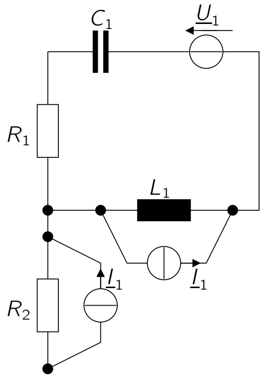
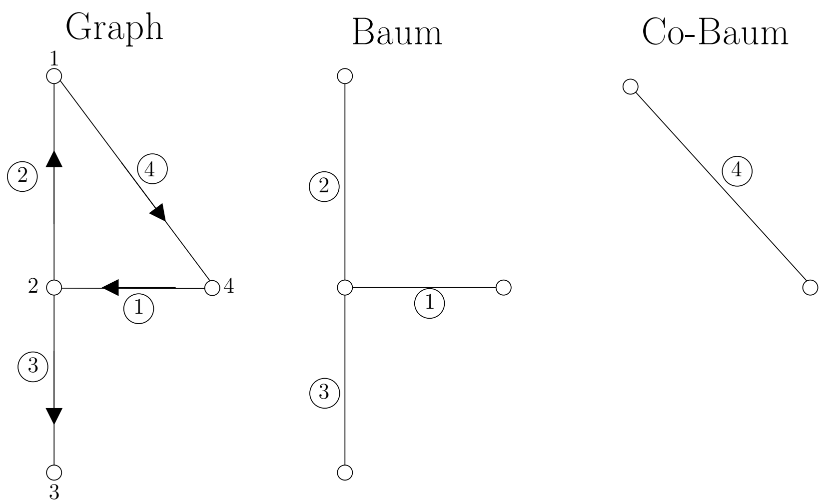
Aufgabe 1

a)



b)



c)

$$Y = \begin{pmatrix} \frac{1}{sL_1} & 0 & 0 & 0 \\ 0 & \frac{1}{R_1} & 0 & 0 \\ 0 & 0 & \frac{1}{R_2} & 0 \\ 0 & 0 & 0 & sC \end{pmatrix}$$

d)

$$A = \text{K}\begin{matrix} \\ 1 \\ 2 \\ 3 \\ 4 \end{matrix}\overset{\text{Z}}{\begin{pmatrix} {\scriptstyle 1} & {\scriptstyle 2} & {\scriptstyle 3} & {\scriptstyle 4} \\ 0 & -1 & 0 & 1 \\ -1 & 1 & 1 & 0 \\ 0 & 0 & -1 & 0 \\ 1 & 0 & 0 & -1 \end{pmatrix}}$$

Knoten 2 als Bezugsknoten → Steichen 2. Zeile:

$$\Rightarrow A = \begin{pmatrix} 0 & -1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & -1 \end{pmatrix}$$

e)

$$Y_n = AYA^T = \begin{pmatrix} 0 & -1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & -1 \end{pmatrix} \begin{pmatrix} \frac{1}{sL_1} & 0 & 0 & 0 \\ 0 & \frac{1}{R_1} & 0 & 0 \\ 0 & 0 & \frac{1}{R_2} & 0 \\ 0 & 0 & 0 & sC \end{pmatrix} \begin{pmatrix} 0 & 0 & 1 \\ -1 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & -1 \end{pmatrix}$$

$$= \begin{pmatrix} 0 & -1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & -1 \end{pmatrix} \begin{pmatrix} 0 & 0 & \frac{1}{sL_1} \\ -\frac{1}{R_1} & 0 & 0 \\ 0 & \frac{1}{R_2} & 0 \\ sC & 0 & -sC \end{pmatrix} = \begin{pmatrix} \frac{1}{R_1} + sC & 0 & -sC \\ 0 & \frac{1}{R_2} & 0 \\ -sC & 0 & \frac{1}{sL_1} + sC \end{pmatrix}$$

$$I_{qn} = A(I_g - YU_g) = \begin{pmatrix} 0 & -1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & -1 \end{pmatrix} \left[\begin{pmatrix} I_1 \\ 0 \\ I_1 \\ 0 \end{pmatrix} - \begin{pmatrix} \frac{1}{sL_1} & 0 & 0 & 0 \\ 0 & \frac{1}{R_1} & 0 & 0 \\ 0 & 0 & \frac{1}{R_2} & 0 \\ 0 & 0 & 0 & sC \end{pmatrix} \begin{pmatrix} 0 \\ 0 \\ 0 \\ U_1 \end{pmatrix} \right]$$

$$= \begin{pmatrix} 0 & -1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & -1 \end{pmatrix} \begin{pmatrix} I_1 \\ 0 \\ I_1 \\ -sC \cdot U_1 \end{pmatrix} = \begin{pmatrix} -sC \cdot U_1 \\ I_1 \\ I_1 + sC \cdot U_1 \end{pmatrix}$$

$$\underbrace{\begin{pmatrix} \frac{1}{R_1} + sC & 0 & -sC \\ 0 & \frac{1}{R_2} & 0 \\ -sC & 0 & \frac{1}{sL_1} + sC \end{pmatrix}}_{Y_n} \underbrace{\begin{pmatrix} U_{n1} \\ U_{n3} \\ U_{n4} \end{pmatrix}}_{\underline{U}_n} = \underbrace{\begin{pmatrix} -sC \cdot U_1 \\ I_1 \\ I_1 + sC \cdot U_1 \end{pmatrix}}_{\underline{I}_{qn}}$$

