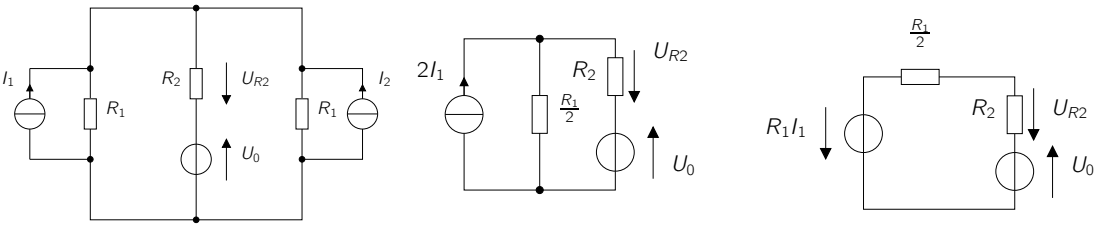
Aufgabe 1

a) (i)



$$U_{R_2} = \frac{R_2}{R_2 + \frac{R_1}{2}}(R_1 I_1 + U_0) = \frac{2R_2}{R_1 + 2R_2}(R_1 I_1 + U_0)$$

(ii)

$$\begin{aligned}
P_{R2} &= \frac{{U_{R2}}^2}{R_2} \\
U_{R1} &= U_0 - U_{R2} \\
\Rightarrow P_{R1} &= \frac{(U_0 - U_{R2})^2}{R_1} \\
&= \frac{1}{R_1}(U_0 - \frac{2R_2}{R_1 + 2R_2}(R_1 I_1 + U_0))^2 \\
&= \frac{1}{R_1}(U_0 \frac{R_1}{R_1 + 2R_2} - 2\frac{R_1 R_2}{R_1 + 2R_2} I_1)^2 \\
\Rightarrow P_\Sigma &= 2P_{R1} + P_{R2} \\
&= \frac{2}{R_1}(\frac{R_1}{R_1 + 2R_2} U_0 - \frac{2R_1 R_2}{R_1 + 2R_2} I_1)^2 + \frac{1}{R_2}(\frac{2R_2}{R_1 + 2R_2}(R_1 I_1 + U_0))^2 \\
&= (\frac{1}{R_1 + 2R_2})^2 [2R_1(U_0 - 2R_2 I_1)^2 + 4R_2(U_0 + R_1 I_1)^2] \\
&= \frac{2}{(R_1 + 2R_2)^2}((R_1 + 2R_2){U_0}^2 + 4R_1 {R_2}^2 {I_1}^2 + 2{R_1}^2 R_2 {I_1}^2) \\
&= \frac{2}{(R_1 + 2R_2)^2}((R_1 + 2R_2){U_0}^2 + 4R_1 R_2 {I_1}^2 (2R_2 + R_1)) \\
&= \frac{2}{(R_1 + 2R_2)^2}({U_0}^2 + 4R_1 R_2 {I_1}^2)
\end{aligned}$$

alternativ: Superposition

$$\Rightarrow P_\Sigma = \frac{{U_0}^2}{R_2 + \frac{R_1}{2}}$$

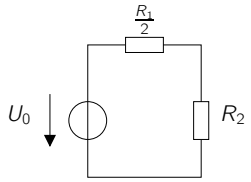


Abbildung 1: $I_0 = 0$

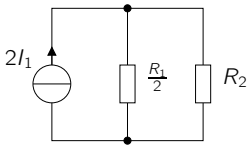


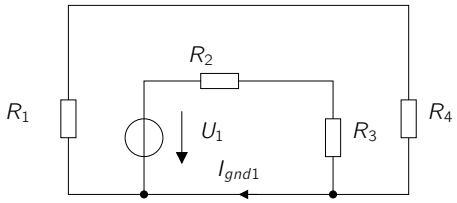
Abbildung 2: $U_0 = 0$

$$\Rightarrow P_\Sigma = \frac{\frac{R_1}{2} R_2}{\frac{R_1}{2} + R_2} 4{I_1}^2$$
$$= \frac{R_1 R_2}{R_1 + 2R_2} 4{I_1}^2$$

b) Maschenumlauf:

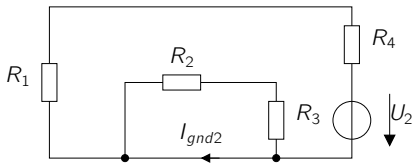
a-c: U_1=U_2
b-c: U_1=-U_3

c) Überlagerungssatz:



U_1 :

$$I_{gnd1} = \frac{U_1}{R_2 + R_3}$$



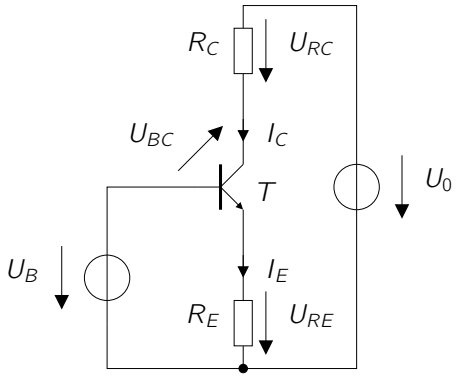
$$U_2:$$

$$I_{gnd2} = \frac{-U_2}{R_1 + R_4}$$

$$\Rightarrow I_{gnd} = I_{gnd1} + I_{gnd2} = \frac{U_1}{R_2 + R_3} - \frac{U_2}{R_1 + R_4}$$

