Filters and Delays

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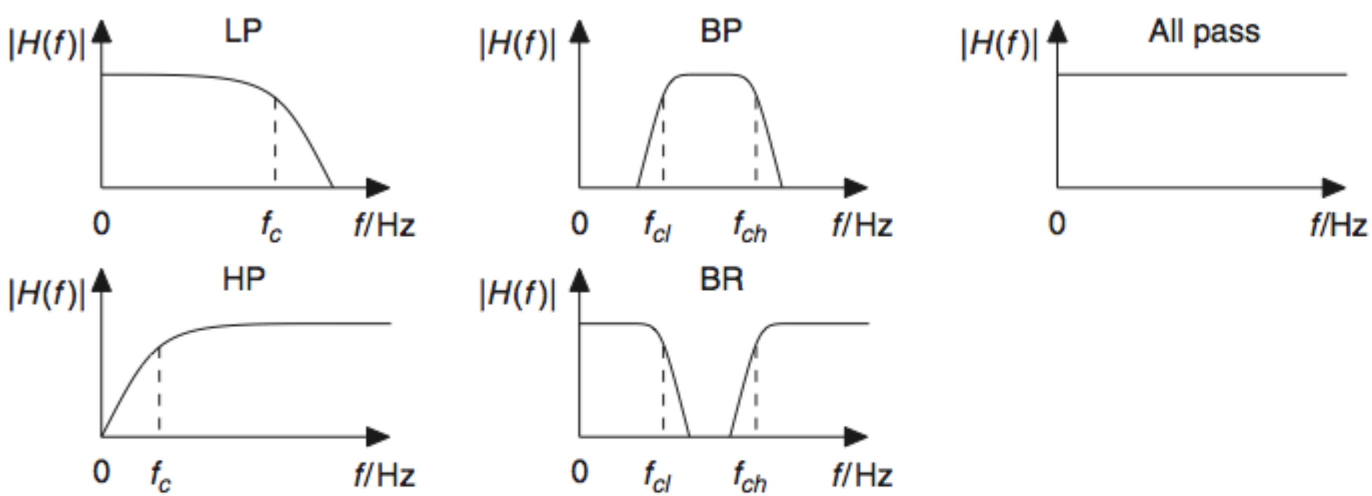
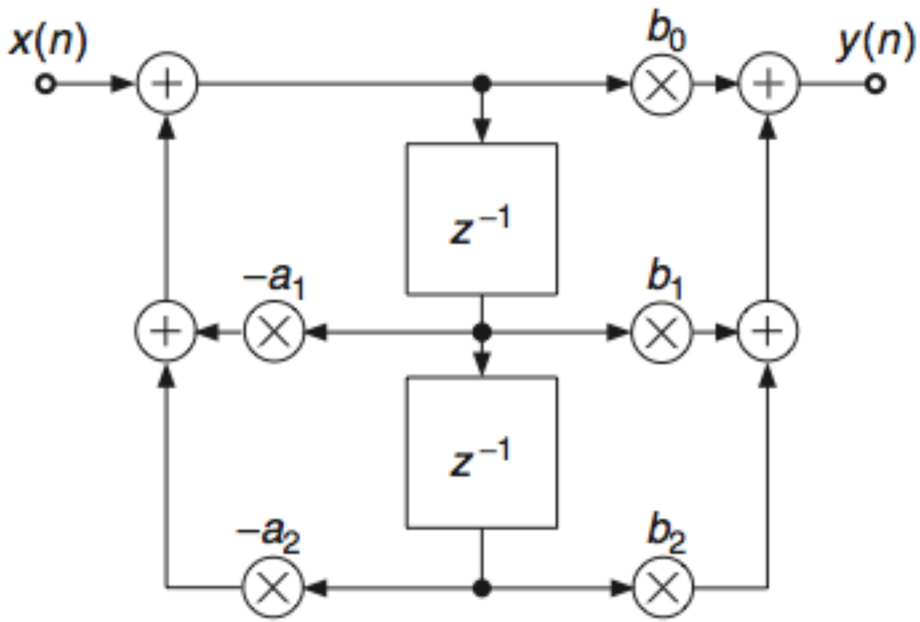
Basic Filters

