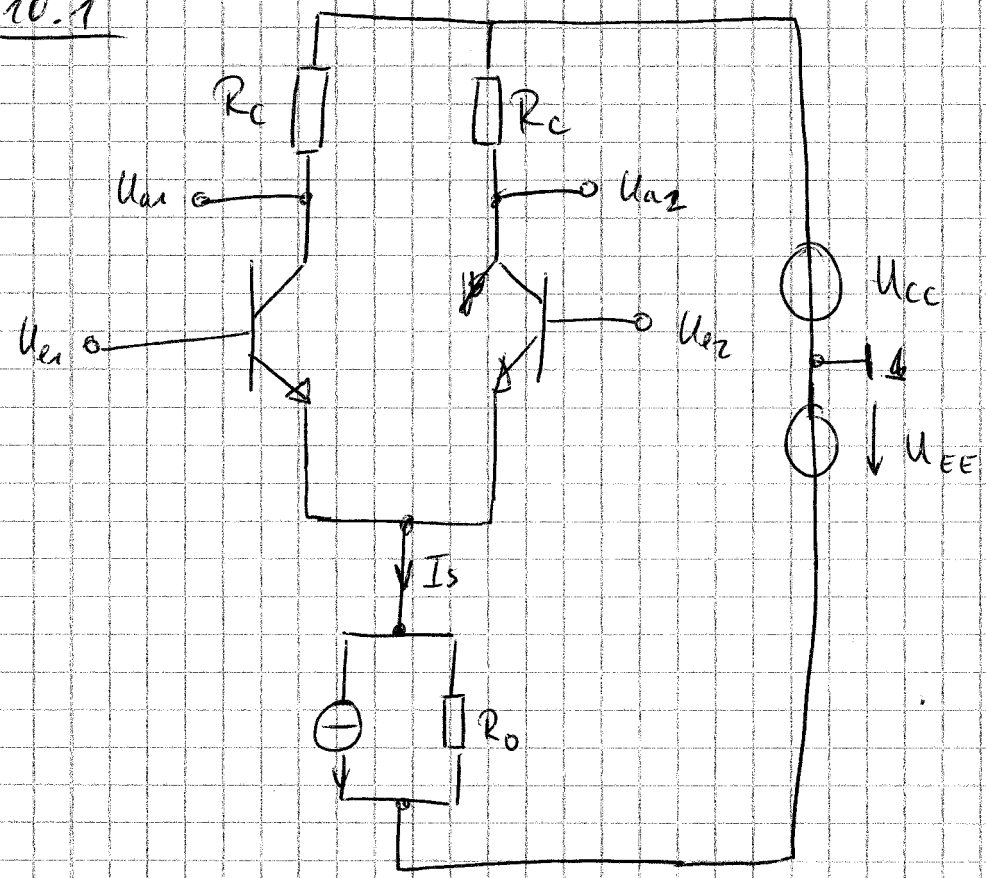
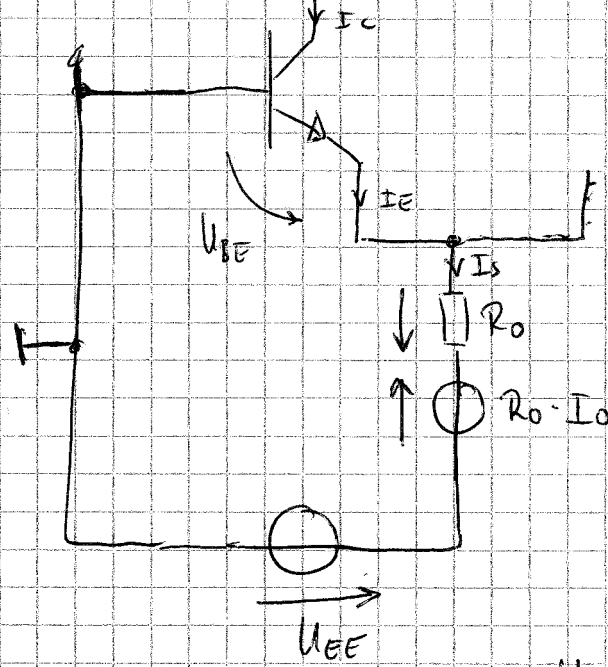
10.1



