NTNU	Emne: IELET2106 Industriell instrumentering Øving: Formeloversikt	Sist oppdatert 24.08.2023

Generelt	
Måleomfang: $\text{Målevariabelomfang} = I_{maks} - I_{min}$ $\text{Målesignalomfang} = O_{maks} - O_{min}$ **Maksimal ulinearitet i % av målesignalomfanget:** $N = \frac{\hat{N}}{O_{maks} - O_{min}} \cdot 100\%$ **Maksimal hysterese i % av målesignalomfanget:** $H = \frac{\hat{H}}{O_{maks} - O_{min}} \cdot 100\%$ **Avvik i % av målesignalomfanget:** $E = \frac{O_{målt} - O_{ideell}}{O_{maks} - O_{min}} \cdot 100\%$ **Måleomformermodell:** $O(I) = (K + K_M \cdot I_M) \cdot I + K_I \cdot I_I + a + N(I)$ **Måleomformermodell parametere:** $K = \frac{O_{maks} - O_{min}}{I_{maks} - I_{min}}$ $a = O(I_{min})$ $K_I = \frac{\Delta O(I_{min})}{\Delta I_I}$ $K_M = \frac{1}{I_{50\%}} \cdot \frac{\Delta O(I_{50\%})}{\Delta I_M}$ $K_M = \frac{1}{I_{50\%}} \cdot \left(\frac{\Delta O(I_{50\%})}{\Delta I_{M,I}} - K_I\right)$ $I_{50\%} = \frac{I_{maks} + I_{min}}{2}$ **Regresjonsanalyse (minste kvadraters metode):** $q = \sum_{i=1}^{n} (y_i - \mathbf{y(x)})^2$ hvis $\mathbf{y(x)} = \mathbf{a} + \mathbf{b} \cdot \mathbf{x}$: $a \cdot n + b \cdot \sum_{i=1}^{n} x_i = \sum_{i=1}^{n} y_i$ $a \cdot \sum_{i=1}^{n} x_i + b \cdot \sum_{i=1}^{n} x_i^2 = \sum_{i=1}^{n} (x_i \cdot y_i)$	**Middelverdi:** $\overline{X} = \frac{1}{n} \cdot \sum_{i=1}^{n} X_i$ **Standardavvik:** $S = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1}^{n} (X_i - \overline{X})^2}$ **Standardavvik til middelverdien:** $S_{\overline{X}} = \frac{S}{\sqrt{n}}$ **95% - konfidensintervall:** $\overline{X} \pm 1{,}96 \cdot S_{\overline{X}}$ **GUM (guide to the expression of uncertainty in measurement):** $\overline{X} \pm k \cdot S_{\overline{X}}$ **Normalfordelingsfunksjon:** $f(x) = \frac{1}{\sqrt{2 \cdot \pi} \cdot \sigma} \cdot e^{-\frac{(X-\overline{X})^2}{2 \cdot \sigma^2}}$ **Usikkerhetsanalyse:** $U = f(u_1, \dots, u_n)$ $\overline{U} \pm \Delta u = f(\overline{u}_1 \pm \Delta u_1, \dots, \overline{u}_n \pm \Delta u_n)$ $\overline{U} = f(\overline{u}_1, \dots, \overline{u}_n)$ $\Delta u = \sqrt{\sum_{i=1}^{n} \left(\frac{\partial f}{\partial u_i} \cdot \Delta u_i\right)^2}$ $\Delta u_r = \frac{\Delta u}{U} = \sqrt{\sum_{i=1}^{n} \left(\frac{\partial f}{\partial u_i} \cdot \frac{\Delta u_i}{U}\right)^2}$

