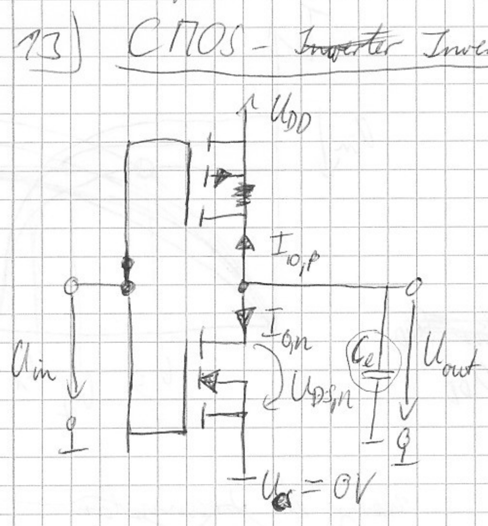
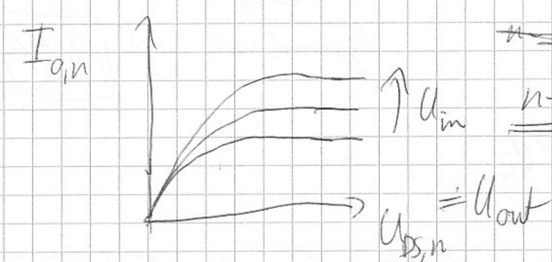
TI Übung 22.1.07

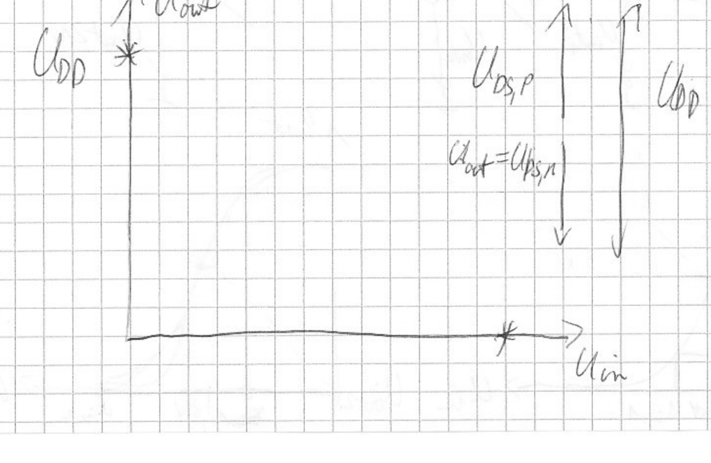
13) CMOS-~~Inverter~~ Inverter



$\beta_n = \beta_p$ $\quad U_{E,n} = -U_{E,p}$

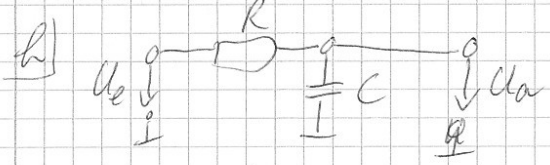


~~n-Kanpl~~ n-Kanal



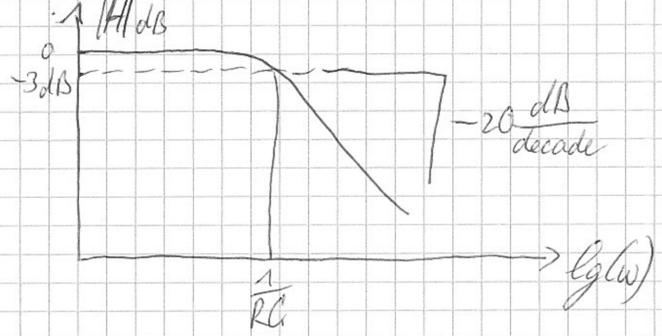
TI3-Übung 29.1.07

h)

