

A1

a) $U_B = 0:$

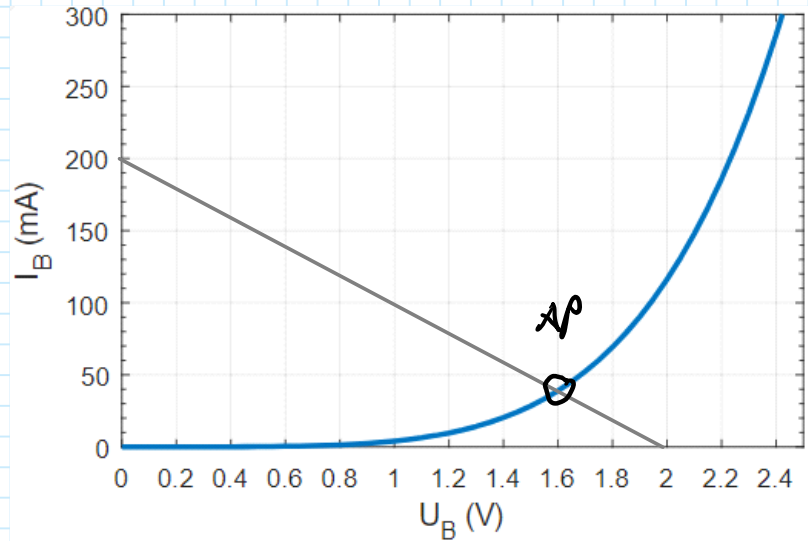
$$\Rightarrow I_B = \frac{U_1}{R} = 200 \text{ mA}$$

$I_B = 0:$

$$\Rightarrow U_B = 2 \text{ V}$$

$$\Rightarrow I_{B,AP} \approx 40 \text{ mA}$$

$$U_{B,AP} \approx 1,6 \text{ V}$$



b) $U_1 = R \cdot (I_B + I_L) + U_2$

$$U_B = U_2$$

$$R_L = 3R$$

$$f(U_2) = R \left(0,1 \cdot 10^{-3} \frac{\text{A}}{\text{V}} \cdot U_2 + 0,5 \cdot 10^{-3} \frac{\text{A}}{\text{V}^3} \cdot U_2^3 + 3,5 \cdot 10^{-3} \frac{\text{A}}{\text{V}^5} \cdot U_2^5 + \frac{U_2}{R_L} \right) + U_2 - U_1$$

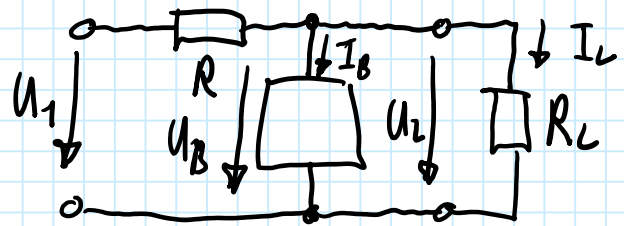
$$f'(U_2) = R \left(0,1 \cdot 10^{-3} \frac{\text{A}}{\text{V}} + 1,5 \cdot 10^{-3} \frac{\text{A}}{\text{V}^3} U_2^2 + 5 \cdot 3,5 \cdot 10^{-3} \frac{\text{A}}{\text{V}^5} U_2^4 + \frac{1}{3R} \right) + 1$$

$$U_2^{(j+1)} = U_2^{(j)} - \frac{f(U_2^{(j)})}{f'(U_2^{(j)})}$$

j	U_2
0	1,6 V
1	1,3927 V
2	1,3654 V
3	1,3650 V

$$\Rightarrow U_2 = 1,365 \text{ V}$$

$$P_{R_L} = \frac{U_2^2}{R_L} = \frac{(1,365 \text{ V})^2}{30 \Omega} = 0,0621 \text{ W}$$



