Design and implementation of chebyshev filters engineering essay

A filter in Digital signal Processing terminology is a nothing but a component which eliminates undesired elements of the signals. For instance noise is an undesired element. Filter extracts the desired parts of the signal. An unfiltered signal is given as an input to the filter and a desired or filtered signal or noise free signal in our context comes as an output depending on the specifications of the filter.

These filter structures are classified into FIR systems and IIR systems depending upon their impulse response.

IIR FILTERS:

Infinite Impulse Response (IIR) Filters are so called, because they have an impulse response function that is non-zero over an infinite length of time. Whereas the FIR filters have fixed duration impulse responses. IIR filters are also called as Recursive filters. The present output of the IIR filters depends not only on the present input but also on the past input and past output. IIR filters can be designed as Analog or Digital filters. Analog filter can be converted into digital filter by using bilinear transformation techniques.

The figure below is the block diagram for an IIR filter

The types of the Infinite Impulse Response Filters are:

Butterworth Filters

Chebyshev type -I Filters

Chebyshev type – II Filters

Elliptic or Cauer Filters

Bessel Filters.

As far as our project is concerned, we are dealing with the implementation of Chebyshev type 1 and type 2 filters in low pass and band pass.

CHEBYSHEV FILTERS:

Chebyshev filters can be designed as analog or digital filters and is an improvement on Butterworth filters. These filters have steeper roll off and more pass band and stop band ripple in type 1 and type 2 respectively. These filters reduce the error between the idealized and the actual filter characteristics at a cost of ripple in the pass band. The Chebyshev filter's most desirable character is its speed. The circuit architecture of these filters is simplified when used in designs.

Type 1 Chebyshev filters:

These filters have Equiripple magnitude response in pass band and Monotonically decreasing magnitude in the stop band. The sharp transition between the pass band and stop band of type1 filter produces smaller absolute errors and faster execution speeds than butterworth filter. The ripples in the pass band have a constant magnitude Rp which is considered as an important design aspect of the filter.

from the figure ripples in pass band and sharper roll off in the stop band can be observed

Figure: Frequency response of type 1 Low pass Chebyshev filter

Type 2 Chebyshev Filters:

These filters are also called as Inverse Chebyshev filters. These filters have Equiripple magnitude response in stop band and Monotonically decreasing magnitude response in the pass band. These filters minimize peak error in the stop band instead of the pass band which is an advantage over Chebyshev type 1 filter. The ripples in the pass band have a constant magnitude Rs which is considered as an important design aspect of the filter.

from the figure ripples in stop band and sharper transition from pass band to stop band can be observed

Figure : Frequency response of type 2 Low pass Chebyshev filters

Interpreting the MATLAB code:

Keywords used:

1. Cheb1ord: This keyword is used to find the order of the filter and cut off frequency.

Syntax: [n, Wn] = cheb1ord (Wp, Ws, Rp, Rs)

2. Cheby1: This keyword is used to find numerator and denominator coefficient vectors.

Syntax: [b, a] = cheby1(n, Wn, Rp)

3. Freqz: This keyword calculates the frequency response of the filter.

Syntax: h= freqz (b, a, w)

Where

n = order of the filter

Wn= cutoff frequency

Wp= pass band frequency

Ws= stop band frequency

Rp= pass band attenuation

Rs= stop band attenuation

[b, a] = numerator and denominator coefficient vectors

Filter Design:

In this Project the Type 1 and type 2 Chebyshev filters are designed using the following specifications:

Pass band Attenuation – rp

Stop band Attenuation – rs

Pass band Frequency – Wp

Stop band Frequency – Ws.

By using these specifications the Order of the filter is determined and the plots of Gain, Phase against Normalized frequency are shown

Chebyshev type – I and II(Low Pass),

Chebyshev Type- I and II(Band Pass), filters are being designed.

CHEBYSHEV TYPE-I LOW PASS FILTER:

Specifications:

Pass band Attenuation (rp) = 7 dB Stop band Attenuation (rs) = 14 dB

Pass band Frequency (Wp) = . 4 Hz

Stop band Frequency (Ws) = . 6 Hz

MATLAB CODE:

```
rp= 7;

rs= 14;

wp=. 4;

ws=. 6;

m= 0: 50;

w= 0: 0. 1: pi;

x= 4*((exp(1i*pi)).^m)+2*(rand(1, 51));

figure(1)

plot(m, x);

title(' Noisy input signal');

[n, wn]= cheb1ord(wp, ws, rp, rs)
```

```
[b, a]= cheby1(n, rp, wn)

[h, ph]= freqz(b, a, w);

y= filter(b, a, x);

[h1, ph1]= freqz(y, 1, w);

p= 20*log(abs(h));

p1= 20*log(abs(h1));

an= angle(h);

an1= angle(h1);

figure(2)

subplot(2, 2, 1);

plot(ph/pi, p);

grid;

ylabel(' Gain(dB)');

xlabel(' Frequency (Normalized)');

title(' Frequency response');

subplot(2, 2, 2);

plot(ph1/pi, p1);
```

