

Mekatronikk og Servoteknikk

Formelhefte

Vedlegg 4 Formelsamling Servo

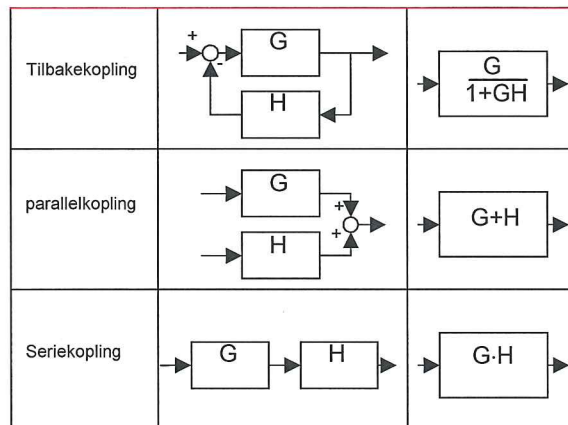
Laplace Transformasjon

Tabell Feil! Det er ingen tekst med den angitte stilen i dokumentet.-2 Laplace Transformasjon

	$f(t)$	$F(s)$
1.	Enhets impuls $\delta(t)$	1
2.	Enhets sprang $1(t)$	$\frac{1}{s}$
3.	Enhets rampe, t	$\frac{1}{s^2}$
4.	t^n ($n = 1, 2, 3, \dots$)	$\frac{n!}{s^{n+1}}$
5.	e^{-at}	$\frac{1}{(s+a)}$
6.	te^{-at}	$\frac{1}{(s+a)^2}$
7.	$\frac{1}{a}(1 - e^{-at})$	$\frac{1}{s(s+a)}$
8.	$\frac{1}{b-a}(e^{-at} - e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
9.	$\frac{1}{b-a}(be^{-bt} - ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
10.	$\frac{1}{ab} \left[1 + \frac{1}{a-b}(be^{-at} - ae^{-bt}) \right]$	$\frac{1}{s(s+a)(s+b)}$
11.	$e^{-at} \sin \omega t$	$\frac{\omega}{(s+a)^2 + \omega^2}$
12.	$\frac{\omega_n}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_n t} \sin(\omega_n \sqrt{1-\zeta^2} t)$ ($0 < \zeta < 1$)	$\frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$
13.	$1 - \frac{1}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_n t} \sin(\omega_n \sqrt{1-\zeta^2} t + \phi)$, $\phi = \tan^{-1} \frac{\sqrt{1-\zeta^2}}{\zeta}$ ($0 < \zeta < 1$, $0 < \phi < \pi/2$)	$\frac{\omega_n^2}{s(s^2 + 2\zeta\omega_n s + \omega_n^2)}$
14.	Sluttverdi teoremet	$\lim_{t \rightarrow \infty} f(t) = \lim_{s \rightarrow 0} sF(s)$

Blokk reduksjon

Tabell Feil! Det er ingen tekst med den angitte stilen i dokumentet.-3 Blokkreduksjon



Avvik
$$e(s) = R(s) \frac{1}{1 + K_p \cdot h_p(s)}$$

Systemtyper

Type nr angir antall reneintegratorer i åpensløyfe

Type 0 $h_{ol}(s) = K_p \cdot F(S)$

Type 1 $h_{ol}(s) = K_v \frac{1}{s} \cdot F(S)$

Type 2 $h_{ol}(s) = K_v \frac{1}{s^2} \cdot F(S)$

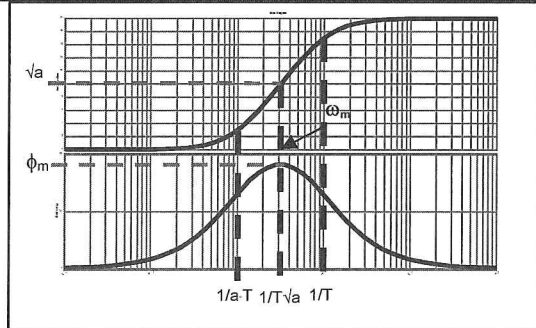
$$F(S) = \frac{(1 + T_a S)(1 + T_b S)(1 + T_c S) \dots}{(1 + T_1 S)(1 + T_2 S)(1 + T_3 S) \dots}$$

Tabell 4 Stasjonært avvik

Referansesignal \Rightarrow System type \Downarrow	Sprang $\frac{R}{s}$	Rampe $\frac{R}{s^2}$	Parabel $\frac{R}{s^3}$
Type 0 $h_{ol}(s) = K_p \cdot F(S)$	$e_{ss} = \frac{R}{1 + K_p}$	$e_{ss} = \infty$	$e_{ss} = \infty$
Type 1 $h_{ol}(s) = K_v \frac{1}{s} \cdot F(S)$	$e_{ss} = 0$	$e_{ss} = \frac{R}{K_v}$	$e_{ss} = \infty$
Type 2 $h_{ol}(s) = K_a \frac{1}{s^2} \cdot F(S)$	$e_{ss} = 0$	$e_{ss} = 0$	$e_{ss} = \frac{R}{K_a}$

