Filtration with IIR for Equalization & Replacing

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GitHub Repo[2]:	https://github.com/attaullahshafiq10/dsp-mini
Plagiarism Report:	10% (Checked from “PCX[3] Pro software”)

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[2] This Code is also available at our GitHub repo, Link [https://github.com/attaullahshafiq10/dsp-mini]
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Contents

Assignment

Filtration Process with IIR

(Analysis of IIR Filtration in terms of Replacing and minimum order)

1 Abstract

2 Filters for IIR are typically employed for applications that don't have too much linear process and memory. These are commonly used in audio equalisation, signal processing, IoT/IIoT smart sensors and high-speed telecom or RF applications and are a key algorithmic design building block. This code demonstrates how simple it is to replace a Butterworth configuration with a Chebyshev or a similar elliptical filter, and at the cost of some ripple in the filter passband and/or stopband to get a steeper roll-off. The designs for the minimum order are then analysed.

3 Introduction & Background of the Project

The IIR filter is categorized by its theoretically infinite impulse response:

$$y(n)=\sum_{k=0}^{\infty}h(k)x(n-k)$$

In reality, the output of the IIR with this equation cannot be determined. Thus, the equation can be reprocessed in the limited number of poles p and q, as defined by the linear constant differential coefficient equation:

$$y(n)=\sum_{k=0}^{q}b(k)x(n-k)-\sum_{k=1}^{p}a(k)y(n-k)$$

Where a(k) and b(k) are the denominator and numerator polynomial coefficients of the filter, the roots of which are equal to the poles and zeros of the filter. The relationship between the difference equation and the z-transform (transfer function) can therefore be defined by using the z-transform delay property.

3.1.1 Butterworth

Butterworth filters are extremely flat in the passenger band and monotonous overall, making them a good choice for DC and charge cells. This rather attractive 'smoothness' is nevertheless the price of lower rolling steepness. In effect, Butterworth has the slowest rollover features of all methods.

3.1.2 Elliptic

Elliptic filters are steeper than Butterworth and Chebyshev filters, but they are equipment for both the passband and stopband. Elliptic filters generally comply with the design requirements in the lowest order of all the methods discussed.

3.1.3 Chebyshev Type I

Chebyshev Type I filters are equiripple in the passband and monotone in the stopband. As such, filters of type I roll out quicker than filters of type II and Butterworth Chebyshev, but to the detriment of wider ribbon ribbons.

3.1.4 Chebyshev Type II

Chebyshev Type II is a monotone filter in the passband and a stopband, making it an advantageous choice for applications in the bridge sensor system. Even though filters designed using the Type II method are slow down to roll-off, the roll-off time is faster than those produced using the Butterworth method. The roll-off time.

4 Similar Projects and Literature Review

We have arranged and studied these all projects. And generate this code accordingly. This code is basically cited from a code used in python[4] and we have generated this as MATLAB code.

4.1.1 IIR Filter Design Using the Helper Modules with Python

The Scipy package signal assists in the design of many digital filter types. In this Project IIR filter designed with jupyter notebook. Here is the link for complete details: https://scikit-dsp-comm.readthedocs.io/en/latest/nb_examples/FIR_and_IIR_Filter_Design.html

4.1.2 Compensate for the Delay Introduced by an IIR Filter

In this Project, Filtering a signal will cause a delay. This means that the output signal is shifted to the input in time. So Infinite impulse response filters delay some of the frequency components more than others. They are effectively distorting the input signal. The filter function compensates for the delays introduced by such filters and thus corrects the distortion of the filter. This "zero-phase filtering" is the result of filtering the signal in the forward and backward directions.