Lowpass (LP)
Highpass (HP)
Bandpass (BP)
Bandreject (BR)
Allpass



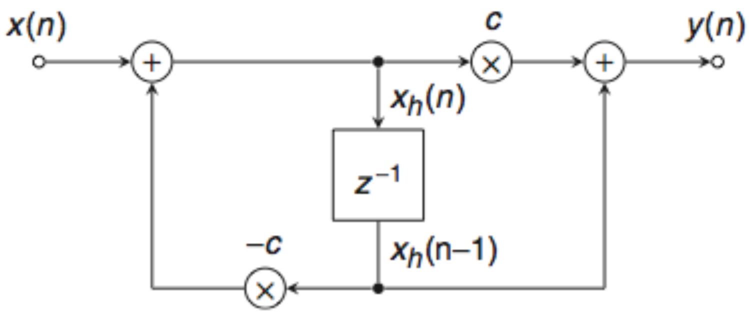
Canonical Filters



	b_0	b_1	a_1
Lowpass	$K/(K+1)$	$K/(K+1)$	$(K-1)/(K+1)$
Highpass	$1/(K+1)$	$-1/(K+1)$	$(K-1)/(K+1)$
Allpass	$(K-1)/(K+1)$	1	$(K-1)/(K+1)$

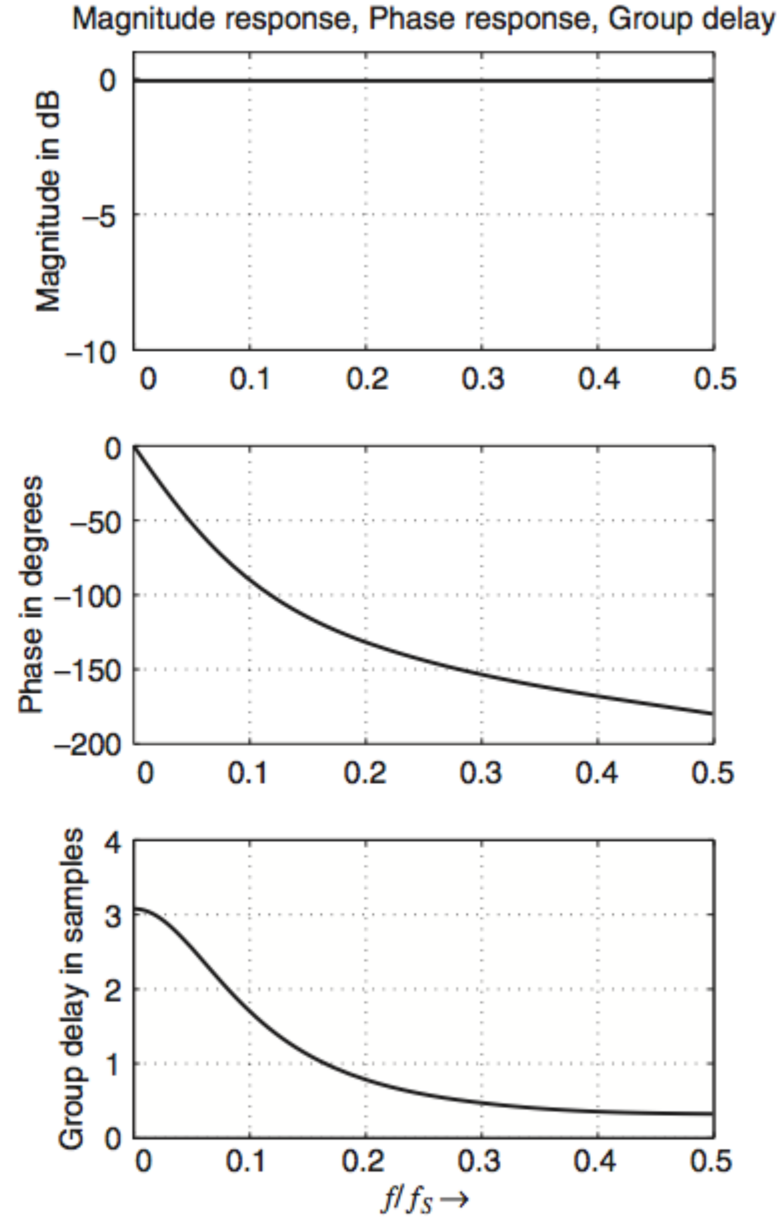
$$K = \tan(\pi f_c / f_S).$$

Allpass Filters