Tabell 5 Lead lag kompensatoren

Lead kompensator



$$h_{\text{lead}}(s) = K \frac{a \cdot Ts + 1}{Ts + 1} \quad a > 1$$

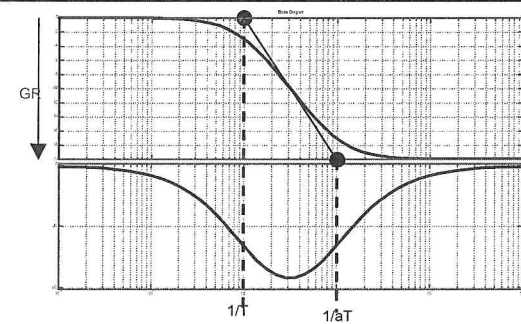
$$\sin(\phi_m) = \frac{a - 1}{a + 1} \quad \text{eller} \quad a = \frac{1 + \sin(\phi_m)}{1 - \sin(\phi_m)}$$

$$|h_{\text{lead}}(j\omega_m)| = |K| \sqrt{a}$$

$$|h_{\text{lead}}(j\omega_m) h_p(j\omega_m)| = 1$$

$$\frac{1}{T \cdot \sqrt{a}} = \omega_m \Rightarrow T = \frac{1}{\sqrt{a} \cdot \omega_m}$$

Lag kompensator

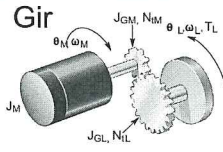
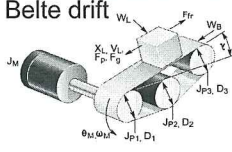
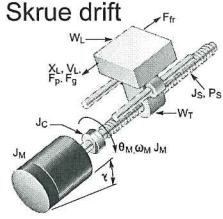


$$h_{\text{lead}}(s) = K \frac{a \cdot Ts + 1}{Ts + 1} \quad a < 1$$

$$GR = a = \frac{1}{F_C} = 10^{\frac{F_C[\text{dB}]}{20}}$$

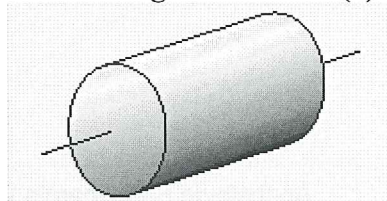
$$\frac{1}{T \cdot a} = \frac{\omega'}{10} \Rightarrow T = \frac{10}{a \cdot \omega'}$$

Tabell Transmisjoner

Transmisjon	Gir	Belte drift	Skrue drift	enhet
Masse treghets moment referert til motor aksel	 $J_{LM} = \frac{J_L}{n^2}$	 $J_{LM} = m_L \cdot r^2$	 $J_{LM} = m_L \left(\frac{p}{2 \cdot \pi} \right)^2$	Kgm ²
Dreievinkel motor	$\theta_m = n \cdot \theta_L$	$\theta_m = \frac{L_L}{r}$	$\theta_m = L_L \left(\frac{2 \cdot \pi}{p} \right)$	[rad]
Vinkelhastighet motor	$\omega_m = n \cdot \omega_L$	$\omega_m = \frac{v_L}{r}$	$\omega_m = V_L \left(\frac{2 \cdot \pi}{p} \right)$	[rad/s]
vinkel akselerasjon motor	$\alpha_m = n \cdot \alpha_L$	$\alpha_m = \frac{a_L}{r}$	$\alpha_m = a_L \left(\frac{2 \cdot \pi}{p} \right)$	[rad/s ²]
Moment motor aksel	$T_m = \frac{T_L}{n}$	$T_m = F_L \cdot r$	$T_m = F_L \cdot \left(\frac{P}{2 \cdot \pi} \right)$	[Nm]
Optimalt omsetningsforhold	$n_{opt} = \sqrt{\frac{J_L}{J_m}}$	$r_{opt} = \sqrt{\frac{J_m}{m}}$	$P_{opt} = 2 \cdot \pi \sqrt{\frac{J_r}{m}}$	

$$T_{rms} = \sqrt{\frac{T_1^2 \cdot t_1 + T_2^2 \cdot t_2 + T_3^2 \cdot t_3}{t_{syklus}}} =$$

Massetreghetsmoment (J)

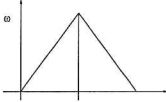
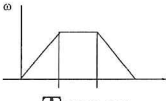
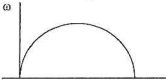