Aufgabe 2

a) Gleichstromersatzschaltbild



b) Dimensionierungsvorschrift

$$
\begin{aligned}
U_{Rc} &= R_C I_C \\
I_C &\approx I_E \; da \; I_B \ll I_C \\
\Rightarrow U_{Rc} &= R_C I_E = \frac{R_C}{R_E} U_{RE} = \frac{R_C}{R_E}(U_B - U_{BE0}) \stackrel{!}{=} \frac{U_0}{2} \\
R_E &= \frac{2R_C}{U_0}(U_B - U_{BE0}) \Leftrightarrow U_B = U_{BE0} + U_0 \frac{R_E}{2R_C}
\end{aligned}
$$

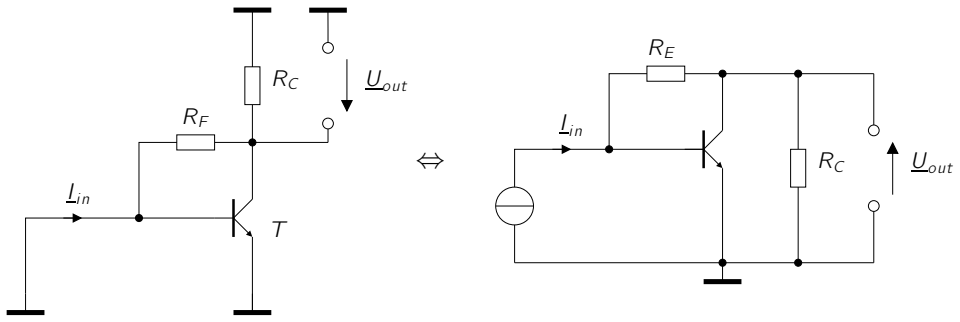
c) normal-aktiv:

$$
\begin{aligned}
&U_{BC}{<}0 \;\Rightarrow\; U_{BC} = U_B - U_0 + U_{RC}{<}0 \\
&U_{RC} = \frac{R_C}{R_E}(U_B - U_{BE0}) \\
&\Rightarrow U_B - U_0 + \frac{R_C}{R_E}{<}0 \;\Leftrightarrow\; U_B(1 + \frac{R_C}{R_E}){<}U_0 + \frac{R_C}{R_E} U_{BE0} \\
&\Leftrightarrow\; U_B{<}\frac{U_0 + \frac{R_C}{R_E} U_{BE0}}{1 + \frac{R_C}{R_E}}
\end{aligned}
$$

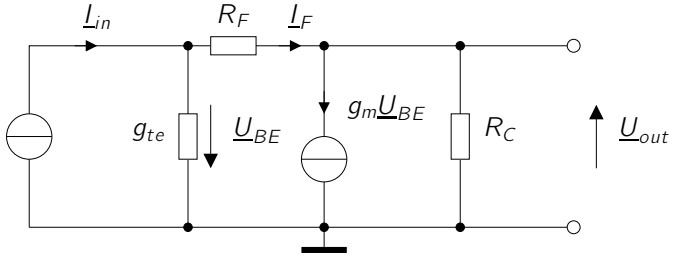
normal-aktiv:

$$
\begin{aligned}
&I_C{>}0 \;\Rightarrow I_G{>}0 \;\Rightarrow U_{RE}{>}0 \;\Rightarrow U_B{>}U_{BE0} \\
&U_{BE0}{<}U_B{<}\frac{U_0 + \frac{R_C}{R_E} U_{BE0}}{1 + \frac{R_C}{R_E}}
\end{aligned}
$$

d) Wechselstromersatzschaltbild



e) Kleinsignal-Wechselstromersatzschaltbild



$$(*)\ \underline{U}_{BE} = -\underline{U}_{out} + R_F \underbrace{(\underline{I}_{in} - g_{te}\underline{U}_{BE})}_{\underline{I}_F} = R_F\underline{I}_F - \underline{U}_{out}$$

$$\underline{U}_{out} = R_C(g_m U_{BE} - I_F)$$

$$\Rightarrow \underline{U}_{out} = R_C(g_m\underline{U}_{BE} - \frac{\underline{U}_{BE} + \underline{U}_{out}}{R_F})$$

