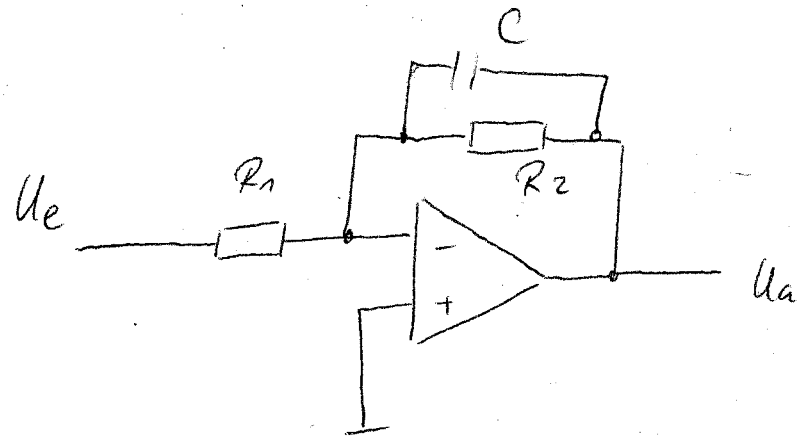
10.9

(a)



(b)

$$\underline{V} = \frac{\underline{U}_a}{\underline{U}_e} = -\frac{R_2}{R_1} \cdot \frac{1}{1 + j\omega R_2 C} \quad \text{(inv. Verst.)}$$

kompl.

GF:

$$45° = +\operatorname{atan}\left(\frac{\omega_{gr} R_2 C}{1}\right)$$

$$\tan 45° = 1 = \omega_{gr} R_2 C$$

$$\omega_{gr} = \frac{1}{R_2 C} \Rightarrow$$

$$f_{gr} = \frac{1}{2\pi R_2 C} = 1{,}6\,\text{kHz}$$

$$R_2 = \frac{1}{2\pi \cdot 1{,}6\,\text{kHz} \cdot C} \Bigg|_{C = 560\,\text{pF}} \text{(E24)}$$

$$R_2 = 178\,\text{k}\Omega \quad \text{(E48)}$$

$$\Rightarrow \quad V_u = -\frac{R_2}{R_1} \cdot \frac{1}{\underbrace{1 + j\omega R_2 C}_{\approx 0 \text{ für } \omega \ll \omega_{gr}}}$$

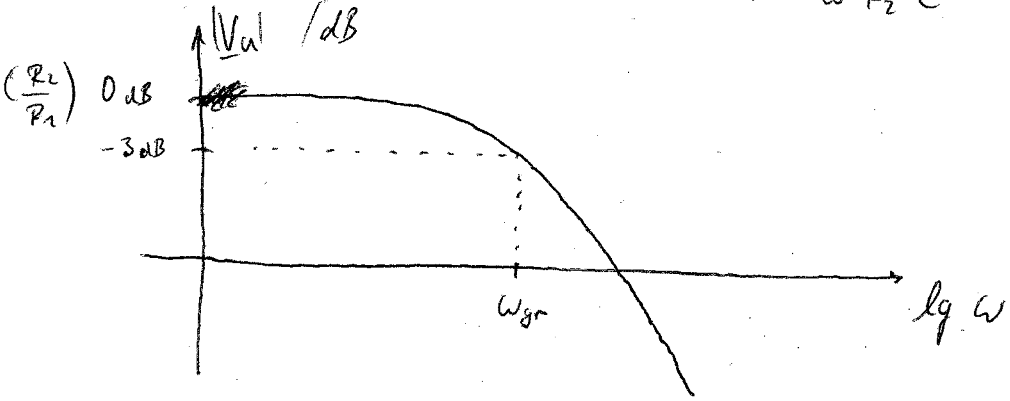
$$\leadsto \quad V_u = -\frac{R_2}{R_1} = -21{,}3$$

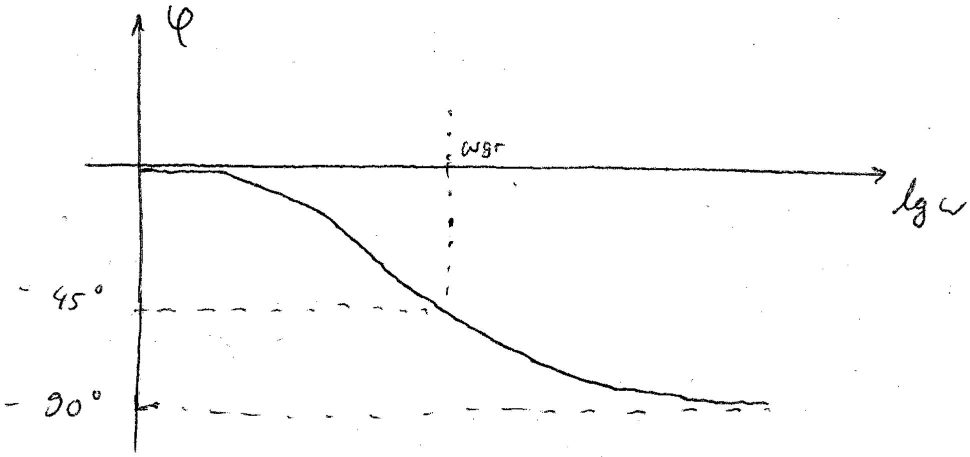
$$R_1 = \frac{R_2}{21{,}3} = \cancel{8{,}19}\ 8{,}25\,\text{k}\Omega \quad (E48)$$

