Administrative

- Updated order of lecture topics – see Trunk
- This week’s lectures and HW are on exam3
  - HW for today is posted in today’s folder
- Next Monday: HW is due *and* Matlab6 is due.
  - Try to spend time on Matlab6 this week, so can use Thurs office hours on it
  - Coding can be a little tricky
- Next Wednesday: Exam3

EE-125:
Digital Signal Processing

Digital IIR Filter Design:
Mapping analog filters to z-land

Professor Tracey

Tufts

Why map analog filters to digital IIR filters?

- A lot of analog filters are well understood and quite effective – we'd like to use them!
  - Sometimes we want to digitally replicate what an analog filter does
  - IIR filters generally offer better attenuation for the same filter length (amount of computation) - remember SNAP filtering from MATLAB3
- IIR filters *do* introduce phase distortion, but
  - Sometimes we don't care
  - Can always fix up phase distortion using forward/backward filtering (filtfilt – remember MATLAB3)

Common IIR Filter Types (P&M 10.3.4)

Type	Characteristic
Butterworth	Monotonic, smooth response; *maximally flat* at F=0, Infinity (N-1 zero derivatives)
Chebyshev Type I	Minimized absolute difference in **passband**; passband ripple, monotonic in stopband
Chebyshev Type II	Minimized absolute difference in **stopband**; via stopband ripple, monotonic in passband
Ellipical	Lowest filter order for given transition band; equiripple in both stop and pass band; optimized for magnitude (phase may be distorted)
Bessel	Linear phase within passband; at expense of magnitude (rolloff is slower than others)

Butterworth

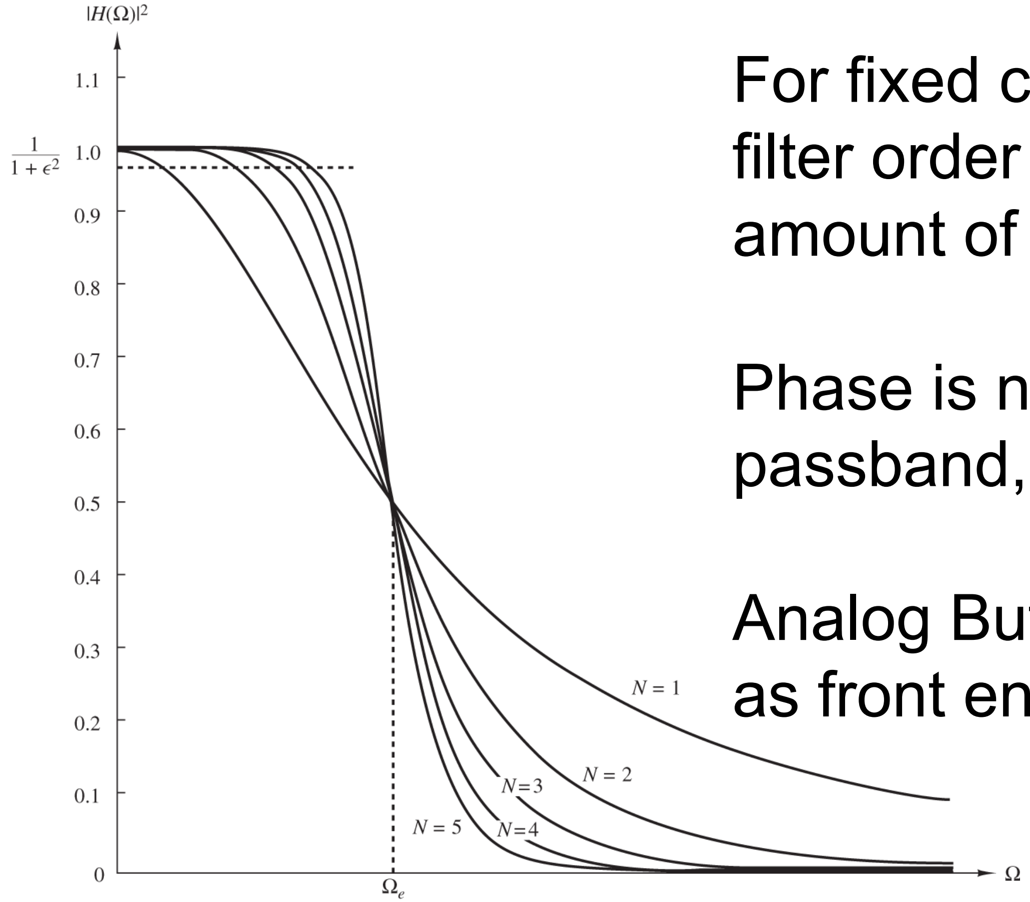

Figure 10.3.10 Frequency response of Butterworth filters.