Here is the link to find this Project: https://www.mathworks.com/help/signal/ug/compensate-for-the-delay-introduced-by-an-iir-filter.html

4.1.3 Digital IIR Filter Design Using Differential Evolution Algorithm (Springer-2005)

In this work, the DE algorithm was applied to the design of digital IIR filters and its performance was compared to that of a genetic algorithm. Here is the link to access[5] this paper: https://link.springer.com/article/10.1155/ASP.2005.1269

4.1.4 Electronic Filter Design

In this book they keep up with major developments in Electronic Filter Design, including the latest developments in both analogue and digital filters. McGraw-classic Hill's Electronic Filter Design Handbook, long established as the "Bible" of practical electronic filter design, has now been completely revised and updated for a new generation of design engineers. Link:[6] https://www.accessengineeringlibrary.com/content/book/9780071471718

[4] https://scikit-dsp-comm.readthedocs.io/en/latest/nb_examples/FIR_and_IIR_Filter_Design.html

[5] Citation: Karaboga, Nurhan. "Digital IIR filter design using differential evolution algorithm." *EURASIP Journal on Advances in Signal Processing* 2005.8 (2005): 856824.

[6] Williams, Arthur B., and Fred J. Taylor. *Electronic filter design handbook*. McGraw-Hill Education, 2006.

5 Aims and Objectives of Project

To create traditional IIR filters. The primary emphasis is on the situation where the parameter of the critical configuration is the cut-off frequency at which the filter power decreases to half (-3 dB) of the nominal passband.

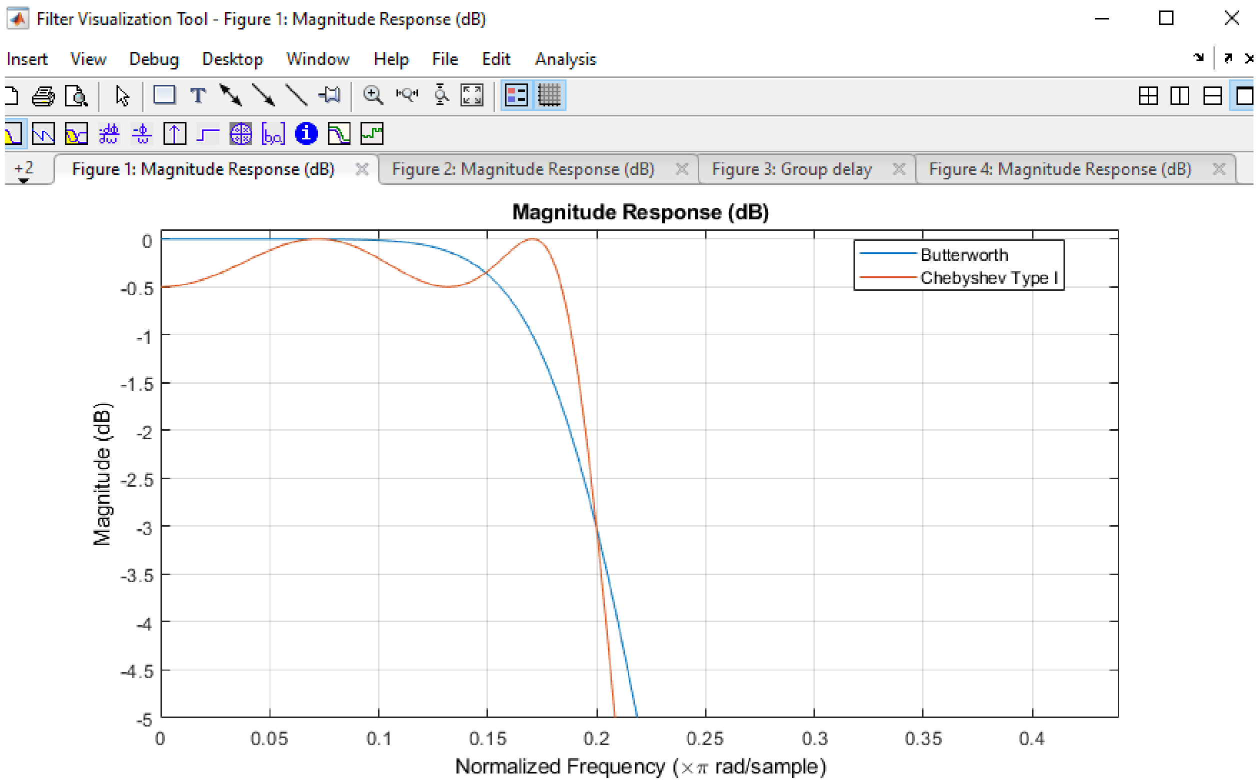
The Butterworth configuration can easily be replaced with either a Chebyshev or an elliptical filter of the same order and the filter can roll out more steeply at the cost of a rib in the bandwidth and/or stop band. The designs of the minimum order are then examined.

