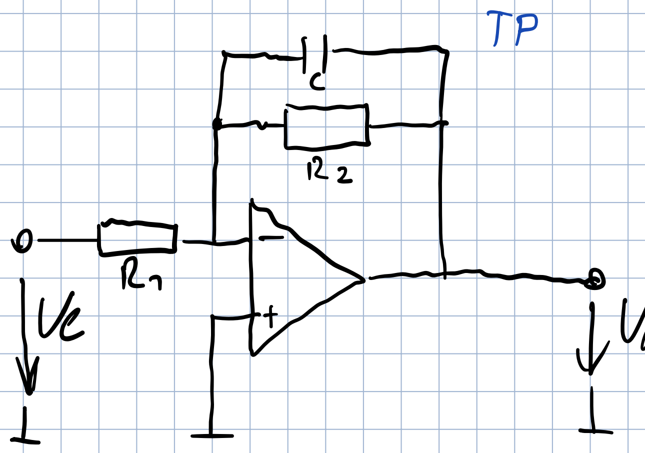
- Filter
  - 1. O
    - $G(j\omega)$, f_g
    - Bode ($|G(j\omega)|$ in dB, φ)
    - Dimensionieren
  - H. O
    - $G(j\omega)$
    - Dim. mit Bessel, ... (a_n, b_n)
- Netzwerk
  - OSI / TCP
  - Adressierung (IP-Adressen, ...)
  - IP-Adr. IPV4 → Subnetting
  - Topologien
- Modulation
  - Analog AM / FM / PM
  - Digital
- Kanalcodierung
  - Hemming Distanz
  - Wiederholungscode
  - Hemming Code
  - Faltungscode
- GSM
  - Aufbau
  - Komponenten
  - Sicherheitsf.
  - MTC, Auth.

Bsp: Filter 1. Ordnung:

TP



$G(j\omega) = \frac{U_a}{U_e} = \frac{R_2 \| C}{R_1} = \underbrace{\frac{R_2}{R_1}}_{K} \cdot \frac{1}{\dots}$

$\omega = 0 \rightarrow G(j\omega) = \frac{R_2}{R_1}$

$\omega = \infty \rightarrow G(j\omega) = 0$

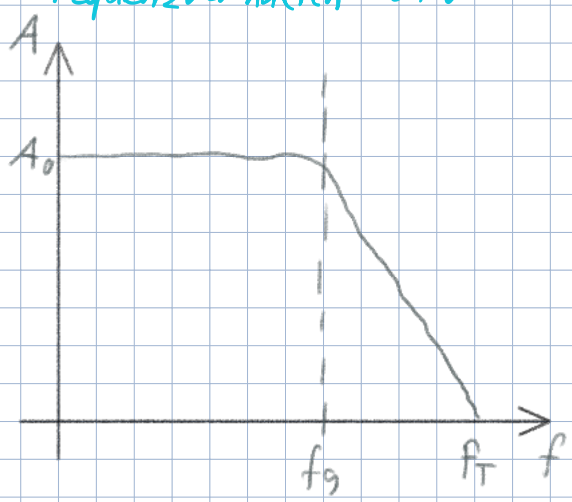
$R \| C: \frac{1}{\frac{1}{R_2} + j\omega C}$

$G(j\omega) = \frac{\frac{1}{\frac{1}{R_2} + j\omega C}}{R_1} = \frac{1}{\frac{R_1}{R_2} + j\omega R_1 C} = \frac{R_2}{R_1} \cdot \frac{1}{1 + \frac{j\omega C}{R}}$

- φ, $|G(j\omega)| \hat{=}$ Bode
- f_g (Re = Im, $-3dB$, $\pm 45°$)
  - $\rightarrow 1 = \frac{\omega_g \cdot C}{R_2} \rightarrow \omega_g = \frac{R_2}{C}$

$\frac{1}{\underbrace{1}_{Re} + \underbrace{\frac{1}{j\omega C}}_{Im}}$ $\frac{1}{j} = -j$

Frequenzverhalten OPV:



$f_g A_0 = f_T \cdot 1 = \text{konst.} \; (f_g \dots f_T)$

Bsp: Subnetting:

$172.16.\underbrace{000000}_{\text{Subnetz } 64}\underbrace{00.0000\ 0000}_{\text{Host } 0 \dots 1023}$

172.16.0.0
255.255.0.0 ✓

1000 Hosts
10 netze

111111|00 0000 0000

255.255.252.|0

172.16.0.0

255.255.252.0

Netz: 172.16.0.0

1. IP: 172.16.0.1

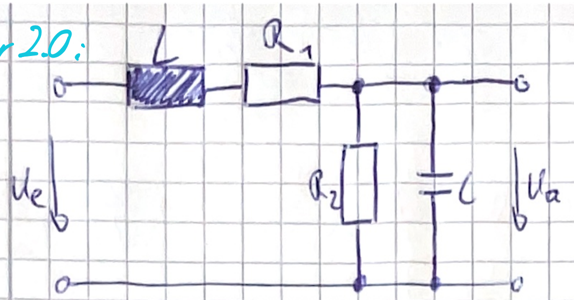
Broadcast: 172.16.3.255

Letzte IP: 172.16.3.254

172.16.4.0 +n·4

172.16.7.255 +n·4

Bsp. Filter 2.0:



$$G(j\omega) = \frac{U_a}{U_e} = \frac{R_2 \| C}{L + R_1 + R_2 \| C} = \frac{\frac{1}{\frac{1}{R_2} + j\omega C}}{j\omega L + R_1 + \frac{1}{\frac{1}{R_2} + j\omega C}}$$

$$= \frac{1}{1 + \frac{R_1}{R_2} + j\omega R_1 C + j\omega \frac{L}{R_2} + j^2 \omega^2 LC}$$

$$= \frac{1}{1 + \frac{R_1}{R_2} + j\omega\left(R_1 C + \frac{L}{R_2}\right) + j^2 \omega^2 LC}$$