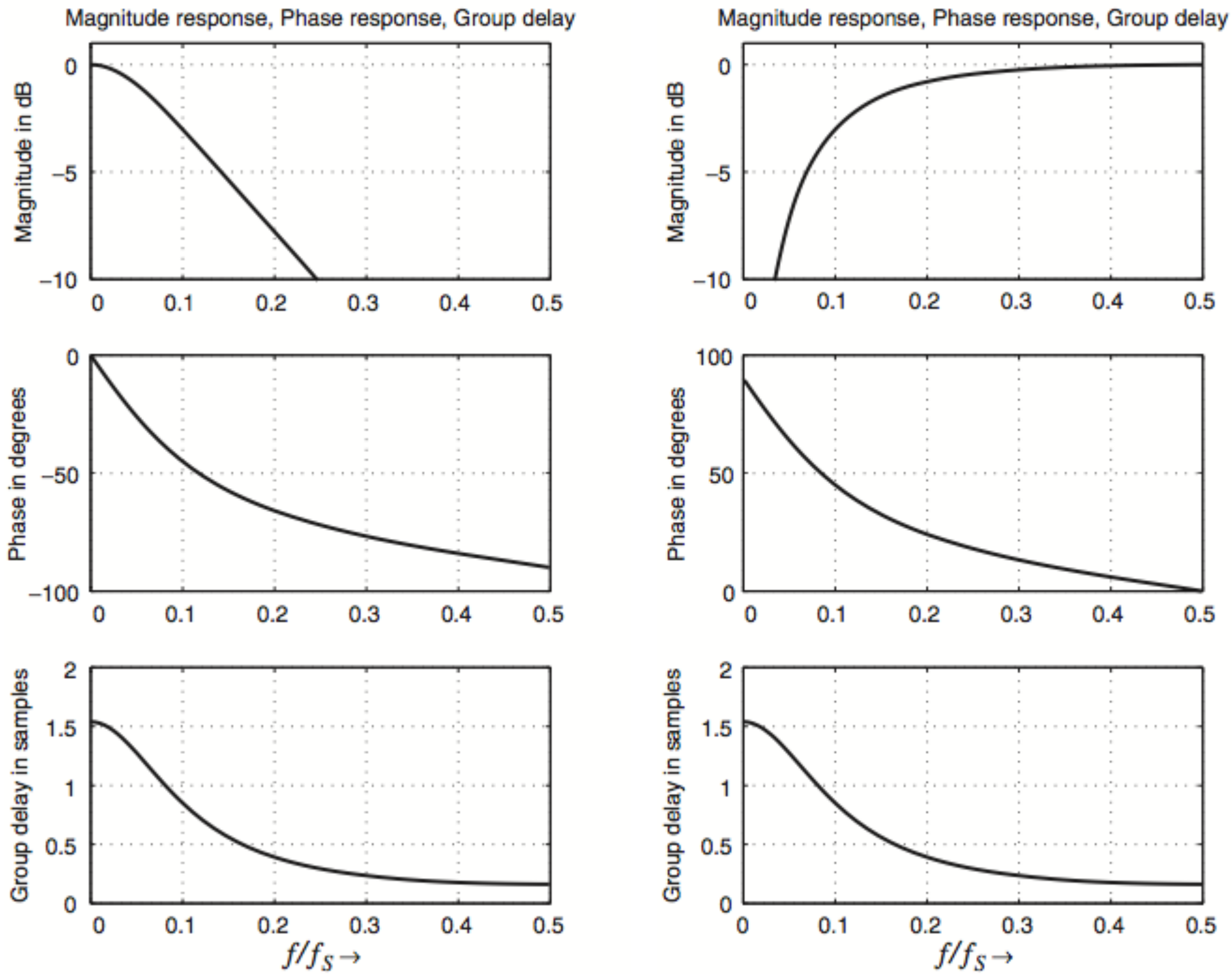


$$A(z) = \frac{z^{-1} + c}{1 + cz^{-1}}$$

$$c = \frac{\tan(\pi f_c/f_S) - 1}{\tan(\pi f_c/f_S) + 1}.$$



Allpass Low/Highpass



Universal Comb

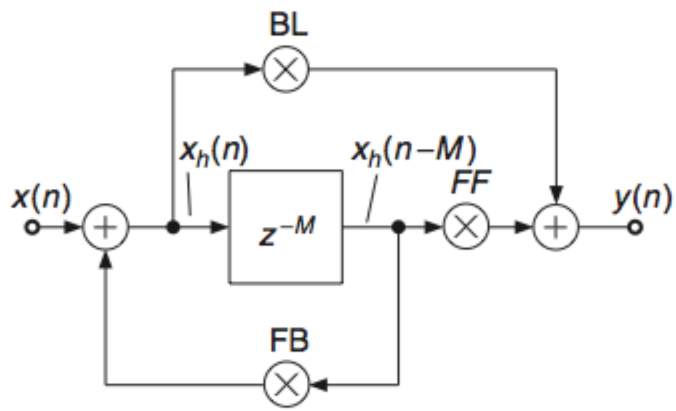


Figure 2.29 Universal comb filter.

Table 2.6 Parameters for universal comb filter.

	BL	FB	FF
FIR comb filter	1	0	g