6 Tools

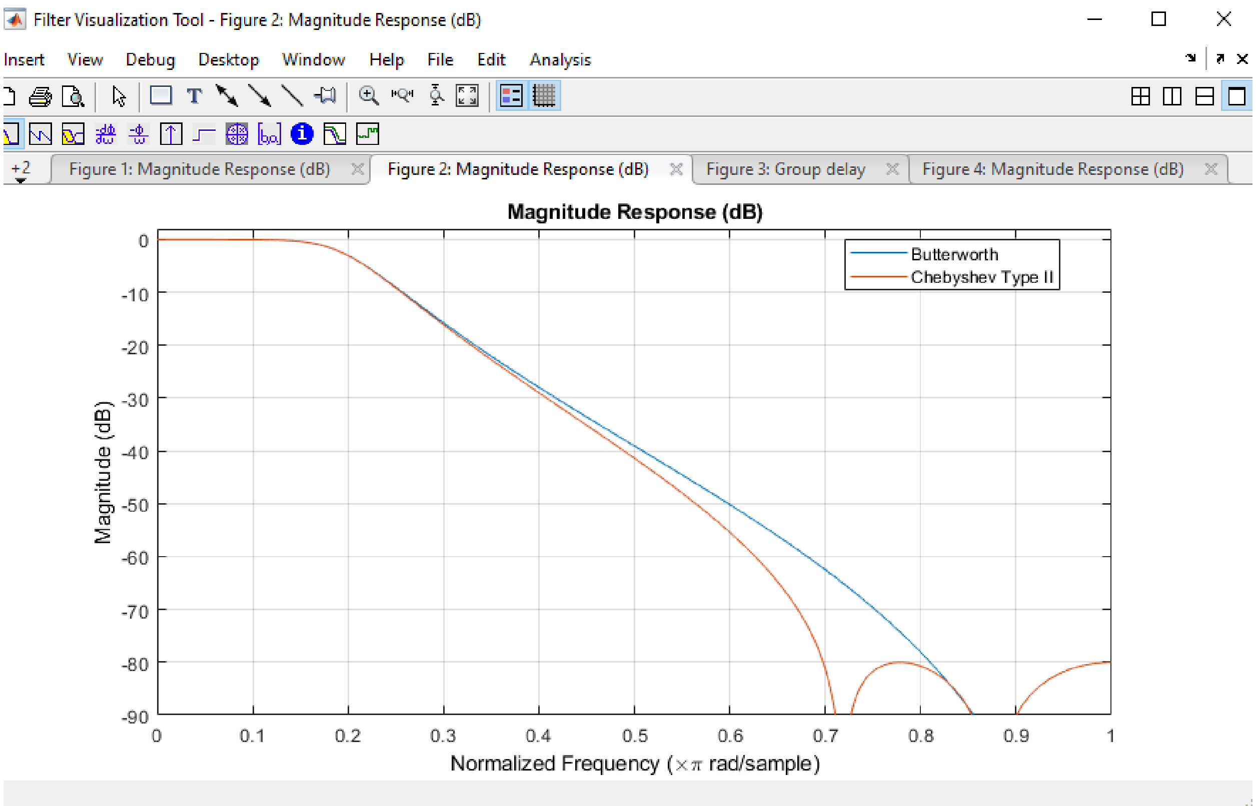
- MATLAB (R2020a)
- DSP Systems Toolbox
- Filter Design Toolbox

