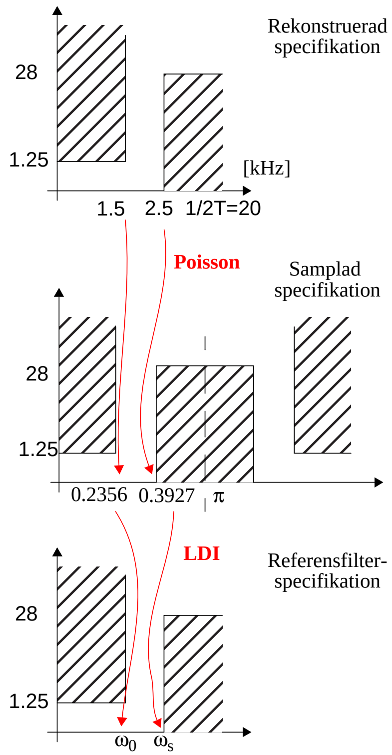
Lektion 9 – Extra

Uppgift K40



$$\omega_c = \omega_0 = 2\pi \cdot 1500 \text{ rad/s}$$

$$s_0 = \frac{\omega_c}{2\sin(\Omega_c/2)} = $$

$$= \frac{3000\pi}{2\sin\left(\left(\frac{1.5}{40}2\pi\right)/2\right)} \approx 40.093 \text{ krad/s}$$

$$\omega_s = 2 s_0 \sin(\Omega_s/2) \approx$$

$$\approx 2 \cdot 40093 \cdot \sin\left(\left(\frac{2.5}{40}2\pi\right)/2\right) \approx$$

$$\approx 15.643 \text{ krad/s}$$

Normerade värden:

$$C_{1n} = C_{3n} = 1.9314,$$

$$C_{2n} = 0.3781 \text{ och}$$

$$L_{2n} = 0.7571$$

Avnormering genom

$$L_i = \frac{R_0}{\omega_0} L_{in} \text{ och } C_i = \frac{1}{\omega_0 R_0} C_{in}$$

Detta ger att:

$$C_1 = C_3 = 204.9nF$$

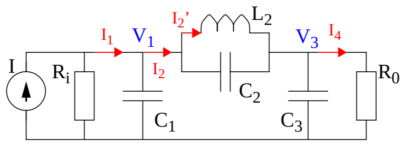
$$L_2 = 80.3mH$$

$$C_2 = 40.1nF$$

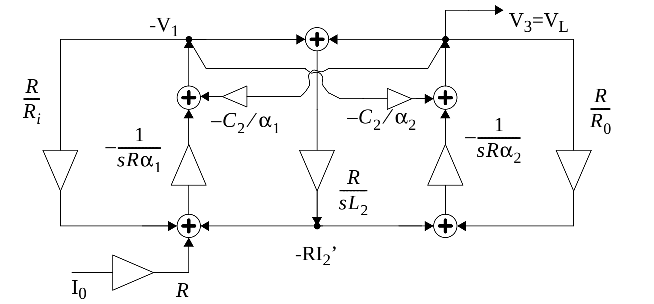
$$RI_0 = RI_i - \frac{R}{R_i} V_1$$

$$V_1 = \frac{1}{sRC_1}(RI_0 - RI_2)$$

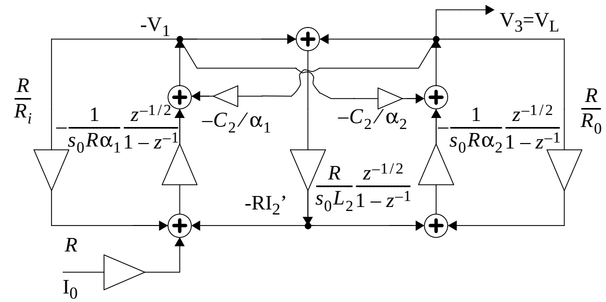
$$RI_2 = \frac{R}{(sL_2) \parallel (1/sC_2)}(V_1 - V_3)$$



