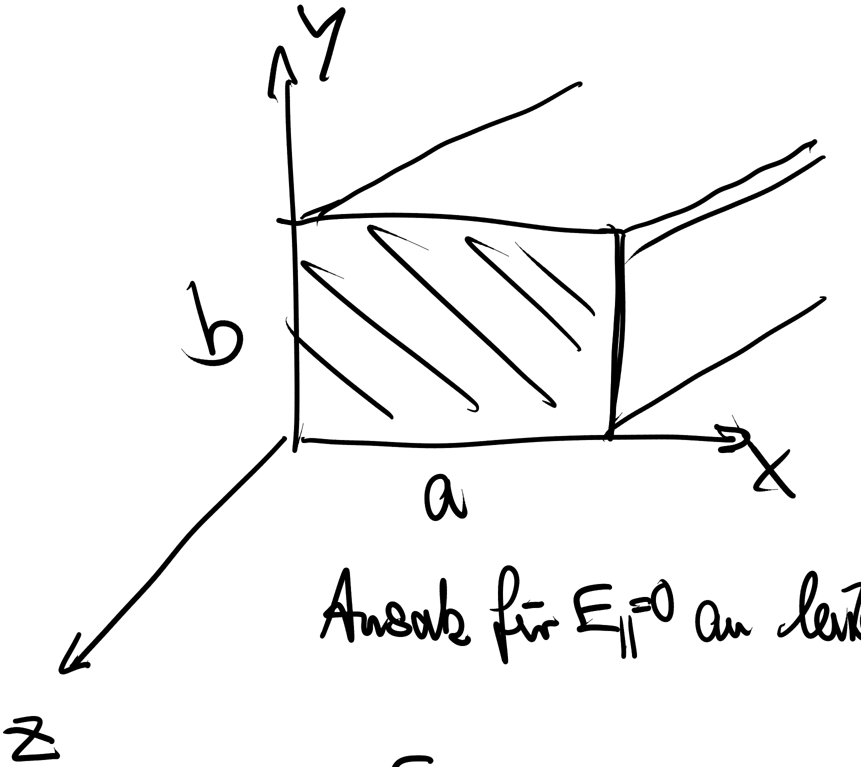
Hohlleiter (Mikrowellen)



Transversale elektrische Welle ($E_z=0$)

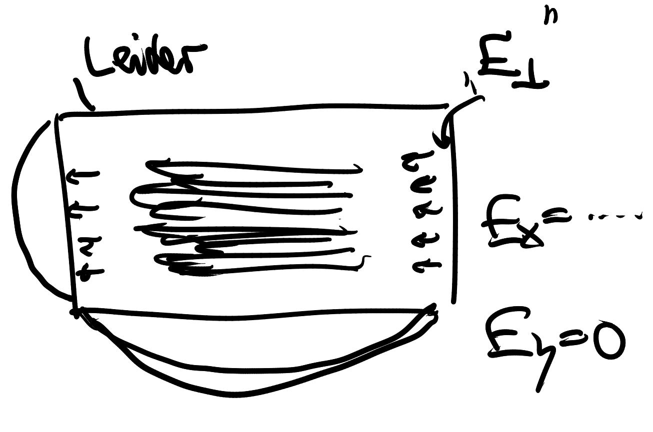
(auch Transversal Magn. $B_z=0$)

Ansatz für $E_{\parallel}=0$ an leitenden Oberflächen

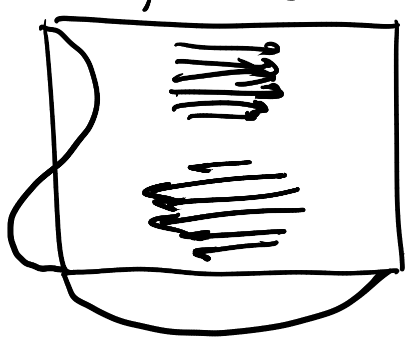
$$E_x = -\frac{m E_0}{b} \cos \frac{n\pi}{a} x \cdot \sin \frac{m\pi}{b} y \cdot \sin(\omega t - kz)$$

$$E_y = \frac{n E_0}{a} \cdot \sin \frac{n\pi}{a} x \cdot \cos \frac{m\pi}{b} y \cdot \sin(\omega t - kz)$$

