Grundlagen der Elektrotechnik und Elektronik3 (SYTE3)

Skriptum zur Vorlesung/Übung der Schulstufe 3

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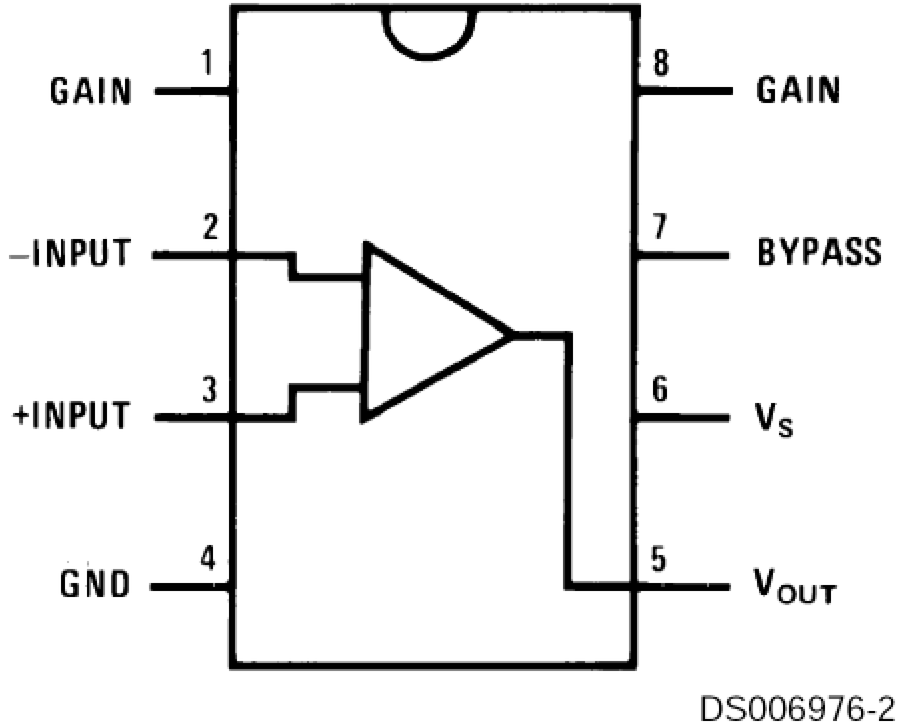
Outlook SYTE3

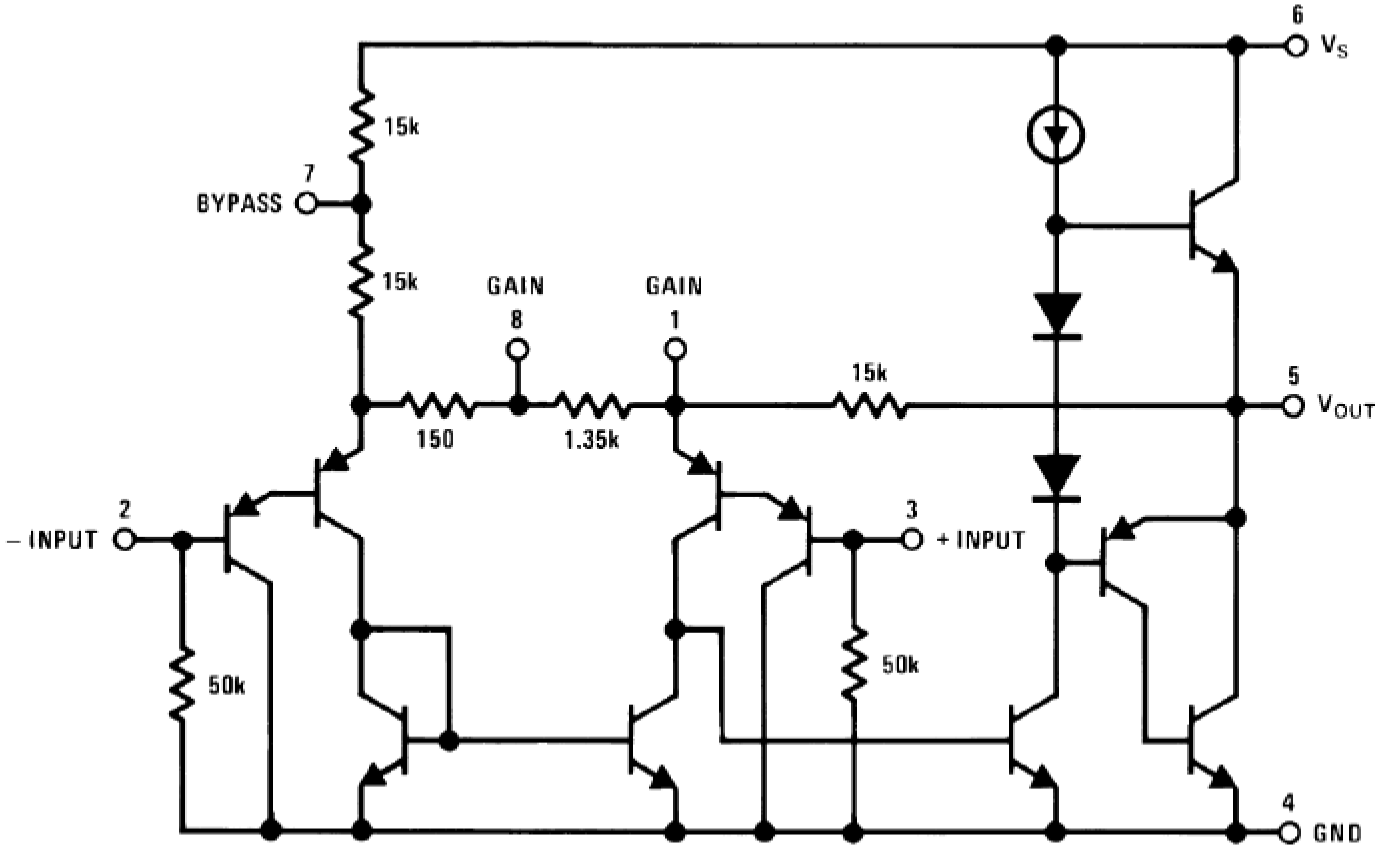
- Operational amplifier
- Converter AD/DA
- Measurements of non electrical quantities
- EMC

Integrated Operational Amplifier



Top View

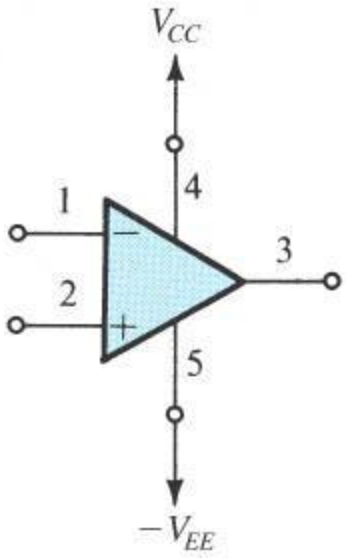
Integrated Operational Amplifier



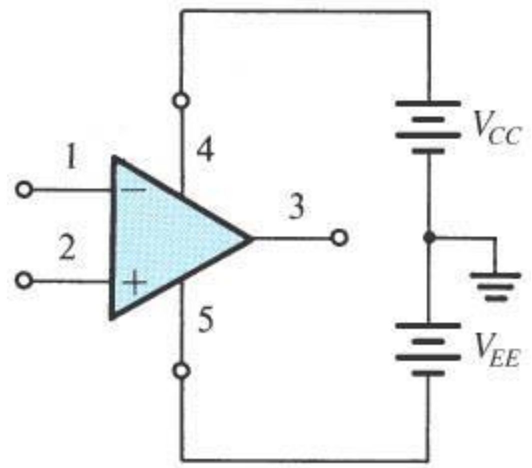
Differential amplifier – Voltage amplifier – Current amplifier

Operational Amplifier

The op amp shown connected to dc power supplies.