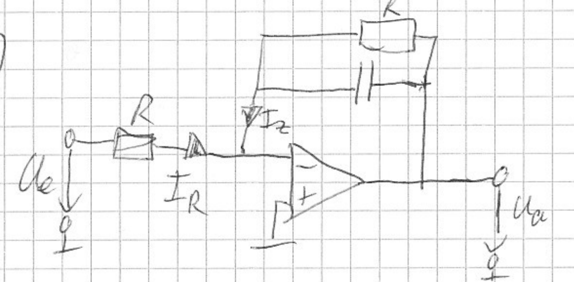


$$U_a = \frac{\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}} U_e = \frac{U_e}{1+j\omega RC}$$

$$H(j\omega) = \frac{U_a}{U_e} = \frac{1}{1+j\omega RC}$$



i)



$$I_R + I_Z = 0$$

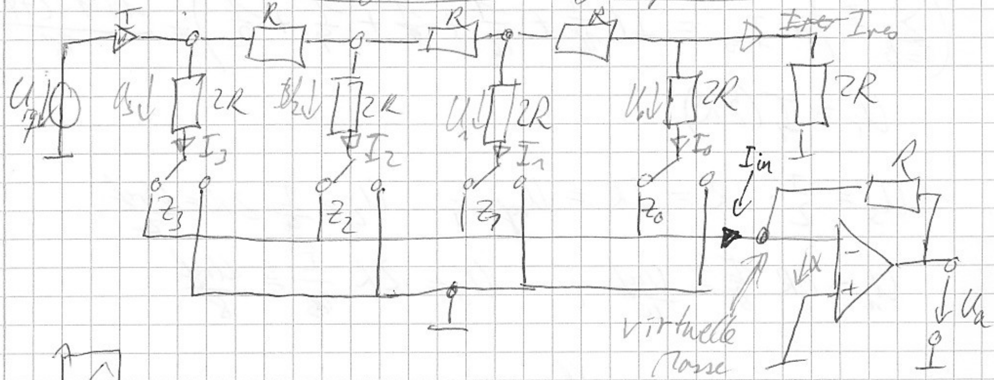
$$\frac{U_e}{R} + \frac{U_a}{Z} = 0$$

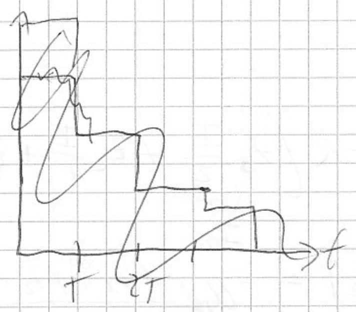
$$\frac{U_a}{U_e} = -\frac{Z}{R} \; ; \; Z = R \,||\, Z_C = \frac{R \cdot \frac{1}{j\omega C}}{R+\frac{1}{j\omega C}} = \frac{R}{1+j\omega RC}$$

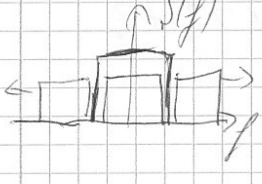
$$H(j\omega) = -\frac{1}{1+j\omega CR}$$

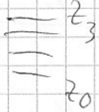
TI 3 Übung 5.2.07

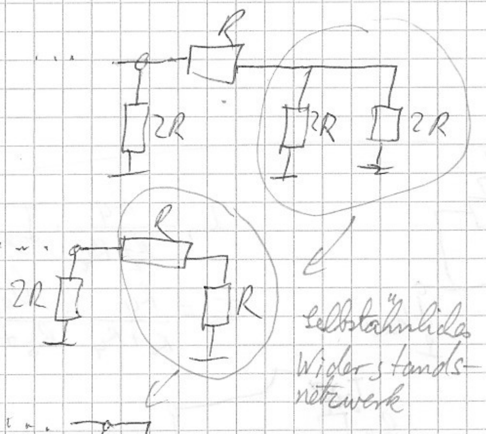
15 D/A-Umsetzung mittels Wägeverfahren

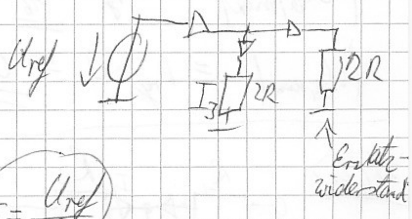












$$I = \frac{U_{ref}}{R}$$

$$I_3 = \frac{2R}{4R} I = \frac{I}{2}$$

$$I_2 = \frac{I_3}{2} = \frac{I}{4}$$

$$I_1 = \frac{I_2}{2} = \frac{I}{8}$$

$I_0 = \frac{I_1}{2} = \frac{I}{16}$; $I_{res} = \frac{I}{16}$

$$\left(\sum_{i=0}^{3} I_i\right) + I_{res} = I\left(\frac{1}{16}+\frac{1}{16}+\frac{1}{8}+\frac{1}{4}+\frac{1}{2}\right) = \frac{1+1+2+4+8}{16} I = 1 I$$