U_{n3} ist entkoppelt ⇒ streichen 2. Zeile und 2. Spalte:

$$\begin{pmatrix} \frac{1}{R_1} + sC & -sC \\ -sC & \frac{1}{sL_1} + sC \end{pmatrix} \begin{pmatrix} U_{n1} \\ U_{n4} \end{pmatrix} = \begin{pmatrix} -sC \cdot U_1 \\ I_1 + sC \cdot U_1 \end{pmatrix}$$

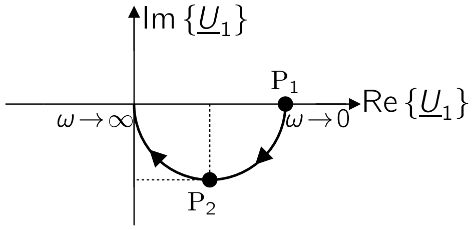
$U_x = -U_{n1}$

$$U_{n1} = \frac{\begin{vmatrix} -sC \cdot U & -sC \\ I_1 + sC \cdot U & \frac{1}{sL_1} + sC \end{vmatrix}}{\begin{vmatrix} \frac{1}{R_1} + sC & -sC \\ -sC & \frac{1}{sL_1} + sC \end{vmatrix}}$$

Aufgabe 2

a) + b)

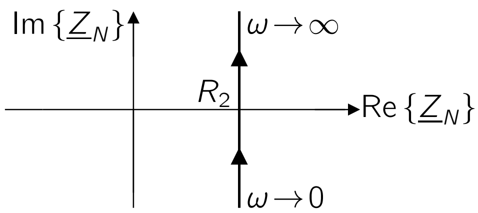
$$\underline{U}_1 = \underline{I}_1 \cdot (R_1 || C_1) = \underline{I}_1 \cdot \frac{\frac{R_1}{j\omega C_1}}{R_1 + \frac{1}{j\omega C_1}} = \frac{R_1}{1 + j\omega R_1 C_1} \cdot \underline{I}_1$$

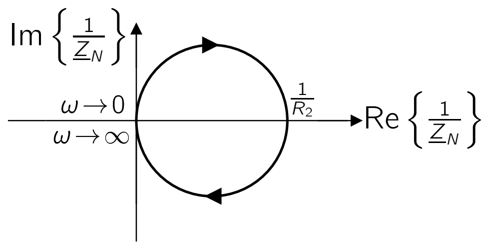


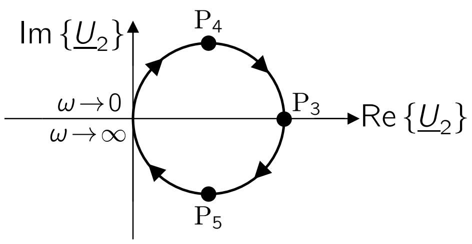
$$P_1 : \underline{U}_1 = R_1 \underline{I}_1$$

$$P_2 : \underline{U}_1 = R_1 \underline{I}_1 \left(\frac{1}{2} - j\frac{1}{2} \right)$$

$$\underline{U}_2 = \underline{U}_0 \cdot \frac{R_2}{\underbrace{R_2 + j\omega L_2 + \frac{1}{j\omega C_2}}_{Z_N}} = \frac{j\omega R_2 C_2}{j\omega R_2 C_2 - \omega^2 L_2 C_2 + 1} \cdot \underline{U}_0$$







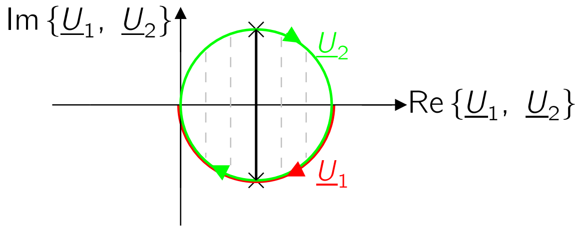
$$P_3 : \underline{U}_2 = \underline{U}_0$$

$$P_4, P_5 : \underline{U}_2 = \frac{\underline{U}_0}{2} (1 \pm j)$$

c)

$$\underline{U}_0 = R_1 \underline{I}_1$$

d)

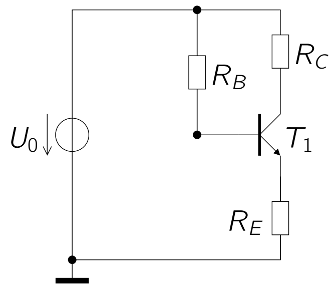


$$
\begin{aligned}
\underline{U}_1 = \frac{R_1 \underline{I}_1}{2}(1-j) &= \frac{R_1 \underline{I}_1}{1+j\omega R_1 C_1} \\
\Leftrightarrow \qquad \frac{1}{2} - \frac{j}{2} &= \frac{1}{1+j\omega R_1 C_1} \\
\Leftrightarrow \qquad \frac{2}{1-j} &= 1 + j\omega R_1 C_1 \\
\Leftrightarrow \qquad 2\frac{1+j}{2} &= 1 + j\omega R_1 C_1 \\
\Leftrightarrow \qquad \omega R_1 C_1 &= 1 \Leftrightarrow \omega = \frac{1}{R_1 C_1}
\end{aligned}
$$

