightarrow\ I_2=U_1\left(g+\frac{1}{sL}\right)\Rightarrow B=\frac{U_1}{I_2}=\frac{1}{g+1/(sL)}=\frac{sL}{gsL+1}$$

$$(2)\rightarrow(1)\Rightarrow I_2\frac{sL}{gsL+1}\left(\frac{1}{sL}+sC\right)=I_1\ \Rightarrow D=\frac{I_1}{I_2}=\frac{sL}{gsL+1}\left(\frac{1}{sL}+sC\right)=\frac{1+s^2LC}{gsL+1}$$

$$[a]=\frac{1}{gsL+1}\begin{bmatrix}1 & sL\\ sC-g & s^2LC+1\end{bmatrix}=\frac{1}{s+1}\begin{bmatrix}1 & s\\ s-1 & 1+s^2\end{bmatrix}=\begin{bmatrix}A & B\\ C & D\end{bmatrix}$$

(3 boda)

Prijenosna funkcija napona:

$$T(s)=\frac{U_2(s)}{U_1(s)}=\frac{Z_2}{AZ_2+B}=\frac{s+1}{s+1}=1$$

Ulazna impedancija u četveropol zaključen s otporom R:

$$Z_{ul1}(s)=\frac{U_1(s)}{I_1(s)}=\frac{AZ_2+B}{CZ_2+D}=\frac{s+1}{s-1+s^2+1}=\frac{s+1}{s(s+1)}=\frac{1}{s}$$

(1 bod)

Odgovori na pitanja:

a) Četveropol nije električki recipročan jer sadrži naponsko ovisni strujni izvor i vrijedi da je:

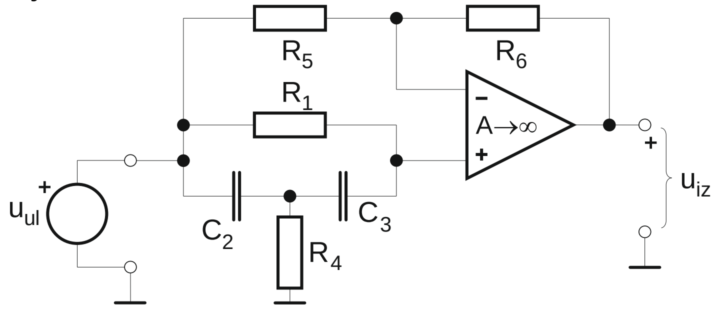
$$|a|=AD-BC=\frac{1+s^2-s(s-1)}{(s+1)^2}=\frac{1+s}{(s+1)^2}=\frac{1}{s+1}\neq 1;$$

b) Četveropol nije električki simetričan jer se parametri A i D razlikuju:

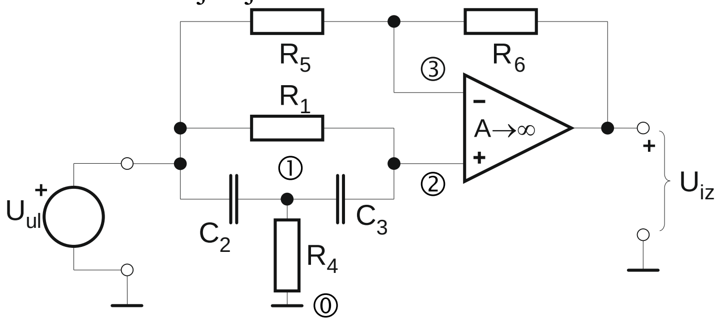
$$A=\frac{1}{s+1}\neq D=\frac{s^2+1}{s+1}$$

(1 bod)

4. Zadan je aktivni-RC električni filtar prikazan slikom s normaliziranim vrijednostima elemenata R_1=1, C_2=1, C_3=1, R_4=1, te R_5=1, R_6=2. a) Izračunati njegovu naponsku prijenosnu funkciju $T(s)=U_{iz}(s)/U_{ul}(s)$. O kojem se tipu filtra radi (NP, VP, PP ili PB)? b) Usporedbom s odgovarajućim općim oblikom prijenosne funkcije filtra 2. stupnja izračunati vrijednost parametara k, ω_p, ω_z, q_p. c) Prikazati raspored polova i nula u kompleksnoj ravnini. d) Nacrtati amplitudno-frekvencijsku karakteristiku.



