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# Types of Filters and Network Synthesis - GATE Study Material in PDF

In these **free** [GATE 2018](#) Notes we will mainly discuss about **Frequency Response, Types of Filters and Network Synthesis**. This is an important part of the chapter of Network Theory. These study notes are useful for **GATE EC, GATE EE, IES, BARC, BSNL, DRDO** and other exams. You can have this study material **downloaded as PDF** so that your GATE preparation is made easy and you ace the exam. Before you start learning about Types of Filters and Network Synthesis, you should read up on the basic concepts.

Recommended Reading –

[Parameters of Periodic Wave Forms](#)

[Sinusoidal Response of Series Circuits](#)

[Sinusoidal Response of Parallel Circuits](#)

[Power Relations in AC Circuits](#)

[Series Resonance](#)

[Parallel Resonance](#)





## Network Theory Revision Test 1

Generally, the filtering action in a circuit is due to the memory elements called inductor and capacitor as their impedance is a function of source frequency. The resistors present in the circuit provide the attenuation to incoming signals.

$$Z_R = R, \quad Z_L = j\omega L, \quad Z_C = 1/j\omega C$$

**iii.** At  $\omega = 0$ :  $Z_L = 0 \Rightarrow$  inductor acts like short circuit.

$Z_C = \infty \Rightarrow$  capacitor acts like open circuit.

**iv.** At  $\omega = \infty$ :  $Z_L = \infty \Rightarrow$  inductor acts like an open circuit.

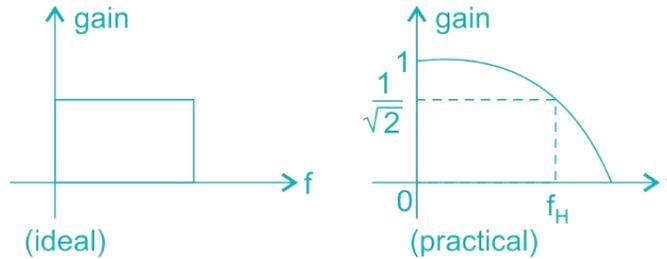
$Z_C = 0 \Rightarrow$  capacitor acts like a short circuit.

Generally, filters are classified into several types

- i. Low Pass Filter
- ii. High Pass Filter
- iii. Band Pass Filter
- iv. Band Reject Filter (or) Notch Filter
- v. All Pass Filter

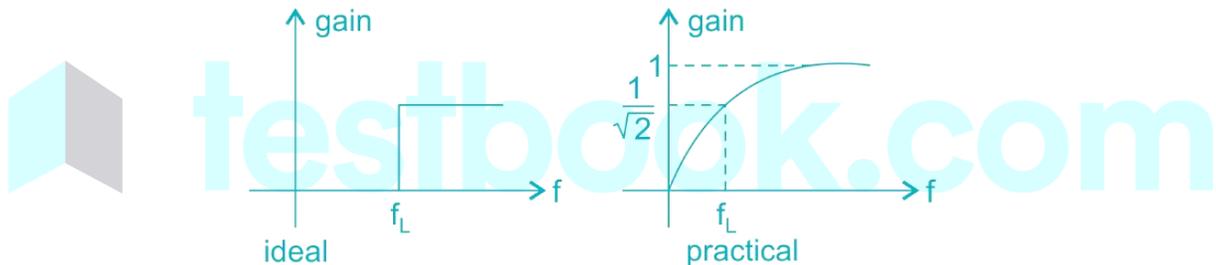
### Low Pass Filter

- It passes only low frequencies.
- It rejects all high frequencies.
- Transfer function is given by  $H(s) = \frac{k}{1+ST}$
- Frequency response of Low Pass Filter is given below.



