Aufgabe 1

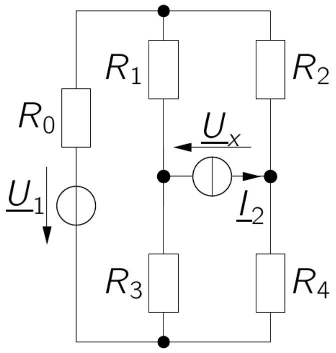
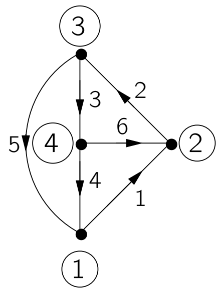


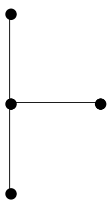
Abb. 1: Gegebenes Netzwerk.

a)

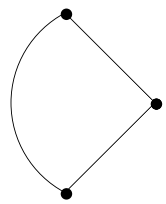
Graph:



Baum:



Co-Baum:



b)

$$A = \begin{array}{c c} & \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \end{array} & \begin{pmatrix} 1 & 0 & 0 & -1 & -1 & 0 \\ -1 & 1 & 0 & 0 & 0 & -1 \\ 0 & -1 & 1 & 0 & 1 & 0 \\ 0 & 0 & -1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Bezugsknoten 2 $\Rightarrow$ streiche 2. Zeile

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

c)

$$Y = \begin{pmatrix} \frac{1}{R_4} & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{1}{R_2} & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{R_1} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{R_3} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{R_0} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$\begin{aligned} Y_n &= AYA^T \\ &= \begin{pmatrix} -1 & 1 & 0 & 0 & 0 & -1 \\ 0 & -1 & -1 & 0 & 1 & 0 \\ 0 & 0 & -1 & 1 & 0 & 1 \end{pmatrix} \begin{pmatrix} \frac{1}{R_4} & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{1}{R_2} & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{R_1} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{R_3} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{R_0} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & -1 & -1 \\ -1 & 0 & 1 \\ -1 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \\ &= \begin{pmatrix} \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_0} & -\frac{1}{R_0} & -\frac{1}{R_3} \\ -\frac{1}{R_0} & \frac{1}{R_2} + \frac{1}{R_1} + \frac{1}{R_0} & -\frac{1}{R_1} \\ -\frac{1}{R_3} & -\frac{1}{R_1} & \frac{1}{R_1} + \frac{1}{R_3} \end{pmatrix} \end{aligned}$$

$$
\begin{aligned}
I_{qn} &= A(I_g - YU_g) \\
&= \begin{pmatrix} 1 & 0 & 0 & -1 & -1 & 0 \\ 0 & -1 & -1 & 0 & 1 & 0 \\ 0 & 0 & -1 & 1 & 0 & 1 \end{pmatrix} \left(\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ -I_2 \end{pmatrix} - Y \cdot \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ -U_1 \\ 0 \end{pmatrix} \right) \\
&= \begin{pmatrix} -\frac{U_1}{R_0} \\ \frac{U_1}{R_0} \\ -I_2 \end{pmatrix}
\end{aligned}
$$

d)

$$
\begin{pmatrix} \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_0} & -\frac{1}{R_0} & -\frac{1}{R_3} \\ -\frac{1}{R_0} & \frac{1}{R_2} + \frac{1}{R_1} + \frac{1}{R_0} & -\frac{1}{R_1} \\ -\frac{1}{R_3} & -\frac{1}{R_1} & \frac{1}{R_1} + \frac{1}{R_3} \end{pmatrix} \begin{pmatrix} U_{n2} \\ U_{n3} \\ U_{n4} \end{pmatrix} = \begin{pmatrix} -\frac{U_1}{R_0} \\ \frac{U_1}{R_0} \\ -I_2 \end{pmatrix}
$$

Einsetzen:
$R_1 = R_2 = R_x$
$R_3 = R_4 = R_y$

$$
\begin{pmatrix} \frac{1}{R_x} + \frac{1}{R_y} + \frac{1}{R_0} & -\frac{1}{R_0} & -\frac{1}{R_y} \\ -\frac{1}{R_0} & \frac{2}{R_x} + \frac{1}{R_0} & -\frac{1}{R_x} \\ -\frac{1}{R_y} & -\frac{1}{R_x} & \frac{1}{R_x} + \frac{1}{R_y} \end{pmatrix} \begin{pmatrix} U_{n2} \\ U_{n3} \\ U_{n4} \end{pmatrix} = \begin{pmatrix} -\frac{U_1}{R_0} \\ \frac{U_1}{R_0} \\ -I_2 \end{pmatrix}
$$

Kramer'sche Regel:

$$
U_x = -U_{n4} = -\frac{det \begin{pmatrix} \frac{1}{R_x} + \frac{1}{R_y} + \frac{1}{R_0} & -\frac{1}{R_0} & -\frac{U_1}{R_0} \\ -\frac{1}{R_0} & \frac{2}{R_x} + \frac{1}{R_0} & \frac{U_1}{R_0} \\ -\frac{1}{R_y} & -\frac{1}{R_x} & -I_2 \end{pmatrix}}{det \begin{pmatrix} \frac{1}{R_x} + \frac{1}{R_y} + \frac{1}{R_0} & -\frac{1}{R_0} & -\frac{1}{R_y} \\ -\frac{1}{R_0} & \frac{2}{R_x} + \frac{1}{R_0} & -\frac{1}{R_x} \\ -\frac{1}{R_y} & -\frac{1}{R_x} & \frac{1}{R_x} + \frac{1}{R_y} \end{pmatrix}}
$$