1.) Arbeitspunkt: U_a, I_C ; $U_{e1} = U_{e2} = 0\,V$

↳ $U_a = U_{a2} = U_{a1}$, $I_{C1} = I_{C2} = I_C$

$I_E \approx I_C$ ↳ $\boxed{I_S = 2 \cdot I_C}$



$I_C =$

Masche:

$U_{BE} + \underbrace{I_S}_{2I_C} R_0 - R_0 \cdot I_0 - U_{EE} = 0$

$\Leftrightarrow I_C = \dfrac{U_{EE} + I_0 R_0 - U_{BE}}{2 \cdot R_0}$

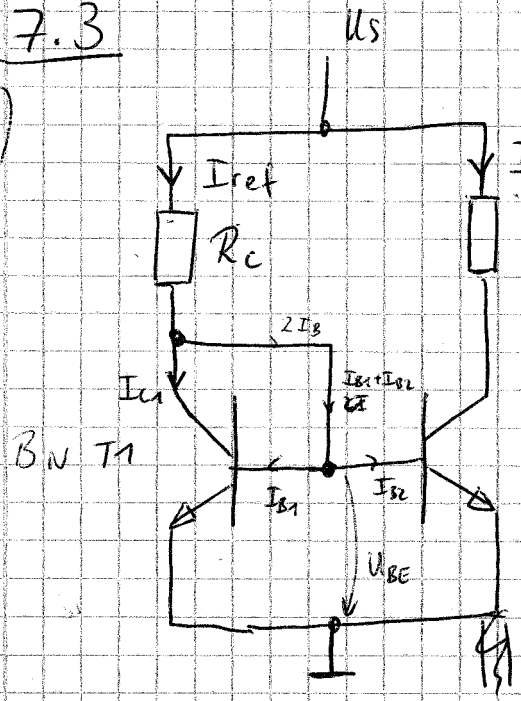
~~$I_C = 572\,\mu A$~~ , $\boxed{I_C = 421{,}5\,\mu A}$

$U_a = U_{CC} - I_C \cdot R_C$

$\boxed{U_a = 8{,}6775\,V}$

7.3

1.)



Gleiche Transistoren, gleiche U_{BE}, $B_{N1} = B_{N2}$

$\rightsquigarrow I_{B1} = I_{B2} = I_B$

bei T1: $U_{BE} = U_{CE}$

Übersetzungsverh. $= 1 \Rightarrow I_{ref} = I_L$

$$I_{ref} = I_{C1} + 2 \cdot I_B$$

$$= I_{C1} + 2 \cdot \frac{I_{C1}}{B_N}$$

$$I_{ref} = I_{C1}\left(1 + \frac{2}{B_N}\right)$$

$$I_{C2} = I_L = A_N I_{ES}\left(e^{\frac{U_{BE}}{U_T}} - 1\right)$$

$$I_{C1} = A_N I_{ES}\left(e^{\frac{U_{BE}}{U_T}} - 1\right)$$

Übers. verh.:

$$\frac{I_{C1}}{I_{ref}} = \frac{A_N I_{ES}\left(e^{\frac{U_{BE}}{U_T}} - 1\right)}{A_N I_{ES}\left(e^{\frac{U_{BE}}{U_T}} - 1\right)\left(1 + \frac{2}{B_N}\right)}$$

$$= \frac{1}{1 + \frac{2}{B_N}} \approx 1 \quad (B_N \to \infty)$$

Fehler:

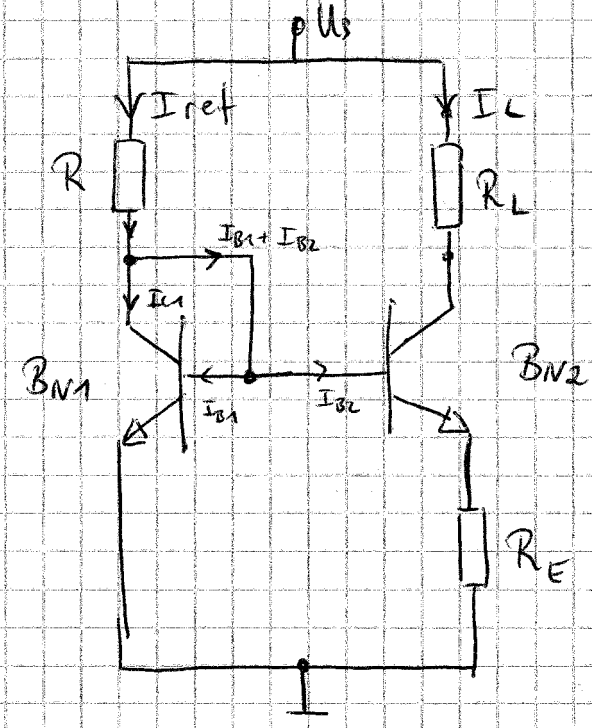
$$\Delta \frac{I_L}{I_{ref}} = 1 - \frac{1}{1 + \frac{2}{B_N}}$$

$$= 1 - \frac{B_N}{B_N + 2}$$

$$= \frac{B_N + 2 - B_N}{B_N + 2}$$

$$\Delta = \frac{2}{B_N + 2}$$

2.)



$$I_{ref} = I_{C1} + I_{B1} + I_{B2}$$

$$I_L = I_{C2} = A_{N2} \cdot I_{ES2} \left(e^{\frac{U_{BE2}}{U_T}} - 1 \right)$$

$$\frac{I_L}{I_{ref}} = \frac{I_L}{\quad}$$

$$I_{C1} = A_{N1} \cdot I_{ES1} \left(e^{\frac{U_{BE1}}{U_T}} - 1 \right)$$

$$I_{B1} = \frac{I_{C1}}{B_{N1}} \qquad I_{B2} = \frac{I_{C2}}{B_{N2}}$$

$$\frac{I_L}{I_{ref}} = \frac{I_{C2}}{I_{C1} + \frac{I_{C1}}{B_{N1}} + \frac{I_{C2}}{B_{N2}}} = \frac{I_{C2}}{I_{C1}\left(1 + \frac{1}{B_{N1}}\right) + \frac{I_{C2}}{B_{N2}}}$$

2)

$$\left(U_{BE2} = U_{BE1} - U_{RE} \right)$$

$$\frac{I_L}{I_{ref}} = \frac{A_{N2} \cdot I_{ES2} \cdot \left(e^{\frac{U_{BE2}}{U_T}} - 1 \right)}{A_{N1} \cdot I_{ES1} \left(e^{\frac{U_{BE1}}{U_T}} - 1 \right) \underbrace{\left(1 + \frac{1}{B_{N1}} \right)}_{\approx \frac{1}{A_{N1}}} + \frac{A_{N2} \cdot I_{ES2} \left(e^{\frac{U_{BE2}}{U_T}} - 1 \right)}{B_{N2}}}$$

$$A_N = \frac{I_C}{I_E} \quad \dots \quad A_N \cdot I_E = I_C$$

$$A_N \cdot (I_C + I_B) = B_N \, I_B$$

$$A_N \left(1 + B_N \right) = B_N$$

$$A_N = \frac{B_N}{1 + B_N} = \frac{1}{1 + \frac{1}{B_N}}$$

$\Rightarrow$ Teilen durch $A_{N2} \cdot I_{ES2} \cdot e \cdot \quad (2+N)$

$$\frac{I_L}{I_{ref}} = \frac{1}{\frac{I_{ES1} \cdot \left(e^{\frac{U_{BE1}}{U_T}} - 1 \right)}{A_{N2} \cdot I_{ES2} \left(e^{\frac{U_{BE2}}{U_T}} - 1 \right)^{*}} + \frac{1}{B_{N2}}}$$

* vernachl.