For fixed cutoff frequency, filter order N determines amount of attenuation

Phase is not linear in passband, but is not too bad..

Analog Butterworths often used as front end in biomed systems

Chebyshev, type I – poles only

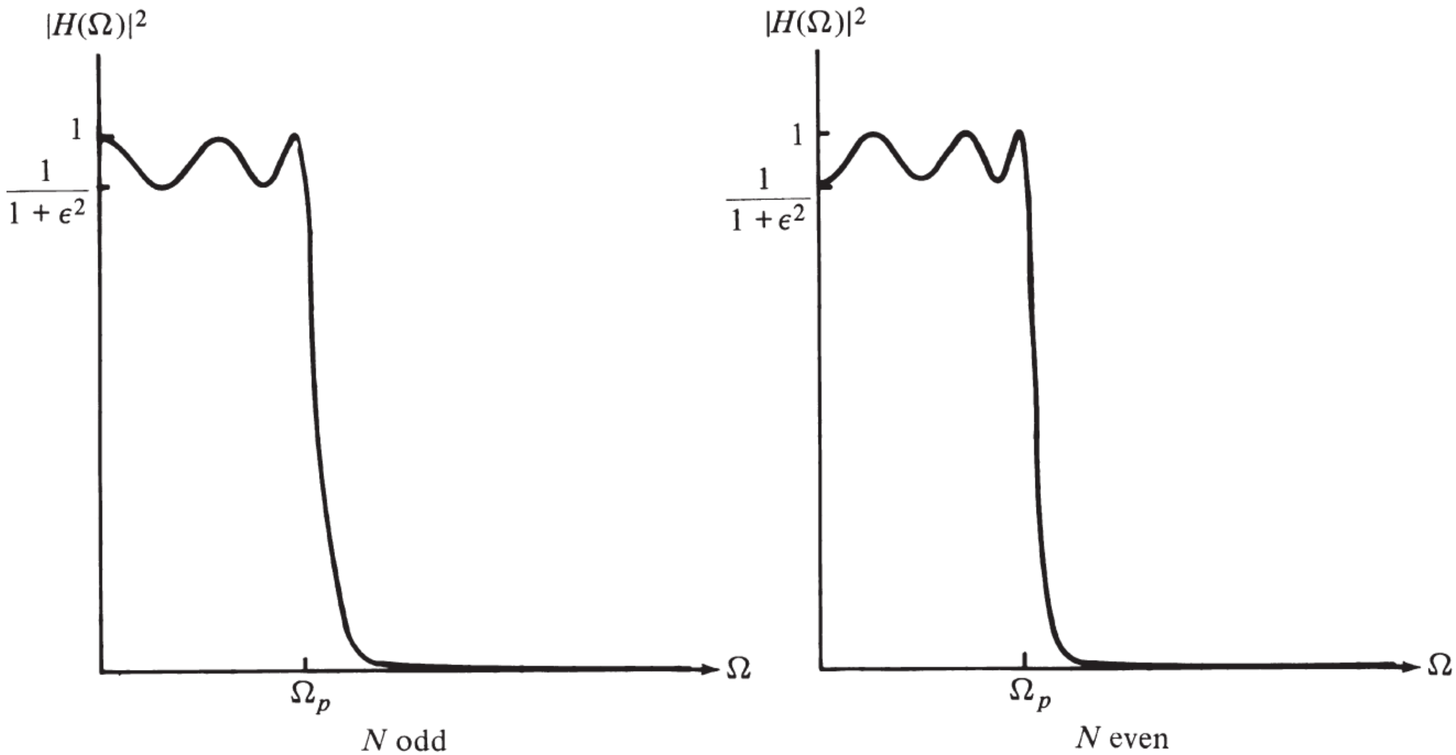

Figure 10.3.11 Type I Chebyshev filter characteristic.

