

# Analog signals from the brain

Chao Huang

# Outline

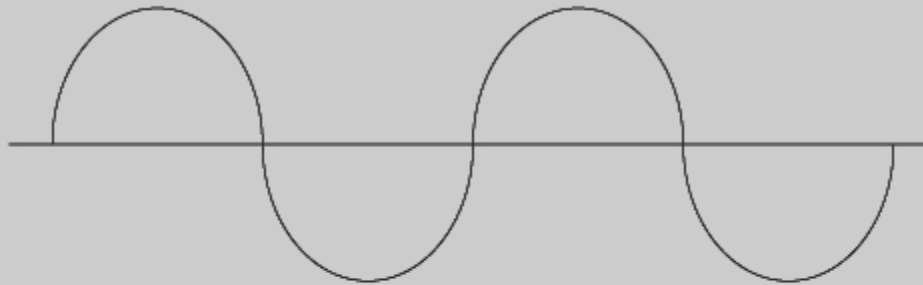
- Analog signals, and analog signals from the brain
- Fourier theorem and Fourier transform
- Spectrum and spectrogram
- Filtering the analog signal

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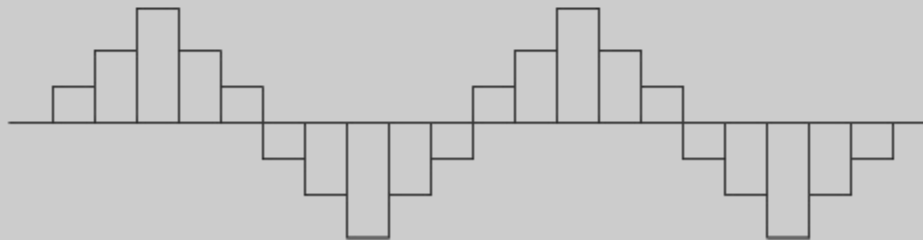
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# Analog vs. digital signals

**Analog**

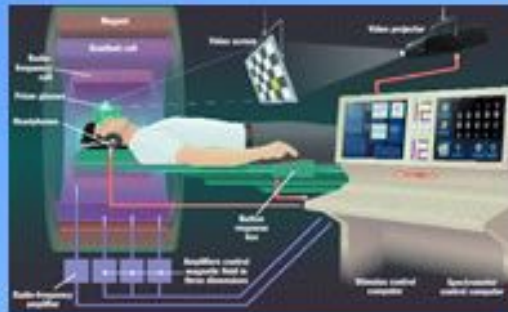


**Digital**

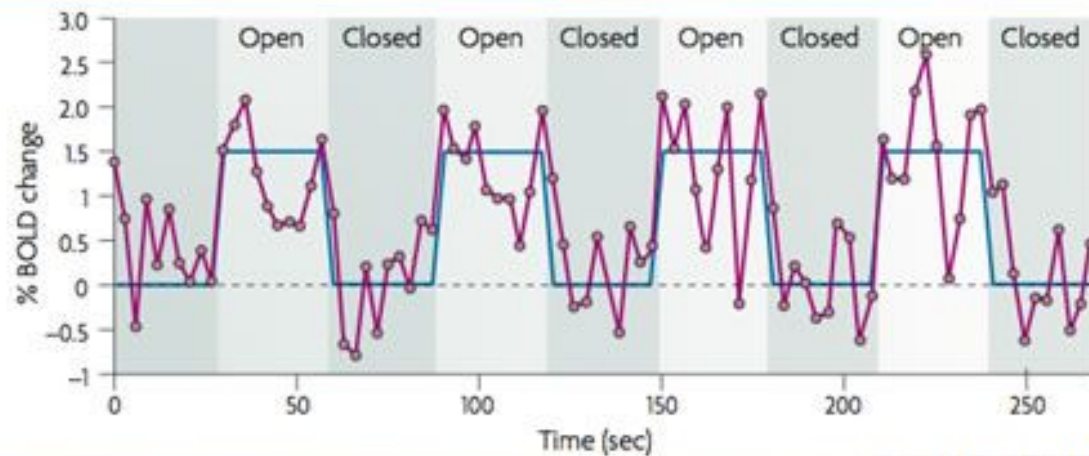
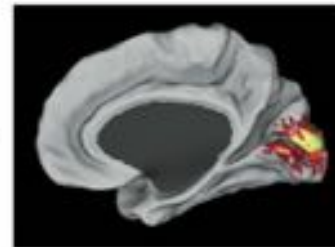


