Das Fachgebiet hat am 18.03.2026 darauf hingewiesen, dass diese Klausuren *alt* sind. Somit sind sie vermutlich nicht sonderlich repräsentativ für die aktuellen Klausuren.

Empirischer Mittelw.

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

emp. Var.

$$s^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i-\bar{x})^2$$

emp. Standardabw.

$$s = \sqrt{s^2}$$

Verteilungsfkt.

$$F_x(x) = \int_{-\infty}^{x} f_x(t)\,dx$$

Erwartungswert

d: $\mu = E\{x\} = \sum_i x_i \cdot P(x=x_i)$

k: $\mu = \int_{-\infty}^{\infty} x \cdot f_x(x)\,dx$

Standardabw.

$$\sigma = \sqrt{Var\{x\}} = \sqrt{E\{(x-\mu)^2\}}$$

Gaußverteilung

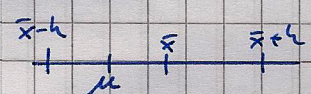
$$F_g(x) = \exp\left(\frac{(x-\mu)^2}{2\cdot Var}\right)\cdot\frac{1}{2\pi\sigma}$$

Varianz

k: $Var\{x\} = \int_{-\infty}^{\infty}(x-\mu)^2 \cdot f_x(x)\,dx$

d: $= \sum_i (x_i-\mu)^2 \cdot P(x=x_i)$

Vertrauensintervall



σ bekannt: $V_{1,2} = \bar{x} \pm \frac{\epsilon\sigma}{\sqrt{N}}$

σ unbek: $V_{1,2} = \bar{x} \pm \frac{t_p s}{\sqrt{N}}$

Methode d. kl. Fehlerquadrate

$$\hat{a} = (x^T \cdot x)^{-1} \cdot x^T \cdot y$$

Ansatz:

$\hat{y}_i = b x_i + a \quad e_i = (y_i - \hat{y}_i)$

$= y_i - b x_i - a$

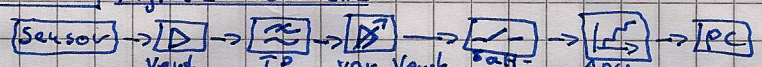
$E = \sum e_i^2 \rightarrow$ ableiten und null setzen

$\frac{\partial \sum e_i^2}{\partial a} \stackrel{!}{=} 0$ ...

Bedingungen kub. Splines

1) Interpolationsbed.: $S_i(x_i) = y_i \;|\; i = 0 \ldots N$
2) Stetigkeit in d. Stützst.: $S_i(x_i) = S_{i-1}(x_i) \;|\; i = 1 \ldots N-1$
3) Stetigkeit der 1. Abl.: $S_i'(x_i+0) = S_{i-1}'(x_i-0) \;|\; i = 1 \ldots N-1$
4) Stetigkeit der 2. Abl.: $S_i''(x_i+0) = S_{i-1}''(x_i-0) \;|\; i = 1 \ldots N-1$
5) Gleiche Krümmung a. d. R.: $S_0''(x_0) = S_{N-1}''(x_N)$

Digitale Messkette



Transformation

$U_{aus} = 1 - e^{a U_{ein}}$

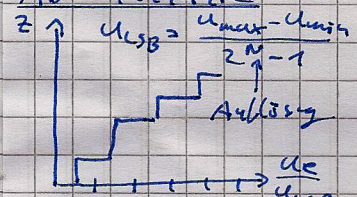
$1 - U_{aus} = e^{a U_{ein}}$

$(1 - U_{aus}) = a U_{ein}$

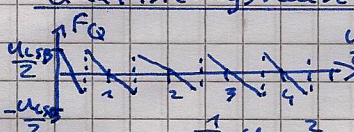
Grenzfrequenz d. Hellkreises

$$f_g = \sqrt{\frac{6\cdot U_{LSB}}{U_{max} - U_{min}}} \cdot \frac{1}{\pi T}$$

ADU-Kennlinie



Quantisierungsrauschen



$F_Q \sigma = \frac{1}{12} U_{LSB}^2$

Streuung: $U_N = \frac{U_{LSB}}{\sqrt{12}}$

$F_Q \leq \pm \frac{1}{2} U_{LSB}$

max Frequ.:

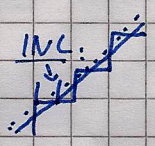
$$f_g = \frac{U_{LSB}}{2\cdot\pi\cdot\hat{u}\cdot T_c}$$

SNR

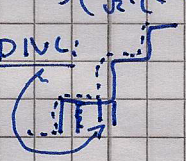
$$\frac{S}{R} = 20\log\left(\frac{U}{\sigma}\right)$$

$$= 20\log\left(\frac{\sqrt{3}}{\sqrt{2}}\left(2^N-1\right)\right)$$

INL:



DNL:



Aliasing Filter

Frequenzen $w_g > \frac{w_0}{2}$ dämpfen: $|A_F(\omega_0/2)|_{dB} \geq 20\cdot\log\left(\frac{U_{max}-U_{min}}{U_{LSB}}\right) = 20\cdot\log\left(2^N-1\right) dB \approx 6{,}02\,N \cdot dB$

Filterordnung: $\frac{dy}{dx} = \frac{|A_F(\omega_0/2)|_{dB}}{\log_{10}\left(\frac{\omega_0/2}{\omega_g}\right) - \log_{10}(1)}$

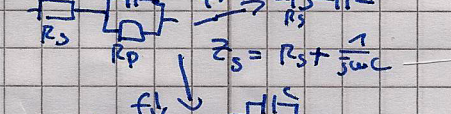
Gleichrichtwert

$$|\bar{i}| = \frac{1}{T}\int_t^{t+T} |i(t)|\,dt$$

Rms-Wert

$$I = \sqrt{\frac{1}{T}\int_t^{t+T} i^2(t)\,dt}$$

realer Kondensator



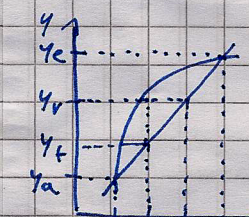
$Z_S = R_S + \frac{1}{j\omega C}$

$\tan\delta = \frac{1}{Q} = \omega R_P \cdot C_P = \frac{R_S}{\omega C_S}$

$Y_P = \frac{1}{R_P} + j\omega C$

$Z_P = \frac{R_P}{1 + j\omega R_P C}$

Kennlinienfehler



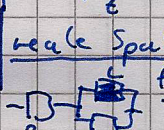
$F_{rlA} = \frac{y_v - y_t}{y_t}$

$F_{rlE} = \frac{y_v - y_t}{y_e}$

$F_r = \frac{y_v - y_t}{y_t - y_a}$

$F_{rlB} = \frac{y_v - y_t}{y_e - y_a}$

realer Spule

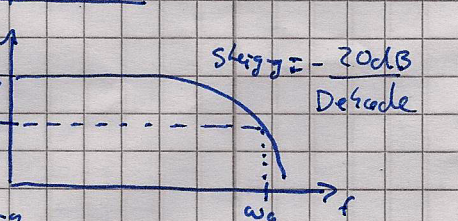


$\frac{1}{Z_P} = \frac{1}{R_P} + \frac{1}{j\omega L}$

$Z_S = R_S + j\omega L$

$\tan\delta = \frac{1}{Q} = \omega R_S L_S = \frac{\omega L_P}{R_P}$

Tiefpassfilter

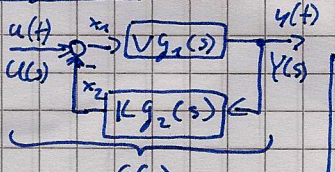


Steigung: $-\frac{20dB}{Dekade}$

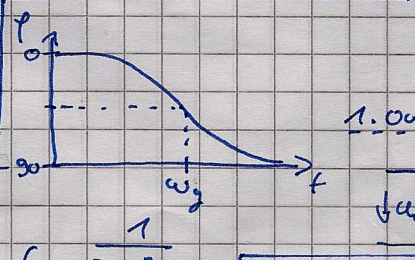
Signalformen

	F-Fakt.	C-Fakt.
⎍	1	1
/\/\	$\sqrt{3}$	$\frac{2}{\sqrt{3}}$
~	2	$\frac{\pi}{2\sqrt{2}}$