c) $R = 0 \Omega \rightarrow u_1 = u_B$

$u_1(t) = \hat{u}_1 \sin(\omega_1 t)$ einsetzen in Polynom

Additionstheoreme

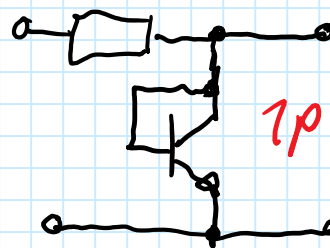
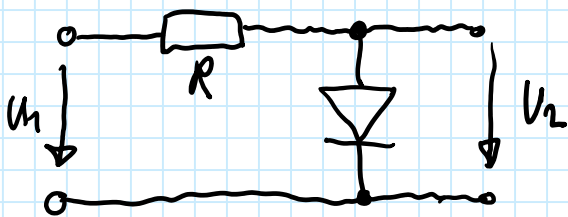
$\sin(\omega_1 t) \rightarrow \sin(\omega_1 t)$

$\sin(\omega_1 t)^3 \rightarrow \frac{1}{4} (3 \sin(\omega_1 t) - \sin(3\omega_1 t))$

$\sin(\omega_1 t)^5 \rightarrow \frac{1}{16} (10 \sin(\omega_1 t) - 5 \sin(3\omega_1 t) + \sin(5\omega_1 t))$

$i_B(t)$ enthält $\omega_1, 3\omega_1, 5\omega_1$

d) Diode $\rightarrow$ in Vorwärtsrichtung wegen U_B & I_B Pfeilung



Bipolartransistor in Diodenschaltung

e) $I_{B,AP} = 40 \text{ mA} = I_0 (e^{a U_B} - 1)$

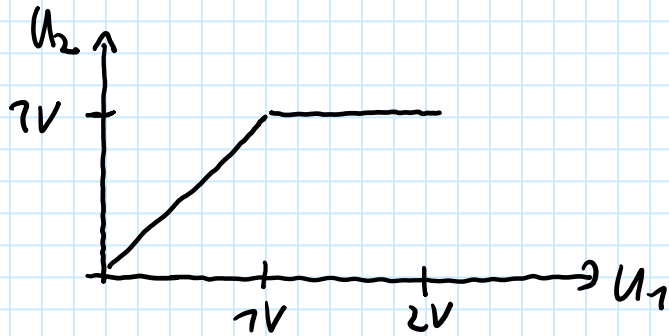
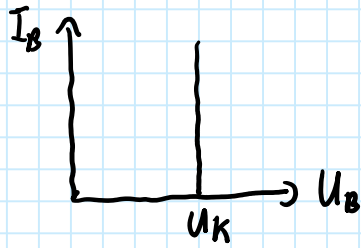
mit $U_{B,AP} = 7,6 \text{ V}$

$I_0 = 7 \cdot 10^{-10} \text{ A}$

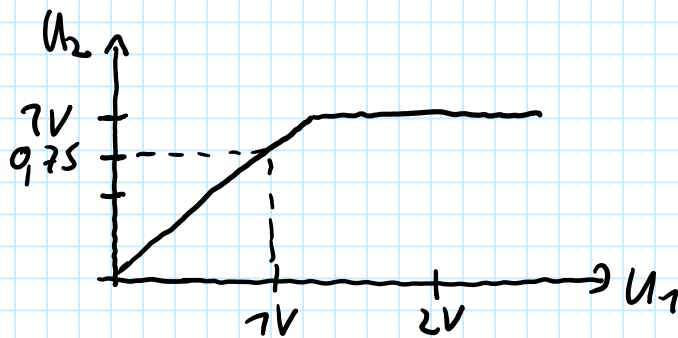
$\ln\left(\frac{40 \text{ mA}}{I_0} + 1\right) \frac{1}{U_B} = a$

$a = 12,38 \frac{1}{\text{V}}$

f) Knickkennlinie $U_K = 7V$



g)



$$U_2 = \frac{3R}{4R} U_1 = \frac{3}{4} U_1$$

2 d)