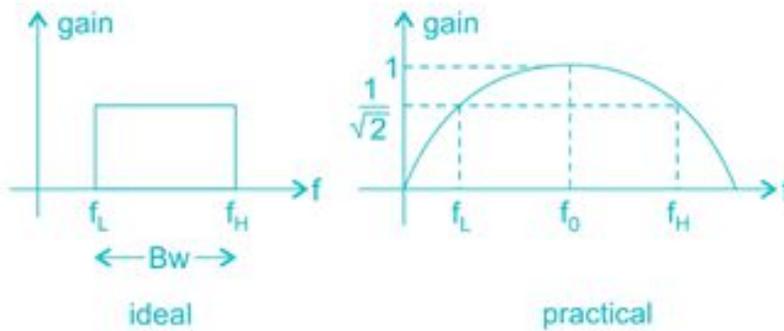
## High Pass Filter

- It passes only high frequencies.
- Attenuates all low frequencies.
- General transfer function of high pass filter is given by  $H(s) = \frac{Ks\tau}{1+s\tau}$
- Frequency response of High Pass Filter is given below.



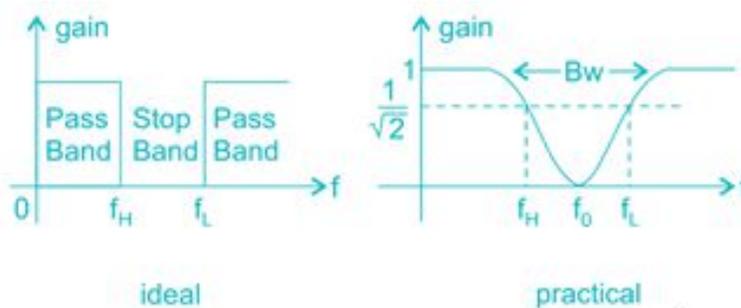
## Band Pass Filter

- It passes only a band of frequencies.
- Attenuates all low frequencies and high frequencies.
- General transfer band pass filter is given by  $H(s) = \frac{Ks}{s^2 + s\frac{\omega_0}{q} + \omega_0^2}$
- Frequency response of Band Pass Filter is given below.



## Band Stop Filter

- Also known as band reject filter (or) Notch filter.
- It passes both high frequencies and low frequencies.
- Attenuates the particular band of frequencies.
- General transfer function,  $H(s) = \frac{K(s^2 + \omega_0^2)}{s^2 + s\frac{\omega_0}{q} + \omega_0^2}$
- Frequency response of Band Stop Filter is given below.



## All Pass Filter

- It passes all frequencies.
- General transfer function  $H(s) = \frac{K(s^2 - s\frac{\omega_0}{q} + \omega_0^2)}{(s^2 + s\frac{\omega_0}{q} + \omega_0^2)}$
- Magnitude of All Pass Filter is always equal to 1.
- The phase of All Pass Filter is always in the range of  $0^\circ$  to  $180^\circ$  (or)  $-180^\circ$  to  $0^\circ$

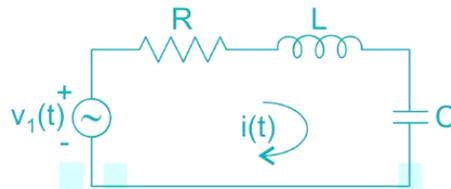


- Zeros and poles of All Pass Filter are symmetric about imaginary axis.
- Frequency response of All Pass Filter is given below.



### Example 1:

The given circuit acts like which type of filter?



**Solution:**

At  $\omega = 0 \Rightarrow$  Inductor,  $X_L = \omega L = 0 \Rightarrow L$  is short circuited.

Capacitor,  $X_C = 1/\omega C = \infty \Rightarrow C$  is open circuited.

$\therefore i(t) = 0$  at low frequencies. So circuit does not pass low frequencies.

Similarly, at  $\omega = \infty$ , the inductor acts like open circuit and capacitor acts like a short circuit.

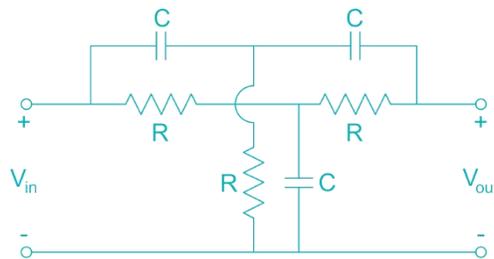
$\therefore i(t) = 0$  at high frequencies. So circuit does not pass high frequencies also.

