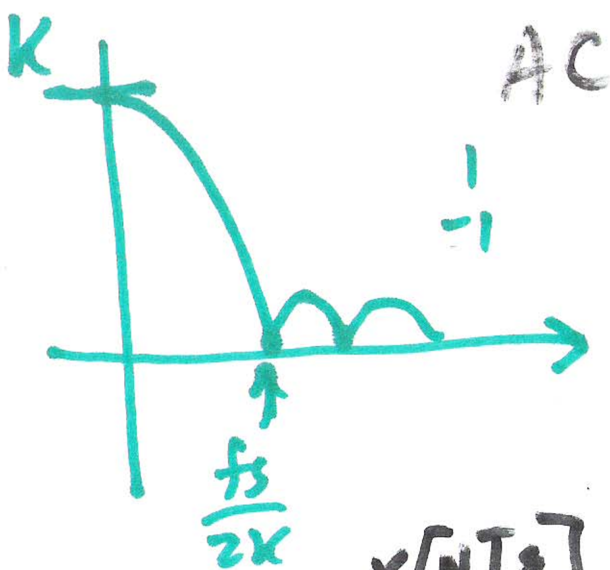
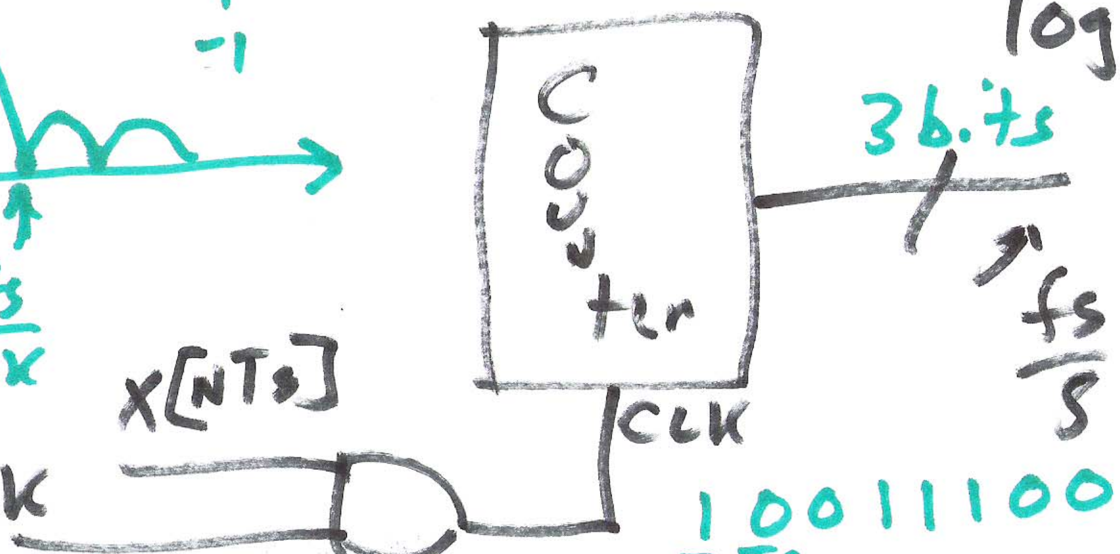
ECE 722
CMOS Mixed-Signal