$$
\begin{aligned}
\underline{U}_2 = \frac{\underline{U}_0}{2}(1+j) &= \frac{R_2}{R_2 + j\omega L_2 + \frac{1}{j\omega C_2}} \underline{U}_0 \\
\Leftrightarrow \qquad 1 + j &= 2\frac{R_2}{R_2 + j\omega L_2 + \frac{1}{j\omega C_2}} \\
\Leftrightarrow \qquad \frac{1}{1+j} &= \frac{1}{2}\left(1 + j\omega\frac{L_2}{R_2} - j\frac{1}{\omega R_2 C_2}\right) \\
\Leftrightarrow \qquad \frac{1-j}{2} &= \frac{1}{2}\left(1 + j\left(\frac{L_2}{R_2 R_1 C_1} - \frac{R_1 C_1}{R_2 C_2}\right)\right) \\
\Leftrightarrow \qquad \frac{L_2}{R_1 R_2 C_1} - \frac{R_1 C_1}{R_2 C_2} &= -1 \\
\Leftrightarrow \qquad L_2 &= -R_1 R_2 C_2 + \frac{R_1^2 C_1^2}{C_2}
\end{aligned}
$$

Aufgabe 3

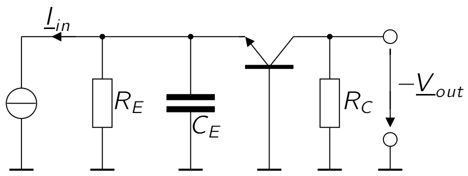
a)



b)

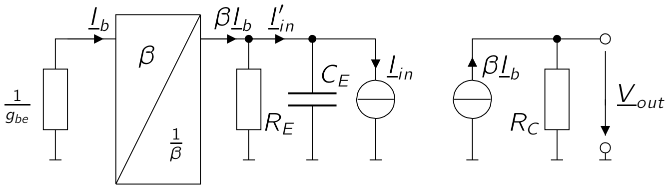
$$U_{CE} = U_{BE} \Rightarrow U_{CB} = 0 = R_B \cdot I_B - R_C \cdot I_C$$
$$= R_B - R_C \cdot B \cdot I_B$$
$$\Leftrightarrow R_B = B \cdot R_C$$
$$\frac{R_B}{R_C} = B$$

c)



Basisgrundschaltung, da Basis auf gemeinsamem Bezugspotential für Ein- und Ausgangssignal

d)



(2014-10-06: in Abb. vertauschtes β und $\frac{1}{\beta}$ im T-Operator korrigiert.)

$$\underline{V}_{out} = \beta \cdot I_b \cdot R_C$$

$$\beta \cdot \underline{I}_b = \underline{I}'_{in} \frac{R_E}{R_E + \frac{1}{\beta \cdot g_{be}}} = \underline{I}'_{in} \frac{R_E}{R_E + \frac{1}{g_m}}$$

$$\underline{I}'_{in} = \underline{I}_{in} \frac{\frac{1}{j\omega C_E}}{\frac{1}{j\omega C_E + R_E || \frac{1}{\beta \cdot g_{be}}}} = \underline{I}_{in} \frac{1}{1 + j\omega C_E \left(R_E || \frac{1}{g_m}\right)}$$

$$\Rightarrow \underline{Z}_T = \frac{\underline{V}_{out}}{\underline{I}_{in}} = R_C \frac{R_E}{R_E + \frac{1}{g_m}} \cdot \frac{1}{1 + j\omega C_E \left(R_E || \frac{1}{g_m}\right)}$$

e)

$$\underline{Z}_T = R_C \frac{R_E}{R_E + \frac{1}{g_m}} \cdot \frac{1}{1 + j\omega C_E \left(R_E || \frac{1}{g_m}\right)}$$

1) $|Z_T(\omega = 0)| = 0.99 \cdot R_C$

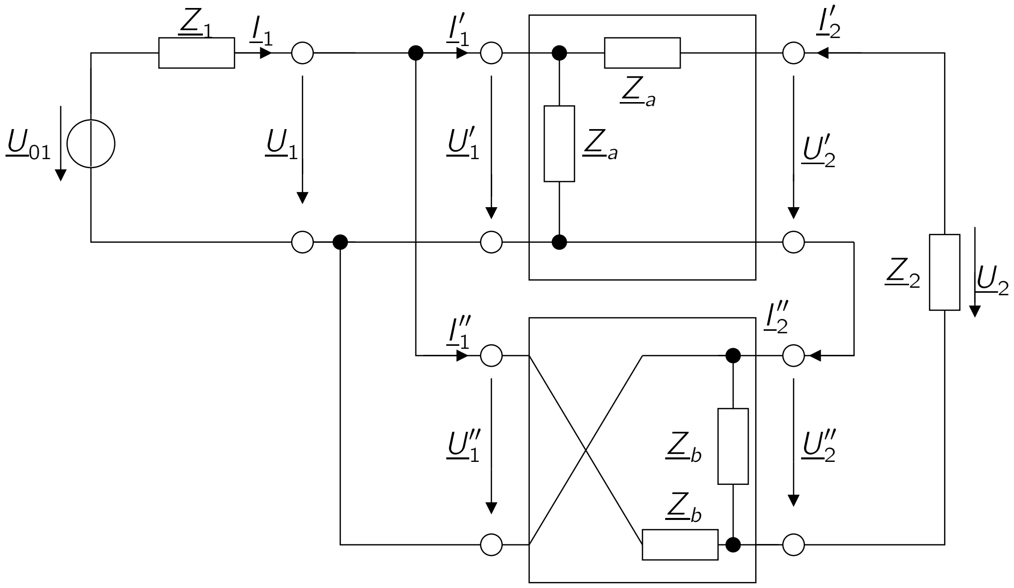
$$\frac{R_E}{R_E + \frac{1}{g_m}} = 0.99 \Leftrightarrow R_E \cdot g_m = \frac{0.99}{0.01} = 99$$