Figur 1 solid sylinder

$$J = \frac{\pi}{32} \cdot L \cdot D^4 \cdot \rho \text{ eller}$$

$$J = \frac{1}{8} \cdot m \cdot D^2$$

Tabell 6 Hastighets profiler

Hastighets profil	Max hastighet Lineær	Max akselerasjon Lineær	Max hastighet Rotasjon	Max akselerasjon Rotasjon
 Triangel	$V_{maks} = \frac{2 \cdot L}{t_d}$	$a_{maks} = \frac{4 \cdot L}{t_d^2}$	$\omega_{maks} = \frac{2 \cdot \theta}{t_d}$	$\alpha_{maks} = \frac{4 \cdot \theta}{t_d^2}$
 Trapez	$V_{maks} = \frac{3}{2} \cdot \frac{L}{t_d}$	$a_{maks} = \frac{9}{2} \cdot \frac{L}{t_d^2}$	$\omega_{maks} = \frac{3}{2} \cdot \frac{\theta}{t_d}$	$\alpha_{maks} = \frac{9}{2} \cdot \frac{\theta}{t_d^2}$
 Parabel	$V_{maks} = \frac{3}{2} \cdot \frac{L}{t_d}$	$a_{maks} = \frac{6 \cdot L}{t_d^2}$	$\omega_{maks} = \frac{3}{2} \cdot \frac{\theta}{t_d}$	$\alpha_{maks} = \frac{6 \cdot \theta}{t_d^2}$

Motor ligninger:

$$\tau_m = \frac{J \cdot R_a}{K_e K_T}$$

$$\tau_{el} = \frac{L_a}{R_a}$$

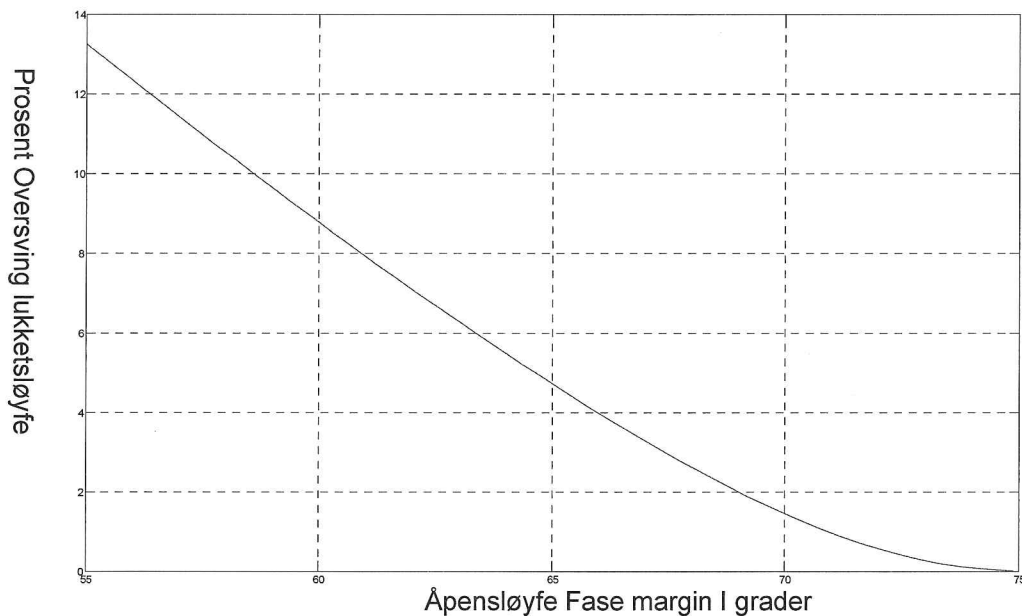
Spenningsbalanse

$$L_a \frac{dI_a}{dt} = U - R_a I_a - K_e \omega$$

Momentbalanse

$$J \frac{d\omega}{dt} = K_T I_a - B \cdot \omega - T_L$$

Oversving som funksjon av fasemargin



Røff beregning av responstid

$$T_r = \frac{1.8}{\omega_{BW}} \text{ og } \omega_{BW} \approx \omega_c$$

Mekatronikk Formler

Vedlegg 1

Formel samling

Elementære funksjoner:

- a) $\ln y = x \Leftrightarrow y = e^x$ $a^x = b \Leftrightarrow x = \log_a b = \frac{\ln b}{\ln a}$
- b) $\ln(AB) = \ln A + \ln B$, $\ln \frac{A}{B} = \ln A - \ln B$ $\ln A^u = u \ln A$
- c) $\sin^2 x + \cos^2 x = 1$ $\tan x = \frac{\sin x}{\cos x}$ $\cot x = \frac{1}{\tan x}$
- c) $\sin(x \pm y) = \sin x \cos y \pm \cos x \sin y$, $\cos(x \pm y) = \cos x \cos y \mp \sin x \sin y$
- d) $\sin 2x = 2 \sin x \cos x$ $\cos 2x = \cos^2 x - \sin^2 x = 2 \cos^2 x - 1 = 1 - 2 \sin^2 x$
- e) $\tan(x \pm y) = \frac{\tan x \pm \tan y}{1 \mp \tan x \cdot \tan y}$
- f) $\cos u \cos v = \frac{1}{2} (\cos(u+v) + \cos(u-v))$
- g) $\sin u \cos v = \frac{1}{2} (\sin(u+v) + \sin(u-v))$ $\sin u \sin v = \frac{1}{2} (\cos(u-v) - \cos(u+v))$
- h) $A \sin x \pm B \cos x = \sqrt{A^2 + B^2} \sin(x \pm \phi)$ der $A > 0, B > 0, \tan \phi = \frac{B}{A}$ og $0 < \phi < \frac{\pi}{2}$