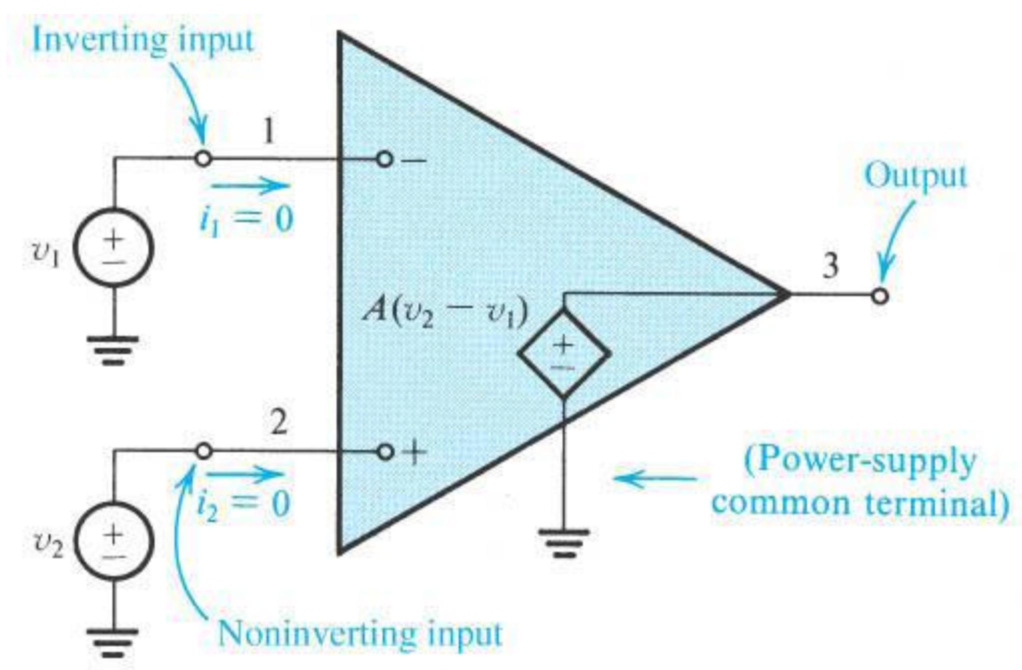
(a)



(b)

Ideal Operational Amplifier

- The gain is ideally infinite (Open loop configuration)
- We will use other components to apply feedback to close the around the op-amp

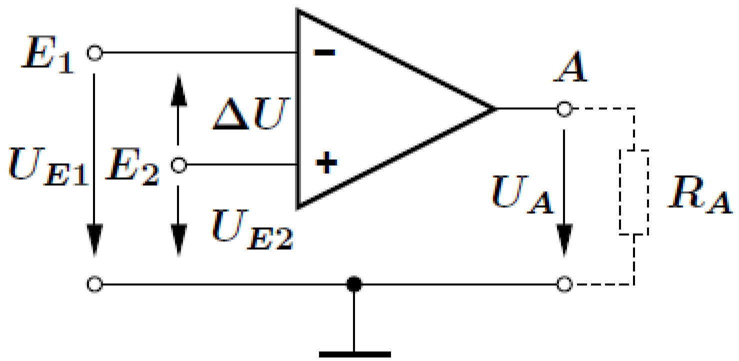


Operational Amplifier

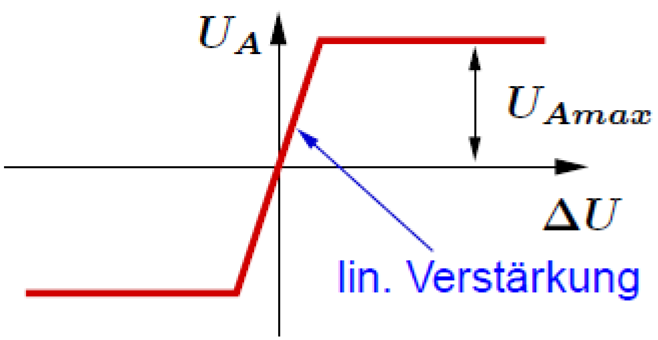
Typical ranges for op amp parameters.

Parameter	Typical range	Ideal values
Open-loop gain, A	10^5 to 10^8	∞
Input resistance, R_i	10^5 to 10^{13} Ω	∞ Ω
Output resistance, R_o	10 to 100 Ω	0 Ω
Supply voltage, V_{CC}	5 to 24 V	

Integrated Operational Amplifier



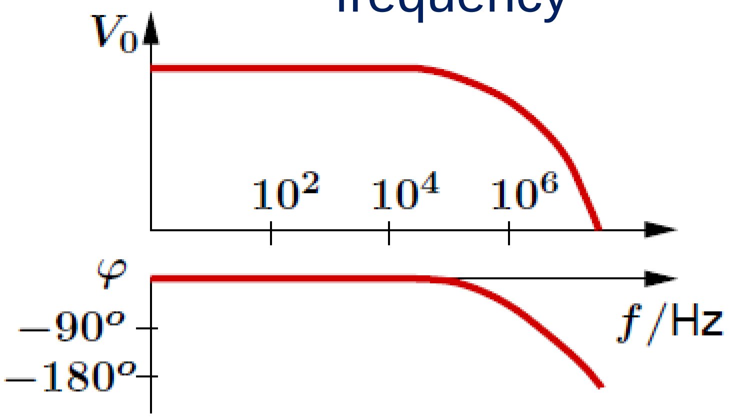
Kennlinie



Open loop gain

$$V_0 = \frac{U_A}{U_{E2} - U_{E1}} = \frac{U_A}{\Delta U}$$
$$\approx 10^4 - 10^6$$

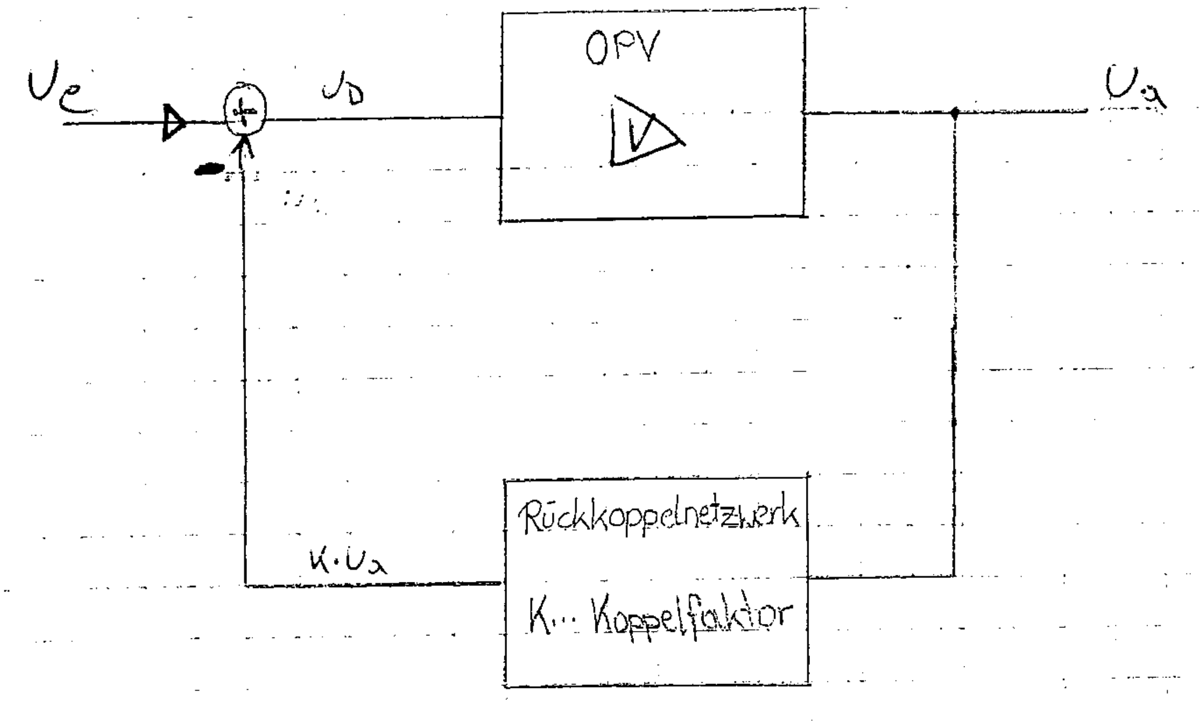
frequency



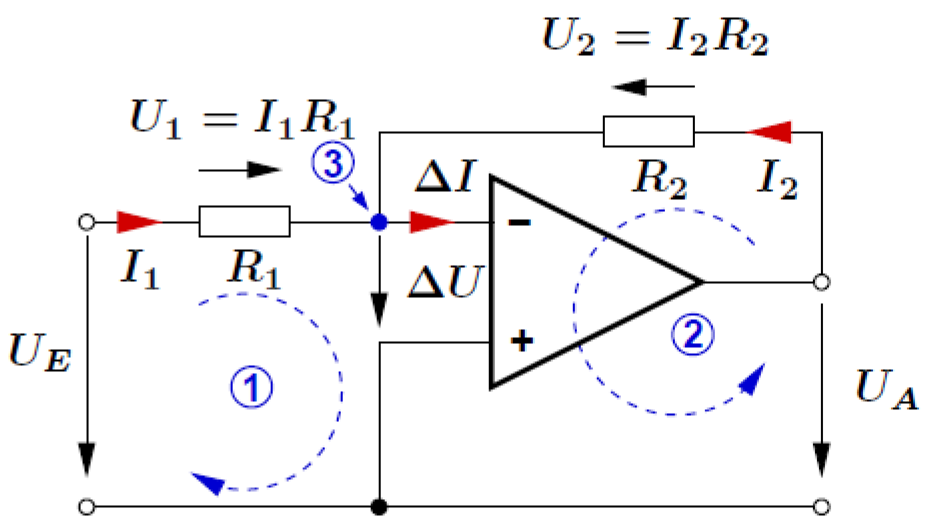
introduction, motivation (5min)

http://www.youtube.com/watch?v=TQB1VlLBgJE&feature=related

Feedback Operational Amplifier



Inverting Amplifier



ideal OPV: $V_0 \to \infty$

$\to \Delta U \approx 0, \ \Delta I \approx 0$

Kirchhoff:

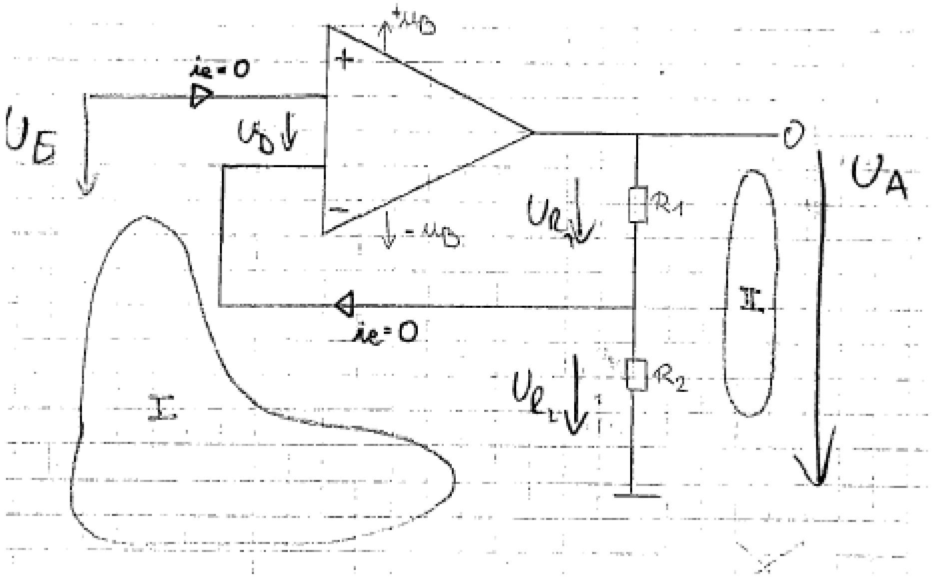
(1) $U_1 - U_E = 0$
(2) $U_2 - U_A = 0$
(3) $I_1 + I_2 = 0$

$$\left.\begin{aligned} U_E &= I_1 R_1 \\ U_A &= I_2 R_2 \\ I_1 &= -I_2 \end{aligned}\right\} \to \boxed{\frac{U_A}{U_E} = -\frac{R_2}{R_1}}$$

Inverting Amplifier

- Negative feedback
- Closed-loop gain depends entirely on passive components and is independent of the op amplifier.
- Engineer can make the closed-loop gain as accurate as he wants as long as the passive components are accurate.

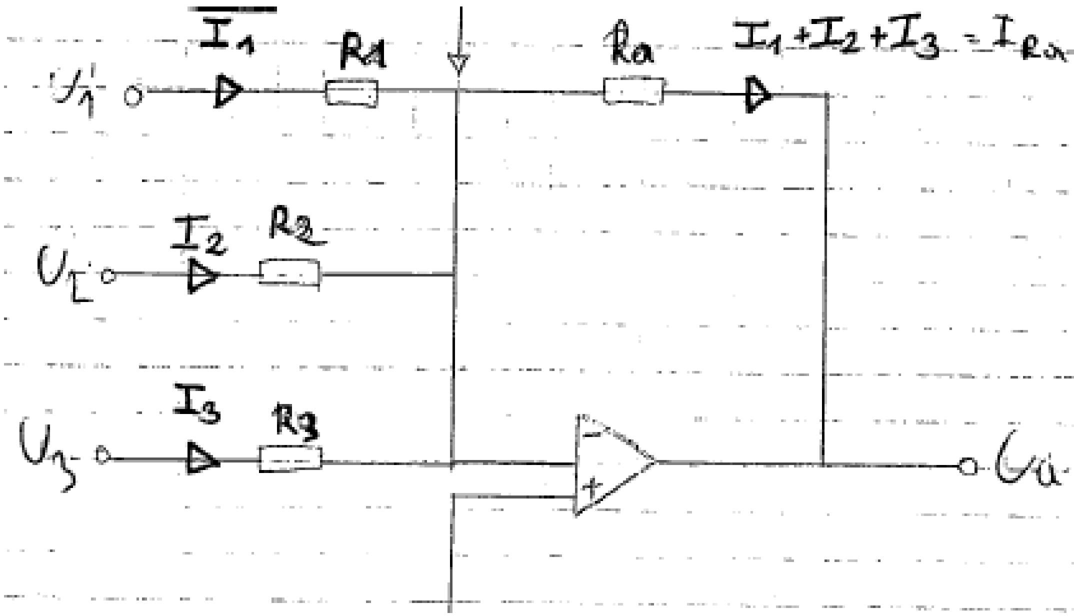
Non Inverting Amplifier



I:	$u_e = u_{R2} + U_D$
	$U_D = 0$
II:	$u_a = u_{R1} + u_{R2}$

$$\boxed{V = u_a / u_e = (u_{R1} + u_{R2}) / u_{R2}}$$

Summing Amplifier



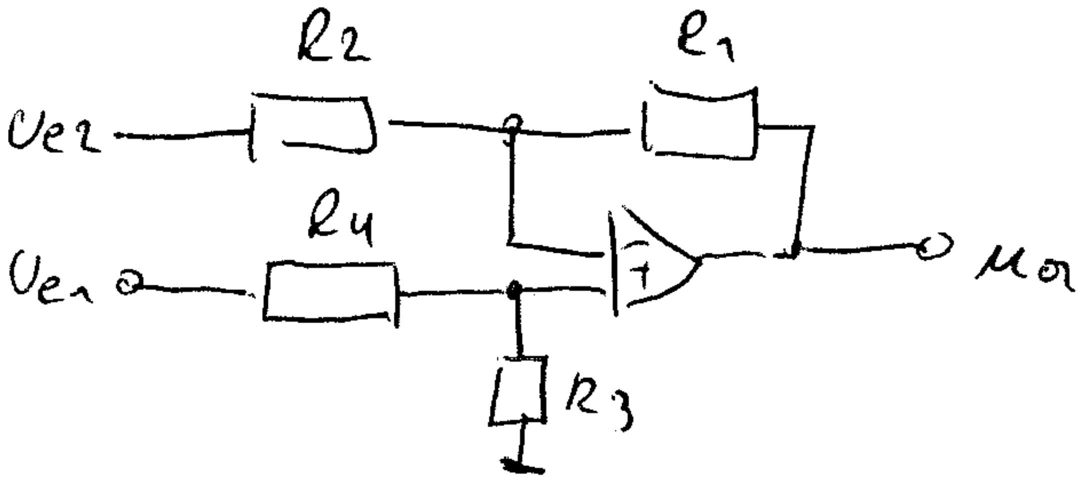
I1=U1/R1
I2=U2/R2
I3=U3/R3

I_{Ra}=I1+I2+I3
U_a/R_a=U1/R1+U2/R2+U3/R3

$$\boxed{U_a=R_a(U1/R1+U2/R2+U3/R3)}$$

The inverting summer is the basic op amp circuit that is used to sum two or more signal voltages, to sum a dc voltage with a signal voltage, etc.

Differential Amplifier



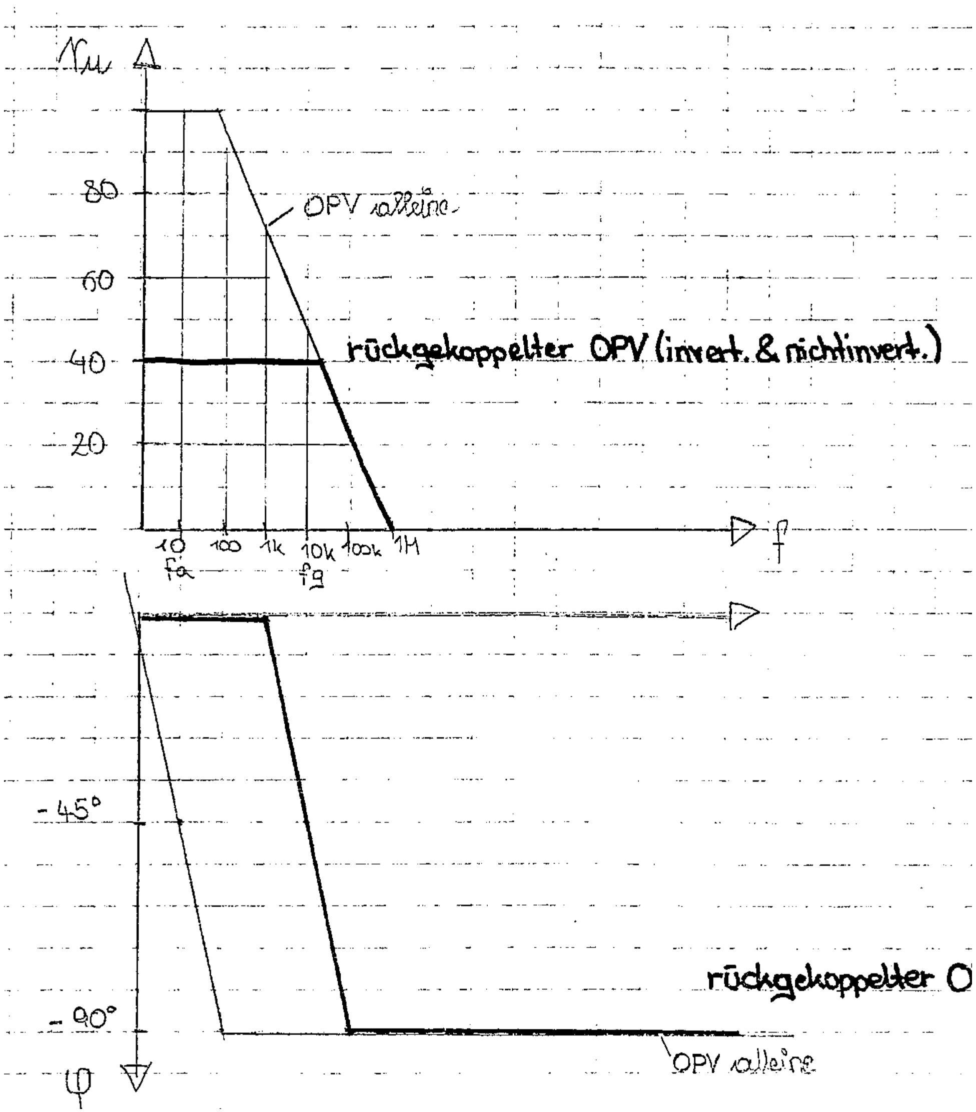
$$u_a=(u_{e1}-u_{e2})*V$$

$V=R1/R2=R3/R4$

A differential amplifier or diff amp is an amplifier which has two inputs and one output. When a signal is applied to one input, the diff amp operates as a non-inverting amplifier. When a signal is applied to the other input, it acts as an inverting amplifier.

