CHALMERS LINDHOLMEN
Institutionen för data- och elektroteknik

2000-03-08

Digital signalbehandling

Digital signalbehandling

Facit till
Lynn, Fuerst:
Introductory Digital Signal Processing

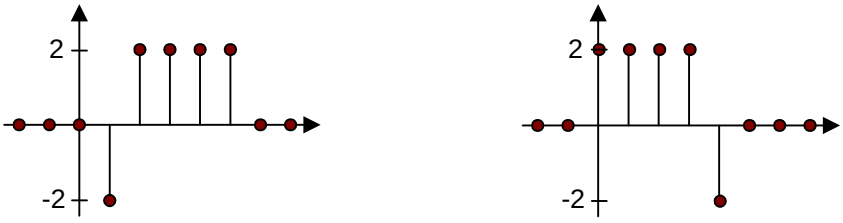
Kapitel 1

1.1 72 Mbit/s

1.2 96 Mbit/s

1.3 2,4 kbit/s

1.4 a) b)



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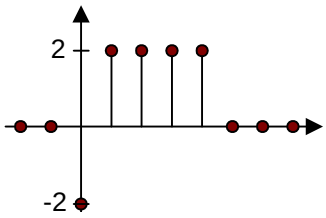
c)



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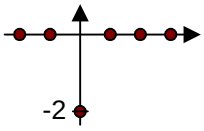
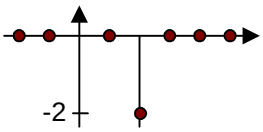


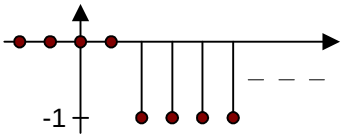
e)



1.6 a) $x[n] = 3 \cdot u[n-1]$ b) $x[n] = -2 \cdot \delta[n+2]$

c) $x[n] = r[n+4] - r[n] - 2 \cdot r[n-7] + 2 \cdot r[n-9]$

1.7 a)



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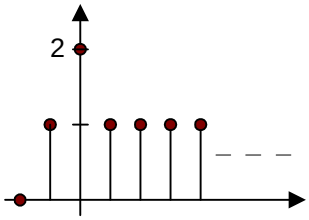
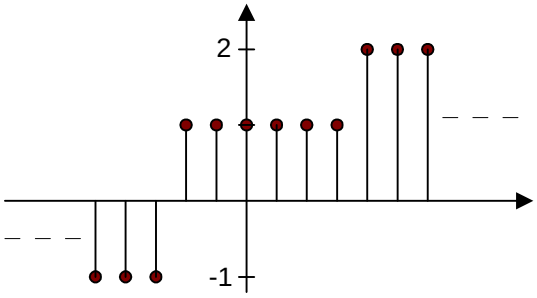


c)



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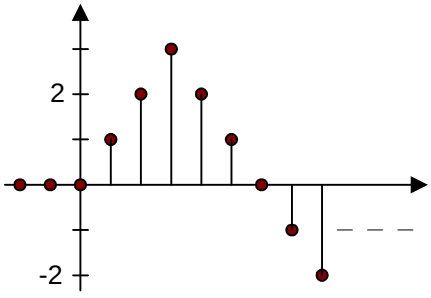
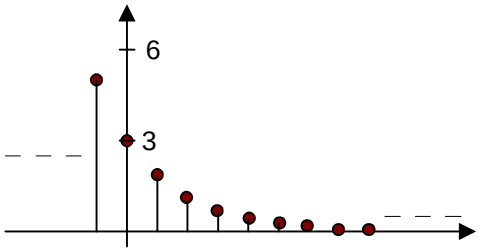
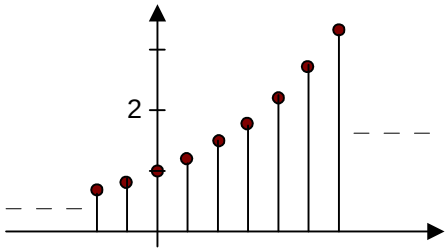


1.8 a) Periodisk, N = 18 b) Periodisk, men inte strikt periodisk
c) Aperiodisk d) Periodisk, N = 20

1.9 a)



b)



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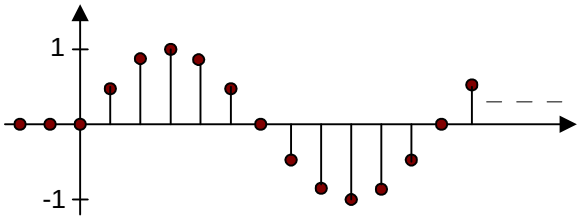
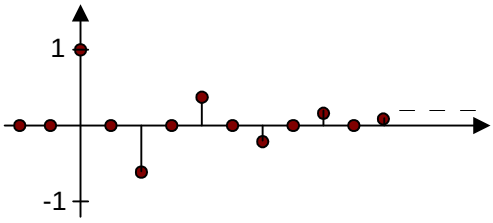


d)

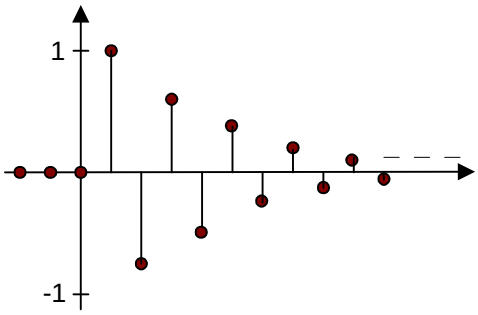


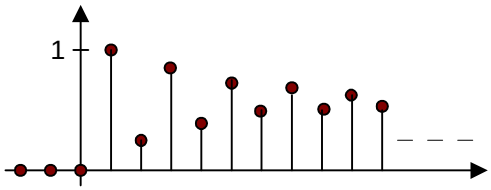
1.10 a) Linjär, ej tidsinvariant, icke-kausal, stabil, minne
b) Olinjär, tidsinvariant, kausal, stabil, minne
c) Linjär, tidsinvariant, kausal, stabil, minne
d) Linjär, tidsinvariant, kausal, instabil, minne
e) Linjär, ej tidsinvariant, kausal, instabil, saknar minne

1.11 a) Inverterbar
b) Icke-inverterbar, vi vet inte insignalens tecken
c) Icke-inverterbar, $x_2[n] = x_1[n] + k \cdot 2 \cdot \pi$

1.12 a) $\alpha = 0{,}75$

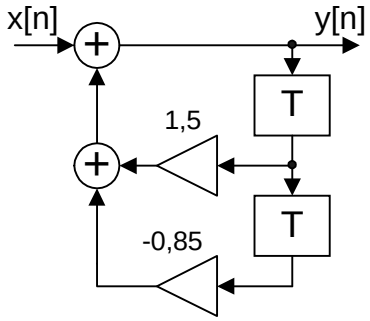
b)



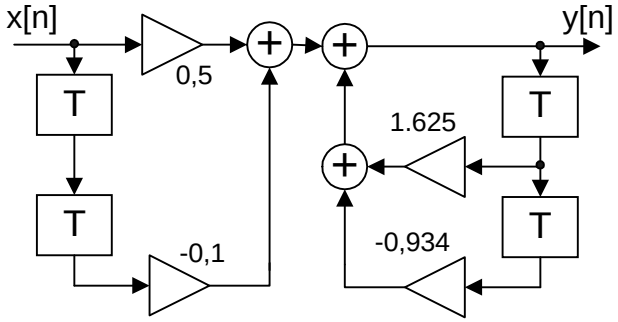


$|\alpha| > 1$ ger instabilitet

1.13



1.14



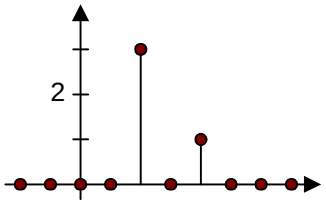
Kapitel 2

2.1 a) $x[n] = \delta[n] + 2 \cdot \delta[n-1] + \delta[n-2]$

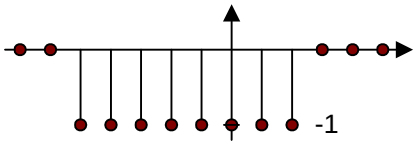
b) $x[n] = 2 \cdot \delta[n+2] + 2 \cdot \delta[n] - 0{,}5 \cdot \delta[n-1] + \delta[n-4]$