7 Result and Discussions

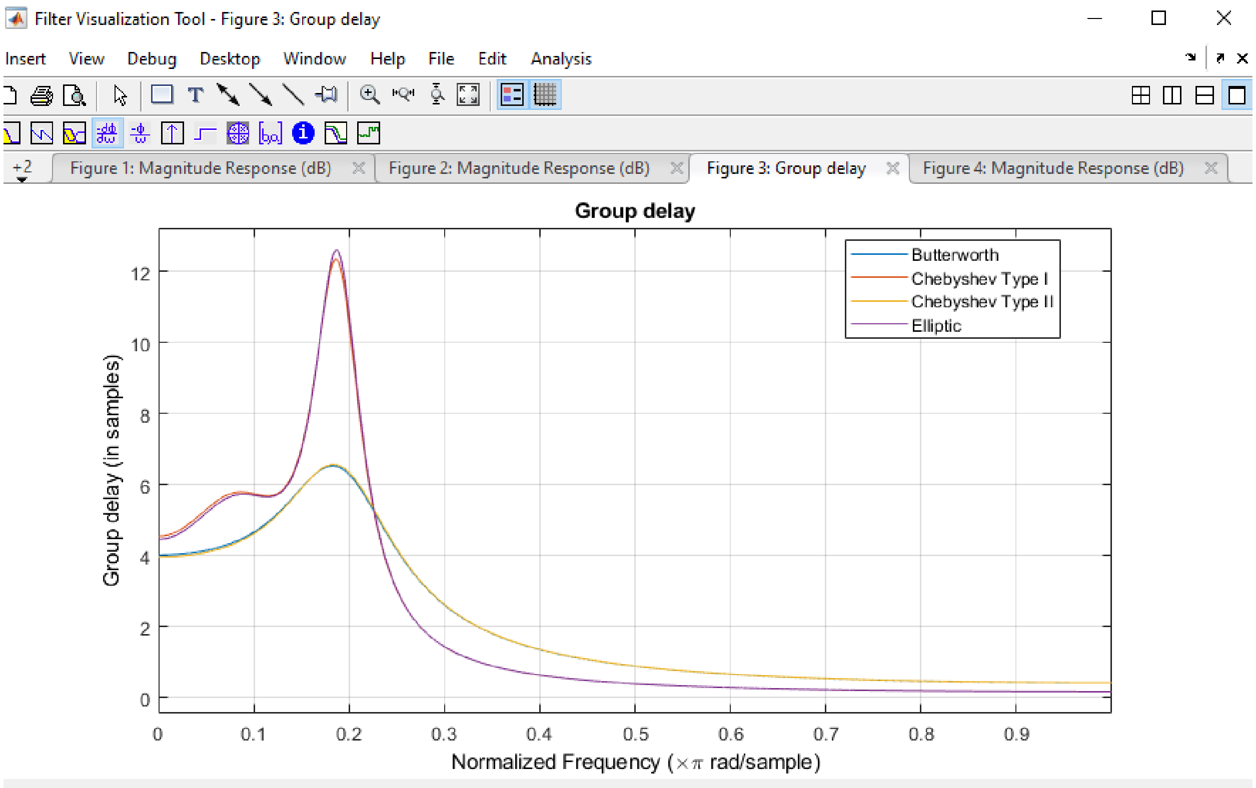
As we mentioned earlier, it is easy to replace the Butterworth design with either a Chebyshev or an elliptical filter of the same order and to obtain a steeper roll-off at the expense of some ripple in the passband and/or the filter stop band. And also mentioned the minimum order designs are explored. So first of all, it explored 8th order filter with a normalized cut-off frequency of 0.4pi. Afterwards, we build a filter Butterworth as flat as possible (no ripple in the passband or in the stopband). Then the Chebyshev type-I architecture enables the ripples in the passband to be controlled. In the stop band, there are yet no ripples. Greater ripples make a steeper roll-off possible. Therefore, we define a 0.5dB limit to peak rib.