# Analog signals from the brain

## Functional MRI

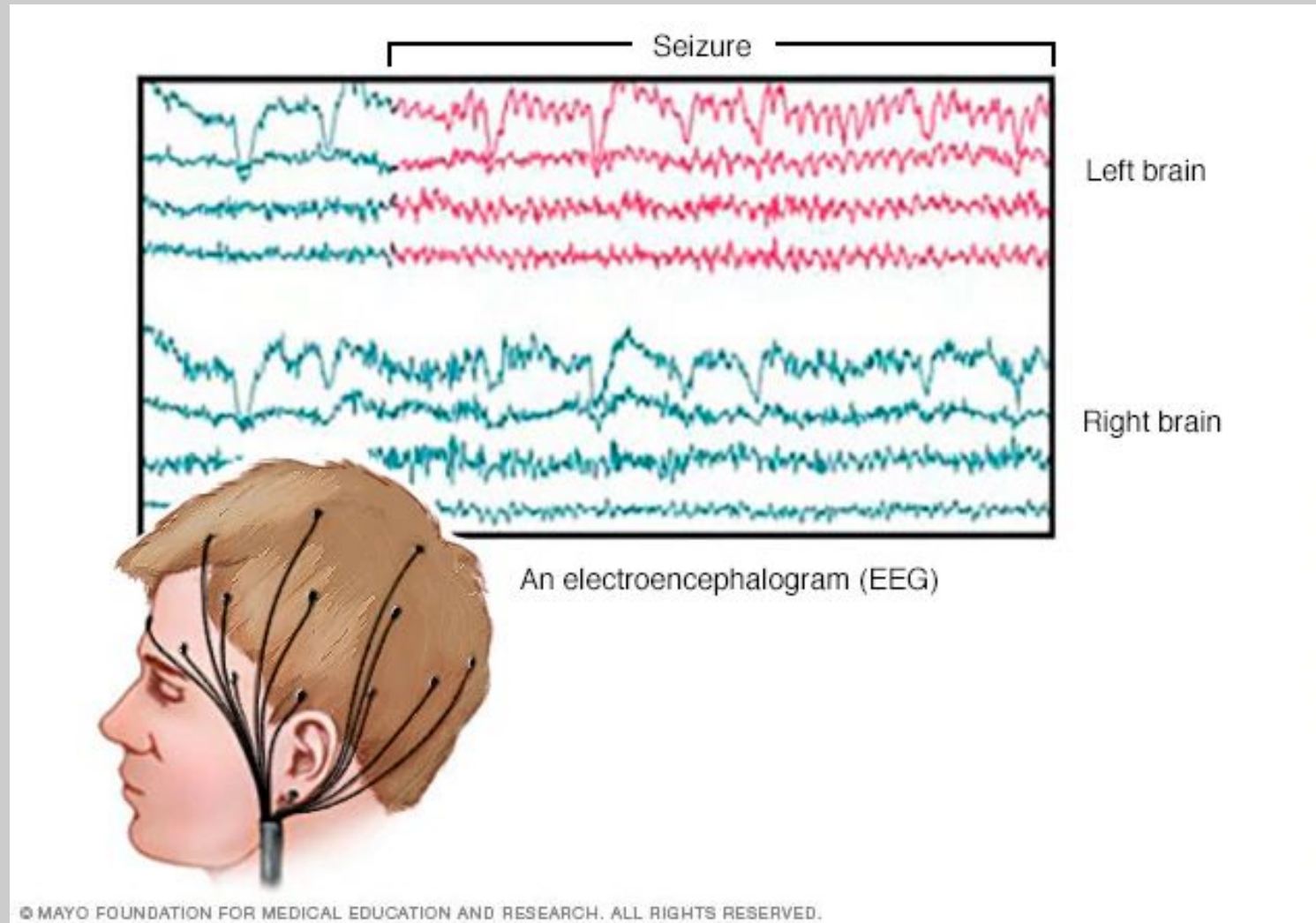


Open - Closed =

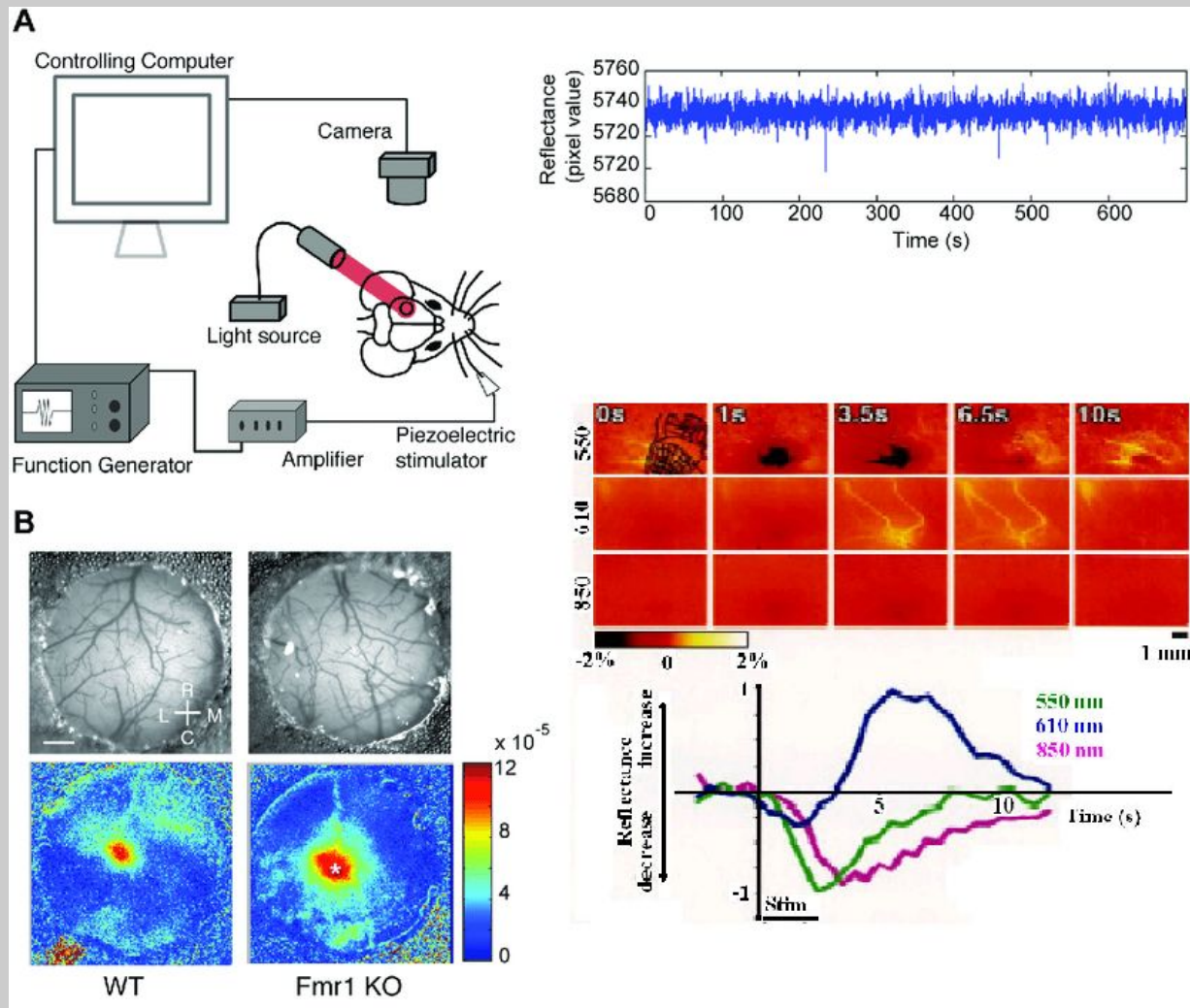


Fox and Raichle 2007