Aufgabe 2

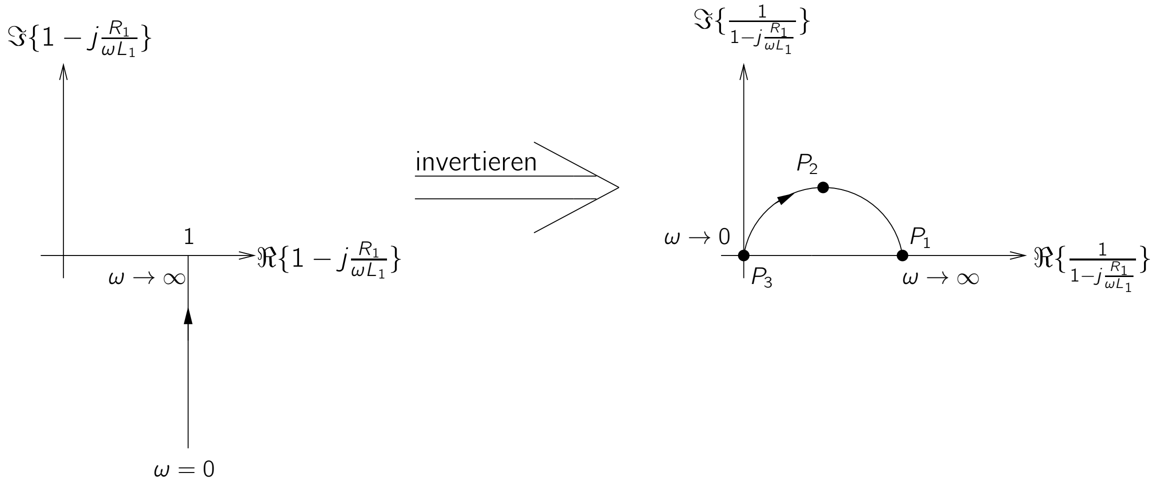
a)

$$\frac{U_x}{U_1} = \frac{j\omega L_1}{R_1 + j\omega L_1} = \frac{1}{1+\frac{R_1}{j\omega L_1}} = \frac{1}{1-j\frac{R_1}{\omega L_1}}$$

$$\frac{U_y}{U_1} = \frac{R_2}{R_2 + j\omega L_2} = \frac{1}{1+j\frac{\omega L_2}{R_2}}$$

b)

$\underline{U}_x$:

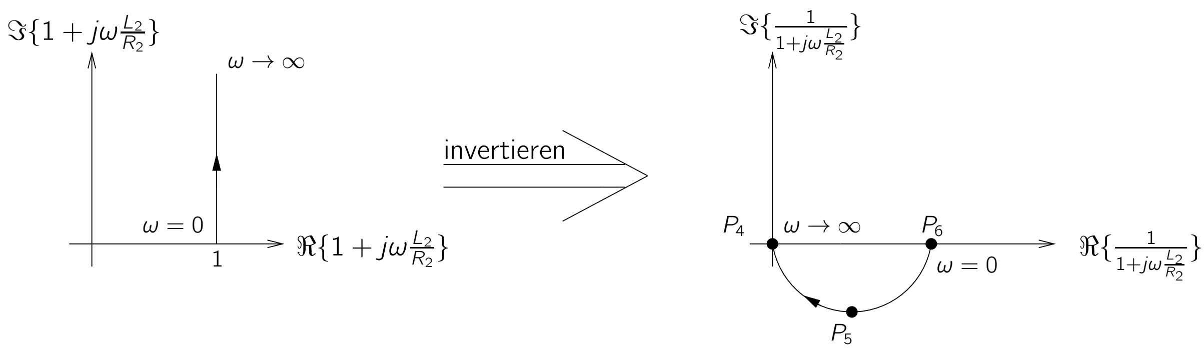


$P_1 : \underline{U}_x\left(\omega = 0\right) = 0$

$P_2 : \underline{U}_x\left(\omega = \frac{R_1}{L_1}\right) = \frac{\underline{U}_1}{2}\left(1+j\right)$

$P_3 : \underline{U}_x\left(\omega \to \infty\right) = \underline{U}_1$

$\underline{U}_y$:



$P_4 : \underline{U}_y\left(\omega \to \infty\right) = 0$

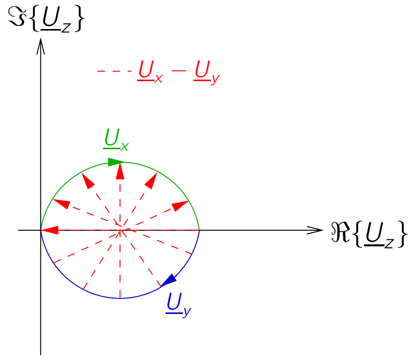
$P_5 : \underline{U}_y\left(\omega = \frac{R_2}{L_2}\right) = \frac{\underline{U}_1}{2}\left(1-j\right)$

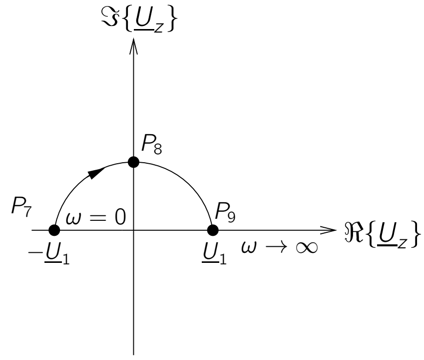
$P_6 : \underline{U}_y\left(\omega = 0\right) = \underline{U}_1$

c)

i)

$R_1 L_2 = R_2 L_1 \rightarrow \frac{R_1}{L_1} = \frac{R_2}{L_2}$
$\underline{U}_z = \underline{U}_x - \underline{U}_y$