$$\frac{I_L}{I_{ref}} = U_{BE2} = U_{BE1} - U_{RE}$$

$$\frac{I_L}{I_{ref}} = \frac{1}{\frac{I_{ES1}}{I_{ES2}} \cdot e^{\frac{U_{BE1} - (U_{BE1} - U_{RE})}{U_T}} \cdot \frac{1}{A_{N2}} + \frac{1}{B_{N2}}}$$

$$\frac{1}{\frac{1 + B_{N2}}{B_{N2}}}$$

$$\frac{I_L}{I_{ref}} = \frac{1}{\frac{I_{ES1}}{I_{ES2}} \cdot e^{\frac{U_{RE}}{U_T}} \cdot \left(1 + B_{N2} \right) + B_N}$$

$$= \frac{B_N}{\frac{I_{ES1}}{I_{ES2}} e^{\frac{U_{RE}}{U_T}} \cdot \left(1 + B_N \right) + 1}$$

des Fehler hängt hauptsächlich von dem Term $e^{\frac{U_{RE}}{U_T}}$ ab.

3.) $I_{ES1} \approx I_{ES2}$ $\quad B_N$ sehr groß

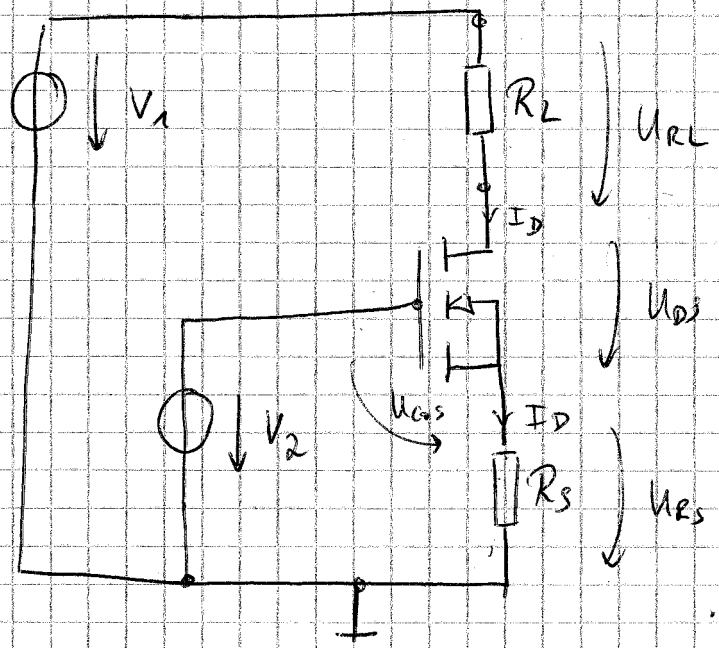
$$\frac{I_C}{I_{ref}} = \frac{1}{e^{\frac{U_{RE}}{U_T}}} = \frac{1}{e^{\frac{U_{BE1} - U_{BE2}}{U_T}}}$$

$$\frac{1}{R_E} = \frac{I_C}{U_T} \cdot \ln\left(\frac{I_C}{I_{ref}}\right)$$

$$\| \; R_E = \frac{U_T}{I_C} \cdot \ln\left(\frac{I_{ref}}{I_C}\right)$$

4.) $\frac{I_C}{I_{ref}} = 100 \Rightarrow R_E = 120\,k\Omega$

7.4



a) $I_D = I_{DSS}\left(1 - \frac{U_{GS}}{U_{GSoff}}\right)^2$ $\qquad V_2 = U_{GS} + U_{RS}$

$V_2 = U_{GS} + I_D \cdot R_S$

$$R_S = \frac{V_2 - U_{GS}}{I_D} = \frac{V_2 - U_{GS}}{I_{DSS}\left(1 - \frac{U_{GS}}{U_{GSoff}}\right)^2}$$

bzw.