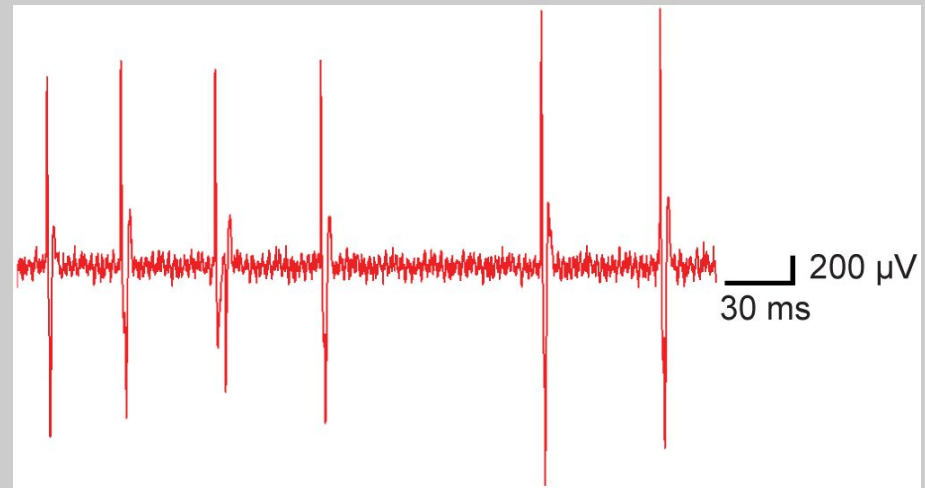
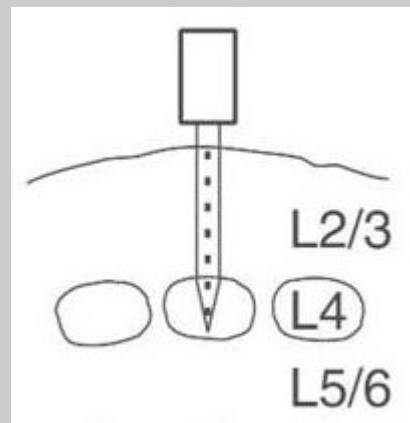
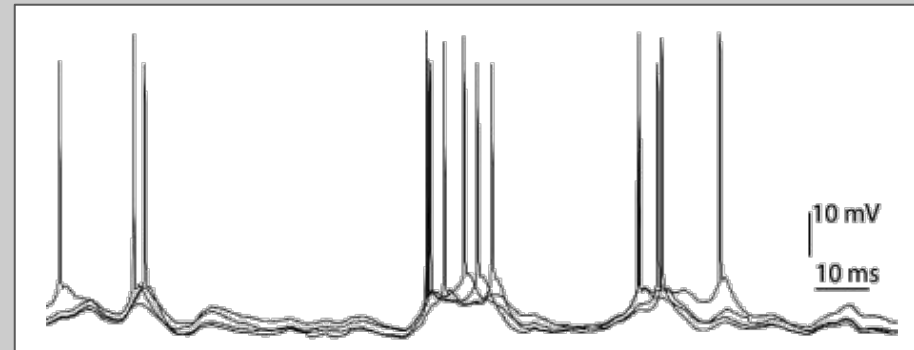
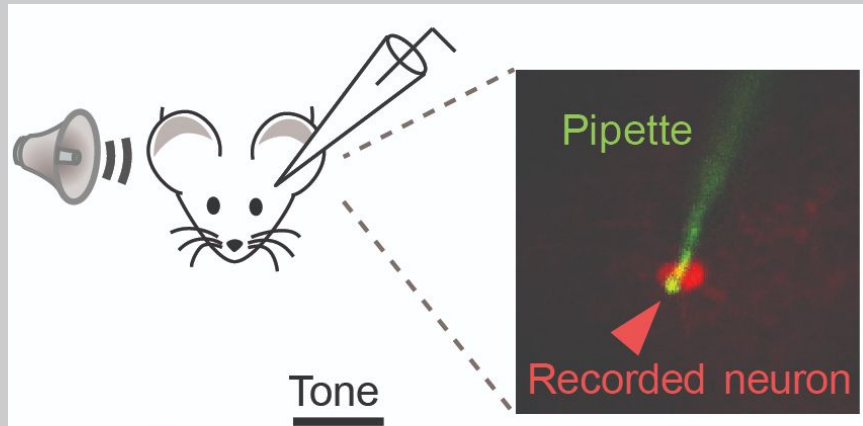
# Analog signals from the brain