Schaltung	a	b
Filter	HP	TP

$$f_g = \frac{1}{2\pi RC} = \frac{1}{2\pi \cdot 10k\Omega \cdot 1\mu F} = \underline{\underline{15,92 \text{ Hz}}}$$

$$\omega_g = 100 \text{ Hz}$$

b) Parallel-Parallel, Reihe-Reihe, Kettschaltung (BP), Reihe-Parallel

Teil Vierpol	a		b	
c) $[A]$	$1 + \frac{1}{j\omega C_a R_a}$	$\frac{1}{j\omega C_a}$	$1 + j\omega R_b C_b$	R_b
	$\frac{1}{R_a}$	1	$j\omega C_b$	1

$$d) [\underline{Y}_{ges}] = [\underline{Y}_a] + [\underline{Y}_b] = \begin{bmatrix} j\omega C_a + \frac{1}{R_b} & -\left(j\omega C_a + \frac{1}{R_b}\right) \\ -\left(j\omega C_a + \frac{1}{R_b}\right) & j\omega(C_a + C_b) + \frac{1}{R_a} + \frac{1}{R_b} \end{bmatrix}$$

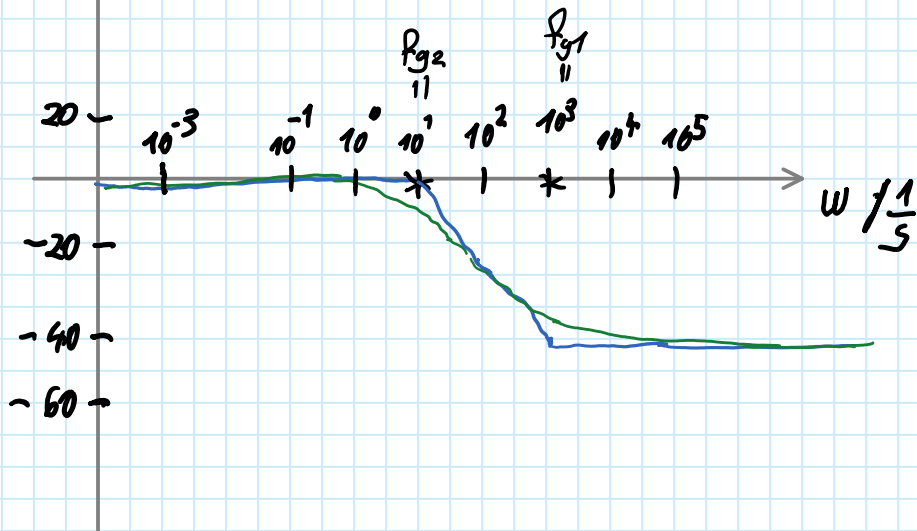
$$[\underline{Y}_{ges}] = \begin{bmatrix} \underline{Y}_{11} & \underline{Y}_{12} \\ \underline{Y}_{21} & \underline{Y}_{22} \end{bmatrix}$$

$$[\underline{A}_{ges}] = \frac{1}{\underline{Y}_{21}} \begin{bmatrix} -\underline{Y}_{22} & -1 \\ -\det(\underline{Y}_{ges}) & -\underline{Y}_{11} \end{bmatrix}$$

$$F(j\omega) = \frac{1}{\underline{A}_{11}} = \frac{j\omega C_a + \frac{1}{R_b}}{j\omega(C_a + C_b) + \frac{1}{R_a} + \frac{1}{R_b}}$$

2e)

1. $F(j\omega)/dB$



f)

1	2	3	4	5
B	C	D	E	A

$$a) \quad \underline{F}(j\omega) = \frac{\underline{V}_2}{\underline{V}_1} = \frac{C//L}{R+C//L} = \frac{\frac{1}{j\omega C + \frac{1}{j\omega L}}}{R + \frac{1}{j\omega C + \frac{1}{j\omega L}}} = \frac{1}{1 + R(j\omega C + \frac{1}{j\omega L})} =$$

