

### PARAMETERS OF A FILTER (36-43)

- ◆ 1. Center frequency,  $f_c$
- ◆ 2. Upper cutoff,  $f_U$
- ◆ 3. Lower cutoff,  $f_L$
- ◆ 4. Bandwidth,  $\Delta f$
- ◆ 5. Attenuation rate

● Attenuation rate quantifies the *selectivity* of a filter

Relative Amplitude in dB

Frequency (Log Scale)

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### IDEALIZED VS. REALIZED FILTER (44)

- When we specify parameters of a real filter, we describe it as if it were an idealized rectangular filter (blue)
- Specification of attenuation rate reveals how much the realized filter (black) departs from the idealized one

Relative Amplitude in dB

Frequency (Log Scale)

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### 1. Low-Pass Filter (46)

- Passes energy below some  $f_U$ : attenuates energy above  $f_U$
- Two parameters:
  - ◆  $f_U$  (upper cutoff)
  - ◆ Attenuation rate
- What is  $\Delta f$ ?
  - ☑  $\Delta f = f_U$

Relative Amplitude in dB

Frequency (Log Scale)

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### 2. High-Pass Filter (47)

- Passes energy above some  $f_L$ : attenuates energy below  $f_L$
- Two parameters; **what are they?**
  - ☑  $f_L$  (lower cutoff)
  - ☑ Attenuation rate
- What is  $\Delta f$ ?
  - ◆  $\Delta f = \Delta f_{sig} - f_L$

Relative Amplitude in dB

Frequency (Log Scale)

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### 3. Band-Pass Filter (48)

- Passes energy between some  $f_L$  and  $f_U$ : attenuates energy below  $f_L$  and above  $f_U$
- All five parameters useful; **what are they?**
  - ☑  $f_c$ ,  $f_L$ ,  $f_U$ ,  $\Delta f$ , and attenuation rate
- What is  $\Delta f$ ?
  - ☑  $\Delta f = f_U - f_L$

Relative Amplitude in dB

Frequency (Log Scale)

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### Band-Pass Filter (49)

- A band-pass filter is a combination of a low-pass & high-pass filter connected in series
- Signal  $\rightarrow$  LP  $\rightarrow$  HP
- ◆ or vice versa

Relative Amplitude in dB

Frequency (Log Scale)

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### a. Band-Pass Filter (constantd band width) (51)

- $\Delta f$  is independent of  $f_c$
- Panel A: Amplitude spectrum of input signal, white noise, X
- Panel B: Two transfer functions, Y & Z
  - ◆  $\Delta f_Y = \Delta f_Z$
- Why do bandwidths of Y and Z appear to be different?
  - ☑ Log scale

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### Band-Pass Filter (constantd band width) (52-53)

- $Y_{dB} < X_{dB}$  Why?
  - ☑ The input signal has been filtered; energy in frequency regions outside of passband has been attenuated
- $Z_{dB} < X_{dB}$  Why?
  - ☑ Same answer
- $Y_{dB} = Z_{dB}$  Why?
  - ☑ Because the two bandwidths are the same!
  - ☑ They appear different due to log scale

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### b. Constant Percentage Bandwidth Filter (55)

- The bandwidth,  $\Delta f$ , is always a constant percentage of the center frequency,  $f_c$ ;  $\Delta f$  is not independent of  $f_c$
- Consider sales tax analogy
  - ◆ Let purchase price be analogous to  $f_c$  and tax be analogous to  $\Delta f$
  - ◆ As purchase price increases by some factor, say 10:1, tax owed increases by same factor, 10:1

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### Constant Percentage Bandwidth Filter (56)

- Suppose constant % is 70.7
- Thus,  $\Delta f = .707(f_c)$
- Calculations
  - ◆  $\Delta f$  for Y = ?
    - >>  $0.707(1000) = 707 \text{ Hz}$
  - ◆  $\Delta f$  for Z = ?
    - >>  $0.707(4000) = 2828 \text{ Hz}$

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### Constant Percentage Bandwidth Filter (57-58)

- Why do the two filters appear to have the same bandwidth?
  - ☑ Log scale
- As before,
  - ◆  $Y_{dB} < X_{dB}$  Why?
    - ☑ The input signal has been filtered
  - ◆  $Z_{dB} < X_{dB}$  Why?
    - ☑ Same answer
- Important point!
  - ◆  $Z_{dB} > Y_{dB}$  Why?
    - ☑  $\Delta f_Z > \Delta f_Y$

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### Common Constant Percentage Bandwidth Filters (octave) (60)

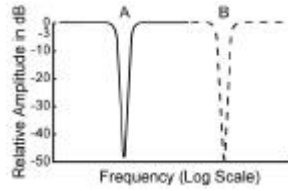
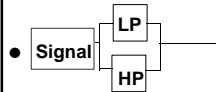
- $f_c$  appears to be at the center of passband, and it is on a log scale
- It is not the arithmetic mean of the two cutoff frequencies
- octave,  $f_U = 2 f_L$ 
  - $f_L = 1000 \times .707 = 707 \text{ Hz}$
  - $f_U = 1000 \times 1.414 = 1414 \text{ Hz}$
  - $\Delta f = f_U - f_L = 1414 - 707 = 707 \text{ Hz}$
- As  $f_c$  changes by some factor,  $f_L$ ,  $f_U$ , and  $\Delta f$  change by the same factor!

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## 4. Band-Reject Filter

(64)

- **Rejects energy between** some  $f_L$  and  $f_U$
- A band-reject filter is a combination of a low-pass & high-pass filter connected **in parallel**



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