$R_1 = R_2$

$$= \frac{1}{1 + 1 + j\omega\left(RC + \frac{L}{R}\right) + j^2 \omega^2 LC}$$

$$= \frac{1}{2} \frac{1}{1 + j\omega\left(\frac{RC}{2} + \frac{L}{2R}\right) + j^2 \omega^2 \frac{LC}{2}}$$

$$= \frac{1}{2} \frac{1}{1 + s_n \omega_g\left(\frac{RC}{2} + \frac{L}{2R}\right) + s_n^2 \omega_g^2 \frac{LC}{2}}$$

$$a_1 = \omega_g\left(\frac{RC}{2} + \frac{L}{2R}\right) = 1{,}3617$$

$$b_1 = \omega_g^2\left(\frac{LC}{2}\right) = 0{,}6180$$

$$f_g = 10\,kHz \rightarrow \omega_g = 62831{,}9\,s^{-1}$$

Ann.: $C = 100nF$

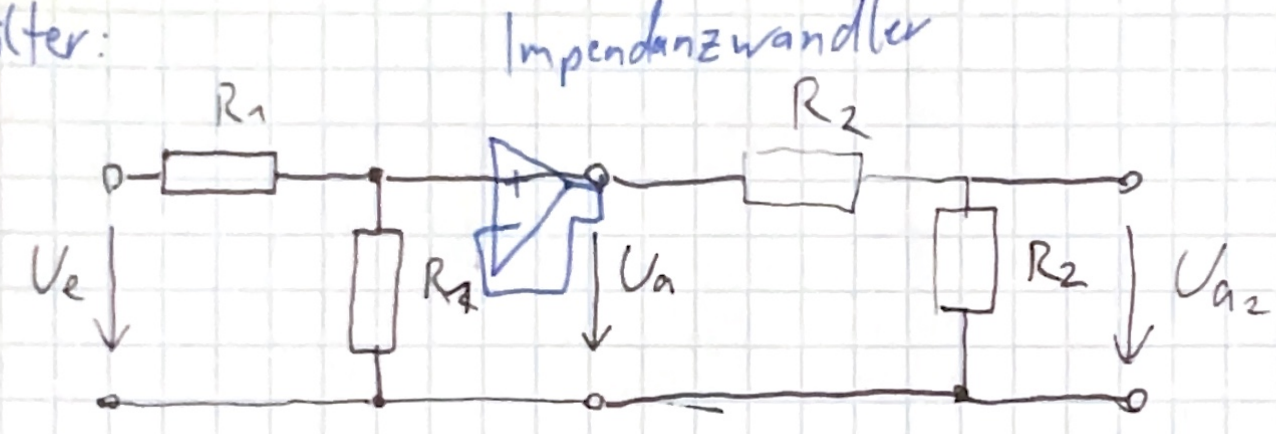
$$L = 2\frac{b_1}{\omega_g^2 C} = \frac{2 \cdot 0{,}6180}{62831{,}9^2 \cdot 100n} =$$

$$\underline{L = 3{,}13\,mH}$$

$R = \ldots = 91{,}58\,\Omega \mid 341{,}86\,\Omega$

Warum Impedanzwandler?

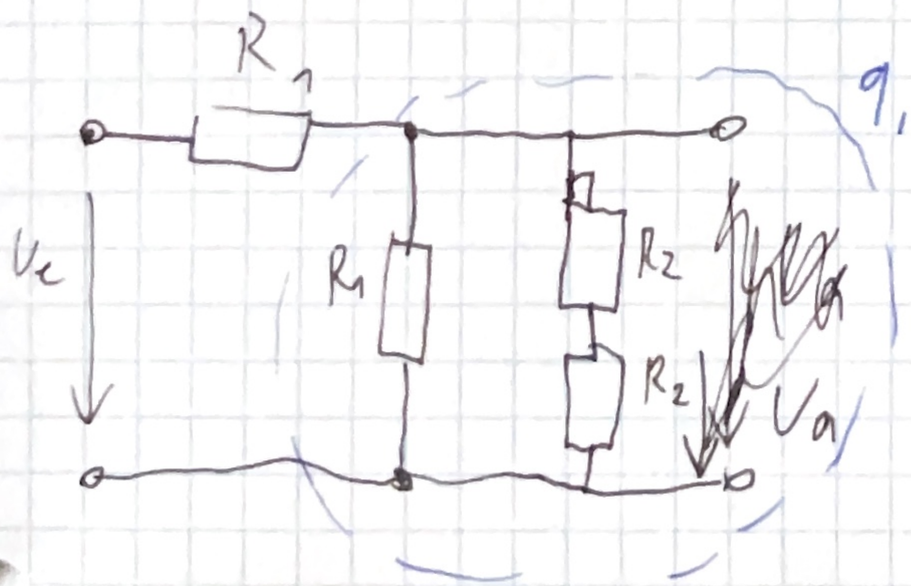
Filter:



$U_{a2} = U_e/4$

$R_1 = 10\,k\Omega$
$V_e = 10\,V$
$R_2 = 500\,k\Omega$

$$\frac{V_a}{V_e} = \frac{R_1}{R_1+R_1} \quad \frac{1}{2} \Rightarrow V_a = \frac{V_e}{2} = 5\,V$$



9,9 kΩ

Netzwerktechnik

192.168.1.24   10.0.0.0   A: 0 ... 127   SNM 255.0.0.0

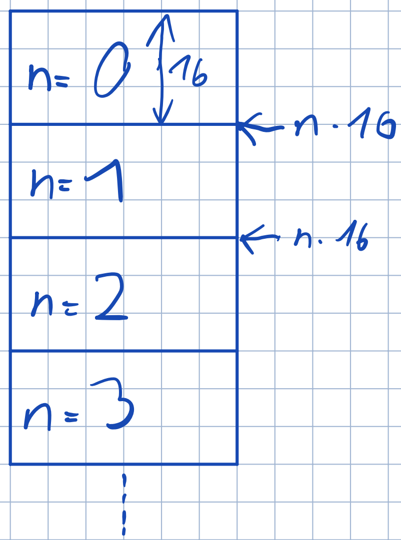
Private: 172.16.x.x / 172.16.x.x / 192.168.x.x