$n=0;\ m=1$



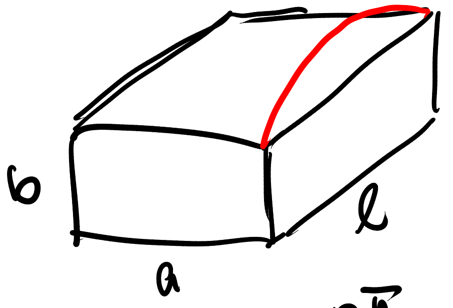
$n=0;\ m=2$



Für jeden Wellentyp (n,m) gibt es eine untere Grenzfrequenz (obere Grenzwellenlänge) unterhalb der es keine Wellenausbreitung gibt:

$$w_g = c\sqrt{\left(\frac{m\pi}{b}\right)^2 + \left(\frac{n\pi}{a}\right)^2}.$$

Resonator:



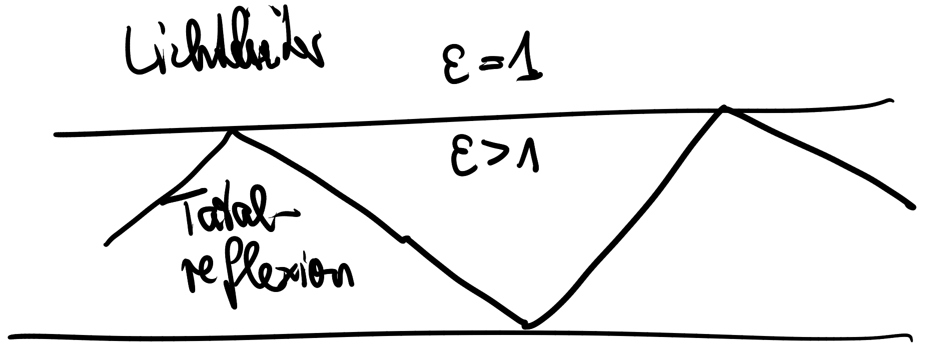
$$\left.\begin{aligned} E_x &= \ldots\ldots \sin\frac{p\pi}{l}z \\ E_y &= \ldots\ldots \sin\frac{p\pi}{l}z \end{aligned}\right\} = 0 \text{ für } n, m \text{ oder } p = 0$$

Eigenfrequenzen: $f_{n,m,p} = \frac{c}{2}\sqrt{\frac{n^2}{a^2} + \frac{m^2}{b^2} + \frac{p^2}{l^2}}$

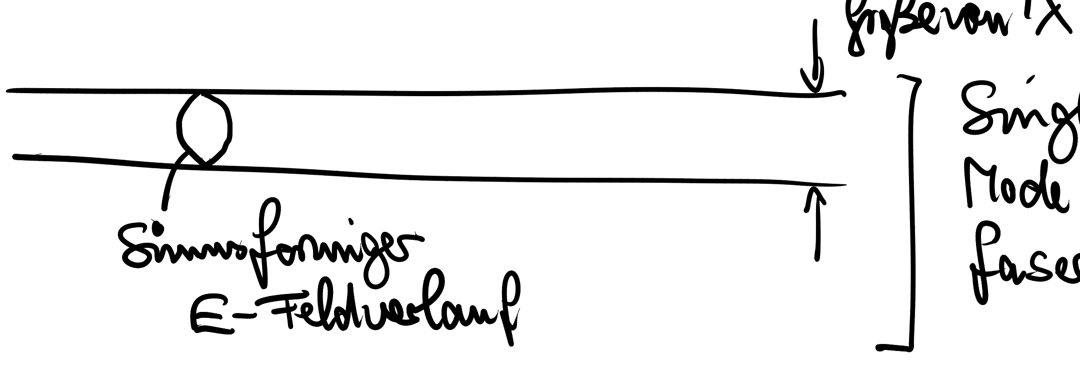
Beispiel: $a = 37\,\text{cm}$, $b = 21\,\text{cm}$, $c = 56\,\text{cm}$