2.2 a) Kausal, stabil
b) Ej kausal, stabil
c) Kausal, stabil
d) Kausal, stabil
e) Kausal, instabil

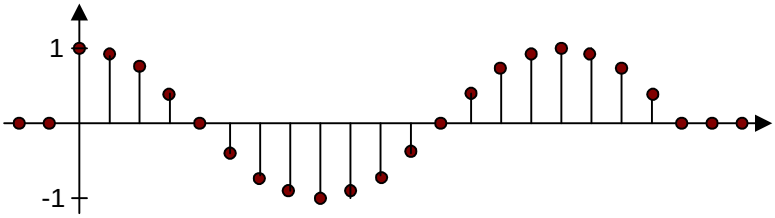
2.3 a)



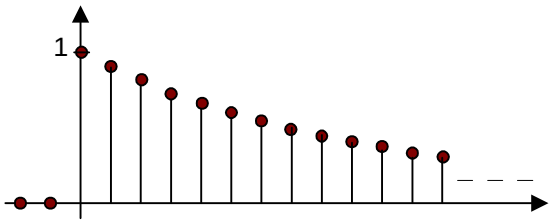
b)



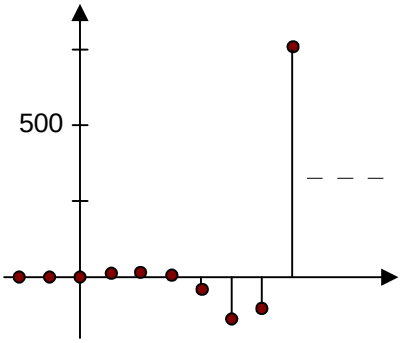
c)



d)

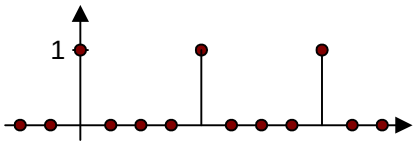


e)

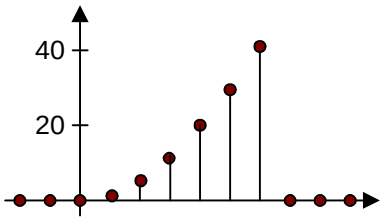


n	h[n]	n	h[n]
0	0	4	-41,32
1	2,287	5	-142,32
2	6,719	6	-112,72
3	2,834	7	720,47

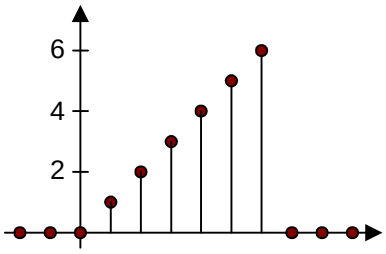
2.4 a)



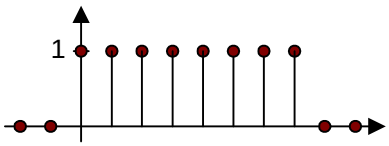
b) Upplaga I av boken (1989)



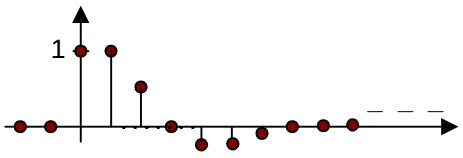
Upplaga II och III av boken (1994 resp 1998)



c)



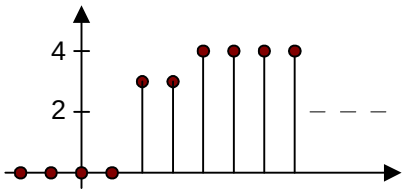
d)



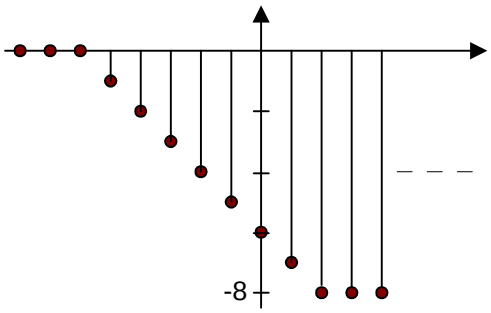
2.6

n	y[n]	n	y[n]
0	1	5	0,0019
1	-0,0498	6	0,0162
2	-0,0406	7	0,0281
3	-0,0279	8	0,0367
4	-0,0133	9	0,0414

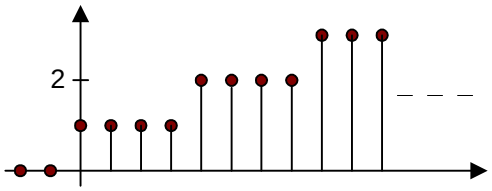
2.7 a) $s[n] = 3 \cdot u[n-2] + u[n-4]$



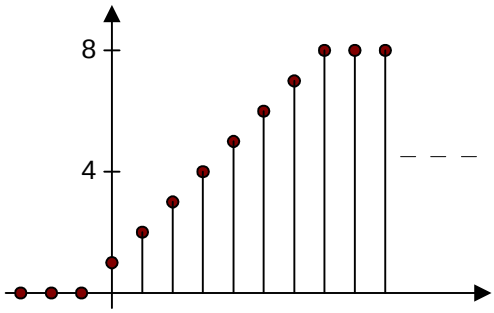
b) $s[n] = r[n-2] - r[n+6]$



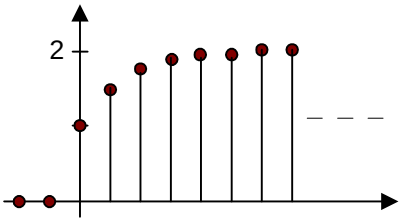
2.8 a)



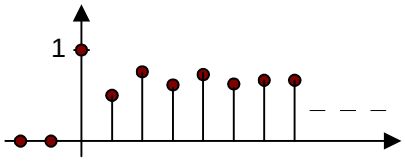
c)



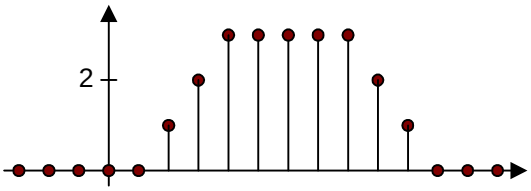
2.9 a) $s[\infty]=2$



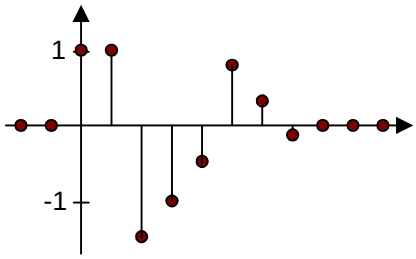
b) $s[\infty]=\frac{2}{3}\approx 0{,}67$



2.10 a)



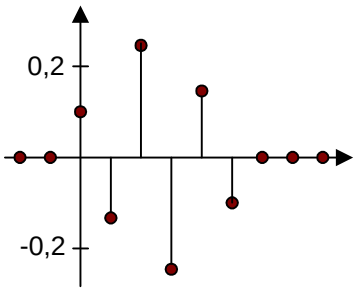
b)



2.11 $0 \le k \le 2$

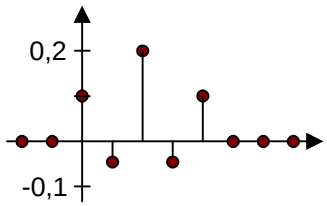
2.12 $y[0]=5{,}29 \quad y[6]=11{,}29 \quad y[20]=13{,}43$

2.13 $h[n]=0{,}05\cdot\{2\cdot\delta[n]-3\cdot\delta[n-1]+5\cdot\delta[n-2]-5\cdot\delta[n-3]+3\cdot\delta[n-4]-2\cdot\delta[n-5]\}$



2.13 forts

$$s[n] = 0{,}05 \cdot \{2 \cdot u[n] - 3 \cdot u[n-1] + 5 \cdot u[n-2] - 5 \cdot u[n-3] + 3 \cdot u[n-4] - 2 \cdot u[n-5]\}$$



Stegsvaret går emot noll eftersom de olika termerna tar ut varandra när vi har nått så långt i tid att insignalen och dess fördröjda varianter alla är ett.
Eftersom vissa frekvenser framhävs medan likspänningstermen dämpas (stegsvaret går mot noll) så har vi nog ett bandpassfilter.