2) $|Z_T(\omega = \omega_{3\text{dB}})| = \frac{1}{\sqrt{2}} |\underline{Z}_T(\omega = 0)|$

$$\omega_{3\text{dB}} = \frac{1}{C_E \left(R_E || \frac{1}{g_m}\right)} = \frac{1}{C_E \frac{R_E}{1 + g_m \cdot R_E}} = \frac{1 + g_m \cdot R_E}{C_E \cdot R_E} = 10^8 \text{ Hz}$$

Aufgabe 4

a)



b)

i)

PSK

ii)

G-Parameter

$$\left.\begin{array}{ll} \underline{U}_1 = \underline{U}_1' = \underline{U}_2', & \underline{I}_1 = \underline{I}_1' + \underline{I}_2'' \\ \underline{I}_2 = \underline{I}_2' = \underline{I}_2'', & \underline{U}_2 = \underline{U}_2' + \underline{U}_2'' \end{array}\right\} \quad \Rightarrow \begin{bmatrix} \underline{I}_1 \\ \underline{U}_2 \end{bmatrix} = [\underline{G}] \begin{bmatrix} \underline{U}_1 \\ \underline{I}_2 \end{bmatrix}$$

$$\underline{I}_1 = \underline{G}_{11}'\underline{U}_1' + \underline{G}_{11}''\underline{U}_1'' + \underline{G}_{12}'\underline{I}_2' + \underline{G}_{12}''\underline{I}_2'' = \left(\underline{G}_{11}' + \underline{G}_{11}''\right)\underline{U}_1 + \left(\underline{G}_{12}' + \underline{G}_{12}''\right)\underline{I}_2$$

$$\underline{U}_2 = \underline{G}_{21}'\underline{U}_1' + \underline{G}_{21}''\underline{U}_1'' + \underline{G}_{22}'\underline{I}_2' + \underline{G}_{22}''\underline{I}_2'' = \left(\underline{G}_{21}' + \underline{G}_{21}''\right)\underline{U}_1 + \left(\underline{G}_{22}' + \underline{G}_{22}''\right)\underline{I}_2$$

c)

$$\underline{G}'_{11} = \left.\frac{\underline{I}'_1}{\underline{U}'_1}\right|_{\underline{I}'_2=0} = \frac{1}{\underline{Z}_a} \qquad \underline{G}'_{12} = \left.\frac{\underline{I}'_1}{\underline{I}'_2}\right|_{\underline{U}'_1=0} = -1$$

$$\underline{G}'_{21} = \left.\frac{\underline{U}'_2}{\underline{U}'_1}\right|_{\underline{I}'_2=0} = 1 \qquad \underline{G}'_{22} = \left.\frac{\underline{U}'_2}{\underline{I}'_2}\right|_{\underline{U}'_1=0} = \underline{Z}_a$$

$$\underline{G}''_{11} = \left.\frac{\underline{I}''_1}{\underline{U}'_1}\right|_{\underline{I}''_2=0} = \frac{1}{2\underline{Z}_b} \qquad \underline{G}''_{12} = \left.\frac{\underline{I}''_1}{\underline{I}''_2}\right|_{\underline{U}''_1=0} = \frac{1}{2}$$

$$\underline{G}''_{21} = \left.\frac{\underline{U}''_2}{\underline{U}''_1}\right|_{\underline{I}''_2=0} = -\frac{1}{2} \qquad \underline{G}''_{22} = \left.\frac{\underline{U}''_2}{\underline{I}''_2}\right|_{\underline{U}''_1=0} = \frac{\underline{Z}_b}{2}$$

$$[\underline{G}] = \begin{bmatrix} \frac{1}{\underline{Z}_a} + \frac{1}{2\underline{Z}_b} & -\frac{1}{2} \\ \frac{1}{2} & \underline{Z}_a + \frac{\underline{Z}_b}{2} \end{bmatrix}$$

d)

$$\underline{U}_2 = -\underline{Z}_2\underline{I}_2$$

$$\underline{U}_2 = \underline{G}_{21}\underline{U}_1 + \underline{G}_{22}\underline{I}_2 \Leftrightarrow -\underline{Z}_2\underline{I}_2 = \underline{G}_{21}\underline{U}_1 + \underline{G}_{22}\underline{I}_2$$

$$\Leftrightarrow \underline{G}_{21}\underline{U}_1 = -\left(\underline{G}_{22} + \underline{Z}_2\right)\underline{I}_2$$

$$\Leftrightarrow \quad \underline{U}_1 = -\frac{\underline{G}_{22} + \underline{Z}_2}{\underline{G}_{21}}\underline{I}_2$$

$$\Rightarrow \underline{I}_1 = \underline{G}_{11}\underline{U}_1 + \underline{G}_{12}\underline{I}_2 = \left(\underline{G}_{12} - \underline{G}_{11}\frac{\underline{G}_{22} + \underline{Z}_2}{\underline{G}_{21}}\right)\underline{I}_2$$

$$\Leftrightarrow \underline{I}_1 = \frac{\underline{G}_{12}\underline{G}_{21} - \underline{G}_{11}\underline{G}_{22} - \underline{G}_{11}\underline{Z}_2}{\underline{G}_{21}}\underline{I}_2$$