$$= \frac{j\omega L}{j\omega L + R + (j\omega)^2 LCR}$$

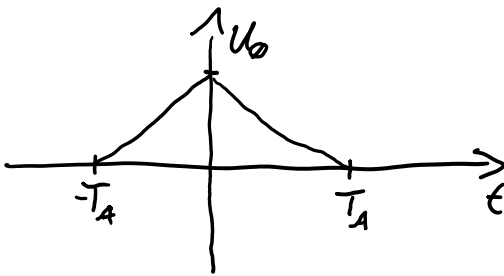
b)

$$\underline{F}(0) = 0$$

$$\underline{F}(\omega \rightarrow \infty) \rightarrow 0$$

Bandpass

c)



d)

$$\underline{V}_1(f) = \int_{-\infty}^{\infty} u_1(t) e^{-j2\pi f t} dt = -\frac{2U_0}{T_A} \int_0^{T_A} t e^{-j2\pi f t} dt + 2U_0 \int_0^{T_A} e^{-j2\pi f t} dt =$$

$$\int t e^{-j2\pi f t} dt = t \frac{e^{-j2\pi f t}}{-j2\pi f} - \int \frac{e^{-j2\pi f t}}{-j2\pi f} dt = t \frac{e^{-j2\pi f t}}{-j2\pi f} - \frac{e^{-j2\pi f t}}{(j2\pi f)^2}$$

$$= -\frac{2U_0}{T_A} \left[t \frac{e^{-j2\pi f t}}{-j2\pi f} - \frac{e^{-j2\pi f t}}{(j2\pi f)^2} \right]_0^{T_A} + 2U_0 \left[\frac{e^{-j2\pi f t}}{-j2\pi f} \right]_0^{T_A} =$$

$$= -\frac{2U_0}{T_A} \left(T_A \frac{e^{-j2\pi f T_A}}{-j2\pi f} - \frac{e^{-j2\pi f T_A}}{(j2\pi f)^2} + \frac{e^{-j2\pi f T_A}}{(j2\pi f)^2} \right) + \frac{U_0}{-j\pi f} (e^{-j2\pi f T_A} - 1)$$

Weitere Umformung nicht nötig

e)

$$\underline{V}_2(f) = \underline{V}_1(f) \cdot \underline{F}(j\omega) \Big|_{\omega=2\pi f}$$

f)

$$a_0 = \frac{U_0}{2} \quad b_0 = 0$$

$$a_v = \frac{2}{T_1} \int_0^{T_1} u_{r,p}(t) \cos(v\omega_1 t) dt = -\frac{4U_0}{T_1 T_1} \int_0^{T_1} t \cos(v\omega_1 t) dt + \frac{4U_0}{T_1} \int_0^{T_1} \cos(v\omega_1 t) dt =$$

$$\left[\int t \cos(v\omega_1 t) dt = t \frac{\sin(v\omega_1 t)}{v\omega_1} - \int \frac{\sin(v\omega_1 t)}{v\omega_1} dt = \right.$$

$$\left. L = t \frac{\sin(v\omega_1 t)}{v\omega_1} + \frac{\cos(v\omega_1 t)}{(v\omega_1)^2} \right]$$

$$\frac{4U_0}{T_1 T_1} \left[t \frac{\sin(v\omega_1 t)}{v\omega_1} + \frac{\cos(v\omega_1 t)}{(v\omega_1)^2} \right]_0^{T_1} + \frac{4U_0}{T_1} \left[\frac{\sin(v\omega_1 t)}{v\omega_1} \right]_0^{T_1} =$$

$$= -\frac{4U_0}{T_1 T_1} \left(T_1 \frac{\sin(v\omega_1 T_1)}{v\omega_1} + \frac{\cos(v\omega_1 T_1)}{(v\omega_1)^2} - \frac{1}{(v\omega_1)^2} \right) + \frac{4U_0}{T_1} \frac{\sin(v\omega_1 T_1)}{v\omega_1} =$$

$$\left[v\omega_1 T_1 = v \frac{2\pi}{T_1} T_1 = v \frac{2\pi}{2T_1} T_1 = v\pi \right]$$

$$= -\frac{4U_0}{2T_1^2} \left(\frac{\cos(v\pi) - 1}{(v\omega_1)^2} \right) \left(= -\frac{2U_0}{T_1^2} \frac{(-1)^v - 1}{(v\omega_1)^2} \right)$$