To avoid offset:R1=R3 und R2=R4.

Bode Diagramm



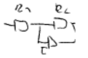
Bode Diagramm

geg.: $\overset{10}{V}$, R_1, $\overset{10\,mV}{U_E}$, $\overset{10\,M}{f_{T\,OPV}}$, $\overset{100\,Hz}{f_{g\,OPV}}$

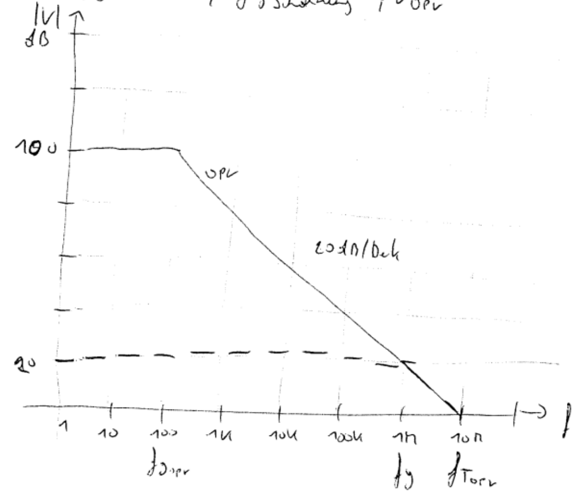
ges.: R_2, U_A

Bode DG, $f_{g\,Schaltung}$, V_{OPV}

$\frac{U_a}{U_e} = V = -\frac{R_2}{R_1}$



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

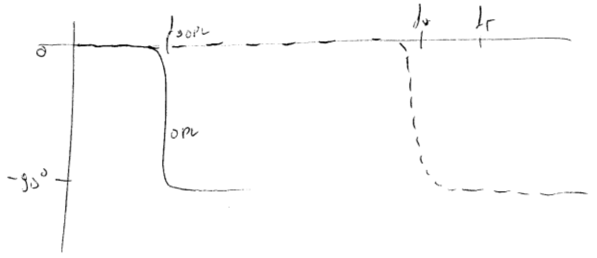


$\Rightarrow V_{OPV} = 100$

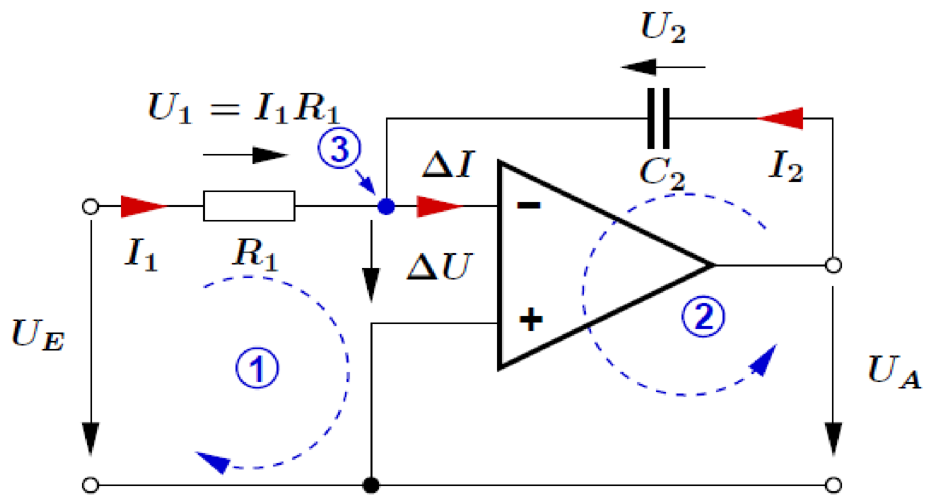
$V = 10 \Rightarrow 20 \log 10 = 20\,dB$

$U_A = V \cdot U_E = 10 \cdot 10\,mV = 100\,mV$

$f_g = 1M\,Hz$



Integrator

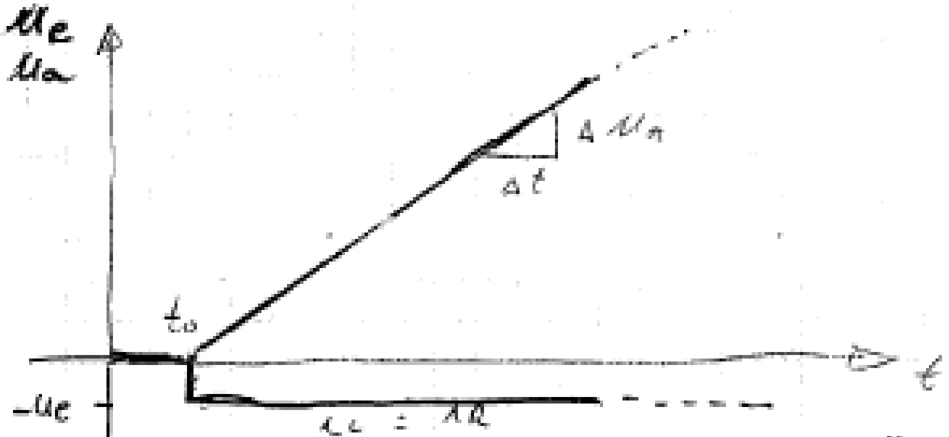


$$U_A(t) = U_A(t_1) - \frac{1}{R_1 C_2} \int_{t_1}^{t} U_E(t)\ \mathrm{d}t$$

If a capacitor is used as the feedback element in the inverting amplifier, the result is an integrator. An intuitive grasp of the integrator action may be obtained from the statement under the section, “Current Output,” that current through the feedback loop charges the capacitor and is stored there as a voltage from the output to ground. This is a voltage input current integrator.

Integrator

Zeitbereich:



$C \cdot \Delta u_a = I \cdot \Delta t \quad , \quad I = \frac{u_e}{R}$

$C \cdot \Delta u_a = \frac{u_e}{R} \Delta t$

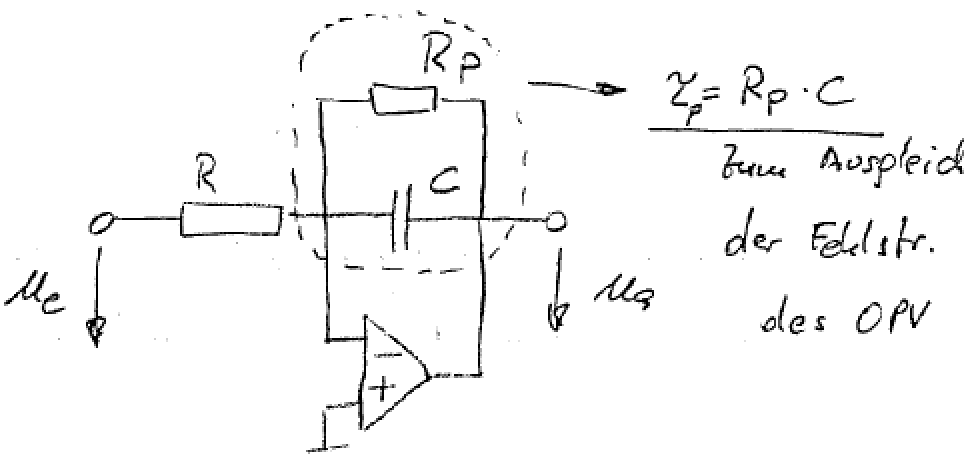
$\Delta u_a = \frac{-u_e}{R \cdot C} \Delta t \qquad \tau = R \cdot C$ … Zeitkonst

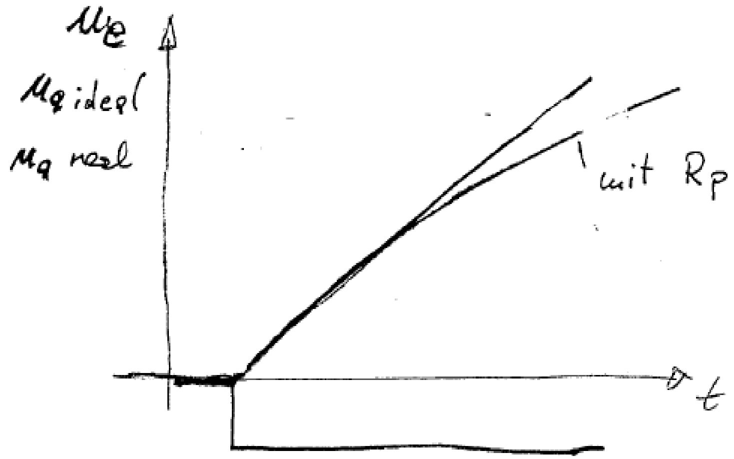
Integrator

Problemes:

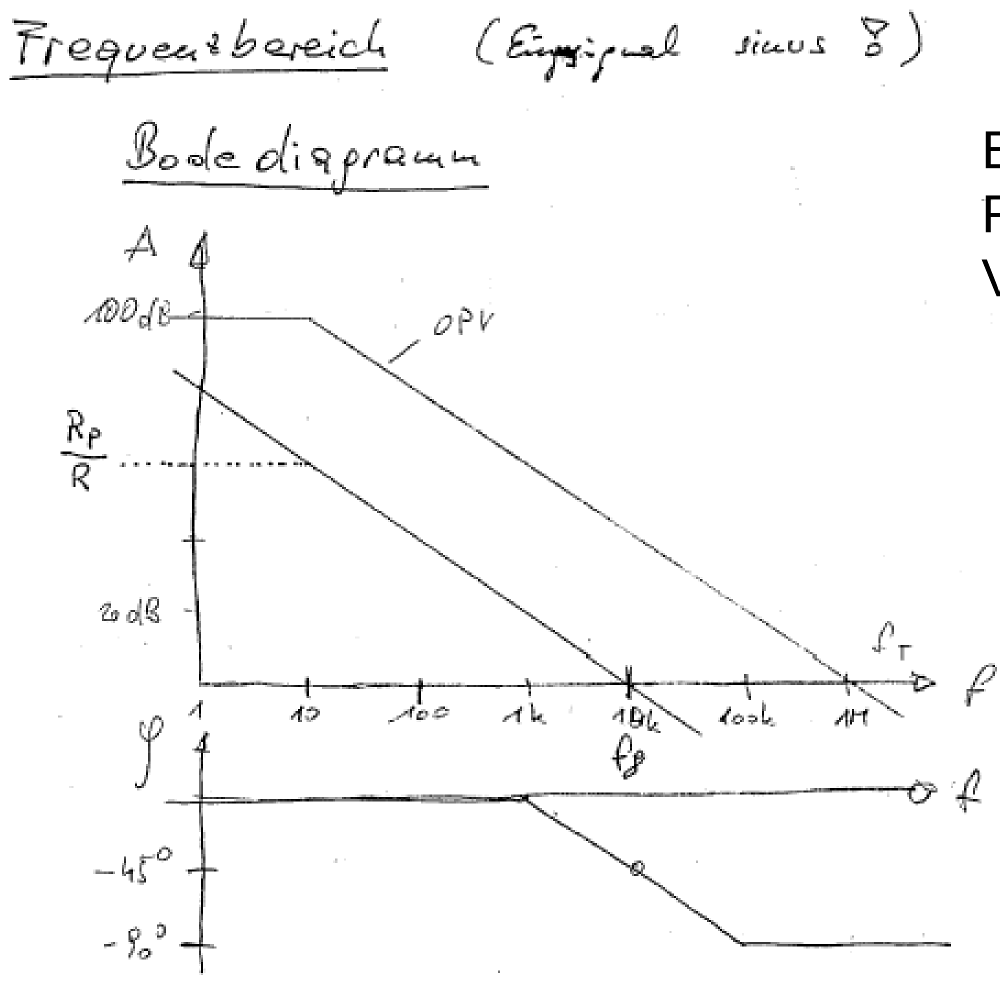
In order to prevent integrator saturation due to infinite dc gain, parallel feedback resistance is included.

Result: non linearity



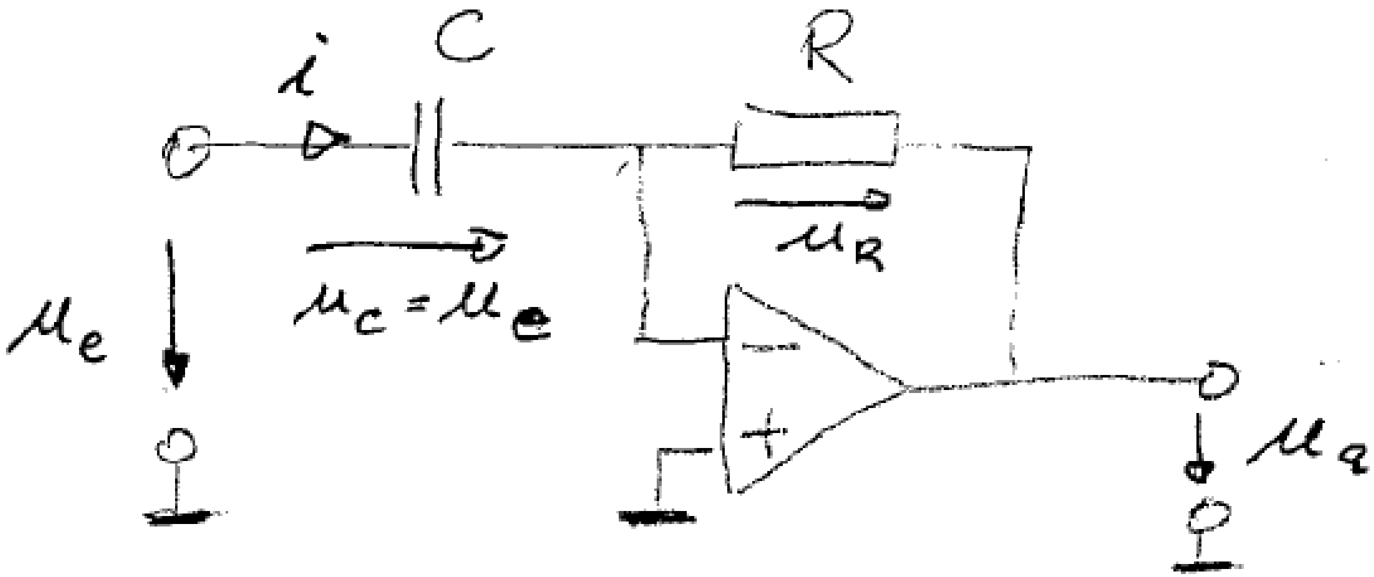


Integrator



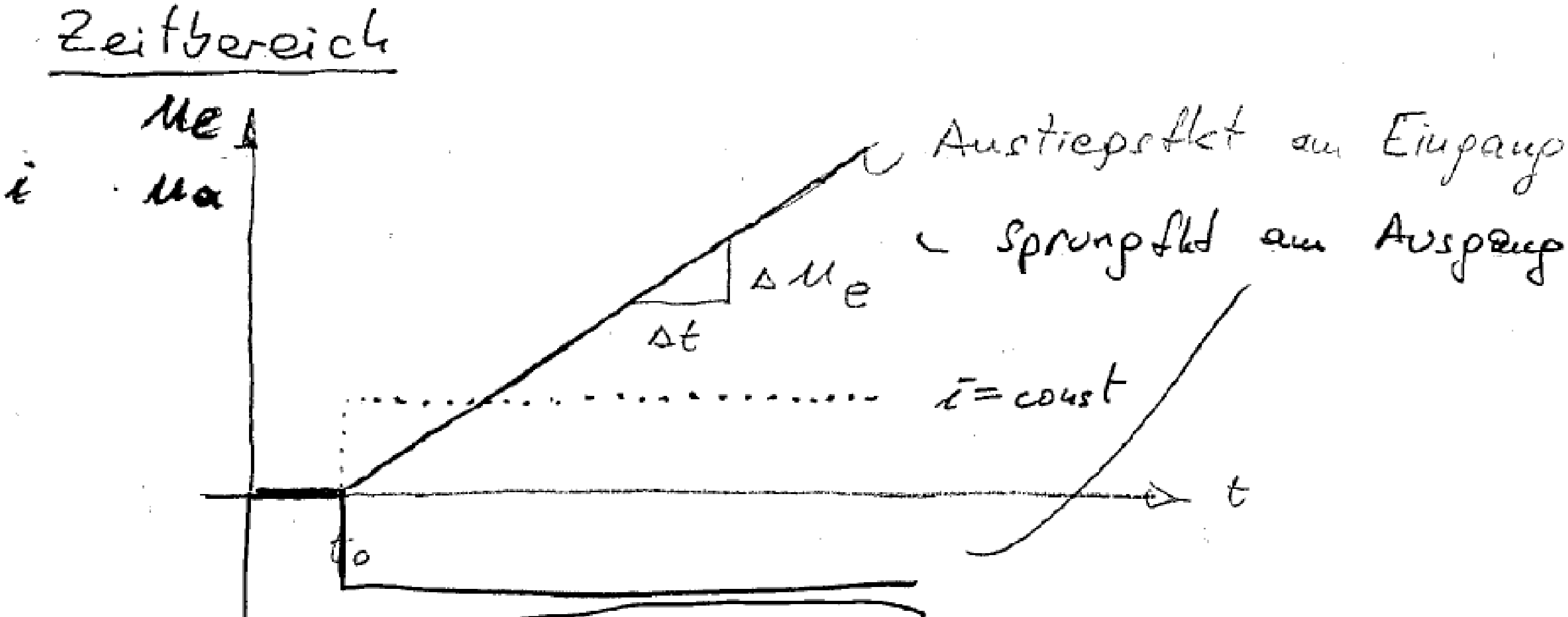
Because of the resistance R_P, the max. Gain is $V_{max}=R_P/R$.