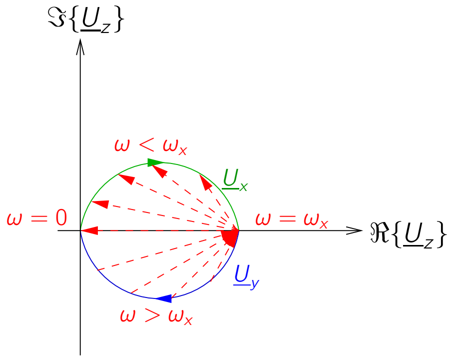


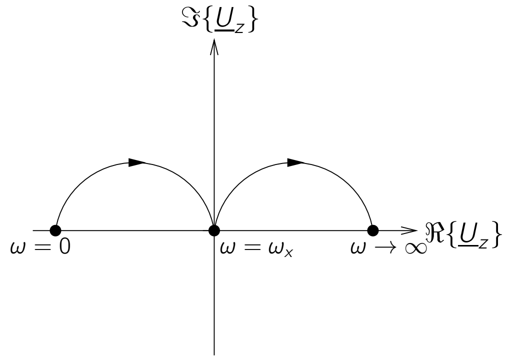
$P_7 : \underline{U}_z\,(\omega = 0) = -\underline{U}_1$
$P_8 : \underline{U}_z\left(\omega = \frac{R_1}{L_1} = \frac{R_2}{L_2}\right) = j\underline{U}_1$
$P_9 : \underline{U}_z\,(\omega \rightarrow \infty) = \underline{U}_1$

ii)

$R_1 \ll \omega_x L_1 \qquad \omega > \omega_x$
$R_2 \gg \omega_x L_2 \qquad \omega < \omega_x$

Bis zur Frequenz ω_x hat $\underline{U}_y$ den Punkt $\underline{U}_1$ noch nicht verlassen, $\underline{U}_x$ endet dort aber Aufgrund der Näherung. Für Frequenzen größer als ω_x bleibt $\underline{U}_x$ näherungsweise konstant bei $\underline{U}_1$, $\underline{U}_y$ dagegen verlässt diesen Punkt und wandert Richtung Ursprung.





Aufgabe 3

a)

Bestimme AP I_c und g_m: Basisspannungsteiler mit zwei gleichen Widerständen ergibt ein Basispotential von $\frac{U_0}{2}$. U_{BE} ist konstant, somit ergibt sich ein Kollektorstrom mit entsprechendem Spannungsabfall über R_E von $I_C = \frac{\frac{U_0}{2} - U_{BE}}{R_E}$
und $g_m = \frac{I_C}{U_T} = \frac{\frac{U_0}{2} - U_{BE}}{R_E \cdot U_T}$ mit $U_T = \frac{k_B T}{e}$.

b)

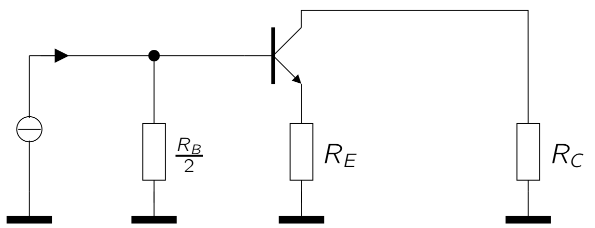
Bedingung für normal-aktiven Bereich: $U_{CB} > 0$ und $U_{BE} > 0$. Maximales und minimales Kollektorpotential:

$$U_{Out,max} = \frac{U_0}{2}$$
$$U_{Out,min} = 0$$

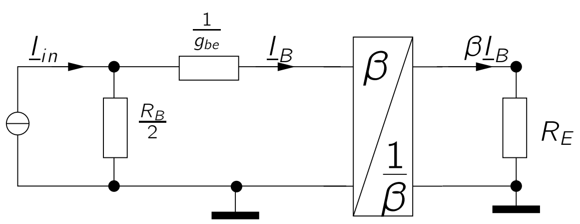
Für das Potential in der Mitte dieses Bereiches gilt demnach $\frac{U_0}{4} = I_C R_C$.
$R_C = \frac{\frac{U_0}{4}}{\frac{U_0}{2} - U_{BE}} \cdot R_E$.

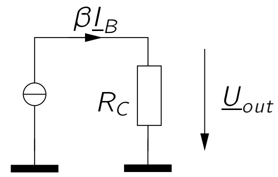
c)

Emitter-Grundschaltung (EGS)



d)





$$U_{out} = R_C \cdot \beta \underline{I}_b$$

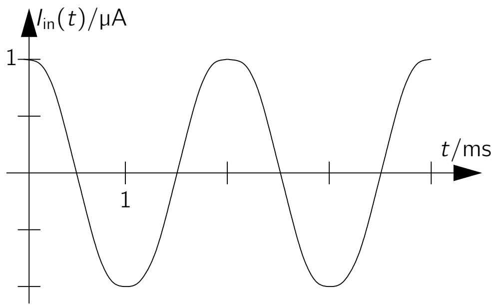
$$\underline{I}_b = \underline{I}_{in} \cdot \frac{\frac{R_B}{2}}{\frac{R_B}{2} + \frac{1}{g_{be}} + \beta R_E}$$

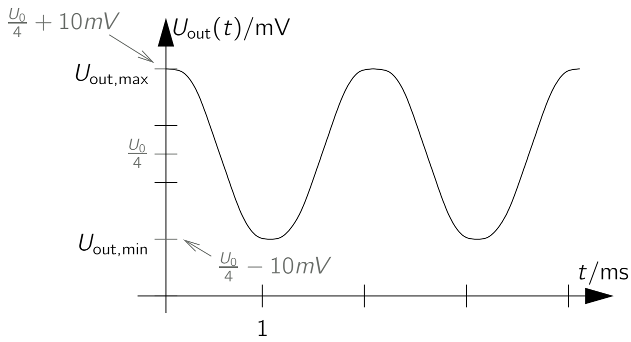
$$\underline{Z}_{trans} = \beta R_C \cdot \frac{\frac{R_B}{2}}{\frac{R_B}{2} + \frac{1}{g_{be}} + \beta R_E}$$

e)

$\underline{Z}_{trans} = \beta R_C = 10\,\mathrm{k\Omega}$
$U_0 = 4\,\mathrm{V}$
$U_{out}(t) = ?$

Der Arbeitspunkt der Ausgangsspannung beträgt $\frac{U_0}{4}$, die Amplitude des Eingangsstrom $1\mu A$. Aufgrund der Transimpedanz ergibt sich eine Amplitude von $|\underline{U}_{out}| = |\underline{Z}_{trans} \cdot \underline{I}_{in}| = 10mV$.