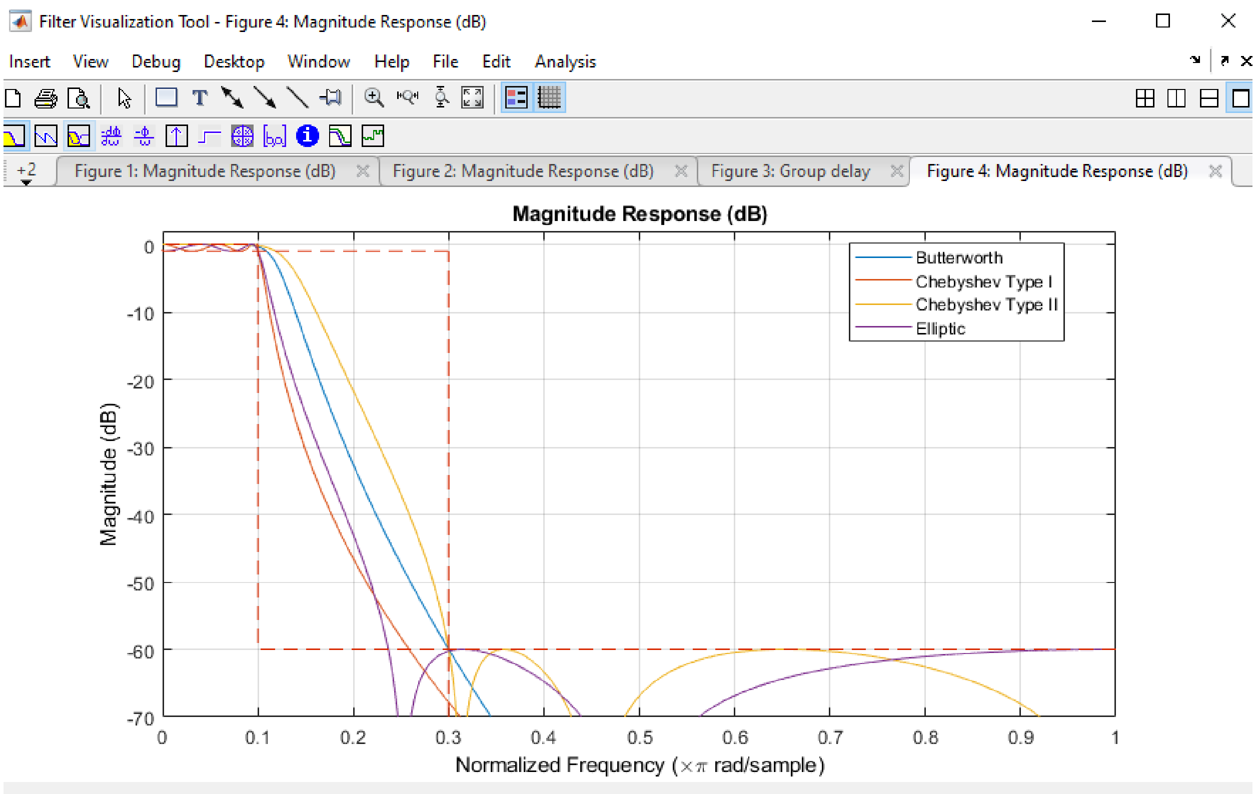
The architecture of the Chebyshev Type II now enables control of the stop-band attenuation. There's no ripples in the passband. A minor reduction in the stopband makes a steeper rollover. An attenuation of 80 dB is defined in this case:



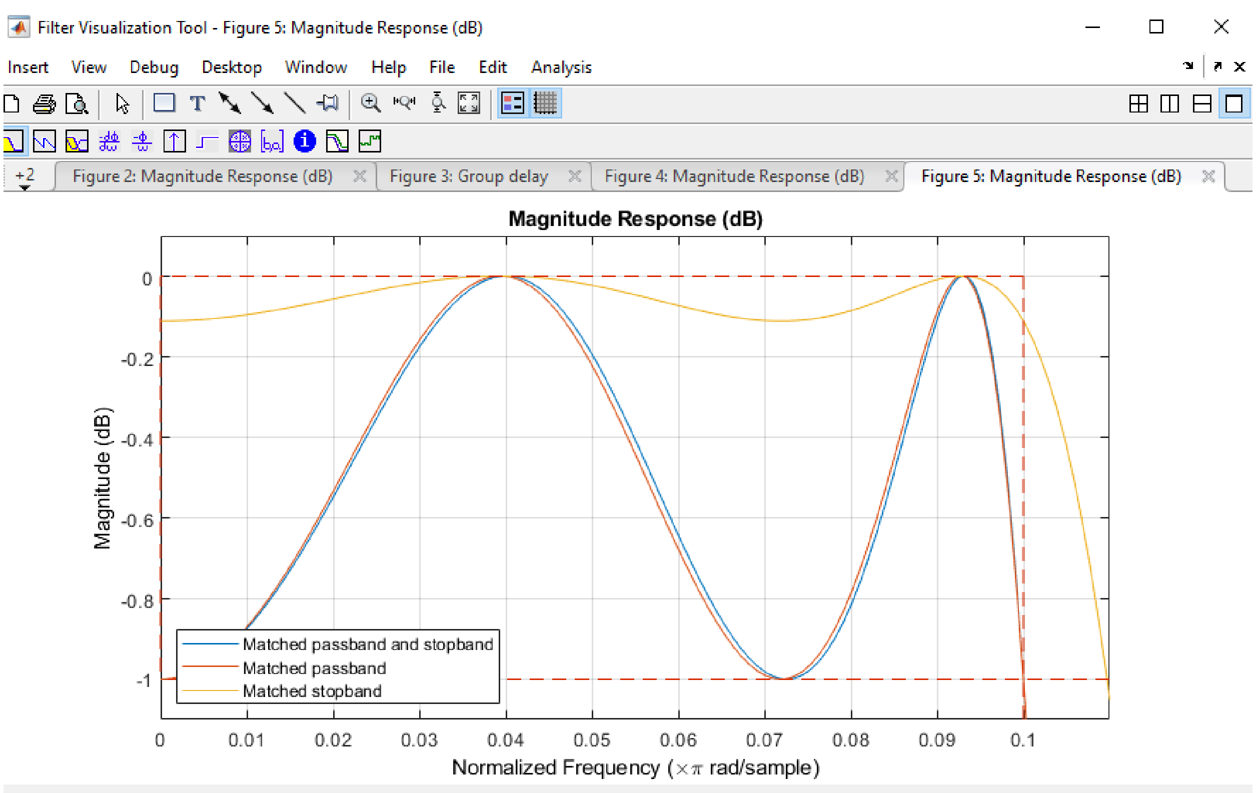
Finally, by rippling both the stop band and the bandwidth, an elliptical filter can provide a steeper roll-off compared to previous designs. We use the same passband and stopband as above to demonstrate this.



