


1  **PARAMETERS OF A FILTER**

- ◆ 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

2  **IDEALIZED VS. REALIZED FILTER**

- 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

3  **1. Low-Pass Filter**

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

4  **2. High-Pass Filter**

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

5  **3. Band-Pass Filter**

- **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  $\Delta f$ ?
  - $\Delta f = f_U - f_L$

6  **Band-Pass Filter**

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

7  **a. Band-Pass Filter** (constantd band width)

- $\Delta f$  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

8  **Band-Pass Filter** (constantd band width)

- $Y_{dB} < X_{dB}$  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

9  **b. Constant Percentage Bandwidth Filter**

● 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

10  **Constant Percentage Bandwidth Filter**

● 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  $Z = ?$

>>  $0.707(4000) = 2828 \text{ Hz}$

11  **Constant Percentage Bandwidth Filter**

● 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?

$\Delta f_Z > \Delta f_Y$

12  **Common Constant Percentage**

**Bandwidth Filters (octave)**

●  $f_c$  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!

13  **4. Band-Reject Filter**

● 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

- Signal            LP  
                          HP