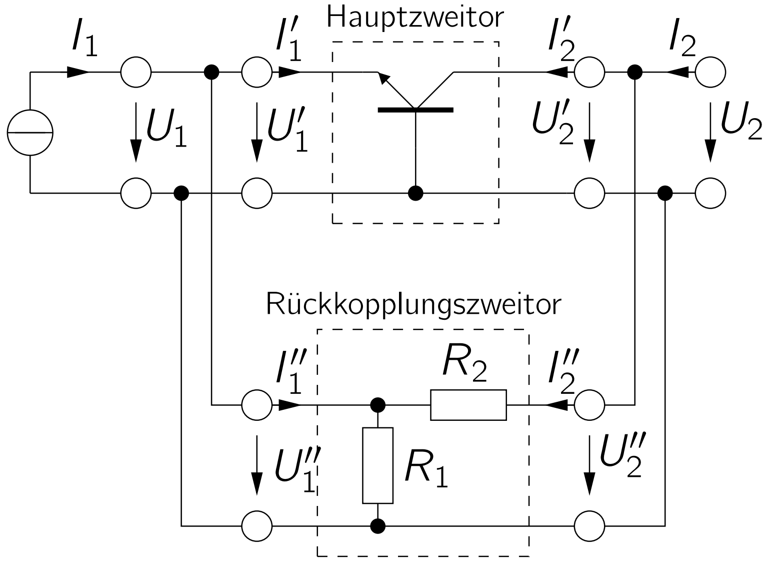


f)

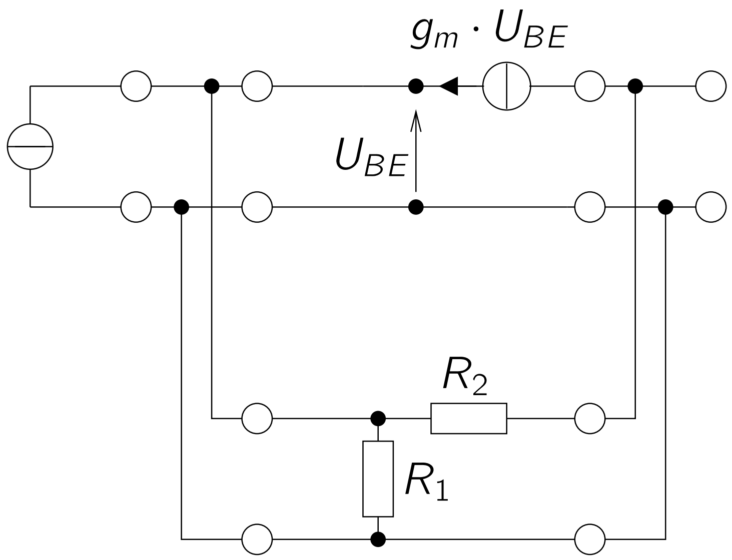
Maximale Ausgangsamplitude: $\|\tilde{U}_{out}\|_{max} = \frac{U_0}{4} = 1\,\mathrm{V}$
$I_{max} \cdot R_C \cdot \beta = 1\,\mathrm{V}$
$I_{max} = \frac{1\,\mathrm{V}}{10\,\mathrm{k\Omega}} = 100\mu A$

Aufgabe 4

a)



b)



c)

i)

Parallel-Parallel-Kopplung (PPK)

ii)

Y-(Admittanz-)Matrix

$$\begin{aligned}
\underline{U}_1 &= \underline{U}_1' = \underline{U}_1'' \\
\underline{I}_1 &= \underline{I}_1' + \underline{I}_1'' \\
&= \underline{Y}_{11}'\underline{U}_1 + \underline{Y}_{11}''\underline{U}_1 + \underline{Y}_{12}'\underline{U}_2 + \underline{Y}_{12}''\underline{U}_2 \\
&= \left(\underline{Y}_{11}' + \underline{Y}_{11}''\right)\underline{U}_1 + \left(\underline{Y}_{12}' + \underline{Y}_{12}''\right)\underline{U}_2
\end{aligned}$$

$$\begin{aligned}
\underline{U}_2 &= \underline{U}_2' = \underline{U}_2'' \\
\underline{I}_2 &= \underline{I}_2' + \underline{I}_2'' \\
&= \underline{Y}_{21}'\underline{U}_1 + \underline{Y}_{21}''\underline{U}_1 + \underline{Y}_{22}'\underline{U}_2 + \underline{Y}_{22}''\underline{U}_2 \\
&= \left(\underline{Y}_{21}' + \underline{Y}_{21}''\right)\underline{U}_1 + \left(\underline{Y}_{22}' + \underline{Y}_{22}''\right)\underline{U}_2
\end{aligned}$$

d)

$$\begin{aligned}
\underline{Y}_{11}' &= \left.\frac{\underline{I}_1'}{\underline{U}_1'}\right|_{\underline{U}_2'=0} = \frac{-g_m \cdot U_{BE}}{-U_{BE}} = g_m \\
\underline{Y}_{21}' &= \left.\frac{\underline{I}_2'}{\underline{U}_1'}\right|_{\underline{U}_2'=0} = \frac{g_m \cdot U_{BE}}{-U_{BE}} = -g_m \\
\underline{Y}_{12}' &= \left.\frac{\underline{I}_1'}{\underline{U}_2'}\right|_{\underline{U}_1'=0} = 0 \\
\underline{Y}_{22}' &= \left.\frac{\underline{I}_2'}{\underline{U}_2'}\right|_{\underline{U}_1'=0} = 0
\end{aligned}$$

