TIPOVI FILTARA

1) NISKOPROPUSNI (NP)

Opća prijenosna karakteristika NP 1. reda

$$H(s) = K \cdot \frac{\omega_g}{s + \omega_g}$$

– II – – II – NP 2. reda

$$H(s) = K \frac{\omega_p^2}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$$

ω_p – frekv. pola

$$s_{p1,2} = \sigma_p \pm j\omega_p$$

Q_p – faktor kvalitete

$$Q_p = -\frac{\omega_p}{2\sigma_p}$$

2) VISOKOPROPUSNI FILTAR (VP)

VP 1. reda

$$H(s) = \frac{K \cdot s}{s + \omega_g}$$

$$Q_p = -\frac{\omega_p}{2\sigma_p}$$

2. reda

$$H(s) = K \frac{s^2}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$$

3. POJASNI PROPUST

$$H(s) = K \frac{s \frac{\omega_p}{Q_p}}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$$

$$\omega_{g,d} = \omega_p \sqrt{1 + \frac{1}{4Q_p^2}} \mp \frac{\omega_p}{2Q_p}$$

$$B = \omega_g - \omega_d = \frac{\omega_p}{Q_p}$$

$$\omega_p^2 = \omega_d \omega_p$$

$\omega_p = \omega_c \rightarrow$ centralna frekv. filtra

$Q \geq 10 \rightarrow$ uski pojas

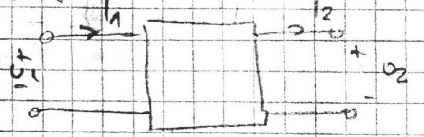
$$\omega_{g,d} \cong \omega_p \mp \frac{\omega_p}{2Q_p} = \omega_p \mp \frac{1}{2} B$$

4. POJASNA BRANA

$$H(s) = K \frac{s^2 + \omega_p^2}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$$

ČETVEROPOLI

① STRUJNE JEDNADŽBE 4-POLA ⇒ y - parametri



$$I_1 = y_{11}U_1 - y_{12}U_2$$
$$I_2 = y_{21}U_1 - y_{22}U_2$$

- ako je I_2 u drugom smjeru

$$I_1 = y_{11}U_1 + y_{12}U_2$$
$$I_2 = y_{21}U_1 + y_{22}U_2$$

$$y_{11} = \left.\frac{I_1}{U_1}\right|_{U_2=0} \qquad y_{21} = \left.\frac{I_2}{U_1}\right|_{U_2=0}$$

$$y_{12} = \left.\frac{I_1}{U_2}\right|_{U_1=0} \qquad y_{22} = -\left.\frac{I_2}{U_2}\right|_{U_1=0}$$

- ako je 4-pol recipročan $\boxed{y_{12} = y_{21}}$

$$[y] = \begin{bmatrix} y_{11} & -y_{12} \\ y_{21} & -y_{22} \end{bmatrix}$$

② NAPONSKE JEDNADŽBE 4-POLA ⇒ z - parametri

$$U_1 = I_1 z_{11} - I_2 z_{12}$$
$$U_2 = I_1 z_{21} - I_2 z_{22}$$

$\boxed{z_{21} = z_{12}}$ uvjet recipročnosti

$$[z] = \begin{bmatrix} z_{11} & -z_{12} \\ z_{21} & -z_{22} \end{bmatrix}$$

$$[z] = [y]^{-1}$$

$$z_{11} = \left.\frac{U_1}{I_1}\right|_{I_2=0} \qquad z_{12} = -\left.\frac{U_1}{I_2}\right|_{I_1=0}$$

$$z_{21} = \left.\frac{U_2}{I_1}\right|_{I_2=0} \qquad z_{22} = -\left.\frac{U_2}{I_2}\right|_{I_1=0}$$

③ PRIJENOSNE JEDNADŽBE ⇒ a parametri

$$U_1 = AU_2 + BI_2$$
$$I_1 = CU_2 + DI_2$$

$$[a] = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

$$A = \left.\frac{U_1}{U_2}\right|_{I_2=0} \qquad B = \left.\frac{U_1}{I_2}\right|_{U_2=0}$$

$$C = \left.\frac{I_1}{U_2}\right|_{I_2=0} \qquad D = \left.\frac{I_1}{I_2}\right|_{U_2=0}$$

uvjet recipročnosti: $\boxed{AD - BC = \Delta}$

ovisnost U_2 i I_2 o U_1 i I_1

pa je $\boxed{\begin{aligned} U_2 &= DU_1 - BI_1 \\ -I_2 &= CU_1 - AI_1 \end{aligned}}$

④ HIBRIDNE JEDNADŽBE => h parametri

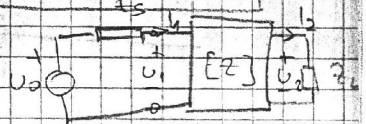
$$\boxed{\begin{aligned} U_1 &= h_{11} I_1 + h_{12} U_2 \\ I_2 &= h_{21} I_1 + h_{22} U_2 \end{aligned}} \qquad [h] = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$$

- ako imamo U_1 i I_2 => $U_2 = ?$ i $I_1 = ?$

$$\boxed{\begin{aligned} I_1 &= g_{11} U_1 + g_{12} I_2 \\ U_2 &= g_{21} U_1 + g_{22} I_2 \end{aligned}}$$ hibridne g jedn.