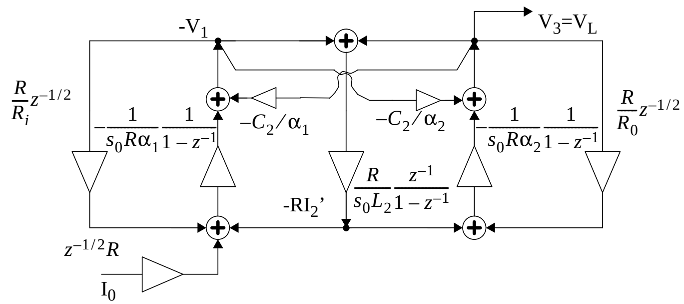
$$V_3 = \frac{1}{sRC_3}(RI_2 - RI_4) \text{ samt } RI_4 = \frac{R}{R_0} V_3 = \frac{R}{R_0} V_L$$

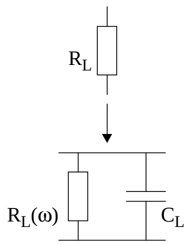


$$s = s_0 \frac{z-1}{z^{1/2}}$$



Elminera $z^{-1/2}$.





Eliminera $\frac{R}{R_L}z^{-1/2}$.

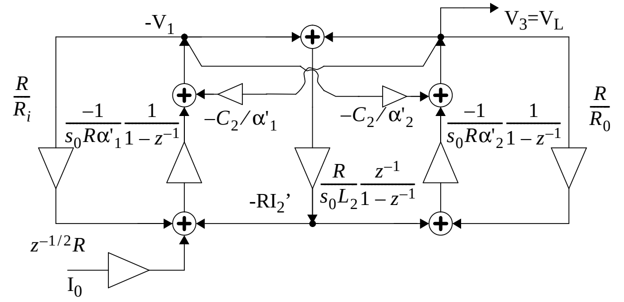
Sätt $R_L = R_L z^{-1/2}$ där $z^{-1/2} = -j\frac{\omega}{2s_0} + \sqrt{1-\left(\frac{\omega}{2s_0}\right)^2}$ vilket ger

$$R_L \to R_L(\omega) \parallel C_L$$

$$C_1' = C_1 - C_i = C_1 - 1/2s_0R_i = C_1 - \sin(\Omega_0T/2)/(\omega_0R_i)$$

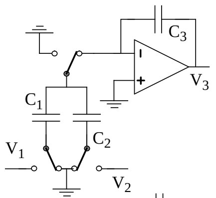
$$C_3' = C_3 - C_L = C_3 - 1/2s_0R_L = C_3 - \sin(\Omega_0T/2)/(\omega_0R_L)$$

α_1 och α_2 ändras till α_1' respektive α_2'.



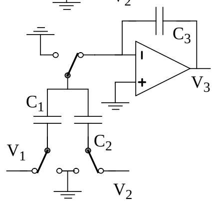
$$V_3(z) = \frac{z^{-1}}{1-z^{-1}}\cdot\left[\frac{C_1}{C_3}\cdot V_1(z) + \frac{C_2}{C_3}\cdot V_2(z)\right]$$

(Snabbkontroll: Ingen direktkoppling mellan in och ut.)



$$V_3(z) = -\frac{1}{1-z^{-1}}\cdot\left[\frac{C_1}{C_3}\cdot V_1(z) + \frac{C_2}{C_3}\cdot V_2(z)\right]$$

(Snabbkontroll: Direktkoppling mellan in och ut.)



Jämförelse av signalvägar

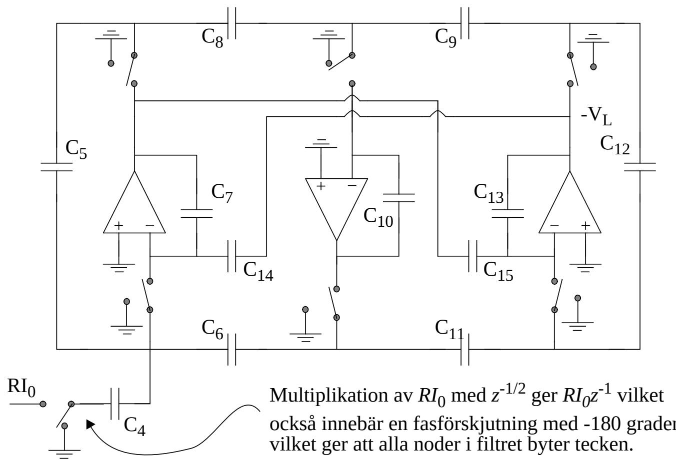
Det antas att $R_i = R_L = R$ och att $s_0 = \frac{\omega_c}{2\sin(\Omega_c/2)}$ och