B: 128 ... 191   255.255.0.0

C: 192 ... 223   255.255.0

Bsp:

- 17 Netze
- je max 520 ~~Host~~
- Class B → 172.168._._



B: 172.16.x.x = IP
255.255.0.0 ⇒ Subnet Mask

$$\underbrace{1111\ 1111.1111\ 1111}_{\text{Netzanteil}}.\underbrace{\overbrace{0000\ 00}^{\text{Subnetz}}\overbrace{00.0000\ 0000}^{0\ldots1023}}_{\text{Hosts}}$$

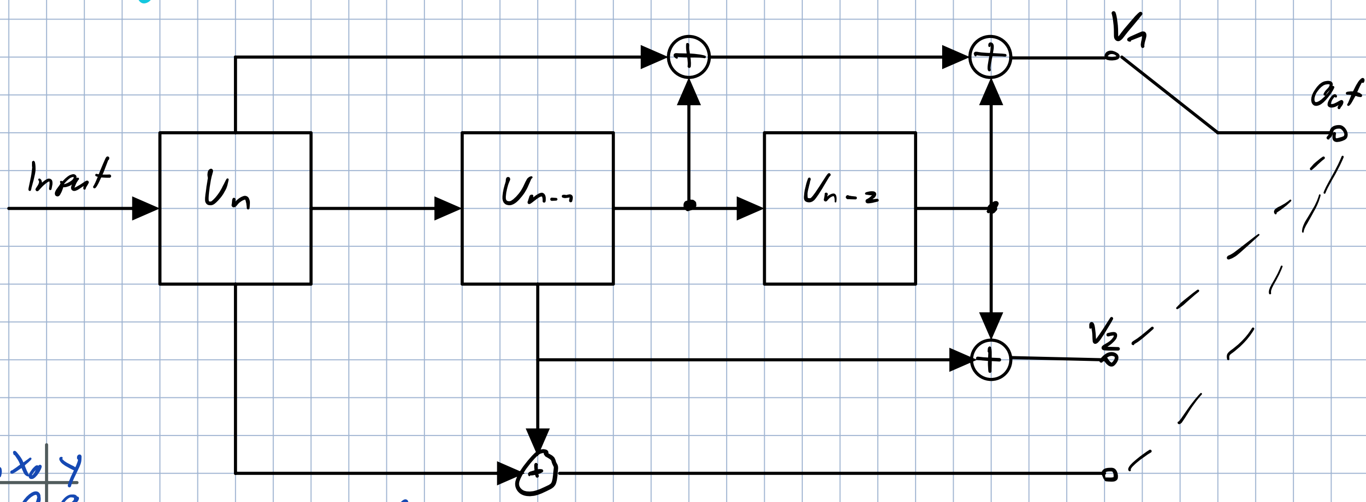
SN0 000000 00
SN1 000001 00
SN2 000010 00
SN3 000011 00
SN16 010000 00

Subn:

SNM: 255.255.252.0

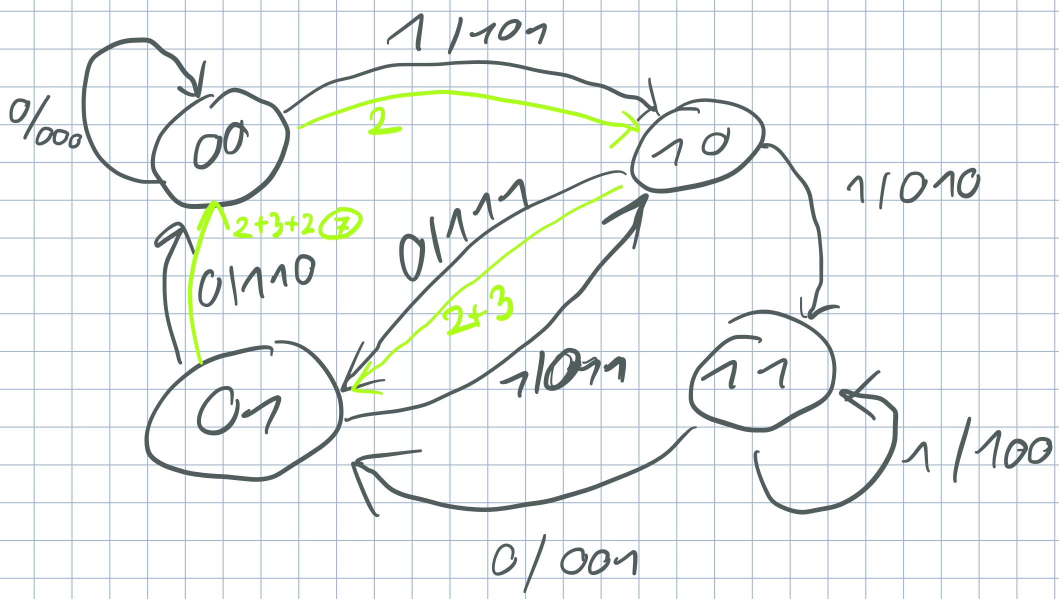
	SN 0:	SN 1:	SN2:
Netz	172.16.0.0	172.16.4.0	172.16.64.0
1 IP	172.16.0.1	172.16.4.1	172.16.64.1
⋮			
Letzte IP	172.16.3.254	172.16.7.254	172.16.67.254
Broadcast	172.16.3.255	172.16.7.255	172.16.67.255

Faltungscode:

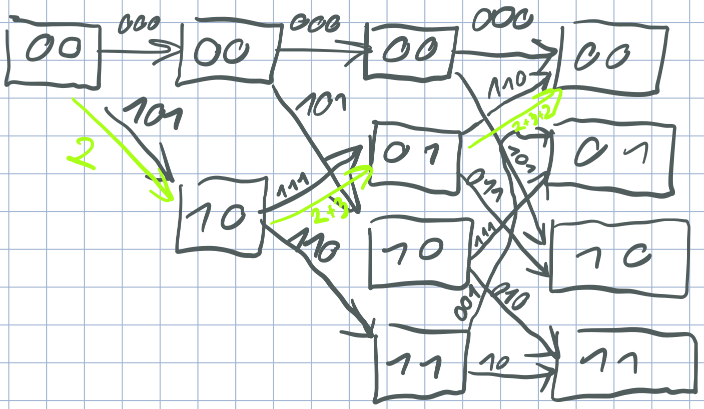


x_n	x_0	y
0	0	0
0	1	1
1	0	1
1	1	0

Zustandsdiagramm:



Trellis-Diagramm:



Kann auch im Zustandsdiagram ermittelt werden

Freie Distanz: 7

6 erkennen

3 korrigieren

Bsp: Bodediagramm & Phasengang:

$\boxed{\text{Betrag komplexe Zahl} = \sqrt{Re^2 + Im^2}}$

1 — 2 — 5

Bis $w_g \cdot 100$ & $w_g / 100$

$C = 470\,pF$
$R = 22\,k\Omega$

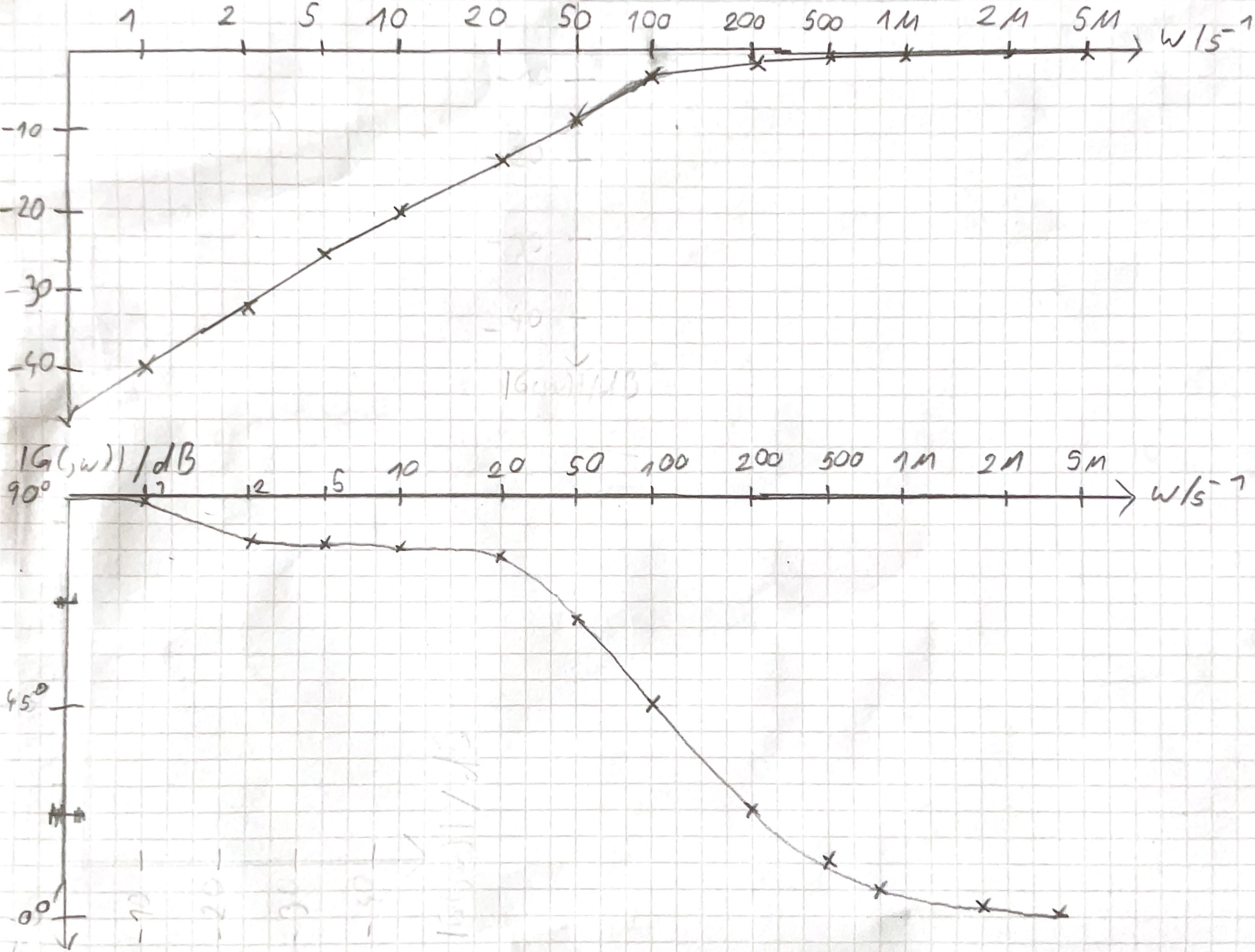
$$G(jw) = \frac{1}{\left(1 + \frac{1}{jwRC}\right)}$$

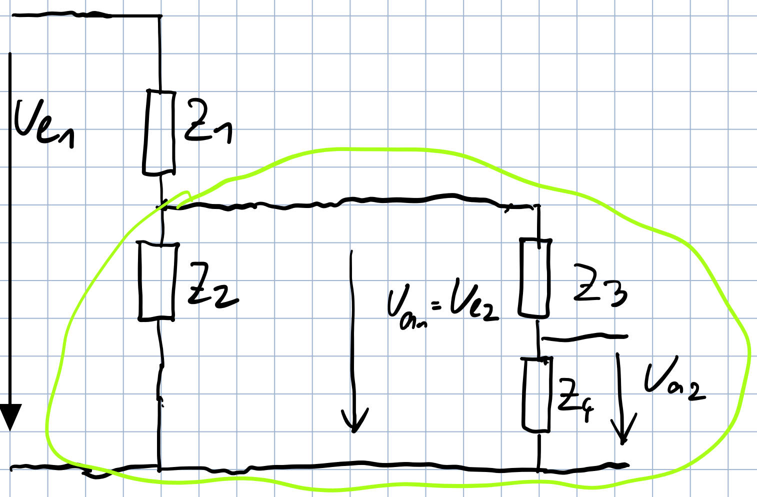
$$|G(jw)| = 20 \log\left(\frac{1}{\sqrt{1 + \left(\frac{1}{wRC}\right)^2}}\right)$$