# Analog signals from the brain

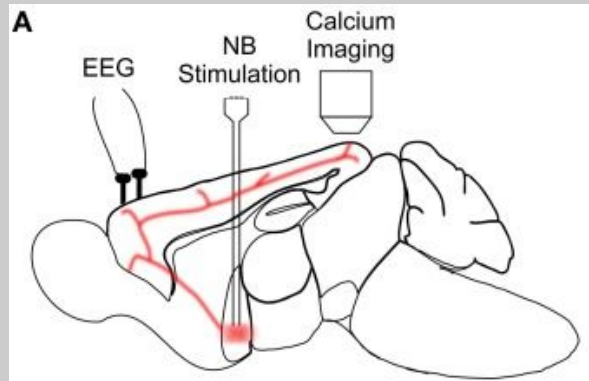


# Analog signals from the brain

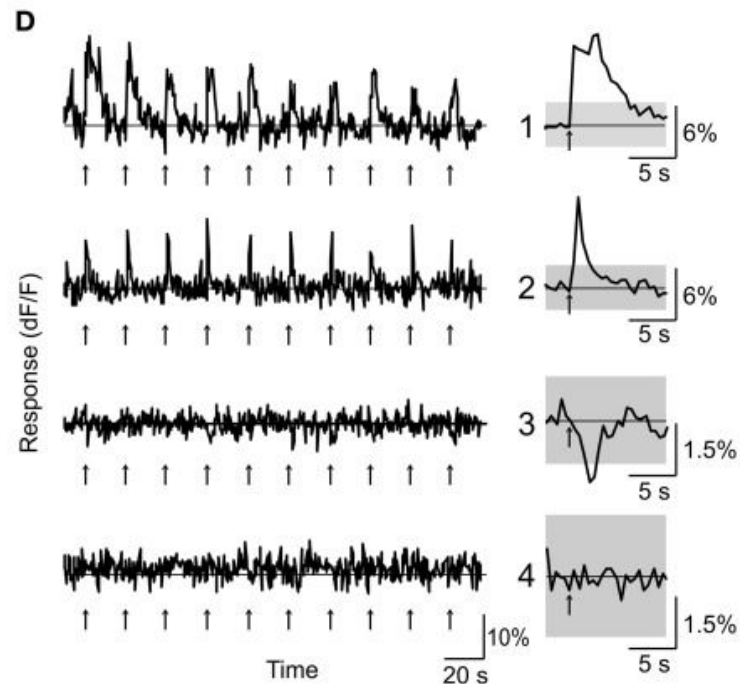
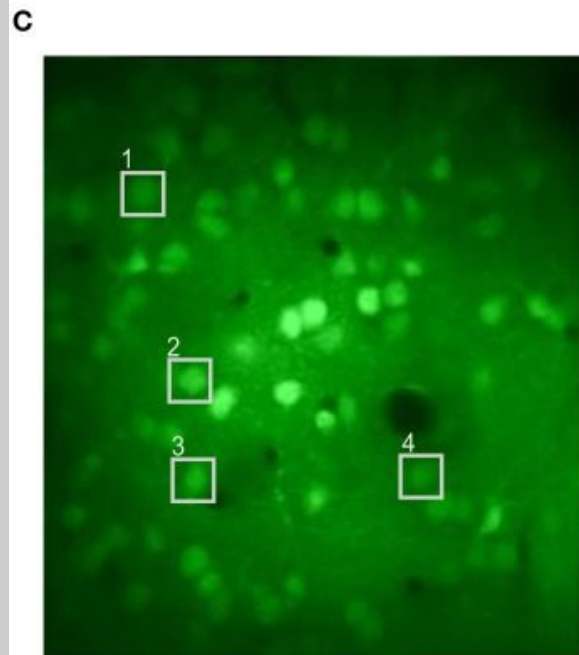




# Analog signals from the brain



Alitto and Dan 2013



...and many more

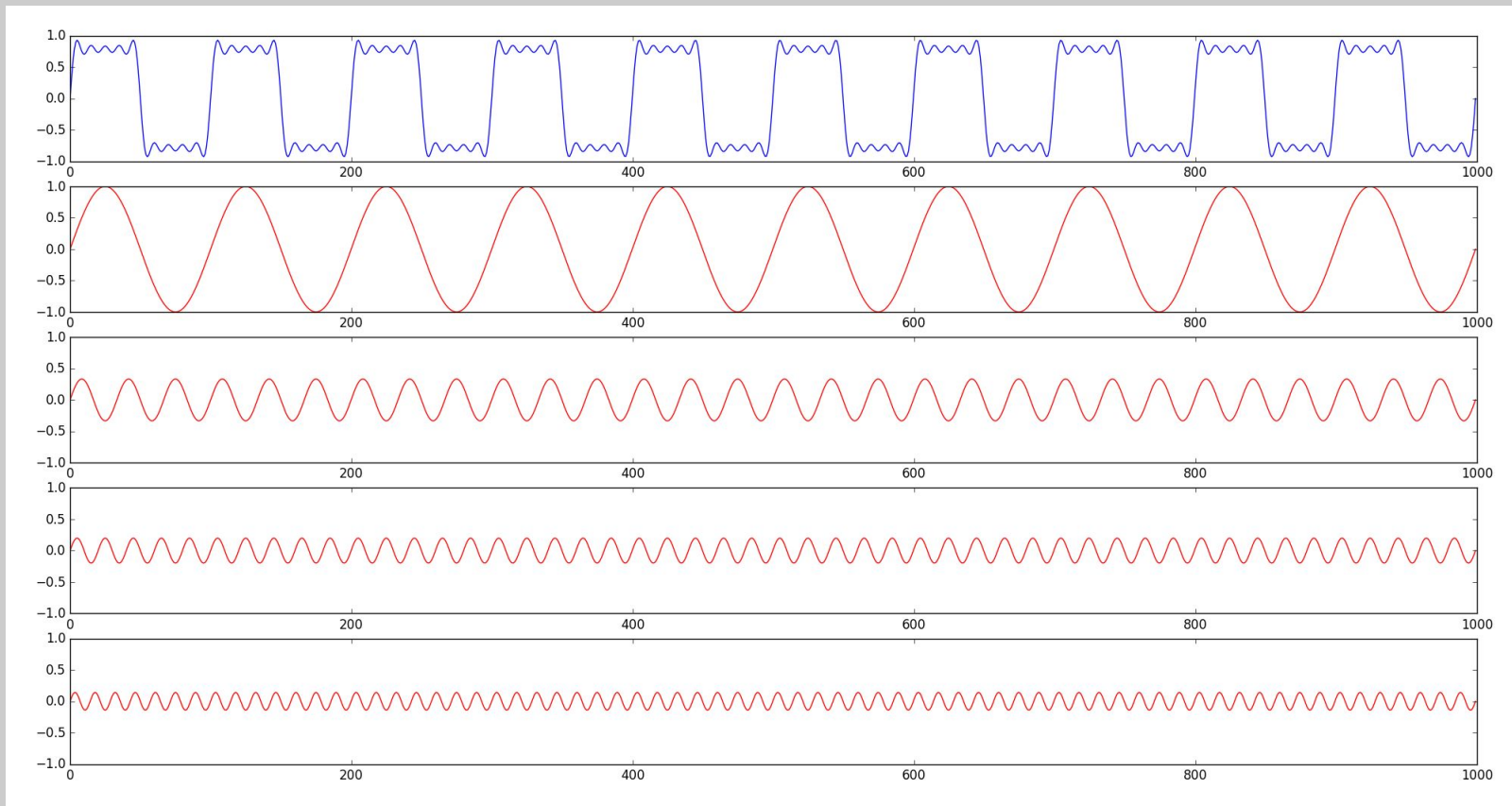
- E.g.
  - Magnetoencephalography (MEG)
  - Local field potential (LFP)
  - ...