Differentiator



Using a capacitor as the input element to the inverting amplifier, yields a differentiator circuit..

Differentiator

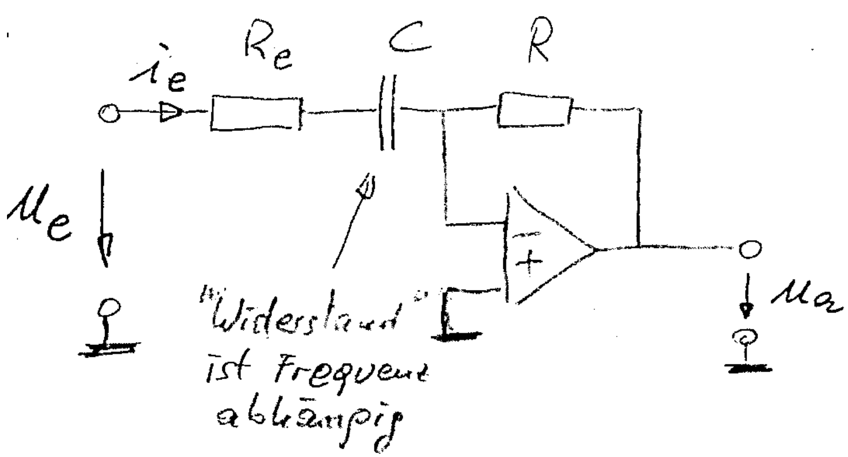


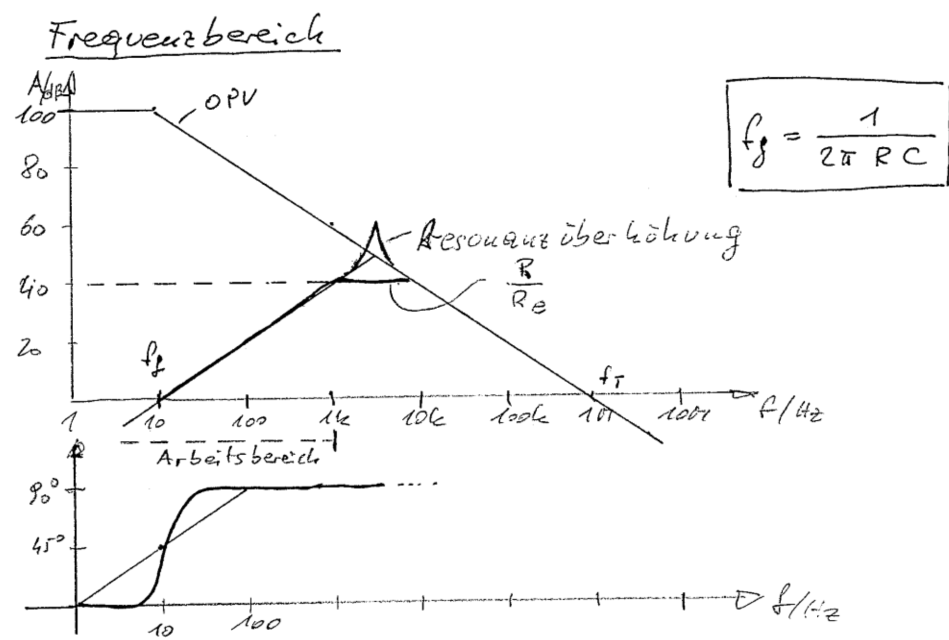
$$\boxed{\Delta u_e = \frac{-u_a}{R \cdot C}\,\Delta t}$$

Differentiator

<u>Problemes:</u>

Bei Eingangssignalen mit hohen Frequenzanteilen wird beim einfachen Differenzierer der Widerstand des C sehr klein, sodaß ein hoher Strom durch den Eingangskreis fließt. Dieser belastet die Spannungsquelle. Um die Belastung der Spannungsquelle zu begrenzen, wird ein R_e in Serie hinzugefügt.

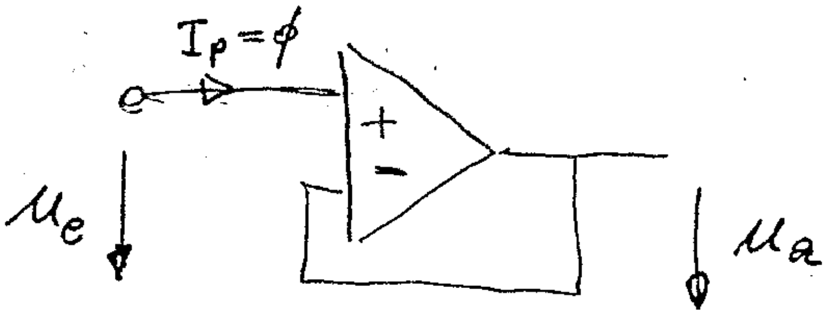




Introduction1 voltage follower

http://www.youtube.com/watch?v=Q3RMFpGGcZM&feature=player_detailpage
http://www.youtube.com/watch?v=ZmYMKASTSO8

