Title/Number:

DSP ECE 623

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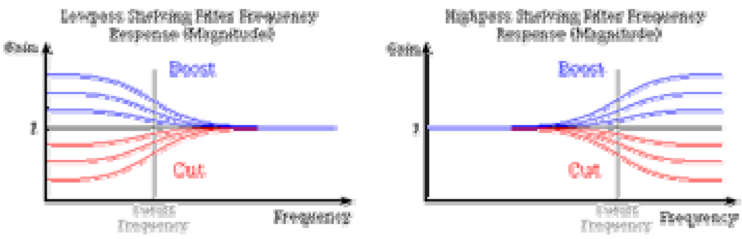
Lecture 20 Introduction to Special types of Digital Filters

- Shelving Filter
- Peaking Filter
- Graphic Equalizer

Shelving Filter

Shelving filters realize tone controls in audio systems. The frequency response of a low-pass (bass) and high-pass (treble) shelving filter is shown below.



Frequency response of a low-pass and high-pass shelving filter.

The transfer function of low-pass shelving filter is implemented as:

$$H(z) = 1 + (\mu - 1)\frac{\alpha(1 + z^{-1})}{1 - \gamma \cdot z^{-1}}$$

The coefficients μ, α, γ are related to the cutoff frequency f_c and the shelving filter boost/cut gain in dB is

$$\gamma = \frac{1 - (4/(1+\mu))\tan(\Omega_c/2)}{1 + (4/(1+\mu))\tan(\Omega_c/2)}$$

$$\alpha = (1 - \gamma)/2$$

where $\Omega_c = 2\pi f_c / f_s$,

The pole of low-pass shelving filter is calculated by:

$$p = \frac{1 - \left(4/(1+\mu)\right)\tan\left(\Omega_c/2\right)}{1 + \left(4/(1+\mu)\right)\tan\left(\Omega_c/2\right)}$$

The transfer function of high-pass shelving filter is implemented as:

$$H(z) = 1 + (\mu - 1)\frac{\alpha(1 - z^{-1})}{1 - \gamma \cdot z^{-1}}$$

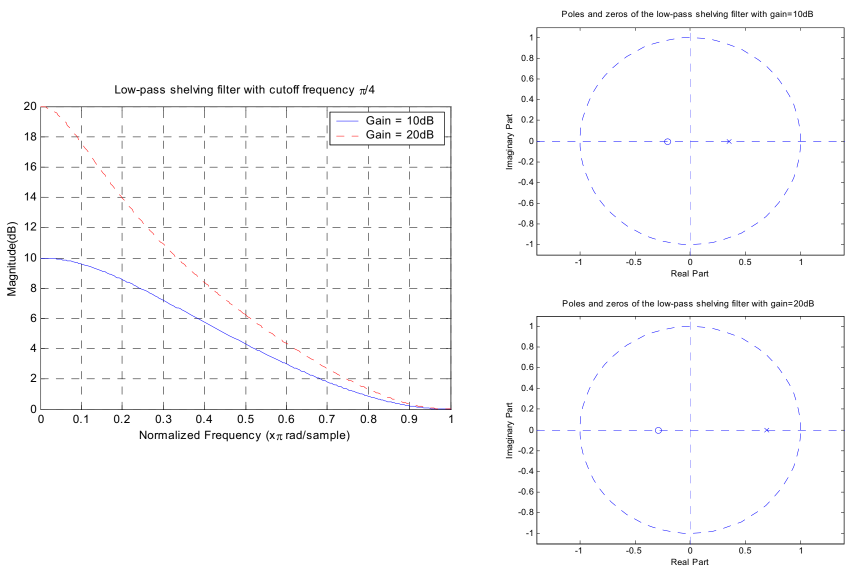
where

$$\gamma = \frac{1 - ((1+\mu)/4)\tan(\theta_c/2)}{1 + ((1+\mu)/4)\tan(\theta_c/2)}$$

