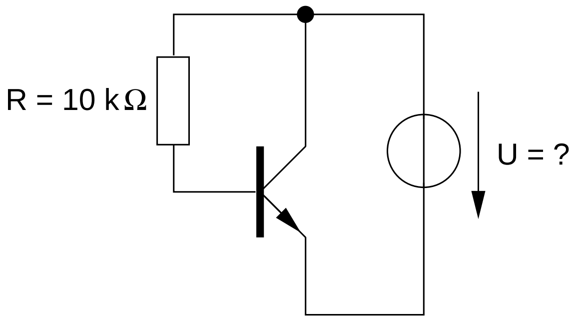
Aufgabe A)



$$I_C = I_S e^{\frac{U_{BE}}{U_T}}, \quad B_F = 200, \quad I_S = 10^{-15} A$$

Annahme: $T = 300$ K $\Rightarrow U_T = 26$ mV

$$I_C = 10 \text{ mA} \Rightarrow I_B = \frac{I_C}{B_F} = \frac{10 \text{ mA}}{200} = 50 \ \mu\text{A}$$

$$I_C = I_S e^{\frac{U_{BE}}{U_T}} \Leftrightarrow lnI_C = lnI_S + \frac{U_{BE}}{U_T}$$
$$\Leftrightarrow U_{BE} = U_T(lnI_C - lnI_S) = U_T ln\frac{I_C}{I_S}$$

$$\Rightarrow U = U_{BE} + RI_B = U_T ln\frac{I_C}{I_S} + RI_B$$
$$= 0,78 \text{ V} + 0,5 \text{ V}$$
$$= 1,28 \text{ V}$$

Temperaturstabilität:

$$U = \text{const} = RI_B + U_{BE}$$

$$\Rightarrow \frac{\mathrm{d}U_{BE}}{\mathrm{d}T} = -R\frac{\mathrm{d}I_B}{\mathrm{d}T} = -\frac{R}{B_F}\frac{\mathrm{d}I_C}{\mathrm{d}T}$$

$$\frac{\mathrm{d}I_C}{\mathrm{d}T} = \left.\frac{\mathrm{d}I_C}{\mathrm{d}T}\right|_{U_{BE}=\text{const}} + S\frac{\mathrm{d}U_{BE}}{\mathrm{d}T}, \qquad S = \frac{I_C}{U_T}$$

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

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

mit $U_g(300\text{ K}) = 1,205\text{ V}$:

$$\Rightarrow \frac{\mathrm{d}I_C}{\mathrm{d}T} \approx 32\ \frac{\mu\text{A}}{\text{K}}$$

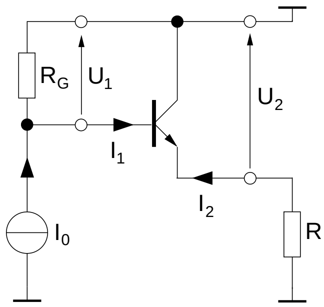
Anschaulich:

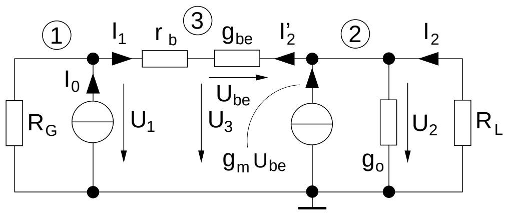
$$T\uparrow \Rightarrow I_C\uparrow \Rightarrow I_B\uparrow \Rightarrow U_{BE}\downarrow \Rightarrow I_C\downarrow$$

$\Rightarrow$AP ist stabil über der Temperatur.

Aufgabe B)

ESB Seite 56:





$$U_{be} = U_3 - U_2 \;\Rightarrow\; g_m U_{be} = g_m U_3 - g_m U_2$$

$$\begin{pmatrix} G_G + g_b & 0 & -g_b \\ 0 & g_0 + G_L + g_{be} & -g_{be} \\ -g_b & -g_{be} & g_b + g_{be} \end{pmatrix} \begin{pmatrix} U_1 \\ U_2 \\ U_3 \end{pmatrix} = \begin{pmatrix} I_0 \\ g_m U_{be} \\ 0 \end{pmatrix} = \begin{pmatrix} I_0 \\ g_m U_3 - g_m U_2 \\ 0 \end{pmatrix}$$

$$\Leftrightarrow \underbrace{\begin{pmatrix} G_G + g_b & 0 & -g_b \\ 0 & g_0 + G_L + g_{be} + g_m & -g_{be} - g_m \\ -g_b & -g_{be} & g_b + g_{be} \end{pmatrix}}_{G} \begin{pmatrix} U_1 \\ U_2 \\ U_3 \end{pmatrix} = \begin{pmatrix} I_0 \\ 0 \\ 0 \end{pmatrix}$$

$$\Rightarrow U_1 = \frac{\begin{vmatrix} I_0 & 0 & -g_b \\ 0 & g_0 + G_L + g_{be} + g_m & -g_{be} - g_m \\ 0 & -g_{be} & g_b + g_{be} \end{vmatrix}}{\det\ G}$$
$$= \frac{I_0(g_0 + G_L + g_{be} + g_m)(g_b + g_{be}) + I_0(-g_{be} - g_m)g_{be}}{\det\ G}$$
$$= \frac{I_0(g_0 + G_L)(g_b + g_{be}) + I_0 g_b(g_{be} + g_m)}{\det\ G}$$