Elektronikk
Ohms lov: $V = R \cdot I$ **Aktiv effekt:** $P = V \cdot I$ **Sinusformede signaler:** $V(t) = \hat{A} \cdot \sin(\omega \cdot t) \quad \text{der} \quad \hat{A} = \sqrt{2} \cdot V_{RMS} \quad \text{og} \quad \omega = 2 \cdot \pi \cdot f$ **Serie- og parallellkobling av motstandere:** $R_s = \sum_{i=1}^{n} R_n \qquad \frac{1}{R_p} = \sum_{i=1}^{n} \frac{1}{R_n}$ **Kondensatorlikning:** $i_C = C \cdot \frac{du_C}{dt}$ **Reaktans for kondensatorer:** $X_C = \frac{1}{j \cdot \omega \cdot C} \quad \text{der} \quad \omega = 2 \cdot \pi \cdot f$ **Spolelikning:** $u_L = L \cdot \frac{di_L}{dt}$ **Reaktans for spoler:** $X_L = j \cdot \omega \cdot L \quad \text{der} \quad \omega = 2 \cdot \pi \cdot f$ **Impedans:** $Z = \text{Resistans} \pm \text{Reaktans} = R \pm X$ **Målebro:** $V_{ut} = V_{ut+} - V_{ut-} = V_{inn} \cdot \left(\frac{Z_3}{Z_1 + Z_3} - \frac{Z_4}{Z_2 + Z_4}\right) \quad \text{(ved ubelastet krets)}$ **Thévenin-ekvivalentskjema:** $V_{ut} = E_{Th} \quad \text{(ved ubelastet krets)}$ $V_{ut} = \frac{R_L}{R_{Th} + R_L} \cdot E_{Th} \quad \text{(ved belastet krets)}$ $R_{Th} = \left(\frac{R_1 \cdot R_3}{R_1 + R_3} + \frac{R_2 \cdot R_4}{R_2 + R_4}\right)$ **Opamp:** $V_{ut} = A \cdot \left(V_{inn} + \frac{V_{CM}}{CMRR}\right) \quad \text{der} \quad CMRR = \frac{A}{A_{CM}}$ **Instrumenteringsforsterker:** $V_{ut} = \left(1 + \frac{2 \cdot R}{R_g}\right) \cdot (V_{i+} - V_{i-})$ **Zenerbarriere:** $E_{total} = \frac{1}{2} \cdot L \cdot I^2 + \frac{1}{2} \cdot C \cdot {V_z}^2 \quad \text{der} \quad I = \frac{V_z}{R_z}$

Strekklapper
$R_0 = \frac{\delta \cdot L}{A_C}$ $\epsilon_L = \frac{\Delta L}{L}$ $\epsilon_D = \frac{\Delta D}{D} = -v_P \cdot \epsilon_L$ $\sigma_a = \frac{F_N}{A_C} = E_m \cdot \epsilon_L$ $\frac{\Delta R}{R_0} = (1 + 2 \cdot v_P) \cdot \epsilon_L + \frac{\Delta\delta}{\delta} = G_m \cdot \epsilon_L$

Trykk- og nivåmåling
$p_{\text{absolutt}} = p_{\text{atmosfære}} + p_{\text{relativt}}$ $\Delta p = \rho \cdot g \cdot \Delta h$ $\Delta p\ [\text{Pa}] = \rho_{H_2O} \cdot g \cdot \Delta p\ [\text{mVs}]$ $V = A_C \cdot h$ $m = \rho \cdot V$ $F = m \cdot g$ $F = A \cdot p$ $C = \frac{\varepsilon \cdot A}{d} \quad \text{der} \quad \varepsilon = \varepsilon_0 \cdot \varepsilon_r$ $L = \frac{\mu \cdot N^2 \cdot A}{x} \quad \text{der} \quad \mu = \mu_0 \cdot \mu_r$ $s = v \cdot t$ $h = \frac{c_{lyd} \cdot t}{2}$ $\lambda = c_{lyd} \cdot T \quad \text{der} \quad T = \frac{1}{f}$ $c_{lyd} = 331{,}5 \cdot \sqrt{1 + \frac{T}{273{,}15}}$ $t = \frac{T \cdot \Delta f}{f_2 - f_1}$ $c' = \sqrt{\frac{c}{\varepsilon_r}}$ $C = \frac{2 \cdot \pi \cdot \varepsilon_0 \cdot \left(H + h \cdot (\varepsilon_r - 1)\right)}{\ln(r_2/r_1)}$ $C = \frac{2 \cdot \pi \cdot \varepsilon_0 \cdot h}{(1/\varepsilon_{r1}) \cdot \ln(D_2/D_1) + (1/\varepsilon_{r2}) \cdot \ln(D_3/D_2)}$ $G = \frac{1}{R} = \frac{\sigma \cdot A_C}{L} \quad \text{der} \quad \sigma = \frac{1}{\delta}$

Strømningsmåling (mengdemåling)
$\tau = \frac{F}{A} = \mu \cdot \frac{dv}{dx}$ $\vartheta = \frac{\mu}{\rho}$ $Re = \frac{\rho \cdot \bar{v} \cdot D}{\mu}$ $q = A \cdot \bar{v}$ $\dot{m} = \rho \cdot A \cdot \bar{v}$ $\frac{p}{\rho} + \frac{1}{2} \cdot \bar{v}^2 + g \cdot z = \text{konstant}$ $E = B \cdot D \cdot \bar{v}$ $S = 0{,}198 \cdot \left(1 - \frac{19{,}7}{Re}\right)$ $f = \frac{S \cdot \bar{v}}{d}$ $\Delta t = t_{BA} - t_{AB} \approx \frac{2 \cdot L \cdot \cos\theta \cdot \bar{v}}{{c_{lyd}}^2}$ $\bar{v} = \frac{L}{2 \cdot \cos\theta} \cdot \frac{t_{BA} - t_{AB}}{t_{BA} \cdot t_{AB}}$