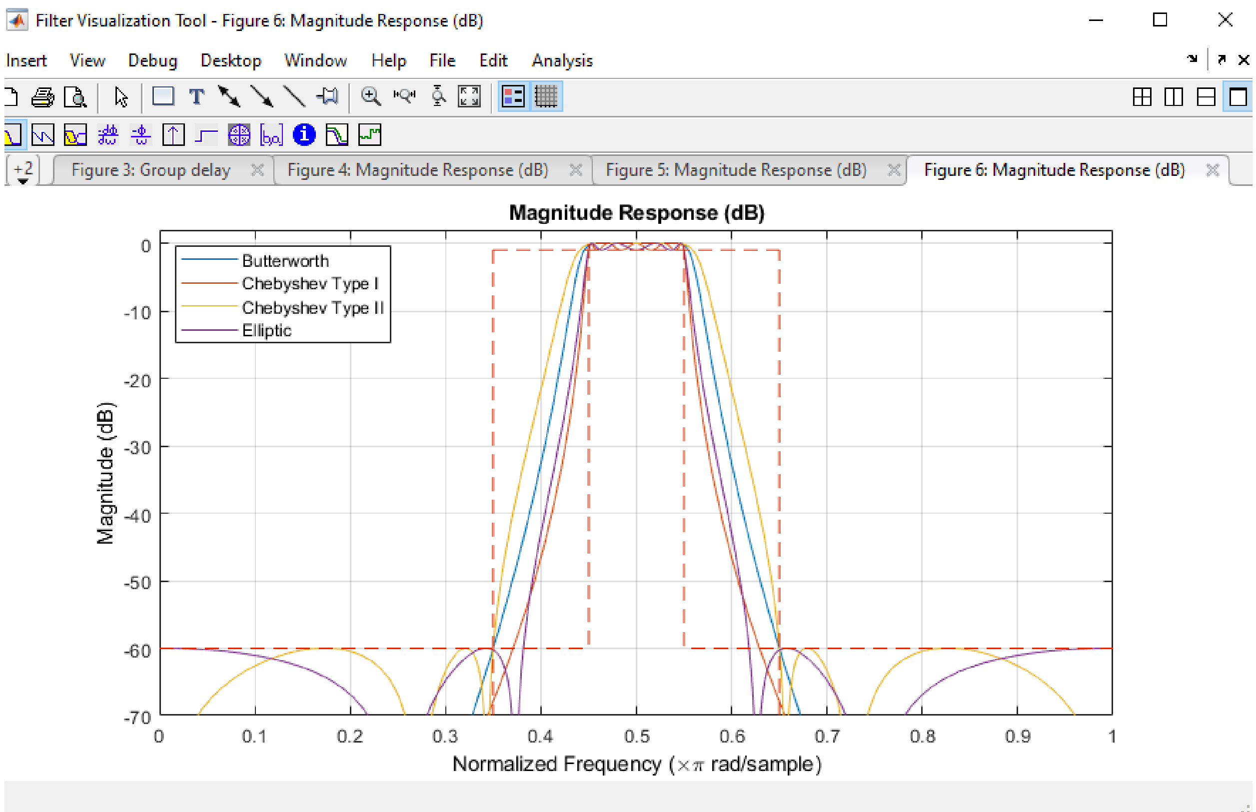
Now we check that all filters have the same-3dB frequency point and that only Butterworth and Chebyshev Type II designs have a perfectly flat passband, for this we used zooming in the passband.



Now we are using Group delay for phase consideration.



Then applied to minimum Order designs in terms of frequencies and the amount of tolerable ripples. After this it extended to highpass, bandpass and bandstop response types. So its minimum order bandpass filters.



8 Complete Program with some specific comments[7]:

```
% Filtration with IIR for Equalization
% Analysis of IIR Filtration in terms of Replacing and minimum order
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%  Authors:
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%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Lowpass Filters
% First, we design a Butterworth filter
fdB = .2;
X = 4;
d = fdesign.lowpass('N,F3dB',X,fdB);
```