2.14 a) $y[n] = \sum_{k=0}^{6} x[n-k]$

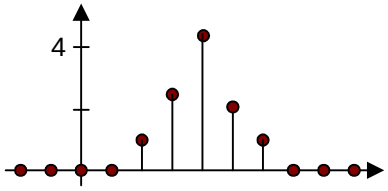
Rekursiv formel: två summationer, åtta minnesceller
Icke-rekursiv formel: sex summationer, sex minnesceller

b) $y[n] = \sum_{k=0}^{n} 0{,}9^k \cdot x[n-k]$

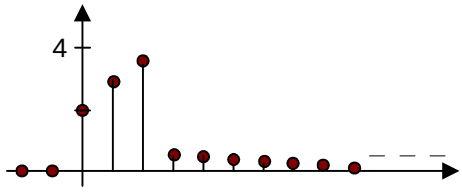
Filtret har inte ändlig längd, då n går emot oändligheten så går även antalet termer i summationen mot oändligheten

2.15

n	h[n]	n	h[n]
0	0	4	4,333
1	0	5	2,167
2	1	6	1
3	2,5	7	0



2.16



2.18 $y_p[n] = u[n] \quad y_h[n] = -0{,}8^{n+1}$

2.19

n	-2	-1	0	1	2	3	4	5	6	7	8	9
$H_p[n]$	0	0	2	-2	0	2	-2	0	2	-2	0	2
$h_h[n]$	2	0	-1	1	-0,5	0	0,25	-0,25	0,13	0	-0,06	0,06

Kapitel 3

3.1 a) $a_0 = 5 \quad a_1 = a_7 = 0{,}5 \quad a_2 = -a_6 = -j \cdot 0{,}5 = 0{,}5\left\langle -\frac{\pi}{2} \right.$

b) $a_0 = a_2 = 0 \quad a_1 = \frac{1-j}{2 \cdot \sqrt{2}} = 0{,}5\left\langle -\frac{\pi}{4} \right. \quad a_3 = \frac{1+j}{2 \cdot \sqrt{2}} = 0{,}5\left\langle \frac{\pi}{4} \right.$

c) $a_0 = 3 \quad a_1 = -1 + j \quad a_2 = -1 \quad a_3 = -1 - j$

3.2 $a_0 = 0 \quad a_1 = 0{,}0107 + j \cdot 0{,}5622 \quad a_2 = 0{,}5671 + j \cdot 0{,}4632$

$a_3 = 0{,}4223 + j \cdot 1{,}4033 \quad a_4 = 0{,}4223 - j \cdot 1{,}4033$

$a_5 = 0{,}5671 - j \cdot 0{,}4632 \quad a_6 = 0{,}0107 - j \cdot 0{,}5622$

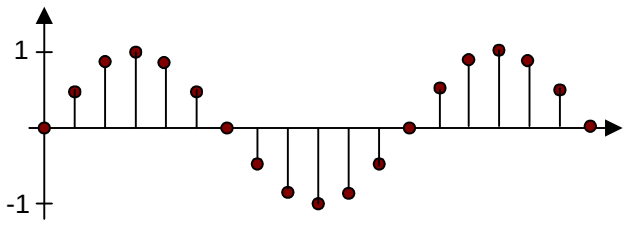
a_0 är noll eftersom signalen saknar likspänningskomponent, a_3 och a_4 är lika stora eftersom signalen har en stark frekvenskomponent vid vinkeln $6\cdot\pi/7 = 2\cdot\pi\cdot 3/7$, dvs vid frekvensen $3/7 \cdot f_s$ som ges av a_3 medan a_4 är motsvarande speglade frekvens på andra sidan $f_s/2$.
Om samplingsfrekvensen är 1 MHz så ger a_2 frekvenskomponenten vid 286 kHz.

3.5 $a_0 = 1 \quad a_1 = a_{63} = 0{,}5 \quad a_8 = -a_{56} = -j \cdot 0{,}5 = 0{,}5\left\langle -\frac{\pi}{2} \right.$

Resten av frekvenskomponeneterna är noll

3.6 $\Phi_k = -\frac{10 \cdot \pi \cdot k}{64}$

3.8



Belopp = 0,518
Fas = 75° = 1,308 radianer

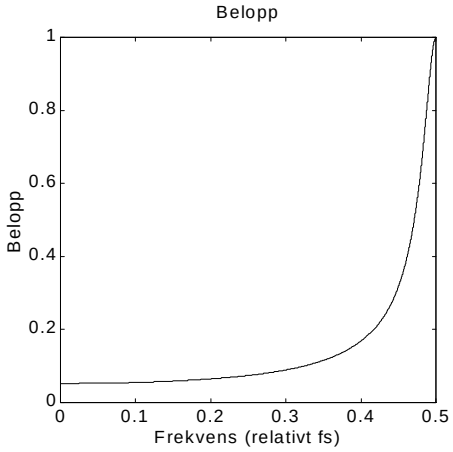
3.11 a) $X(\Omega) = 1 + 2 \cdot e^{-j \cdot \Omega} + e^{-j \cdot 2 \cdot \Omega}$ b) $X(\Omega) = 2 \cdot j \cdot \sin(\Omega)$

c) $X(\Omega) = 1 + 2 \cdot \cos(\Omega) + 2 \cdot \cos(2 \cdot \Omega) + 2 \cdot \cos(3 \cdot \Omega)$

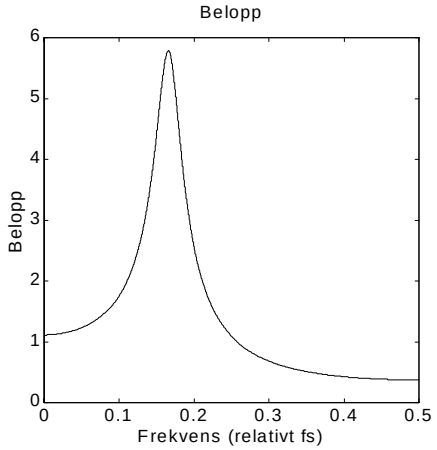
3.12 $H(\Omega) = 4 + 2 \cdot e^{-j \cdot \Omega} + e^{-j \cdot 2 \cdot \Omega}$ b) $H(\Omega) = \frac{1 - e^{-j \cdot 7 \cdot \Omega}}{1 - e^{-j \cdot \Omega}}$

c) $H(\Omega) = \frac{1}{1 - 0{,}8 \cdot e^{-j \cdot \Omega}}$

3.13 $H(\Omega) = \frac{0{,}1}{1 + 0{,}9 \cdot e^{-j \cdot \Omega}} = \frac{0{,}1}{1 + 0{,}9 \cdot \cos(\Omega) - j \cdot 0{,}9 \cdot \sin(\Omega)}$



3.14 $|H(\Omega)| = \frac{1}{\sqrt{[1 - 0{,}9 \cdot \cos(\Omega) + 0{,}8 \cdot \cos(2 \cdot \Omega)]^2 + [0{,}9 \cdot \sin(\Omega) - 0{,}8 \cdot \sin(2 \cdot \Omega)]^2}}$



3.15 a) $|H(0)| = 1{,}019$

b) $|H(0{,}1 \cdot \pi)| = 0{,}000816$

Kapitel 4

4.1 $X(z)=\dfrac{3}{z^2\cdot(z-a)}$ b) $X(z)=2\cdot\dfrac{z^8-1}{z^7\cdot(z-1)}$

4.2 a) $X(z)=\sum_{k=0}^{\infty}0{,}5^k\cdot z^{-(k+1)}=z^{-1}\cdot\sum_{k=0}^{\infty}0{,}5^k\cdot z^{-k}=z^{-1}+0{,}5\cdot z^{-2}+0{,}5^2\cdot z^{-3}+0{,}5^3\cdot z^{-4}+\ldots$

b) $X(z)=\sum_{k=0}^{\infty}(-1.1)^k\cdot z^{-k}=1-1{,}1\cdot z^{-1}+1{,}1^2\cdot z^{-2}-1{,}1^3\cdot z^{-3}+1{,}1^4\cdot z^{-4}+\ldots$

c) $X(z)=1+2\cdot\sum_{k=1}^{\infty}z^{-k}=1+2\cdot z^{-1}+2\cdot z^{-2}+2\cdot z^{-3}+2\cdot z^{-4}+\ldots$

