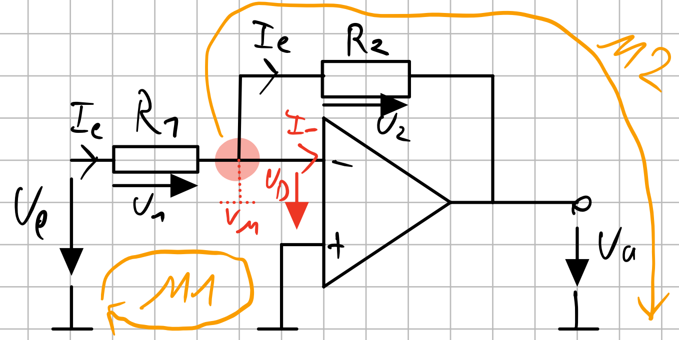
Invertierender Verstärker (INV)



Annahme:

$I_- = 0$

$U_D = 0$

$V_U = \frac{U_a}{U_e}$

$V_M = \ldots$ Virtuelle Masse „Summationspunkt" (keine niederohmige Verbindung zu Masse!)

(Potential wie Masse → hat aber keine Verbindung auf Masse)

M_1:

$-U_e + U_1 + \underbrace{U_D}_{0} = 0 \Rightarrow U_e = U_1 + U_D$

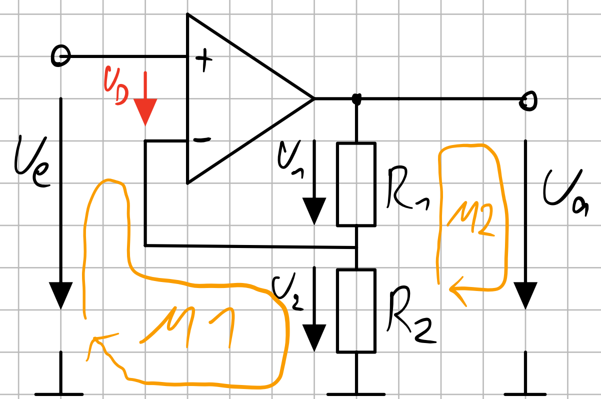
M_2:

$U_2 + U_a = 0 \Rightarrow U_a = -U_2$

$V_U = \frac{U_a}{U_e} = \frac{-\cancel{I_e} \cdot R_2}{\cancel{I_e} \cdot R_1}$

$$\boxed{V_U = -\frac{R_2}{R_1}}$$

2) Nichtinvertierender Verstärker



Annahme:

$U_D = 0$

$I_+, I_- = 0$

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

M_1:

$-U_e + U_D + U_2 = 0 \Rightarrow U_e = U_2 \Rightarrow U_e = R_2 I_2$

M_2:

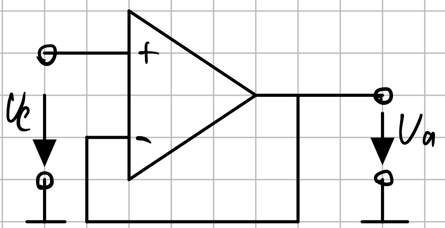
$U_a - U_1 - U_2 = 0 \Rightarrow U_a = U_1 + U_2 \Rightarrow I \cdot R_1 + I R_2$

$$V_u = \frac{U_a}{U_e} = \frac{I(R_1+R_2)}{I\ R_2} = \frac{R_1+R_2}{R_2} = 1 + \frac{R_1}{R_2}$$

$$\boxed{V_u = 1 + \frac{R_1}{R_2}}$$

Sonderfall: $V_u = 1$

$R_1 = 0, \quad R_2 = \infty$

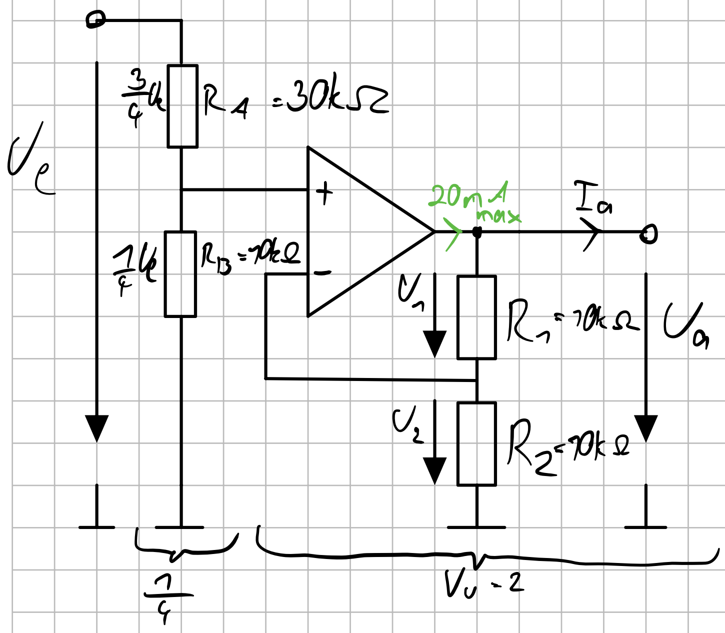


→ Spannungsfolger
Impedanzwandler

Bsp.:

Schaltung mit einem NINV

$V_u = 0,5$



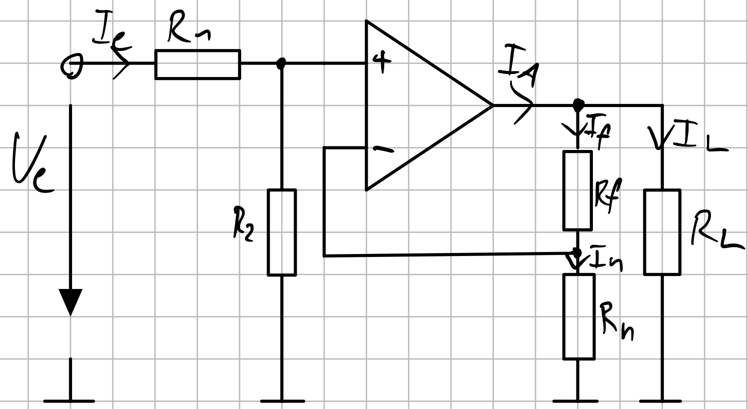
Bsp:

$I_2 = 0{,}04\,mA$

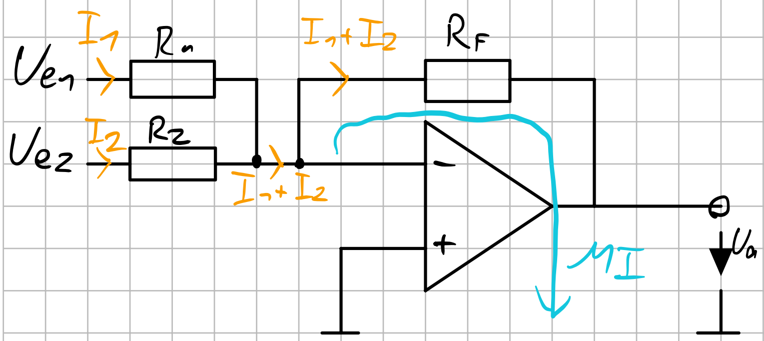
$R_1 = 10\,k\Omega,\ R_2 = 40\,k\Omega$

$R_f = 60\,k\Omega,\ R_n = 12\,k\Omega$

$R_L = 200\,k\Omega$



Summierverstärker



$U_D = 0V$

$I_+, I_- = 0A$

$$I_1 = \frac{V_{e1}}{R_1}$$

$$I_2 = \frac{V_{e2}}{R_2}$$

M_I: $-U_D + U_F + U_a = 0$

$U_a = -U_F$

$$U_a = -U_F = -(I_1+I_2)R_F = -\left(\frac{V_{e1}}{R_1} + \frac{V_{e2}}{R_2}\right)\cdot R_F$$

$$= -\left(V_{e1}\frac{R_F}{R_1} + V_{e2}\frac{R_F}{R_2}\right)$$

$$\boxed{U_a = -\left(\sum_{i=1}^{x} \frac{V_{ei}}{R_i}\right) R_F}$$

Summe

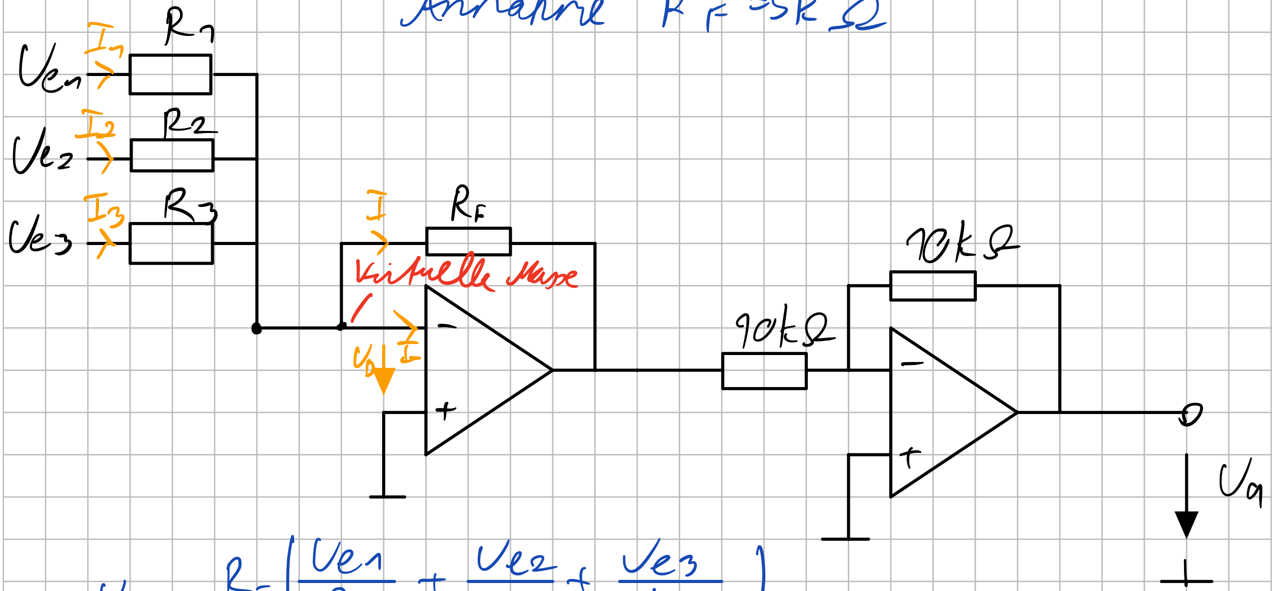
Bsp. Die Formel $2 \times U_{e1} + 3 \cdot U_{e2} + U_{e3} = U_a$

soll mit einem Summierverstärker realisiert werden.