n,m,p	1,0,1	102	011	201	111	012
f/MHz	486	672	763	856	864	869

Lichtleiter



Multimode

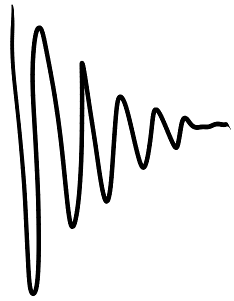


Single Mode-Glasfaser

Der Wechselstromwiderstand (Impedanz)

Lösung des Reihenschwingkreises:

$$I_1 = \hat{I}\,\underbrace{e^{-R/2L\,t}}\cdot\cos(\omega t+\varphi)$$

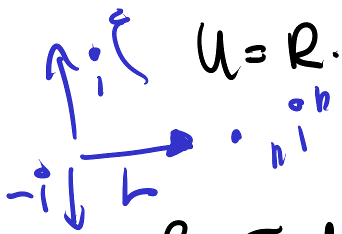


⇝ Komplexwertiger Strom $\underline{I} = I_1 + i I_2$

$$= \hat{I}\,e^{-R/2L\,t}\cdot e^{i(\omega t+\varphi)}$$

Der physikalische Sachverhalt wird durch $\mathrm{Re}(\underline{I})$ dargestellt. Elegant: es gilt für Differentiation und für Integration von Wechselströmen $\sim e^{i(\omega t+\varphi)}$

$$\frac{d}{dt}\underline{I} = i\omega\,\underline{I}$$

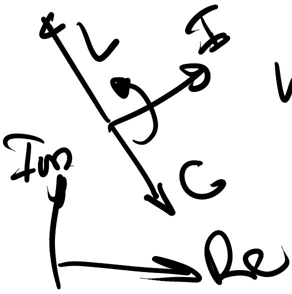


$U = R\cdot I$

$$\int \underline{I}\,dt = \frac{1}{i\omega}\,\underline{I}$$

Also wegen: $\underline{U_L} = L\dot{I} = \underbrace{i\omega L}_{\text{„R"}}\cdot\underline{I}$ für Induktivität

„R" $= Z = i\omega L$



und $\underline{U_C} = \frac{1}{C}\int\underline{I}\,dt = \frac{\underline{I}}{i\omega C}$ für Kapazität.