Regelkreis



$G(s) = \frac{Y(s)}{U(s)} = \frac{VG_2(s)}{1 + VG_2(s)\cdot KG_2(s)}$



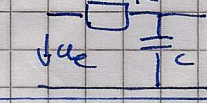
max. Fehlergrenzen

für komplexe Widerstand

$$\Delta z = \left|\frac{\partial z}{\partial R}\cdot g_R\right| + \left|\frac{\partial z}{\partial C}\cdot g_C\right| = g_z$$

allg.: $g = \pm \sum_{i=1}^{N} \left|\frac{dy}{dx_i}\, g_i\right|$

1. Ordnung



mit L u. R. s. 2. Seite

Charakteristika der Sprungantwort

$$f_c = \frac{1}{2\pi R\cdot C}$$

Einschwingzeit t_e: zw. SPd. Tangente in 0,5 h_∞ und h_∞

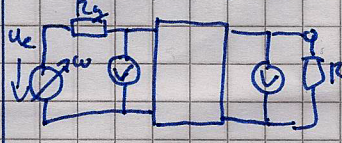
Anstiegszeit: $t_r = t_{90} - t_{10}$ Sprungantwort von 10% auf 90% des Endwertes

Einstellzeit t_s: def. Toleranzband wird nicht mehr verlassen

Verzugszeit: t_v: zw. Sprungeinsatz und Schnittp. von Wendetang. mit Nulllinie

Ausgleichszeit: t_g: zw. Schnittp. der WT u. NL und stat. Wert

Betragsfrequenzgang messen



$u_e(t) = \hat{u}_e \sin(\omega t)$

$u_a(t) = \hat{u}_a \sin(\omega t + \varphi)$

Leistungsmessung

$u \sim, i \sim$

$U_{eff} = \frac{\hat{u}}{\sqrt{2}}$

$p(t) = P + S\cos(2\omega t + \varphi_u + \varphi_i)$

$P = U \cdot I \cdot \cos\varphi = S \cdot \cos\varphi$

$Q = U \cdot I \cdot \sin\varphi = S \cdot \sin\varphi$

$S = U \cdot I$

W.F. $\lambda = \frac{P}{S} = \cos\varphi$ Bl.F. $\sin\varphi = \frac{Q}{S}$

Wechselstrommessbrücke

1. Abgleichbed.: $\frac{Z_1}{Z_2} = \frac{Z_3}{Z_4}$

2. Abgleichbed.: $\varphi_1 - \varphi_2 = \varphi_3 - \varphi_4$

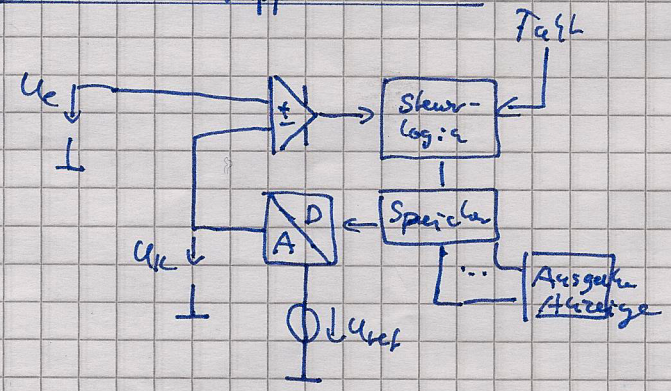
Empfindlichkeit: $\frac{\partial U}{\partial Z_x}$