4.3 $X(z)=2\cdot\dfrac{z^6-1}{z^7\cdot(z-1)}+z^{-9}-\dfrac{0{,}5}{z^9\cdot(z-0{,}5)}$

4.4 $X_1(z)=1-z^{-2}+z^{-3}$ $X_2(z)=2\cdot z^{-1}+z^{-2}-z^{-3}$

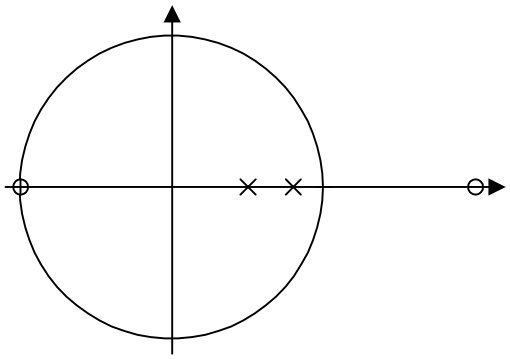
$X_1(z)\cdot X_2(z)=2\cdot z^{-1}+z^{-2}-3\cdot z^{-3}+z^{-4}+2\cdot z^{-5}-z^{-6}$

4.5 $X(z)=1+2\cdot z^{-1}+3\cdot z^{-2}+z^{-3}-z^{-4}+z^{-5}$ $H(z)=1+z^{-1}+z^{-2}$

$X(z)\cdot H(z)=1+3\cdot z^{-1}+6\cdot z^{-2}+6\cdot z^{-3}+3\cdot z^{-4}+z^{-5}+z^{-7}$

4.6 a) $x[n]=\left(\dfrac{1}{\sqrt{2}}\right)^n\cdot\sin\left(\dfrac{n\cdot\pi}{4}\right)\cdot u[n]$ b) $x[n]=\left[2{,}5-1{,}5\cdot(0{,}8)^{n-2}\right]\cdot u[n-2]$

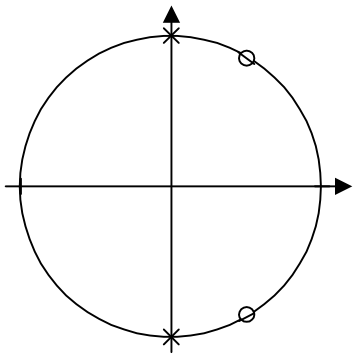
4.8 a) Nollställen: -1 och 2
Poler: 0,5 och 0,8
Kausalt, stabilt



4.8 b) Nollställen: $0{,}5 \pm j \cdot 0{,}866$

Poler: $\pm j$

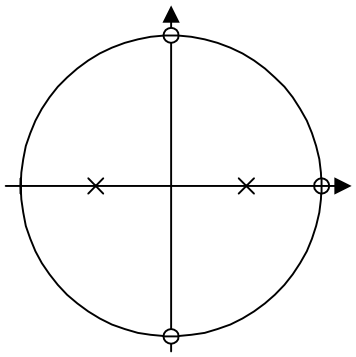
Kausalt, instabilt



c) Nollställen: 1 och $\pm j$

Poler: $\pm 0{,}5$

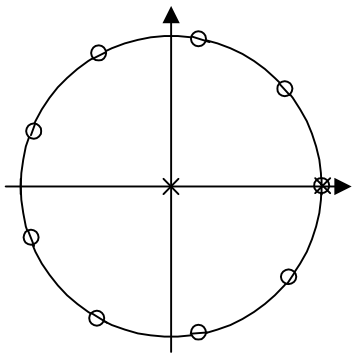
Ej kausalt, stabilt



d) Nollställen: $1\angle\frac{2\cdot\pi\cdot n}{9} \quad 0 \le n \le 8$

Poler: 0 och 1

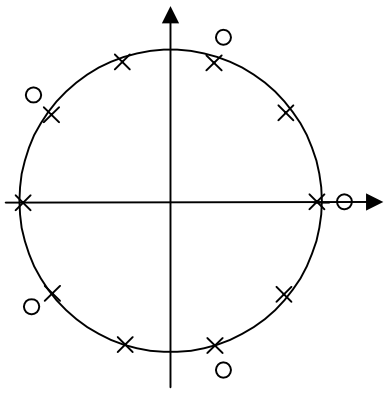
Kausalt, stabilt



4.8 a) Nollställen: $1{,}15\angle\frac{2\cdot\pi\cdot n}{5} \quad 0 \le n \le 4$

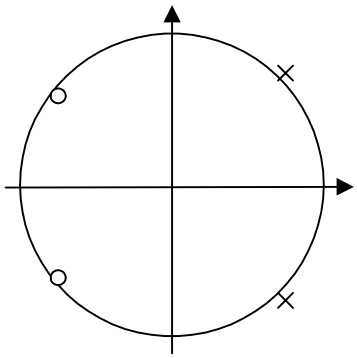
Poler: $0{,}98\angle\frac{2\cdot\pi\cdot n}{10} \quad 0 \le n \le 9$

Stabilt



4.9 b) Nollställen: $-0{,}75 \pm j \cdot 0{,}58$
Poler: $0{,}75 \pm j \cdot 0{,}73$

Instabilt



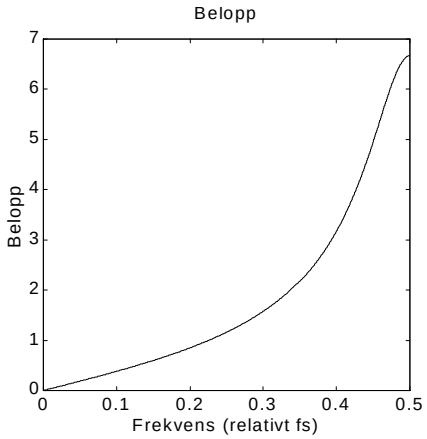
4.10 *Kommentar:* Eftersom eventuella förstärkningskonstanter inte syns i pol/nollställesdiagram är dessa inte med i svaren

a) $x[n] = \left[1 - (-0{,}8)^n\right] \cdot u[n]$

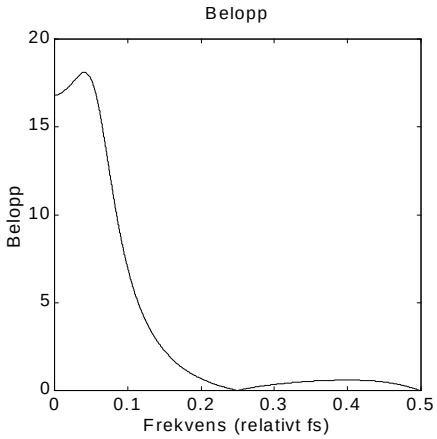
b) $x[n] = \cos\left(\frac{2 \cdot \pi \cdot n}{3}\right) \cdot u[n]$