grid;

ylabel(' Gain(dB)(noisy input)');

xlabel(' Frequency (Normalized)');

title(' Frequency response(noisy input)');

subplot(2, 2, 3);

plot(ph/pi, an);

grid;

ylabel(' Phase (Radians)');

xlabel(' Frequency (Normalized)');

title(' Phase plot');

subplot(2, 2, 4);

plot(ph1/pi, an1);

grid;

ylabel(' Phase(Radians)(noisy input)');

xlabel(' Frequency (Normalized)');

title(' Phase plot(noisy input)');

Results:

N= Filter Order = 2

Cutoff Frequency Wn = 0. 4000

Numerator Coefficients b = 0. 0853 0. 1707 0. 0853

Denominator Coefficients a = 1. 0000 -0. 9131 0. 6772

SIMULATION RESULTS:

CHEBYSHEV TYPE – II LOW PASS FILTERS:

Specifications:

Pass band Attenuation (rp) = 7 dB

Stop band Attenuation (rs) = 14 dB

Pass band Frequency (Wp) = . 4 Hz

Stop band Frequency (Ws) = . 6 Hz

MATLAB CODE:

rp= 7;

rs= 14;

wp=. 4;

ws=. 6;

m= 0: 50;

```
w= 0: 0. 1: pi;

x= 4*((exp(1i*pi)).^m)+2*(rand(1, 51));

figure(1)

plot(m, x);

title(' Noisy input signal');

[n, wn]= cheb2ord(wp, ws, rp, rs)

[b, a]= cheby2(n, rp, wn)

[h, ph]= freqz(b, a, w);

y= filter(b, a, x);

[h1, ph1]= freqz(y, 1, w);

p= 20*log(abs(h));

p1= 20*log(abs(h1));

an= angle(h);

an1= angle(h1);

figure(2)

subplot(2, 2, 1);

plot(ph/pi, p);
```

grid;

ylabel(' Gain(dB)');

xlabel(' Frequency (Normalized)');

title(' Frequency response');

subplot(2, 2, 2);

plot(ph1/pi, p1);

grid;

ylabel(' Gain(dB)(noisy input)');

xlabel(' Frequency (Normalized)');

title(' Frequency response(noisy input)');

subplot(2, 2, 3);

plot(ph/pi, an);

grid;

ylabel(' Phase (Radians)');

xlabel(' Frequency (Normalized)');

title(' Phase plot');

subplot(2, 2, 4);

plot(ph1/pi, an1);

grid;

ylabel(' Phase(Radians)(noisy input)');

xlabel(' Frequency (Normalized)');

title(' Phase plot(noisy input)');

Results:

Filter Order n = 2

Cutoff Frequency wn = 0. 6000

Numerator Coefficients b = 0. 5267 0. 6135 0. 5267

Denominator Coefficients a = 1. 0000 0. 3410 0. 3260

SIMULATION RESULTS:

CHEBYSHEV TYPE-I BAND PASS FILTER:

Specifications:

Pass band Attenuation (rp) = 5 dB Stop band Attenuation (rs) = 20 dB

Pass band Frequency (Wp) = 0. 3 TO 0. 6 Hz

Stop band Frequency (Ws) = 0. 1 TO 0. 7Hz

MATLAB CODE:

rp= 5;

```
rs= 20;

wp=[. 3,. 6];

ws=[. 1,. 7];

m= 0: 50;

w= 0: 0. 1: pi;

x= 4*((exp(1i*pi)).^m)+2*(rand(1, 51));

figure(1)

plot(m, x);

title(' Noisy input signal');

[n, wn]= cheb1ord(wp, ws, rp, rs)

[b, a]= cheby1(n, rp, wn)

[h, ph]= freqz(b, a, w);

y= filter(b, a, x);

[h1, ph1]= freqz(y, 1, w);

p= 20*log(abs(h));

p1= 20*log(abs(h1));

an= angle(h);
```

an1= angle(h1);

figure(2)

subplot(2, 2, 1);

plot(ph/pi, p);

grid;

ylabel(' Gain(dB)');

xlabel(' Frequency (Normalized)');

title(' Frequency response');

subplot(2, 2, 2);

plot(ph1/pi, p1);

grid;

ylabel(' Gain(dB)(noisy input)');

xlabel(' Frequency (Normalized)');

title(' Frequency response(noisy input)');

subplot(2, 2, 3);

plot(ph/pi, an);

grid;

ylabel(' Phase (Radians)');

xlabel(' Frequency (Normalized)');

title(' Phase plot');

subplot(2, 2, 4);

plot(ph1/pi, an1);

grid;

ylabel(' Phase(Radians)(noisy input)');

xlabel(' Frequency (Normalized)');

title(' Phase plot(noisy input)');

