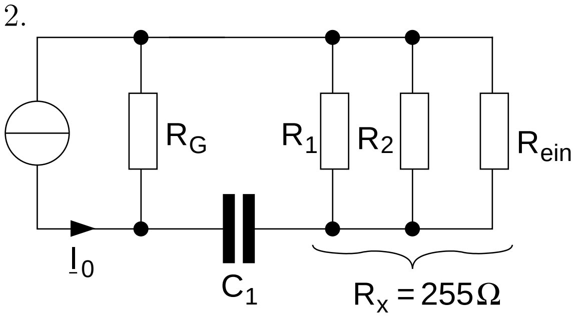
Aufgabe A)

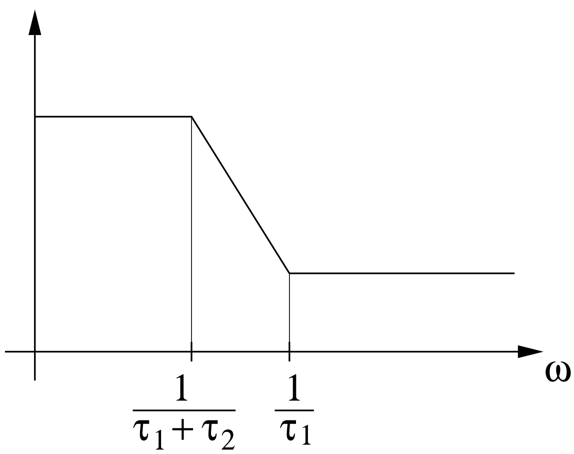
1. $I_C = 10\ mA \rightarrow I_B = \frac{I_C}{\beta_0} = 0,1\ mA$
Daumenregel: $I_{ST} = 10 I_B = 1\ mA \quad \rightarrow \frac{U_{CC}}{I_{ST}} = R_{ges} = \frac{5\ V}{1\ mA} = 5000\ \Omega$
$U_E = R_E I_C = 100\ \Omega \cdot 0,01\ A = 1\ V$
Aus Maschenumlauf folgt:

$$U_{R2} = U_{BE} + U_{RE} = 1,7\ V$$
$$\rightarrow R_2 = \frac{U_{R2}}{I_{ST}} = \frac{1,7\ \text{V}}{1\ \text{mA}} = 1700\ \Omega$$
$$\rightarrow R_1 = R_{ges} - R_2 = 3300\ \Omega$$

2.



$$U_1 = -\underline{I}_0 \left[R_G || \left(\frac{1}{j\omega C_1} + R \right) \right] = -\underline{I}_0 \frac{R_G \frac{1+j\omega\tau_1}{j\omega C_1}}{R_G + \frac{1+j\omega\tau_1}{j\omega C_1}}$$
$$U_1 = R_G I_0 \frac{1 + j\omega\tau_1}{1 + j\omega(\tau_1 + \tau_2)}$$
$$\text{mit } \tau_1 = C_1 R_x, \tau_2 = C_1 R_G$$



$$|\underline{U}_1| = R_G \underline{I}_0 \frac{\sqrt{1 + (\omega\tau_1)^2}}{\sqrt{1 + \omega^2(\tau_1 + \tau_2)^2}}$$

$$|\underline{U}_1(f \to \infty)| = R_G \underline{I}_0 \frac{\tau_1}{\tau_1 + \tau_2}$$

$$\omega = \frac{1}{\tau_1}:$$

$$|\underline{U}_1(\omega = \tfrac{1}{\tau_1})| = R_G \underline{I}_0 \frac{\sqrt{2}}{\sqrt{1 + (\frac{\tau_1+\tau_2}{\tau_1})^2}} \leq R_G \underline{I}_0 \frac{\sqrt{2}}{\frac{\tau_1+\tau_2}{\tau_1}} = \sqrt{2}\, \underbrace{R_G \underline{I}_0 \frac{\tau_1}{\tau_1 + \tau_1}}_{|\underline{U}_1(f \to \infty)|}$$

$$\Rightarrow 2\pi f_{gu} = \frac{1}{\tau_1} = \frac{1}{C_1 R_x} \quad \Leftrightarrow C_1 = \frac{1}{2\pi f_{gu} R_x} \approx 6\ \mu\text{F}$$