c) $x[n] = (0{,}8)^n \cdot \sin\left(\frac{\pi \cdot n}{2}\right) \cdot u[n]$

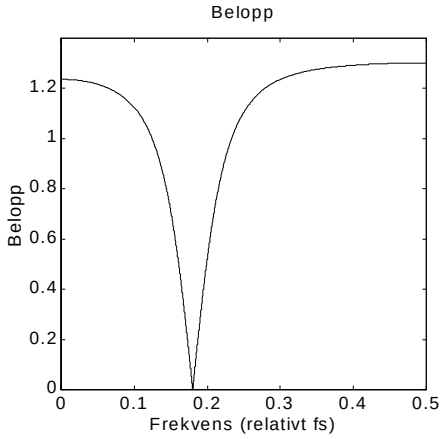
4.11 a) Högpassfilter



b) Lågpassfilter

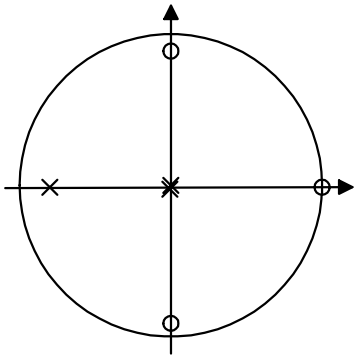


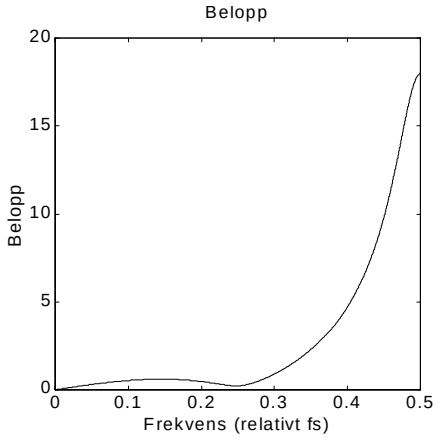
c) Notchfilter



4.12 Nollställen: 1 och $\pm 0{,}89 \cdot j$

Poler: -0,8 och dubbelpol i origo





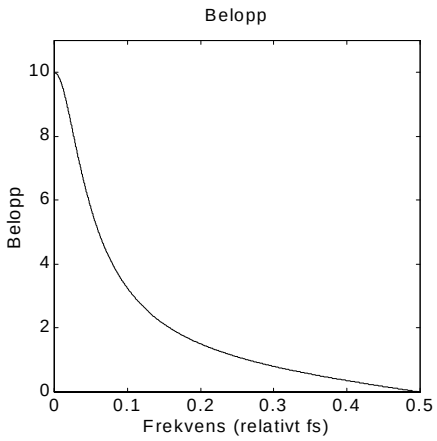
4.13 $$H(z) = \frac{(z-1)\cdot\left(z - e^{j\cdot\frac{\pi}{3}}\right)\cdot\left(z - e^{-j\cdot\frac{\pi}{3}}\right)}{z\cdot\left(z - 0{,}9\cdot e^{j\cdot\frac{2\cdot\pi}{3}}\right)\cdot\left(z - 0{,}9\cdot e^{-j\cdot\frac{2\cdot\pi}{3}}\right)} = \frac{(z-1)\cdot\left(z^2 - 2\cdot\cos\left(\frac{\pi}{3}\right) + 1\right)}{z\cdot\left(z^2 - 1{,}8\cdot\cos\left(\frac{2\cdot\pi}{3}\right) + 0{,}81\right)}$$

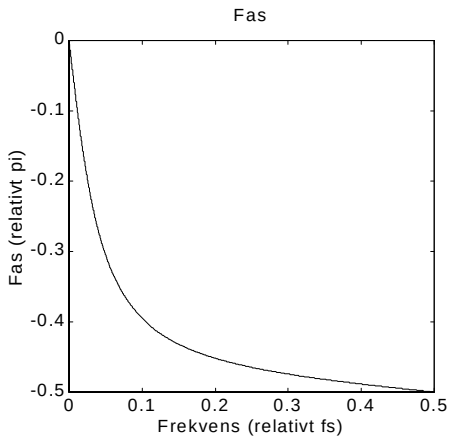
$$y[n] = x[n] - 2\cdot x[n-1] + 2\cdot x[n-2] - x[n-3] - 0{,}9\cdot y[n-1] - 0{,}81\cdot y[n-2]$$

$$h[n] = \delta[n] - 2{,}9\cdot\delta[n-1] + 3{,}8\cdot\delta[n-2] - 2{,}071\cdot\delta[n-3] - 1{,}2141\cdot\delta[n-4] + \ldots$$

4.14 a) $y[n] = x[n] + x[n-1] + 0{,}8\cdot y[n-1]$

b) $h[n] = \delta[n] + 1{,}8\cdot\delta[n-1] + 1{,}44\cdot\delta[n-2] + 1{,}15\cdot\delta[n-3] + 0{,}9216\cdot\delta[n-4] + \ldots$





4.15 $-2 < \alpha < 2 \quad \beta < 1$

a) $\alpha \approx 1$

d) $\alpha \approx -1$

4.17 Med randvillkor $y[-1]=y[-2]=0$

$$Y_0(z)=\frac{z^2}{z^2-z+0{,}8}\cdot X(z)$$

Med randvillkor $y[-1]=y[-2]=1$

$$Y(z)=\frac{0{,}2\cdot z^2-0{,}8\cdot z+X(z)\cdot z^2}{z^2-z+0{,}8}=\frac{0{,}2\cdot z^2-0{,}8\cdot z}{z^2-z+0{,}8}+Y_0(z)$$

Randvillkorens bidrag till impulssvaret

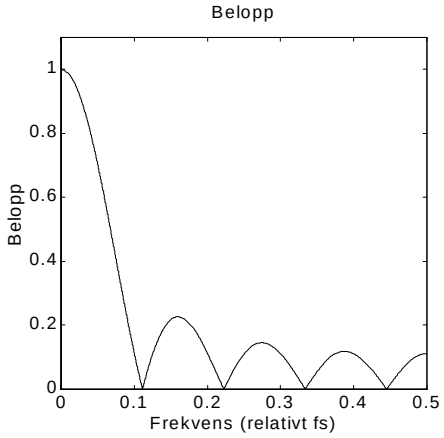
$$h_r[n]=0{,}2\cdot\delta[n]-0{,}6\cdot\delta[n-1]-0{,}76\cdot\delta[n-2]-0{,}28\cdot\delta[n-3]-3{,}28\cdot\delta[n-4]+\ldots$$

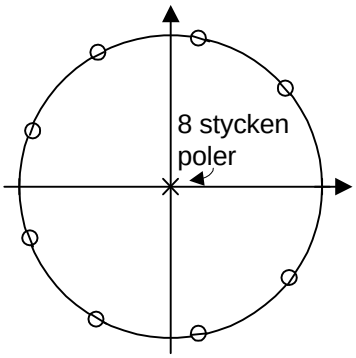
4.18 a) $H(z)=\frac{z\cdot(z-1)}{z^2+0{,}5\cdot z+0{,}5}$ b) $H(z)=\frac{z^2}{z^2+0{,}5\cdot z+0{,}5}$

Impulssvaret blir noll om $y[-1]=-2$ och $y[-2]=4$

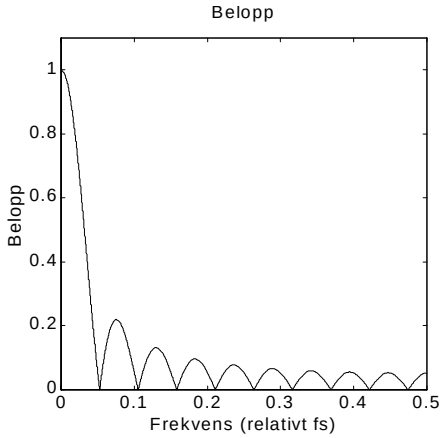
Kapitel 5

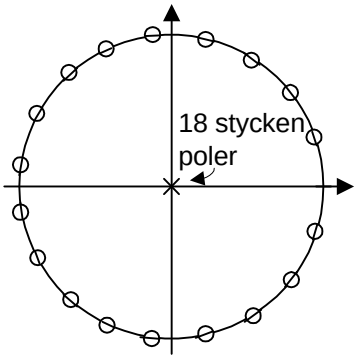
5.1 a)



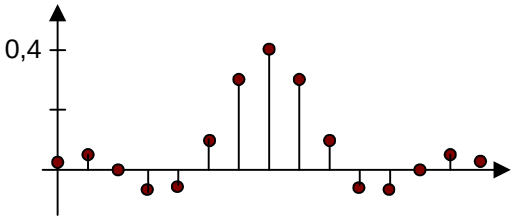


b)

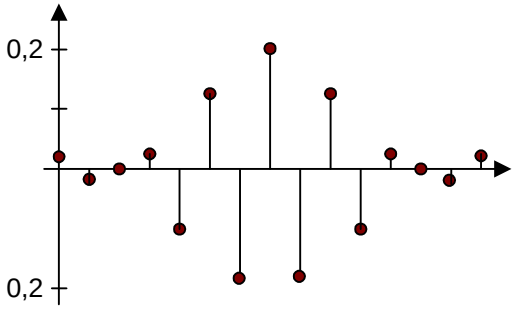




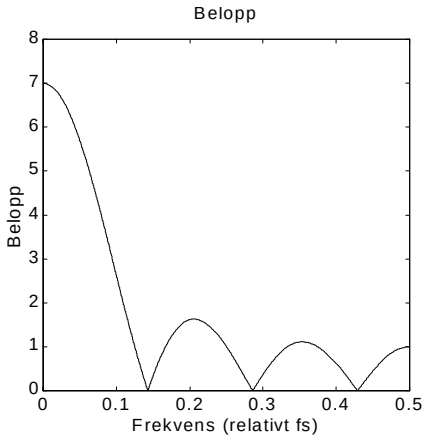
5.3 a)