$$\Rightarrow U_2 = \frac{\begin{vmatrix} G_G + g_b & I_0 & -g_b \\ 0 & 0 & -g_{be} - g_m \\ -g_b & 0 & g_b + g_{be} \end{vmatrix}}{\det\ G}$$
$$= \frac{I_0 g_b(g_{be} + g_m)}{\det\ G}$$

$$\Rightarrow U_3 = \frac{\begin{vmatrix} G_G + g_b & 0 & I_0 \\ 0 & g_0 + g_{be} + G_L + g_m & 0 \\ -g_b & -g_{be} & 0 \end{vmatrix}}{\det\ G}$$
$$= \frac{I_0 g_b(g_0 + G_L + g_{be} + g_m)}{\det\ G}$$

$\underline{V_U = \frac{U_2}{U_1}}$:

$$V_U = \frac{U_2}{U_1} = \frac{I_0 g_b(g_{be} + g_m)}{I_0(g_0 + G_L)(g_b + g_{be}) + I_0 g_b(g_{be} + g_m)}$$
$$= \frac{(g_{be} + g_m)\frac{1}{r_b}}{g_0(g_b + g_{be}) + G_L(g_b + g_{be}) + \frac{1}{r_b}(g_{be} + g_m)}$$
$$= \frac{(g_{be} + g_m)\frac{1}{r_b}}{\underbrace{(g_b + g_{be})(g_0 + G_L)}_{a} + \underbrace{\frac{1}{r_b}(g_{be} + g_m)}_{b}}$$
$$\overset{a \ll b}{=} 1$$

$\underline{V_I = \frac{I_2}{I_1}}$:

$$\begin{aligned}
I_1 &= g_b(U_1 - U_3) \\
&= I_0 g_b \frac{(g_0 + g_{be} + G_L + g_m)(g_b + g_{be}) - g_{be}(g_{be} + g_m) - g_b(g_0 + g_{be} + G_L + g_m)}{\det\ G} \\
&= I_0 g_b \frac{(g_0 + g_{be} + G_L + g_m)g_{be} - g_{be}(g_{be} + g_m)}{\det\ G} \\
&= I_0 g_b \frac{g_{be}(g_0 + G_L)}{\det\ G}
\end{aligned}$$

$$I_2 = -U_2 G_L = -I_0 \frac{g_b G_L (g_{be} + g_m)}{\det\ G}$$

$$\begin{aligned}
\Rightarrow V_I = \frac{I_2}{I_1} &= \frac{-I_0 g_b G_L (g_{be} + g_m)}{I_0 g_b g_{be}(g_0 + G_L)} \\
&= -\frac{G_L(g_{be} + g_m)}{g_{be}(g_0 + G_L)} \overset{G_L \gg g_0}{\approx} \frac{-(g_{be} + g_m)}{g_{be}} = -1 - \beta \overset{\beta \gg 1}{\approx} -\beta
\end{aligned}$$

$\underline{R_{ein} = \frac{U_1}{I_1}}$:

$$\begin{aligned}
\Rightarrow R_{ein} = \frac{U_1}{I_1} &= \frac{I_0[(g_{be} + g_b)(g_0 + G_L) + g_b(g_{be} + g_m)]}{I_0 g_b g_{be}(g_0 + G_L)} \\
&= \frac{g_{be}(g_0 + G_L)}{g_b g_{be}(g_0 + G_L)} + \frac{g_b(g_0 + G_L + g_{be} + g_m}{g_b g_{be}(g_0 + G_L)} \\
&= r_b + \frac{g_0 + \frac{1}{R_L} + g_{be} + g_m}{g_{be}(g_0 + \frac{1}{R_L})} \\
&\overset{\frac{1}{R_L} \gg g_0}{\approx} r_b + R_L \frac{\frac{1}{R_L} + g_{be} + g_m}{g_{be}} = r_b + \frac{1}{g_{be}} + R_L + \frac{g_m}{g_{be}} R_L, \quad \beta = \frac{g_m}{g_{be}} = \frac{1}{g_{be} r_e} \Leftrightarrow \frac{1}{g_{be}} = \beta r_e \\
&= r_b + r_e + R_L + \beta R_L \\
&\overset{\beta \gg 1}{\approx} r_b + \beta(R_L + r_e)
\end{aligned}$$

$R_{aus} = \frac{U_2}{I_2}$:

$$\begin{aligned} I_2 &= g_0 U_2 + I_2' - g_m U_{be} \\ &= g_0 U_2 + I_2' + \underbrace{\frac{g_m}{g_{be}}}_{\beta} I_2' \\ &= g_0 U_2 + (1+\beta)\frac{1}{\frac{1}{g_{be}} + r_b + R_G} U_2 \end{aligned}$$

$$\Rightarrow R_{aus} = \frac{U_2}{I_2} = \frac{1}{g_0 + \underbrace{\frac{1+\beta}{\frac{1}{g_{be}} + r_b + R_G}}_{a}}$$

$$\overset{\beta \gg 1,\ g_0 \ll a}{\approx} \frac{R_G + r_b}{\beta} + r_e$$