$U_i = I_i(2R)$

$U_3 = \frac{I}{2}\cdot 2R = IR = U_{ref}$; $U_2 = \frac{I}{4} 2R = \frac{U_{ref}}{2}$

$U_1 = 2R\frac{I}{8} = \frac{U_{ref}}{4}$; $U_0 = 2R\frac{I}{16} = \frac{U_{ref}}{8}$

$\cancel{I_{in}\ U_a}$ $I_{in} + \frac{U_a}{R} = 0$

$$U_a = -RI_{in} = -R\cdot\sum_{i=0}^{3} I_i Z_i = -R\left(Z_3 \underbrace{\frac{I}{2}}_{I_3} + Z_2\frac{I}{4}+Z_1\frac{I}{8}+Z_0\frac{I}{16}\right)$$

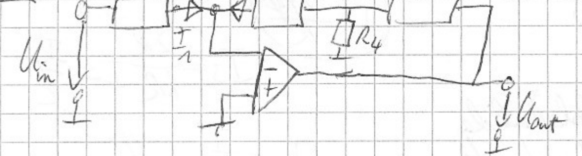
$$= -U_{ref}\left(\frac{Z_3}{2}+\frac{Z_2}{4}+\frac{Z_1}{8}+\frac{Z_0}{16}\right) = -U_{ref}\frac{8Z_3+4Z_2+2Z_1+1Z_0}{16}$$

$\boxed{U_a = -U_{ref}\cdot\frac{Z}{16}}$ $Z = 8\cdot Z_3 + 4Z_2 + 2Z_1 + Z_0$

$|U_{a,max}| = U_{ref}\cdot\frac{15}{16}$

$|U_{a,min}| = U_{ref}\cdot 0 = \underline{\underline{0}}$

16/1

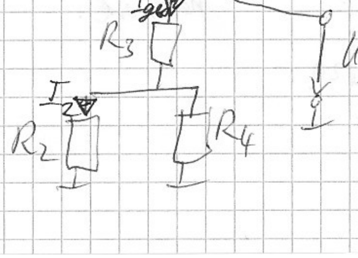


$I_2 = \frac{R_4}{R_2+R_4}\cdot I_{ges}$

$I_2 = \frac{R_4}{R_2+R_4}\cdot\frac{U_a}{R_3+R_2\|R_4}$

$I_1 + I_2 = 0$

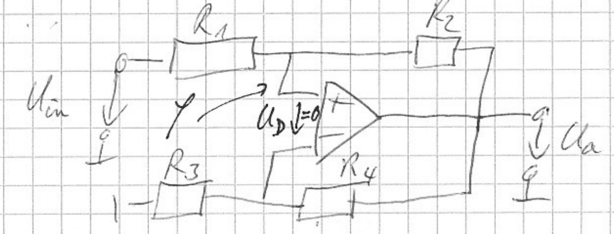
$\frac{U_{in}}{R_1} +$

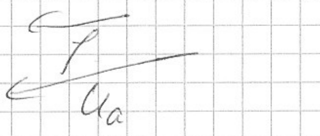


TT-3 Übung 15.2.07

$$\frac{U_{in}}{R_1} + \frac{R_4}{R_2+R_4} \cdot \frac{U_a}{R_3 + R_2 \| R_4} = 0 \Rightarrow U_a = \dots$$

16 2.





$$\varphi = U_a \cdot \frac{R_3}{R_3+R_4}$$

$$I_3 + I_4 = 0 \quad ; \quad \frac{0-\varphi}{R_3} + \frac{U_a - \varphi}{R_4} = 0$$