IIR comb filter	c	g	0
Allpass	a	$-a$	1
Delay	0	0	1

Equalizers

- EQs shape the spectrum by enhancing (boost/cut) certain frequencies while others remain unaffected
- Usually built as a series of independently controlled 1st order Shelving and Peak filters

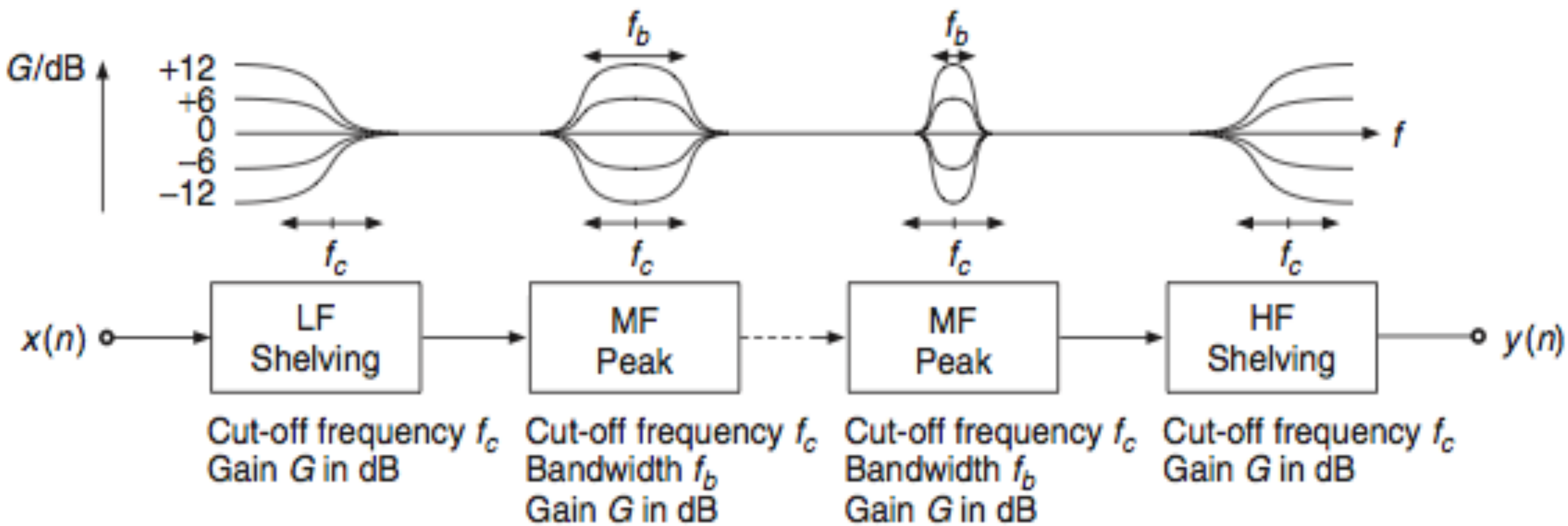


Figure 2.15 Series connection of shelving and peak filters.

