COMSATS Fall 2014 (Rev. 3.0)

Electronics II

Lecture 19
Filters II

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Previous Lecture

- Filters
  - Basics of Filters.
  - Transfer Function, Magnitude and Phase Response of Filters.
  - Classification of Filters.
  - Important Properties/ Parameters of Filters.

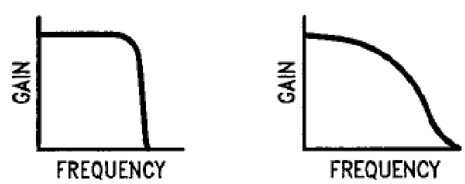
Session Overview

Topic	Filters
Concepts	Important Properties of Filters, Low Pass Filter, High Pass Filter, Band Pass Filter, Band Stop Filter.
Recommended Reading	Section 14-6 of [1] Section 11-5 of [2] Sections 1.0, 1.1, 1.4 of [3]
Keywords	Filter, Low Pass, High Pass, Band Pass, Band Stop, Active, Passive.

Filter Properties

Monotonicity

- A filter has a monotonic amplitude response if its gain slope never changes sign.
- This implies that gain always increases with the increasing frequency or always decreases with the increasing frequency.
- This is applicable only in high pass and low pass filters whereas band pass and band stop cannot have this property for their total bandwidth.

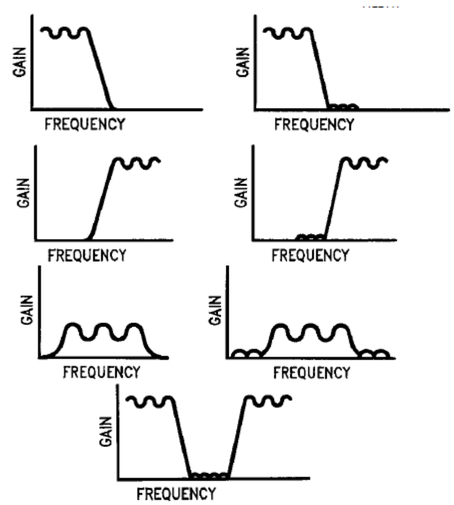


Application Note 779: A Basic Introduction to Filters- Active, Passive and Switched Capacitor, Texas Instruments Inc.

Filter Properties

Pass Band Ripple

- If a filter is not monotonic in its pass band, the transfer function will have fluctuations in the pass band.
- These fluctuations are called as *ripples*. Some systems/ applications might not require the monotonicity, but ripple should have a limited value.



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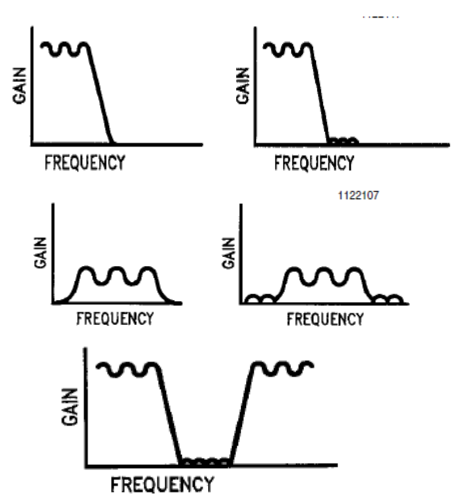
Filter Properties

Stop Band Ripple

- The phenomenon of ripple is also present in the stop band.
- Stop band ripple is usually not of concern if the signal in the stop band is sufficiently attenuated.



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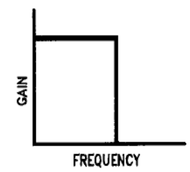
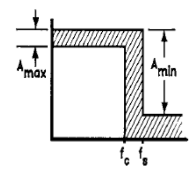
Practical Filter Design and Ideal Filter

- The main goal in filter design in to attain the *ideal filter* characteristics.
- Practically, the ideal filter is not realizable because of certain limitations so an acceptable filter design depends upon various inter related factors which include
  - Amplitude response.
  - Transient response.
  - Physical size and cost of circuit.