$$\Leftrightarrow \underline{F}_I = \frac{\underline{I}_2}{\underline{I}_1} = \frac{\underline{G}_{21}}{\underline{G}_{12}\underline{G}_{21} - \underline{G}_{11}\left(\underline{G}_{22} + \underline{Z}_2\right)}$$

$$= \frac{\frac{1}{2}}{-\frac{1}{2}\cdot\frac{1}{2} - \left(\frac{1}{\underline{Z}_a} + \frac{1}{2\underline{Z}_b}\right)\left(\underline{Z}_a + \frac{\underline{Z}_b}{2} + \underline{Z}_2\right)}$$

$$= \frac{\frac{1}{2}\underline{Z}_a\underline{Z}_b}{-\frac{1}{4}\underline{Z}_a\underline{Z}_b - \left(\underline{Z}_b + \frac{\underline{Z}_a}{2}\right)\left(\underline{Z}_a + \frac{\underline{Z}_b}{2} + \underline{Z}_2\right)}$$

$$= \frac{\frac{1}{2}\underline{Z}_a\underline{Z}_b}{-\frac{\underline{Z}_a\underline{Z}_b}{4} - \underline{Z}_b\underline{Z}_a - \frac{\underline{Z}_b^2}{2} - \frac{\underline{Z}_a^2}{2} - \frac{\underline{Z}_a\underline{Z}_b}{4} - \underline{Z}_b\underline{Z}_2 - \frac{\underline{Z}_a\underline{Z}_2}{2}}$$

$$= \frac{-\underline{Z}_a\underline{Z}_b}{\underline{Z}_a^2 + 3\underline{Z}_a\underline{Z}_b + \underline{Z}_b^2 + \underline{Z}_2\left(2\underline{Z}_b + \underline{Z}_a\right)}$$

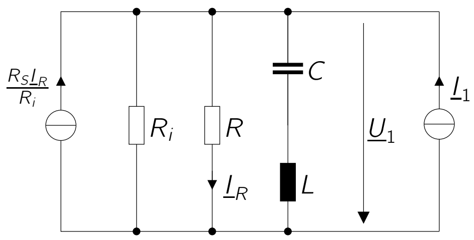
$$\Rightarrow \underline{Z}_a = 0 \vee \underline{Z}_b = 0$$

$$|\underline{Z}_a|\,,\ |\underline{Z}_b|\,,\ |\underline{Z}_2| \rightarrow \infty$$

Aufgabe 5

a)

$$\underline{Z}(s) = \frac{\underline{U}_1}{\underline{I}_1}$$



$$\underline{U}_1 = R\underline{I}_R$$

$$\underline{I}_R = \left(\underline{I}_1 + \frac{R_s}{R_i}\underline{I}_R\right)\frac{\frac{1}{R}}{\frac{1}{R} + \frac{1}{R_i} + \frac{1}{sL + \frac{1}{sC}}}$$

$$= \left(\underline{I}_1 + \frac{R_s}{R_i}\underline{I}_R\right)\frac{R_i\left(s^2LC + 1\right)}{(R_i + R)\left(s^2LC + 1\right) + sRR_iC}$$

$$\underline{I}_R = \underline{I}_1\frac{\alpha}{\beta} + \frac{R_s}{R_i}\frac{\alpha}{\beta}\underline{I}_R$$

$$\Leftrightarrow \underline{I}_R\left(1 - \frac{\alpha}{\beta}\frac{R_s}{R_i}\right) = \underline{I}_1\frac{\alpha}{\beta}$$

$$\Leftrightarrow \underline{I}_R = \underline{I}_1\frac{\frac{\alpha}{\beta}}{1 - \frac{R_s}{R_i}\frac{\alpha}{\beta}} = \frac{\alpha}{\beta - \frac{R_s}{R_i}\alpha}\underline{I}_1$$

$$= \frac{s^2R_iLC + R_i}{(R_i + R)\left(s^2LC + 1\right) + sRR_iC - R_s\left(s^2LC + 1\right)}\underline{I}_1$$

$$\underline{U}_1 = R\underline{I}_R = \frac{\left(s^2LC + 1\right)RR_i}{(R_i + R)\left(s^2LC + 1\right) + sRR_iC - R_s\left(s^2LC + 1\right)}\underline{I}_1$$

$$\Rightarrow \underline{Z} = \frac{\left(s^2LC + 1\right)RR_i}{\left(s^2LC + 1\right)(R + R_i - R_s) + sRR_iC}$$

b)

Oszillator soll Spannung $\underline{U}$ erzeugen
→ hochohmige Last an Tor 1
→ Ansteuerung mit Stromquelle
I → 0 ⇒ hochohmige Last

c)

$$\frac{1}{LC} + \frac{RR_i}{L(R+R_i-R_s)}s + s^2 = 0$$

$$s_{1,2} = -\frac{RR_i}{2L(R+R_i-R_s)} \pm \sqrt{\frac{R^2R_i^2}{4L^2(R+R_i-R_s)^2} - \frac{1}{LC}}$$

entdämpft, falls $\text{Re}\{s_{1,2}\} \geq 0$

$$\Rightarrow R_s > R + R_i$$

d)