[7] https://github.com/attaullahshafiq10/dsp-mini

```
Hbutter = design(d,'butter','SystemObject',true);
% Now Chebyshev, to allow ripples in the passband to be controlled. No waves
on the stopband are yet.
Ap=.5;
setspecs(d,'N,F3dB,Ap',X,fdB,Ap);
Hcheby1=design(d,'cheby1','SystemObject',true);
hfvt=fvtool(Hbutter,Hcheby1,'Color','white');
axis([0 .44 -5 .1])
legend(hfvt,'Butterworth','Chebyshev Type I');
%Chebyshev TypeII design It allows the stopband attenuation to be managed.
Ast=80;
setspecs(d,'N,F3dB,Ast',X,fdB,Ast);
Hcheby2 = design(d,'cheby2','SystemObject',true);
hfvt = fvtool(Hbutter,Hcheby2,'Color','white');
axis([0 1 -90 2])
legend(hfvt,'Butterworth','Chebyshev Type II');
% In contrast to previous designs an elliptical filter can have a steeper
roll-off by allowing both the stopband as well as the passband to rip.
setspecs(d,'N,F3dB,Ap,Ast',X,fdB,Ap,Ast);
Hellip=design(d,'ellip','SystemObject',true);
hfvt=fvtool(Hbutter,Hcheby1,Hcheby2,Hellip,'Color','white');
axis([0 1 -90 2])
legend(hfvt, ...
    'Butterworth','Chebyshev Type I','Chebyshev Type II','Elliptic');
% Now set the access
axis([0 .44 -5 .1])
% Group Delay checking
hfvt.Analysis='grpdelay';

% Minimum Order Designs
Ap = 1;
Ast = 60;
Fp = .1;
Fst = .3;

setspecs(d,'Fp,Fst,Ap,Ast',Fp,Fst,Ap,Ast);
Hbutter=design(d,'butter','SystemObject',true);
Hcheby1=design(d,'cheby1','SystemObject',true);
Hcheby2=design(d,'cheby2','SystemObject',true);
Hellip=design(d,'ellip','SystemObject',true);
hfvt=fvtool(Hbutter,Hcheby1,Hcheby2,Hellip, 'DesignMask', 'on',...
    'Color','white');
axis([0 1 -70 2])
legend(hfvt, ...
    'Butterworth','Chebyshev Type I','Chebyshev Type II','Elliptic');

% 7th, 6th, 5th order (Chebyshev techniques)
order(Hbutter)
order(Hcheby1)
order(Hcheby2)
order(Hellip)

% Now Matching the Passband or Stopband Specifications
Hellipmin1    = design(d, 'ellip', 'MatchExactly', 'passband',...
    'SystemObject',true);
Hellipmin2 = design(d, 'ellip', 'MatchExactly', 'stopband',...
```

```
    'SystemObject',true);
hfvt=fvtool(Hellip, Hellipmin1, Hellipmin2, 'DesignMask', 'on',...
    'Color','white');
axis([0 1 -80 2]);
legend(hfvt, 'Matched passband and stopband', ...
    'Matched passband', 'Matched stopband', ...
    'Location', 'Northeast')

% compare passband edges
axis([0 .11 -1.1 0.1]);
legend(hfvt, 'Location', 'Southwest')

% verifying that, resulting order of filters are not changed
order(Hellip)
order(Hellipmin1)
order(Hellipmin2)

% Now finally. Highpass, Bandpass and Bandstop Filters
d=fdesign.bandpass('Fst1,Fp1,Fp2,Fst2,Ast1,Ap,Ast2', ...
    .35,.45,.55,.65,60,1,60);
Hbutter=design(d,'butter','SystemObject',true);
Hcheby1=design(d,'cheby1','SystemObject',true);
Hcheby2=design(d,'cheby2','SystemObject',true);
Hellip=design(d,'ellip','SystemObject',true);
hfvt=fvtool(Hbutter,Hcheby1,Hcheby2,Hellip, 'DesignMask', 'on',...
    'Color','white');
axis([0 1 -70 2])
legend(hfvt, ...
    'Butterworth','Chebyshev Type I','Chebyshev Type II','Elliptic',...
    'Location', 'Northwest')
% end
```

9 References

Classical IIR filter design: a practical guide, https://www.advsolned.com , accessed on 11 jan 2021

Karaboga, Nurhan. "Digital IIR filter design using differential evolution algorithm." *EURASIP Journal on Advances in Signal Processing* 2005.8 (2005): 856824.

Williams, Arthur B., and Fred J. Taylor. *Electronic filter design handbook*. McGraw-Hill Education, 2006.

Classic IIR Filter Design, https://www.mathworks.com , accessed on 12,13,14,15,16 January 2021

Compensate for the Delay Introduced by an IIR Filter, https://www.mathworks.com , accessed on,14 and 15 January 2021

https://github.com/mwickert/scikit-dsp-comm , accessed on 16 January 2021

Minimum order for elliptic filters, https://www.mathworks.com , accessed on 16 January 2021

https://www.mathworks.com/help/signal/ref/cheby1.html , accessed on 15 January 2021