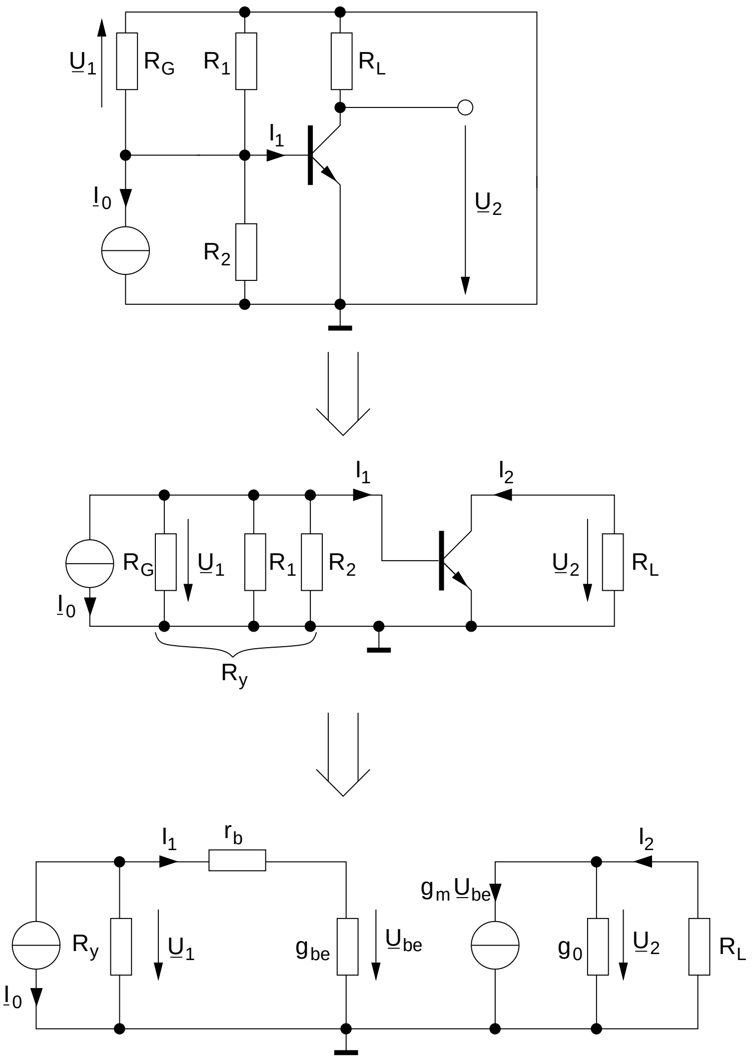
3.

$$|R_E \parallel C_2| = \tfrac{1}{100} R_E$$

$$\Leftrightarrow \left| \frac{R_E}{j\omega_{gu} R_E C_2 + 1} \right| = \frac{1}{100} R_E$$

$$\Leftrightarrow \sqrt{1 + (\omega_{gu} R_E C_2)^2} = 100 \Rightarrow C_2 = \sqrt{\frac{100^2 - 1}{\omega_{gu}^2 R_E^2}} \approx 1,6\ \text{mF}$$

4.



$$g_m = \left.\frac{\partial I_C}{\partial U_{BE}}\right|_{U_{CE}=0} = \frac{\partial}{\partial U_{BE}}(I_S e^{\frac{U_{BE}}{U_T}}) = \frac{I_{C0}}{U_T} = \frac{10mA}{27mV} \approx 0,37 \text{ S}$$

$$\frac{1}{g_{be}} = \frac{\partial U_{BE}}{\partial I_B} = \frac{\partial U_{BE}}{\partial I_C}\frac{\partial I_C}{\partial I_B} = \frac{1}{g_m}\beta_0 \Leftrightarrow g_{be} = \frac{g_m}{\beta_0} = 3,7 \text{ mS}$$

$$g_0 = \frac{\partial I_C}{\partial U_{CE}} = \frac{\partial}{\partial U_{CE}}(I_S(1+\frac{U_{CE}}{U_A})e^{\frac{U_{BE}}{U_T}}) = \frac{I_S e^{\frac{U_{BE}}{U_T}}}{U_A} = \frac{10mA}{100V} = 100\ \mu\text{S}$$

5.