Differensiallikninger av 2. orden

Differensiallikningen $ay'' + by' + cy = 0$, der a, b og c er konstanter og $a \neq 0$, har den generelle løsningen

- a) $y = C_1 e^{r_1 x} + C_2 e^{r_2 x}$ hvis $a\lambda^2 + b\lambda + c = 0$ har to ulike reelle røtter r_1 og r_2
- b) $y = (C_1 + C_2 x)e^{rx}$ hvis $a\lambda^2 + b\lambda + c = 0$ har dobbelroten r
- c) $y = e^{\alpha x} (A \cos \beta x + B \sin \beta x)$ hvis $a\lambda^2 + b\lambda + c = 0$ har komplekse røtter $\alpha \pm i\beta$

Setninger om forventning og varians for stokastiske variable

- a) La X_1, X_2, \dots, X_n være stokastiske variable og a_1, a_2, \dots, a_n, b være konstanter
- (i) Da er $E(a_1 X_1 + a_2 X_2 + \dots + a_n X_n + b) = a_1 E(X_1) + a_2 E(X_2) + \dots + a_n E(X_n) + b$
- (ii) Hvis X_1, X_2, \dots, X_n er uavhengige er
- $$\text{Var}(a_1 X_1 + a_2 X_2 + \dots + a_n X_n + b) = a_1^2 \text{Var}(X_1) + a_2^2 \text{Var}(X_2) + \dots + a_n^2 \text{Var}(X_n)$$
- b) Spesialtilfelle av a) : Hvis X_1, X_2, \dots, X_n er uavhengige stokastiske variable og alle har samme forventning μ og samme varians σ^2 vil $E(\bar{X}) = \mu$ og
- $$\text{Var}(\bar{X}) = \frac{\sigma^2}{n} \quad \text{der } \bar{X} = \frac{1}{n} \sum_{i=1}^n X_i$$
- c) Normalfordelingen
- $$f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{1}{2} \frac{(x-\mu)^2}{\sigma^2}}$$
- $$E(X) = \mu \quad \text{Var}(X) = \sigma^2 \quad \text{Var}(\bar{X}) = \frac{\sigma^2}{n} \quad \sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

d) Standard normalfordeling $Z = \frac{X - \mu}{\sigma}$

$I = \left[\bar{x} - u_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}}, \bar{x} + u_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}} \right]$	Konfidensintervall for μ når σ er kjent
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Fei i sammensatte målinger

$$R = f(x, y, z)$$

$$\sigma_R = \sqrt{\sigma_x^2 \left(\frac{\partial R}{\partial x} \right)^2 + \sigma_y^2 \left(\frac{\partial R}{\partial y} \right)^2 + \sigma_z^2 \left(\frac{\partial R}{\partial z} \right)^2}$$

Kurvetilpassing

$$Y_m = [y_1 \ y_2 \ y_3 \ \dots \ y_m]$$

$$y = C_0 + C_1 \cdot x + C_2 \cdot x^2 + C_3 \cdot x^3 \dots C_n \cdot x^n$$

$$C = (X^T X)^{-1} X^T \cdot Y_m$$

$$\text{Der } X = \begin{bmatrix} 1 & X_1 & \dots & X_1^n \\ 1 & X_2 & & X_2^n \\ \vdots & \vdots & & \vdots \\ 1 & X_m & & X_m^n \end{bmatrix}$$