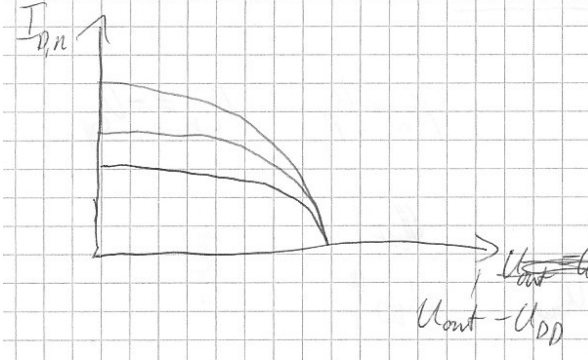
$$\frac{U_a}{R_4} = \varphi\left(\frac{1}{R_3} + \frac{1}{R_4}\right) \cancel{= 0}$$

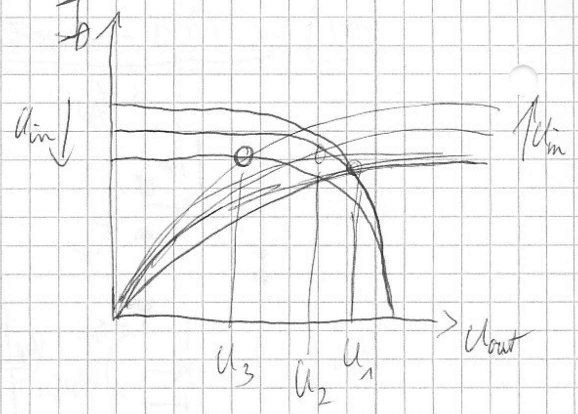
$$\Rightarrow \varphi = \frac{R_3 R_4}{R_3+R_4} U_a \cdot \frac{1}{R_4}$$

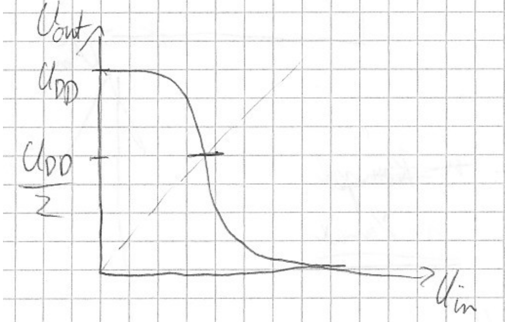
$$\frac{U_{in}}{R_1} - \frac{U_a}{R_1} \frac{R_3}{R_3+R_4} + \frac{U_a}{R_2} - \frac{U_a}{R_2} \cdot \frac{R_3}{R_3+R_4} = 0$$

$$\frac{U_{in}}{R_1} = U_a \left[\frac{R_3}{(R_3+R_4)R_1} + \frac{R_3}{R_3(R_3+R_4)} - \frac{1}{R_2}\right]$$