Voltage Follower

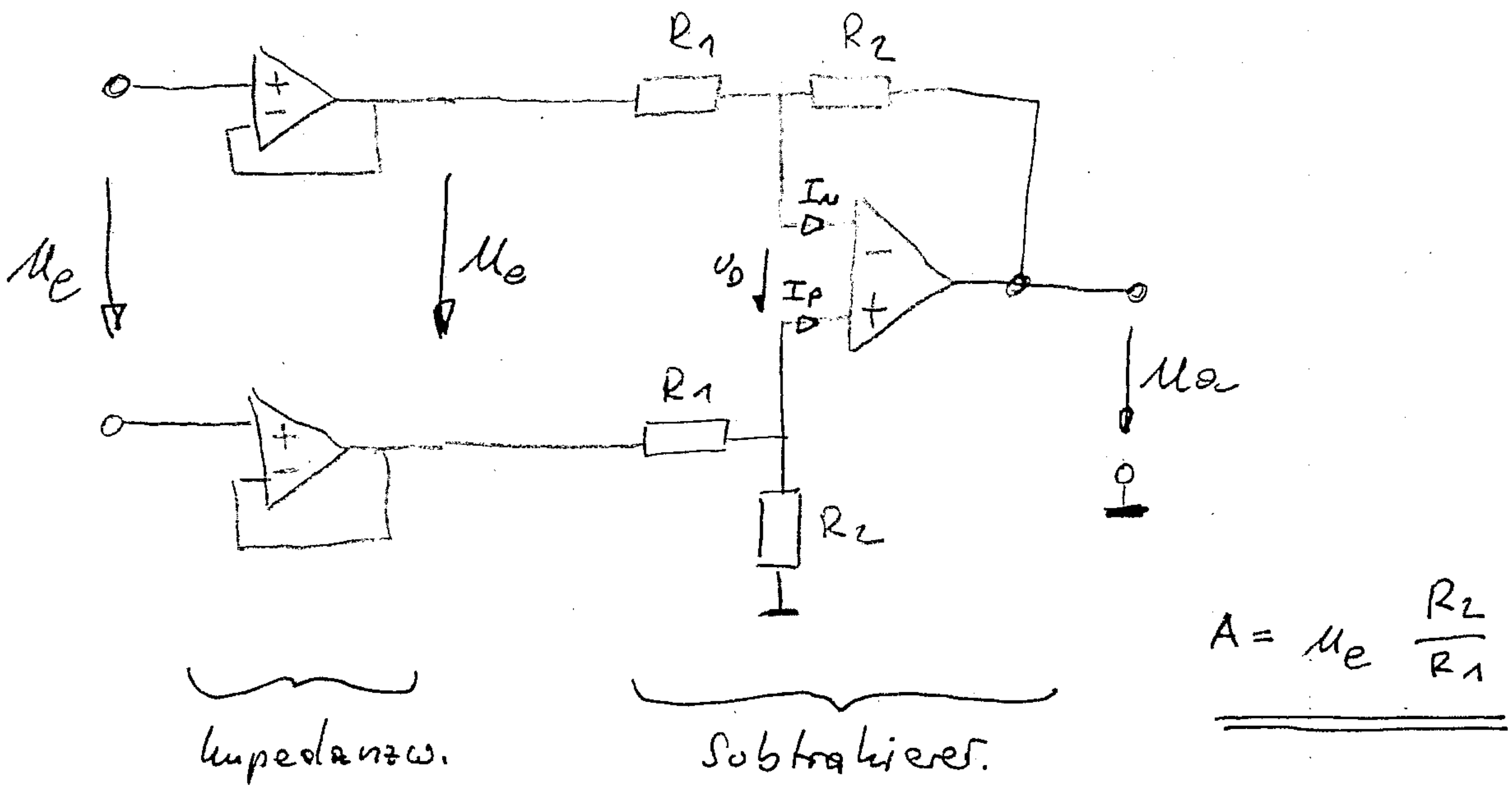


$$u_a = u_e$$

$$A = 1 \qquad (0\ \mathrm{dB})$$

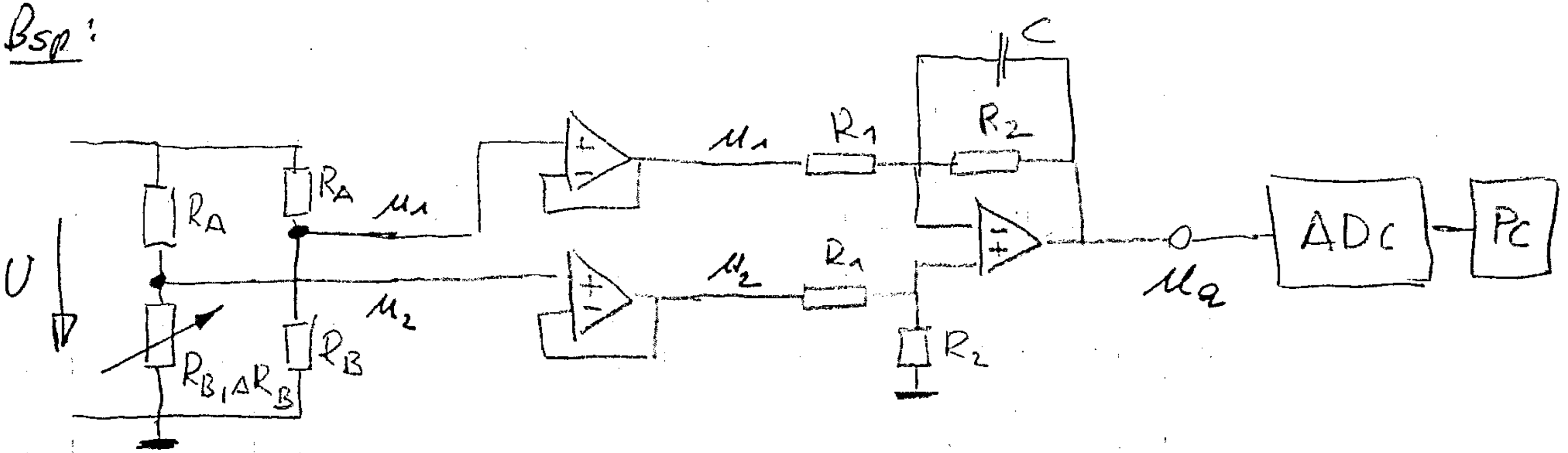
Because the output node is connected directly to the inverting input instead of through a voltage divider, the circuit is said to have 100% feedback. Because v+ = v−, it follows that vO = vI . Therefore, the circuit has unity voltage gain. The voltage follower is often used to isolate a low resistance load from a high output resistance source. That is, the voltage follower supplies the current to drive the load while drawing no current from the input circuit.

Voltage Follower



Voltage Follower

Bsp:

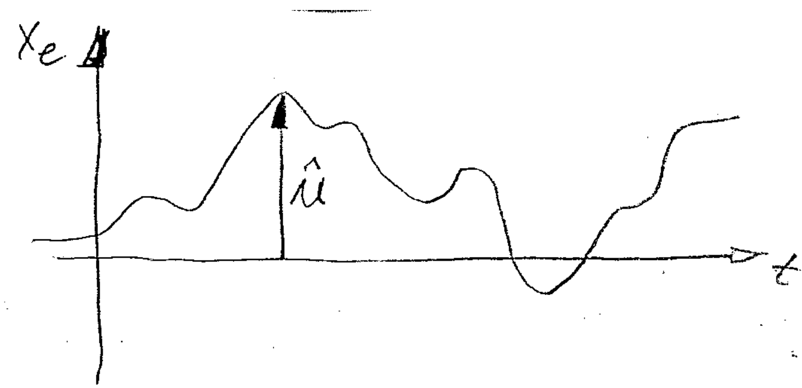


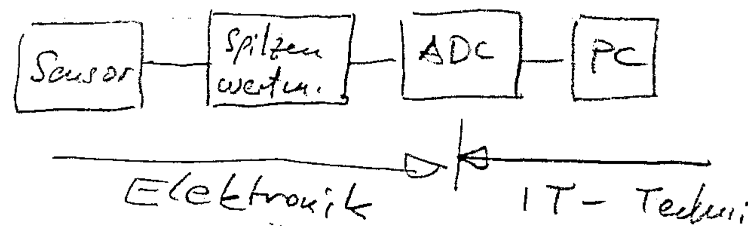
$$u_1 = U \frac{R_B}{R_A + R_B}$$

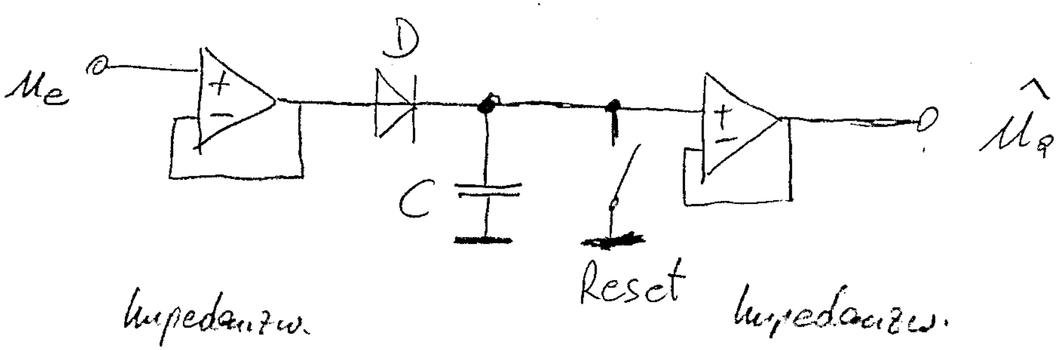
$$u_2 = U \frac{R_B + \Delta R_B}{R_A + R_B + \Delta R_B}$$