(a) "ideal" Low-Pass Filter Response



(b) Amplitude Response Limits for a Practical Low-Pass Filter

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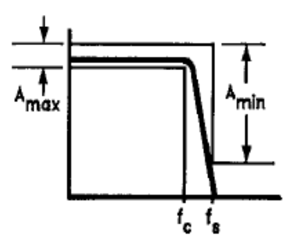
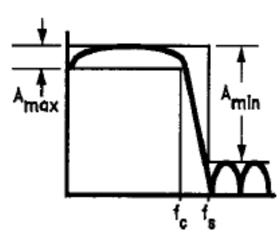
Practical Filter Design and Ideal Filter

- Four parameters are critical in the given figure.
  - Maximum allowable change in the pass band gain, A_{max}.
  - Minimum allowable attenuation in the stop band, A_{min}.
  - Cut off Frequency, f_c.
  - Frequency at which the stop band begins, f_s.
- Two possible responses within the desired limits are shown but there are infinite possible responses. So how to choose the best one?





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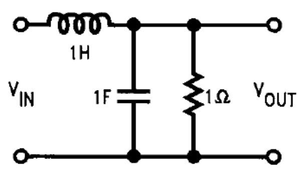
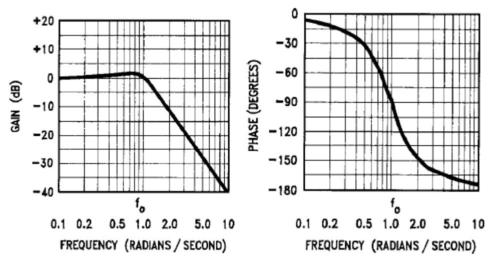
Low Pass Filter (Passive)

- Passes all the frequencies lower than the cut off frequency, *fc*, while stopping all the frequencies above the cut off.
- A passive low pass filter is shown in the figure using inductor, capacitor and resistor.



$$H_{LP}(s) = \frac{V_{OUT}}{V_{IN}} = \frac{1}{s^2 + s + 1}$$



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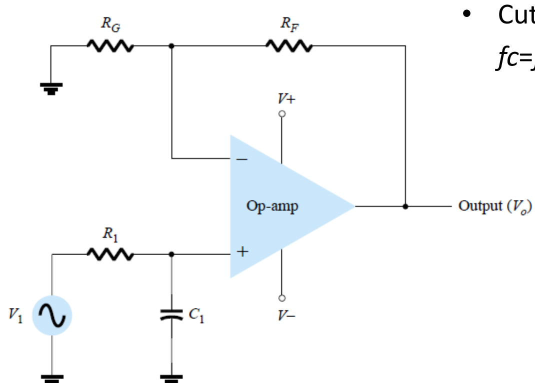
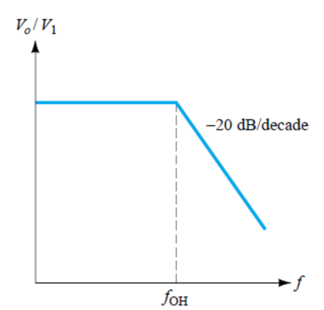
Low Pass Filter (Active) 1st Order



- Voltage Gain= $1 + (R_f/R_G)$
- Cut off frequency, *fc* or f_{OH}

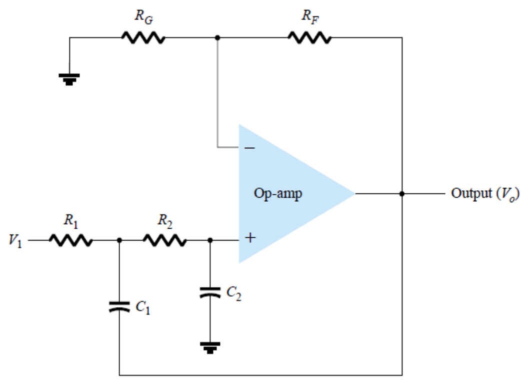
$f_c = f_{OH} = 1/(2\pi R_1 C_1)$

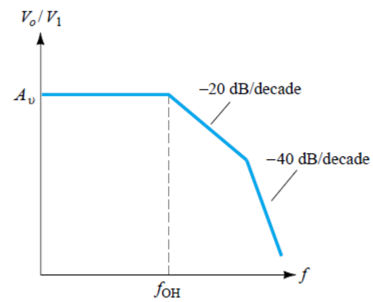


Robert L. Boylestad, *Electronic Devices and Circuit Theory*, 8th Edition, Pearson Education Inc, ISBN: 81-7808-590-9.