statistische Sicherheit

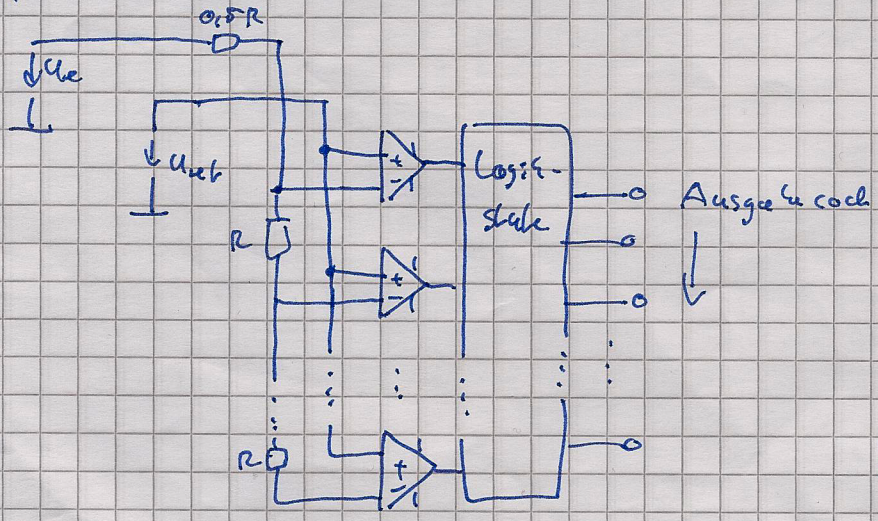
aus Tabelle

$V_{1,2} = \bar{x} \pm \frac{\epsilon \cdot \sigma}{\sqrt{N}}$

Sukzessive Approximation



paralleles Umsetzverfahren



$U \sim, I \sim$

$P = U \cdot I_1 \cdot \cos\varphi_1$

$S = U \cdot \sqrt{I_1^2 + I_2^2 + \ldots + I_N^2}$

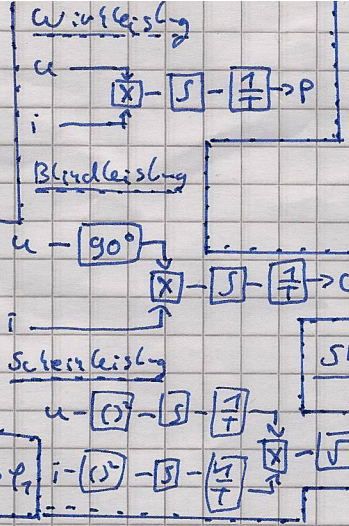
$Q_1 = U \cdot I_1 \cdot \sin\varphi_1$

$D = U \cdot \sqrt{I_2^2 + I_3^2 + \ldots + I_N^2}$

$Q = \sqrt{Q_1^2 + D^2}$

$\lambda = \frac{P}{S} = \frac{I_1}{I}\cos\varphi_1 = g \cdot \cos\varphi_1$

L.F.



mit Dimmer

$P(\vartheta) = \frac{1}{2\pi}\int_0^{2\pi} u(\omega t) \cdot i(\omega t, \vartheta)\, d\omega t$

$= \frac{1}{\pi}\int_\vartheta^\pi \hat{u}\sin(\omega t) \cdot \hat{i}\sin(\omega t)\, d\omega t$

$= \frac{\hat{u}\hat{i}}{2\pi}\int_\vartheta^\pi \sin^2(\omega t)\, d\omega t$

$= \frac{\hat{u}\hat{i}}{2\pi}\left(\pi - \vartheta + \frac{1}{2}\sin(2\vartheta)\right)$

Strom am Dimmer

$I = \sqrt{\frac{1}{T}\int_0^T i^2(t)\, dt}$

$= \hat{i}\sqrt{\frac{1}{2\pi}\left(\pi - \vartheta + \frac{1}{2}\sin(2\vartheta)\right)}$

Scheinleistung am Dimmer

$S = U_{eff} \cdot I_{eff}$

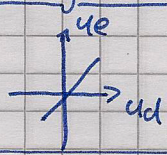
Verzerrungsleistung

$D = \sqrt{(U_{eff} \cdot I_{eff})^2 - P^2 - Q_1^2}$

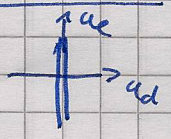
Filterordnung Aliasing Filter

$$-20\left(\log_{10}\left(\frac{U_{SS}}{U_{max} - U_{min}}\right)\right) \Big/ \left(\log_{10}\left(\frac{\omega_S}{2\omega_g}\right)\right)$$

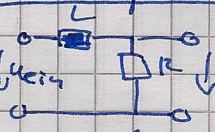
phasengleichheit



Phase + Betrag



L-R-Tiefpass 1. Ord



$f_g = \frac{1}{2\pi} \cdot \frac{R}{L}$

$A(\omega) = \frac{U_{aus}}{U_{ein}} = \frac{1}{\sqrt{1 + \left(\frac{\omega \cdot L}{R}\right)^2}}$

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

Klausureinsicht 04.03.2013
13 Uhr, EN 403