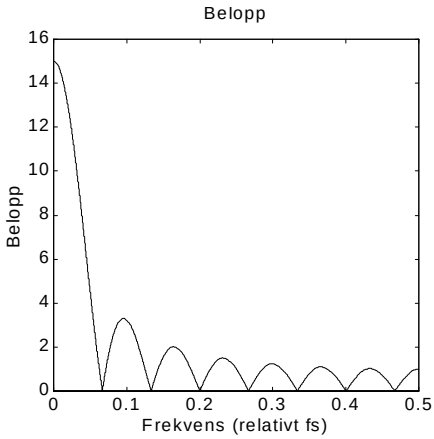
b)



5.5 a)



b)



5.7 a)

$w[0]=1$ $\quad w[1]=w[-1]=0{,}933$

$w[2]=w[-2]=0{,}75$ $\quad w[3]=w[-3]=0{,}5$

$w[4]=w[-4]=0{,}25$ $\quad w[5]=w[-5]=0{,}067$

b)

$w[0]=1$ $\quad w[1]=w[-1]=0{,}9384$

$w[2]=w[-2]=0{,}77$ $\quad w[3]=w[-3]=0{,}54$

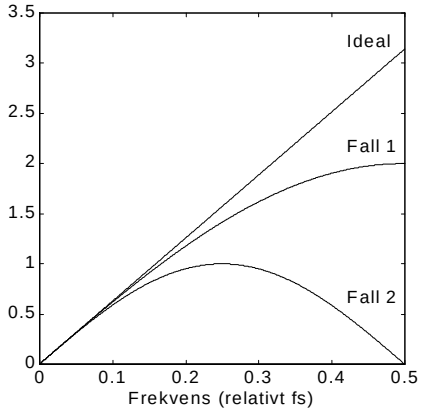
$w[4]=w[-4]=0{,}31$ $\quad w[5]=w[-5]=0{,}1416$

$w[6]=w[-6]=0{,}08$

5.11 a) $\alpha \approx 5 \quad N = 2 \cdot M + 1 = 67$

5.12 a) $\alpha \approx 4{,}091 \quad N = 2 \cdot M + 1 = 37$

5.14



5.14 forts

I det första fallet är skillnaden 0,143 dB

I det andra fallet är skillnaden 0,579 dB

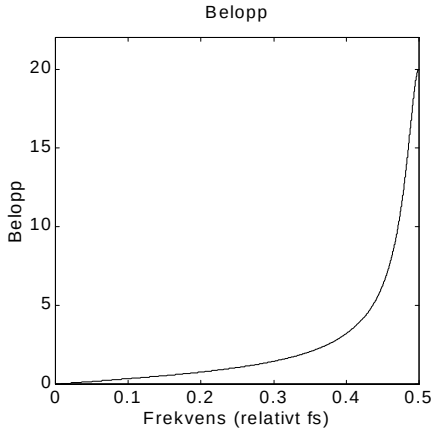
5.15 $b[0] = 0$

$$b[n] = \begin{cases} \dfrac{1}{\pi \cdot n^2} \cdot (-1)^{\frac{n+1}{2}} & \textit{då n är udda} \\ \dfrac{1}{\pi \cdot n^2} \cdot (-1)^{\frac{n}{2}} & \textit{då n är jämn} \end{cases}$$

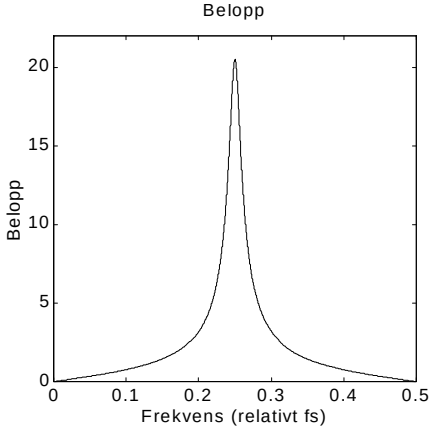
Digital signalbehandling
Facit till
Lynn,Fuerst: Introductary Digital Signal Processing
sida 22

Kapitel 6

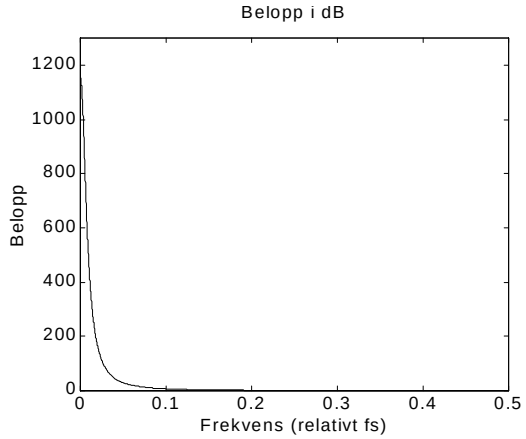
6.1 a)



b)

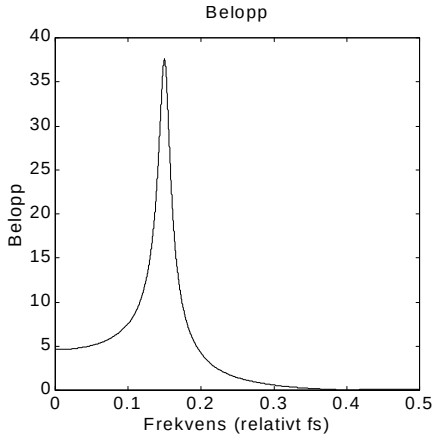


c)



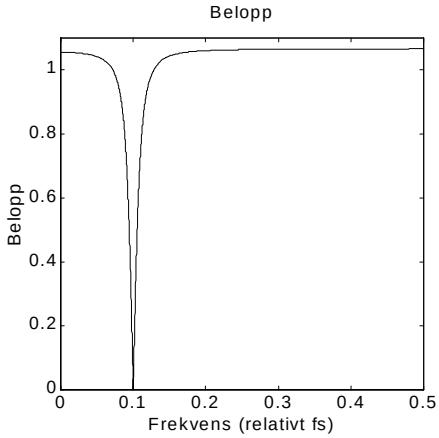
6.3 a) 20 dB b) 0 dB c) -60 dB
d) -67,96 dB e) $\rightarrow -\infty$

6.4 Nollställen i $1\langle\pm 0{,}8\cdot\pi$
Poler i $0{,}9529\langle\pm 0{,}3\cdot\pi$

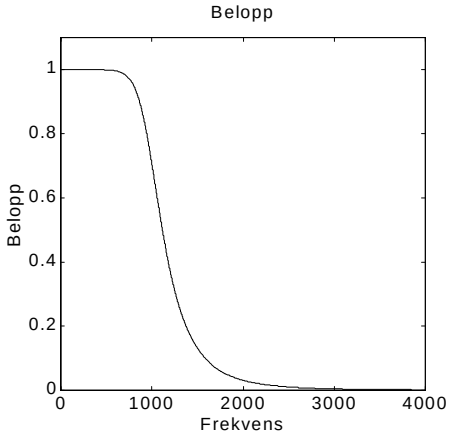


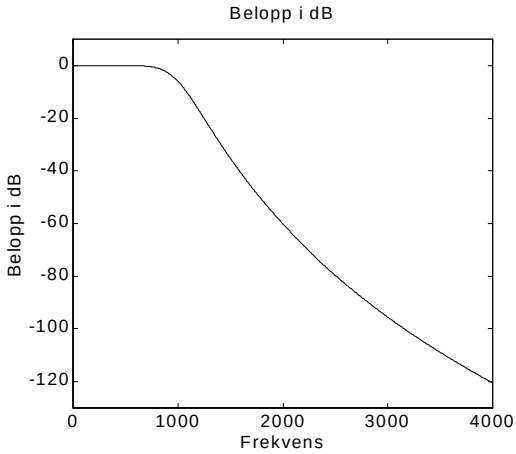
6.5 Nollställen i $1\angle\pm 0{,}2\cdot\pi$