$Q = C\cdot U$

$= \frac{-i\,\underline{I}}{\omega C}$

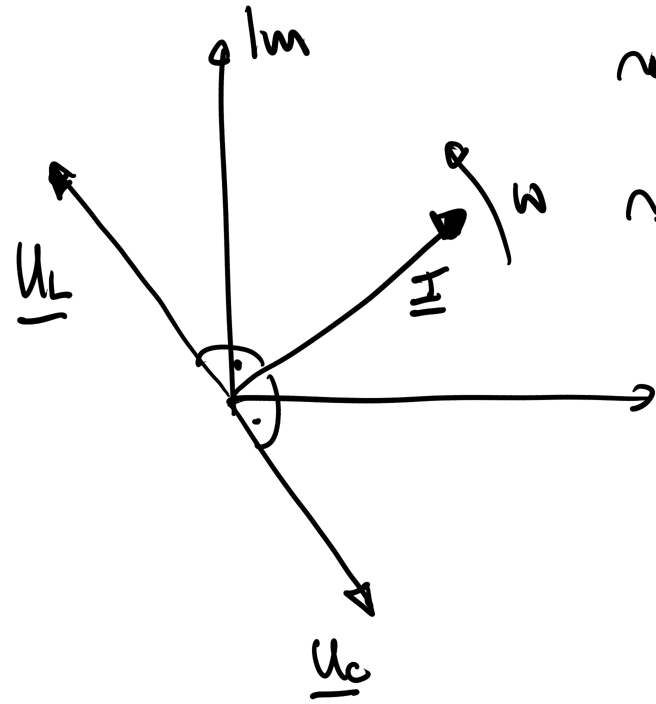
$Z = \frac{1}{i\omega C}$

Aus Verallgemeinerung von $U = R\cdot I$ ins $\mathbb{C}$ ergibt sich $\underline{U} = \underline{Z}\cdot\underline{I}$ mit komplexwertiger Impedanz

$$Z = R + i\omega L + \frac{1}{i\omega C}$$

→ Behandlung von Z wie R in Schaltbildern.

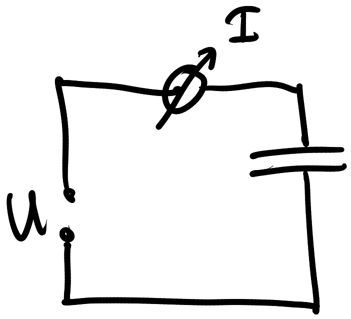
In der Komplexen Ebene:



~ induzierte Spannung eilt dem Strom voraus.

~ kapazitive Spannung hinkt hinterher.

Exp: Kapazität und Induktivität $U = \hat{U} \sin(\omega t)$

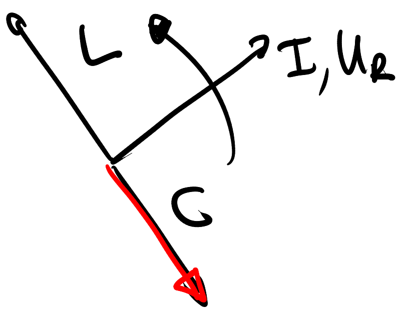


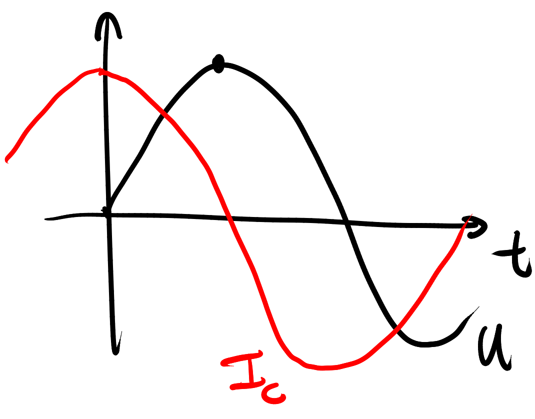
$\dot{Q} = C\dot{U}$

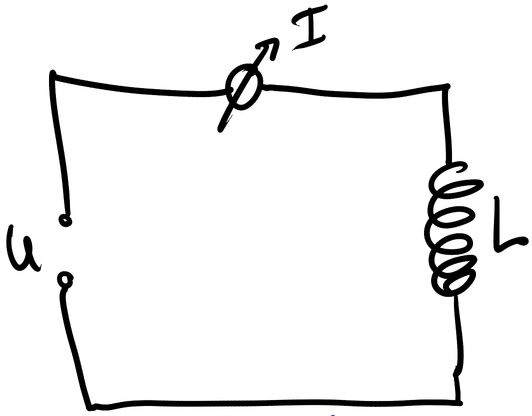
$I = \omega C \hat{U} \cos \omega t$

Kapazität

hinkt hinterher.