Rješenje: Laplaceova transformacija i jednadžbe čvorišta:



Metoda napona čvorišta:

$$(1)\ U_1\left(sC_2+sC_3+\frac{1}{R_4}\right)-U_2sC_3=U_{ul}sC_2\ \Big/\cdot R_4$$

$$(2)\ -U_1sC_3+U_2\left(\frac{1}{R_1}+sC_3\right)=U_{ul}\frac{1}{R_1}\ \Big/:sC_3$$

$$(3)\ U_3\left(\frac{1}{R_5}+\frac{1}{R_6}\right)=U_{ul}\frac{1}{R_5}+U_{iz}\frac{1}{R_6}\ \Big/\cdot R_5R_6$$

$$(4)\ \underline{A(U_2-U_3)=U_{iz}\ \Rightarrow\ U_2=U_3\ \ (A\to\infty)}$$

Slijedi postepeno računanje korak po korak

$(3)\Rightarrow U_3(R_5+R_6)=U_{ul}R_6+U_{iz}R_5\ \Rightarrow U_3=U_{ul}\dfrac{R_6}{R_5+R_6}+U_{iz}\dfrac{R_5}{R_5+R_6}$;Uz oznaku $\alpha=\dfrac{R_5}{R_5+R_6}\Rightarrow$

$U_3=U_{ul}(1-\alpha)+U_{iz}\alpha$; Zajedno sa (4) $\Rightarrow$ $U_2=U_3=U_{ul}(1-\alpha)+U_{iz}\alpha$

$(2)\Rightarrow\ U_1=U_2\left(\dfrac{1}{sC_3R_1}+1\right)-U_{ul}\dfrac{1}{sC_3R_1}$

$(1)\Rightarrow\ U_1(sR_4C_2+sR_4C_3+1)-U_2R_4sC_3=U_{ul}R_4sC_2$; (2) $\to$ (1) (rješavamo se U_1) $\Rightarrow$

$$\left[U_2\left(\frac{1}{sC_3R_1}+1\right)-U_{ul}\frac{1}{sC_3R_1}\right](sR_4C_2+sR_4C_3+1)-U_2R_4sC_3=U_{ul}R_4sC_2$$

$$U_2\left(\frac{1}{sC_3R_1}+1\right)(sR_4C_2+sR_4C_3+1)-U_2R_4sC_3=U_{ul}\frac{1}{sC_3R_1}(sR_4C_2+sR_4C_3+1)+U_{ul}R_4sC_2\ \Big/\cdot sC_3R_1$$

$$U_2(sC_3R_1+1)(sR_4C_2+sR_4C_3+1)-U_2R_1R_4s^2C_3^2=U_{ul}(s^2R_1C_2C_3R_4+sR_4C_2+sR_4C_3+1)$$

$$U_2(s^2R_1C_2C_3R_4+sC_3R_1+sR_4C_2+sR_4C_3+1)=U_{ul}(s^2R_1C_2C_3R_4+sR_4C_2+sR_4C_3+1)$$

$$[U_{ul}(1-\alpha)+U_{iz}\alpha](s^2R_1C_2C_3R_4+sC_3R_1+sR_4C_2+sR_4C_3+1)=U_{ul}(s^2R_1C_2C_3R_4+sR_4C_2+sR_4C_3+1)$$

$$U_{iz}\alpha(s^2R_1C_2C_3R_4+sC_3R_1+sR_4C_2+sR_4C_3+1)=$$

$$U_{ul}(s^2R_1C_2C_3R_4+sR_4C_2+sR_4C_3+1)-U_{ul}(1-\alpha)(s^2R_1C_2C_3R_4+sC_3R_1+sR_4C_2+sR_4C_3+1)$$