9/26/14

Lowpass Sinc Filters
Accumulate & Dump





$\log_2 K$ $K = 256$

$K = 8$

$\log_2 2^3 = 3\text{-bit}$

$\log_2 2^8 = 8\text{-bit}$

1 0 0 1 1 1 1 0 0

Ts Ts

4

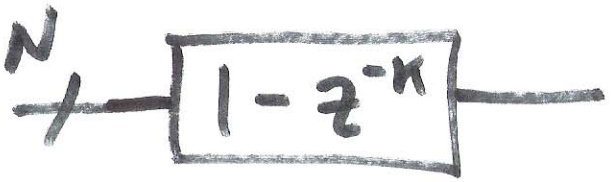
1 0 1 0 1 0 1 0

$2T_s = \frac{f_s}{2}$

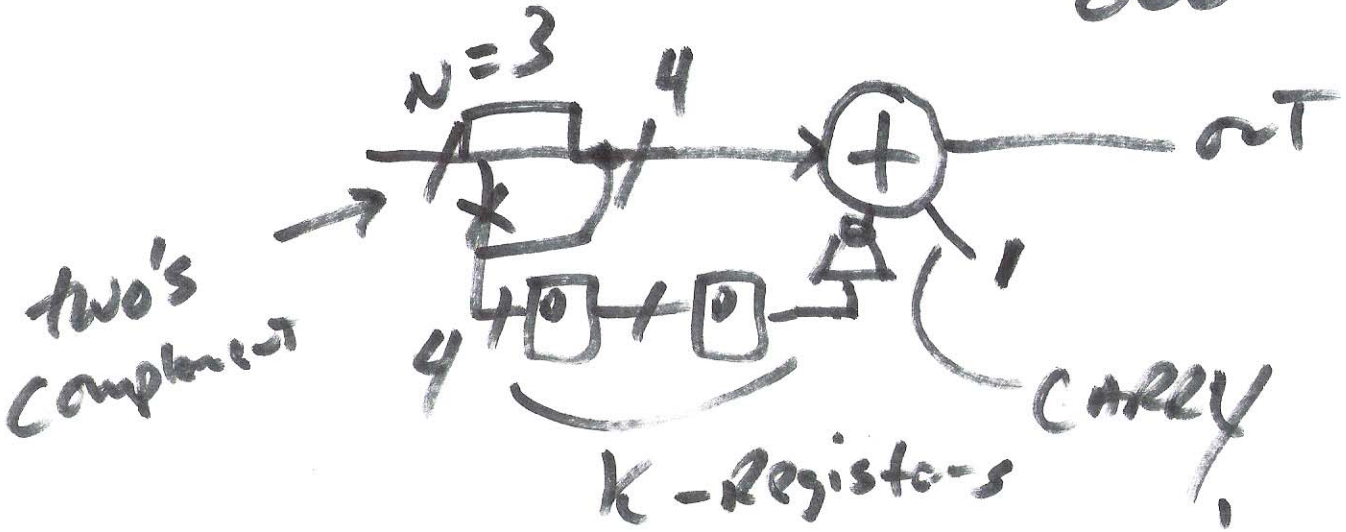
11110000 $\frac{f_s}{8}$

UNLV ELECTRICAL & COMPUTER ENGINEERING

CMOSedu.com



111 0011 → +3
100 000 → 0
000 1100 → -4



$$\begin{array}{r} 3 \\ -(-4) \\ \hline +7 \rightarrow 0111 \end{array}$$

$$+3 \quad 0011$$
$$-(-4) \rightarrow 1000$$
$$\quad\quad\quad\;\; 1$$
$$\hline$$
$$\quad\quad 00$$
$$0111 \text{ yay!}$$

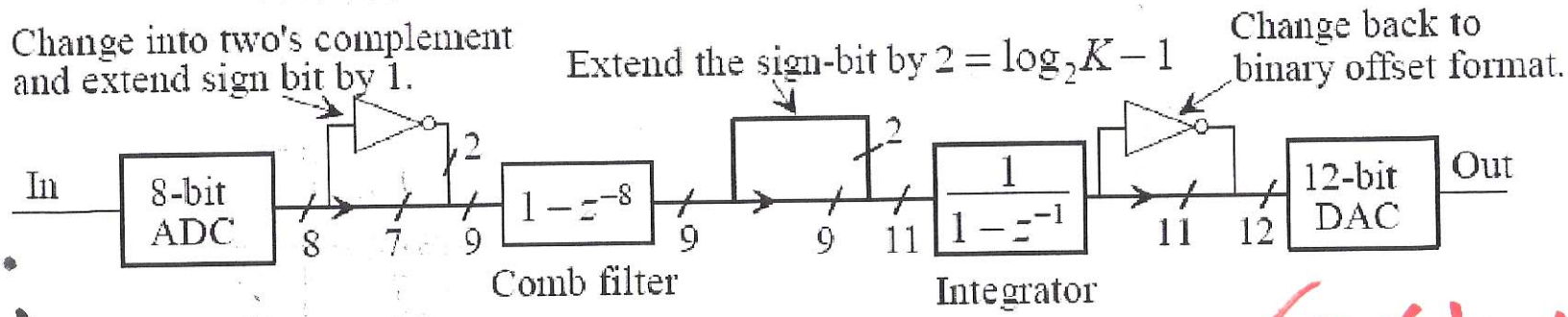


Figure 4.14 Digital filter sketch for Ex. 4.3.