$ges: \underline{V}_U = \frac{\underline{U}_2}{\underline{U}_1}, \quad \underline{V}_I = \frac{\underline{I}_2}{\underline{I}_1}, \quad \underline{R}_{ein} = \frac{\underline{U}_1}{\underline{I}_1}, \quad \underline{R}_{aus} = \frac{\underline{U}_2}{\underline{I}_2}$

$$\underbrace{\begin{pmatrix} G_y + g_b & -g_b & 0 \\ -g_b & g_b + g_{be} & 0 \\ 0 & g_m & g_0 + G_L \end{pmatrix}}_{\underline{\mathrm{Y}}} \begin{pmatrix} \underline{U}_1 \\ \underline{U}_{be} \\ \underline{U}_2 \end{pmatrix} = \begin{pmatrix} -\underline{I}_0 \\ 0 \\ 0 \end{pmatrix}$$

$\underline{V}_U$:

$$\underline{U}_2 = \frac{\begin{vmatrix} G_y + g_b & -g_b & -\underline{I}_0 \\ -g_b & g_b + g_{be} & 0 \\ 0 & g_m & 0 \end{vmatrix}}{\det(\underline{\mathrm{Y}})} = \frac{-g_m g_b \underline{I}_0}{\det(\underline{\mathrm{Y}})}$$

$$\underline{U}_1 = \frac{\begin{vmatrix} -\underline{I}_0 & -g_b & 0 \\ 0 & g_{be} + g_b & 0 \\ 0 & g_m & g_0 + G_L \end{vmatrix}}{\det(\underline{\mathrm{Y}})} = \frac{\underline{I}_0 (g_{be} + g_b)(g_0 + G_L)}{\det(\underline{\mathrm{Y}})}$$

$$\Rightarrow \underline{V}_U = \frac{\underline{U}_2}{\underline{U}_1} = -\frac{g_m g_b}{(g_{be} + g_b)(g_0 + G_L)} \overset{G_L \gg g_0, g_b \gg g_{be}}{\approx} -g_m R_L$$

$\underline{V}_I$:

$$\underline{I}_1 = \frac{\underline{U}_1}{\frac{1}{g_{be}} + \frac{1}{g_b}} = \frac{g_b g_{be}}{g_b + g_{be}} \underline{U}_1 = g_b g_{be} (g_0 + G_L) \frac{\underline{I}_0}{\det(\underline{\mathrm{Y}})}$$

$$\underline{I}_2 = -\frac{\underline{U}_2}{R_L} = \frac{g_m g_b}{R_L} \frac{\underline{I}_0}{\det(\underline{\mathrm{Y}})}$$

$$\Rightarrow \underline{V}_I = \frac{\underline{I}_2}{\underline{I}_1} = \frac{g_m G_L}{g_{be}(g_0 + G_L)} \overset{\beta_0 = \frac{g_m}{g_{be}}}{=} \frac{\beta_0}{1 + R_L g_0}$$

$\underline{R}_{ein}$:

$$\Rightarrow \underline{R}_{ein} = \frac{\underline{U}_1}{\underline{I}_1} = \frac{g_b + g_{be}}{g_b g_{g_b e}} = r_b + \frac{1}{g_{be}} = r_b + \frac{\beta_0}{g_m} \stackrel{r_e = \frac{1}{g_m}}{=} r_b + \beta_0 r_e$$

$\underline{R}_{aus}$:

$$\Rightarrow \underline{R}_{ein} = \frac{\underline{U}_2}{\underline{I}_2} = \frac{1}{g_0}$$