Shelving Filter

- 1st-order design:
  - Can be constructed based on a 1st-order allpass

$$H(z) = 1 + \frac{H_0}{2}\left[1 + \pm A(z)\right] \quad (\text{LF/HF} + / -)$$

  - leads to the difference equation:

$$x_h(n) = x(n) - c_{B/C} x_h(n-1)$$

$$y_1(n) = c_{B/C} x_h(n) + x_h(n-1)$$

$$y(n) = \frac{H_0}{2}\left[x(n) \pm y_1(n)\right] + x(n).$$

  - Gain (dB) can be adjusted through:

$$H_0 = V_0 - 1 \quad \text{with} \quad V_0 = 10^{G/20}.$$

  - Frequency response slope limited to 6 dB / octave

Shelving coeffs

- Other parameters can be adjusted:
  - c_B = boost frequency
  - c_C = cut-off frequency
- 1st-order LF
- 1st-order HF

$$
\begin{cases}
c_B = \dfrac{\tan(\pi f_c/f_S) - 1}{\tan(\pi f_c/f_S) + 1}, \\[2ex]
c_C = \dfrac{\tan(\pi f_c/f_S) - V_0}{\tan(\pi f_c/f_S) + V_0}
\end{cases}
$$

$$
\begin{cases}
c_B = \dfrac{\tan(\pi f_c/f_S) - 1}{\tan(\pi f_c/f_S) + 1} \\[2ex]
c_C = \dfrac{V_0 \tan(\pi f_c/f_S) - 1}{V_0 \tan(\pi f_c/f_S) + 1}.
\end{cases}
$$