$z_p = 1$

Im

z-plane

$z_p = .707 + j.707$

$\left(z + \frac{1}{\sqrt{2}} + j\frac{1}{\sqrt{2}}\right)$

$(z+j)\cdot\left(z - \frac{1}{\sqrt{2}} - \right)$

Re

$(1 - z^{-8}) = ($

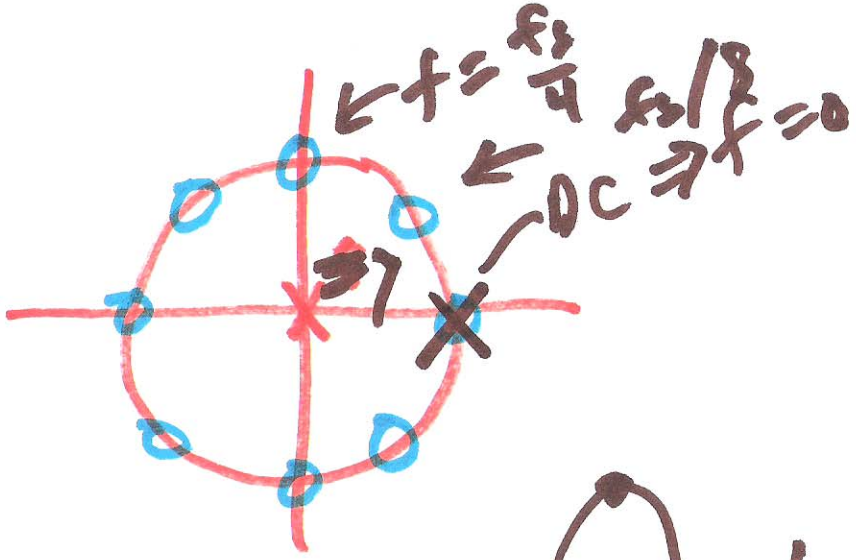
$\left(\frac{z^8 - 1}{z^8}\right) =$

$\frac{(z-1)(z+1)(z-j)\cdot}{z^8}$

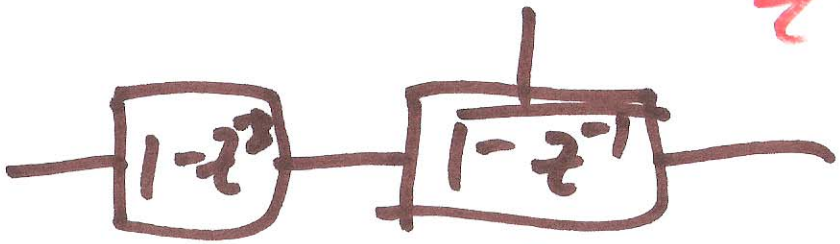
1

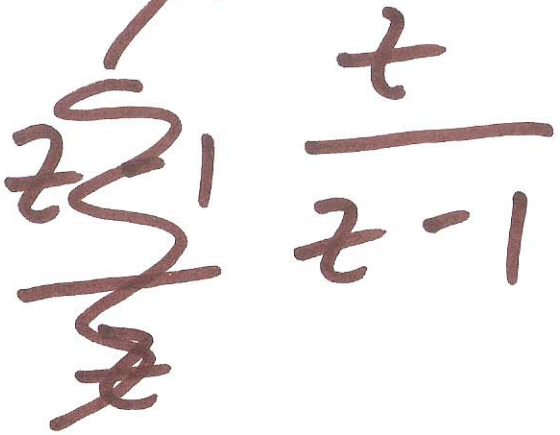
1

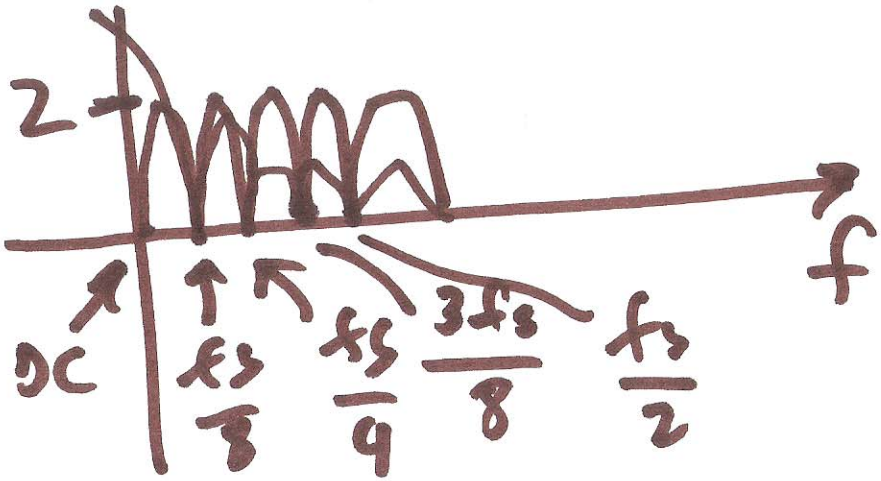
3)