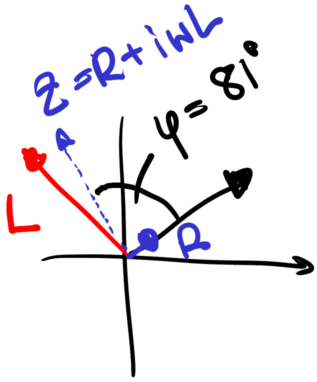


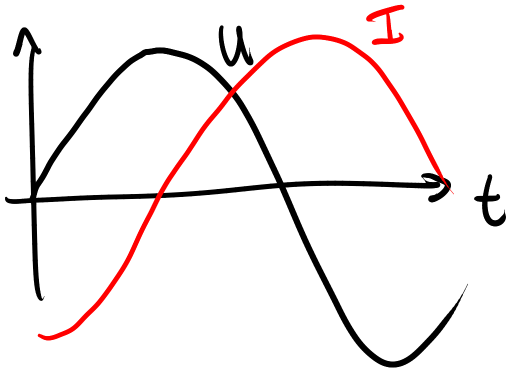




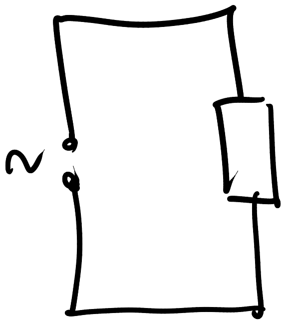
$U = L\dot{I}$

$I = -\frac{\hat{U}}{\omega L}\cos\omega t$



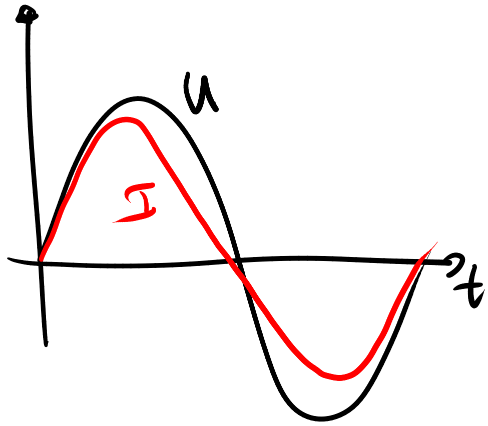


Wechselstromleistung



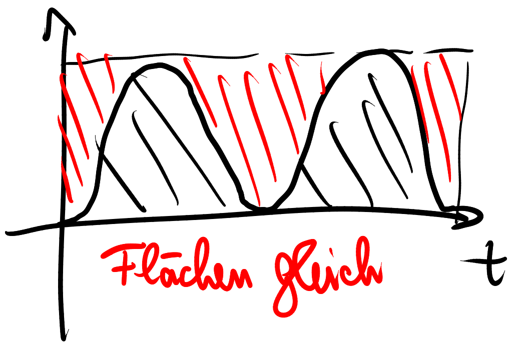
$U(t) = U_0 \cos\omega t$

$I(t) = \frac{U_0}{R}\cos\omega t$



$W(t) = U(t)\cdot I(t)$

$= \frac{U_0^2}{R}\cos^2\omega t$: instantan



$\overline{W} = \frac{1}{2}\frac{U_0^2}{R}$: mittlere Leistung (über T)

gem. über eine Periode

→ Oft: Definition von Wechselspannung $\hat{U} \to \frac{\hat{U}}{\sqrt{2}}$

Eine Gleichspannung von $U_0/\sqrt{2}$ ergäbe dieselbe Leistung

$$U_{eff} = \frac{U_0}{\sqrt{2}} \quad \sim \quad W = \frac{1}{2}\frac{U_0^2}{R}$$

$$= \frac{U_{eff}^2}{R}$$

Angabe an Steckdose.

wie von Gleichspannung gewohnt.