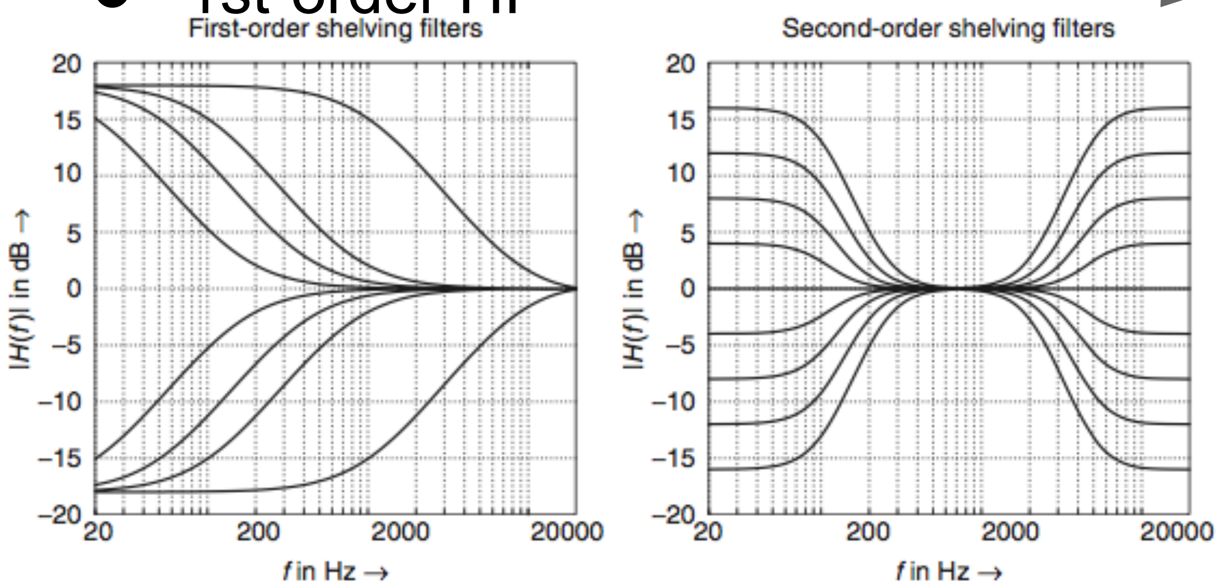


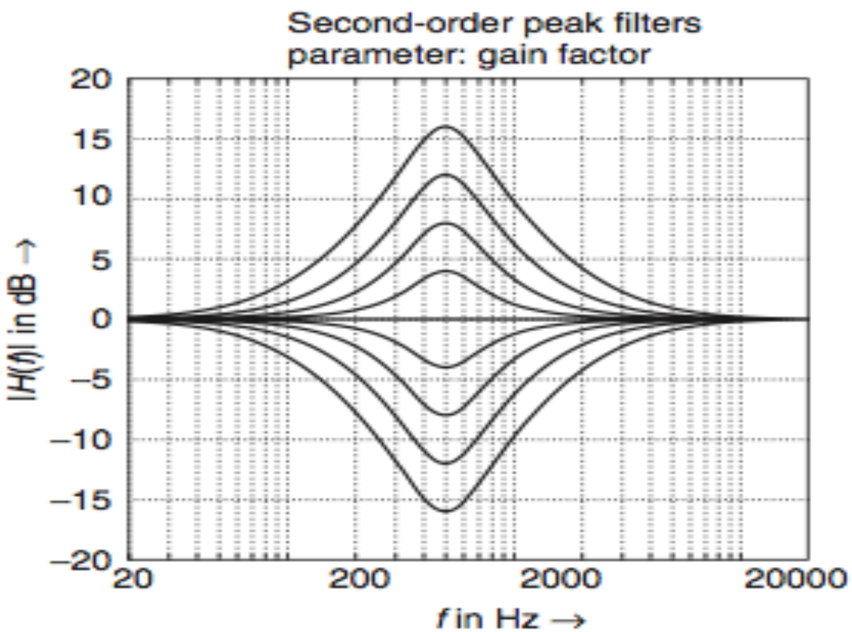
Figure 2.17 Frequency responses for first-order and second-order shelving filters.

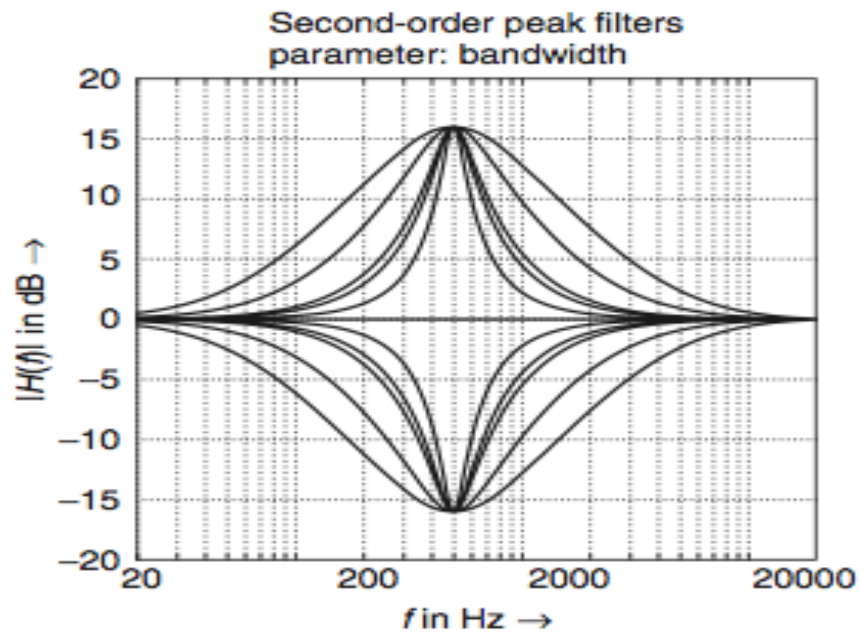
Peak Filter

- 2nd order difference equation:

$$y(n) = \frac{H_0}{2}\left[x(n) - y_1(n)\right] + x(n).$$

- Offers almost independent control over the 3 musical parameters: fc, fb, G
- Q factor = fb/fc





Delay-based effects

- Example: Vibrato effect
  - Similar to Doppler, the idea that varying the distance (i.e. time delay) will affect the pitch
  - Periodical variation of the time delay produces a periodical pitch variation
  - Need a delay-line and LFO to drive delay time
  - typical params: LFO = 5-->14Hz / Width = 5-->10ms
  - Others effects include flanger, chorus, slapback, echo...

Table 2.8 Typical delay-based effects.

Delay range (ms) (Typ.)	Modulation (Typ.)	Effect name
0 ... 20	–	Resonator
0 ... 15	Sinusoidal	Flanging
10 ... 25	Random	Chorus
25 ... 50	–	Slapback
> 50	–	Echo