$v\pi$

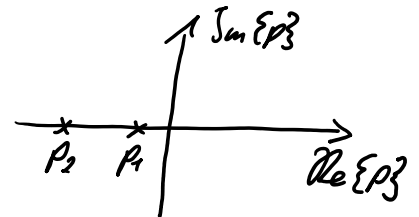
$$u_{1,p}(t) = \frac{U_0}{2} - \frac{2U_0}{T_A^2} \sum_{v=1}^{\infty} \frac{\cos(v\pi) - 1}{(v\omega_1)^2} \cos(v\omega_1 t)$$

$$u_{2,p}(t) = - \frac{2U_0}{T_A^2} \sum_{v=1}^{\infty} \frac{\cos(v\pi) - 1}{(v\omega_1)^2} A(v\omega_1) \cos(v\omega_1 t + \psi(v\omega_1))$$

$$a) \quad \underline{F}_1(p) = \frac{\underline{U}_{CL}}{\underline{U}_1} = \frac{\frac{1}{pC_L}}{R + pL + \frac{1}{pC_L}} = \frac{1}{p^2 LC_L + pRC_L + 1}$$

$$b) \quad p_{1,2} = -\frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC_L}} = -2,5 \cdot 10^8 \frac{1}{s} \pm 2,490 \cdot 10^8 \frac{1}{s}$$

$$p_1 = -1,0 \cdot 10^6 \frac{1}{s} \quad p_2 = -4,99 \cdot 10^8 \frac{1}{s}$$



c) Begründung: 1) Geladene Energiespeicher
 2) Schaltung wird nicht durch Spannungs- oder Stromquelle gespeist (+1)

$$i_{CB} = C_B \frac{du_B}{dt} \quad \bullet \text{---} \circ \quad \underline{I}_{CB}(p) = C_B (p \underline{U}_1(p) - u_1(0))$$

$$u_R = R \cdot i_R \quad \bullet \text{---} \circ \quad \underline{U}_R(p) = R \underline{I}_R(p)$$

$$u_L = L \frac{di_L}{dt} \quad \bullet \text{---} \circ \quad \underline{U}_L(p) = L \cdot (p \underline{I}_L(p) - i_L(0)) = L p \underline{I}_L(p)$$

$$i_{CL} = C_L \frac{du_{CL}}{dt} \quad \bullet \text{---} \circ \quad \underline{I}_{CL}(p) = C_L (p \underline{U}_{CL}(p) - u_{CL}(0))$$

$$\underline{I}_{CB} = -\underline{I}_R = -\underline{I}_{CL} = -\underline{I}_L$$

$$0 = \underline{U}_{CL}(p) - \underline{U}_1(p) + \underline{U}_R(p) + \underline{U}_L(p)$$

$$= \underline{U}_{CL}(p) - \left(\frac{\underline{I}_{CB}(p)}{pC_B} + \frac{u_1(0)}{p} \right) + R \underline{I}_R(p) + pL \underline{I}_L(p)$$

$$= \underline{U}_{CL}(p) + \frac{\underline{I}_{CL}(p)}{pC_B} - \frac{u_1(0)}{p} + R \underline{I}_{CL}(p) + pL \underline{I}_{CL}(p)$$

$$0 = \underline{U}_{dL}(p) + \underline{I}_{dL}(p) \left(\frac{1}{pC_B} + R + pL \right) - \frac{u_r(0)}{p}$$

$$= \underline{U}_{dL}(p) + C_L p \underline{U}_{dL}(p) \left(\frac{1}{pC_B} + R + pL \right) - C_L u_r(0) \left(\frac{1}{pC_B} + R + pL \right) - \frac{u_r(0)}{p}$$

$$= \underline{U}_{dL} \left(1 + \frac{C_L}{C_B} + pRC_L + p^2LC_L \right) - C_L u_r(0) \left(\frac{1}{pC_B} + R + pL \right) - \frac{u_r(0)}{p}$$