a) Zeichne die Schaltung

b) Dimensioniere die Bauteile

Annahme $R_F = 5k\Omega$



$$U_a = -R_F\left(\frac{U_{e1}}{R_1} + \frac{U_{e2}}{R_2} + \frac{U_{e3}}{R_3}\right)$$

$$U_a = -\left(\underbrace{\frac{R_F}{R_1}U_{e1}}_{2U_{e1}} + \underbrace{\frac{R_F}{R_2}U_{e2}}_{3U_{e2}} + \frac{R_F}{R_3}U_{e3}\right)$$

$$\frac{R_F}{R_1}U_{e1} = 2U_{e1} \quad | \cdot R_1 \quad | :2$$

$$\frac{R_F}{2} = R_1$$

$$R_1 = \frac{5k\Omega}{2}$$

$$R_1 = 2{,}5k\Omega$$

$$\frac{R_F}{R_2}\cancel{U_{e2}} = 3U_{e2} \quad | \cdot R_2 \quad | :3$$

$$\frac{R_F}{3} = R_2$$

$$R_2 = \frac{5k\Omega}{3}$$

$$R_2 = 1{,}66k\Omega$$

$$\frac{R_F}{R_3}U_{e3} = U_{e3} \quad | \cdot R_3$$

$$R_3 = R_F = 5k\Omega$$

Bsp. Eine 4 bit Zahl aus einem µ-Controller – 4 Ausgänge ($a_0 \ldots a_3$); 3,3V; max 1mA/Ausgang – soll in eine Spannung von 0...10V umgewandelt werden.

a) Zeichne die Schaltung

b) Dimensioniere die Bauteile

c) Ermittle alle Potentiale der Schaltung für die Zahl Z=6

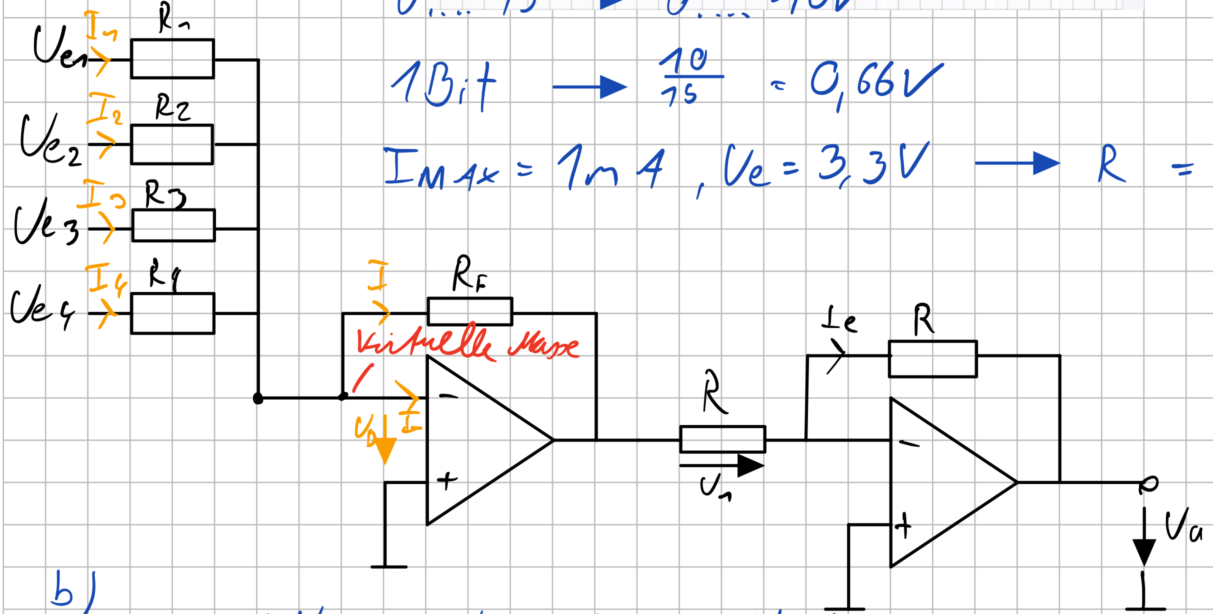
a_3	a_2	a_1	a_0	Dez	U_a
0	0	0	0	0	0V
0	0	0	1	1	...
1	1	1	1	15	10V

a)

$0 \ldots 15 \longrightarrow 0 \ldots 10V$

$1\,Bit \longrightarrow \frac{10}{15} = 0{,}66V$

$I_{MAX} = 1mA,\ U_e = 3{,}3V \longrightarrow R = \frac{3{,}3V}{1mA} = 3{,}3k\Omega$



b)

$$U_a = -R_F\left(\frac{U_{e1}}{R_1} + \frac{U_{e2}}{R_2} + \frac{U_{e3}}{R_3} + \frac{U_{e4}}{R_4}\right)$$

$$U_a = -\left(\frac{R_F}{R_1}U_{e1} + \frac{R_F}{R_2}U_{e2} + \frac{R_F}{R_3}U_{e3} + \frac{R_F}{R_4}U_{e4}\right)$$

$$U_a = -R_F\left(1\frac{U_{e1}}{R_1} + 2\frac{U_{e2}}{R_2} + 4\frac{U_{e3}}{R_3} + 8\frac{U_{e4}}{R_4}\right) \longrightarrow$$

$R_4 = 10k\Omega$

$R_3 = 2R_4$

$R_2 = 4R_4$

$R_1 = 8R_4$

R	$\frac{R}{2}$	$\frac{R}{4}$	$\frac{R}{8}$
$8R$	$4R$	$2R$	R

1)

$$-10V = -R_F\left(\frac{3{,}3V}{80k\Omega} + \frac{3{,}3V}{40k\Omega} + \frac{3{,}3V}{20k\Omega} + \frac{3{,}3V}{10k\Omega}\right)$$

$\longrightarrow -R_F =$

2)

$$-\frac{10}{15} = -R_F \cdot \frac{3{,}3V}{80k\Omega} \Rightarrow R_F = \frac{10 \cdot 80k\Omega}{15 \cdot 3{,}3V} = 16{,}2k\Omega$$

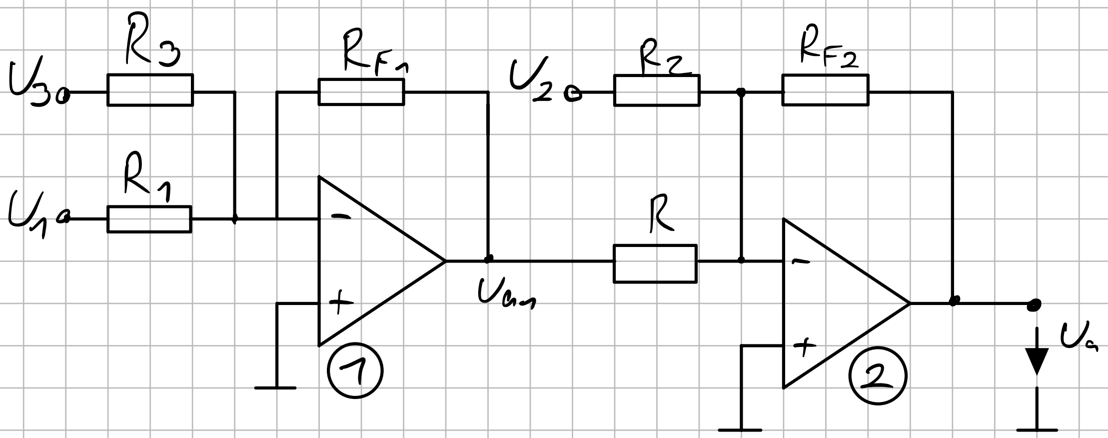
Bsp:

1) Mit einer Summierverstärkerschaltung sollen Eingangsspannungen addiert werden: $U_A = 1{,}7 U_3 - 1 U_2 + 2{,}5 U_1$

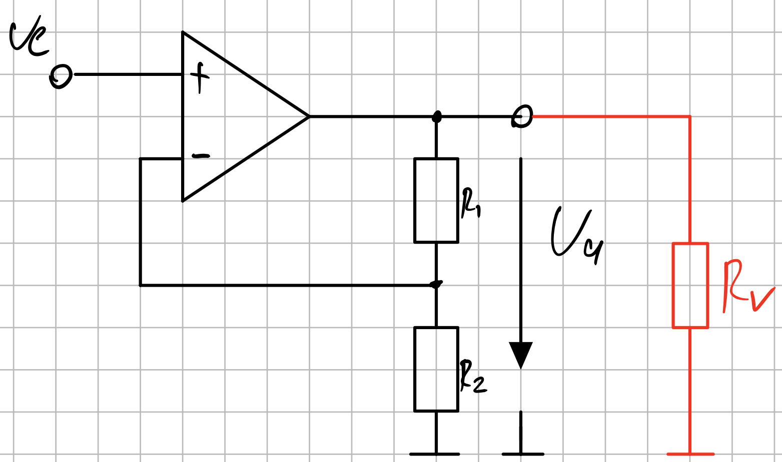
Zeichne die Schaltung mit allen Spannungsversorgungen und dimensioniere alle Widerstände (es darf mehr als 1 OPV verwendet werden)

$$\frac{U_a}{U_e} = -(\dots)$$

$$U_{a1} = -(1{,}7 U_3 + 2{,}5 U_1)$$



2) Entwerfen Sie eine Schaltung mit einem NINV mit Verstärkung 3,7. Technische Daten OPV: max. Ausgangsstrom 15 mA, Versorgung: +/- 30 V



Falsch (da $I_{max} = 15\,mA$)

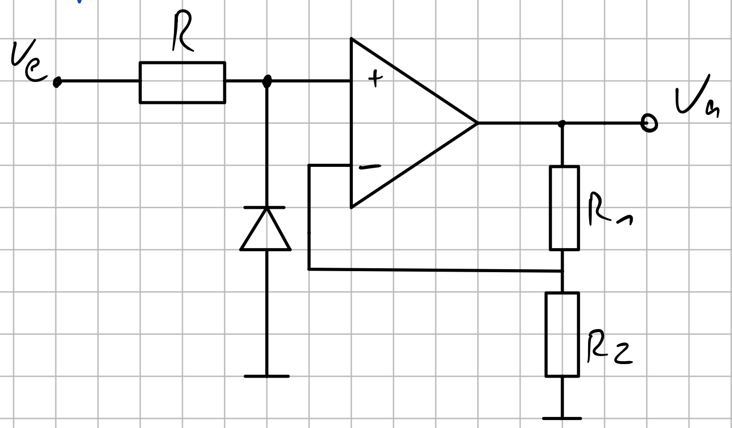
$$\frac{U_a}{U_e} = \frac{R_1 + R_2}{R_2} = 1 + \frac{R_1}{R_2}$$

Ann. $R_1 = 1\,k\Omega$

$$R_2 = \frac{R_1}{2{,}7} = 370\,\Omega$$

Besser: $I_F < 1\,mA \Rightarrow R_1 + R_2 > 30\,k\Omega \left(\frac{U_{max}}{I_F}\right)$

Bsp:



Z-Diode: $I_{Z max} = 10mA$

$U_Z = 3{,}9V \,/\, 5{,}6V$

$U_{e max} = 20V$

OPV: $I_{max} = 25mA$

Gesucht: R_1, R_2, R wenn $U_a = 10V$

Spannungsverlauf U_a $U_e = 0 \ldots 20V$

Diode 1

$U_R = U_e - U_Z = 16{,}1V$

$$R = \frac{U_R}{I_{Z max}} = \frac{16{,}1V}{10mA} = \underline{\underline{1{,}61k\Omega}}$$

$$\frac{U_a}{U_e} = 1 + \frac{R_1}{R_2} = \frac{10V}{3{,}9V} = 1 + \frac{R_1}{R_2} \Rightarrow 1{,}6 = \frac{R_1}{R_2}$$

Ann. $R_1 = \underline{\underline{1{,}6k\Omega}}$

$$1{,}6 = \frac{1{,}6k\Omega}{R_2} \rightarrow = \frac{1{,}6k\Omega}{\underline{\underline{1k\Omega}}}$$

Diode 2

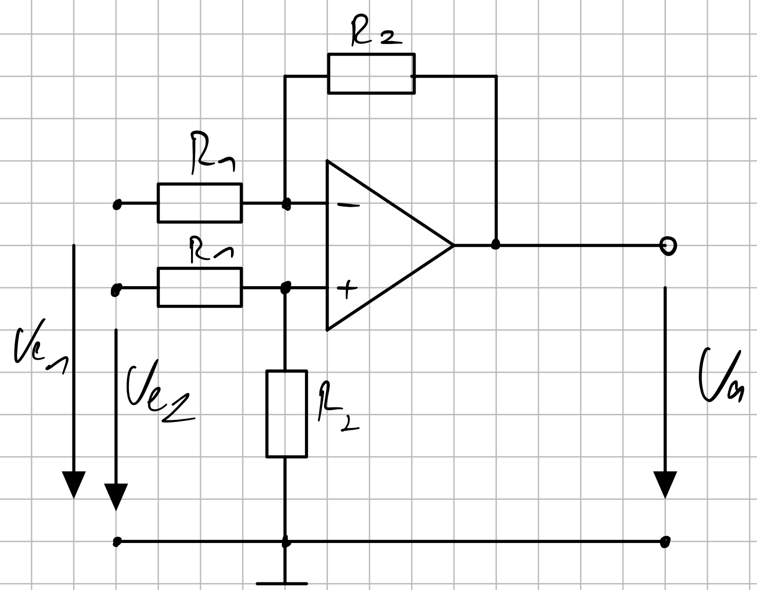
$U_R = U_e - U_Z = 14{,}4V$

$$R = \frac{U_R}{I_{Z max}} = \frac{14{,}4V}{10mA} = \underline{\underline{1{,}44k\Omega}}$$

Ann. $R_1 = \underline{\underline{800\Omega}}$

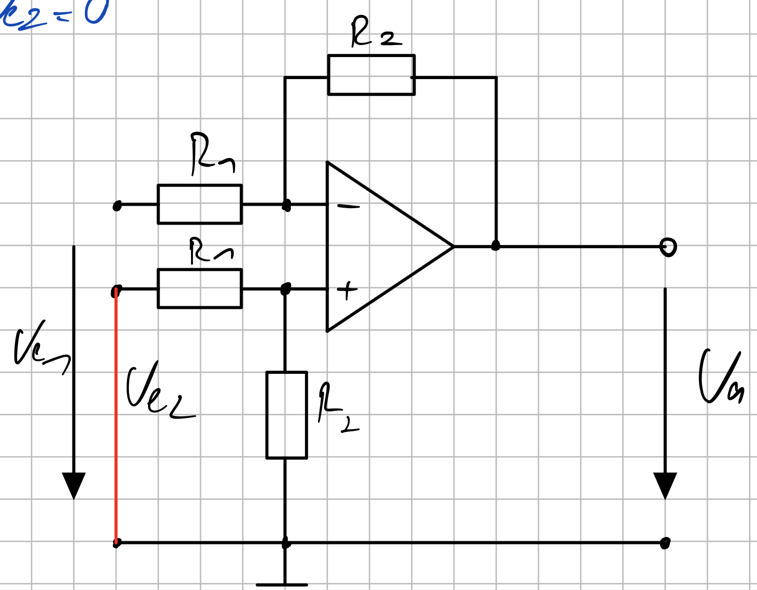
$$\frac{U_a}{U_e} = 1 + \frac{R_1}{R_2} = \frac{10V}{5{,}6V} = 1 + \frac{R_1}{R_2} \Rightarrow 0{,}8 = \frac{R_1}{R_2} = \frac{800\Omega}{\underline{\underline{1k\Omega}}}$$

Differenzverstärker

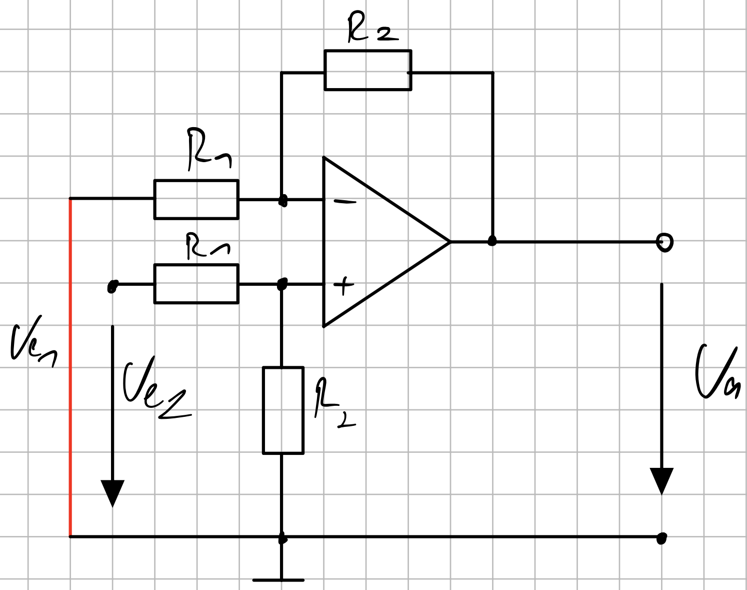


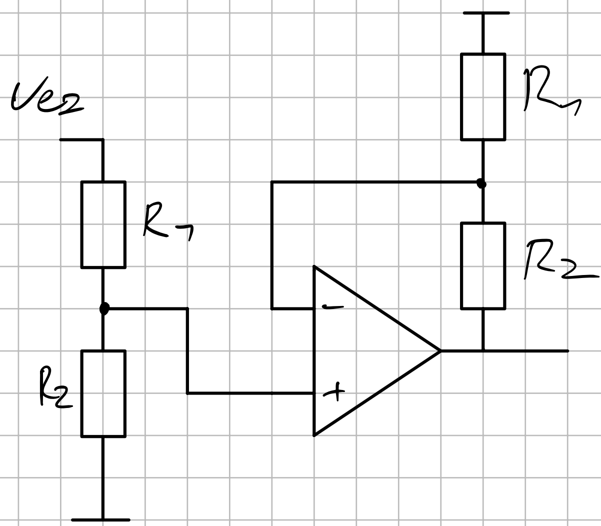
Überlagerungssatz nach Helmholtz

1) $U_{e2} = 0$



→ INV $U_a = U_{e1} \cdot -\frac{R_2}{R_1}$





$$U_{a_2} = U_{e2} \cdot \frac{R_2}{R_1+R_2} \cdot \frac{R_1+R_2}{R_1} = U_{e2} \cdot \frac{R_2}{R_1}$$

$$U_a = U_{a1} + U_{a2} = U_{e1} \cdot \left(-\frac{R_2}{R_1}\right) + U_{e2} \cdot \frac{R_2}{R_1} = \left(U_{e2} - U_{e1}\right) \cdot \frac{R_2}{R_1}$$

$$\boxed{U_a = \left(U_{e2} - U_{e1}\right) \cdot \frac{R_2}{R_1}}$$

Nachteile:

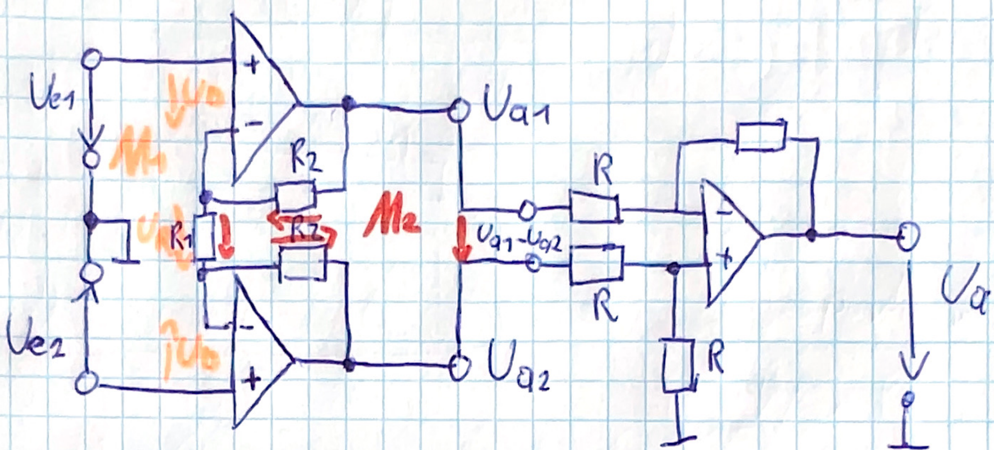
- niedrigen Eingangswiderstand bei großer Verstärkung
  → nur kleine Abweichung der Innenwiderstände führt zu starker Verschlechterung der Gleichtaktunterdrückung

HWE

Instrumentenverstärker A1

hohe Gleichtaktunterdrückung

hoher Eingangswiderstand



M_1: $U_D + U_R - U_D + U_{e2} - U_{e1} = 0$

$U_D = 0$

$U_R + U_{e2} - U_{e1} = 0$

$U_R = U_{e1} - U_{e2}$

M_2: $(U_{a1} - U_{a2}) - U_{R2} - U_{R1} - U_{R2} = 0$

$U_{a1} - U_{a2} = U_{R2} + U_{R1} + U_{R2}$

1. $U_a = U_{a2} - U_{a1} \Rightarrow | -U_a = U_{a1} - U_{a2} |$

2. $$\frac{U_{a1} - U_{a2}}{U_{e1} - U_{e2}} = \frac{R_2 + R_1 + R_2}{R_1}$$

$$V_U = \frac{-U_a}{U_{e1} - U_{e2}} = \frac{R_1 + 2R_2}{R_1}$$

gesamte Schaltung

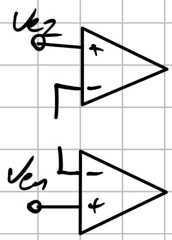
$$V_u = \frac{U_a}{U_e} = -\frac{R_1 + 2R_2}{R_1} = -\left(1 + \frac{2R_2}{R_1}\right)$$

Bsp.:

$U_{e1} = 1V$
$U_{e2} = 0{,}5V$ } $U_{e1} - U_{e2} = -0{,}5V$
$U_u = 3V$

$V_u = 6$

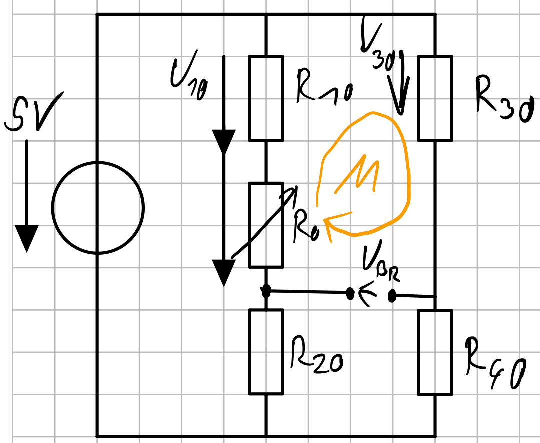
$U_e = U_{e2} - U_{e1} = -(U_{e1} - U_{e2})$



$$V_u = \frac{U_a}{U_e}$$

$U_e \leftarrow U_{e1} - U_{e2}$

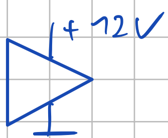
Bsp.:



$R_p = 0..250\,\Omega$

$R_x = 10k\Omega$

1) U_{BR} Grenzwerte (max, min)
2) Instr. Verstärker: $R_2 = 30k\Omega$, $U_a = 0 \ldots 10V$
3) Anschluß $U_{BR} \rightarrow U_a$ positiv
4) $U_{B_{OPV}} = +12V$ ist es möglich?