Temperaturmåling
$t_{°C} = \frac{5}{9} \cdot (t_{°F} - 32)$ $t_K = t_{°C} + 273{,}15$ $t_R = t_{°F} + 459{,}6$ $R_t = R_0 \cdot (1 + A \cdot t + B \cdot t^2 + \cdots)$ $R_t = R_0 \cdot (1 + A \cdot t + B \cdot t^2 + C \cdot (t - 100) \cdot t^3) \quad \text{der} \quad C = 0 \text{ når } t > 0℃$ $R_T = R_0 \cdot e^{\beta \cdot \left(\frac{1}{T} - \frac{1}{T_0}\right)}$ $f_t = f_0 \cdot (1 + A \cdot t + B \cdot t^2 + C \cdot t^3)$ $u_A = \int_{t_2}^{t_1} \alpha_A(T) \cdot dT \approx \alpha_A \cdot (t_1 - t_2)$ $t = \sum_0^N a_n \cdot E^n$ $\mathcal{R}_T = \sigma \cdot T^4$ $\mathcal{R}_{T,reell} = \varepsilon_\lambda \cdot \mathcal{R}_T$ $\mathcal{R}_\lambda = \frac{c_1 \cdot \lambda^{-5}}{e^{\frac{c_2}{\lambda \cdot T}} - 1} \approx \frac{c_1 \cdot \lambda^{-5}}{e^{\frac{c_2}{\lambda \cdot T}}}$ $\mathcal{R}_{\lambda,reell} = \varepsilon_\lambda \cdot \mathcal{R}_\lambda$ $\lambda_{maks} \cdot T = 2{,}898 \cdot 10^{-3}\ m \cdot K$ $\frac{T_t}{T_m} = \frac{1}{{\varepsilon_\lambda}^{1/4}}$ $\frac{1}{T_t} - \frac{1}{T_m} = \frac{\lambda \cdot \ln(\varepsilon_\lambda)}{c_2}$ $\frac{1}{T_t} - \frac{1}{T_m} = \frac{\ln(\varepsilon_{\lambda 1}/\varepsilon_{\lambda 2})}{c_2 \cdot \left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)}$

Posisjonsmåling
$V_o = \frac{x}{x_{maks}} \cdot V_s$ $\Delta\varphi = \frac{360^o}{N}$ $\Delta\varphi_{4x} = \frac{360^o}{4 \cdot N}$ $f = \frac{k_T}{T}$ $k_m = 60 \cdot f$ $n = \frac{k_m}{k_o}$ $\Delta n = \frac{60}{k_o \cdot T}$ $\Delta\varphi = \frac{360^o}{2^N}$ $(g_3 g_2 g_1 g_0)_{gray} \rightarrow (b_3 b_2 b_1 b_0)_{binær} \quad \text{der} \quad b_3 = g_3, b_2 = g_2 \text{ OR } g_3, b_1 = g_1 \text{ OR } b_2, b_0 = g_0 \text{ OR } b_1$

Akselerasjonsmåling
$F = m \cdot a = m \cdot \ddot{x}_m$ $F = D \cdot \dot{x}_0$ $F = k \cdot x_0$ $x_0 = x_i - x_m$ $\omega_0 = 2 \cdot \pi \cdot f_0 = \sqrt{\frac{k}{m}}$ $\zeta = \frac{D}{2 \cdot \sqrt{k \cdot m}}$ $z = \sqrt{(1 - u^2)^2 + (2 \cdot \zeta \cdot u)^2} \quad \text{der} \quad u = \frac{\omega}{\omega_0}$ $\left\lvert\frac{x_0}{x_i}\right\rvert = \frac{u^2}{z}$ $\left\lvert\frac{{\omega_0}^2 \cdot x_0}{a_0}\right\rvert = \frac{1}{z} \quad \text{der} \quad a_0 = \omega^2 \cdot x_i$

Konstanter
Permittivitet for vakuum: $\varepsilon_0 = 8{,}854 \cdot 10^{-12}$ F/m   Permeabilitet for vakuum: $\mu_0 = 4\pi \cdot 10^{-7}$ H/m   Tyngdeakselerasjon: $g = 9{,}81$ m/s^2 Lyshastighet: $c = 2{,}9979 \cdot 10^8$ m/s   Stefan − Boltzmanns konstant: $\sigma = 5{,}6705 \cdot 10^{-8}$ W/(m$^2 \cdot$ K^4)   Plancks konstant: $h = 6{,}6262 \cdot 10^{-34}$ J $\cdot$ s   Boltzmanns konstant: $k = 1{,}3807 \cdot 10^{-23}$ J/K $c_1 = 2 \cdot \pi \cdot h \cdot c^2 \approx 3{,}742 \cdot 10^{-16}$ W $\cdot$ m^2 $c_2 = h \cdot c/k \approx 0{,}0144$ m $\cdot$ K