(c)

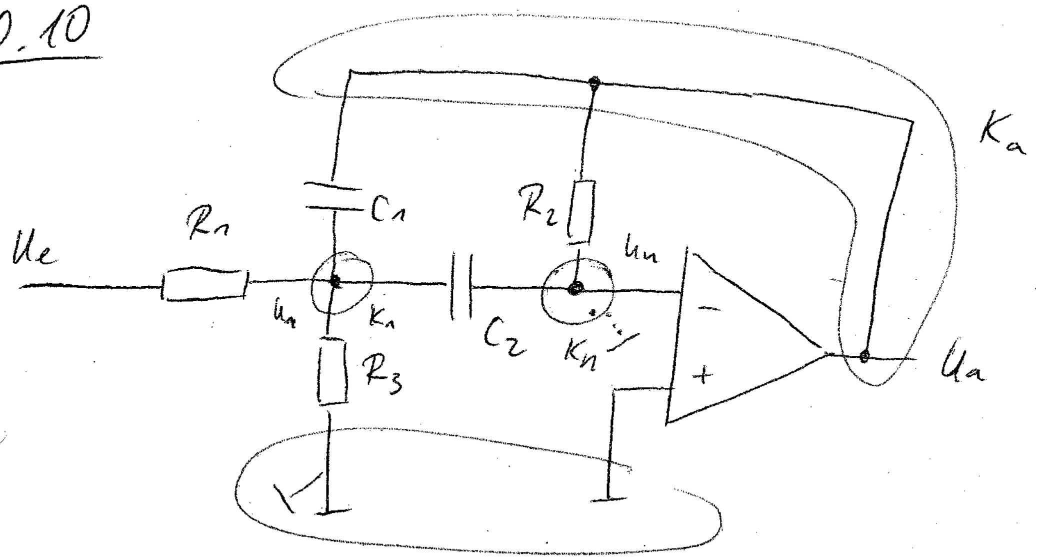
$$\underline{V}_u = -\frac{R_2}{R_1} \cdot \frac{1}{1 + j\omega R_2 C}$$

$$|\underline{V}_u| = \frac{R_2}{R_1} \cdot \frac{1}{\sqrt{1 + \omega^2 R_2^2 C^2}}$$





10.10



(a)

K_n: Virtuelle Masse ~ $U_n = 0$

$$K_1:\quad 0 = \frac{U_1 - U_e}{R_1} + \frac{U_1 - 0}{R_3} + \frac{U_1 - U_a}{\frac{1}{j\omega C_1}} + \frac{U_1 - \cancel{U_n}^{\,0}}{\frac{1}{j\omega C_2}}$$

$$K_a:\quad 0 = \frac{U_a - \cancel{U_n}^{\,0}}{R_2} + \frac{U_a - U_1}{\frac{1}{j\omega C_1}}$$

$$K_1:\quad 0 = U_1 \overbrace{\left(\frac{1}{R_1} + \frac{1}{R_3} + j\omega C_1 + j\omega C_2\right)}^{P_1} - \frac{U_e}{R_1} - U_a \cdot \underbrace{j\omega C_1}_{P_3}$$

$$K_2:\quad 0 = U_a \underbrace{\left(\frac{1}{R_2} + j\omega C_1\right)}_{P_2} - \cancel{U_a}\, U_1 \cdot \underbrace{j\omega C_1}_{P_3}$$

Matrix:

$$\begin{pmatrix} \frac{U_e}{R_1} \\ 0 \end{pmatrix} = \begin{pmatrix} P_1 & P_3 \\ P_3 & P_2 \end{pmatrix} \begin{pmatrix} U_1 \\ U_a \end{pmatrix}$$

$$\Delta = \det \begin{pmatrix} P_1 & P_3 \\ P_3 & P_2 \end{pmatrix} = P_1 \cdot P_2 - P_3^2$$

$$\Delta_2 = \det \begin{pmatrix} P_1 & \frac{U_e}{R_1} \\ P_3 & 0 \end{pmatrix} = 0 - \frac{U_e}{R_1} \cdot P_3$$

$$U_a = \frac{\Delta_2}{\Delta} = \frac{-\frac{U_e}{R_1} \cdot P_3}{P_1 \cdot P_2 - P_3^2} = \frac{-\frac{U_e}{R_1}}{\frac{P_1 \cdot P_2}{P_3} - P_3}$$

$$\frac{U_a}{U_e} = \cancel{-\frac{1}{R_1} \cdot \frac{1}{\frac{P_1 P_2}{P_3}}} \quad \frac{1}{\frac{P_1 P_2}{P_3} - P_3}$$

$$\cancel{= -\frac{1}{R_1} \cdot \frac{1}{\frac{\left(\frac{1}{R_1} + \frac{1}{R_3} + j\omega(C_1 + C_2)\right) \cdot \left(\frac{1}{R_2} + j\omega C_1\right)}{j\omega C_1} - j\omega C_1}}$$