$$\begin{aligned}
\underline{Y}_{11}'' &= \left.\frac{\underline{I}_1''}{\underline{U}_1''}\right|_{\underline{U}_2''=0} = \frac{1}{R_1} + \frac{1}{R_2} \\
\underline{Y}_{21}'' &= \left.\frac{\underline{I}_2''}{\underline{U}_1''}\right|_{\underline{U}_2''=0} = -\frac{1}{R_2} \\
\underline{Y}_{12}'' &= \left.\frac{\underline{I}_1''}{\underline{U}_2''}\right|_{\underline{U}_1''=0} = -\frac{1}{R_2} \\
\underline{Y}_{22}'' &= \left.\frac{\underline{I}_2''}{\underline{U}_2''}\right|_{\underline{U}_1''=0} = \frac{1}{R_2}
\end{aligned}$$

$$\begin{aligned}
\Rightarrow \underline{Y} &= \underline{Y}' + \underline{Y}'' \\
&= \begin{pmatrix} g_m + \frac{1}{R_1} + \frac{1}{R_2} & -\frac{1}{R_2} \\ -g_m - \frac{1}{R_2} & \frac{1}{R_2} \end{pmatrix}
\end{aligned}$$

e)

$\underline{I}_2 = 0 = \underline{Y}_{21}\underline{U}_1 + \underline{Y}_{22}\underline{U}_2 \Leftrightarrow \underline{U}_1 = -\frac{\underline{Y}_{22}}{\underline{Y}_{21}}\underline{U}_2$

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

$\Leftrightarrow \frac{\underline{U}_2}{\underline{I}_1} = \frac{1}{\underline{Y}_{12} - \frac{\underline{Y}_{11}\underline{Y}_{22}}{\underline{Y}_{21}}} = \frac{\underline{Y}_{21}}{\underline{Y}_{12}\underline{Y}_{21} - \underline{Y}_{11}\underline{Y}_{22}} = \underline{Z}_T$

Einsetzen:
$\underline{Z}_T = \frac{1}{-\frac{1}{R_2} + \frac{\frac{1}{R_1} + \frac{1}{R_2} + g_m}{g_m + \frac{1}{R_2}}} = R_1 R_2 \cdot \left(g_m + \frac{1}{R_2}\right)$

f)

Aufgabenteil wurde in Klausur nicht bewertet. Für $R_2 = 0$ (Kurzschluss) ist die Transimpedanz am geringsten, und steigt linear proportional zu $R_1 \cdot g_m$.

Aufgabe 5

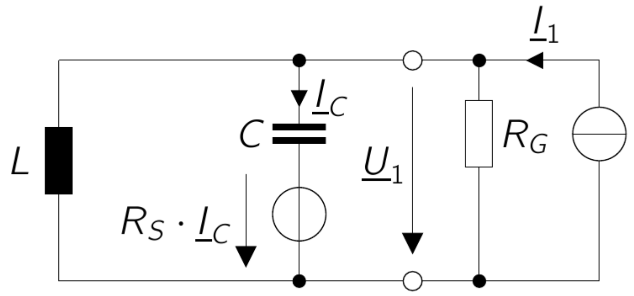


Abb. 5: Zu untersuchende Schaltung.

a)

Übertragungsfunktion: $F(s) = \frac{I_C}{I_1}$

$I_C \frac{1}{j\omega C} + R_S I_C = (I_1 - I_C) \cdot \frac{sLR_G}{sL+R_G} = U_{out}$

$I_C = I_1 \cdot \frac{\frac{sLR_G}{sL+R_G}}{\frac{1}{sC}+R_S+\frac{sLR_G}{sL+R_G}} = I_1 \cdot \frac{s^2LCR_G}{(1+R_SsC)(sL+R_G)+s^2LCR_G}.$

Damit: $F(s) = \frac{s^2LCR_G}{(1+R_SsC)(sL+R_G)+s^2LCR_G}.$

b)

Verantwortlich für Stabilität: Pole der Wirkungsfunktion
Alle Wirkungsfunktionen mit gleicher Ursache haben die gleichen Pole (Determinante der Knotenadmittanzmatrix). $\Rightarrow$ Untersuchung der Stabilität mit jeder Wirkungsfunktion des Netzwerkes möglich.
$\underline{Z}(s)$ hat die gleiche Pole wie $\underline{F}(s)$.

c)

Pole von $F(s)$:
$s^2\left(R_SLC + R_GLC\right) + s\left(L + R_SR_GC\right) + R_G = 0$

$s_{1/2} = -\frac{1}{2}\frac{L+R_SR_GC}{R_SLC+R_GLC} \pm \sqrt{\left(\frac{1}{2}\frac{L+R_SR_GC}{R_SLC+R_GLC}\right)^2 - \frac{R_G}{R_SLC+R_GLC}} = \sigma_0 \pm j\omega_0$

mit $\sigma_0 = -\frac{1}{2}\frac{L+R_SR_GC}{R_SLC+R_GLC}$ und

$\omega_0 = \sqrt{-\left(\frac{1}{2}\frac{L+R_SR_GC}{R_SLC+R_GLC}\right)^2 + \frac{R_G}{R_SLC+R_GLC}}.$

d)

Aufklingende, sinusförmige Oszillation:
$\Re\{s_{1/2}\} = \sigma_0 > 0$ und
$\Im\{s_{1/2}\} = \omega_0 \neq 0$

mit $R_G > -R_s$.

Entsprechend der Bedingung $\sigma_0 > 0$ ergibt dies:
$L + R_s R_G C < 0$ mit $R_s < 0$, $R_G > 0$ und $R_G > -R_s$, zu
$R_G > -\frac{L}{R_s C}$.