$C_i' = C_i - 1/2s_0R$

SC-filter	Signalflödesschema	Resultat
$[-V_1]_E = -\frac{C_4}{C_7}\frac{z^{-1/2}}{1-z^{-1}}$	$[-V_1]_E = -\frac{1}{s_0R_i\alpha_1'}\cdot\frac{z^{-1/2}}{1-z^{-1}}$	$\frac{C_4}{C_7} = \frac{1}{s_0R_i\alpha_1'}$
$[-V_1]_{-RI_2'} = -\frac{C_6}{C_7}\frac{1}{1-z^{-1}}$	$[-V_1]_{-RI_2'} = -\frac{1}{s_0R\alpha_1'}$	$\frac{C_6}{C_7} = \frac{1}{s_0R\alpha_1'}$
$[-V_1]_{-V_1} = -\frac{C_5}{C_7}\frac{1}{1-z^{-1}}$	$[-V_1]_{-V_1} = -\frac{1}{s_0R\alpha_1'}\frac{R}{R_i} = -\frac{1}{s_0R_i\alpha_1'}$	$\frac{C_5}{C_7} = \frac{1}{s_0R_i\alpha_1'}$
$[-RI_2']_{-V_1} = \frac{C_8}{C_{10}}\frac{z^{-1}}{1-z^{-1}}$	$[-RI_2']_{-V_1} = \frac{R}{s_0L_2}\frac{z^{-1}}{1-z^{-1}}$	$\frac{C_8}{C_{10}} = \frac{R}{s_0L_2}$
$[-RI_2']_{V_3} = \frac{C_9}{C_{10}}\frac{z^{-1}}{1-z^{-1}}$	$[-RI_2']_{V_3} = \frac{R}{s_0L_2}\frac{z^{-1}}{1-z^{-1}}$	$\frac{C_9}{C_{10}} = \frac{R}{s_0L_2}$
$[V_3]_{-RI_2'} = -\frac{C_{11}}{C_{13}}\cdot\frac{1}{1-z^{-1}}$	$[V_3]_{-RI_2'} = -\frac{R}{R_L}\cdot\frac{1}{s_0RC_3}\cdot\frac{1}{1-z^{-1}}$	$\frac{C_{11}}{C_{13}} = \frac{1}{s_0R_L\alpha_3'}$
$[V_3]_{V_3} = -\frac{C_{12}}{C_{13}}\frac{1}{1-z^{-1}}$	$[V_3]_{V_3} = -\frac{R}{R_L}\cdot\frac{1}{s_0RC_3}\cdot\frac{1}{1-z^{-1}}$	$\frac{C_{12}}{C_{13}} = \frac{1}{s_0R_L\alpha_3'}$

För återkopplingarna gäller att:

$[-V_1]_{V_3} = -\frac{C_{14}}{C_7}$	$[-V_1]_{V_3} = -\frac{C_2}{\alpha_1'}$	$\frac{C_{14}}{C_7} = \frac{C_2}{\alpha_1'}$
$[V_3]_{-V_1} = -\frac{C_{15}}{C_{13}}$	$[V_3]_{-V_1} = -\frac{C_2}{\alpha_3'}$	$\frac{C_{15}}{C_{13}} = \frac{C_2}{\alpha_3'}$



Multiplikation av RI_0 med $z^{-1/2}$ ger RI_0z^{-1} vilket också innebär en fasförskjutning med -180 grader, vilket ger att alla noder i filtret byter tecken.