$$= R_C(g_m - \frac{1}{R_F})U_{BE} - \frac{R_C}{R_F}\underline{U}_{out}$$

$$\left.\begin{array}{l} \Leftrightarrow (1 + \frac{R_C}{R_F})\underline{U}_{out} = R_C(g_m - \frac{1}{R_F})\underline{U}_{BE} \\ (*) \rightarrow (1 + R_F g_{te})\underline{U}_{BE} = R_F\underline{I}_{in} - \underline{U}_{out} \end{array}\right\} (1 + \frac{R_C}{R_F})\underline{U}_{out} = \frac{R_C(g_m - \frac{1}{R_F})}{1 + R_F g_{te}}(R_F\underline{I}_{in} - \underline{U}_{out})$$

$$\Leftrightarrow \underbrace{((1 + \frac{R_C}{R_F})(1 + R_F g_{te} + R_C(g_m - \frac{1}{R_F}))}_{(1+R_F g_{te}+\underbrace{R_E g_{te} + R_C g_m}_{\approx R_C g_m})\underline{U}_{out} = R_C R_F(g_m - \frac{1}{R_F})\underline{I}_{in}} \quad \underline{U}_{out} = R_C R_F(g_m - \frac{1}{R_F})\underline{I}_{in}$$

$$\Rightarrow \underline{H} = \frac{R_C R_F(g_m - \frac{1}{R_F})}{1 + R_F g_{te} + R_C g_m}$$

Aufgabe 3

a)

$$I_{Cmax} = \frac{U_0}{R_C} = \frac{5V}{500\Omega} = 10mA$$

b)

$$I_B = 75\mu A$$

c)

$$i_B(t) = \frac{U_{in}(t) - U_{BE}}{R_1 + R_B} \quad \Leftrightarrow R_B = \frac{U_{in}(t) - U_{BE}}{i_B(t)} - R_1$$
$$R_B = \frac{5V - 0.7V}{75\mu A} - 200\Omega = 57.13k\Omega$$

d)

$$I_{Cmax} = \frac{U_0 - U_{CEmin}}{R_C} = \frac{5V - 0.2V}{500\Omega} = 9.6mA$$
$$\Rightarrow \ 4\% Abweichung$$

Keine neue Dimensiunierung notwendig, da Änderung klein ist und außerdem gefordert ist, dass $U_{CE}(t) \leq 0.2$V und mit 9.6mA statt 10mA $U_{CE}(t)$ etwas kleiner sein wird, die Forderung also noch erfüllt ist.

Aufgabe 4

a)

$$
\begin{aligned}
i_{in}(t) &= C\frac{d_{u_{out}}}{dt} \\
i_{in} &= \frac{u_{in}(t) - u_{out}}{R} \\
\Rightarrow & u_{in}(t) - u_{out}(t) = RC\frac{d_{u_{out}}}{dt}
\end{aligned}
$$

$$
\begin{aligned}
\rightarrow & \ 0 \leq t < DT \\
& RC\frac{d_{u_{out}}}{dt} + u_{out}(t) = U_0 \\
\rightarrow & DT \leq t < T \\
& RC\frac{d_{u_{out}}}{dt} + u_{out}(t) = 0
\end{aligned}
$$

b)

$$
\begin{aligned}
i_{in} &\approx \frac{u_{in}(t) - U_{out}}{R} \\
\Rightarrow & u_{in}(t) - U_{out} = RC\frac{d_{u_{out}}}{dt} \\
& \rightarrow 0 \leq t \ DT : \\
& RC\frac{d_{u_{out}}}{dt} = U_0 - U_{out} \\
& \rightarrow DT \leq t \ T : \\
& RC\frac{d_{u_{out}}}{dt} = -U_{out}
\end{aligned}
$$

c) Lösen der Gleichung:

$$
\begin{aligned}
\rightarrow & \int_0^{DT} RC\frac{d_{u_{out}}}{dt} = \int_0^{DT} (U_0 - U_{out})dt \\
\Leftrightarrow & RC(\underbrace{U_{out}(DT)}_{U_{out,max}} - \underbrace{U_{out}(0)}_{U_{out,min}}) = (U_0 - U_{out})DT \\
\rightarrow & \int_{DT}^{T} RC\frac{d_{u_{out}}}{dt} = \int_{DT}^{T} (-U_{out})dt \\
\Leftrightarrow & RC(\underbrace{U_{out}(T)}_{U_{out,min}} - \underbrace{U_{out}(DT)}_{U_{out,max}}) = -U_{out}(T - DT) \\
\Rightarrow & \left.\begin{array}{c} RC(U_{out,max} - U_{out,min}) = (U_0 - U_{out})DT \\ RC(U_{out,min} - U_{out,max}) = -U_{out}(T - DT) \end{array}\right\} (+)
\end{aligned}
$$

$$
\Rightarrow 0 = U_0 DT - U_{out}T \Leftrightarrow U_{out} = U_0 D
$$

d) Dimensionierungvorschrift:

$$RC(U_{out,min} - U_{out,max}) = U_{out}(D - T)T$$
$$\Leftrightarrow C = \frac{U_{out}}{\Delta U_{out}} \frac{T}{R}(1 - D) = C = \frac{U_0}{\Delta U_{out}} \frac{T}{R}(1 - D)$$