FILTERS

Boosting and attenuating certain frequencies

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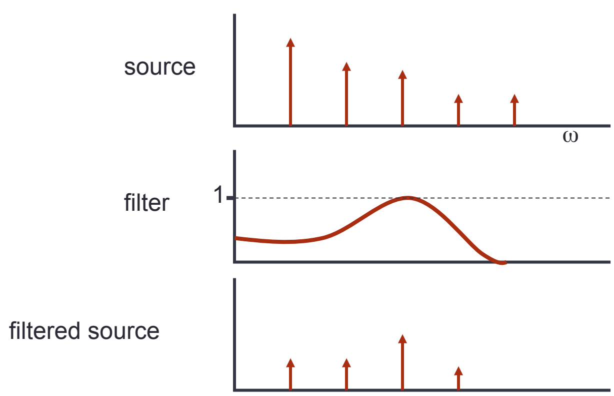
Filters

- What is filtering?



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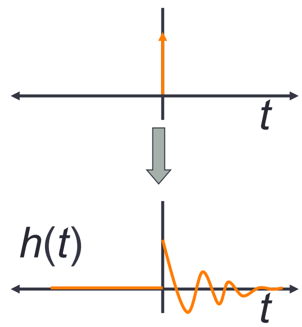
Some Intuition

- Suppose we know what a filter does to an impulse:



- This is called the *impulse response* *h*(*t*) of the filter

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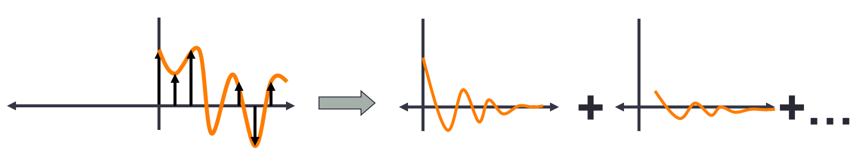
Superposition Principle

- Most filters are *linear time invariant* which implies that the superposition principle holds:
  Response(A+B) = Response(A) + Response(B)
- Using superposition principle, we can sum up impulse responses to get response to signal



See: http://www.jhu.edu/signals/convolve/
And http://lpsa.swarthmore.edu/Convolution/Convolution3.html

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Convolution

$$y(t) = \int x(\tau)h(t-\tau)d\tau$$

- This expresses the infinite superposition of *h* scaled by the input signal *x*.
- This is the *convolution* of *x* and *h*: $y = x * h$
- Convolution in the time domain is multiplication in the frequency domain: $Y = X \times H$

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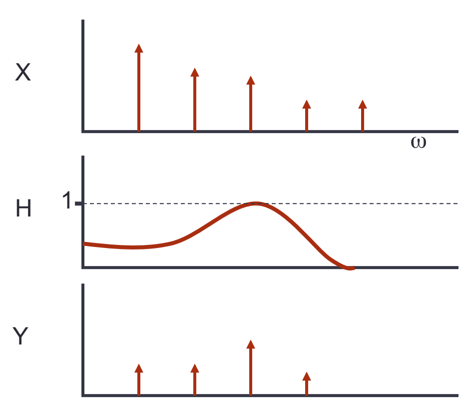
Back to where we started…

Multiplication is easier to think about, so that's why we like to describe filters as operating in the frequency domain



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What about phase?

- Yes, filters can change phase
- In fact an all-pass filter has an amplitude response of 1 (unity gain at all frequencies)
- For the complete story, represent H as complex…

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Complex Frequency Response

$$H(\omega) = U(\omega) + iV(\omega)$$

$$|H(w)| = \sqrt{U^2(\omega) \ + V^2(\omega)}$$

$$\angle H(\omega) = \arctan(V(\omega) / U(\omega))$$

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Filters in Nyquist

- LP – low-pass
- HP – high-pass
- RESON – resonance
- ARESON – complement

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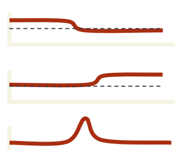
More Filters

- LOWPASS2, HIGHPASS2, BANDPASS2, NOTCH2, ALLPASS2– biquad filter variants

- EQ-LOWSHELF
- EQ-HIGHSHELF
- EQ-BAND
- LOWPASS[4,6,8], HIGHPASS[4,6,8]



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Time-Varying Filters

- Time-varying filters are based on time invariant filters; simply change parameters
- Filter equation parameters are often expensive to compute, so change parameters at control rate
- Parameter changes can insert energy into filter system, and interpolated parameters can create instabilities – numerically difficult

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Examples

```
play reson(buzz(20, c3, const(0)),
           pwlv(100, 0.5, 3000, 1, 100),
           1000, 1) ~ 5

play reson(buzz(20, c3, const(0)),
           pwlv(100, 0.5, 3000, 1, 100),
           200, 1) ~ 5

play lp(buzz(20, c3, const(0)),
        pwev(20, 0.5, 3000, 1, 100)) ~ 5
```


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