$$1 = w_g RC \Rightarrow w_g = \frac{1}{RC} = 96{,}71\,ks^{-1}$$

$$\varphi = -\arctan\left(-\frac{1}{wRC}\right)$$

w s^{-1}	$\lvert G(jw)\rvert$/dB	φ/°
1	−39,7	89,407
2	−33,69	88,815
5	−25,73	87,040
10	−19,77	84,097
20	−13,69	78,316
50	−6,83	62,667
96,7	−3,01034	45
200	−0,9125	25,806
500	−0,1595	10,947
1 M	−0,0404	5,524
2 M	−0,0101	2,768
5 M	−0,00163	1,108
10 M	−0,000406	0,554

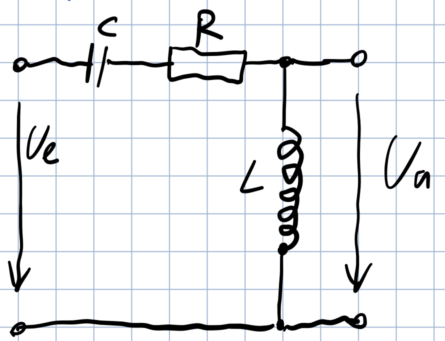

1 2 5 10 20 50 100 200 500 1M 2M 5M
w/s⁻¹
-10
-20
-30
-40
|G(jw)| / dB
1 2 5 10 20 50 100 200 500 1M 2M 5M
w/s⁻¹
90°
45°
0°



Deshalb Impedanzwandler bei Filter höheren O.

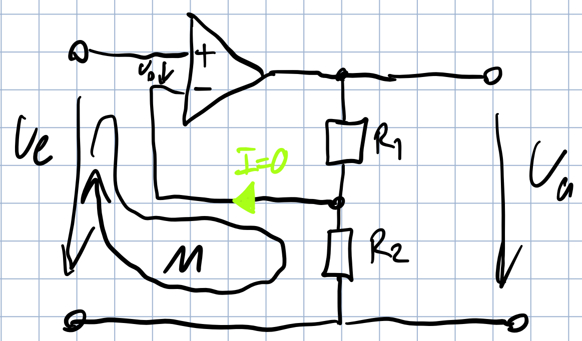
$Z_3 + Z_4 << Z_2$

Bsp:



$$G(j\omega) = \frac{U_a}{U_e} = \frac{j\omega L}{R + j\omega L + \frac{1}{j\omega C}} \cdot \frac{j\omega C}{j\omega C}$$

$$= \frac{j^2\omega^2 LC}{Rj\omega C + j^2\omega^2 LC + 1} = \frac{j^2\omega^2 LC}{1 + j\omega RC + j^2\omega^2 LC}$$

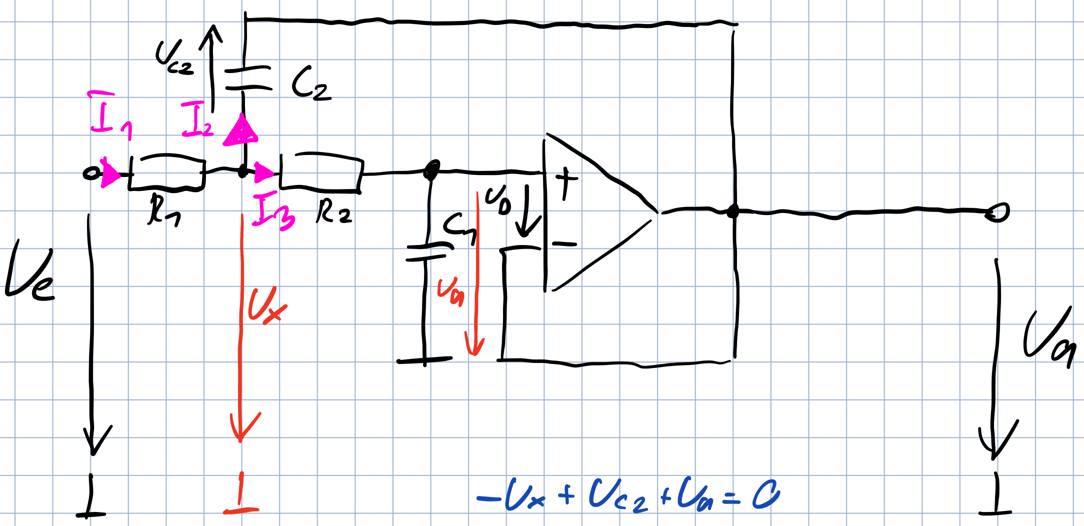


$-U_e + U_{R2} = 0$

$\underline{\underline{U_{R2} = U_e}}$

$$\frac{U_a}{\underset{U_e}{U_{R2}}} = \frac{R_1 + R_2}{R_2} = \frac{U_a}{U_e} \Rightarrow \frac{U_a}{U_e} = 1 + \frac{R_1}{R_2}$$