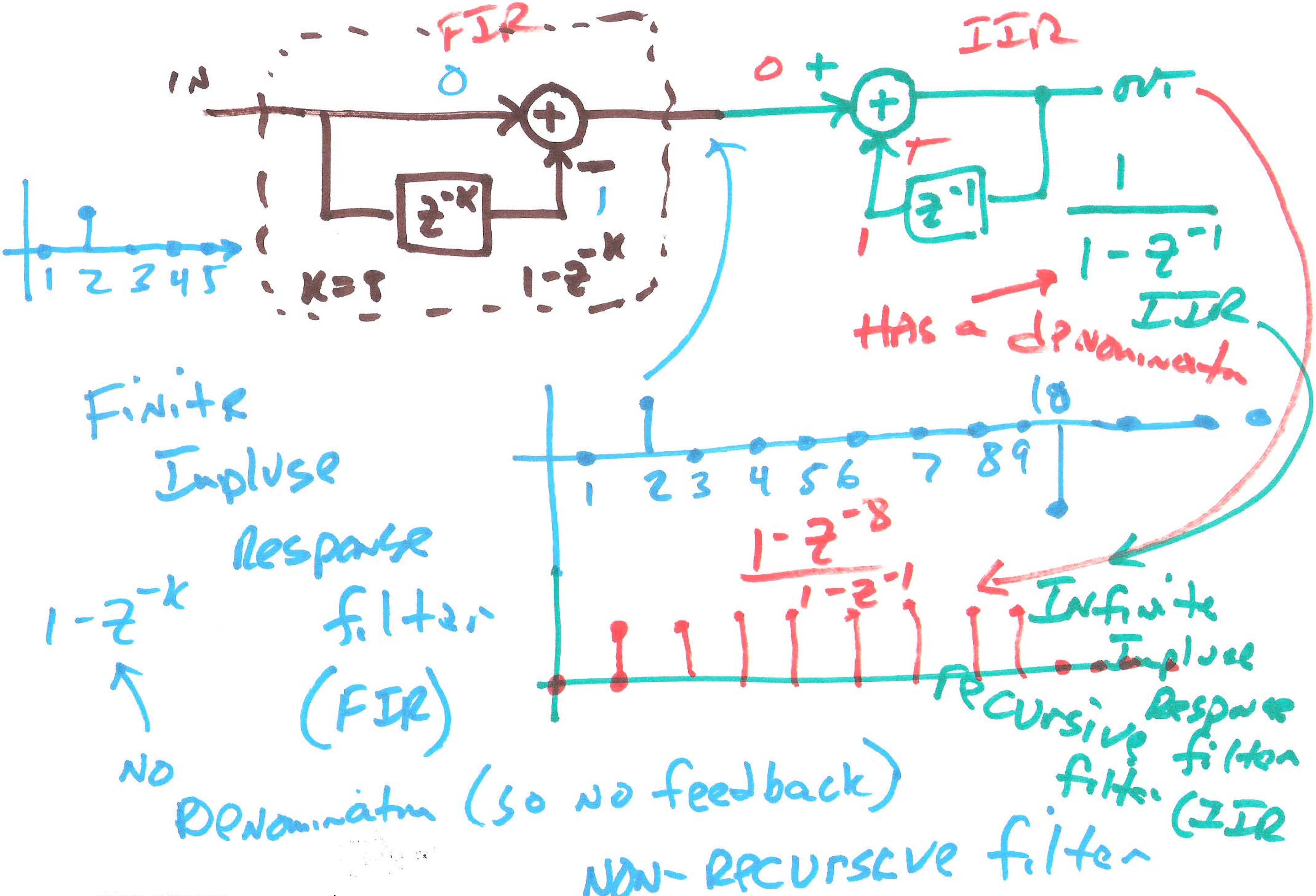


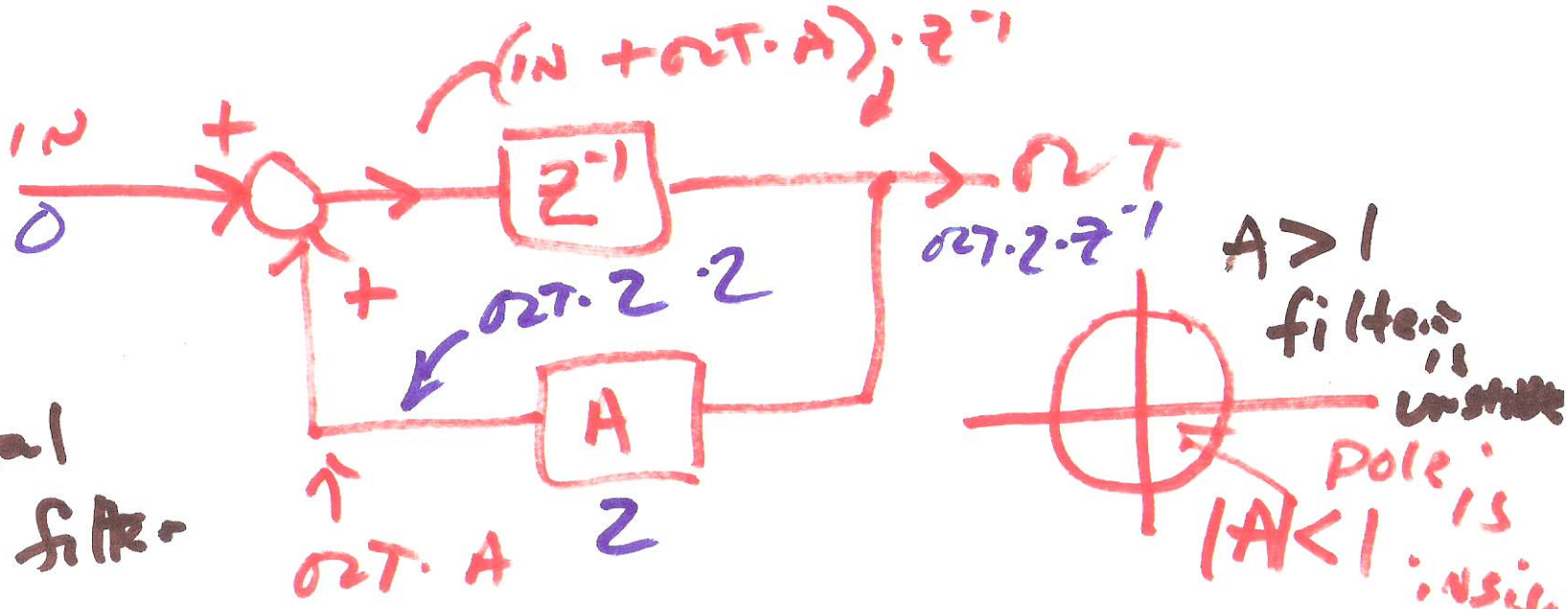
$$1 - z^{-8} = \frac{z^8 - 1}{z^8}$$








FIR
IN
0
z^{-K}
1
$1-z^{-K}$
K=8
1 2 3 4 5
IIR
0 +
OUT
+
z^{-1}
1
$\frac{1}{1-z^{-1}}$
IIR
HAS a denominator
Finite Impulse Response filter (FIR)
$1-z^{-K}$
NO Denominator (so no feedback)
NON-RECURSIVE filter
1 2 3 4 5 6 7 8 9
18
$\frac{1-z^{-8}}{1-z^{-1}}$
Infinite Impulse Response filter (IIR
Recursive filter