$$\begin{aligned}
s_{1,2} &= +\frac{R^2}{4LR} \pm \sqrt{\frac{R^2}{16L^2} - \frac{1}{LC}} \\
&= \sigma \pm j\omega \\
&\Rightarrow \sigma = \frac{R}{4L} \\
\omega &= -\sqrt{\frac{1}{LC} - \frac{R^2}{16L^2}}
\end{aligned}$$

$$\text{, falls} \frac{1}{LC} > \frac{R^2}{16L^2}$$

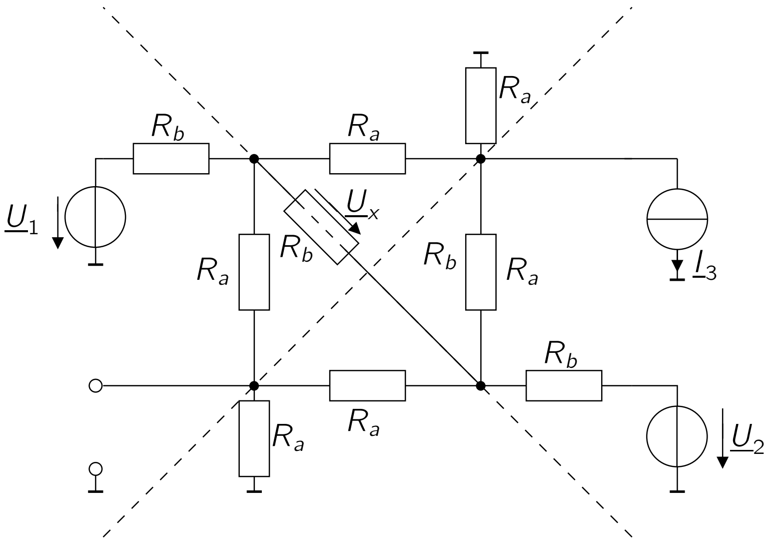
$$16L > R^2C$$

e)

$$\begin{aligned}
\underline{U}_1(s) &= \underline{Z}(s) \cdot \underline{I}(s) \\
\underline{Z}(s) &= -\frac{R^2\left(1+s^2LC\right)}{LC2R\,(s-s_1)\,(s-s_2)} = -\frac{R}{2LC}\frac{1+s^2LC}{(s-s_1)\,(s-s_2)} \\
\underline{I}(s) &= 1 \\
\underline{U}_1(s) &= -\frac{R}{2LC}\frac{1+s^2LC}{(s-s_1)\,(s-s_2)} \\
u_1(t) &= \sum_{i=1}^{2} \frac{\underline{Z}(s)}{\underline{N}'(s)} e^{st}\Bigg|_{s=s_i} \\
&= -\frac{R}{2LC}\left[\frac{1+s_1^2LC}{s_1-s_2}e^{s_1t} + \frac{1+s_2^2LC}{s_2-s_1}e^{s_2t}\right]
\end{aligned}$$

Aufgabe 6

a)

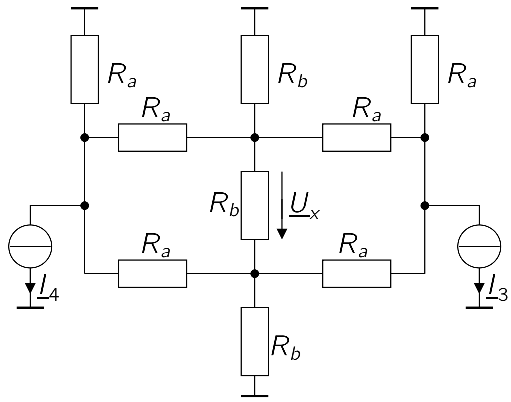


1)

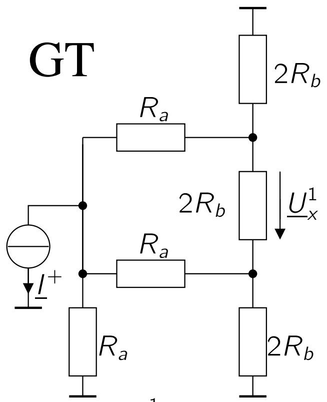
$$\underline{U}_1 = \underline{U}_2 = 0$$

$$\underline{I}_4 = \underline{I}^+ + \underline{I}^- = 0 \quad , \quad \underline{I}_3 = \underline{I}^+ - \underline{I}^-$$

$$\underline{I}^+ = \frac{\underline{I}_3 + \underline{I}_4}{2} = \frac{\underline{I}_3}{2} \quad , \quad \underline{I}^- = \frac{\underline{I}_4 - \underline{I}_3}{2} = -\frac{\underline{I}_3}{2}$$

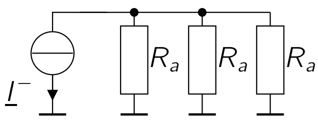


GT



$\underline{U}_x^1 = 0$

GGT



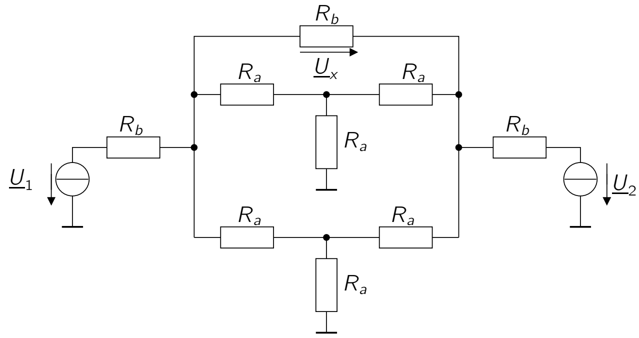
$\underline{U}_x^2 = 0$

2)