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# Fourier theorem

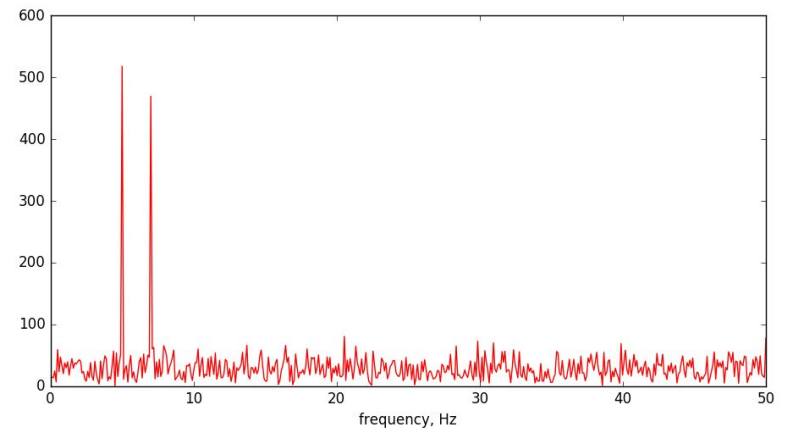
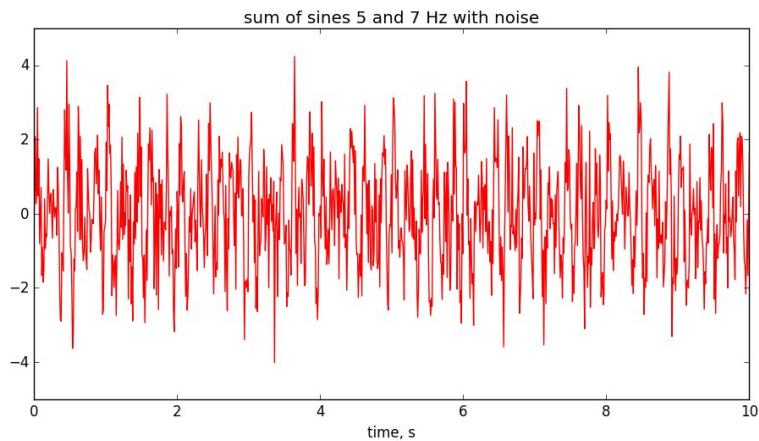
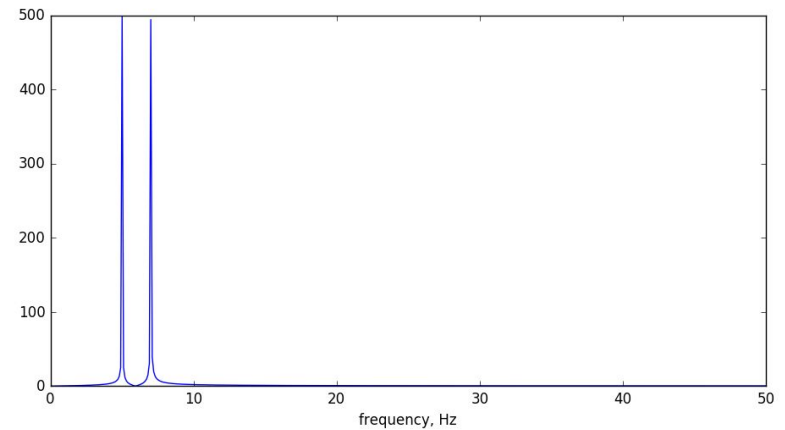
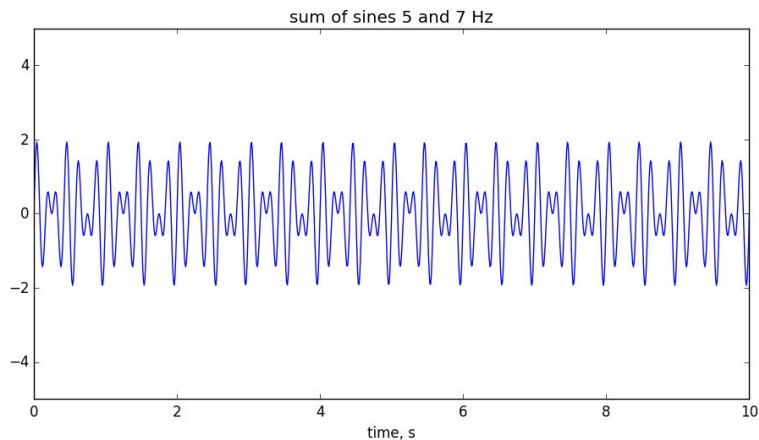
- Any periodic functions (or time series in our case) can be represented as infinite sums of sine waves