$$U_{iz}\alpha(s^2R_1C_2C_3R_4+sC_3R_1+sR_4C_2+sR_4C_3+1)=$$

$$U_{ul}(s^2R_1C_2C_3R_4+sR_4C_2+sR_4C_3+1)-U_{ul}(s^2R_1C_2C_3R_4+sC_3R_1+sR_4C_2+sR_4C_3+1)+$$

$$+U_{ul}\alpha(s^2R_1C_2C_3R_4+sC_3R_1+sR_4C_2+sR_4C_3+1)$$

$$T(s)=\frac{U_{iz}(s)}{U_{ul}(s)}=\frac{s^2R_1C_2C_3R_4+s\left[C_3R_1\left(1-\frac{1}{\alpha}\right)+R_4C_2+R_4C_3\right]+1}{s^2R_1C_2C_3R_4+s(C_3R_1+R_4C_2+R_4C_3)+1}$$

Konačno je:

$$T(s)=\frac{U_{iz}(s)}{U_{ul}(s)}=\frac{s^2+s\frac{C_3R_1(1-1/\alpha)+R_4C_2+R_4C_3}{R_1C_2C_3R_4}+\frac{1}{R_1C_2C_3R_4}}{s^2+s\frac{C_3R_1+R_4C_2+R_4C_3}{R_1C_2C_3R_4}+\frac{1}{R_1C_2C_3R_4}}=\frac{s^2+1}{s^2+3s+1}$$ **(2 boda)**

Usporedbom s odgovarajućim općim oblikom prijenosne funkcije filtra 2. stupnja izračunati parametre k, ω_p, q_p, ω_z.

$$T(s)=\frac{U_{iz}(s)}{U_{ul}(s)}=k\cdot\frac{s^2+\omega_z^2}{s^2+(\omega_p/q_p)\cdot s+\omega_p^2}\quad\Rightarrow\quad\omega_p=\omega_z=1,\quad q_p=\frac{1}{3},\quad k=1$$

-o kojem se tipu filtra radi (NP, VP, PP ili PB)? $\Rightarrow$ PB **(1 bod)**

Raspored polova i nula u kompleksnoj ravnini: **(1 bod)**

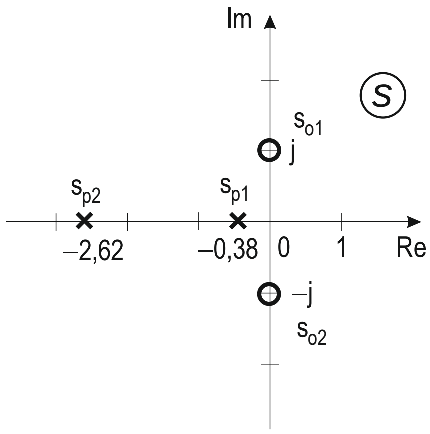
Nule $s^2+1=0\ \Rightarrow\ s_{o1,2}=\pm j$

Polovi $s^2+3s+1=0\Rightarrow s_{p1,2}=-\frac{3}{2}\pm\sqrt{\frac{9}{4}-1}=-\frac{3}{2}\pm\frac{\sqrt{5}}{2}$; $s_{p1}=-0{,}381966$; $s_{p2}=-2{,}61803$.

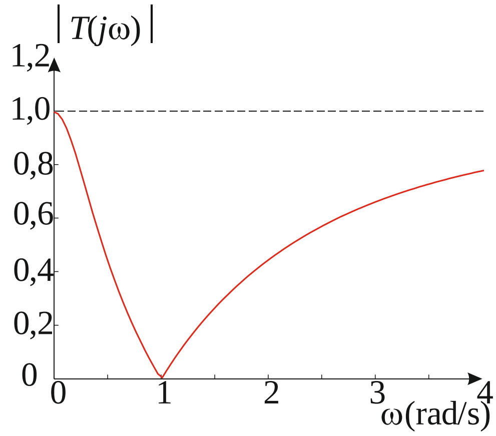
Amplitudno-frekvencijska (A-F) karakteristika **(1 bod)**

$$s=j\omega\Rightarrow\qquad T(j\omega)=\frac{-\omega^2+1}{-\omega^2+3\cdot j\omega+1}\qquad\Rightarrow\qquad|T(j\omega)|=\frac{|1-\omega^2|}{\sqrt{(1-\omega^2)^2+(3\cdot\omega)^2}}$$