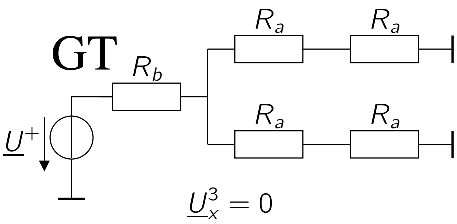
$$\underline{I}_3 = 0$$

$$\underline{U}_1 = \underline{U}^+ + \underline{U}^- \quad , \quad \underline{U}_2 = \underline{U}^+ - \underline{U}^-$$

$$\underline{U}^+ = \frac{\underline{U}_2 + \underline{U}_1}{2} \quad , \quad \underline{U}^- = \frac{\underline{U}_1 - \underline{U}_2}{2}$$

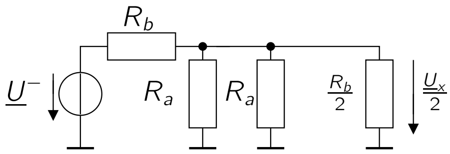


GT



$$\underline{U}_x^3 = 0$$

GGT



b)

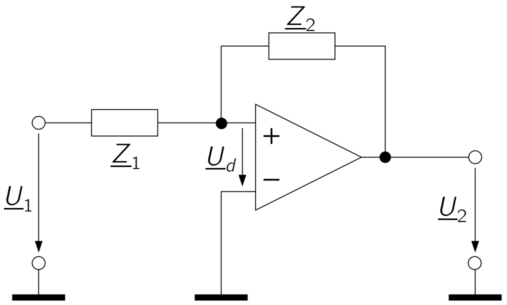
$$\frac{\underline{U}_x}{2} = \underline{U}^- \cdot \frac{R_a||R_a||\frac{R_b}{2}}{R_b + (R_a||R_a||\frac{R_b}{2})} \overset{(*)}{=} \frac{\frac{1}{2}R_aR_b}{R_b(R_a+R_b) + \frac{1}{2}R_aR_b}\underline{U}^-$$

$$\Rightarrow \underline{U}_x = \frac{R_a}{3R_a + 2R_b} \cdot (\underline{U}_1 - \underline{U}_2)$$

$$(*) \qquad R_a||R_a||\frac{R_b}{2} = \frac{\frac{R_a}{2}\frac{R_a}{2}}{\frac{R_a}{2} + \frac{R_a}{2}} = \frac{1}{2}\frac{R_aR_b}{R_a + R_b}$$

Aufgabe 7

a)



$$\underline{U}_2 = \underline{v}_u \underline{U}_d$$

$$\underline{U}_d = \frac{\underline{Z}_2}{\underline{Z}_1 + \underline{Z}_2}\underline{U}_1 + \frac{\underline{Z}_1}{\underline{Z}_1 + \underline{Z}_2}\underline{U}_2$$

$$\Leftrightarrow \frac{\underline{U}_2}{\underline{v}_u} = \frac{\underline{Z}_2}{\underline{Z}_1 + \underline{Z}_2}\underline{U}_1 + \frac{\underline{Z}_1}{\underline{Z}_1 + \underline{Z}_2}\underline{U}_2$$

$$\Leftrightarrow \underline{U}_2 \left(\frac{1}{\underline{v}_u} - \frac{\underline{Z}_1}{\underline{Z}_1 + \underline{Z}_2}\right) = \frac{\underline{Z}_2}{\underline{Z}_1 + \underline{Z}_2}\underline{U}_1$$

$$\Leftrightarrow \underline{U}_2 \frac{\underline{Z}_1 + \underline{Z}_2 - \underline{v}_u \underline{Z}_1}{\underline{v}_u (\underline{Z}_1 + \underline{Z}_2)} = \frac{\underline{Z}_2}{\underline{Z}_1 + \underline{Z}_2}\underline{U}_1$$

$$\Leftrightarrow \underline{F}_u = \frac{\underline{U}_2}{\underline{U}_1} = \frac{\underline{v}_u \underline{Z}_2}{\underline{Z}_1 + \underline{Z}_2 - \underline{v}_u \underline{Z}_1} = \frac{\underline{v}_u \frac{\underline{Z}_2}{\underline{Z}_1 + \underline{Z}_2}}{1 - \underline{v}_u \frac{\underline{Z}_1}{\underline{Z}_1 + \underline{Z}_2}}$$

b)

$$\underline{Z}_1' = R_1;\ \underline{Z}_2' = R_1 + \frac{1}{j\omega C_1};\ \underline{Z}_1'' = \frac{1}{j\omega C_2};\ \underline{Z}_2'' = R_2;\ \underline{v}_u' = \underline{v}_u'' = \alpha$$

$$\Rightarrow \underline{F}_k = \frac{\underline{v}_u' \underline{Z}_2'}{\underline{Z}_1' + \underline{Z}_2' - \underline{v}_u' \underline{Z}_1'} \cdot \frac{\underline{v}_u'' \underline{Z}_2''}{\underline{Z}_1'' + \underline{Z}_2'' - \underline{v}_u'' \underline{Z}_1''}$$

$$= \frac{\alpha \left(R_1 + \frac{1}{j\omega C_1}\right)}{R_1 + R_1 + \frac{1}{j\omega C_1} - \alpha R_1} \cdot \frac{\alpha R_2}{\frac{1}{j\omega C_2} + R_2 - \alpha \frac{1}{j\omega C_2}}$$

$$= \frac{1 + j\omega R_1 C_1}{\frac{1 + j\omega 2 R_1 C_1}{\alpha} - j\omega R_1 C_1} \cdot \frac{j\omega R_2 C_2}{\frac{1 + j\omega R_2 C_2}{\alpha} - 1}$$

