Section 3a: Early auditory system
(an extended LSI example)
The sensitivity of the basilar membrane's vibration at frequencies ranging from 25 Hz to 8000 Hz, as measured by Bekesy (1955).
Figure 6-14 Threshold response curves for auditory nerve fibers in the cat (based on Whitfield, 1968).
Critical Bands

- Loudness summation
- Critical band masking

“Designing” Filters

\[ y(t) = V_c = \frac{1}{C} \int I \, dt \quad \text{or} \quad I = C \frac{dV_c}{dt} \]
\[ x(t) - y(t) = V_R = iR \]
\[ x - y = RC \frac{dy}{dt} = \tau \frac{dy}{dt} \]

For \( x = 0 \), solutions have the form \( y = Ae^{-\tau t} \)

Frequency response of RC low-pass filter: log-log Bode plot

\[ H(\omega) = \frac{1}{i\tau \omega + 1} \]
Cascaded or Gamma Filters

\[ y \propto t^\gamma e^{-t/\tau} \]

\[ H(\omega) = \left( \frac{1}{i\omega\tau + 1} \right) \]

Gammatone Filters

\[ y \propto t^{N-1} e^{-t/\tau} \cos(\omega t - \phi) \]

Speech Spectrogram
Example – Bass/Treble filters

Miles Davis  
"Half Nelson"  

Signal  
Frequency content  

Filter  
Low-pass or  
Bass Filter  

Bass only:  

Treble only:  

Time  

Prev  
Next  

Low-pass or  
Bass Filter  

High-pass or  
Treble Filter
Example – Bass/Treble filters

Miles Davis
"Half Nelson"

Bass only:

Treble only:

Low-pass or Bass Filter

High-pass or Treble Filter

Fourier spectrum representation of sound

Fourier spectrum representation of sound
This works for all “musical sounds”

Fundamental frequency and harmonics

Standing waves in a vibrating string
Flute (open pipe) harmonics

Other notes (shorten the pipe)

Reinforcing a harmonic (forcing a “node”)