



Electronics II

Lecture 21 Filters IV

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Previous Lecture

- Types of Filter
 - Band Pass Filter.
 - Band Stop Filter.
 - All Pass Filter.



Session Overview

| | |
|----------------------------|---|
| Topic | Classic Filter Functions . Feedback Amplifiers (Introduction). |
| Concepts | Classic Filter Response: Butterworth, Chebyshev, Elliptic, Bessel. |
| Recommended Reading | Section 11-5 of [2] Section 1.4 of [3] Sections 17-1 & 17-2 of [1] |
| Keywords | Butterworth, Chebyshev, Elliptic, Bessel, Ripple, Roll Off, Pass Band, Stop Band. |



Classic Filter Functions

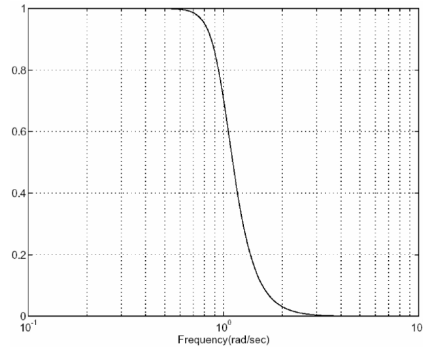
- Classic filter functions were developed by mathematicians and each one of these aim to optimize certain property.
- This can also be termed as the filter classification on the basis of design types.
- Four of these classical filter functions are discussed in this lecture.
- Butterworth.
- Chebyshev.
- Elliptic.
- Bessel



Butterworth Filter

- Flattest pass band with no or minimum ripple.
- Roll off is smooth and monotonic.
- Roll off rate is 20dB/decade for each pole.
- Reasonably good phase response with moderate phase distortion.

$$H(\omega) = \frac{1}{1 + \left(\frac{\omega}{\omega_0}\right)^{2n}}$$

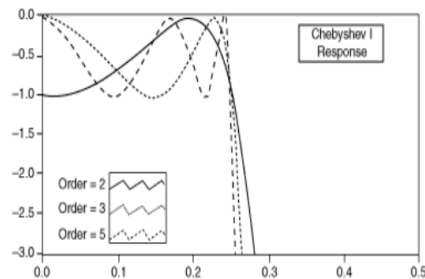


Source Document: Classical Filters (<http://194.81.104.27/~brian/DSP/ClassicFilters.pdf>)



Chebyshev Filter

- Better roll off than Butterworth.
- As the roll off increases, the ripples in the pass band also increase and transient response degrades.
- Chebyshev filters where the ripples are allowed only in the pass band are called '*Type I filters*'.
- Chebyshev filters with ripples in stop band only are '*Type II filters*'.
- Chebyshev filters have a poor phase response.
- Filter of order n will have n-1 pass band ripples.

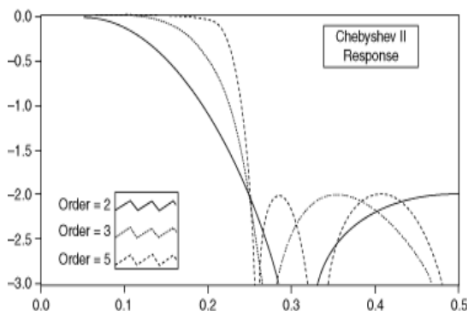


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Chebyshev vs Butterworth

- For a pass band flatness within 0.1dB and stop band attenuation of 20 dB, we need
 - 8th order Chebyshev filter **OR**
 - 19th order Butterworth filter.
- Chebyshev filter can achieve a sharper transition between the pass band and stop band with a lower order filter as compared to the Butterworth.
- Thus, a Chebyshev filter produces smaller absolute errors and faster execution speed than Butterworth.