Aufgabe B)

$$I_C \approx I_S(T) e^{\frac{U_{BE}(T)}{U_T(T)}} = I_C(T, U_{BE}(T))$$

$$\Rightarrow \frac{\mathrm{d}I_C}{\mathrm{d}T} = \frac{\partial I_C}{\partial T}\Big|_{U_{BE}=\text{const}} + \frac{\partial I_C}{\partial U_{BE}} \frac{\mathrm{d}U_{BE}}{\mathrm{d}T}; \frac{\partial I_C}{\partial U_{BE}} = \frac{I_C}{U_T}$$

$$U_T = \frac{kT}{U_T}; I_S = C n_i^2 = C T^3 e^{-\frac{W_g}{kT}}$$

$$\Rightarrow \frac{\partial I_C}{\partial T}\Big|_{U_{BE}=\text{const}} = \frac{\partial I_S}{\partial T} e^{\frac{UBE}{U_T}} - \underbrace{I_S e^{\frac{UBE}{U_T}}}_{I_C} \frac{U_{BE}}{U_T^2} \frac{k}{q}$$

$$\begin{aligned} \frac{\partial I_S}{\partial T} &= 3CT^2 e^{-\frac{W_g}{kT}} + CT^3 e^{-\frac{W_g}{kT}} \left(\frac{W_g}{k^2 T^2} k - \frac{1}{kT} \frac{\mathrm{d}W_g}{\mathrm{d}T}\right) \\ &= \frac{3}{T} CT^3 e^{-\frac{W_g}{kT}} + CT^3 e^{-\frac{W_g}{kT}} \frac{1}{kT^2} \left(W_g - T \frac{\mathrm{d}W_g}{\mathrm{d}T}\right) \\ &= \frac{3}{T} I_S + \frac{1}{T} I_S \underbrace{\frac{q}{kT}}_{\frac{1}{U_T}} \underbrace{\frac{1}{q}\left(W_g - T \frac{\mathrm{d}W_g}{\mathrm{d}T}\right)}_{=:U_g(T)} \\ &= \frac{1}{T} I_S \frac{1}{U_T} (3U_T + U_g) \end{aligned}$$

$$\Rightarrow \frac{\partial I_C}{\partial T}\bigg|_{U_{BE}=\text{const}} = \frac{I_S e^{\frac{U_{BE}}{U_T}}}{U_T}\frac{1}{T}(3U_T + U_g) - \frac{I_C}{U_T}\frac{1}{T}U_{BE}$$
$$= \frac{I_C}{U_T}\frac{1}{T}(3U_T + U_g - U_{BE})$$

$$\Rightarrow \frac{\mathrm{d}I_C}{\mathrm{d}T} = \frac{I_C}{U_T}\frac{1}{T}(3U_T + U_g - U_{BE}) + \frac{I_C}{U_T}\frac{\mathrm{d}U_{BE}}{\mathrm{d}T}$$

$$I_C = \text{const} \Rightarrow \frac{\mathrm{d}I_C}{\mathrm{d}T} = 0$$

$$\Leftrightarrow \frac{\mathrm{d}U_{BE}}{\mathrm{d}T}\bigg|_{I_C=\text{const}} = -\frac{1}{T}(3U_T + U_g - U_{BE})$$

Aufgabe C)

1.
Aus Maschenumlauf:

$$\underline{U}_D + \underline{U}_{aus}\frac{R_2}{R_2 + R_1} - \underline{U}_{ein} = 0 \qquad \underline{U}_{aus} = \underline{v}_u\underline{U}_d \Rightarrow \underline{U}_d = \frac{\underline{U}_{aus}}{\underline{v}_u}$$

$$\Leftrightarrow \underline{U}_{ein} = \frac{\underline{U}_{aus}}{\underline{v}_u} + \underline{U}_{aus}\frac{R_2}{R_2 + R_1}$$

$$\Leftrightarrow \frac{\underline{U}_{ein}}{\underline{U}_{aus}} = \frac{1}{\underline{v}_u} + \frac{R_2}{R_2 + R_1} = \frac{R_1 + R_2 + R_2\underline{v}_u}{\underline{v}_u(R_1 + R_2)}$$

$$\Leftrightarrow \frac{\underline{U}_{aus}}{\underline{U}_{ein}} = \frac{\underline{v}_u(R_1 + R_2)}{(R_1 + R_2) + R_2\underline{v}_u} = \frac{\underline{v}_u}{1 + \frac{R_2}{R_1+R_2}\underline{v}_u}$$

2.
Vergleich: $\underline{F}_a = \underline{v}_u \quad \underline{F}_2 = \frac{R_2}{R_1 + R_2}$