$\alpha \to \infty$

$$\Rightarrow \underline{F}_k = \frac{(1 + j\omega R_1 C_1)\, j\omega R_2 C_2}{j\omega R_1 C_1}$$

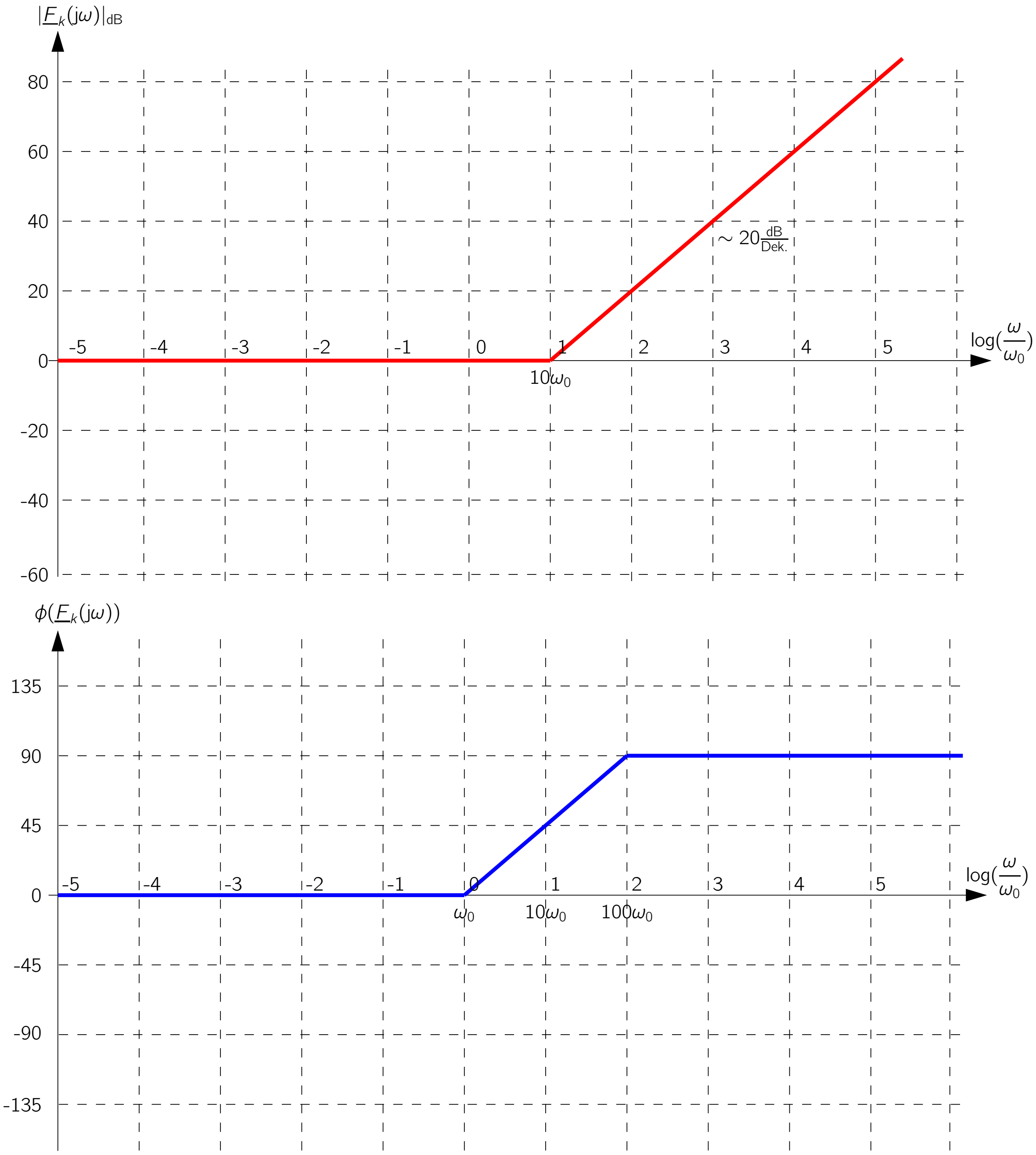
c)

$$0 \leq \omega \leq 10\omega_0 : \ \text{0dB}, \qquad \omega > 10\omega_0 : \ \text{20dB pro Dekade}$$

$$\Rightarrow R_1C_1 = R_2C_2 = \frac{1}{10\omega_0} \qquad \Rightarrow \underline{F}_k = 1 + j\frac{\omega}{10\omega_0}$$

$$\left(\omega_\alpha = \omega_\mu = \omega_\gamma = \frac{1}{10\omega_0}\right)$$

d)



|F_k(jω)|_dB
80
60
40
20
0
-20
-40
-60
-5 -4 -3 -2 -1 0 1 2 3 4 5
log(ω/ω0)
10ω0
~ 20 dB/Dek.
ϕ(F_k(jω))
135
90
45
0
-45
-90
-135
-5 -4 -3 -2 -1 0 1 2 3 4 5
log(ω/ω0)
ω0
10ω0
100ω0