$$R_S = \frac{V_2 - \left(\sqrt{\frac{I_D}{I_{DSS}}} + 1\right) U_{GSoff}}{I_D}$$

b) $V_1 = U_{RL} + U_{DS} + U_{RS}$, $R_{L\min} = 0\,\Omega$

$$R_{L\max} = \frac{V_1 - U_{DS} - U_{RS}}{I_D} = \frac{V_1 - U_{DS} - I_D \cdot R_S}{I_D}$$

$$= \frac{V_1 - U_{DS}}{I_D} - R_S$$

$$U_{DS} = U_{GS} - U_{GSoff}$$

$$= \left(\sqrt{\frac{I_D}{I_{DSS}}} + 1\right) U_{GSoff} - U_{GSoff}$$

$$= U_{GSoff}\left(\sqrt{\frac{I_D}{I_{DSS}}}\right)$$

↖ Einsetzen

$$R_{L\,max} = \frac{V_1 - U_{GSoff}\sqrt{\frac{I_D}{I_{DSS}}}}{I_D} - R_S$$

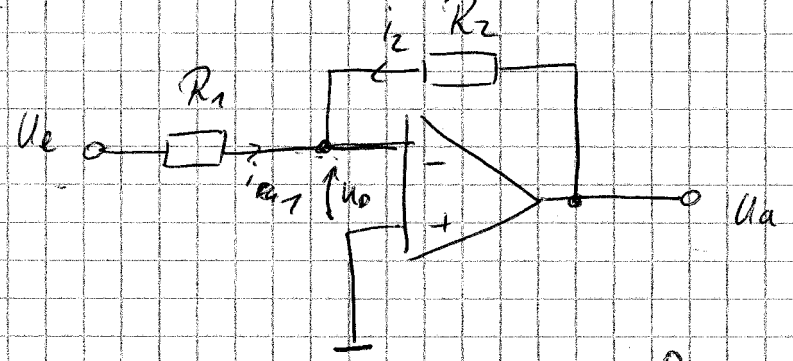
e) ⓐ $R_L = 0\,\Omega$

$$P_{VM} = U_{DS_{max}} \cdot I_D = (V_1 - I_D R_S) I_D$$

f) $$P_{VR_S} = I_D^2 \cdot R_S$$

10.2

1)



2) $U_a = V_0 \cdot U_D = V_0 (\cancel{U_p} - U_n)$ $\quad (U_p = 0)$

$= - V_0 \cdot U_n$

Überlagerung:

$$U_n = U_n|_{U_e=0} + U_n|_{U_a=0}$$

$$U_n = U_e \frac{R_2}{R_1+R_2} + U_a \cdot \frac{R_1}{R_1+R_2}$$

$$U_a = - V_0 \left(U_e \frac{R_2}{R_1+R_2} + U_a \frac{R_1}{R_1+R_2} \right)$$

$$= - V_0 U_e \frac{R_2}{R_1+R_2} - V_0 U_a \frac{R_1}{R_1+R_2}$$

$$U_a \left(1 + V_0 \frac{R_1}{R_1+R_2} \right) = - V_0 U_e \frac{R_2}{R_1+R_2}$$

$$\frac{U_a}{U_e} = V = \frac{- V_0 \frac{R_2}{R_1+R_2}}{1 + V_0 \frac{R_1}{R_1+R_2}} = - \frac{V_0 R_2}{(R_1+R_2) + V_0 R_1}$$

$$V = - \frac{R_2}{\frac{R_1+R_2}{V_0} + R_1}$$

40 dB $\Rightarrow$ ~~100x~~ $\frac{u_a}{u_e} = 100$

$R_1 = 10\,k\Omega$ $\quad V_0 \to \infty$

$$|V| = \left| -\frac{R_2}{R_1} \right| = 100$$

$$R_2 = 100 \cdot R_1 = 1\,M\Omega$$

4.)

$$\Delta V = \underbrace{V_{ideal}}_{-\frac{R_2}{R_1}} - \underbrace{V_{real}}_{-\left(-\frac{R_2}{\frac{R_1+R_2}{V_0} + R_1}\right)}$$