Standard normalfordeling

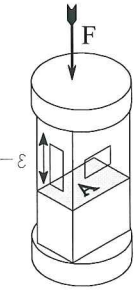
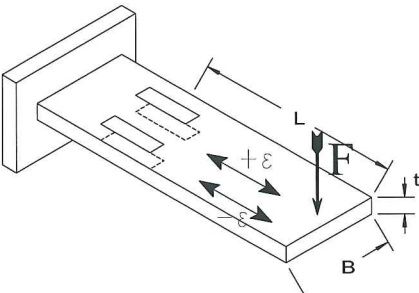
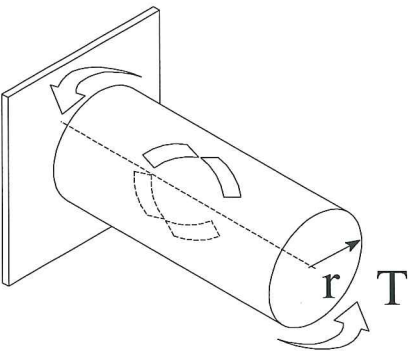
z	0	1	2	3	4	5	6	7	8	9
0,0	0,50000	0,50399	0,50798	0,51197	0,51595	0,51994	0,52392	0,52790	0,53188	0,53586
0,1	0,53983	0,54380	0,54776	0,55172	0,55567	0,55962	0,56356	0,56749	0,57142	0,57535
0,2	0,57926	0,58317	0,58706	0,59095	0,59483	0,59871	0,60257	0,60642	0,61026	0,61409
0,3	0,61791	0,62172	0,62552	0,62930	0,63307	0,63683	0,64058	0,64431	0,64803	0,65173
0,4	0,65542	0,65910	0,66276	0,66640	0,67003	0,67364	0,67724	0,68082	0,68439	0,68793
0,5	0,69146	0,69497	0,69847	0,70194	0,70540	0,70884	0,71226	0,71566	0,71904	0,72240
0,6	0,72575	0,72907	0,73237	0,73565	0,73891	0,74215	0,74537	0,74857	0,75175	0,75490
0,7	0,75804	0,76115	0,76424	0,76730	0,77035	0,77337	0,77637	0,77935	0,78230	0,78524
0,8	0,78814	0,79103	0,79389	0,79673	0,79955	0,80234	0,80511	0,80785	0,81057	0,81327
0,9	0,81594	0,81859	0,82121	0,82381	0,82639	0,82894	0,83147	0,83398	0,83646	0,83891
1,0	0,84134	0,84375	0,84614	0,84849	0,85083	0,85314	0,85543	0,85769	0,85993	0,86214
1,1	0,86433	0,86650	0,86864	0,87076	0,87286	0,87493	0,87698	0,87900	0,88100	0,88298
1,2	0,88493	0,88686	0,88877	0,89065	0,89251	0,89435	0,89617	0,89796	0,89973	0,90147
1,3	0,90320	0,90490	0,90658	0,90824	0,90988	0,91149	0,91309	0,91466	0,91621	0,91774
1,4	0,91924	0,92073	0,92220	0,92364	0,92507	0,92647	0,92785	0,92922	0,93056	0,93189
1,5	0,93319	0,93448	0,93574	0,93699	0,93822	0,93943	0,94062	0,94179	0,94295	0,94408
1,6	0,94520	0,94630	0,94738	0,94845	0,94950	0,95053	0,95154	0,95254	0,95352	0,95449
1,7	0,95543	0,95637	0,95728	0,95818	0,95907	0,95994	0,96080	0,96164	0,96246	0,96327
1,8	0,96407	0,96485	0,96562	0,96638	0,96712	0,96784	0,96856	0,96926	0,96995	0,97062
1,9	0,97128	0,97193	0,97257	0,97320	0,97381	0,97441	0,97500	0,97558	0,97615	0,97670
2,0	0,97725	0,97778	0,97831	0,97882	0,97932	0,97982	0,98030	0,98077	0,98124	0,98169
2,1	0,98214	0,98257	0,98300	0,98341	0,98382	0,98422	0,98461	0,98500	0,98537	0,98574
2,2	0,98610	0,98645	0,98679	0,98713	0,98745	0,98778	0,98809	0,98840	0,98870	0,98899
2,3	0,98928	0,98956	0,98983	0,99010	0,99036	0,99061	0,99086	0,99111	0,99134	0,99158
2,4	0,99180	0,99202	0,99224	0,99245	0,99266	0,99286	0,99305	0,99324	0,99343	0,99361
2,5	0,99379	0,99396	0,99413	0,99430	0,99446	0,99461	0,99477	0,99492	0,99506	0,99520
2,6	0,99534	0,99547	0,99560	0,99573	0,99585	0,99598	0,99609	0,99621	0,99632	0,99643
2,7	0,99653	0,99664	0,99674	0,99683	0,99693	0,99702	0,99711	0,99720	0,99728	0,99736
2,8	0,99744	0,99752	0,99760	0,99767	0,99774	0,99781	0,99788	0,99795	0,99801	0,99807
2,9	0,99813	0,99819	0,99825	0,99831	0,99836	0,99841	0,99846	0,99851	0,99856	0,99861
	0	1	2	3	4	5	6	7		

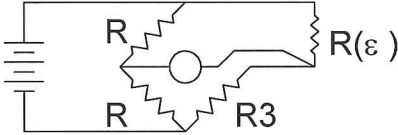
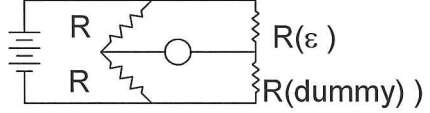
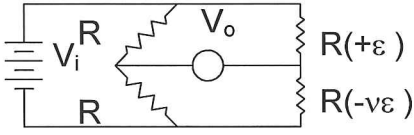
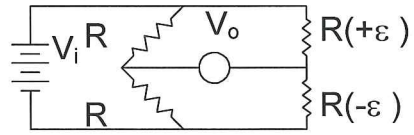
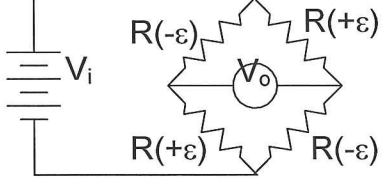
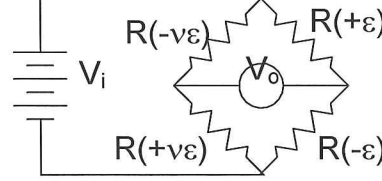
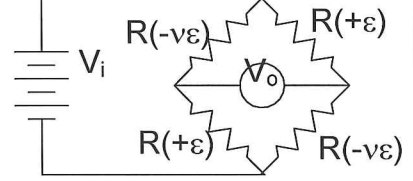
Laplace transformasjon