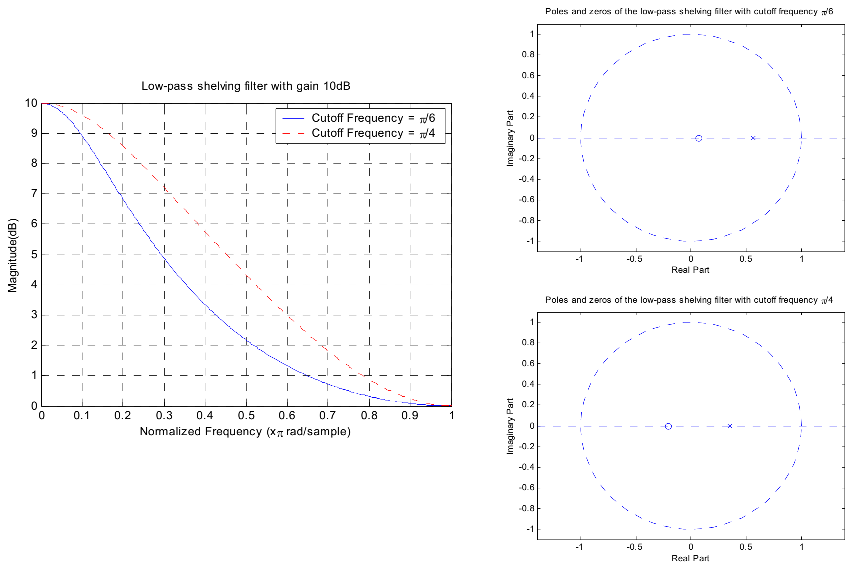
$$\alpha = (1+\gamma)/2$$

The pole of high-pass shelving filter is calculated by:

$$p = \frac{1 - \left((1+\mu)/4\right)\tan\left(\theta_c/2\right)}{1 + \left((1+\mu)/4\right)\tan\left(\theta_c/2\right)}$$



Frequency response and pole-zero plot of the low-pass shelving filters with different gains.



Frequency response and pole-zero plot of the low-pass shelving filters with different cutoff frequency .

Tone Control Block in J-DSP

The low frequencies are affected by bass adjustments with the audio signal processed through low-pass shelving filters. The high frequencies are affected by treble adjustments with the audio signal processed through high-pass shelving filters. A J-DSP simulation using the Tone Control .

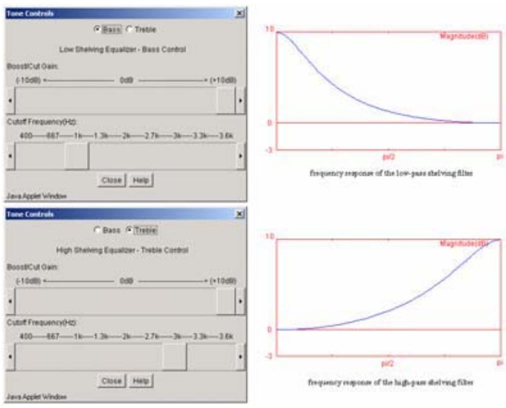
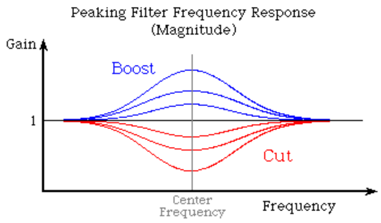


Figure J-DSP simulation using the tone control block.

Peaking Filter

In addition to bass and treble controls, peaking filter is designed to boost or cut a small portion of the audio spectrum in “mid” band. The figure below shows frequency response of a peaking filter.



Frequency response of a peaking filter.

The transfer function of peaking filter is implemented as

$$H(z) = 1 + (\mu - 1)\frac{\alpha(1 - z^{-2})}{0.5 - \gamma \cdot z^{-1} + \beta \cdot z^{-2}}$$