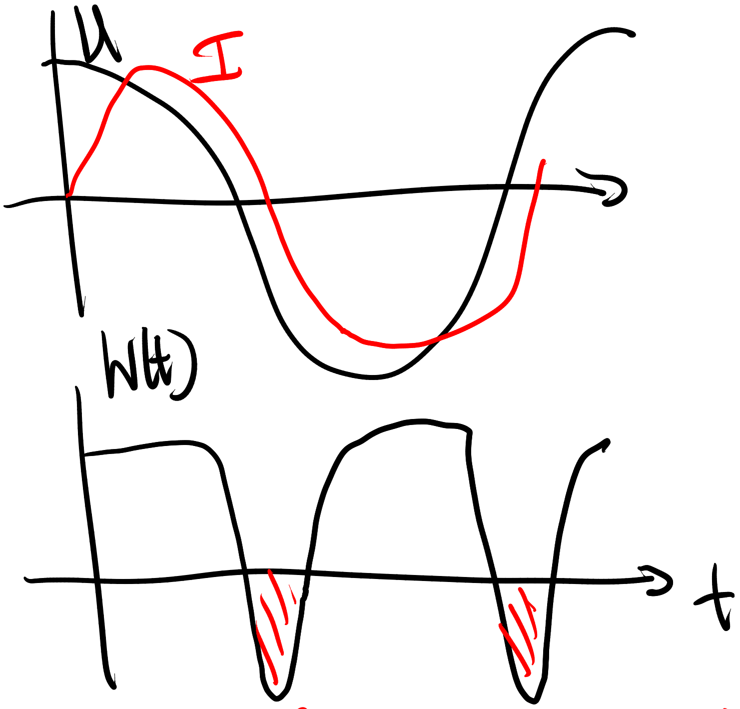
Netzspannung $U_{eff} = 230V$

$U_{max} = U_0 = \sqrt{2}\, U_{eff} = 325V.$

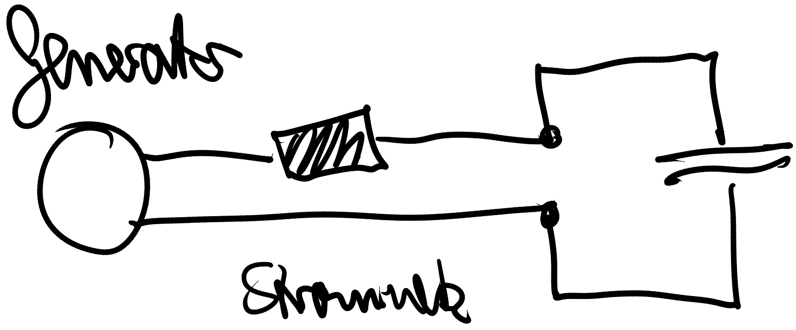
Stromkreis der L, C, R enthält

$$U(t) = U_0 \cos \omega t$$

$$I(t) = I_0 \cos(\omega t \pm \varphi)$$

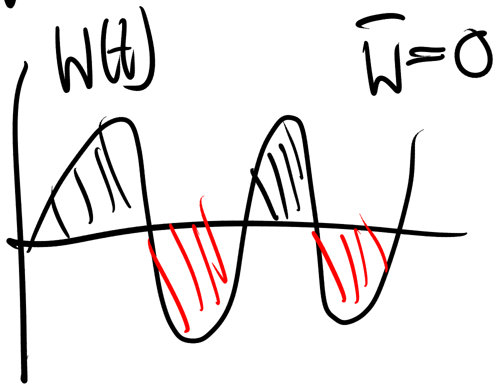


Rückspeisung ans Netz.