Karakteristične točke A-F karakteristike $|T(j0)|=1$; $|T(j1)|=0$; $|T(j\infty)|=1$.

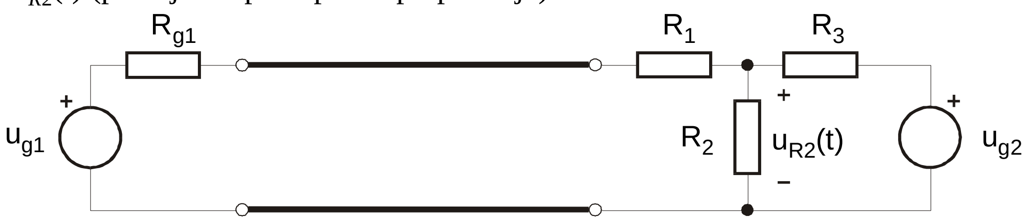


Raspored nula i polova u s-ravnini



Amplitudno frekvencijska karakteristika

5. Zadana je linija s primarnim parametrima R=0,8Ω/km, G=12,5mS/km, L=1,6μH/km i C=25nF/km. Duljina linije je 10km. Unutrašnji otpori generatora prilagođeni su zrcalnoj impedanciji linije. Zadano je: R_1=4Ω, R_2=6Ω, $u_{g1}(t)$=$u_{g2}(t)$=4$S(t)$. Koliki je R_3? Odrediti i nacrtati $u_{R2}(t)$ (primijeniti postupak superpozicije).



Rješenje: Ispitajmo da li vrijedi $\frac{R}{L}=\frac{G}{C}$ odnosno $\frac{0{,}8}{1{,}6\cdot 10^{-6}}=\frac{12{,}5\cdot 10^{-3}}{25\cdot 10^{-9}}$. Vrijedi! ⇒

To je linija bez distorzije. Računamo sekundarne parametre po pojednostavljenim formulama

$$Z_0=\sqrt{\frac{L}{C}}=\sqrt{\frac{1{,}6\cdot 10^{-6}}{25\cdot 10^{-9}}}=\sqrt{64}=8\Omega$$

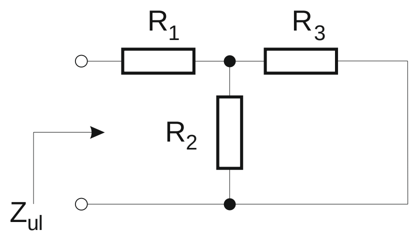
$$\gamma=\sqrt{RG}+s\sqrt{LC}=\sqrt{0{,}8\cdot 12{,}5\cdot 10^{-3}}+s\sqrt{1{,}6\cdot 10^{-6}\cdot 25\cdot 10^{-9}}=0{,}1+s\cdot 0{,}2\cdot 10^{-6}$$

(1 bod)

Metoda superpozicije:

a) izvor $u_{g2}(t)$ isključen

$R_{g1}=8\Omega$ zbog prilagođenja.