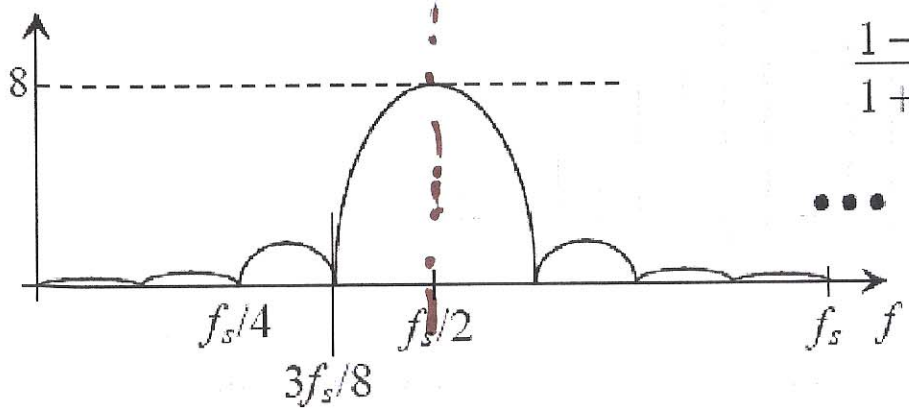


Stable Digital filter has poles inside the unit circle

$$OUT = (IN + OUT \cdot A)\, z^{-1}$$ the unit circle

$$OUT\,(1 - A z^{-1}) = IN\, z^{-1}$$

$$\frac{OUT}{IN} = \frac{z^{-1}}{1 - A z^{-1}} = \frac{1}{z - A}$$



$$\frac{1-z^{-8}}{1+z^{-1}} = \frac{z^8-1}{z^7(z+1)}$$

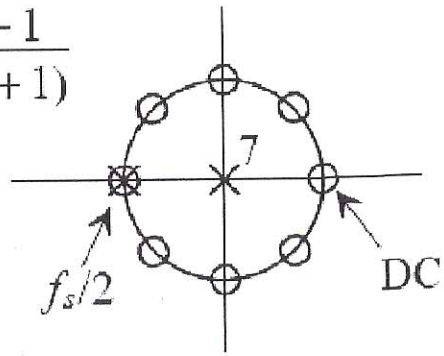
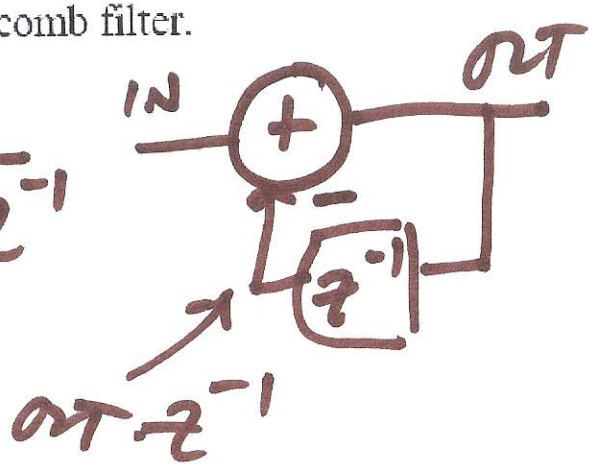


Figure 4.19 A highpass filter implementation using a comb filter.