Vilket ger att:

$$\frac{C_4}{C_7}=\frac{C_5}{C_7}=\frac{C_6}{C_7}=\left[\frac{\omega_c R(C_1+C_2)}{2\sin(\Omega_c/2)}-\frac{R}{2R}\right]^{-1},\ \frac{C_{11}}{C_{13}}=\frac{C_{12}}{C_{13}}=\left[\frac{\omega_c R(C_3+C_2)}{2\sin(\Omega_c/2)}-\frac{R}{2R}\right]^{-1}$$

$$\frac{C_8}{C_{10}}=\frac{C_9}{C_{10}}=\frac{2R\sin\left(\frac{\Omega_c}{2}\right)}{\omega_c L_2}$$

$$\frac{C_{14}}{C_{13}}=\frac{C_2}{C_2+C_1-\frac{\sin(\Omega_c/2)}{R_i\omega_c}}\text{ och }\frac{C_{15}}{C_{13}}=\frac{C_2}{C_2+C_3-\frac{\sin(\Omega_c/2)}{R_L\omega_c}}$$

Med värden insatta så fås att:

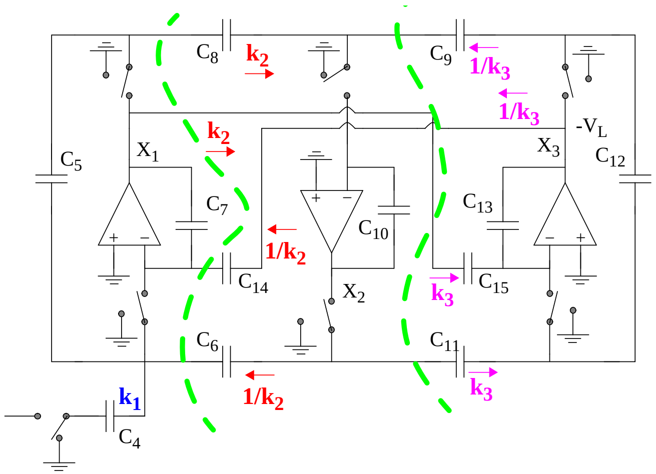
$$\frac{C_4}{C_7}=\frac{C_5}{C_7}=\frac{C_6}{C_7}=\frac{C_{11}}{C_{13}}=\frac{C_{12}}{C_{13}}=\left[\frac{2\pi\cdot 1500\cdot 1000\cdot(204.9n+40.1n)}{2\sin(0.2356/2)}-\frac{1}{2}\right]^{-1}\approx 0.1072$$

$$\frac{C_8}{C_{10}}=\frac{C_9}{C_{10}}=\frac{2\cdot 1000\cdot\sin(0.2356/2)}{3000\pi\cdot 80.3m}\approx 0.3106$$

$$\frac{C_{14}}{C_{13}}=\frac{C_{15}}{C_{13}}=\frac{40.1n}{40.1n+204.9n-\frac{\sin(0.2356/2)}{1000\cdot 3000\pi}}\approx 0.1725$$

Välj till exempel alla “integratorkapacitanser” lika: $C_7 = C_{10} = C_{13} = 47nF$. Ur detta kan alla andra kapacitanser lösas.

Skalning:

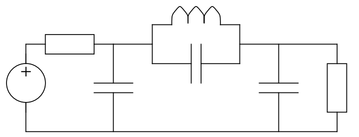


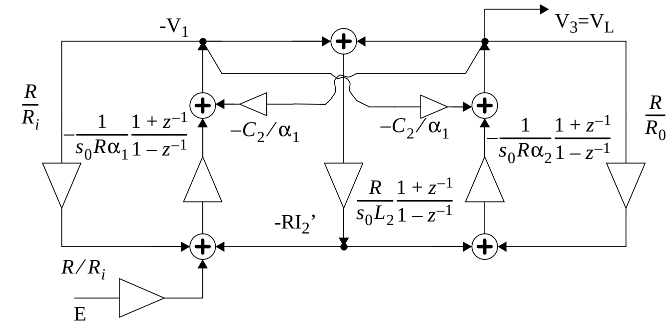
Uppgift Bilinjära filter

$C_{1n} = C_{3n} = 0.989727$ $L_{2n} = 1.086872$

$C_{2n} = 0.052941$ $A_{max} = 0.0988\,\text{dB}$,

$A_{min} = 40.8\,\text{dB}$, $\Omega_s = 3.6279553$





1) Ersätt alla R med $R\frac{(1+z^{-1})}{2}$

2) Utnyttja att: $\frac{(1+z^{-1})^2}{2(1-z^{-1})}=\frac{2z^{-1}}{1-z^{-1}}+\frac{1-z^{-1}}{2}$ och $\frac{1+z^{-1}}{2}=1-\frac{1-z^{-1}}{2}$