Low Pass Filter (Active) 2nd Order

- Voltage Gain= ?
- Cut Off Frequency= ?





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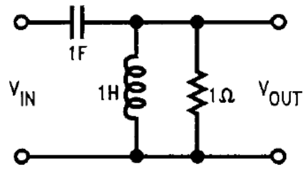
Low Pass Filter

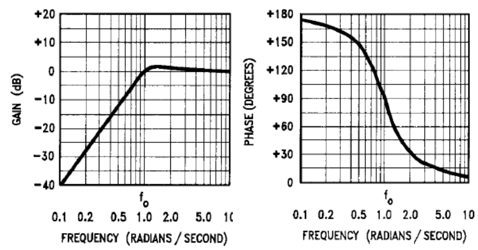
- *Example 15.12 (Boylestad):* Calculate the cut off frequency of a low pass filter with R1= 1.2kΩ and C1= 0.02µF.

High Pass Filter (Passive)

- The high pass filter is opposite of low pass filter . This implies that it passes the frequencies above the cut off frequency, *fc*, while blocks all the frequencies below *fc*.
- The simplest passive high pass filter can be made by interchanging the capacitor and inductors in the low pass filter configuration studied earlier.



$$H_{HP}(s) = \frac{V_{OUT}}{V_{IN}} = \frac{s^2}{s^2 + s + 1}$$



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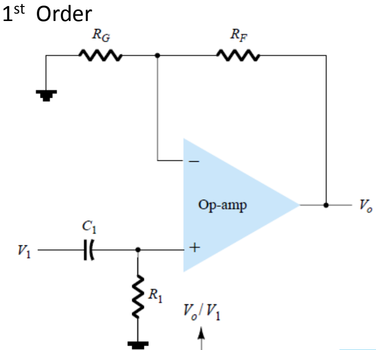
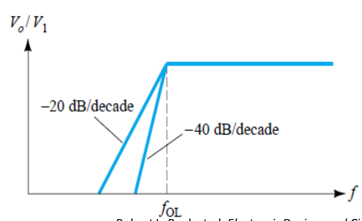
High Pass Filter (Active)

1st Order



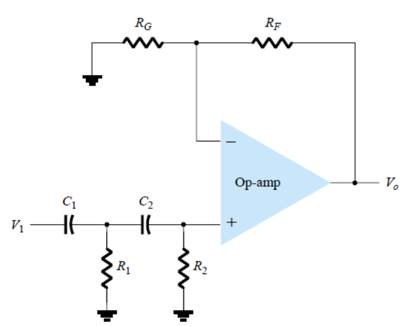


- Cut off Frequency, *fc* or f_{OL}

  $fc = f_{OL} = 1/(2\pi R_1 C_1)$

  Gain= ?

2nd Order



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High Pass Filter

- *Example 15.13 (Boylestad):*

Next Lecture

- Band Pass Filter.
- Band Stop Filter.

References

[1] Robert L. Boylestad, *Electronic Devices and Circuit Theory,* 8th Edition, Pearson Education Inc, ISBN: 81-7808-590-9.

[2] Theodore F. Bogart, Jeffery S. Beasley, Guilermo Rico, Electronics Devices and Circuits, 6th Edition, Pearson Education Inc, ISBN: 978-81-775-8887-3

[3] Kerry Lacanette. Application Note 779: A Basic Introduction to Filters-Active, Passive and Switched Capacitor, Texas Instruments, Literature Number: SNOA224A, April 2010 .

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