# Different frequencies contain different information

- For extracellular recordings:
  - Low frequencies (<1000 Hz): LFP
  - High frequencies (>1000 Hz): spikes
- For eeg:
  - Delta (< 4 Hz): slow-wave sleep, attention
  - Alpha (8-15 Hz): relax; inhibitory control
  - Gamma (> 32 Hz): short term memory, cognitive
  - ...

# Frequency information is more resistant to noise



# Fourier transform

- Decomposes a time series into its frequency components
- Time information is lost



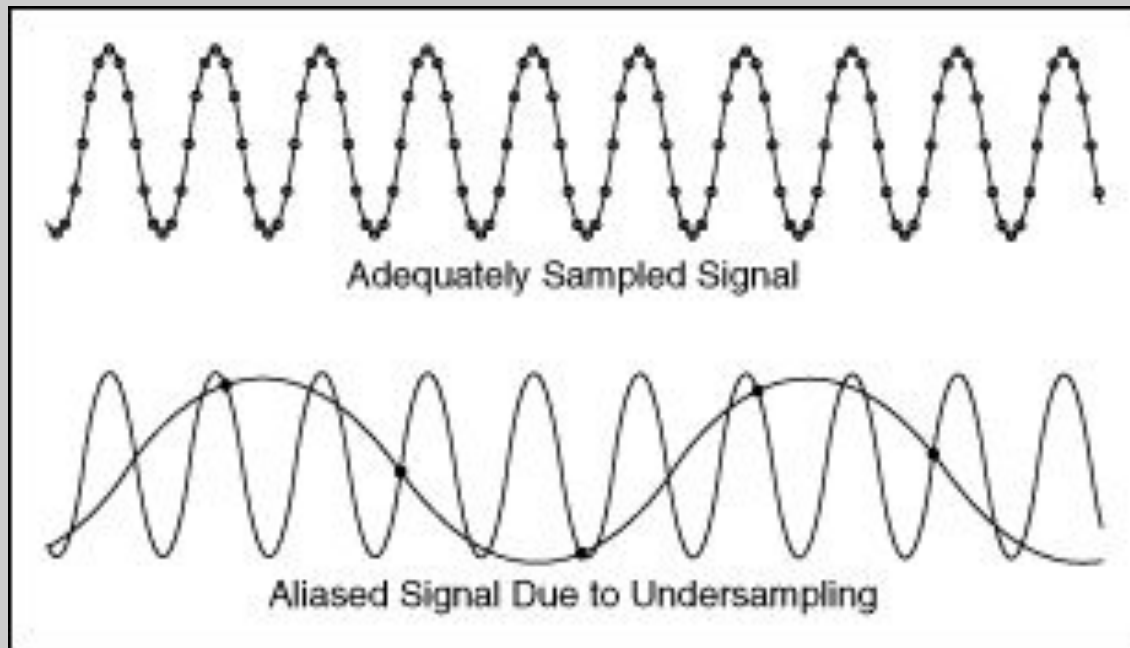
# Fourier transform

- Commonly done with fast fourier transform (fft) algorithm
- `Numpy.fft.fft` or `scipy.fftpack.fft`
- Calculate frequencies up to  $\text{sampling\_freq}/2$  - the Nyquist frequency