p-Kanal



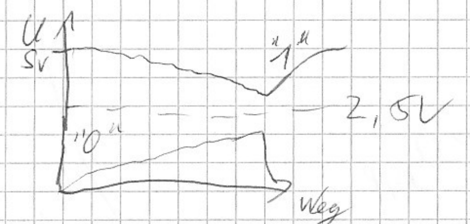


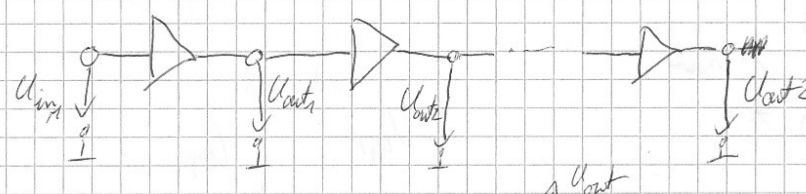


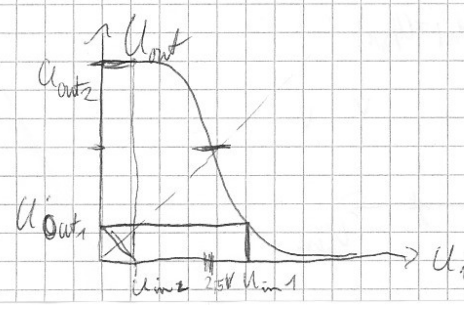
Wenn die Transistoren selbe Eingan

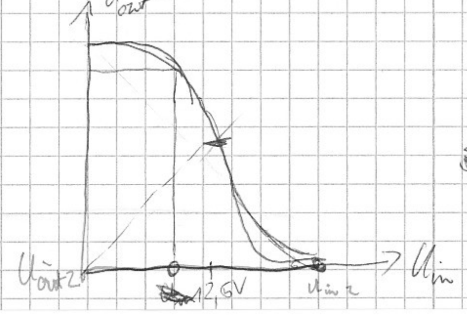
Symmetrisch weil $\boxed{\beta_n = \beta_p}$

13.2 Regenerative Eigenschaften einer Inverterkette



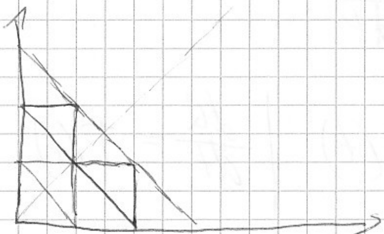






TI 3 Übung 22.1.07

zu 13.2

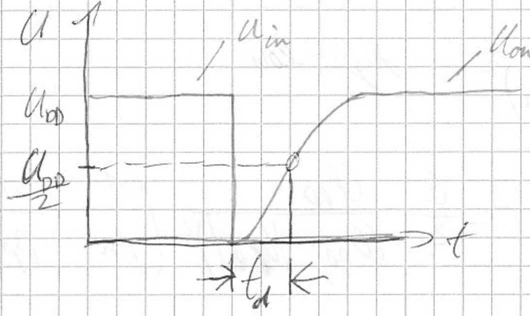


=> drehen uns im Kreis da Steigung der Kennungslinie ≤ 1 !

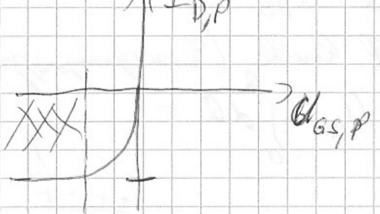
=> es muss gelten: $\left|\frac{\partial U_{out}}{\partial U_{in}}\right| > 1 \quad \Big| U_{low,high} \quad \Big| U_{in} \leq U_{high,min}$

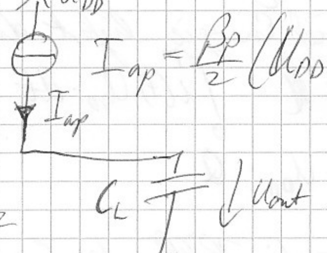
$$\left|\frac{\partial U_{out}}{\partial U_{in}}\right| \leq 1 \quad \text{const}$$

13.3 Dynamisches Verhalten



~~Lade~~ Ladestrom $i(t)$ der Kapazität kann durch einen mittleren Strom I_{ap} approximiert werden.





$$I_{ap} = \frac{\beta_P}{2}\left(U_{DD} - |U_{E,P}|\right)^2$$

$$|I_{D,P}| = \frac{\beta_P}{2}\left(U_{DD} - |U_{E,P}|\right)^2$$

$$C_L = \frac{Q}{U_{out}} \quad \Big| \ \frac{d}{dt}$$

$$\frac{dU_{out}}{dt} = \frac{1}{C_L}\, i(t) \quad \Big| \ \frac{dQ}{dt} = I(t)$$

$$dt = C_L \frac{dU_{out}}{i(t)}$$

$$t_d = C_L \int_0^{U_{DD}/2} \frac{dU_{out}}{i(U_{out})}$$

$$t_d = \frac{C_L}{I_{ap}} \cdot \frac{U_{DD}}{2} = \frac{C_L U_{DD}}{2} \cdot \frac{2}{\beta_p (U_{DD} - |U_{t,p}|)^2}$$

$$\boxed{t_d = C_L \frac{U_{DD}}{\beta_p (U_{DD} - |U_{t,p}|)^2}}$$ low-High

$$t_d = C_L \frac{U_{DD}}{\beta_n (U_{DD} - U_{t,n})^2}$$ High-low

b) $$t_d = \frac{t_{dLH} + t_{dHL}}{2} = \frac{C_L}{2} \cdot \frac{U_{DD}}{(U_{DD} - |U_t|)^2} \left(\frac{1}{\beta_n} + \frac{1}{\beta_p} \right)$$