Chebyshev, type II – poles and zeros

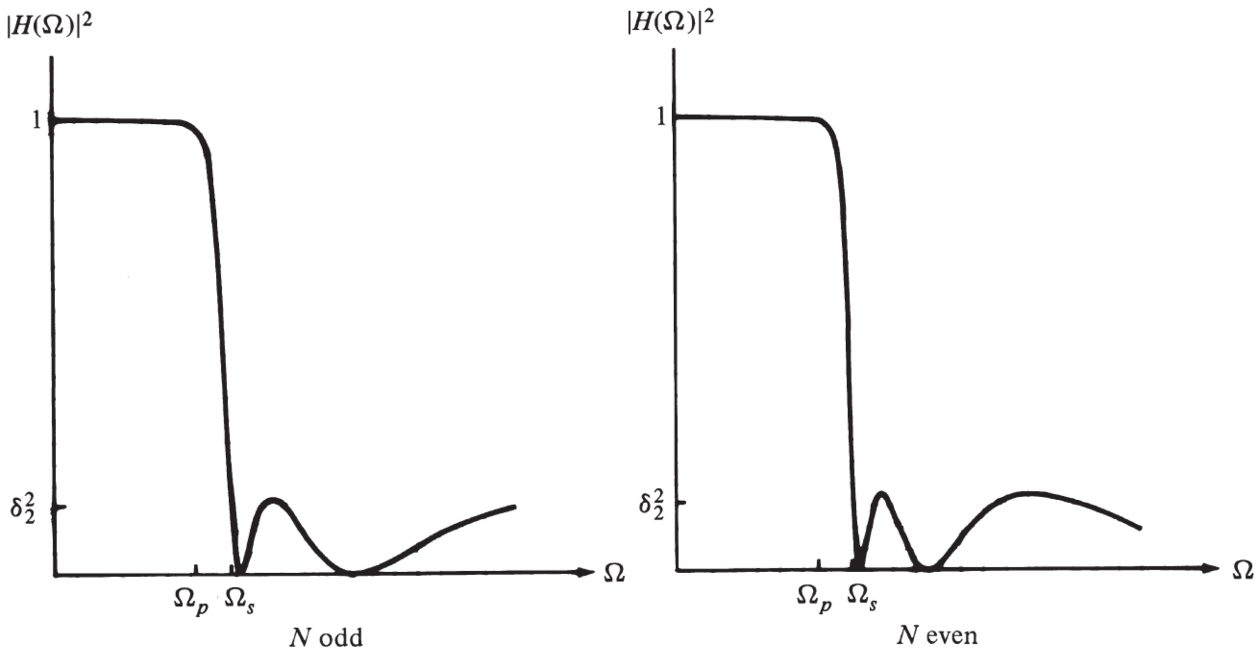

Figure 10.3.13 Type II Chebyshev filters.

Elliptical filters – optimally fast transition, ripple in both stop and pass bands