	f(t)	F(s)
1.	Enhets impuls $\delta(t)$	1
2.	Enhets sprang $1(t)$	$\frac{1}{s}$
3.	Enhets rampe , t	$\frac{1}{s^2}$
4.	t^n (n=1, 2, 3,.....)	$\frac{n!}{s^{n+1}}$
5.	e^{-at}	$\frac{1}{(s+a)}$
6.	te^{-at}	$\frac{1}{(s+a)^2}$
7.	$\frac{1}{a}(1-e^{-at})$	$\frac{1}{s(s+a)}$
8.	$\frac{1}{b-a}(e^{-at} - e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
9.	$\frac{1}{b-a}(be^{-bt} - ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
10.	$\frac{1}{ab}\left[1 + \frac{1}{a-b}(be^{-at} - ae^{-bt})\right]$	$\frac{1}{s(s+a)(s+b)}$
11.	$e^{-at} \sin \omega t$	$\frac{\omega}{(s+a)^2 + \omega^2}$
12.	$\frac{\omega_n}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_n t} \sin(\omega_n \sqrt{1-\zeta^2} t)$ ($0 < \zeta < 1$)	$\frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$
13.	$1 - \frac{1}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_n t} \sin(\omega_n \sqrt{1-\zeta^2} t + \phi)$, $\phi = \tan^{-1} \frac{\sqrt{1-\zeta^2}}{\zeta}$ ($0 < \zeta < 1$, $0 < \phi < \pi/2$)	$\frac{\omega_n^2}{s(s^2 + 2\zeta\omega_n s + \omega_n^2)}$
14.	Sluttverdi teoremet	$\lim_{t \rightarrow \infty} f(t) = \lim_{s \rightarrow 0} sF(s)$

Strekkklapp måling

$$\varepsilon = \frac{\Delta L}{L} \quad \frac{\Delta R}{R} = GF \frac{\Delta L}{L}$$

Kompresjon	Nedbøyning	Torsjon
		
$\varepsilon = \frac{F}{E \cdot A}$	$\varepsilon = \frac{6 \cdot F \cdot L}{E \cdot B \cdot t^2}$	$\varepsilon = \frac{T}{\pi \cdot G \cdot r^3}$

<p>Kvart Bro</p> 		
$\varepsilon \approx \frac{4 \cdot V_o}{GF \cdot V_i}$	$\varepsilon \approx \frac{4 \cdot V_o}{GF \cdot V_i}$	
<p>Halv bro</p> <p>Aksiell</p> 	<p>Bøying</p> 	
$\varepsilon = \frac{4V_o}{V_i \cdot GF(1+\nu)}$	$\varepsilon = \frac{2 \cdot V_o}{GF \cdot V_i}$	
<p>Fullbro</p> 		<p>Aksiell</p> 
$\varepsilon = \frac{V_o}{GF \cdot V_i}$	$\varepsilon = \frac{2V_o}{V_i \cdot GF[(1+\nu) - \frac{V_o}{V_i}(1-\nu)]}$	$\varepsilon = \frac{4V_o}{V_i \cdot GF[(1+\nu) - \frac{V_o}{V_i}(1-\nu)]}$

Elektriske kretser

resistans i en ledere

$$R = \rho \frac{l}{A}$$

ρ = Resistivitet [Ωm]

l = lengde [m]

A = Areal [m^2]