# Aliasing

- Undersampling results in misidentification of signal frequency

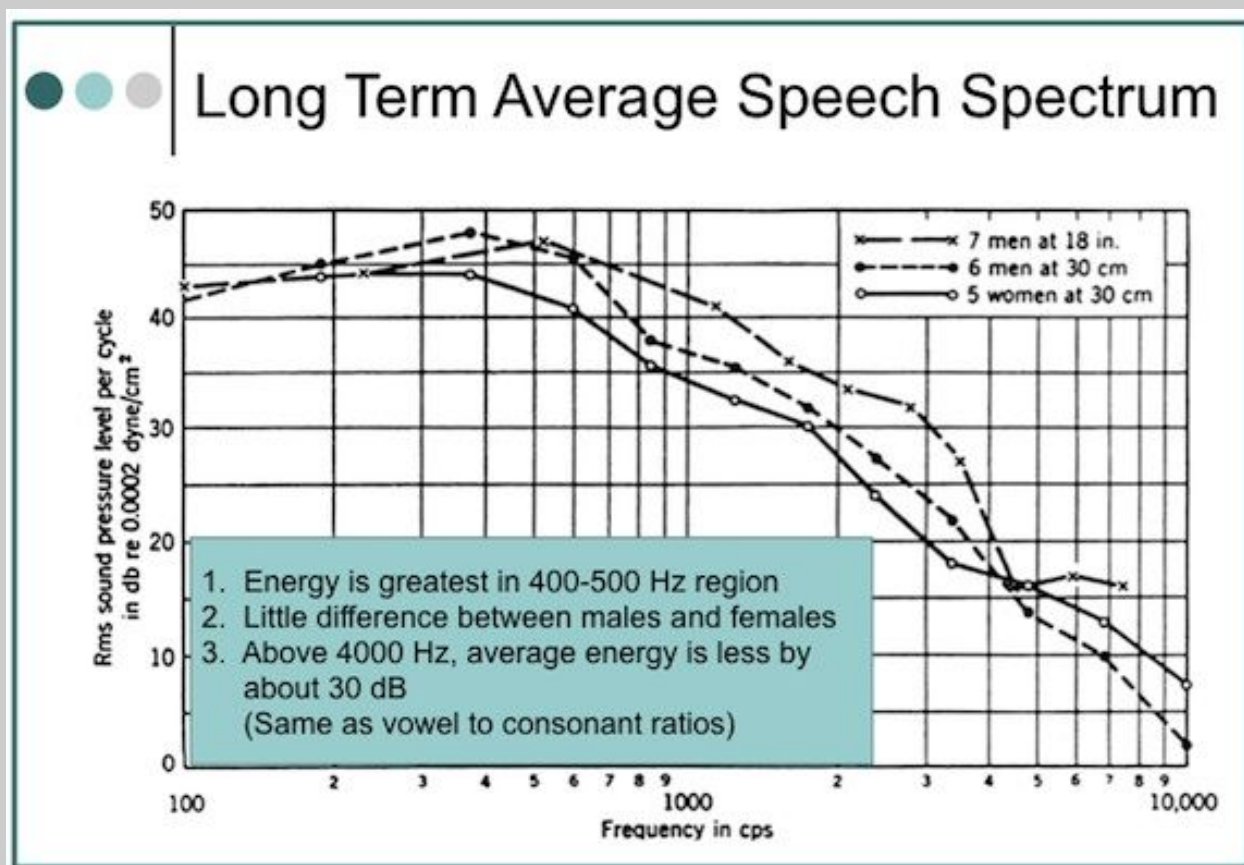


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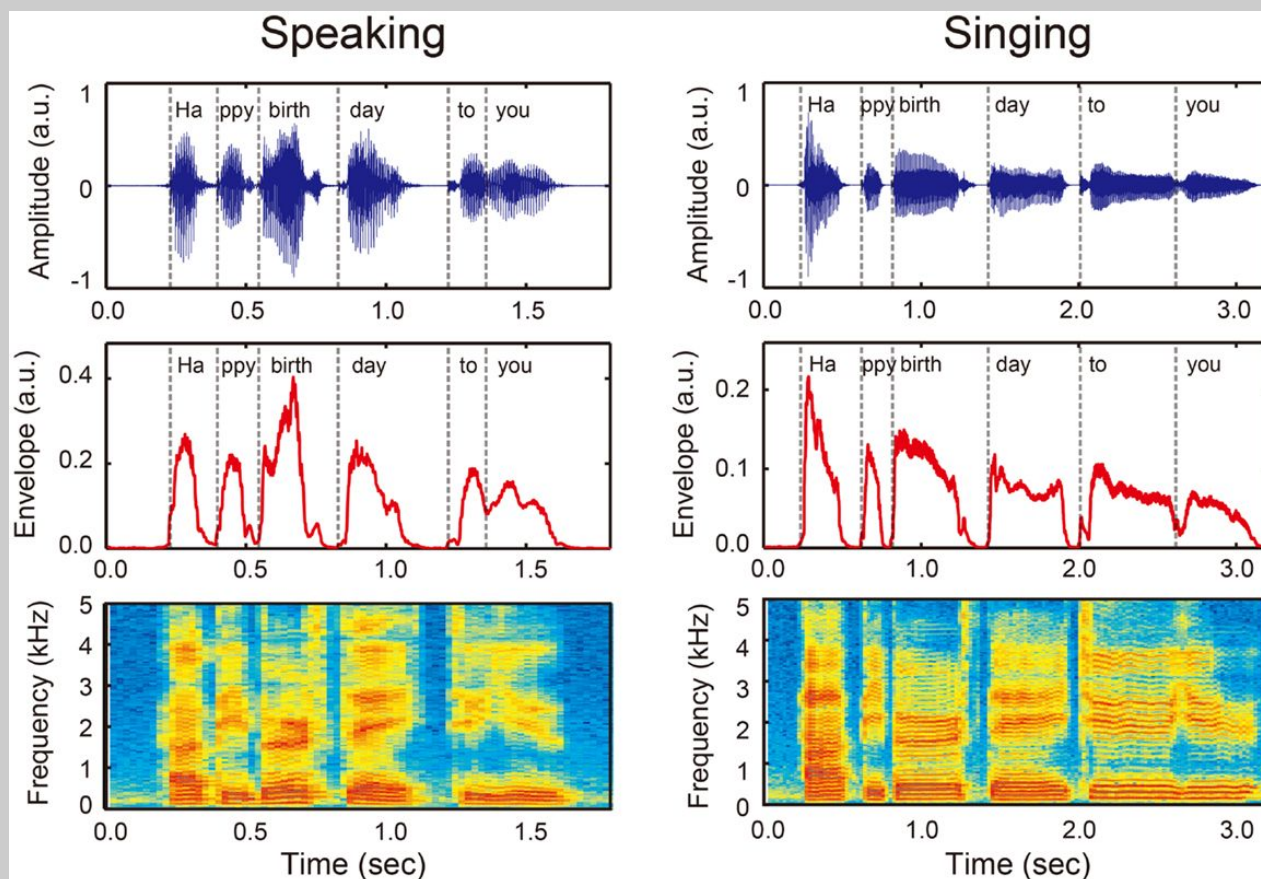
# Spectrum