Poler i $0{,}93721\angle\pm 0{,}2\cdot\pi$

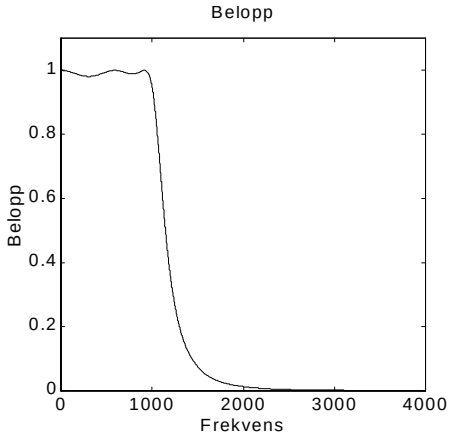


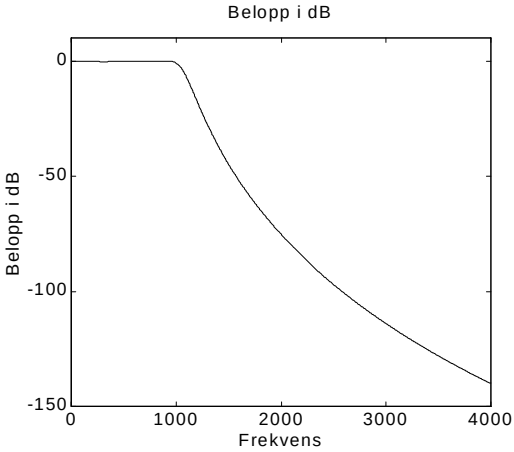
6.7 a)



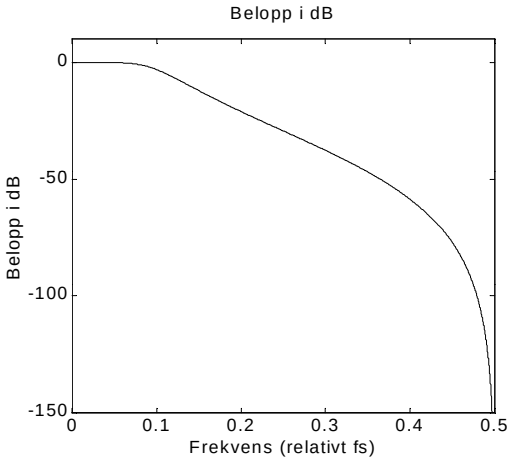


b)





6.8



6.10 Gradtal 6

6.13 $y[n] = x[n] - 0{,}99094 \cdot x[n-1] + 1{,}7236 \cdot y[n-1] - 0{,}74082 \cdot y[n-2]$

6.14 $y[n] = x[n] - 0{,}93282 \cdot x[n-1] + 1{,}28963 \cdot y[n-1] - 0{,}40657 \cdot y[n-2]$

6.17 Kamfilter $q_k[n] = x[n] - 0{,}998^{90} \cdot x[n-90] = x[n] - 0{,}8351 \cdot x[n-90]$

Sex stycken resonatorer

$y_0[n] = q_k[n] + 1{,}529 \cdot y_0[n-1] - 0{,}996 \cdot y_0[n-2]$

$y_1[n] = q_k[n] + 1{,}4358 \cdot y_0[n-1] - 0{,}996 \cdot y_0[n-2]$

$y_2[n] = q_k[n] + 1{,}3356 \cdot y_0[n-1] - 0{,}996 \cdot y_0[n-2]$

$y_3[n] = q_k[n] + 1{,}2289 \cdot y_0[n-1] - 0{,}996 \cdot y_0[n-2]$

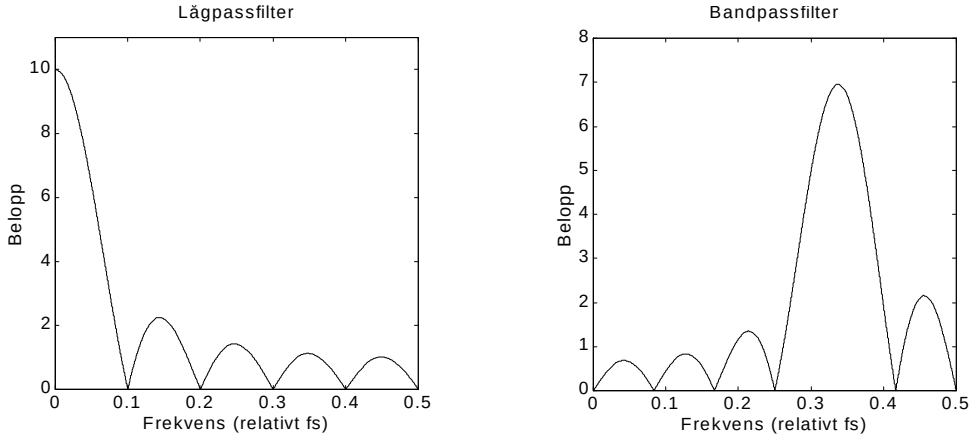
$y_4[n] = q_k[n] + 1{,}1161 \cdot y_0[n-1] - 0{,}996 \cdot y_0[n-2]$

$y_6[n] = q_k[n] + 0{,}998 \cdot y_0[n-1] - 0{,}996 \cdot y_0[n-2]$

Total utsignal

$y[n] = y_0[n] - y_1[n] + y_2[n] - y_3[n] + 0{,}5 \cdot y_4[n] - 0{,}5 \cdot y_5[n]$

6.19 a)



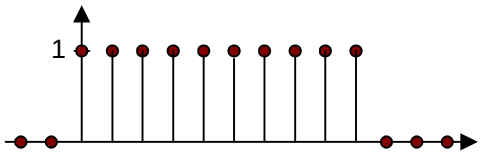
6.19 b) Lågpassfiltret

$$y[n] = x[n] - x[n-10] + y[n-1]$$

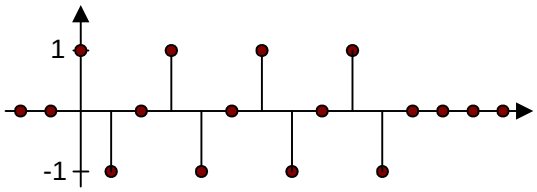
Bandpassfiltret

$$y[n] = x[n] - x[n-12] - y[n-1] - y[n-2]$$

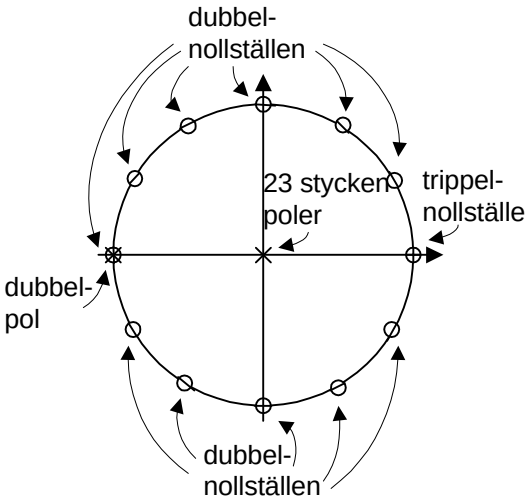
c) Lågpassfiltret

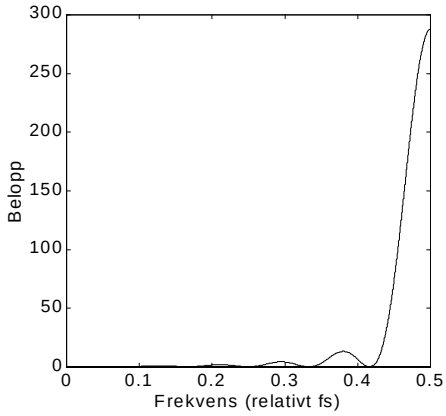


Bandpassfiltret



6.20 a)

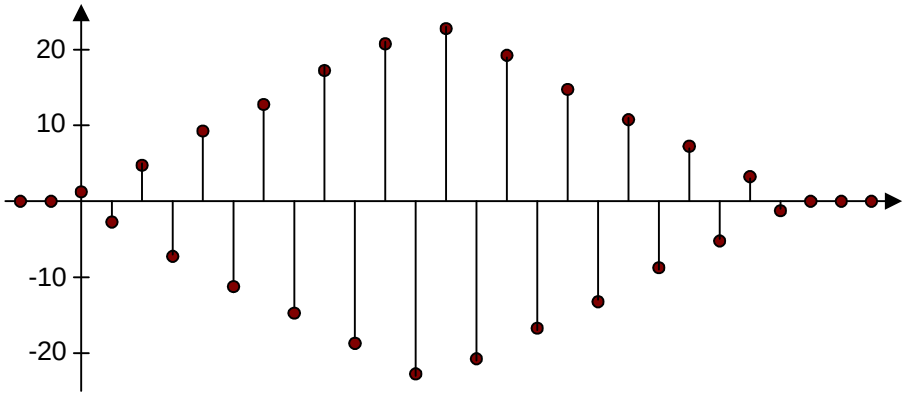




b)

$$y[n] = x[n] - x[n-1] - 2 \cdot x[n-12] + 2 \cdot x[n-13] + x[n-24] - x[n-25] -$$
$$- 2 \cdot y[n-1] + y[n-2]$$