PRIJENOSNE FUNKCIJE z- parametrima

- prijenosna fja struje



$$H_i(s) = \frac{I_2}{I_1} = \frac{z_{21}}{z_L + z_{22}}$$

- naponska prij. fja $H_u(s) = \frac{U_2}{U_1} = \frac{z_L z_{21}}{z_{11}(z_{22} + z_L) - z_{12} z_{21}} = \frac{z_L z_{21}}{\Delta z + z_{11} z_L}$

$\Delta z = z_{11} z_{22} - z_{12} z_{21}$

$$H_u(s) = \frac{U_2}{U_0} = \frac{z_L z_{21}}{(z_{11} + z_s)(z_{22} + z_L) - z_{12} z_{21}}$$

PRIJENOSNE FUNKCIJE y - parametrima

- ista slika

$$H_u(s) = \frac{y_{21}}{Y_L + y_{22}}$$

$$H_i = \frac{Y_L y_{21}}{y_{11}(y_{22} + Y_L) - y_{12} y_{21}}$$

PRIJENOSNE F-JE A-parametrima

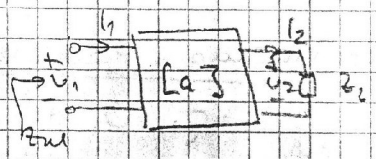
$$H_u(s) = \frac{U_2}{U_1} = \frac{Z_L}{AZ_L + B}$$

isto struja

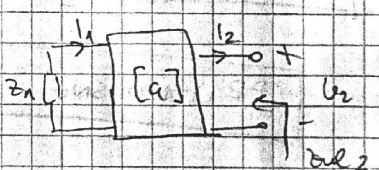
$$H_i = \frac{I_2}{I_1} = \frac{1}{CZ_L + D}$$

$$U(s) = \frac{U_2}{U_0} = \frac{Z_L}{AZ_L + B + Z_S(CZ_L + D)}$$

$$Z_{ul_1} = \frac{U_1}{I_1} = \frac{AZ_2 + B}{CZ_2 + D}$$



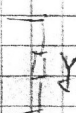
$$Z_{ul_2} = \frac{U_2}{I_2} = \frac{DZ_1 + B}{CZ_1 + A}$$



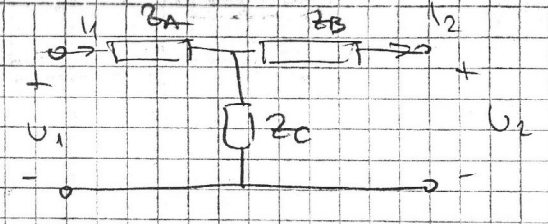
$$Z_{ul_1} = Z_{11} - \frac{Z_{12} Z_{21}}{Z_2 + Z_{22}}$$

$$Z_{ul_2} = -\frac{U_2}{I_2} = Z_{22} - \frac{Z_{12} Z_{21}}{Z_{11} + Z_1}$$

$$Y_{ul_1} = y_{11} - \frac{y_{12} y_{21}}{Y_2 + y_{22}}$$



$$Y_{ul_2} = y_{22} - \frac{y_{12} y_{21}}{Y_1 + y_{11}}$$



$Z_A = Z_{11} - Z_{12}$

$Z_B = Z_{22} - Z_{12}$

$Z_C = Z_{12} - Z_{21}$

⇒ vrijedi za reciprocni 4-pol !