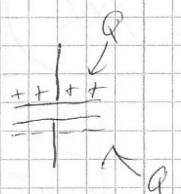
13.4 Dynamischer Leistungsverbrauch

a) $0 \to 1$: Laden des Kondensators

$$W = \frac{1}{2} C_L U_{DD}^2 = \frac{1}{2} Q \cdot U_{DD}$$

Wieviel Energie liefert die ~~Quel~~ Quelle (Versorgungsspannung)?

$$W = \int_0^T i(t)\, U_{DD} \cdot dt = U_{DD} \cdot \int_0^Q dQ =$$ $\quad i(t) = \frac{dQ}{dt}$



$$= U_{DD} \cdot Q$$

nur die Hälfte der Energie die von der Quelle kommt wird in C_L gespeichert!

TI 3 Übung 22.1.07

1 → 0 | gesamte Energie der Quelle geht in Wärme über!

Schaltstatistik

c) $P_{ap} = \frac{1}{T}\int_0^T i(t)\, U_{DD}\, dt = \frac{U_{DD}\, Q}{T} \cdot \rho \qquad 0 \leq \rho \leq 1$

$P_{ap} = f_T\, U_{DD}\, Q \cdot \rho$

Clock

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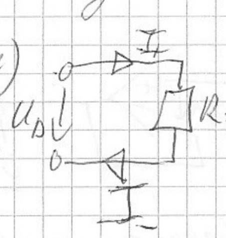
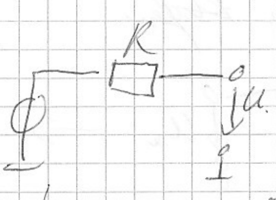
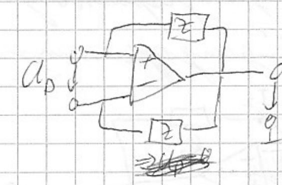
14a)





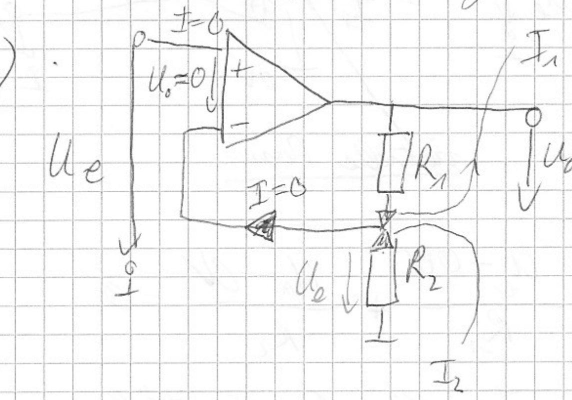
$R_i \to \infty$, R_a ~~∞~~ $= 0$, $A_D \to \infty$ } idealer Operationsverstärker

~~Mitko~~
Mitkopplung - instabil ⇒ System schwingt



Gegenkopplung ⇒ $\cancel{U_D} = 0$

b)



~~$+U_1 + I_2$~~

$+I_1 + I_2 = 0$

1. Schritt: Knotengl. am Eingang vom OP

$$\frac{U_a - U_e}{R_1} + \frac{-U_e}{R_2} = 0$$

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

$$A = \frac{U_a}{U_e} = \frac{R_1 + R_2}{R_2} = 1 + R_1/R_2$$

2. Schritt

Einsetzen der Ströme durch U_a, U_e und Impedanzen.