Form: $$\frac{U_a}{U_e} = -\frac{a p C}{1 + b p C + c p^2 C^2} \Bigg|_{p = j\omega}$$

$$\frac{U_a}{U_e} = -\frac{1}{R_1} \cdot \frac{P_3}{P_1 \cdot P_2 - P_3^2}$$

$$= -\frac{1}{R_1} \cdot \frac{p C_1}{\left(\frac{1}{R_1} + \frac{1}{R_3} + p(C_1 + C_2)\right) \cdot \left(\frac{1}{R_2} + p C_1\right) - p C_1}$$

c) $$\frac{U_a}{U_e} = -\frac{1}{R_1} \cdot \frac{pC_1}{\frac{1}{R_2}\left(\frac{1}{R_1}+\frac{1}{R_3}\right) + pC_1\left(\frac{1}{R_1}+\frac{1}{R_3}\right) + p(C_1+C_2)\cdot\frac{1}{R_2} + p^2 C_1(C_1+C_2) - pC_1}$$

p ausklammern

$$= -\frac{1}{R_1} \frac{pC_1}{\frac{1}{R_2}\left(\frac{1}{R_1}+\frac{1}{R_3}\right) + p\left(C_1\cdot\frac{1}{R_1}+\frac{1}{R_3}+(C_1+C_2)\cdot\frac{1}{R_2}-C_1\right) \cancel{+ p^2 C_1^2 + C_1 C_2 + p^2 C_1 C_2} + p^2 C_1(C_1+C_2)}$$

$$\underline{V} = -\frac{1}{R_1} \frac{pC_1}{\frac{1}{R_2}\left(\frac{1}{R_1}+\frac{1}{R_3}\right) + p\cdot C_1\left(\frac{1}{R_1}+\frac{1}{R_3}+1/R_2+\frac{C_2}{R_2}-1\right) + p^2 C_1(C_1+C_2)}$$

(b) @ $\omega_{res} \Rightarrow Im\{\underline{V}\}=0$

$$\underline{V} = -\frac{1}{R_1} \cdot \frac{j\omega C_1\left(\frac{1}{R_2}\left(\frac{1}{R_1}+\frac{1}{R_3}\right) - \omega^2 C_1(C_1+C_2) - j\omega C_1(\ldots)\right)}{\left(\frac{1}{R_2}\left(\frac{1}{R_1}+\frac{1}{R_3}\right) - \omega^2 C_1(C_1+C_2)\right)^2 + \left(\omega C_1(\ldots)\right)^2}$$

$$= -\frac{1}{R_1} \cdot \frac{j\omega C_1 \frac{1}{R_2}\left(\frac{1}{R_1}+\frac{1}{R_3}\right) - j\omega^3 C_1((C_1+C_2) + \omega^2 C_1^2(\ldots)}{-//-}$$

$$\curvearrowright \quad \underline{\cancel{j}\omega C_1 \cdot \frac{1}{R_2}\left(\frac{1}{R_1}+\frac{1}{R_3}\right) - \cancel{j}\omega^3 C_1(C_1+C_2) = 0}$$

$-//-$

$$\underbrace{\omega_{res} C_1 \cdot \frac{1}{R_2}\left(\frac{1}{R_1}+\frac{1}{R_3}\right)}_{a} - \omega_{res}^3 \underbrace{C_1 (C_1+C_2)}_{b} = 0$$

$$a \cdot x \cancel{+} - b \cdot x^3 = 0$$

$$x\,(\underbrace{a - bx^2}_{\cancel{x_{20}},\ x_{30}}) = 0$$

$x_0 = 0$

$$\omega_{res}^2 = \cancel{\pm\sqrt{}} \frac{\cancel{C_1} \cdot \frac{1}{R_2}\left(\frac{1}{R_1}+\frac{1}{R_3}\right)}{\cancel{C_1}(C_1+C_2)}$$

$$\omega_{res} = \sqrt{\frac{\frac{1}{R_2}\left(\frac{1}{R_1}+\frac{1}{R_3}\right)}{C_1+C_2}}$$

$$= \sqrt{\frac{\frac{1}{20k\Omega} \cdot \left(\frac{1}{10k\Omega}+\frac{1}{200\Omega}\right)}{7{,}9\,nF + 7{,}9\,nF}}$$

$$= 787{,}72\ \frac{1}{s}$$

$$f_{res} = 125{,}37\ Hz$$

stimmt nicht ☺

Verstärkung bei f_{res}: $V_{res} = -1$

10.11

(a)