Sailen - Key - Tiefpass: 2.0:



$$-U_x + U_{c2} + U_a = 0$$

$$U_{c2} = U_x - U_a$$

1) Knoten

$$I_1 - I_2 - I_3 = 0$$

2) U_x

$$\frac{U_x}{U_a} = \frac{\left(R_2 + \frac{1}{j\omega C_1}\right) \cdot I_3}{\frac{1}{j\omega C_1} \cdot I_3} \qquad \frac{j\omega C}{j\omega C}$$

$$U_x = (1 + j\omega R_2 C_1)\, U_a$$

3)

$$I_1 = \frac{U_{R1}}{R_1} = \frac{U_e - U_x}{R_1} = \underline{\underline{\frac{U_e - (1 + j\omega R_2 C_1)\, U_a}{R_1}}}$$

$$U_{c2} = \underline{\underline{U_x - U_a}}$$

$$I_2 = \frac{U_{c2}}{X_{c2}} = \frac{U_x - U_a}{X_{c2}} = \frac{U_x - U_a}{\frac{1}{j\omega C}} = (U_x - U_a)\, j\omega C_2$$

$$= \left(\underbrace{(\cancel{1} + j\omega R_2 C_1)\, U_a}_{U_x} - \cancel{U_a}\right) j\omega C_2$$

$$I_2 = \underline{\underline{U_a \cdot j^2 \omega^2 R_2 C_1 C_2}}$$

$$I_3 = \frac{U_a}{\frac{1}{j\omega C_1}} = \underline{\underline{U_a\, j\omega C_1}}$$

$$I_1 = \frac{U_e - (1+j\omega R_2C_1)U_a}{\cancel{R_1}} \qquad I_2 = U_a j^2\omega^2 R_2C_1C_2 R_1 \qquad I_3 = U_a j\omega C_1 R_1$$

$$0 = U_e - U_a - U_a j\omega R_2C_1 - U_a j^2\omega^2 R_1R_2C_1C_2 - U_a \cdot j\omega R_1C_1$$

$$U_e = U_a(1 + j\omega C_1(R_1+R_2) + j^2\omega^2 R_1R_2C_1C_2)$$

$$U_e = U_a(1 + s_n\omega_g C_1(R_1+R_2) + s_n^2\omega_g^2 R_1R_2C_1C_2)$$

$$\frac{U_a}{U_e} = \frac{1}{1 + s_n \underbrace{\omega_g C_1(R_1+R_2)}_{a_1} + s_n^2 \underbrace{\omega_g^2 R_1R_2C_1C_2}_{b_1}}$$

$$a_1 = \omega_g C_1(R_1+R_2) \qquad R_1 = R_2 \Rightarrow C_1 = \frac{a_1}{\omega_g \underbrace{(R_1+R_2)}_{2R}}$$

$$b_1 = \omega_g^2 R_1R_2C_1C_2 \qquad C_2 = \frac{b_1}{\omega_g^2 R_1R_2C_1}$$

Mit α (wenn NINV statt Impedanzwandler)

$$U_x = (1+j\omega R_2C_1)\frac{U_a}{\alpha} \qquad I_1 = \left(U_e - \frac{(1+j\omega R_2C_1)U_a}{\alpha}\right)\frac{1}{R_1}$$

$$I_2 = (U_x - U_a)j\omega C_2 = \left(\frac{U_a}{\alpha}(1+j\omega R_2C_1) - U_a\right)\cdot j\omega C_2$$

$$U_a \rightarrow \frac{\alpha U_a}{U_a}$$

$$= \left(\frac{U_a}{\alpha} + \frac{U_a\ j\omega R_2C_1}{\alpha} - \frac{\alpha U_a}{U_a}\right)j\omega C_2$$

$$= \left(\frac{U_a - \alpha U_a}{\alpha}\right.$$

$$= U_a\left(\frac{1-\alpha}{\alpha} + \frac{j\omega R_2C_1}{\alpha}\right)j\omega C_2$$

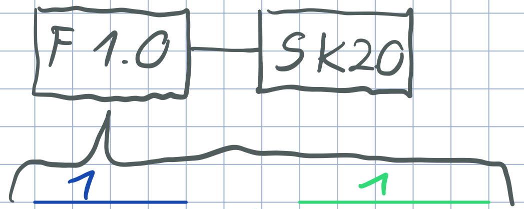
Dann wieder so weiter wie vorher

Filter 3.0:

Achtung Filter 1.0 hat jetzt auch Filterkoeffizienten!

z.B:

Bessel	a_1	b_1
1.0.	1,7423	0
2.0.	1,6374	1,0248



$$\frac{1}{1+j\omega RC} \rightarrow \frac{1}{1+\underbrace{s\,\omega_g RC}_{a_1}}$$

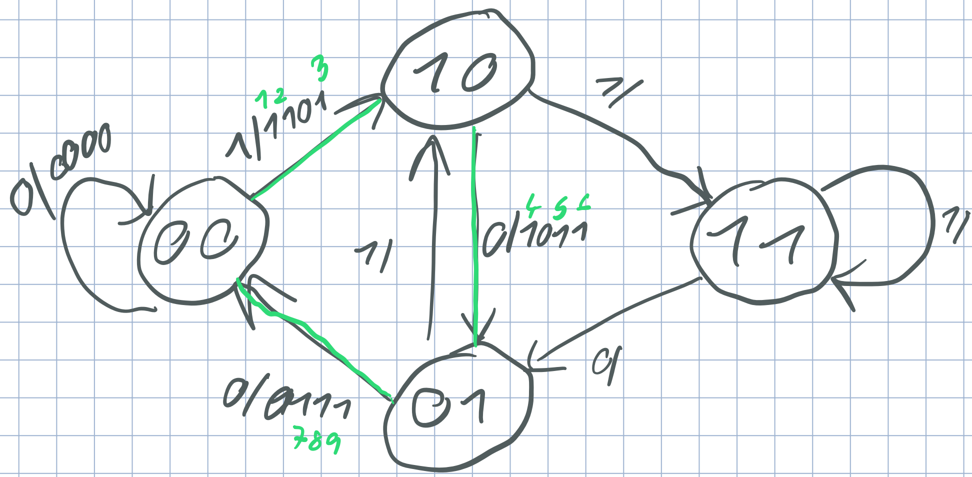
Faltungscode:

① $U_n \oplus U_{n-1}$

② $U_n \oplus U_{n-2}$

③ $U_{n-1} \oplus U_{n-2}$

④ $U_n \oplus U_{n-1} \oplus U_{n-2}$



Freie Distanz: 9

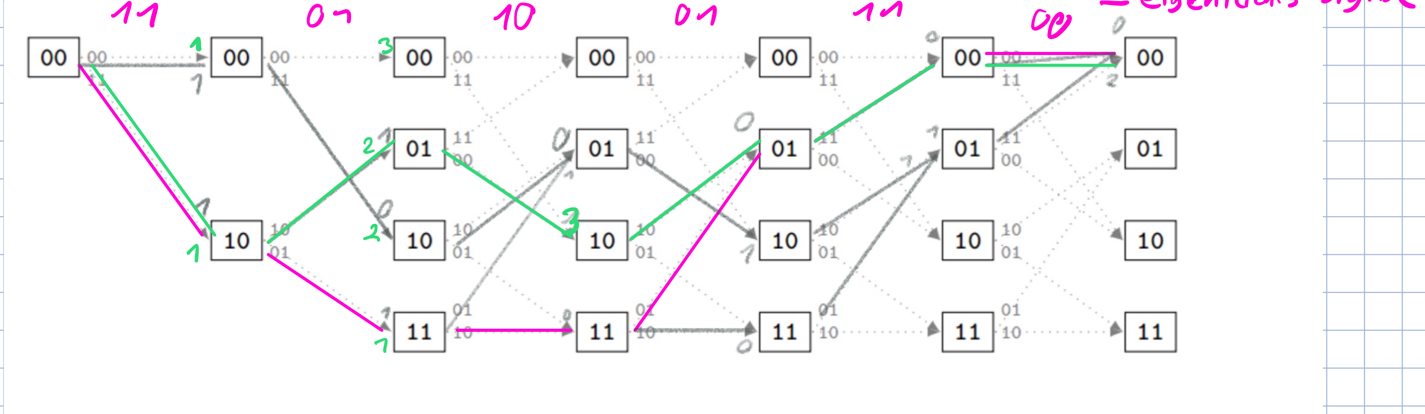
4 beheben

8 erkennen

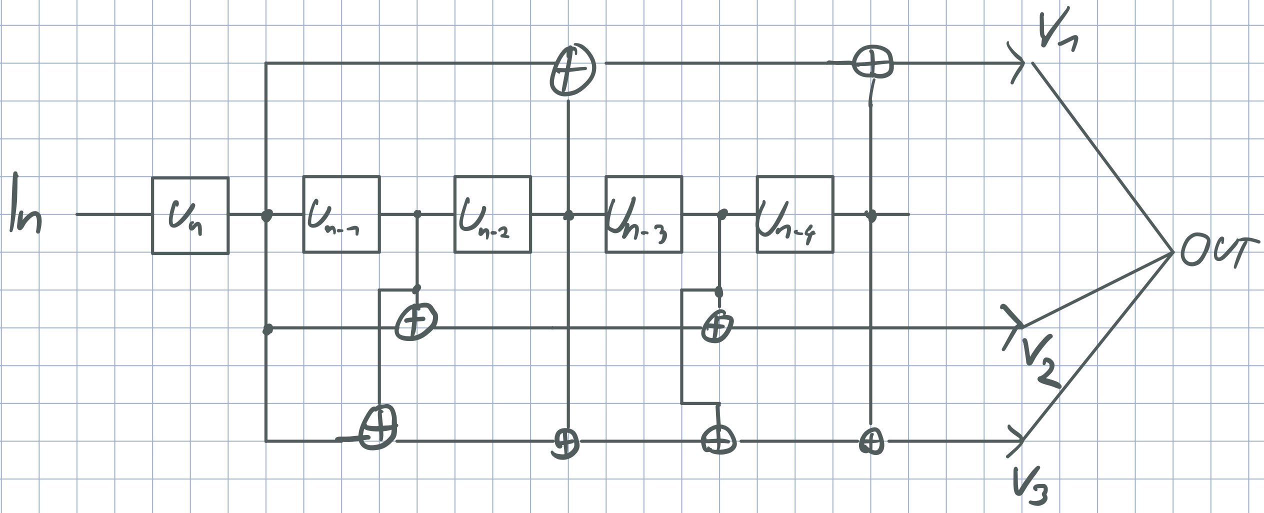
Bsp Viterbi-Bit-Decoder (anderer Faltungscode)

10 11 10 10 11 00 – Fehler (4)

11 01 10 01 11 00 – eigentliches Signal



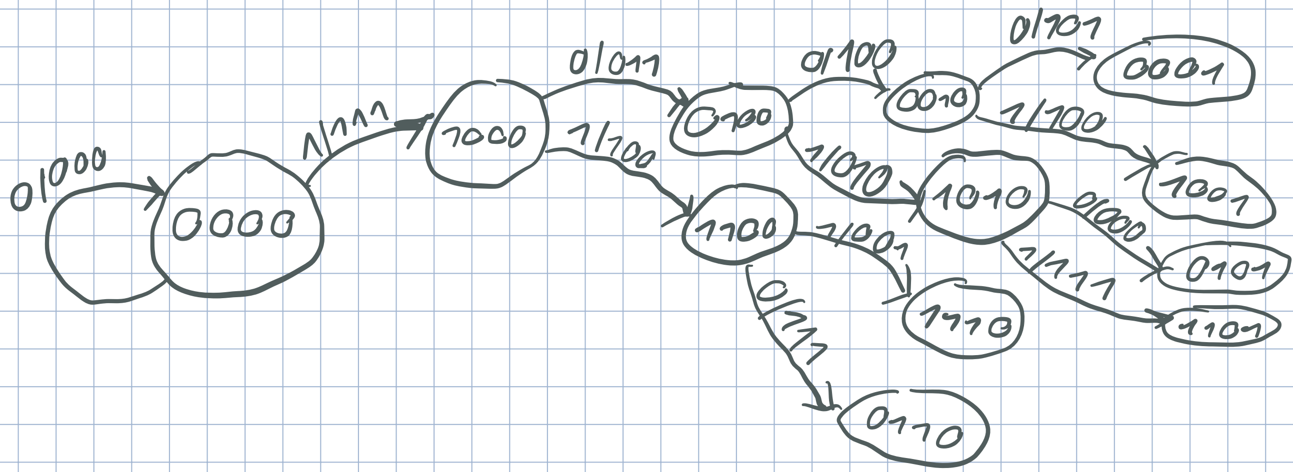
H = 5 4 erkennen 2 Beheben ⇒ Deshalb Weg unterschiedlich