RESULTS:

Filter Order n = 3

Cutoff frequency Range wn = 0. 3000 0. 6000

Numerator Coefficients b = 0. 0154 0 -0. 0463 0 0. 0463 0 -0. 0154

Denominator Coefficients a = 1. 0000 -0. 8796 2. 2820 -1. 3689 2. 0391 -0. 6699 0. 6706

SIMULATION RESULTS:

CHEBYSHEV TYPE – II BAND PASS FILTERS:

Specifications:

Pass band Attenuation (rp) = 5 dB

Stop band Attenuation (rs) = 20 dB

Pass band Frequency (Wp) = 0. 3 TO 0. 6 Hz

Stop band Frequency (Ws) = 0. 1 TO 0. 7 Hz

MATLAB CODE:

```
rp= 5;

rs= 20;

wp=[. 3,. 6];

ws=[. 1,. 7];

m= 0: 50;

w= 0: 0. 1: pi;

x= 4*((exp(1i*pi)).^m)+2*(rand(1, 51));

figure(1)

plot(m, x);

title(' Noisy input signal');

[n, wn]= cheb2ord(wp, ws, rp, rs)

[b, a]= cheby2(n, rp, wn)
```

```
[h, ph]= freqz(b, a, w);

y= filter(b, a, x);

[h1, ph1]= freqz(y, 1, w);

p= 20*log(abs(h));

p1= 20*log(abs(h1));

an= angle(h);

an1= angle(h1);

figure(2)

subplot(2, 2, 1);

plot(ph/pi, p);

grid;

ylabel(' Gain(dB)');

xlabel(' Frequency (Normalized)');

title(' Frequency response');

subplot(2, 2, 2);

plot(ph1/pi, p1);

grid;
```

ylabel(' Gain(dB)(noisy input)');

xlabel(' Frequency (Normalized)');

title(' Frequency response(noisy input)');

subplot(2, 2, 3);

plot(ph/pi, an);

grid;

ylabel(' Phase (Radians)');

xlabel(' Frequency (Normalized)');

title(' Phase plot');

subplot(2, 2, 4);

plot(ph1/pi, an1);

grid;

ylabel(' Phase(Radians)(noisy input)');

xlabel(' Frequency (Normalized)');

title(' Phase plot(noisy input)');

RESULTS:

Filter Order n = 3

Cutoff Frequency range wn = 0. 1000 0. 7000

Numerator Coefficients b = 0. 6086 -0. 3630 -0. 9445 -0. 0000 0. 9445 0. 3630 -0. 6086

Denominator Coefficients a = 1. 0000 -0. 9824 -0. 6541 0. 0776 0. 9201 0. 0578 -0. 3666

SIMULATION RESULTS:

DISCUSSION OF RESULTS:

Characteristics of type 1 Chebyshev low pass observed:

Ripple at 0. 3dB in the pass band

Monotonic in stop band with steeper roll off

Characteristics of type II Chebyshev low pass observed:

Ripple in stop band

Monotonic in pass band

Steeper roll off and an additional feature of no pass band ripple

Characteristics of type 1 Chebyshev Band pass observed:

Ripple between 0. 3 and 0. 6dB in the pass band

Monotonic in stop band

Characteristics of type II Chebyshev Band stop observed:

Ripple is observed around 0. 3 and 0. 6 dB and others are rejected in the pass band

APPLICATIONS:

POWERLINE FREQUENCY FILTERING APPLICATIONS

BIOMEDICAL APPLICATIONS

SPECIFIC APPLICATION:

ELECTRO CARDIOGRAM in which the noise due to the following sources is eliminated using type II Chebyshev filter.

Power line Interface

Electrode Contact Noise

Muscle Contraction

Motion Artifacts

Electro Surgical Noise

Instrumentation Noise

CONCLUSION:

We designed and implemented the Chebyshev filters with added noise in the input and observed the frequency responses of the type 1 and type 2 Chebyshev filters for both band pass and low pass in MATLAB. We observed that for type 1 Chebyshev low pass filter, there is a ripple in the pass band. For type 2 Chebyshev low pass filter, there is a ripple in the stop band. for

type 1 Chebyshev band pass filter, there is a ripple in the pass band. For type 2 Chebyshev band pass filter, there is a ripple in the stop band. The common characteristic observed in all the Chebyshev filters is the steeper roll of in stop band.