seriekoppling

$$R_S = R_1 + R_2 + \dots$$

parallellkoppling

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

kondensator

$$Q = CU$$

$$U_C = \frac{1}{C} \int_0^t I \cdot dt$$

RC ledd

$$\tau = RC$$

V_F = sluttverdi

RC ledd oppladning /utladning

$$U_C(t) = V_F - (V_F - V_I)e^{-t/\tau}$$

V_I = startverdi

plattkondensator

$$C = \epsilon \frac{A}{d} = \epsilon_r \epsilon_0 \frac{A}{d}$$

ϵ_0 = permittivitet vakuum

ϵ_r = Relativpermittivitet

A er det felles arealet

d er avstanden mellom platene

dielektrisitetskonstanten for vakuum

$$\epsilon_0 \approx 8,854 \cdot 10^{-12} \text{ C}^2/(\text{Nm}^2)$$

Reluktans

$$\mathfrak{R} = \frac{L}{\mu_0 \mu_r \cdot A}$$

L = Lengde, $\mu_0 = 4\pi \times 10^{-7}$

A = Areal. μ_r = Relativ permeabilitet

Induktans

$$L = \frac{N^2}{\mathfrak{R}}$$

N = Viklingstall

Induktiv reaktans

$$X_L = j\omega L$$

Kapasitiv reaktans

$$X_C = \frac{1}{j\omega C}$$

Kirchhoffs første lov

$$\sum_{n \in \text{Nod}} I_n = 0$$

I et punkt

Kirchhoffs andre lov

$$\sum_{Krets} V_n = 0$$

I en sløyfe

Faradays induksjons lov

$$e = -N \frac{d\phi_m}{dt}$$

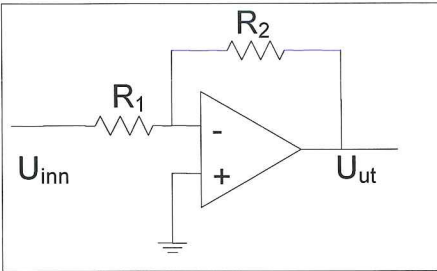
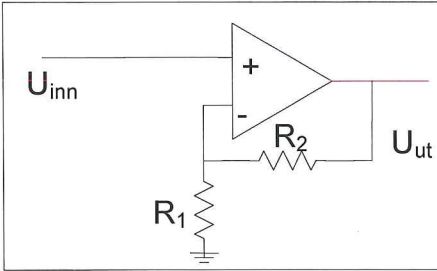
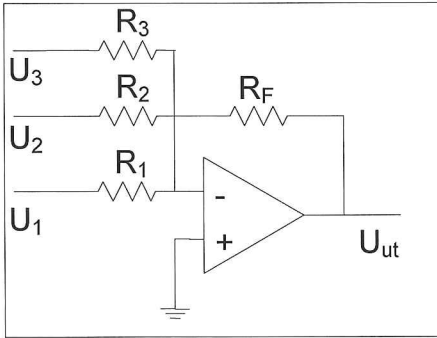
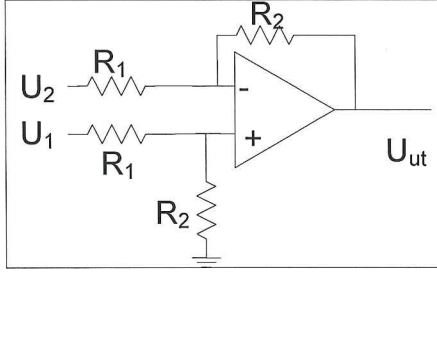
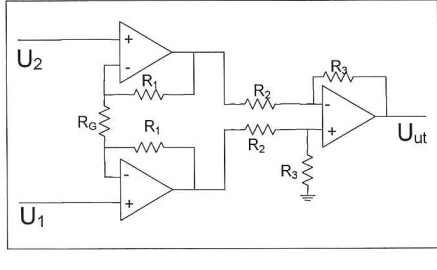
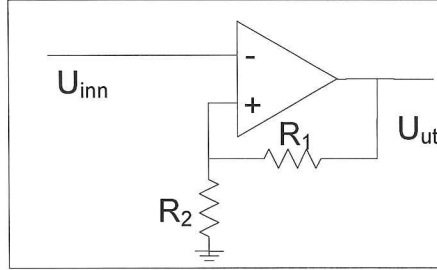
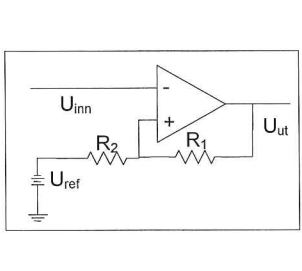
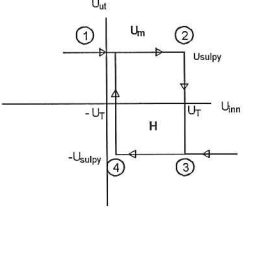
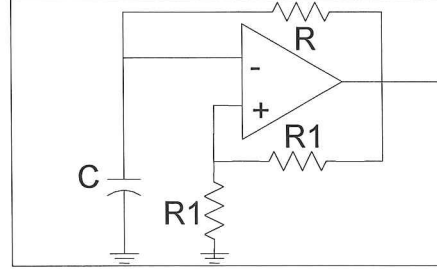
Fluks og induktans