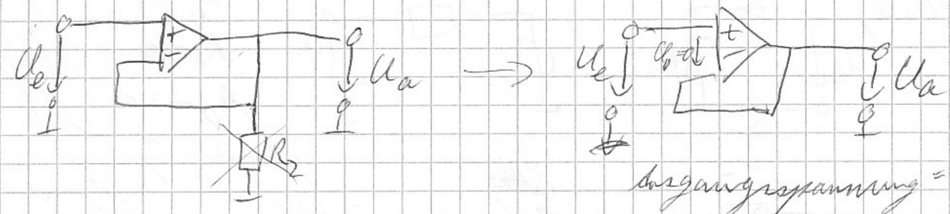
$$U_e = \frac{R_2}{R_1 + R_2} U_a \quad \text{Spannungsteiler}$$

~~Z/R~~

c) $R_1 \to 0$

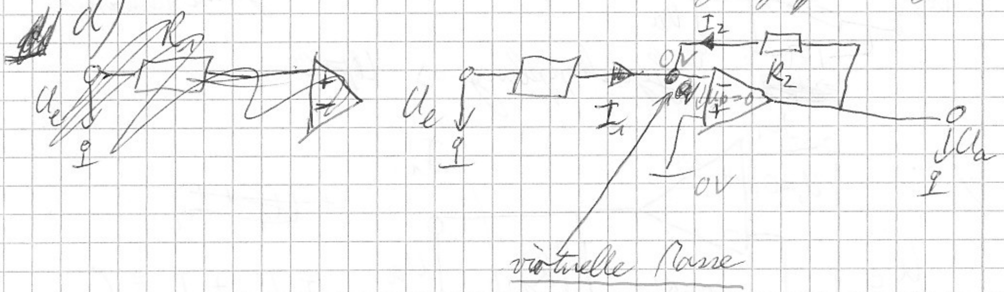
$\lim_{R_1 \to 0} A = 1 \Rightarrow \boxed{U_a = U_e}$ Spannungsfolger

Entkopplung von Stufen



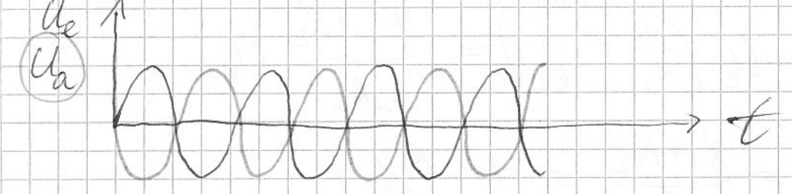
Ausgangsspannung =
= Eingangsspannung

d)

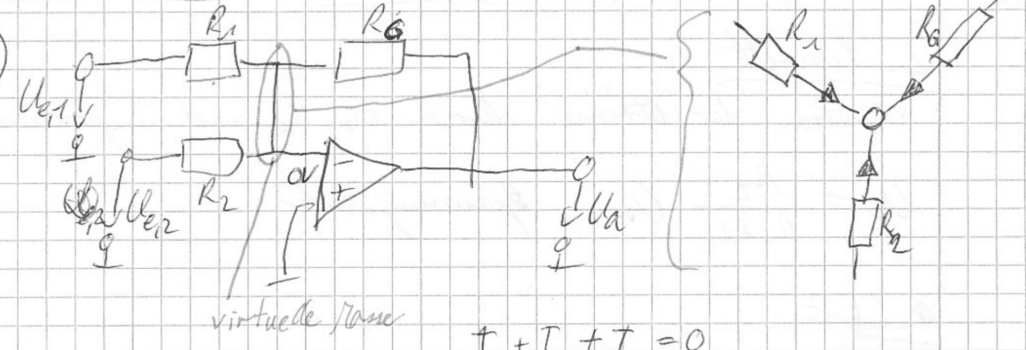


$$\Rightarrow I_1 + I_2 = 0 \,; \quad \frac{U_e - 0V}{R_1} + \frac{U_a - 0V}{R_2} = 0$$

$$\Rightarrow \frac{U_a}{U_e} = -\frac{R_2}{R_1}$$ <u>Invertierender Verstärker</u>



e)