where

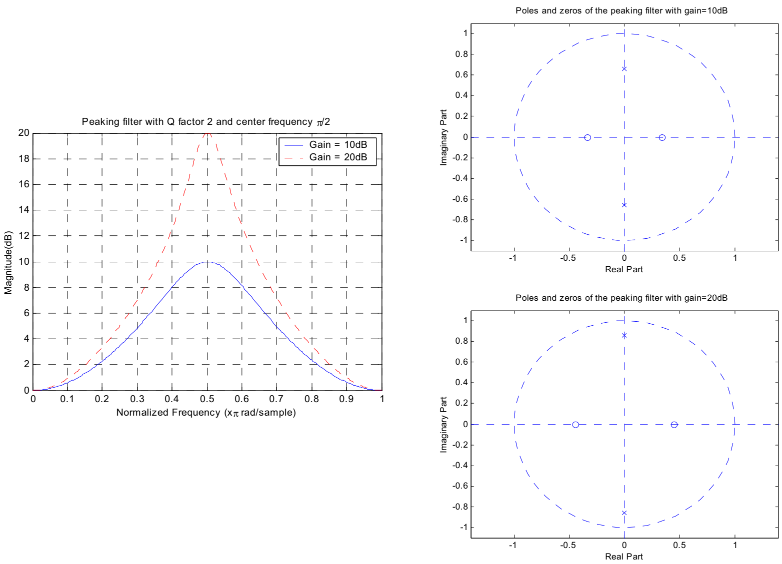
$$\beta = \frac{1}{2} \cdot \frac{1 - (4/(1+\mu))\tan(\theta_0/2Q)}{1 + (4/(1+\mu))\tan(\theta_0/2Q)}$$

$$\gamma = (0.5 + \beta)\cos(\theta_0)$$

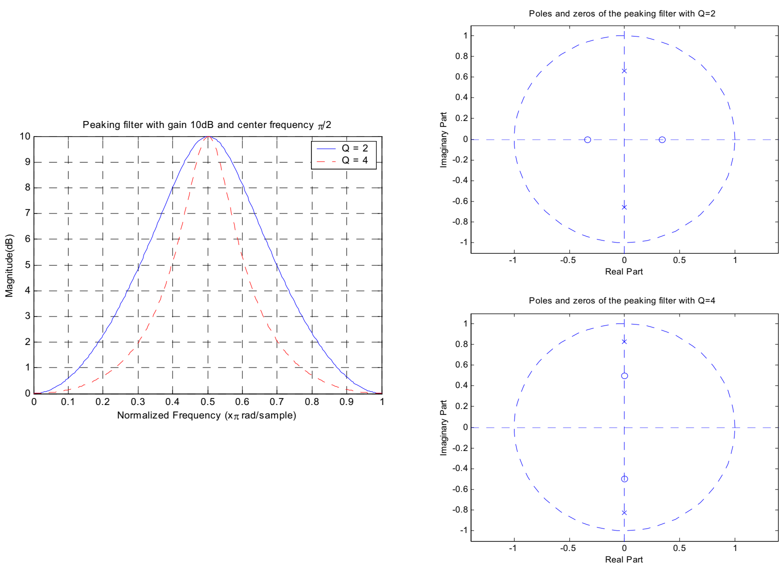
$$\alpha = (0.5 - \beta)/2$$

The poles of peaking filter are calculated by:

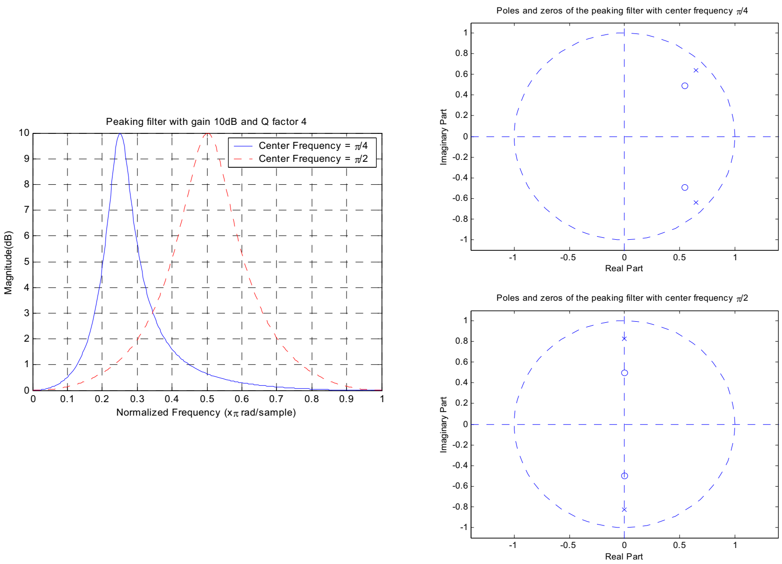
$$p_1 = \frac{\cos\theta_0 + \sqrt{\left(4/(1+\mu)\right)^2 \tan^2\left(\theta_0/2Q\right) - \sin^2\theta_0}}{1 + \left(4/(1+\mu)\right)\tan\left(\theta_0/2Q\right)}, \quad p_2 = \frac{\cos\theta_0 - \sqrt{\left(4/(1+\mu)\right)^2 \tan^2\left(\theta_0/2Q\right) - \sin^2\theta_0}}{1 + \left(4/(1+\mu)\right)\tan\left(\theta_0/2Q\right)}$$