1)

$M: U_{30} + U_{BR} - U_p - U_{10} \Rightarrow U_{BR} = U_p + U_{10} - U_{30}$

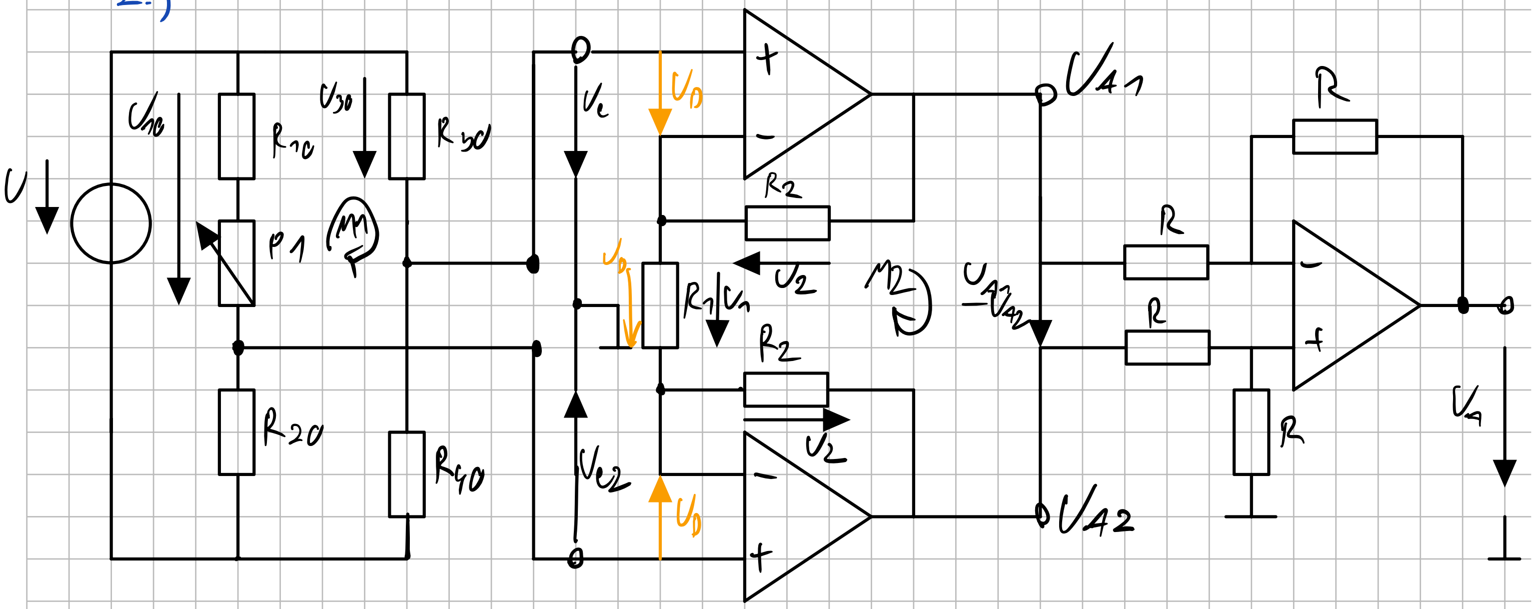
$$\frac{U_{10}}{U_e} = \frac{R_{10} + R_p}{R_{10} + R_p + R_{20}} = \frac{10k + 250\Omega}{10k + 10k + 250\Omega} \cdot 5V = 2{,}51V$$

$U_{0R} =$

$\frac{U_{30}}{U_e} = \frac{R_{30}}{R_P + R_{10} + R_{20}} = \frac{10k}{150\Omega + 10k + 10k} \cdot 5V = 2{,}57V$

$U_{10} - U_{30} = 30{,}80\,mV = U_{BR_{max}}$ $\quad U_{BR_{min}} = 0V$

2.)



$\frac{10V}{324}$

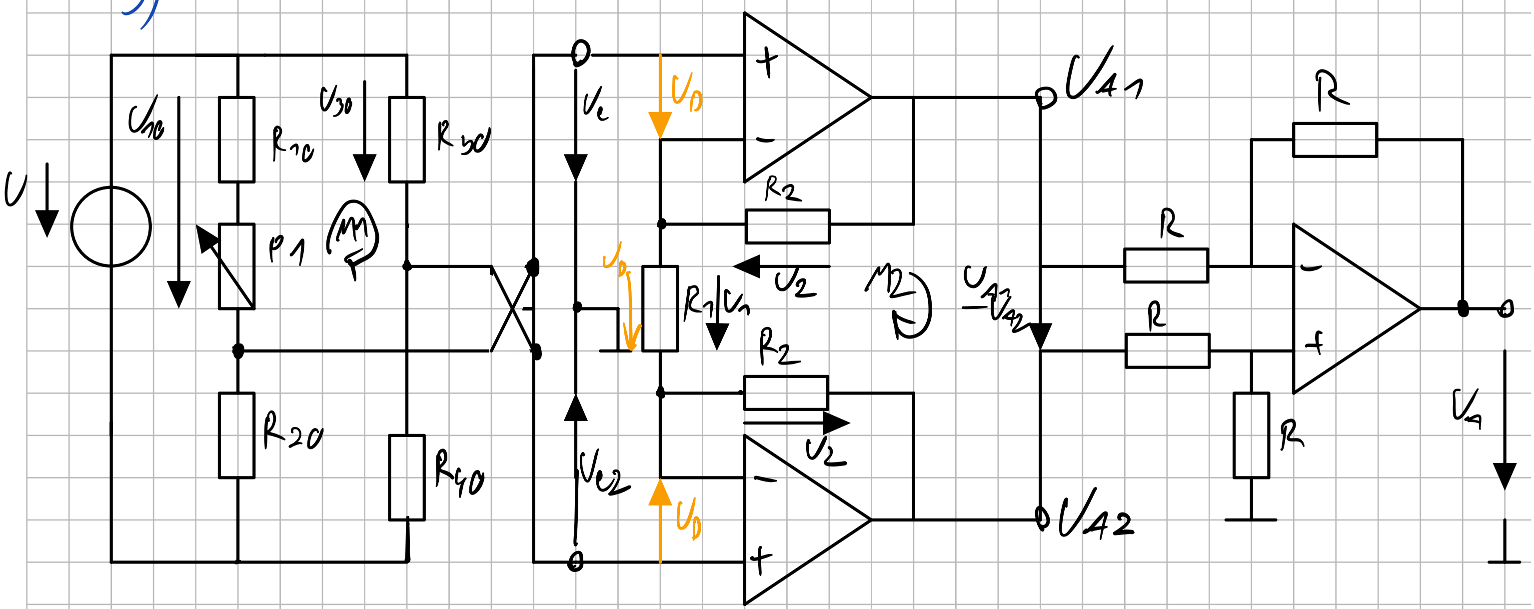
$30{,}86mV \cdot 324 = 10V$

$V_u = -\left(1 + \frac{2R_2}{R_1}\right)$ $\quad V_U = 324$

$324 = -\left(1 + \frac{2R_2}{R_1}\right)$

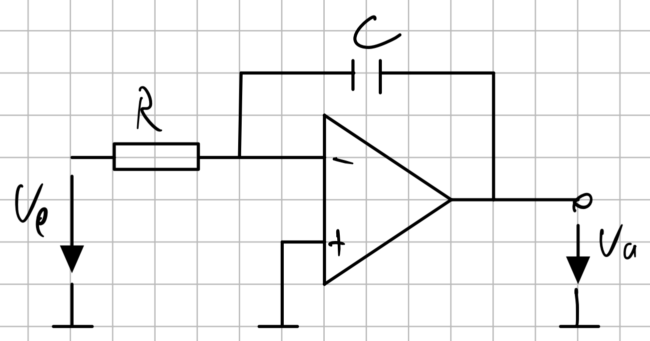
$R_1 = \frac{1 + 60000\,\Omega}{324} = 186{,}2\,\Omega$

3)



Entweder einen NIV anhängen oder die U_{BR} Anschlüsse tauschen.

Integrator:



Wiederholung Kondensator.

$Q = C \cdot U_C$

$\frac{dQ}{dt} = C \cdot \frac{dU_C}{dt}$

$I_C = C \frac{dU_C}{dt} \Rightarrow U_C = \frac{1}{C} \cdot \int I_C \cdot dt$

$I_C = \frac{U_e}{R} \Rightarrow U_C = \frac{1}{RC} \int U_e \cdot dt$

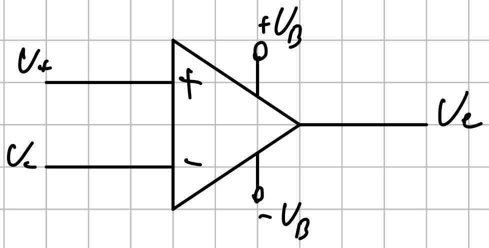
$U_a = -U_C$

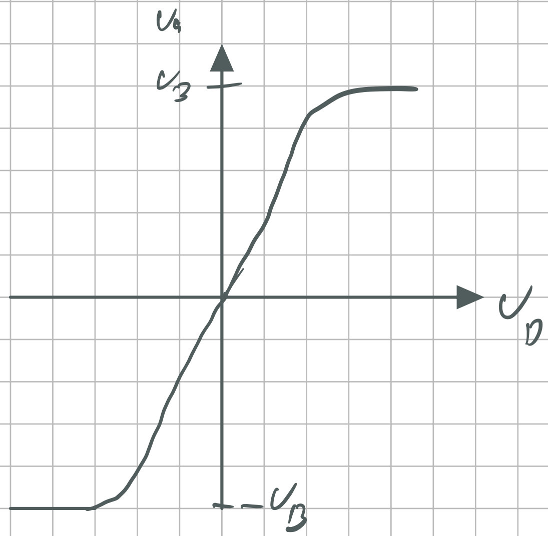
$U_a = -\frac{1}{RC} \int U_e \cdot dt$

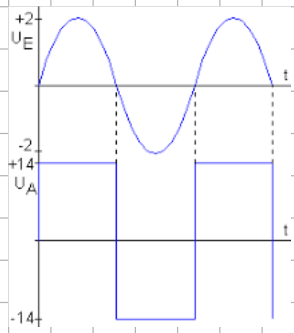
Ann. U_e = konstant

$U_a = -\frac{1}{RC} \cdot U_e \cdot t$

Komperator:

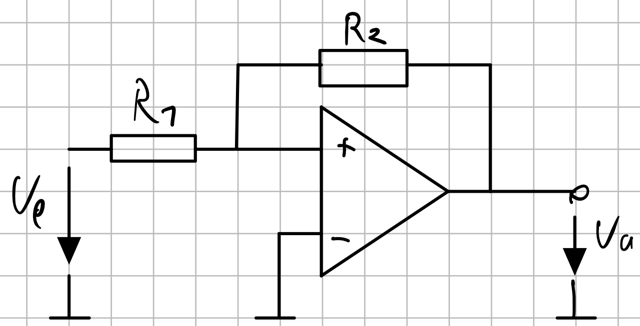


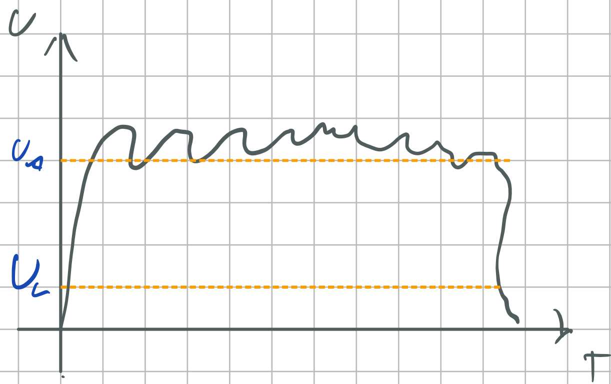




Schmitt - Trigger

1) Nicht invertiert ST





a) Schaltschwelle U_S (Ausschaltschwelle)

Anfangsbed. $U_a = +U_B$

$$\frac{U_1}{U_2} = \frac{R_1}{R_2} = \frac{U_e}{-U_a}$$

Kirchhoff

$$U_2 + U_a - U_D = 0 \Rightarrow U_2 = -U_a$$

$U_e = U_{S-}$, $U_a = U_B$

$$\frac{U_{S-}}{-(+U_B)} = \frac{R_1}{R_2} \Rightarrow \boxed{U_{S-} = -U_{B_{max}} \cdot \frac{R_1}{R_2}}$$

U_{Bmax}

$\left.\begin{matrix} U_{Bmax} \\ U_{Bmin} \end{matrix}\right\}$ Versorgungsspannung

b) U_{S+} ... Einschaltschwelle

Ausgangsb.: $U_a = U_{Bmin}$

$$\frac{U_{S+}}{-U_{Bmin}} = \frac{R_1}{R_2} \Rightarrow \boxed{U_{S+} = -U_{Bmin} \frac{R_1}{R_2}}$$

$$U_{S-} = -\frac{R_1}{R_2} \cdot U_{B\,max}$$

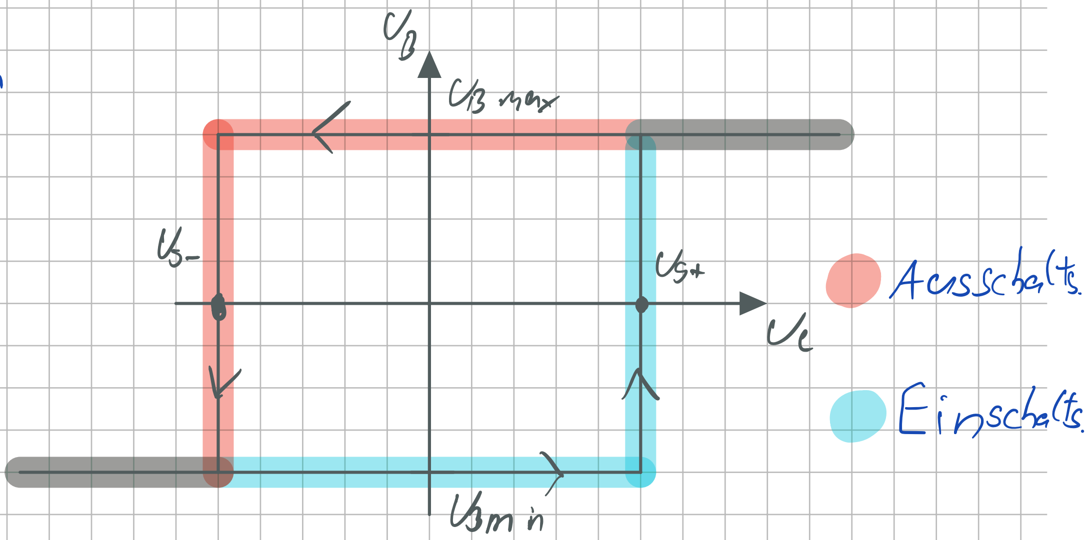
$$U_{S+} = -\frac{R_1}{R_2} \cdot U_{B\,min}$$

Bsp. $\pm 10V$

$R_2 = R_1 \cdot 4$

$U_{S-} = -2{,}5$

$U_{S+} = +2{,}5$



Bsp:

Bsp.) (Versorgungsspannung)

U_e ... sinusförmig $\hat{U} = 5V, 50Hz$ Ausgangsspannung $+10V/-10V$

Schaltschwellen $\pm 1{,}5V$

1.) Dimensioniere die Schaltung Ann: $R_1 = 10k\Omega$

2.) Zeichne den Spannungsverlauf für U_e, U_A

Ann.

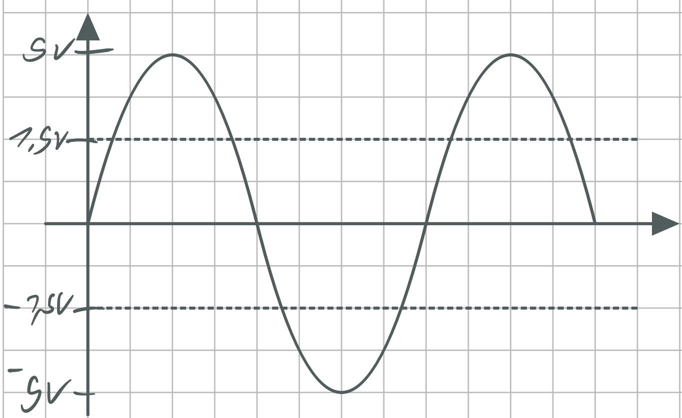
R_1, R_2

$$U_{S-} = -\frac{R_1}{R_2} \cdot U_{B\,max}$$

$$-1{,}5V = -\frac{R_1}{R_2} \cdot 10V$$

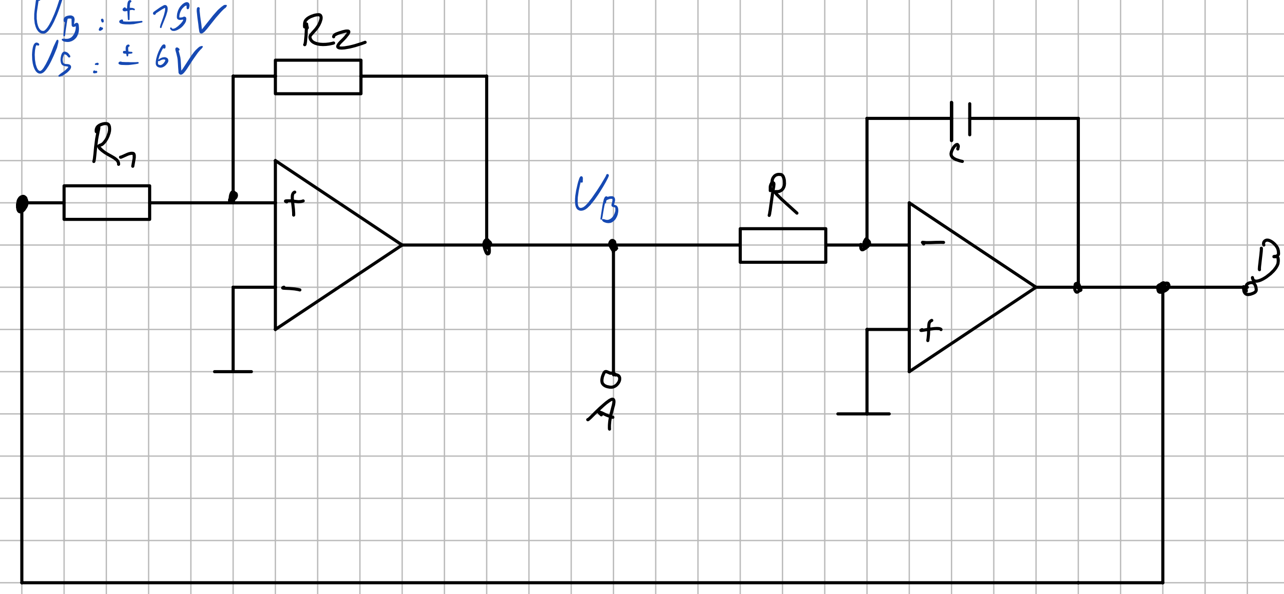
$$\frac{1{,}5V}{10V} = \frac{R_1}{R_2}$$

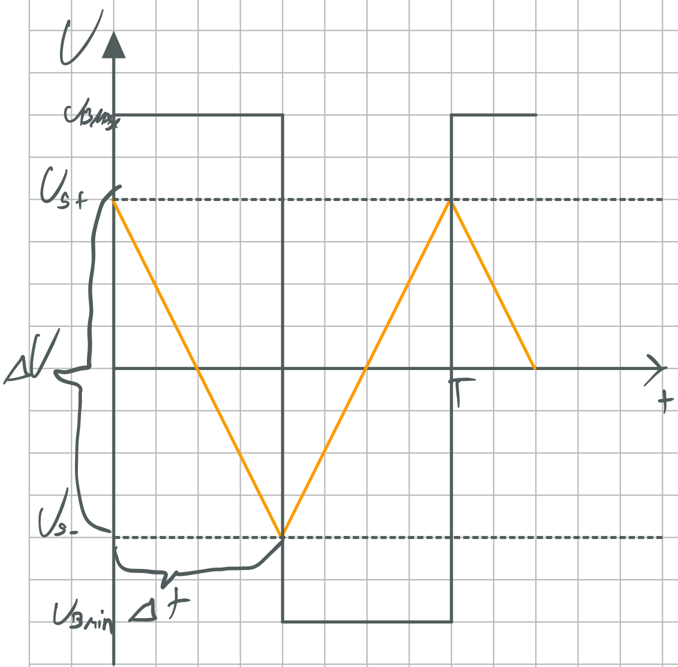
Ann. $R_1 = 15k\Omega$, $R_2 = 100k\Omega$