1) $U_n \oplus U_{n-2} \oplus U_{n-4}$

2) $U_n \oplus U_{n-1} \oplus U_{n-3}$

3 $U_n \oplus U_{n-1} \oplus U_{n-2} \oplus U_{n-3} \oplus U_{n-4}$

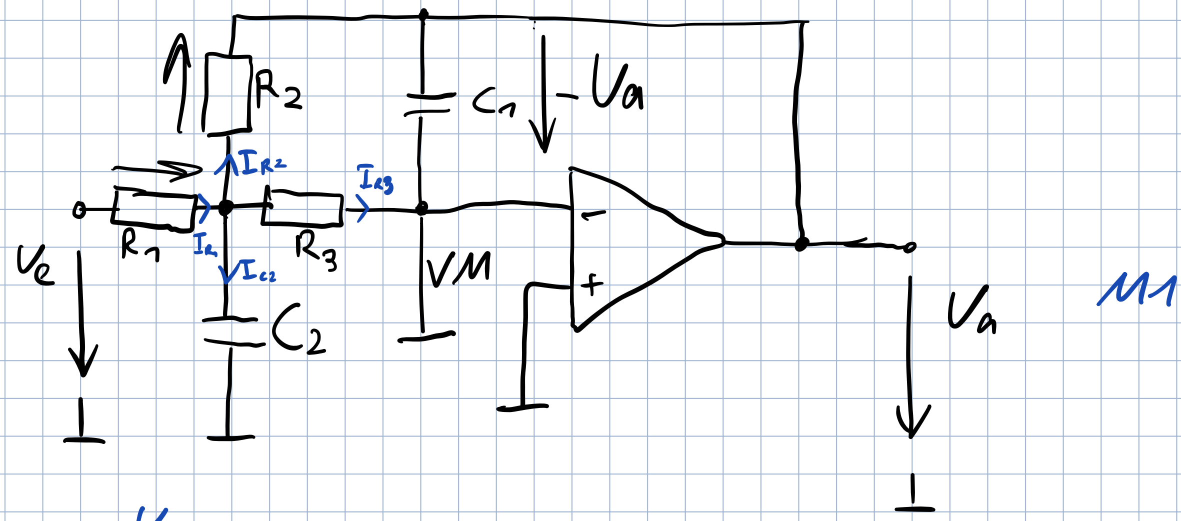


Subnetting:

6×200H
3×500H
2×700H

Klasse B Netz

Sallen - Key mit mehrfacher Rückkopplung:



$$I_{C1} = \frac{-U_a}{\frac{1}{j\omega C_1}}$$

$$M1: -U_{C2} + U_{R2} + U_a = 0$$

$$U_{C2} = U_{R3} = I_{C1} \cdot R_3$$

$$\Rightarrow I_{R1} = \frac{U_{R1}}{R_1} = \frac{U_e - U_{C2}}{R_1}$$

$$I_{R2} = \frac{U_{R2}}{R_2} = \frac{M1}{R_2} = \frac{U_c - U_a}{R_2}$$

$$U_{C2} = U_{R3} = I_{R3} \cdot R_3$$

$$I_{R3} = \frac{U_{C1}}{\frac{1}{j\omega C_1}} = -U_a \, j\omega C_1$$

$$I_{C2} = \frac{U_{C2}}{\frac{1}{j\omega C_2}} = -U_a \cdot j\omega C_1 R_3 \cdot j\omega C_2 = -U_a \cdot j^2 \omega^2 R_3 C_1 C_2$$

$$I_{R1} = \frac{U_{R1}}{R_1} = \frac{U_e - U_{C2}}{R_1} = \frac{U_e + U_a \cdot j\omega R_3 C_1}{R_1} = \frac{U_e}{R_1} + U_a \cdot \frac{j\omega C_1 R_3}{R_1}$$

$$I_{R2} = \frac{U_{C2} - U_a}{R_2} = \frac{-U_a \cdot j\omega R_3 C_1 - U_a}{R_2}$$

$$= U_a \frac{-1 - j\omega R_3 C_1}{R_2} = -U_a \frac{1 + j\omega R_3 C_1}{R_2}$$

$$-U_{C2} + U_{R2} + U_a = 0$$

$$U_{R2} = U_{C2} - U_a$$

$$I_{R1} - I_{R2} - I_{R3} - I_{C2} = 0$$

$$I_{R1} = \frac{U_e}{\cancel{R_1}} + U_a \cdot \frac{j\omega C_1 R_3}{\cancel{R_1}} \quad R_2$$

$$I_{R2} = -U_a \frac{1+j\omega R_3 C_1}{\cancel{R_2}} \quad R_1 \qquad I_{R3} = -U_a\, j\omega C_1 R_1 R_2$$

$$I_{C2} = -U_a\, j^2 \omega^2 R_3 C_1 C_2 R_1 R_2$$

$$0 = U_e + U_a(j\omega C_1 R_2 R_3) - U_a(1+j\omega R_3 C_1) R_1 - U_a\, j\omega R_1 R_2 C_1 - U_a j^2 \omega^2 R_1 R_2 R_3 C_1 C_2$$

$$U_e = -U_a(j\omega C_1 R_2 R_3) + U_a(1 - j\omega R_3 C_1) R_1 + U_a j\omega R_1 R_2 C_1 + U_a j^2 \omega^2 R_1 R_2 R_3 C_1 C_2$$

$$U_e = -U_a\Big((j\omega C_1 R_2 R_3) - (1 - j\omega R_3 C_1) R_1 - j\omega R_1 R_2 C_1 - j^2\omega^2 R_1 R_2 R_3 C_1 C_2\Big)$$

$$\frac{U_a}{U_e} = -\frac{1}{1+}$$

Lsg:

$$\frac{U_a}{U_e} = -\frac{R_2}{R_1} \cdot \frac{1}{1 + j\omega C\left(R_2 + R_3 + \frac{R_2 R_3}{R_1}\right) + j^2\omega^2 R_2 R_3 C_1 C_2}$$