Damit überhaupt ein Imaginärteil existiert, muss
$\frac{R_G}{R_S LC + R_G LC} > \left(\frac{1}{2}\frac{L + R_S R_G C}{R_S LC + R_G LC}\right)^2$
gelten. Diese quadratische Ungleichung in R_s aufgelöst ergibt die Bedingung
$\frac{L}{R_G C} - 2\sqrt{\frac{L}{C}} < R_s < \frac{L}{R_G C} + 2\sqrt{\frac{L}{C}}$.

e)

Wert von R_G für Aufklingen: $\Re\{s_{1/2}\} = \sigma_0 > 0$.

$\frac{1}{2}\frac{L + R_s R_G C}{R_S LC + R_G LC} < 0$
Nenner ist postiv wegen $R_G + R_s > 0$. Dies führt zu $R_G > -\frac{L}{R_S C}$.
Richtung des Ungleichheitszeichen kommt dadurch zustande, da R_s negativ ist.

Aufgabe 6

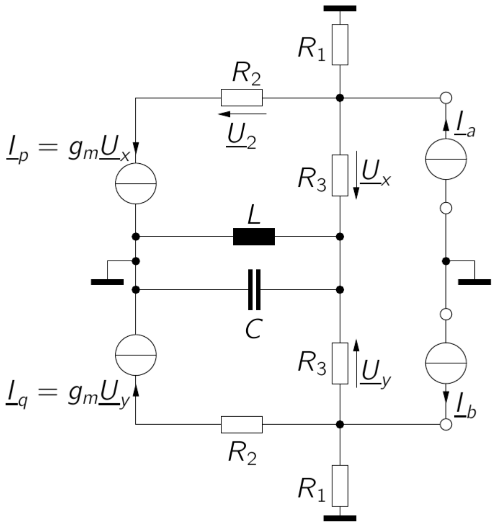
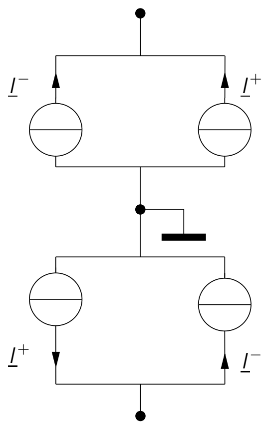


Abb. 6: Zu untersuchende Schaltung.

a)

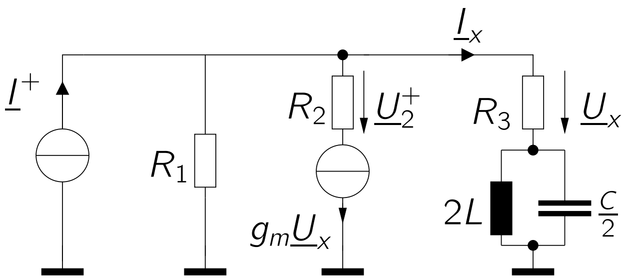


Phasoren:
$\underline{I}_a = \underline{I}^+ + \underline{I}^-$
$\underline{I}_b = \underline{I}^+ - \underline{I}^-$

$\underline{I}^+ = \frac{\underline{I}_a + \underline{I}_b}{2}$
$\underline{I}^- = \frac{\underline{I}_a - \underline{I}_b}{2}$

b) und c)

Gleichtakt:



$\underline{Z} := j\omega 2L \| \frac{2}{j\omega C} = \frac{j\omega 2L}{1-\omega^2 CL}$

$\underline{I}_x = \left(\underline{I}^+ - g_m\underline{U}_x\right) \cdot \underline{X}$ mit

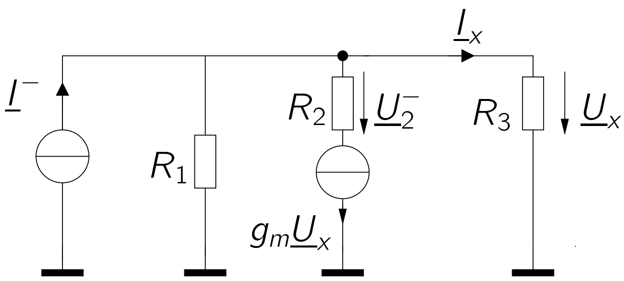
$\underline{X} := \frac{R_1}{R_1+R_3+\underline{Z}}$

$\underline{U}_x = R_3\underline{I}_x = R_3\underline{X}\ \underline{I}^+ - g_m R_3 \underline{X}\ \underline{U}_x$

$\underline{U}_x = \frac{R_3\underline{X}\underline{I}^+}{1+g_m R_3\underline{X}}$

$\underline{U}_2^+ = g_m\underline{U}_x R_2 = \frac{g_m R_2 R_3 \underline{X}\ \underline{I}^+}{1+g_m R_3\underline{X}}$

Gegentakt:



$\underline{I}_x = \left(\underline{I}^- - g_m\underline{U}_x\right) \cdot \underline{Y}$ mit

$\underline{Y} := \frac{R_1}{R_1+R_3}$

$\underline{U}_x = \frac{R_3\underline{Y}\underline{I}^-}{1+g_m R_3\underline{Y}}$

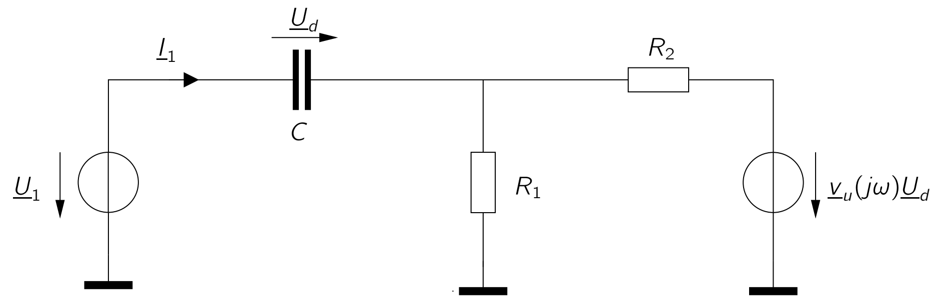
$\underline{U}_2^- = \frac{g_m R_2 R_3 \underline{Y}\ \underline{I}^-}{1+g_m R_3\underline{Y}}$