$$\frac{1}{1+z^{-1}}$$



$$\frac{OUT}{IN} = \frac{1}{1+z^{-1}} \qquad OUT = IN - OUT \cdot z^{-1}$$

$$OUT(1+z^{-1}) = IN$$

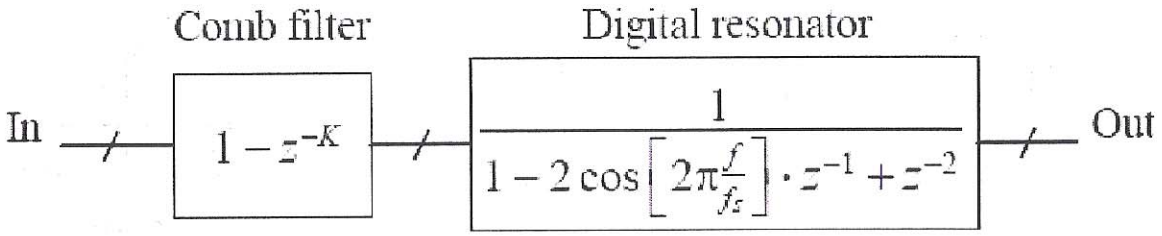


Figure 4.20 Implementing a sinc-shaped bandpass filter.

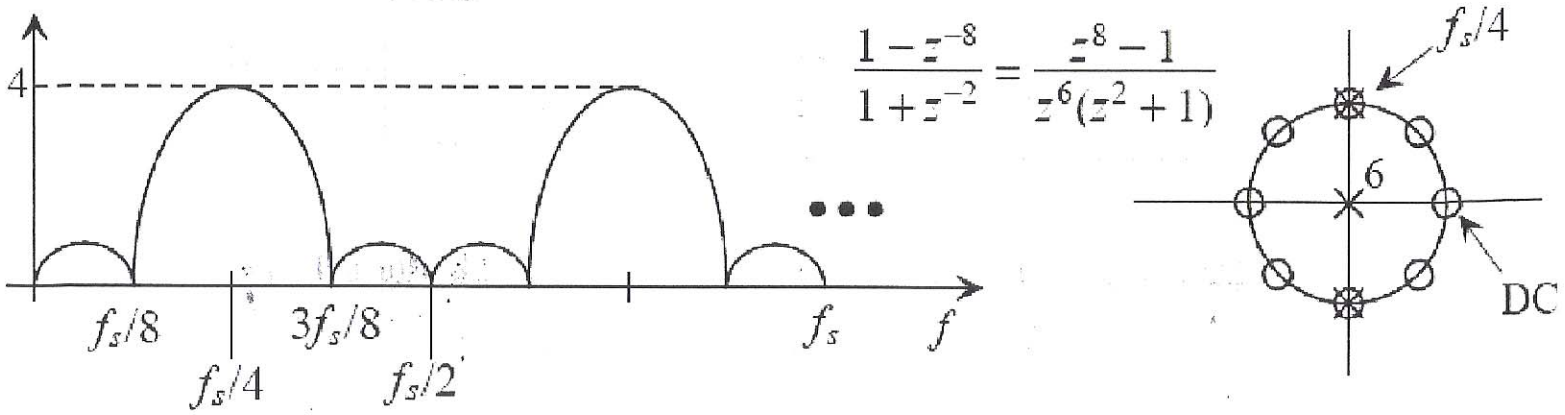


Figure 4.21 A bandpass filter implementation using a comb filter and digital resonator.

$$\frac{1}{1+z^{-2}} \Rightarrow \frac{z^2}{z^2+1} = \frac{z^2}{(z+j)(z-j)}$$

9)

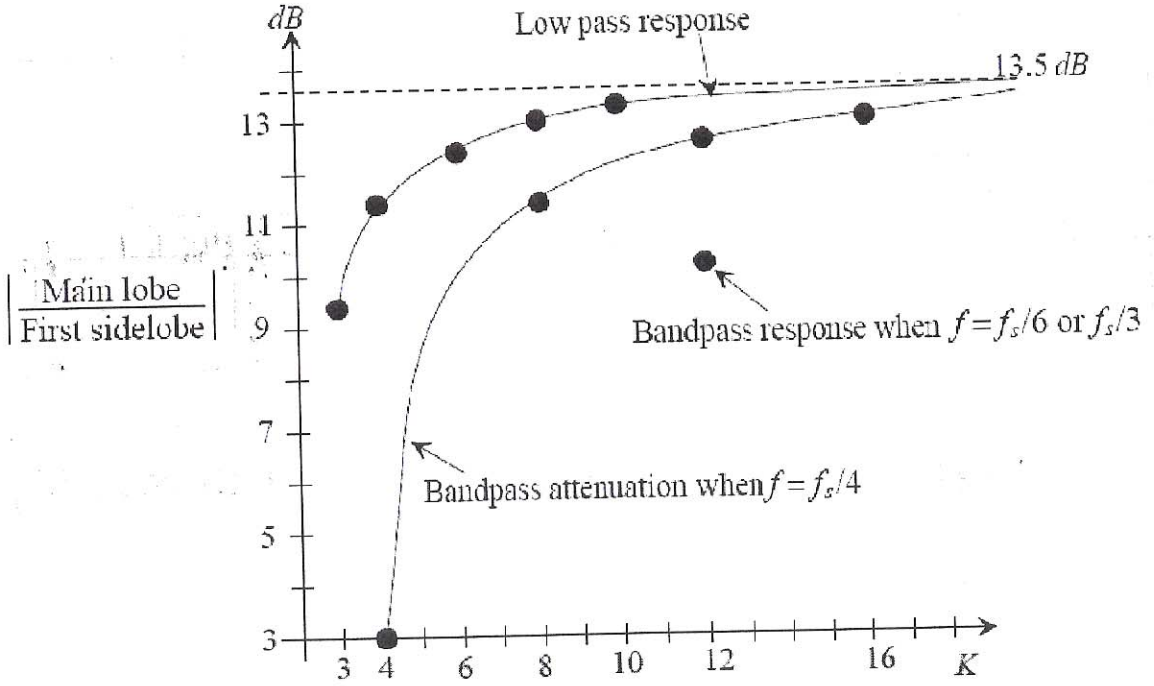
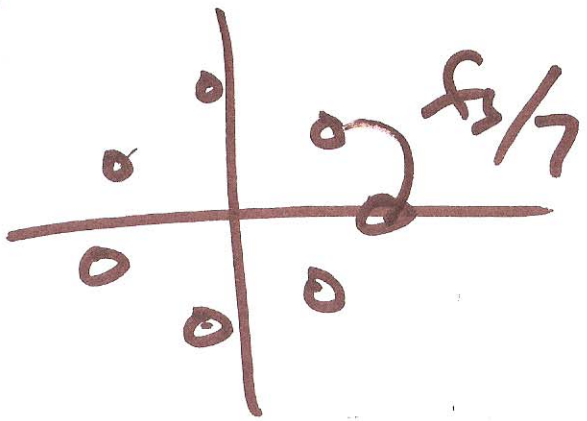