Bsp:

$U_B: \pm 15V$
$U_S: \pm 6V$





Anm. OPV Sym. Versorgung $\pm U_B$

U_{SAT} ...... Sättigungsspannung (U_{Bmax} oder U_{Bmin})

$U_C \hat{=} U_{SAT}$

$$\boxed{f = \frac{1}{4RC \cdot \frac{R_1}{R_2}}}$$

Schmitt-Trigger:

$$U_{S+} = -U_{Bmin} \frac{R_1}{R_2} \rightarrow \frac{U_H}{2}$$

Integrator:

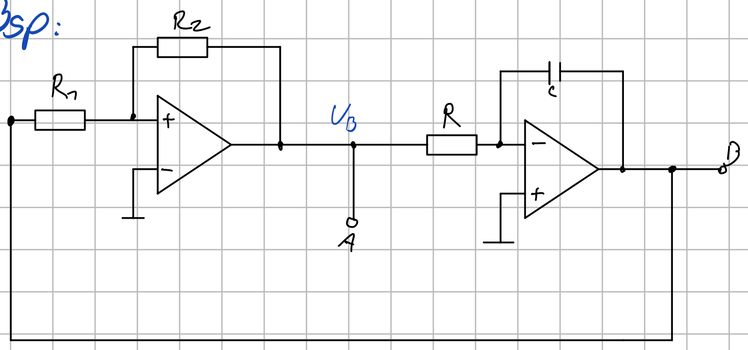
$$\Delta U_D = -\frac{1}{RC} \cdot U_e \cdot \Delta t \Rightarrow \frac{\Delta U_D}{\Delta T} = -\frac{1}{RC} \cdot U_e$$

U_H, $\frac{T}{2}$

$$\frac{\Delta U_D}{\Delta t} = -\frac{1}{RC} \cdot \cancel{U_{SAT}} = \frac{2 \cancel{U_{SAT}} \cdot \frac{R_1}{R_2}}{\frac{T}{2}} \Rightarrow \frac{1}{RC} = \frac{2 \frac{R_1}{R_2} \cdot 2}{T}$$

$$\boxed{T = 4RC \cdot \frac{R_1}{R_2}}$$

Bsp:



$R_1 = 10\,k\Omega$
$R_2 = 22\,k\Omega$
$R = 10\,k\Omega$
$C = 56\,nF$

Beispiel:

$R_1 = 10k\Omega$
$R_2 = 22k\Omega$
$R = 10k\Omega$
$C = 56nF$
$U_{BMAX} = +14V$
$U_{BMIN} = -14V$

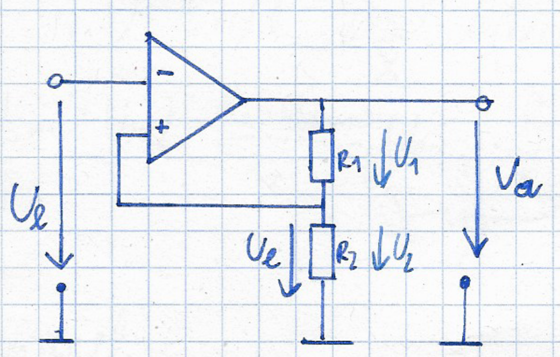
ges: f, zeichnen: U_{R_1}, U_D

$$U_{S+} = -U_{BMIN} \cdot \frac{R_1}{R_2} = 6{,}36V$$

$$U_{S-} = -U_{BMAX} \cdot \frac{R_1}{R_2} = -6{,}36V$$

$$f = \frac{1}{4 \cdot RC \cdot \frac{R_1}{R_2}} = \underline{982{,}14\,Hz}$$

2. Invertierender Schmitt-Trigger



a) Ausschaltschwelle: U_{eaus}, $U_a = U_{BMAX}$

$$\frac{U_a}{U_e} = \frac{R_1+R_2}{R_2} \quad \Big| \quad \frac{U_{BMAX}}{U_{eAUS}} = \frac{R_1+R_2}{R_2}$$

$$\Rightarrow \boxed{U_{eAUS} = U_{BMAX} \cdot \frac{R_2}{R_1+R_2}}$$

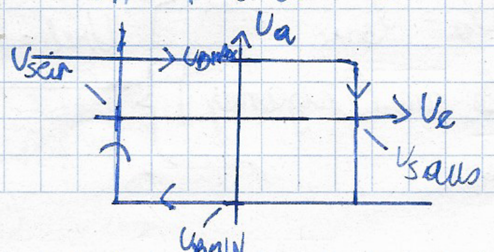
Ausgangssituation:
$U_e = U_{eaus}$; $U_a = U_{BMAX}$

Ausgangssituation:
$U_e = U_{eein}$; $U_a = U_{BMIN}$ $\boxed{U_{eein} = U_{BMIN} \cdot \frac{R_2}{R_1+R_2}}$

b) Einschaltschwelle: U_{eein}, $U_a = U_{BMIN}$

$$\boxed{U_{eein} = \frac{R_2}{R_1+R_2} \cdot U_{BMIN}}$$

c) Hysterese: $U_H = |U_{eein} - U_{eaus}|$



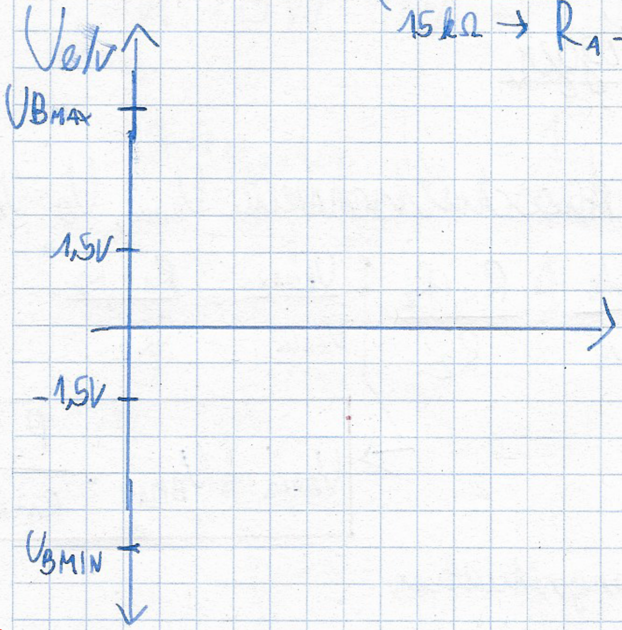
Beispiel: U_e … sinusförmig $\hat{U} = 5V, 50Hz, 20ms$, Ausgangsspannung: $+10V / -10V$, Schaltschwellen: $\pm 1{,}5V$

1.) Dimensioniere die Schaltung Ann. $R_2 = 15k\Omega$

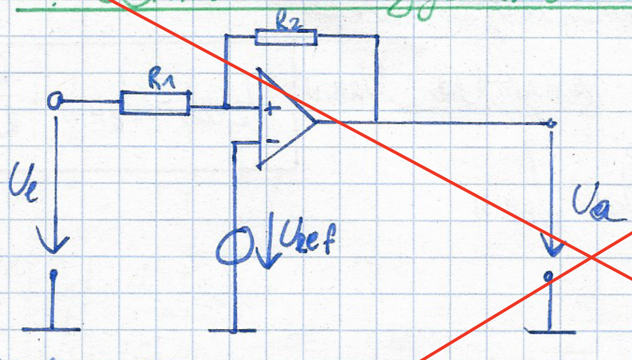
2.) Zeichne den Spannungsverlauf für U_e, U_a

$$\frac{U_a}{U_e} = \frac{R_1 + R_2}{R_2} = \frac{10V}{1{,}5V}$$

$15k\Omega \rightarrow R_1 - R_2 = 100k\Omega \rightarrow R_1 = 85k\Omega$



~~3. Schmitt-Trigger mit einstellbaren Schwellen~~

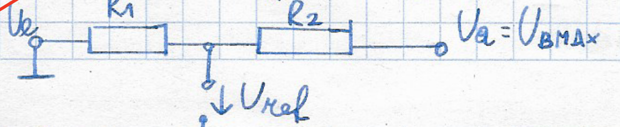


~~Helmholtz:~~

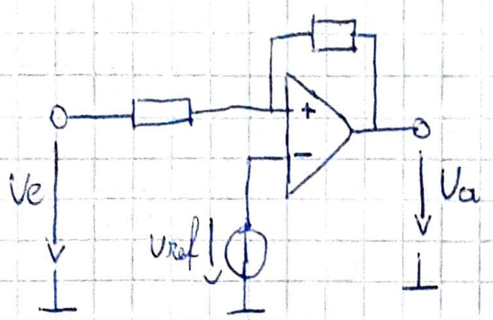
~~1) Ausgangsseit.: U_{s-} an U_e, $U_a = U_{BMAX}$~~

~~a) $U_{s-} = 0$ (Spannungsquelle an Eingang)~~

~~$U_{ref} = U_{BMAX} \cdot \frac{R_1}{R_1 + R_2}$~~



Schmitt trigger mit einstellbarer Schwelle



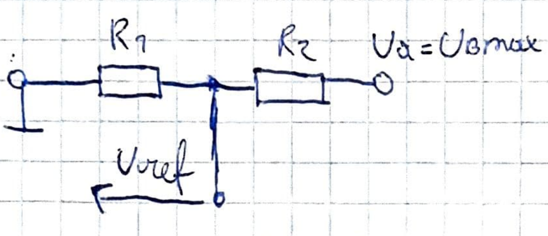
$$U_{S-} = \underbrace{U_{ref}\,\frac{R_1+R_2}{R_2}}_{0\text{ Punkt Verschiebung}} - U_{Bmax}\cdot\frac{R_1}{R_2}$$

$$U_{S+} = U_{ref}\,\frac{R_1+R_2}{R_2} - U_{Bmin}\cdot\frac{R_1}{R_2}$$

① Helmholz (Ausgangssituation)

~~Ua für~~ U_{S-} an U_e, $U_a = U_{Bmax}$

ⓐ $U_{S-} = 0$ (Spannungsquelle am Eingang)

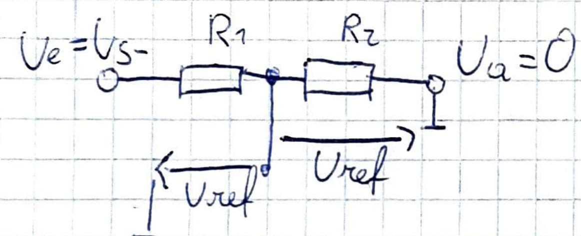


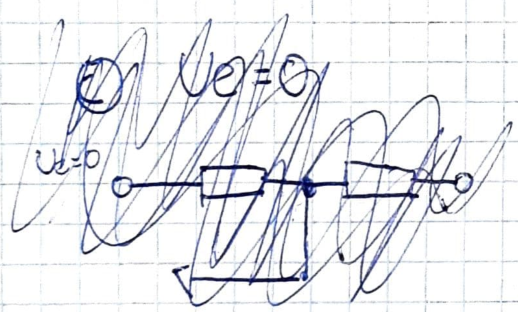
$$U_{Bmax}\cdot\frac{R_1}{R_1+R_2} + U_{S-}\cdot\frac{R_2}{R_1+R_2} = U_{ref}$$

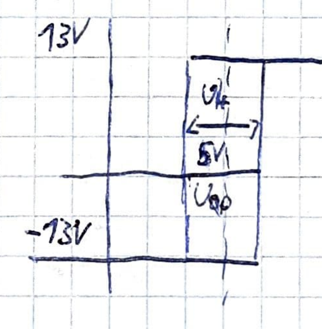
$$U_{S-} = \left(U_{ref} - U_{Bmax}\cdot\frac{R_1}{R_1+R_2}\right)\cdot\frac{R_2+R_1}{R_2}$$

$$= U_{ref}\cdot\frac{R_1+R_2}{R_2} - U_{Bmax}\cdot\frac{R_1}{R_2}$$

ⓑ $U_a = 0$ (Spg.Q am Ausgang)







Bsp.