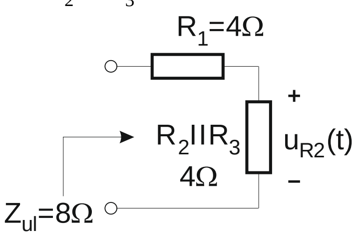


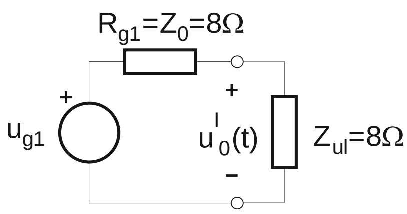
$$Z_{ul}=8\Omega=R_1+\frac{R_2R_3}{R_2+R_3}\ \Rightarrow\ Z_{ul}(R_2+R_3)=(R_2+R_3)R_1+R_2R_3$$

$$\Rightarrow\ Z_{ul}R_2+Z_{ul}R_3=R_1R_2+(R_1+R_2)R_3\ \Rightarrow\ Z_{ul}R_3-(R_1+R_2)R_3=R_1R_2-Z_{ul}R_2\ \Rightarrow$$

$$R_3=\frac{R_1R_2-Z_{ul}R_2}{Z_{ul}-(R_1+R_2)}=\frac{4\cdot 6-8\cdot 6}{8-(4+6)}=\frac{-24}{-2}=12\Omega$$

$$R_2\|R_3=\frac{R_2R_3}{R_2+R_3}=\frac{6\cdot 12}{6+12}=4\Omega$$





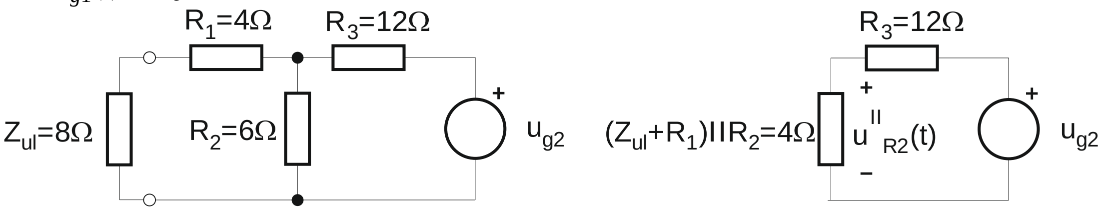
$$u_0^I=\frac{u_{g1}}{2}$$

$$g_1=\gamma\cdot l_1=\left(0{,}1+s\cdot 0{,}2\cdot 10^{-6}\right)\cdot 10=1+s\cdot 2\cdot 10^{-6}$$

$$U_{R2}^I(s)=\frac{U_{g1}}{2}\cdot\frac{1}{2}\cdot e^{-1}\cdot e^{-s\cdot 2\cdot 10^{-6}}=\frac{1}{s}e^{-1}\cdot e^{-s\cdot 2\cdot 10^{-6}}$$

(2 boda)

b) izvor $u_{g1}(t)$ isključen



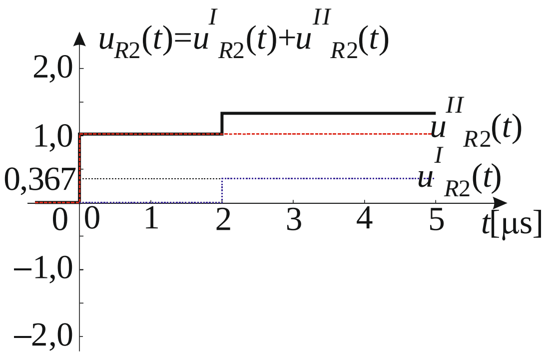
$$U_{R2}^{II}(s)=U_{g2}\cdot\frac{4}{12+4}=U_{g2}\cdot\frac{4}{16}=U_{g2}\cdot\frac{1}{4}=\frac{1}{s}$$

(1 bod)

c) ukupan napon na R_2:

$$U_{R2}(s)=U_{R2}^{I}(s)+U_{R2}^{II}(s)=\frac{1}{s}e^{-1}\cdot e^{-s\cdot 2\cdot 10^{-6}}+\frac{1}{s}$$

$$u_{R2}(t)=u_{R2}^{I}(t)+u_{R2}^{II}(t)=\frac{1}{e}S(t-2\cdot 10^{-6})+S(t)=0{,}367879\ \cdot S(t-2\cdot 10^{-6})+S(t)$$



(1 bod)