$$= -\frac{R_2}{R_1} - \left(-\frac{R_2}{\frac{R_1+R_2}{V_0} + R_1}\right)$$

$\curvearrowright$ $\frac{\Delta V}{V_{ideal}} = 0{,}01 \Rightarrow$ ~~4~~

$$= \frac{R_2}{\frac{R_1+R_2}{V_0} + R_1} \cdot \frac{R_1}{R_2} - 1$$

$$= \frac{1}{\frac{(R_1+R_2)}{R_1 V_0} + 1} - 1$$

$$1{,}01 = \frac{1}{\frac{R_1+R_2}{R_1 \cdot V_0} + 1}$$

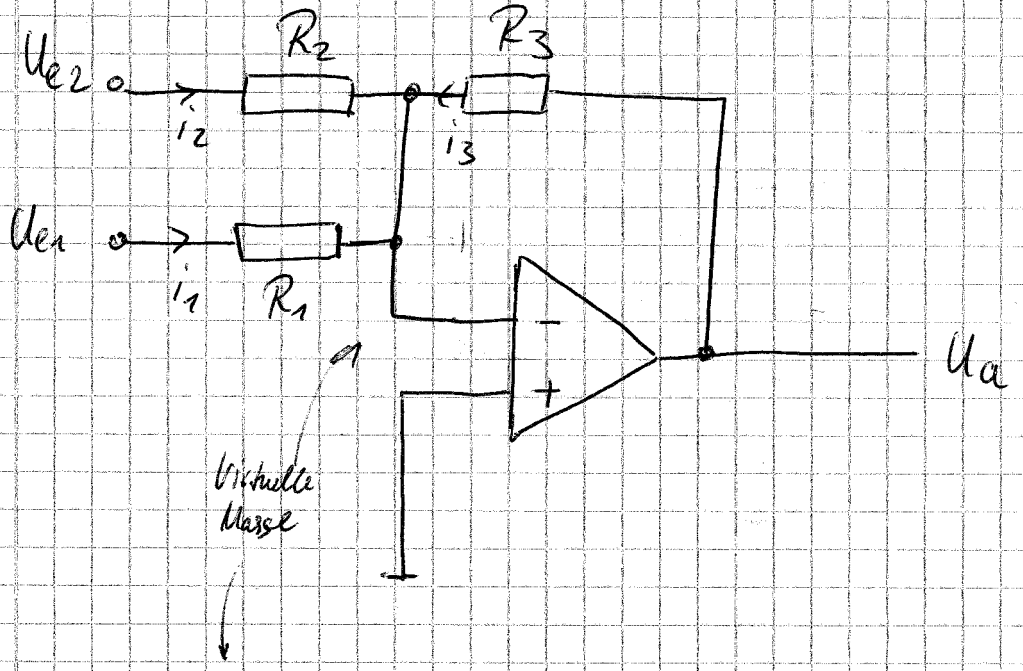
$$\frac{1}{1{,}01} - 1 = \frac{R_1+R_2}{R_1 \cdot V_0}$$

$$V_{0\,1\%} = \frac{R_1 + R_2}{\left(\frac{1}{1{,}01} - 1\right) \cdot R_1}$$

$$\boxed{V_{0\,1\%} = 10201}$$

10.7

1.)



$$i_1 + i_2 + i_3 = 0$$

$$\frac{U_{e1}}{R_1} + \frac{U_{e2}}{R_2} + \frac{U_a}{R_3} = 0$$

$$\| \quad U_a = -\underbrace{\frac{R_3}{R_1}}_{=0,5} \cdot U_{e1} - \underbrace{\frac{R_3}{R_2}}_{0,25} \cdot U_{e2}$$

2.)

U_{e1}	1 V	10 V	-2 V	-8 V
U_{e2}	1 V	-10 V	-8 V	-1,6 V
U_a	-0,75 V	-2,5 V	3 V	4,4 V

3.)