Figure 4.22 Lowpass and bandpass filter attenuation versus number of comb filter zeroes, K.

$1 - z^{-7}$



10)

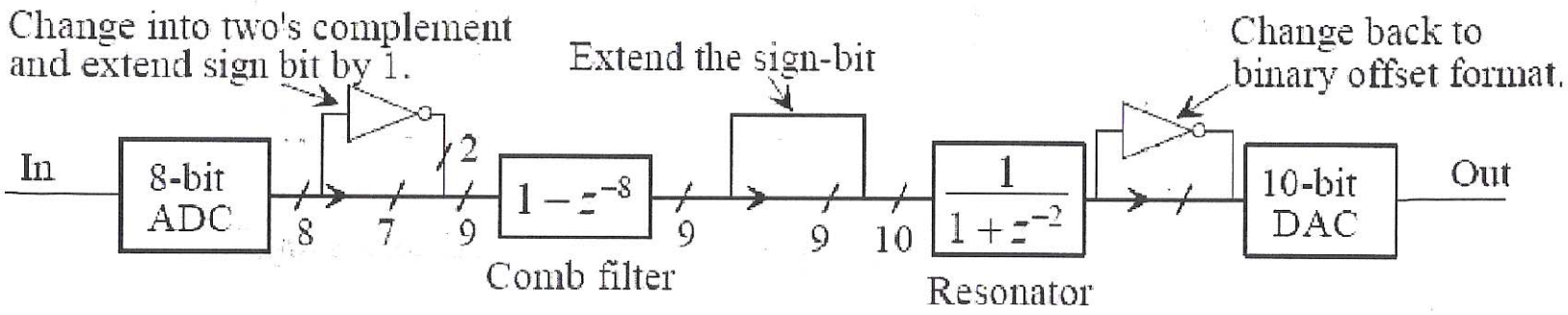
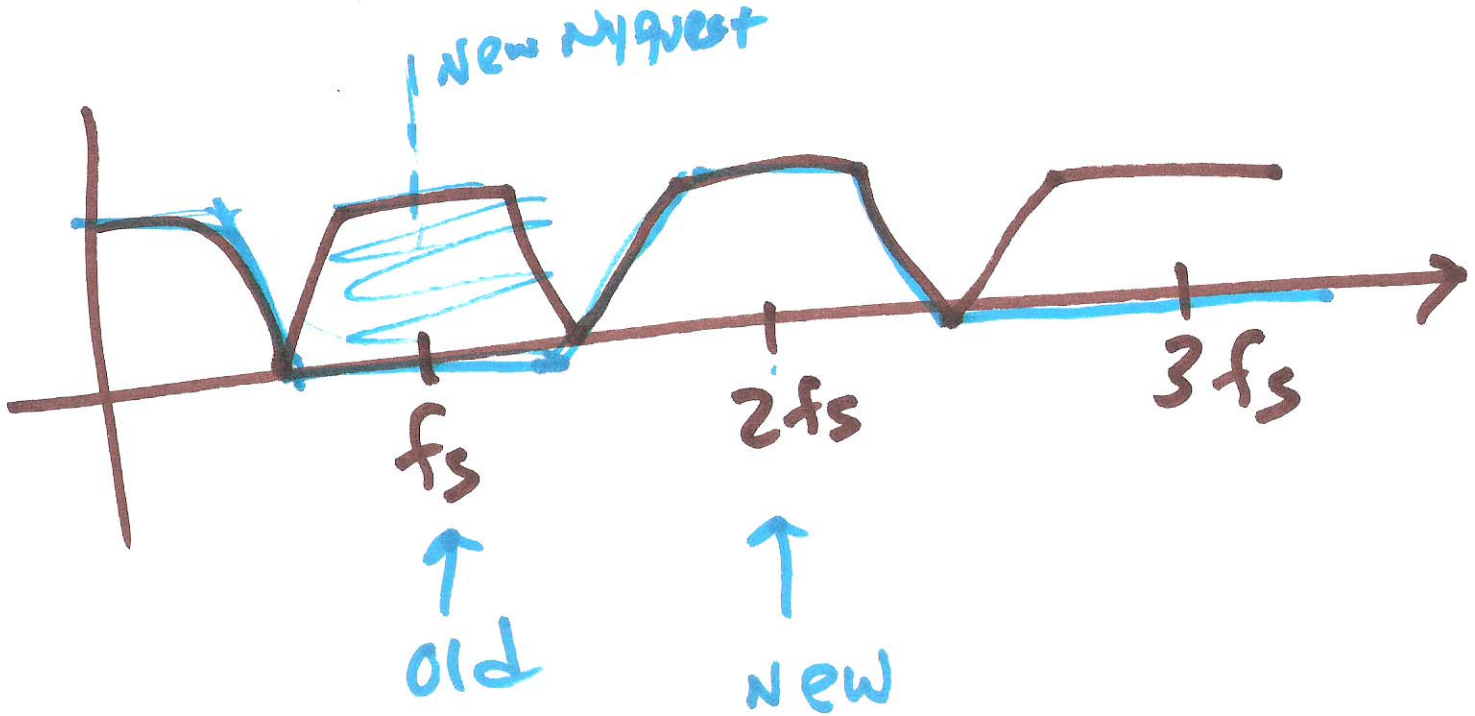