Frequency response and pole-zero plot of the peaking filter with different gains.



Frequency response and pole-zero plot of the peaking filter with different Q factors.



Frequency response and pole-zero plot of the peaking filter with different center frequency.

Peaking Filter Block in J-DSP

A J-DSP simulation using the Peaking Filter block is shown below

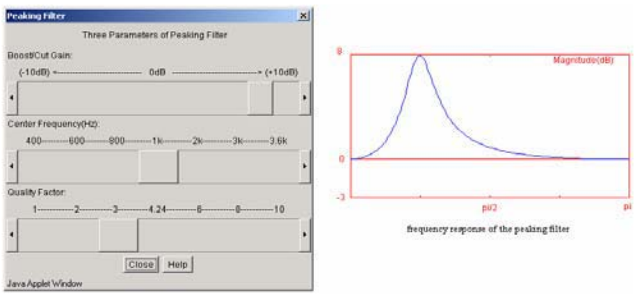
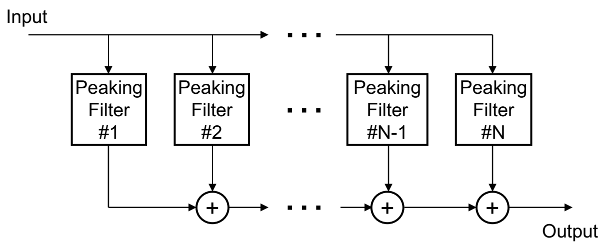


Figure 9: J-DSP simulation using the peaking filter block.

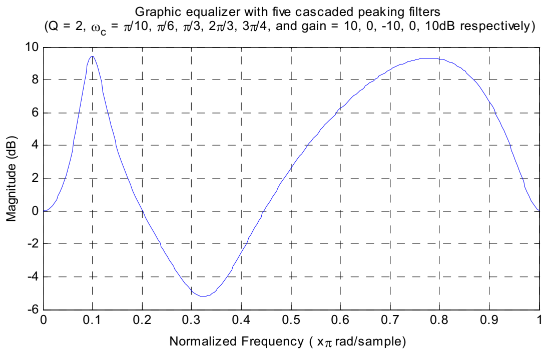
Graphic Equalizer

- A graphic equalizer uses a cascade of peaking filters
- It alters the frequency response of each band by varying the corresponding peaking filter's gain.



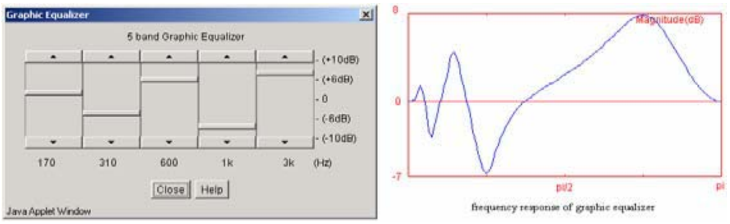
A diagram of a graphic equalizer with N bands of control.

MATLAB Simulation



Graphic Equalizer Block in J-DSP

A J-DSP simulation using the Graphic Equalizer block is shown below. The sliders are a graphic representation of the frequency response applied to the input audio signal, hence the name “graphic” equalizer.



-DSP simulation using the graphic equalizer block.