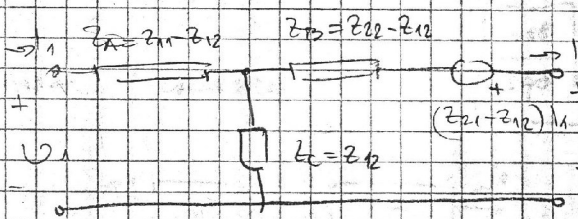
⇒ ako se radi o nereciprocnom 4-polu

$Z_{12} \neq Z_{21}$

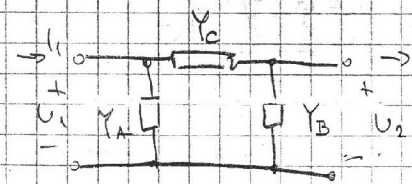
$U_1 = I_1 Z_{11} - I_2 Z_{12}$

$U_2 = I_1 Z_{12} - I_2 Z_{22} + I_1 (Z_{21} - Z_{12})$

nap. izvor



EKVIVALENTNI 4-POL U Π - SPOJU



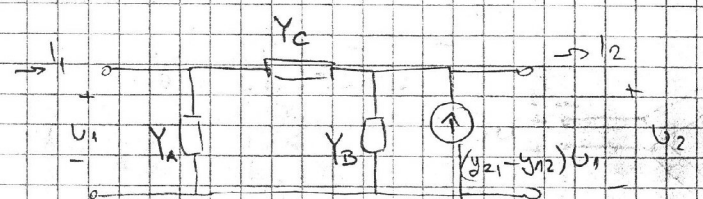
- za reciprocni 4-pol

$Y_A = y_{11} - y_{12}$

$Y_B = y_{22} - y_{12}$

$Y_C = y_{12} = y_{21}$

- nereciprocni cetveropol



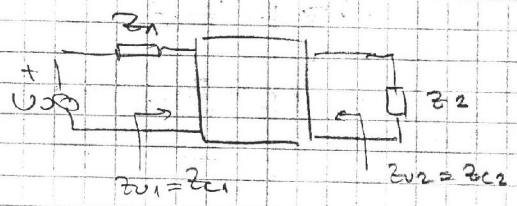
$I_1 = y_{11} U_1 - y_{12} U_2$

$I_2 = y_{12} U_1 - y_{22} U_2 + (y_{21} - y$

U_1

= naponski izvor

- ako vijedi



$Z_{c1} = Z_1$ i $Z_2 = Z_{c2}$ $\Rightarrow$ prilagođen po trećem paru

$$Z_{c1} = \sqrt{Z_{p1} Z_{k1}} = \sqrt{\frac{Z_{11}}{Y_{11}}}$$

$$Z_{c2} = \sqrt{Z_{p2} Z_{k2}} = \sqrt{\frac{Z_{22}}{Y_{22}}}$$

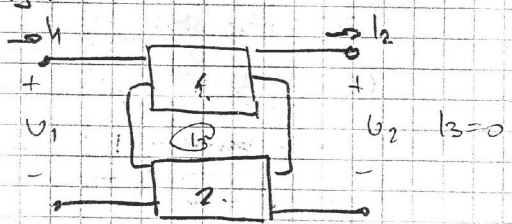
Z_{p1} – na prazno $\rightarrow$ s ulaza sa 1,1'

Z_{k2} – na kratko s 2,2'

$$\left| th\,(\gamma) = \sqrt{\frac{Z_{c1}}{Z_{p1}}} = \sqrt{\frac{Z_{c2}}{Z_{p2}}} \right|$$

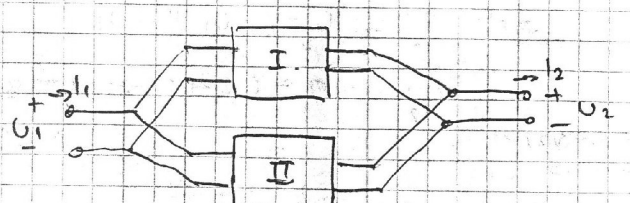
POVEZIVANJE 4-POLA

① SERIJA



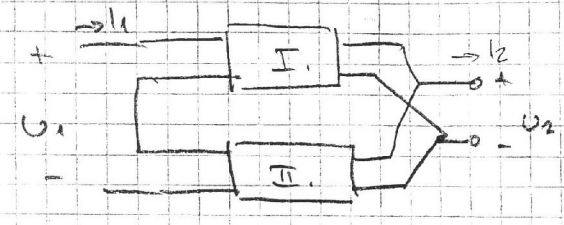
$$[Z] = [Z'] + [Z'']$$

② PARALELA



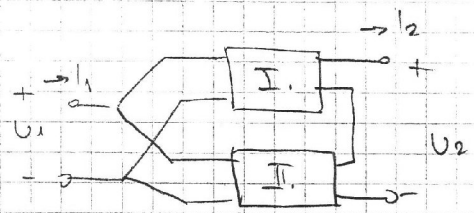
$$[Y] = [Y'] + [Y'']$$

③ SERIJSKO - PARALELNI



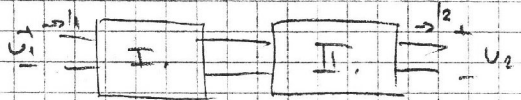
$$[h] = [h'] + [h'']$$

④ PARALELNO - SERIJSKI



$$[g] = [g'] + [g'']$$

⑤ LANAC (KASKADA)