6.20 c)



6.22

					Differenser		
Ω	Idealt	Running Sum	Trapets-regeln	Simpson´s regel	Running Sum	Trapets-regeln	Simpson´s regel
0,2·π	4,0364	4,1798	3,7939	4,0993	0,1434	-0,2925	0,0079
0,5·π	-3.9224	-3,0103	-4,0206	-7,5218	0,9121	-2,0982	0,4001
0,9·π	-9,0278	-5,913	-22,0263	1,073	3,1148	-12,9985	10,1008

Digital signalbehandling
Facit till
Lynn,Fuerst: Introductary Digital Signal Processing
sida 28

Kapitel 7

7.1 Modifiera algoritmen till

$$X[k] = A \cdot \sum_{n=0}^{N-1} x[n] \cdot e^{j \cdot \frac{B \cdot k \cdot n}{N}}$$

så kan samma algoritm användas. Vid DFT-beräkning använder vi $\begin{cases} A = 1 \\ B = -2 \cdot \pi \end{cases}$ och vid IDFT-beräkning använder vi $\begin{cases} A = \frac{1}{N} \\ B = 2 \cdot \pi \end{cases}$

7.3 a) $3 \cdot X[k]$ b) $X[k] \cdot e^{-j \cdot \frac{2 \cdot \pi \cdot 2 \cdot k}{N}}$

c) $X[k] \cdot \left(2 + e^{j \cdot \frac{2 \cdot \pi \cdot k}{N}} \right)$ d) $\frac{1}{N} \cdot \sum_{m=0}^{N-1} X[m] \cdot X[k-m] \cdot e^{-j \cdot \frac{2 \cdot \pi \cdot m}{N}}$

7.4 a) En reell signal ger en komplex DFT
b) En reell och jämn signal ger reella jämna DFT-komponenter
c) En reell och udda funktion ger imaginära udda DFT-komponenter
d) En komplex signal ger en komplex DFT

7.5 Signalen får bara innehålla frekvenskomponenter $2 \cdot k \cdot \frac{f_s}{N}$ där k är ett heltal

7.6 a) $X[0] = 0 \quad X[1] = 2$
b) $X[0] = 7 \quad X[1] = j \quad X[2] = -3 \quad X[3] = -j$

7.7 Spektrat är periodiskt och komponenterna $X[0] .. X[7]$ är de samma
$X[-8] = X[8] \quad X[-7] = X[9] \quad X[-6] = X[10] \quad X[-5] = X[11]$
$X[-4] = X[12] \quad X[-3] = X[13] \quad X[-2] = X[14] \quad X[-1] = X[15]$

7.8 a) Komponenterna $X[9]$ och $X[31]$
b) $X[0] = X[39] = 0$

7.11

	$W_N^{k \cdot n}$	n			
		0	1	2	3
k	0	1	1	1	1
	1	1	-j	-1	j
	2	1	-1	1	-1
	3	1	j	-1	-j

7.12 $X[k] = X_1[k] + W_N^k \cdot X_2[k]$

7.14 a) 18,3 b) 102,4 c) 4096

7.15 b)

x[0]	x[8]	x[4]	x[12]	x[2]	x[10]	x[6]	x[14]
x[1]	x[9]	x[5]	x[13]	x[3]	x[11]	x[7]	x[15]

7.16

x[0]	x[16]	x[8]	x[24]	x[4]	x[20]	x[12]	x[28]
x[2]	x[18]	x[10]	x[26]	x[6]	x[22]	x[14]	x[30]
x[1]	x[17]	x[9]	x[25]	x[5]	x[21]	x[13]	x[29]
x[3]	x[19]	x[11]	x[27]	x[7]	x[23]	x[15]	x[31]

7.18 a) Decimation-in-time FFT b) Decimation-in-frequency FFT

Kapitel 8

8.4 a) $X[8]$ och $X[56]$

b) $X[7]$ (och $X[57]$) är näst störst. Relativ storlek -6,55 dB

c) 480 Hz

8.5 a) De största komponenterna (i avtagande ordning) blir $X[43]$, $X[44]$ och $X[42]$

Dämpningen av $X[44]$ relativt $X[43]$ blir 3,52 dB (0,667)

Dämpningen av $X[42]$ relativt $X[43]$ blir 10,9 dB (0,286)

b) De största komponenterna (i avtagande ordning) blir $X[41]$, $X[40]$ och $X[42]$

Dämpningen av $X[40]$ relativt $X[41]$ blir 9,25 dB (0,345)

Dämpningen av $X[42]$ relativt $X[41]$ blir 13,8 dB (0,204)

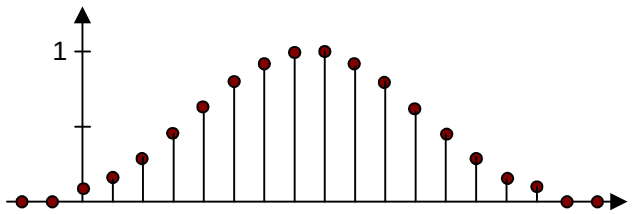
8.6 a) 21,48 Hz

b) $\frac{\pi}{64} = 0{,}0491$ radianer

c) 5,86 mHz

8.8

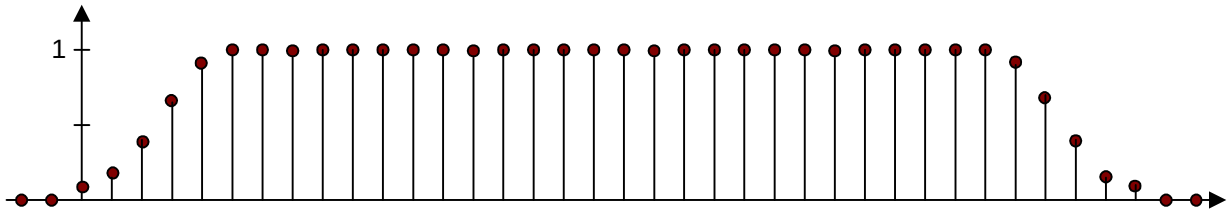
n	0, 15	1, 14	2, 13	3, 12	4, 11	5, 10	6, 9	7, 8
W[n]	0,08884	0,15752	0,28444	0,45026	0,62974	0,79556	0,92248	0,99116



Värdena närmast centerlinjen är 0,99116

8.9

n	0, 31	1, 30	2, 29	3, 28	4, 27	5 - 26
W[n]	0,08	0,16785	0,39785	0,68215	0,91215	1



8.12

n	h[n]	n	h[n]	n	h[n]	n	h[n]
0	1	16	-0,423	32	0,127	48	-0,029
1	1,5	17	-0,425	33	0,091	49	-0,012
2	1,4	18	-0,278	34	0,029	50	0,007
3	0,825	19	-0,056	35	-0,035	51	0,021
4	0,047	20	0,153	36	-0,076	52	0,025
5	-0,63	21	0,276	37	-0,085	53	0,02
6	-0,985	22	0,285	38	-0,063	54	0,009
7	-0,943	23	0,192	39	-0,022	55	-0,004
8	-0,576	24	0,046	40	0,021	56	-0,013
9	-0,063	25	-0,094	41	0,049	57	-0,017
10	0,395	26	-0,18	42	0,057	58	-0,014
11	0,646	27	-0,191	43	0,043	59	-0,006
12	0,634	28	-0,133	44	0,016	60	0,002
13	0,401	29	-0,037	45	-0,012	61	0,009
14	0,063	30	0,057	46	-0,032	62	0,011
15	-0,246	31	0,117	47	-0,038	63	0,009

a) Upplösning 15,6 Hz b) Upplösning 1,95 Hz

8.14 En period vid cyklisk faltning

0 4 1 -3 1 1

Linjär faltning ger följden

1 1 -1 0 0 0 3 0 -2 1 1