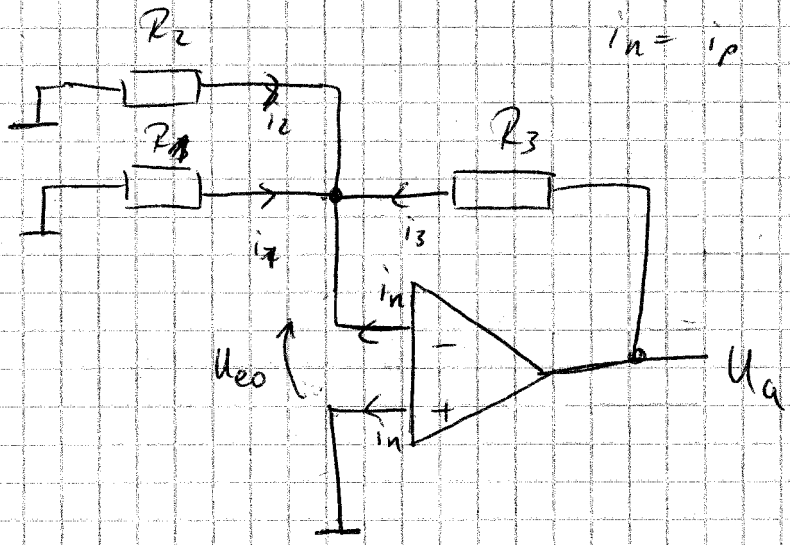
$$\left.\begin{aligned} \frac{R_3}{R_1} &= 2 \\ \frac{R_3}{R_2} &= 3 \end{aligned}\right\} \quad \frac{3 \cdot R_2}{R_1} = 2 \Rightarrow \boxed{\frac{R_2}{R_1} = \frac{2}{3}}$$

$R_3 = 2 \cdot R_1$,

z.B. $R_1 = 6\,k\Omega$ $\quad \Rightarrow R_2 = 4\,k\Omega$

$R_3 = 12\,k\Omega$

4.)



$i_n = i_p$

$$i_1 + i_2 + i_3 + i_n = 0$$

$$\frac{U_{eo}}{R_1} + \frac{U_{eo}}{R_2} + \frac{U_a + U_{eo}}{R_3} + i_n = 0$$

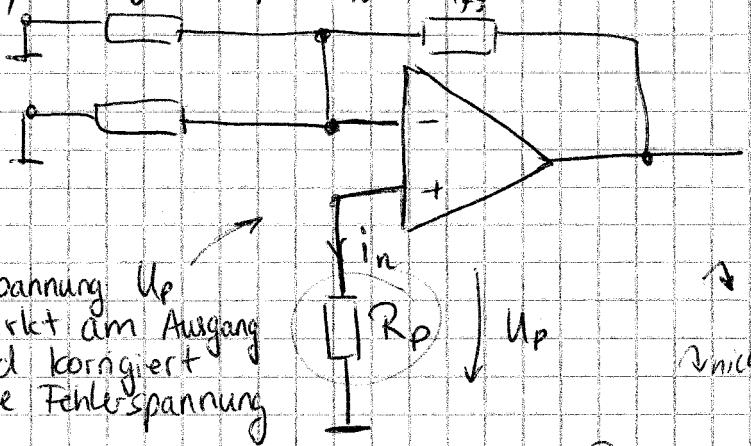
$$\rightarrow U_a = R_3 \left(-i_n - \frac{U_{eo}}{R_1} - \frac{U_{eo}}{R_2} \right) - U_{eo}$$

$$= \underbrace{-R_3 \cdot i_n}_{\text{Fehlersp.}} \underbrace{- \frac{R_3}{R_1} U_{eo} - \frac{R_3}{R_2} U_{eo} - U_{eo}}_{\text{Summ. verst.}}$$

$$U_a = -22{,}5\ mV$$

5.)

$U_0 = U_p - U_n = \frac{R_3}{R_2} U_{eo} -$



Spannung U_p wirkt am Ausgang und korrigiert die Fehlerspannung

↘ $U_{komp.} = R_{\frac{R_3}{R_2}} i_n = V \cdot U_p$

↘ nichtinv. Verst. bezgl. Spannung U_p

über Widerstand

$$U_{komp} = \underbrace{U_p}_{} \left(1 + \frac{R_3}{R_1 \parallel R_2} \right) = i_n \cdot R_3$$

$$\rightarrow i_n \cdot R_p \left(1 + \frac{R_3}{R_1 \parallel R_2} \right) = i_n \cdot R_3$$

$$R_p = \frac{1}{\frac{1}{R_3} + \frac{1}{R_1 \parallel R_2}}$$

$$\longrightarrow R_p = \frac{1}{\frac{1}{5k\Omega} + \frac{1}{(10k\Omega \,//\, 20k\Omega)}}$$

$$\boxed{R_p = 2,8574k\Omega}$$