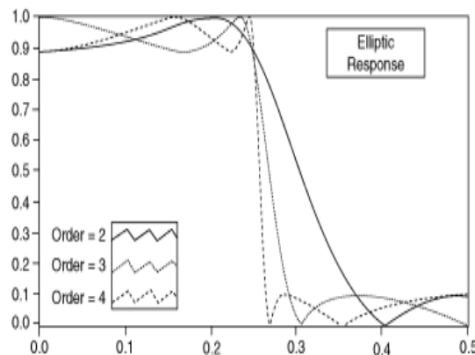


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Elliptic Filter

- Characterized by fastest roll off rate among Butterworth, Chebyshev and Bessel filters.
- Steepest roll off accounts for its wide spread uses.
- Amplitude response has ripples in pass band as well as in stop band.
- Phase response is very non linear.
- Better suited only for applications where phase shift, ringing etc are not a matter of concern.

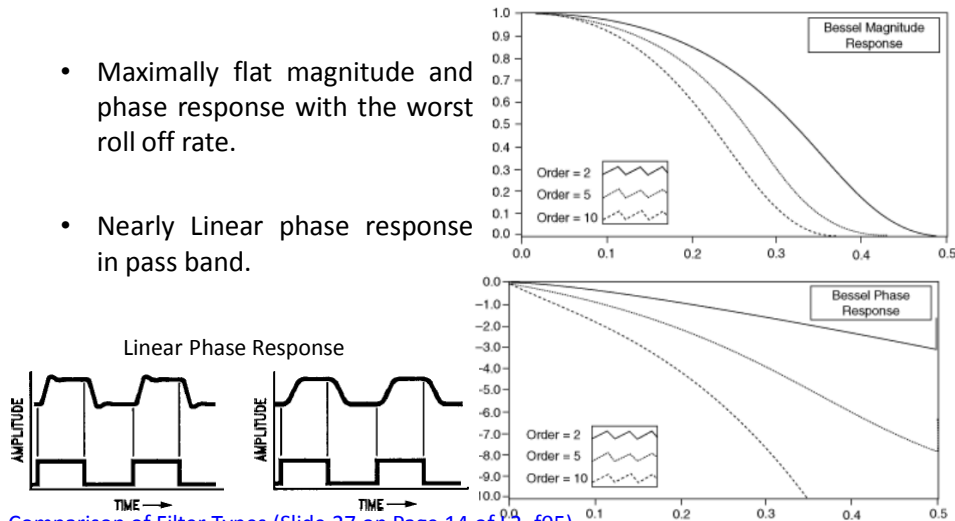


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Bessel OR Thompson Filter

- Maximally flat magnitude and phase response with the worst roll off rate.
- Nearly Linear phase response in pass band.



[Comparison of Filter Types \(Slide 27 on Page 14 of 12 f05\)](#)

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Filter Stability and Applications

- For a stable filter all of the poles must be located in the left half s- plane.
- What are different applications of filters?



Summary (Filters)

- In these 4 lectures, following areas are covered
 - Filter Basic Definition and Functionality.
 - Filter Transfer Function.
 - Filter Magnitude and Phase Response .
 - Classification of Filters (Order of Filter)
 - Classification of Filters (Circuitry Used)
 - Classification of Filters (Allowed Frequencies)
 - Classification of Filters(Response Types)
 - Filter Stability Study.
 - Applications of Filters.



References

- [1] Robert L. Boylestad, *Electronic Devices and Circuit Theory*, 8th Edition, Pearson Education Inc, ISBN: 81-7808-590-9.
- [2] Theodore F. Bogart, Jeffery S. Beasley, Guillermo Rico, *Electronics Devices and Circuits*, 6th Edition, Pearson Education Inc, ISBN: 978-81-775-8887-3
- [3] Kerry Lacanette. Application Note 779: A Basic Introduction to Filters-Active, Passive and Switched Capacitor, Texas Instruments, Literature Number: SNOA224A, April 2010 .
URL to fulltext: <http://www.ti.com/lit/an/snoa224a/snoa224a.pdf>