- The (power) spectrum of a time series (a signal) describes the power of each frequency components in that time series



# Spectrogram

- The spectrogram of a time series (a signal) is the power spectrum of the time series as a function of time



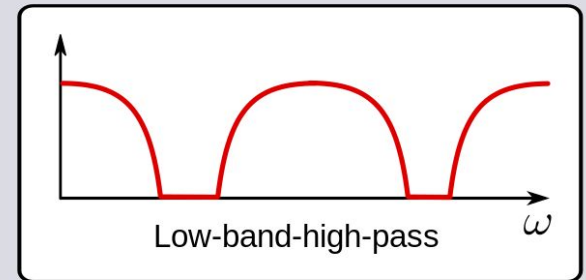
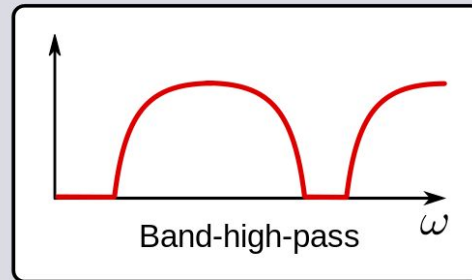
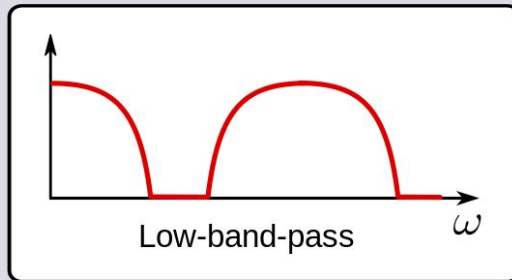
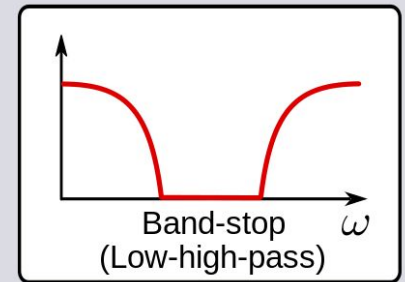
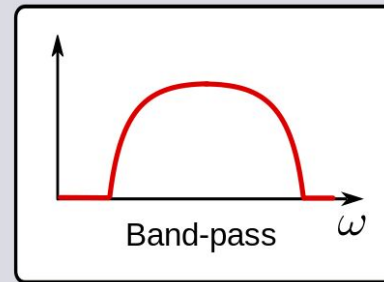
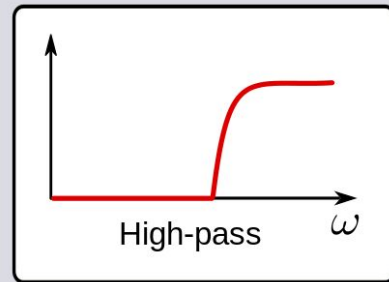
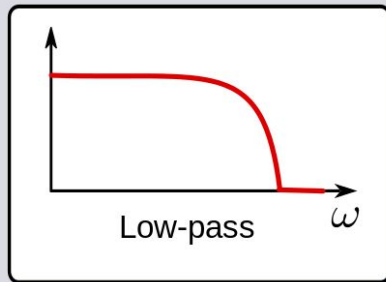
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# Filtering the signal

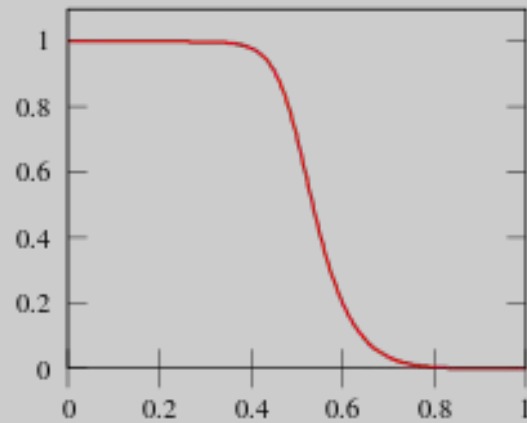
- The process of removing some unwanted features in the signal
- Most times in the frequency domain

# Filter types

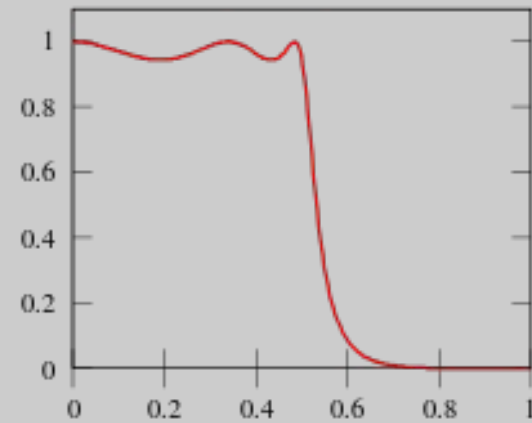


# Filter families (example)

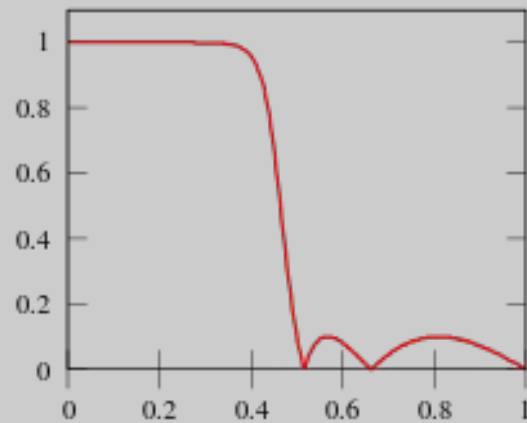
Butterworth



Chebyshev type 1



Chebyshev type 2



Elliptic