$U_H = 2V$ $\quad U_B = \pm 13V$ $\quad U_{0P} = 5V$

Dimensionieren sie die Schaltung

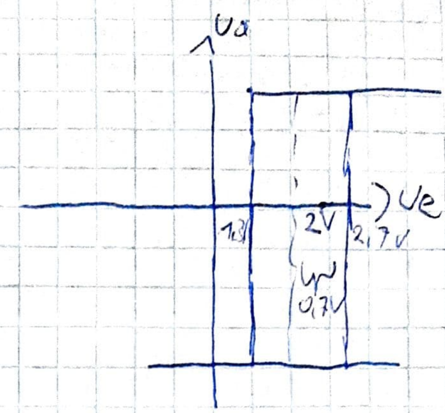
$U_{ref}\cdot\frac{R_1+R_2}{R_1} = U_{0P}$

$U_{ref} = ?$ $\quad R_1 = ?$ $\quad R_2 = ?$

$U_{S+} = U_{Bmin}\cdot\frac{R_1}{R_2}$ $\qquad R_2 = \frac{U_{Bmin}}{U_{S+}}\cdot R_1 = \frac{-13V}{6V}\cdot 10k\Omega = 130k\Omega$

$U_{ref} = U_{0P}\cdot\frac{R_2}{R_1+R_2} = U_{0P}\cdot\frac{130k\Omega}{140k\Omega} = 4{,}64V$

Bsp $U_{S-} = 1{,}3V$
$U_{S+} = 2{,}7V$



~~Us- = ...~~

$$U_{S-} = U_{ref}\,\frac{R_1 + R_2}{R_2} - U_{BMax} \cdot \frac{R_1}{R_2}$$

$$U_{ref} = U_{Bmax} \cdot \frac{R_1}{R_1+R_2} + U_{S-} \cdot \frac{R_2}{R_1+R_2}$$

Angenommen:

$\pm 12V$
$R_1 = 10k$

$$0{,}7V = U_{Bmax} \cdot \frac{R_1}{R_2}$$

$$\frac{0{,}7V}{12V} = \frac{10k\Omega}{R_2} \Rightarrow R_2 = 171k\Omega$$

$$U_{Sp} = U_{ref} \cdot \frac{R_1+R_2}{R_2} \Rightarrow U_{ref} = \frac{171k\Omega}{181k\Omega} \cdot 2V = 1{,}82V$$

Bsp

$U_{S-} = 1{,}3V$
$U_{S+} = 2{,}7V$

Ang. $\pm 12V$

$R_1 = 10k$

$$0{,}7V = U_{B\,max} \frac{R_1}{R_2}$$

$$\frac{0{,}7V}{12V} = \frac{10k}{R_2} \Rightarrow R_2 = \underline{171k\Omega}$$

$$U_{\emptyset p} = U_{ref} \cdot \frac{R_1+R_2}{R_2} \Rightarrow U_{ref} = \frac{171k\Omega}{181k\Omega} \cdot 2V = \underline{\underline{1{,}82V}}$$

Aufgaben:

1) $U_{S+} = 2{,}1V$, $U_{S-} = -2{,}1V$, $U_B = \pm 12V$
U_e sinusförm. $\hat{U} = 10V$, $50Hz$
- Schaltung
- R
- Spannungsverlauf U_a, U_e

2) $U_{S+} = -1{,}3V$, $U_{S-} = 1{,}3V$, $U_B = \pm 12V$
U_e Dreieckform $U_{pp} = 10V$, $1kHz$
– // –
– // –
– // –

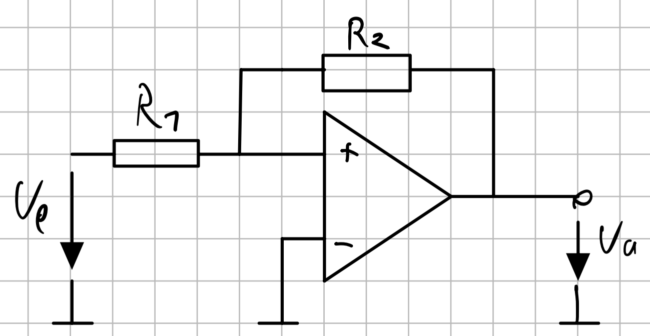
Lösung

1) $R_1 = 10k\Omega$ $R_2 = 57{,}4k\Omega$

2) $R_1 = 97k\Omega$ $R_2 = 12k\Omega$

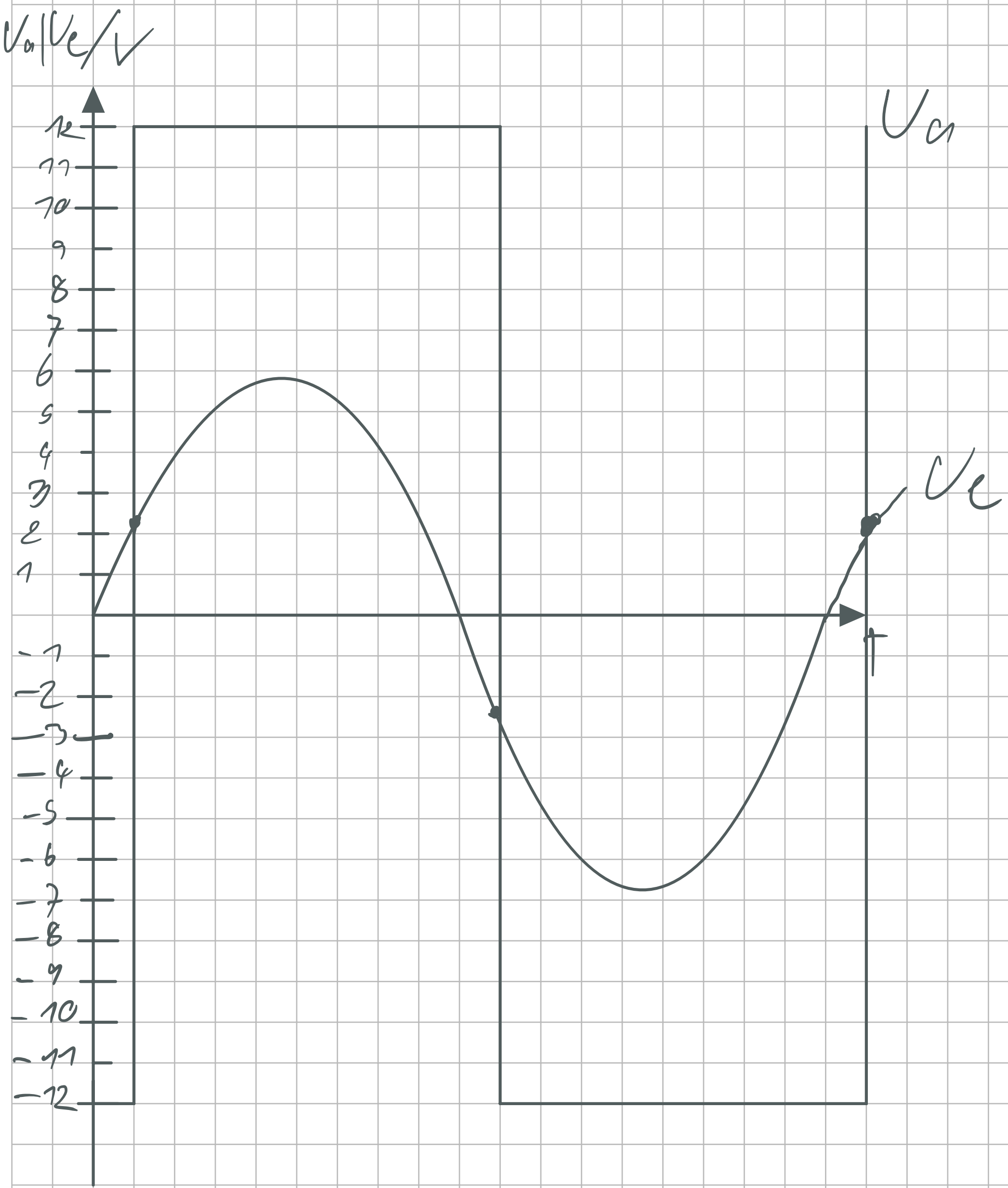
$R_1 = 100k$ $R_2 = 12{,}15k\Omega$

7)