$\underline{U}_2 = \underline{U}_2^+ + \underline{U}_2^- = \frac{g_m R_2 R_3 \underline{X}}{1+g_m R_3\underline{X}} \cdot \frac{\underline{I}_a+\underline{I}_b}{2} + \frac{g_m R_2 R_3 \underline{Y}}{1+g_m R_3\underline{Y}} \cdot \frac{\underline{I}_a-\underline{I}_b}{2}$

d)

Vorzeichenänderung im Gegentakt

Aufgabe 7



a)

$\underline{I}_1 = \underline{U}_d j\omega C$

$\frac{\underline{U}_1-\underline{U}_d}{R_1} = I_1 + \frac{\underline{v}_u(j\omega)\underline{U}_d-\underline{U}_1+\underline{U}_d}{R_2} = \underline{U}_d j\omega C + \frac{\underline{v}_u(j\omega)\underline{U}_d-\underline{U}_1+\underline{U}_d}{R_2}$

$\underline{U}_1 - \underline{U}_d = \underline{U}_d j\omega R_1 C + \frac{R_1}{R_2}(\underline{v}_u(j\omega)+1)\underline{U}_d - \frac{R_1}{R_2}\underline{U}_1$

$\underline{U}_1(1+\frac{R_1}{R_2}) = \underline{U}_d(j\omega R_1 C + 1 + \frac{R_1}{R_2}(\underline{v}_u(j\omega)+1))$

$\underline{U}_d = \underline{U}_1 \frac{1+\frac{R_1}{R_2}}{j\omega R_1 C+\frac{R_1}{R_2}(\underline{v}_u(j\omega)+1)+1}$

$\underline{U}_2 = \underline{v}_u(j\omega)\underline{U}_d = \underline{U}_1 \frac{\underline{v}_u(j\omega)(1+\frac{R_1}{R_2})}{\frac{R_1}{R_2}\underline{v}_u(j\omega)+\frac{R_1}{R_2}+j\omega R_1 C+1}$

$\underline{U}_2 = \frac{1+\frac{R_1}{R_2}}{\frac{R_1}{R_2}+\frac{1}{\underline{v}_u(j\omega)}(1+\frac{R_1}{R_2}+j\omega R_1 C)}\underline{U}_1$

$\underline{F}(j\omega) = \frac{\underline{U}_2}{\underline{U}_1} = \frac{\frac{1}{R_1}+\frac{1}{R_2}}{\frac{1}{R_2}+\frac{1}{\underline{v}_u(j\omega)}(\frac{1}{R_1}+\frac{1}{R_2}+j\omega C)}$

b)

$|\underline{v}_u| \to \infty$

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

c)

$\underline{F}(j\omega) = \frac{\left(1+\frac{R_1}{R_2}\right)\frac{\underline{v}_u(j\omega)}{1+\frac{R_1}{R_2}+j\omega R_1 C}}{1+\frac{R_1}{R_2}\cdot\frac{\underline{v}_u(j\omega)}{1+\frac{R_1}{R_2}+j\omega R_1 C}} = \frac{\underline{F}_a}{1+\underline{F}_2\underline{F}_a}$

mit der Schleifenverstärkung

$\underline{F}_2\underline{F}_a = \frac{R_1}{R_2}\frac{\underline{v}_u(j\omega)}{1+\frac{R_1}{R_2}+j\omega R_1 C}.$

mit $F_2 = \frac{1}{1+\frac{R_2}{R_1}}$ aus Aufgabenteil b)

Damit ergibt sich:

$\underline{F}_a = \frac{F_2 \underline{F}_a}{\underline{F}_2} = \left(1 + \frac{R_1}{R_2}\right) \frac{\underline{v}_u(j\omega)}{1+\frac{R_1}{R_2}+j\omega R_1 C}$ und

$\underline{F}_2 = \frac{R_1}{R_1+R_2}$.