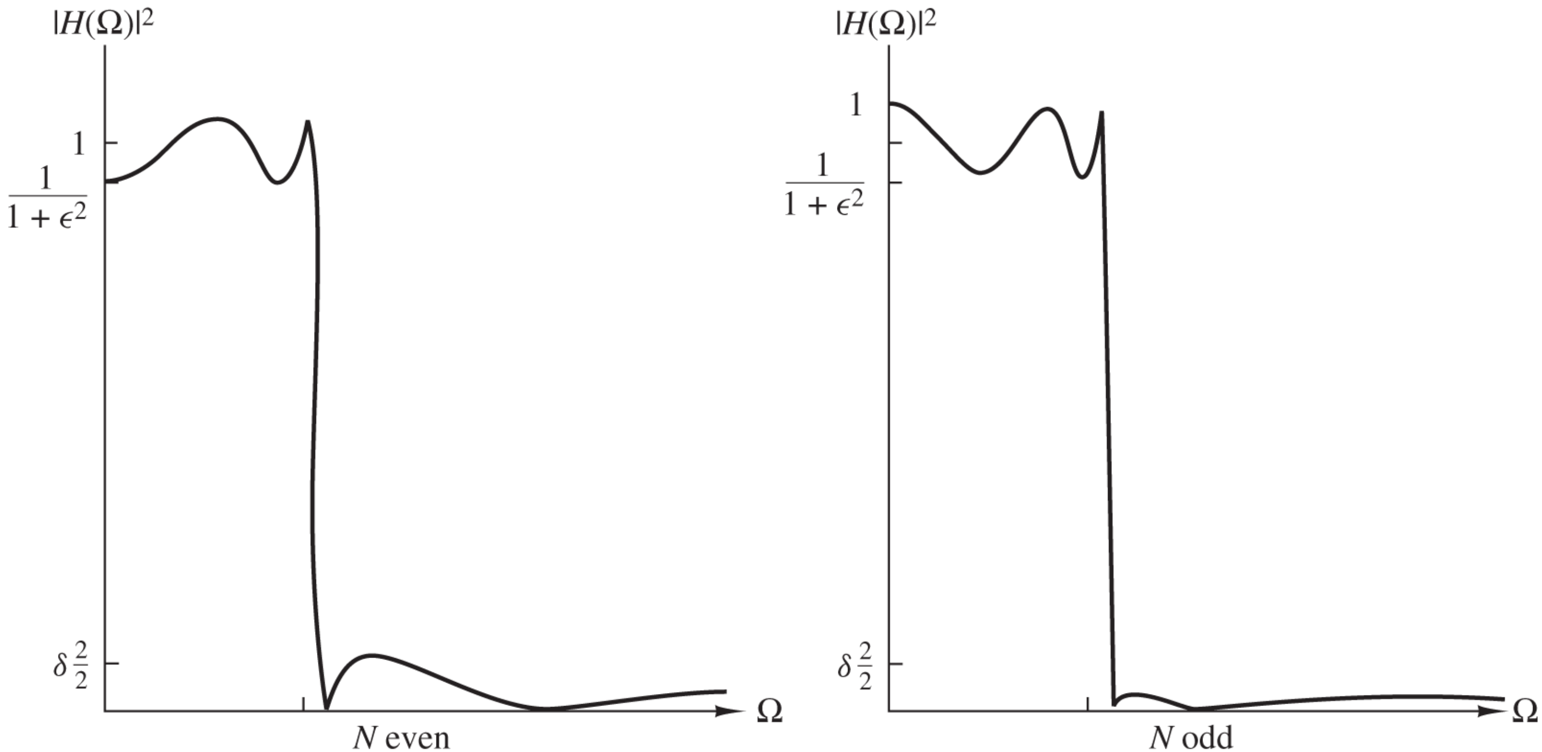

Figure 10.3.14 Magnitude-squared frequency characteristics of elliptic filters.

Bessel – linear phase in passband

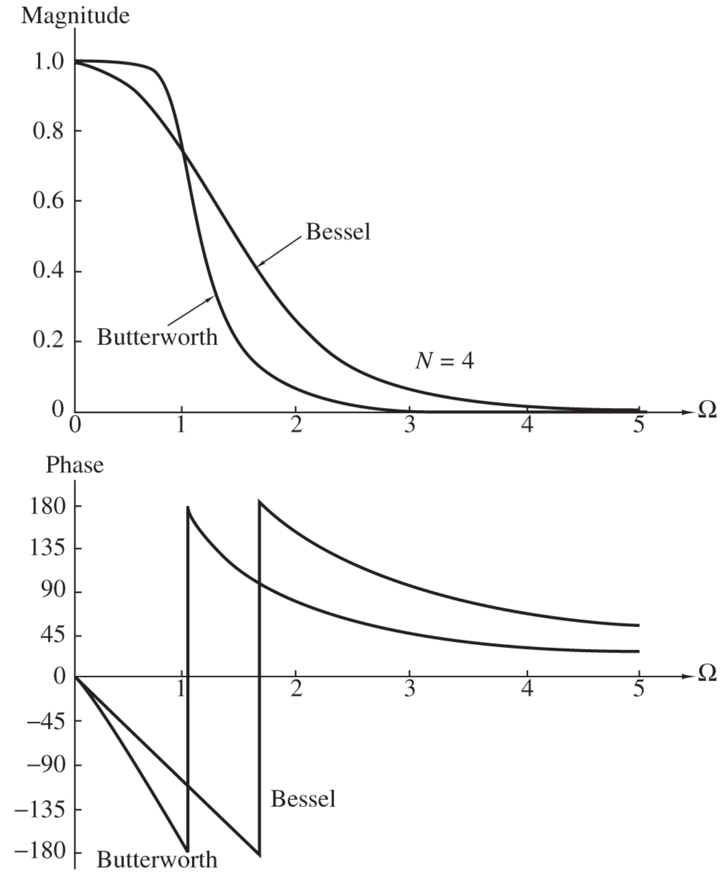

Figure 10.3.15 Magnitude and phase responses of Bessel and Butterworth filters of order $N = 4$.

Some final points on IIR…

- Mapping above let us translate existing analog designs into digital filters. What if we want to start from scratch?
- If we know the desired impulse response h(n), we can come up with a pole/zero (or all-pole model that fits it).
  - Example: Prony’s method models data as sum of damped exponentials. Can be useful in modeling data (tires, ocean modes)
- If we have a desired frequency response, we can use the Yule-Walker method. Comes up with IIR that matches desired; may not be optimal
- An interesting article on the history and stability issues in IIR: “The rise and fall of recursive digital filters,” Charles M. Rader, IEEE Signal Processing magazine, 2006