$$\underline{U}_{dL}(p) = C_L u_r(0) \frac{\frac{1}{pC_B} + R + pL}{1 + \frac{C_L}{C_B} + pRC_L + p^2LC_L} + u_r(0) \frac{1}{p \left(1 + \frac{C_L}{C_B} + pRC_L + p^2LC_L \right)}$$

d)

$$u_{dL}(0) = \frac{U_{00}}{2} \quad ; \quad u_r(0) = 0$$

$$\underline{U}_{dL}(p) = \frac{U_{00}}{2} \left(\frac{1}{p} - \frac{1}{p \left(1 + \frac{C_L}{C_B} + pRC_L + p^2LC_L \right)} \right) = \frac{U_{00}}{2} \left(\frac{1}{p} - \frac{1}{LC_L p} \frac{1}{p^2 + p \frac{R}{L} + \frac{1}{LC_L} + \frac{1}{LC_B}} \right)$$

PBZ:

$$p_{1,2} = -\frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC_L} - \frac{1}{LC_B}} = -2,5 \cdot 10^8 \frac{1}{s} \pm 2,387 \cdot 10^8 \frac{1}{s}$$

$$p_1 = -1,125 \cdot 10^7 \frac{1}{s}$$

$$p_2 = -4,887 \cdot 10^9 \frac{1}{s}$$

→ Starke Dämpfung

$$\frac{1}{p(p-p_1)(p-p_2)} \stackrel{!}{=} \frac{\underline{A}}{p} + \frac{\underline{B}}{p-p_1} + \frac{\underline{C}}{p-p_2}$$

$$\underline{A} = \frac{1}{p_1 p_2}$$

$$\underline{B} = \frac{1}{p_1(p_1-p_2)}$$

$$\underline{C} = \frac{1}{p_2(p_2-p_1)}$$

$$\underline{U}_{dL}(p) = \frac{U_{DD}}{2} \left(\frac{1}{p} - \frac{1}{L C_L} \left(\frac{A}{p} + \frac{B}{p-p_1} + \frac{C}{p-p_2} \right) \right)$$

$$\downarrow$$

$$u_{dL}(t) = \frac{U_{DD}}{2} \left(s(t) - \frac{1}{L C_L} \left(A s(t) + B s(t) e^{p_1 t} + C s(t) e^{p_2 t} \right) \right)$$

e)

$$u_{dL}(t \rightarrow \infty) = \frac{U_{DD}}{2} \left(1 - \frac{A}{L C_L} \right) = \frac{U_{DD}}{2} \left(1 - \frac{1}{p_1 p_2 L C_L} \right)$$

$$p_1 p_2 = \left(-\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{L C_L} - \frac{1}{L C_B}} \right) \left(-\frac{R}{2L} - \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{L C_L} - \frac{1}{L C_B}} \right) =$$

$$= \left(\frac{R}{2L}\right)^2 - \left(\frac{R}{2L}\right)^2 + \frac{1}{L C_L} + \frac{1}{L C_B} = \frac{1}{L} \left(\frac{1}{C_L} + \frac{1}{C_B} \right)$$

$$u_{dL}(t \rightarrow \infty) = \frac{U_{DD}}{2} \left(1 - \frac{1}{1 + \frac{C_L}{C_B}} \right) = \frac{U_{DD}}{2} \frac{C_L}{C_L + C_B}$$

f)

$$Q_1(t=0) = C_B U_{DD}$$

$$Q_1(t \rightarrow \infty) + Q_{dL}(t \rightarrow \infty) = Q_1(0) + Q_{dL}(0)$$

$$Q_{dL}(t=0) = C_L \frac{U_{DD}}{2}$$

$$t \rightarrow \infty : u_1 = u_{dL}$$

$$U_{DD} \left(C_B + \frac{C_L}{2} \right) = u_{dL}(t \rightarrow \infty) (C_B + C_L) \Leftrightarrow u_{dL}(t \rightarrow \infty) = U_{DD} \frac{C_B + \frac{C_L}{2}}{C_B + C_L}$$