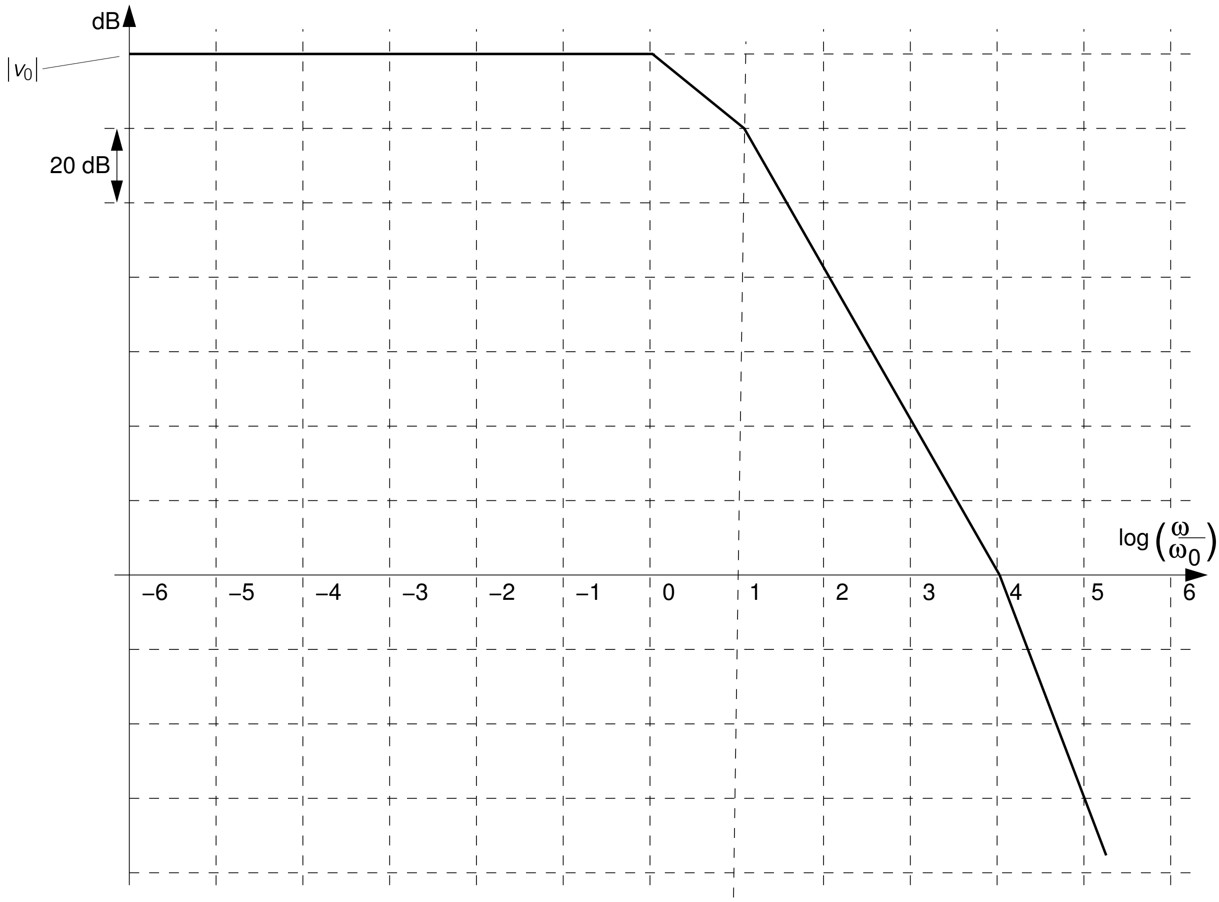
d)

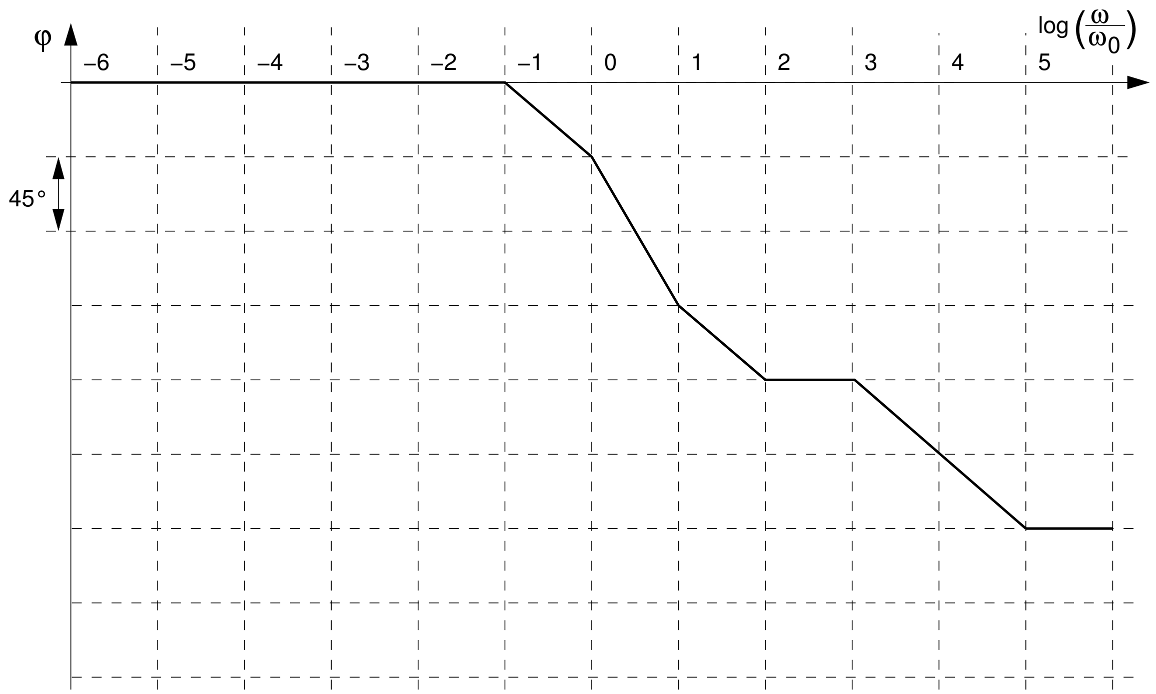
$\underline{F}_a = \left(1 + \frac{R_1}{R_2}\right) \frac{\underline{v}_u(j\omega)}{1+\frac{R_1}{R_2}+j\omega R_1 C} = \left(1 + \frac{R_1}{R_2}\right) \frac{\underline{v}_u(j\omega)}{(1+\frac{R_1}{R_2})(1+j\frac{\omega R_1 C}{1+\frac{R_1}{R_2}})} = \frac{\underline{v}_u(j\omega)}{1+j\omega\frac{R_1 C}{1+\frac{R_1}{R_2}}} = \frac{\underline{v}_u(j\omega)}{1+j\frac{\omega}{\omega_0}}$

mit $C = \frac{R_1+R_2}{R_1 R_2 \omega_0}$.

$\underline{F}_a = \frac{v_0}{(1+j\frac{\omega}{\omega_0})(1+j\frac{\omega}{10\omega_0})(1+j\frac{\omega}{10000\omega_0})}$

$\lim\limits_{\omega\to 0} \underline{F}_a(j\omega) = v_0$


dB
$|v_0|$
20 dB
$\log\left(\frac{\omega}{\omega_0}\right)$
–6
–5
–4
–3
–2
–1
0
1
2
3
4
5
6


φ
$\log\left(\frac{\omega}{\omega_0}\right)$
–6
–5
–4
–3
–2
–1
0
1
2
3
4
5
45°