$$I_1 + I_2 + I_G = 0$$

$$\frac{U_{e,1} - 0V}{R_1} + \frac{U_{e,2} - 0V}{R_2} + \frac{U_a}{R_G} = 0$$

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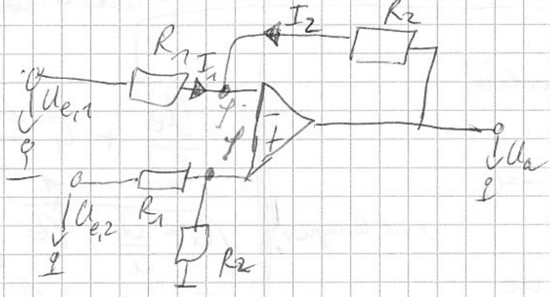
$$U_a = -R_G\left(\frac{U_{e,1}}{R_1} + \frac{U_{e,2}}{R_2}\right)$$

$$U_a = -\left(\frac{R_G}{R_1}\cdot U_{e,1} + \frac{R_G}{R_2}\cdot U_{e,2}\right)$$

$(z = -(\alpha x_1 + \beta x_2))$

Invertierender Addierer

14.5



$$\varphi = U_{e,2}\frac{R_2}{R_1+R_2}$$

$I_1 + I_2 = 0$ $\quad$ ~~$U_{e,1} + U$~~ $\quad \frac{U_{e,1}-\varphi}{R_1} + \frac{U_a-\varphi}{R_2} = 0$

$$\frac{U_{e,1} - U_{e,2}\frac{R_2}{R_1+R_2}}{R_1} + \frac{U_a}{R_2} - \frac{U_{e,2}R_2}{(R_1+R_2)\cdot R_2} = 0$$

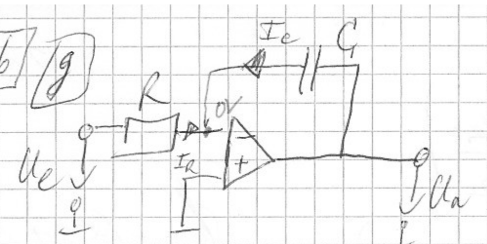
$$-\frac{U_a}{R_2} = \frac{U_{e,1}}{R_1} - \frac{U_{e,2}}{R_1+R_2}\left(\frac{R_2}{R_1}+1\right)$$

$$U_a = -\frac{R_2}{R_1}\cdot U_{e,1} + U_{e,2}\frac{R_2}{\cancel{R_1+R_2}}\cdot\frac{\cancel{R_2+R_1}}{R_1}$$

$$U_a = \frac{R_2}{R_1}\left(U_{e,2} - U_{e,1}\right) \qquad z = \alpha(x_1 - x_2)$$

Nicht invertierende Subtraktion

14.6 g



~~$I_R + I_C = 0$~~

$I_R + I_C = 0$

Frequenzbereich

$$\frac{U_e}{R} + \frac{U_a}{\frac{1}{j\omega C_1}} = 0$$

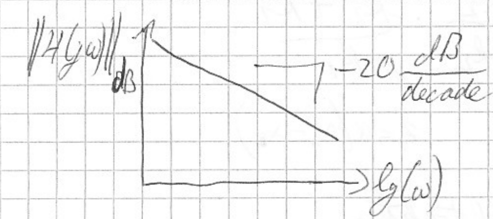
j ist komplex!

$$-U_a\, j\, \omega C_1 = \frac{U_e}{R}$$

$$\Rightarrow H(j\omega) = \frac{U_a}{U_e} = -\frac{1}{j\omega R C_1}$$

$$H(j\omega) = \frac{j}{\omega R C_1}$$

$$\|H(j\omega)\| = \frac{1}{\omega R C_1}$$



Zeitbereich

$$\frac{U_e}{R} + C_1 \frac{dU_a(t)}{dt} = 0$$

$$\boxed{C = \frac{Q}{U}\,;\; U = \frac{Q}{C} \,\Big|\, \frac{d}{dt} \qquad I_C(t) = C_1 \frac{dU_c}{dt}}$$

$$\frac{dU_a}{dt} = -\frac{1}{RC_1} U_e(t)$$

$$U_a(t) - U_a(t=0) = -\frac{1}{RC_1} \int_0^t U_e(t)\,dt$$

$$\int f(x)\,dx \;\circ\!-\!\bullet\; \frac{F(j\omega)}{j\omega}$$