3) Slå ihop konstanttermer och eliminera slingor som tar ut varandra.

4) Sätt alla integratorer ensamma (utan koefficienter) – skriv koefficienter i andra grenar.

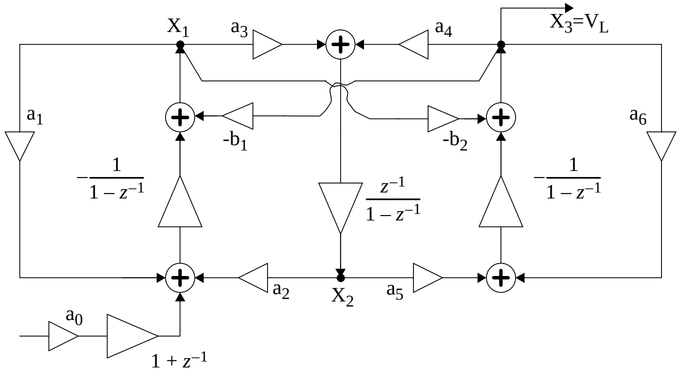
5) Ersätt slutligen med SC-integratorer

Enligt formelsamling:

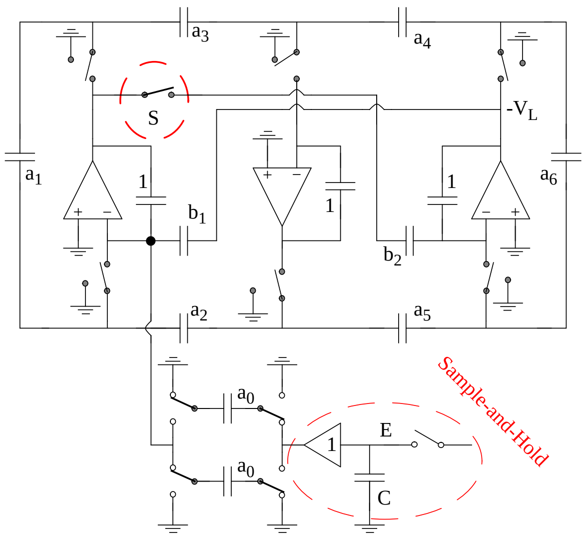
$$a_0=\frac{k_1}{R\alpha+R/L_2-1},\ a_1=\frac{2}{R\alpha+R/L_2-1},\ a_2=\frac{2}{(R\alpha+R/L_2-1)k_2},\ a_3=\frac{2Rk_2}{L_2},$$

$$a_4=\frac{2R}{L_2k_3},\ a_5=\frac{2k_3}{R\alpha+R/L_2-1},\ a_6=\frac{2}{R\alpha+R/L_2-1},$$

$$b_1=\frac{RC_2+R/L_2}{(R\alpha+R/L_2-1)k_2k_3},\ b_2=\frac{(RC_2+R/L_2)k_2k_3}{R\alpha+R/L_2-1}\text{ och }C_1=C_3,\ \alpha=C_1+C_2$$



Realisering med SC-integratorer.



$$R = R_i = R_L = 1 \text{ och } L_2 = \frac{L_{2n}}{\tan(\Omega_{cut}/2)} \text{ och } C_i = \frac{C_{in}}{\tan(\Omega_{cut}/2)}$$

$a_0 \approx 0.7479$; $a_1 = a_6 = a_2 = a_5 \approx 1.4957$; $a_3 = a_4 \approx 1.0624$; $b_1 = b_2 \approx 0.4658$