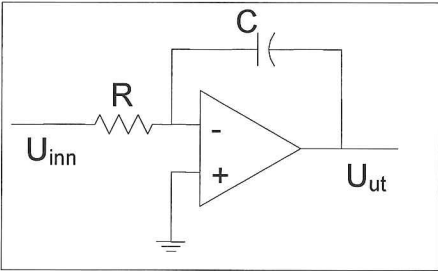
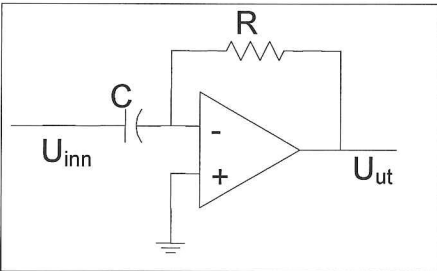
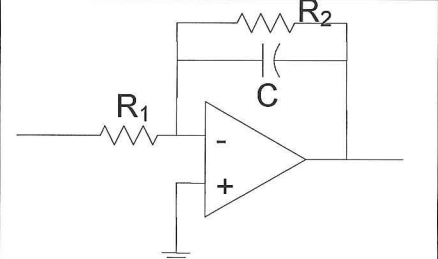
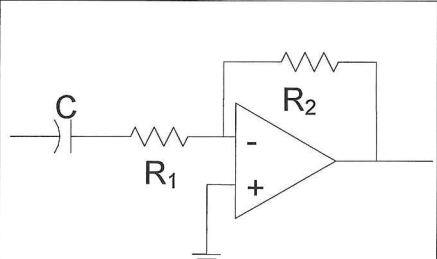
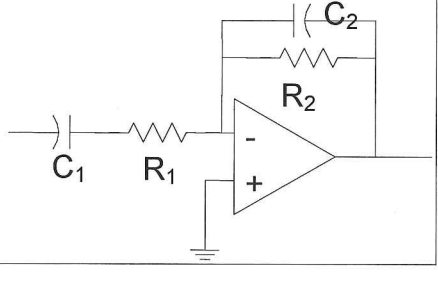
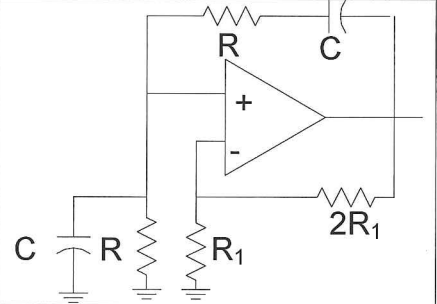
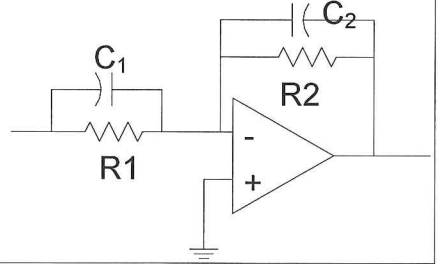
$$\Phi = BA_{\perp} = BA \cos \alpha$$

$$\epsilon = lvB$$

$$\epsilon = N \frac{\Delta\Phi}{\Delta t} \text{ eller } \epsilon = N \frac{d\Phi}{dt}$$

$$\epsilon = L \frac{\Delta i}{\Delta t} \text{ eller } \epsilon = L \frac{di}{dt}$$

	
<p>Inverterende kopling</p> $\frac{U_{ut}}{U_{inn}} = -\frac{R_2}{R_1}$	<p>Ikke Inverterende kopling</p> $\frac{U_{ut}}{U_{inn}} = 1 + \frac{R_2}{R_1}$
	
<p>Sumator</p> $U_{ut} = -\left(\frac{R_F}{R_1} U_1 + \frac{R_F}{R_2} U_2 + \frac{R_F}{R_3} U_3\right)$	<p>Differensial forsterker</p> $U_{ut} = \frac{R_2}{R_1} (U_1 - U_2)$
	
<p>Instrumenterings forsterker</p> $U_{ut} = \left(1 + \frac{2R_1}{R_G}\right) \cdot \frac{R_3}{R_2} \cdot (U_1 - U_2)$	<p>Schmitt-triggere</p> $H = \frac{2 \cdot R_2}{R_2 + R_1} U_{supply} \Rightarrow U_{\pm T} = \pm \frac{R_2}{R_2 + R_1} U_{supply}$
 	
<p>Schmitt-triggere</p> $H = \frac{2 \cdot R_2}{R_2 + R_1} U_{supply} \quad U_m = \frac{R_1}{R_2 + R_1} U_{ref}$	<p>Relaksjons oscillator</p> $f = \frac{1}{2.2 \cdot RC} \Rightarrow T_p = 2.2 \cdot RC$

	
<p>Integrator</p> $U_{ut} = -\frac{1}{RC} \int_0^t U_{inn} dt$	<p>Derivator</p> $U_{ut} = -RC \frac{dU_{inn}}{dt}$
	
<p>Lavpass</p> $H(j\omega) = -\frac{R_2}{R_1} \cdot \frac{1}{j\omega R_2 C + 1}$	<p>Høypass</p> $H(j\omega) = -\frac{j\omega R_2 C}{j\omega R_1 C + 1}$
	
<p>Båndpass</p> $H(j\omega) = \frac{j\omega R_2 C_1}{(j\omega R_2 C_2 + 1)(j\omega R_1 C_1 + 1)}$	<p>Wien bridge oscillator $f = \frac{1}{2 \cdot \pi RC}$</p>
	
<p>Lead eller lag</p> $H(j\omega) = \frac{R_2}{R_1} \cdot \frac{j\omega C_2 R_2 + 1}{j\omega C_1 R_1 + 1}$	