$$u_a = (u_2 - u_1) \frac{R_2}{R_1}$$

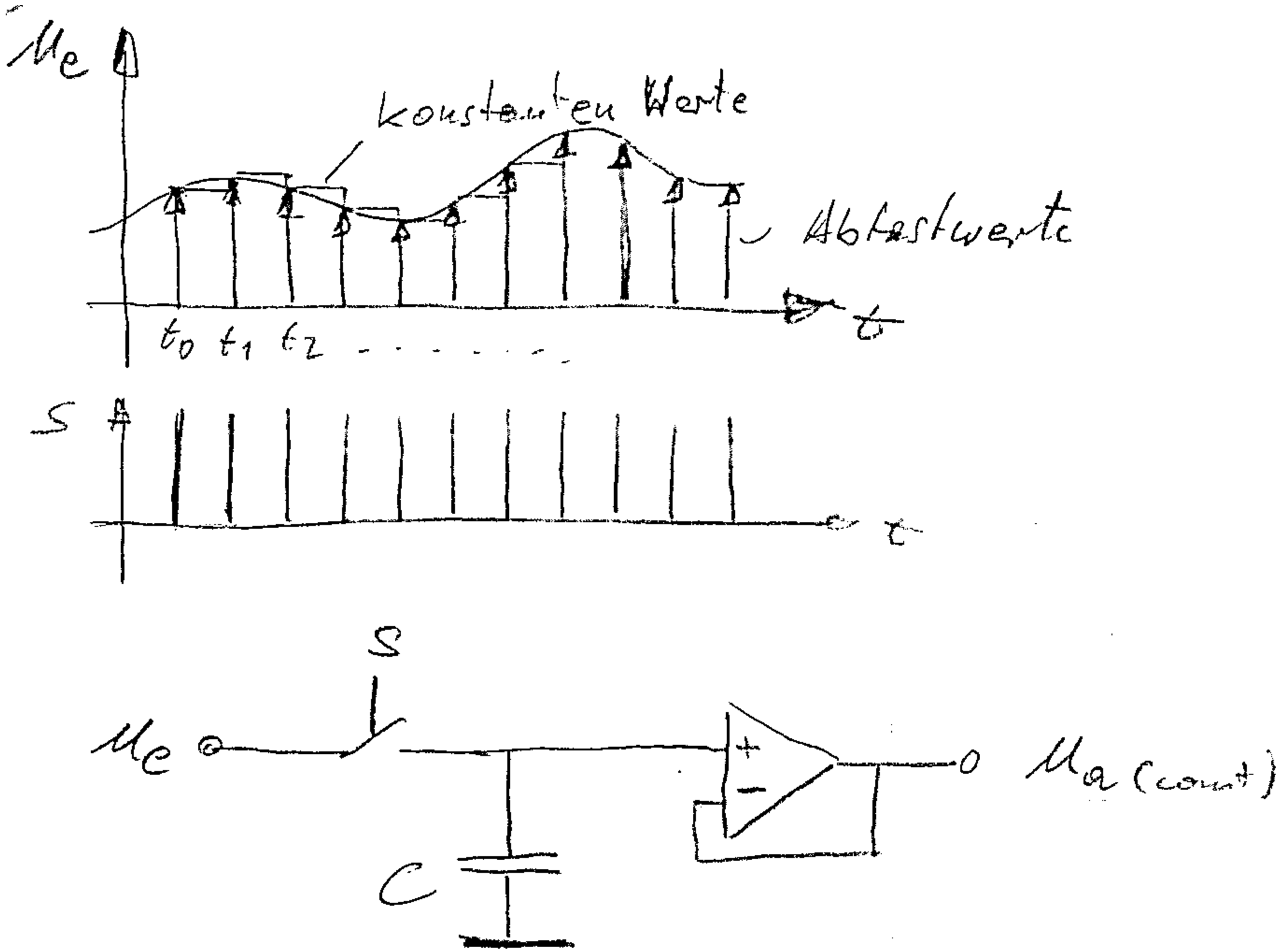
Peakdetector



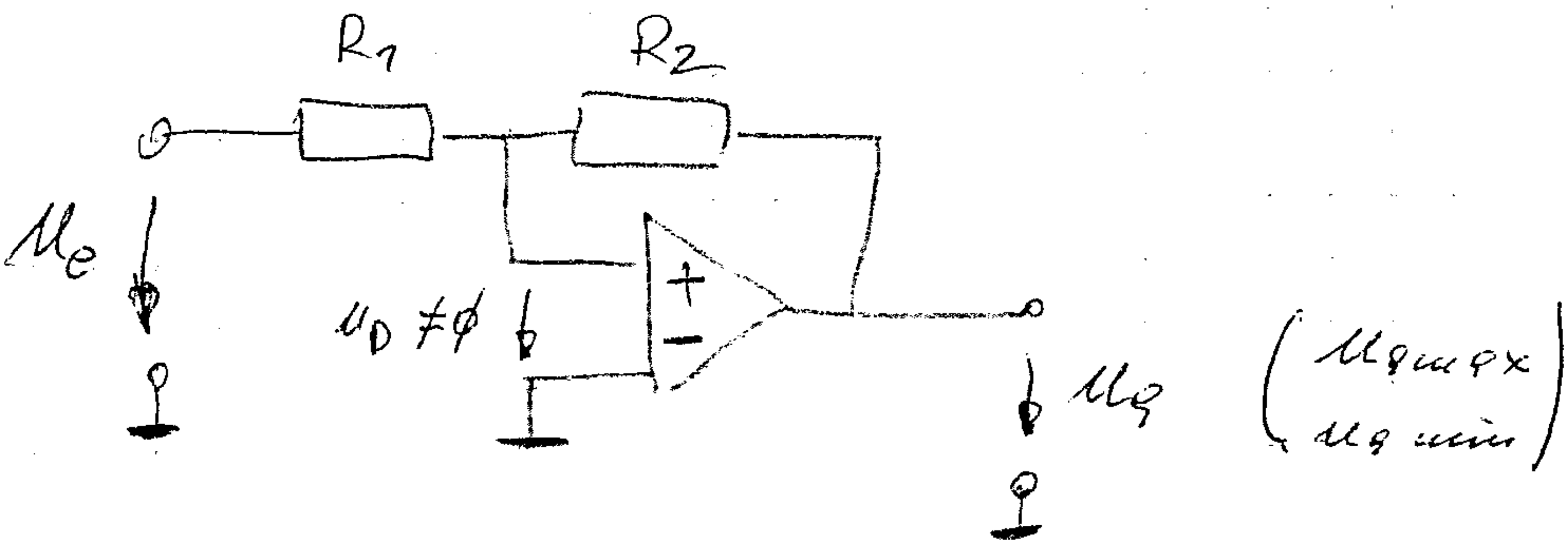




Sampling Detector

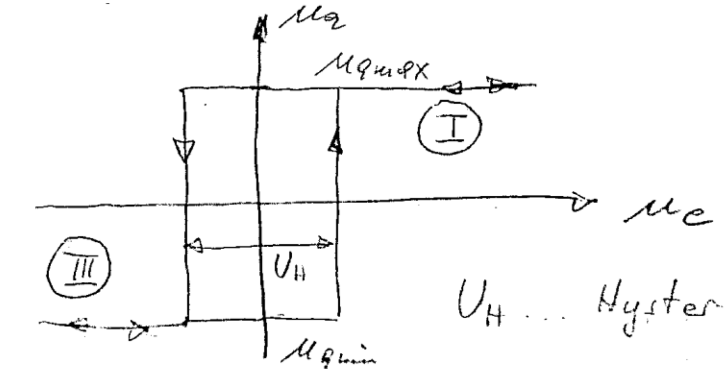


Non Inverting Schmitt-Trigger



Positive feedback is often used with comparator circuits. The feedback is applied from the output to the non-inverting input of the op amp. This is in contrast to the circuits covered in the preceding sections of this chapter where feedback is applied to the inverting input.

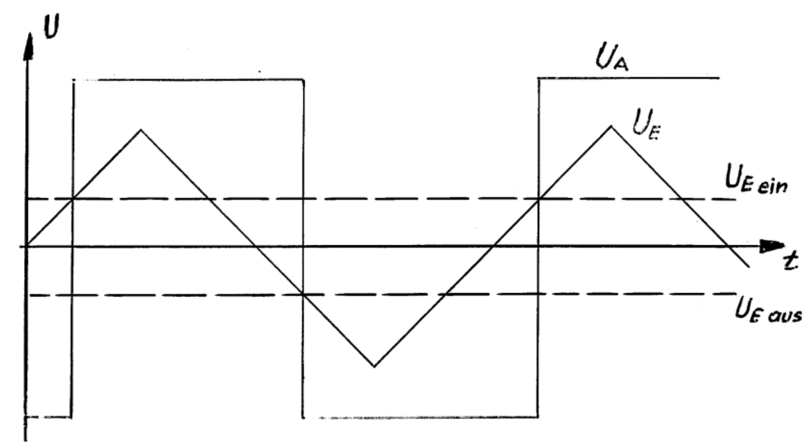
Non Inverting Schmitt-Trigger



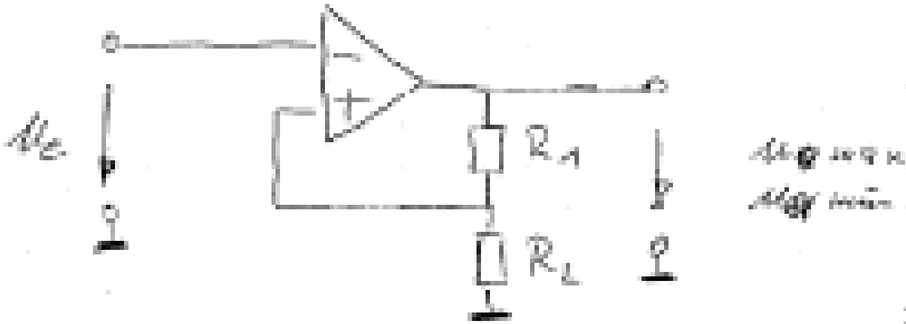
U_H … Hysteresespg

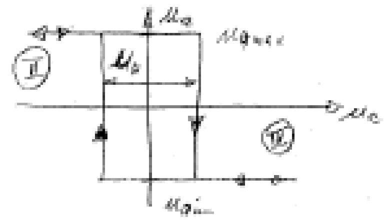
Nichtinv.: U_a $+u_e \Rightarrow +u_{amax}$ I

$-u_e \Rightarrow -u_{amin}$ III



Inverting Schmitt-Trigger





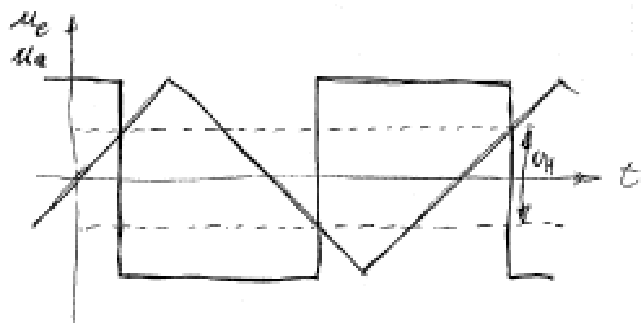
U_H.. Hysteresespannung

$+u_e \Rightarrow - u_{a\,min}$

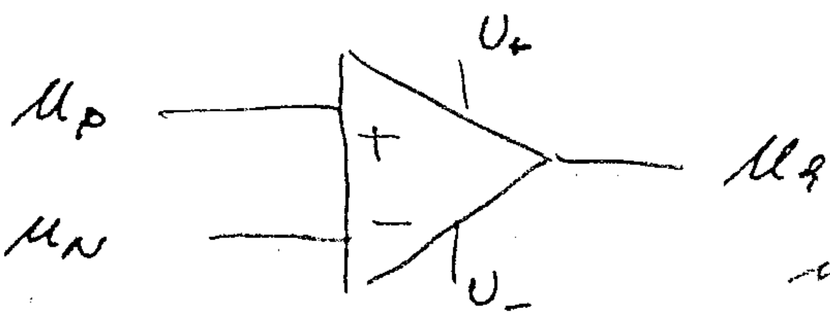
$-u_e \Rightarrow + u_{a\,max}$

Die U_H wird durch das Widerstandsverhältnis R_1, R_2 eingestellt

$$U_H = \frac{R_1}{R_1 + R_2}\left(U_{a\,max} - u_{a\,min}\right)$$



Comparator



$u_P > u_N \Rightarrow u_a = U_+$

$u_P < u_N \Rightarrow u_a = U_-$