$$[a] = [a'] \cdot [a'']$$

SIMETRIČNI ČETVEROPOLI

y-parametri: $y_{11} = y_{22}$

z-parametri: $z_{11} = z_{22}$

a-parametri: $A = D$

hibridni h: $\begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} = -1$

hibridni g: $\begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} = 1$

LINIJE

$$\gamma = \sqrt{(R+j\omega L)(G+j\omega C)} \rightarrow \text{faktor prijenosa (propagacije)}$$

$$\cosh jx = \cos x$$
$$\sinh jx = j\sin x$$

$$Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}} \rightarrow \text{karakt. impedancija}$$

→ koef. refleksije na izlazu

$$\Gamma_2 = \frac{Z_2 - Z_0}{Z_2 + Z_0}$$

— II — na ulazu

$$\Gamma_1 = \frac{Z_1 - Z_0}{Z_1 + Z_0}$$

linija ⇒ simetričan 4-pol

$$\gamma = \alpha + j\beta$$ → karakt. (prirodni) faktor gušenja

→ — II — faktor fazne

$$\boxed{v = \frac{\omega}{\beta}}$$ → brzina širenja vala

$$\lambda = \frac{P}{\beta}$$ → period → valna dulj.

$$\boxed{\lambda = \frac{2\pi}{\beta}}$$

1. LINIJA BEZ GUBITAKA

$R = 0$, $G = 0$

$$Z_0 = \sqrt{\frac{L}{C}} = \text{konst.} \qquad \gamma = j\omega\sqrt{LC}$$

→ sinusna pobuda

$$\gamma = j\omega\sqrt{LC} = j\beta$$

2. LINIJA BEZ DISTORZIJE

$$\frac{R}{L} = \frac{G}{C} \Rightarrow \frac{R}{G} = \frac{L}{C} \Rightarrow RC = GL$$

$$Z_0 = \sqrt{\frac{L}{C}} \qquad \gamma = \sqrt{RG} + j\omega\sqrt{LC}$$

nova pobuda

$$\gamma = \sqrt{RG} + j\omega\sqrt{LC}$$

$$\alpha = R\sqrt{\frac{C}{L}} = \sqrt{RG} \qquad \beta = \omega\sqrt{LC}$$

$$\gamma = \sqrt{RG} + s\sqrt{LC}$$

$$\alpha \quad \beta s$$

$$U(l) = U(0) \cdot e^{-\alpha} \cdot e^{-\frac{s}{v}}$$

3. RC-LINIJA

$G = 0 \quad L = 0$

$$Z_0 = \sqrt{\frac{R}{j\omega C}}$$

$$\gamma = \sqrt{\frac{\omega RC}{2}} + j\sqrt{\frac{\omega RC}{2}}$$

4. LINIJA S MALIM GUBICIMA

$\omega L \gg R \qquad \omega C \gg G$

$$U(l) = U(0) \cdot e^{-\gamma l}$$

→ako je $Z_2 = Z_0 \Rightarrow Z_{ul} = Z_0$ → prilagođenje!

- linija zaključena sa Z_0 → kao beskonačno duga (nema reflektirane)

$I(0) = 0$

$U(0) = 0$

$$U(x) = U(0)\operatorname{ch}(\gamma x) - Z_0 I(0)\operatorname{sh}(\gamma x)$$

$$I(x) = -\frac{U(0)}{Z_0}\operatorname{sh}(\gamma x) + I(0)\operatorname{ch}(\gamma x)$$

- za $x = l$

$$U(0) = U(l)\operatorname{ch}(\gamma l) + Z_0 I(l)\operatorname{sh}(\gamma l)$$

$$I(0) = \frac{U(l)}{Z_0}\operatorname{sh}(\gamma l) + I(l)\operatorname{ch}(\gamma l)$$

$$Z_{ul} = \frac{Z_2\operatorname{ch}\gamma l + Z_0\operatorname{sh}\gamma l}{\frac{Z_2}{Z_0}\operatorname{sh}\gamma l + \operatorname{ch}\gamma l}$$

$$Z_{ul} = \frac{U(0)}{I(0)} \qquad Z_2 = \frac{U(l)}{I(l)}$$

$$Z_{ul} = \frac{U(l)\operatorname{ch}(\gamma l) + I(l) Z_0 \operatorname{sh}\gamma l}{\frac{U(l)}{Z_0}\operatorname{sh}\gamma l + I(l)\operatorname{ch}\gamma l}$$

$Z_2 = Z_0 \Rightarrow Z_{ul} = Z_0$

prilagođenje