Figure 4.24 Digital filter sketch for Ex. 4.7.

$f_s = 100\text{MHz}$

$f_s/4$

11)


New Nyquist
fs
2fs
3fs
old
New

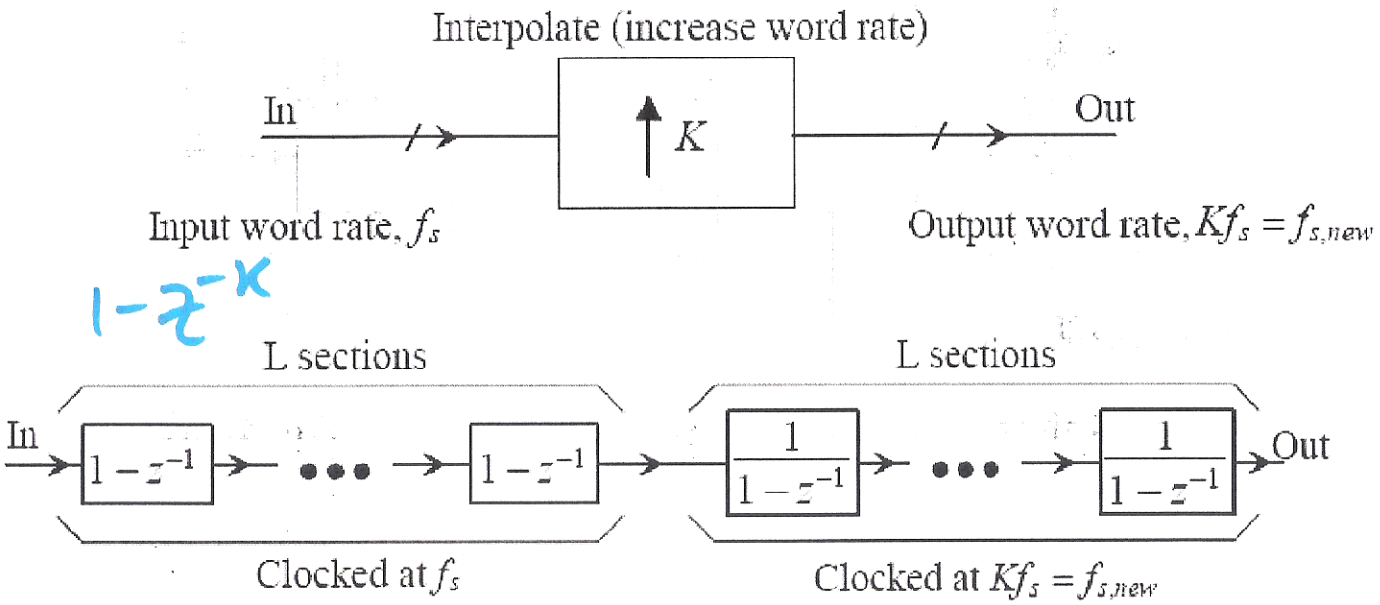


Figure 4.28 Interpolating using Sinc filters for image removal.

1-delay = K-delays

T_s = $\frac{T_s}{K}$