$\varphi = 90°$

$\overline{W} = 0$



Verluste im Stromnetz

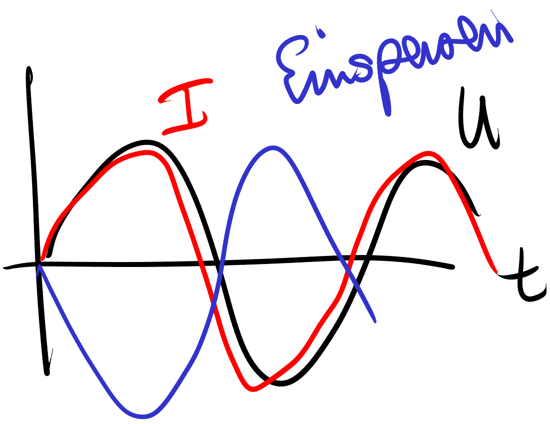
Stromzähler $\overline{W}=0$ anzeigt

Verboten

→ Teil von Endverbrauchern.

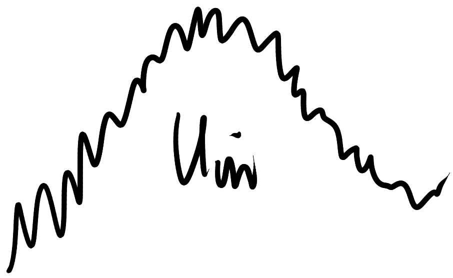
Zweirichtungszähler

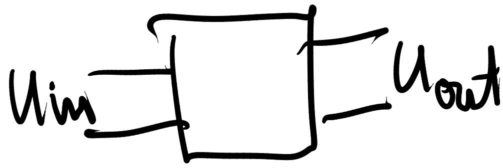
Gleichspannung → Wechselrichtung

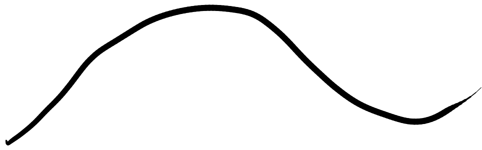


Hoch & Tiefpaßfilter

Motivation: Verrauschtes Signal

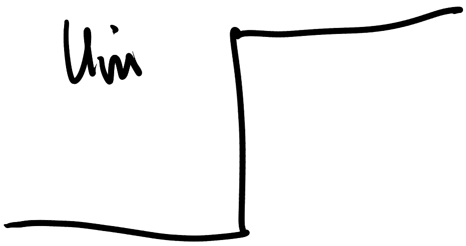


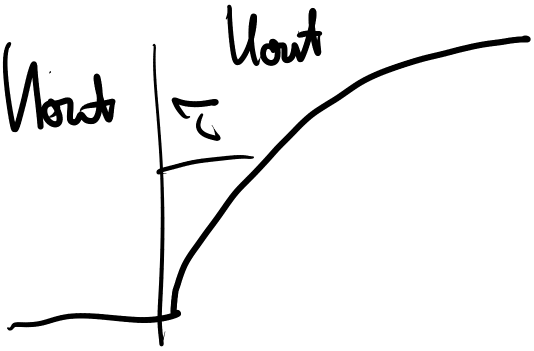


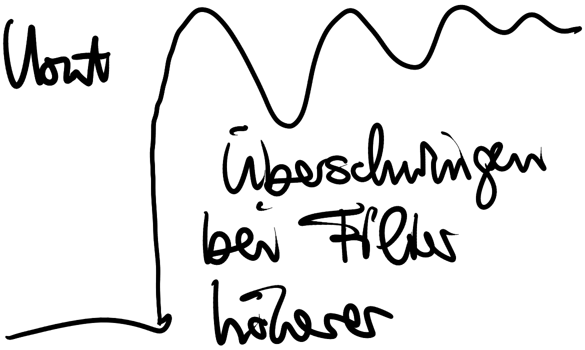


Hochfrequenzen herausfiltern.

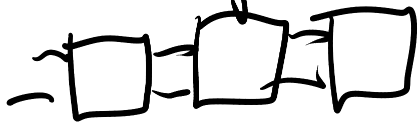
Nachteil







Überschwingen bei Filter höherer Ordnung



→ Einfacher Fall:

Tief & Hochpaß

1. Ordnung

Hoch/Tiefpaß?