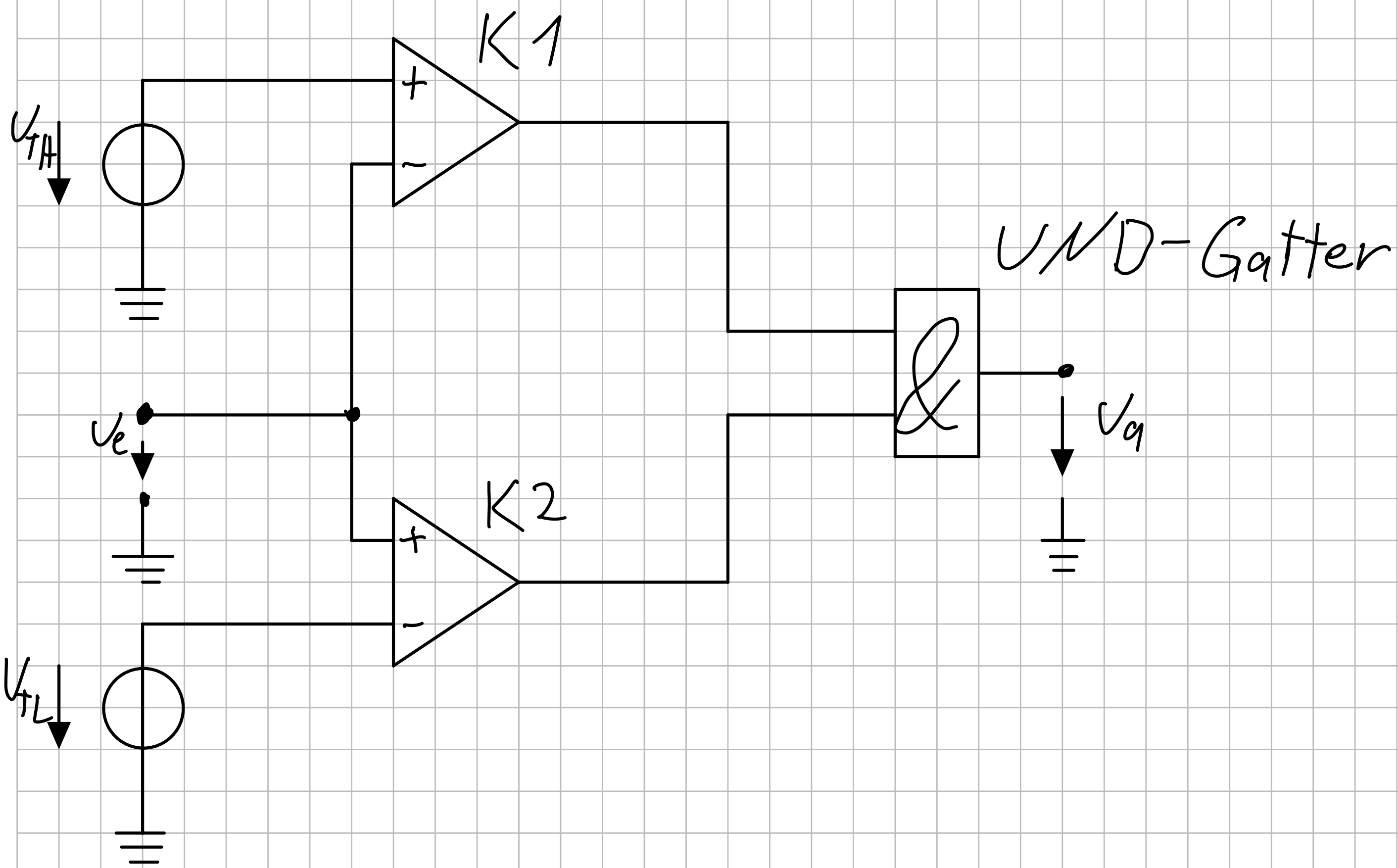
$$U_{S-} = -\frac{R_1}{R_2} \cdot U_{Bmax} \Rightarrow \frac{U_S}{U_{Bmax}} = \frac{R_1}{R_2} = \frac{2{,}1V}{12V} = \frac{2{,}1k\Omega}{12k\Omega}$$

Ann. $R_1 = \quad k\Omega$, $R_2 = 12\,k\Omega$



2)

Fensterkomperator:



$U_e < U_{TH} \longrightarrow 1$

$U_e > U_{TL} \longrightarrow 1$

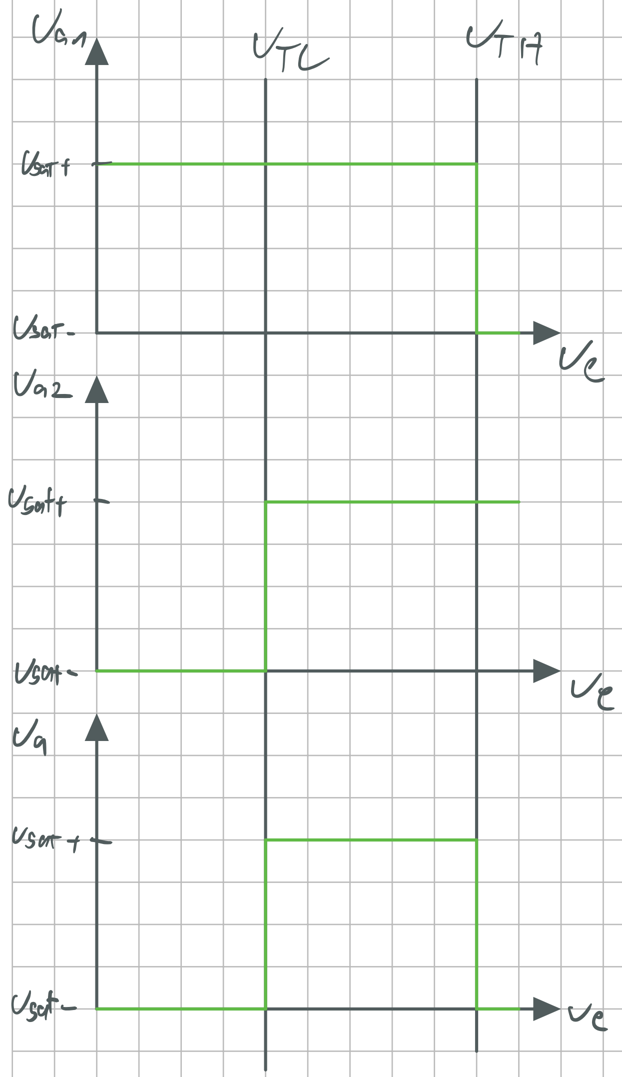
$((U_e < U_{TH}) \& (U_e > U_{TL})) = 1$

OPV1: $U_e < U_{TH} \rightarrow U_{a1} \rightarrow U_{sat+}$

OPV2: $U_e > U_{TL} \rightarrow U_{a1} \rightarrow U_{sat+}$

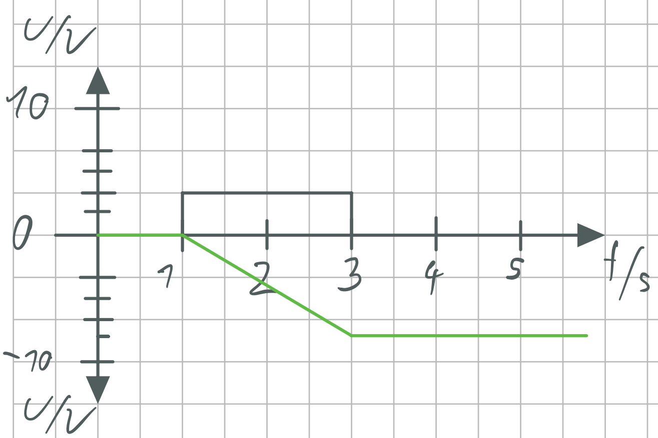
OPV1: $U_e > U_{TH} \rightarrow U_{a2} \rightarrow U_{sat-}$

OPV2: $U_e < U_{TL} \rightarrow U_{a2} \rightarrow U_{sat-}$



Bsp. Integrator

$$U_a = -\frac{1}{RC} \cdot U_e \cdot t$$

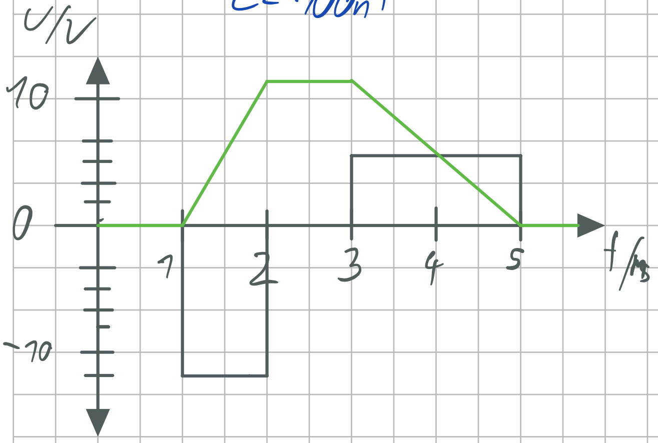


$R = 1\,M\Omega$
$C = 1\,\mu F$

$$U_a = -\frac{1}{1M\Omega \cdot 1\mu F} \cdot 4V \cdot 2s$$

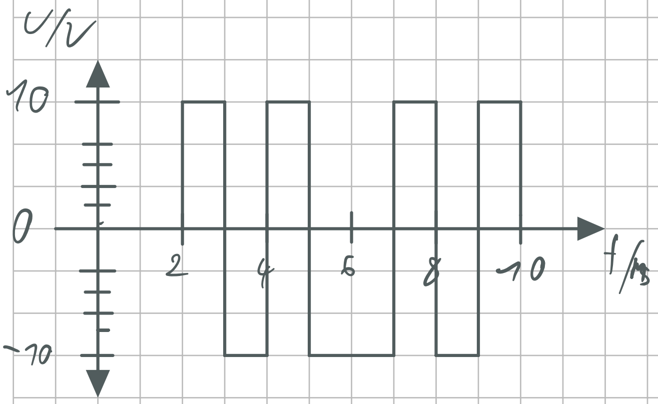
$$U_a = -8V$$

$R = 10k\Omega$
$C = 100nF$

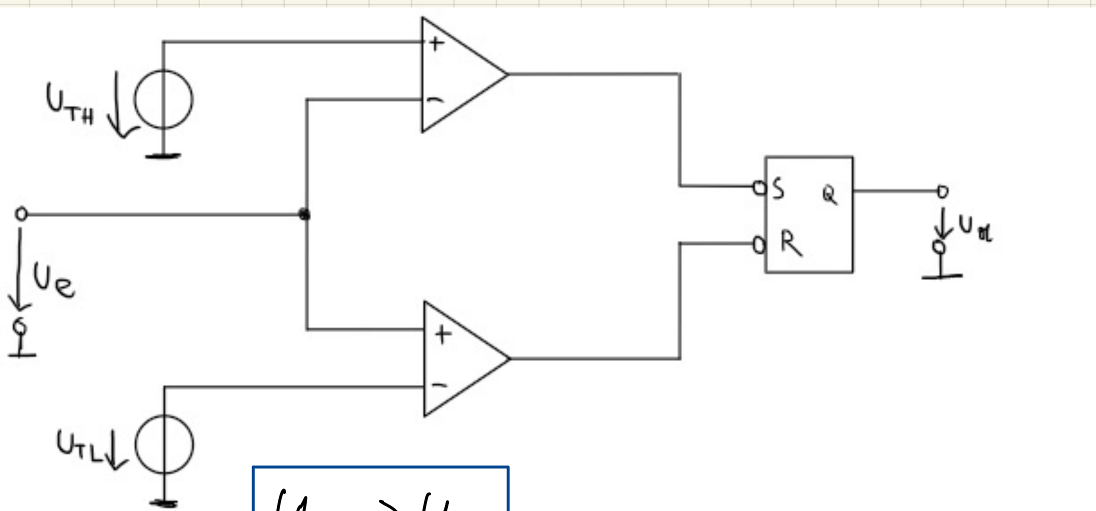


$$V_{a_1} = -\frac{1}{10k\Omega \cdot 100nF} \cdot -12V \cdot (1ms) =$$
$$= 12V$$

$$V_{a_2} = -\frac{1}{10k\Omega \cdot 100nF} \cdot 6V (\cdot 2ms)$$
$$= -12V$$



Präzisions-Schmitt-Trigger



WT

$\bar{R}$	$\bar{S}$	Q
0	0	undef
0	1	0
1	0	1
1	1	Speichern

$\boxed{U_{TH} > U_{TL}}$

	K_1	K_2	Q
$U_e < U_{TL}$	H	L	L
$U_e > U_{TL}$, $< U_{TH}$	H	H	S
$U_e > U_{TH}$	L	H	H