At  $\omega_0 = \frac{1}{\sqrt{LC}}$  i. e. at resonance the  $L$  and  $C$  circuit acts like a short circuit. Now current is flowing in the given circuit so the given circuit acts like a band pass filter.



### Example 2:

The circuit given below acts like which type of filter?



### Solution:

At  $\omega = 0$ : Inductor is short circuited.

Capacitor is open circuited.

$$\therefore V_{out} = V_{in}$$

At  $\omega = \infty$ : Inductor is open circuited.

Capacitor is short circuited.

$$\therefore V_{out} = V_{in}$$

At  $\omega = \omega_0 = \text{i.e. at notch frequency } V_{out} = 0$

$\therefore$  So given circuit acts like a band stop filter.

### Example 3:

The following 2<sup>nd</sup> order transfer function represents which type of filter

$$H(s) = \frac{s^2+1}{s^2+s+1}$$

### Solution:



Given,

$$H(s) = \frac{s^2+1}{s^2+s+1}$$

$$\text{At } \omega = 0 \Rightarrow s = j\omega = 0 \Rightarrow H(s) = 1$$

i.e. circuit passes low frequencies.

$$\text{At } \omega = \infty \Rightarrow s = j\omega = \infty \Rightarrow H(s) = 1$$

i.e. circuit also passes high frequencies.

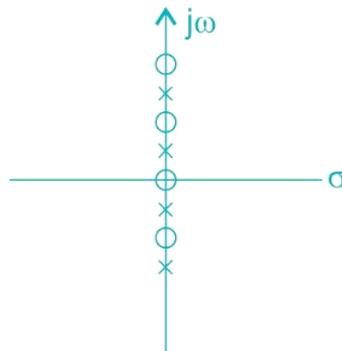
$$\text{At } \omega = 1 \Rightarrow s = j\omega = j \Rightarrow H(s) = 0$$

i.e. circuit has a notch frequency of 1 rad/sec.

So, the given circuit acts like a band stop filter.

## Elements of Network Synthesis

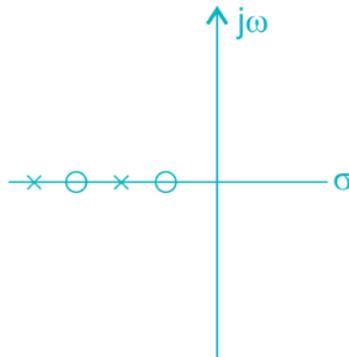
i. For the driving point LC impedance function, poles and zeros are alternate and lies only on  $j\omega$  axis



$$\text{Ex: } Z(s) = \frac{s(s^2+2)(s^2+4)}{(s^2+1)(s^2+3)}$$

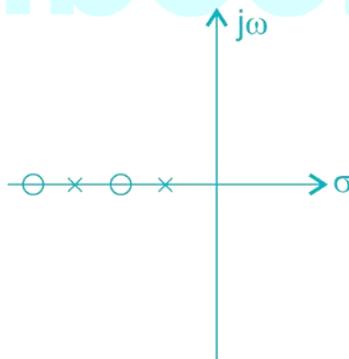


ii. For the driving point RL impedance function, poles and zeros are alternate lies only on the negative real axis and nearest to the origin is zero (zero can be at the origin)



$$\text{Ex: } Z(s) = \frac{(s+3)(s+5)}{(s+4)(s+6)}$$

iii. For the driving point RC impedance function the poles and zeros are alternate, lie only on the negative real axis and nearest to the origin is pole (pole can be at the origin)



$$\text{Ex: } Z(s) = \frac{(s+4)(s+6)}{(s+3)(s+5)}$$

iv. For the driving point RLC impedance function the poles and zeros are complex conjugate pairs and they are symmetric with respect to the negative real axis

**Note:**



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- In the above cases instead of impedance functions if admittance functions are given then they are to be converted into the impedance functions first and later the above tests are to be performed.
- RL Impedance Function = RC Admittance Function
- RL Impedance Function = RL Admittance Function
- Immitance can be Impedance (or) Admittance

Did you like this article on Types of Filters and Network Synthesis? Let us know in the comments. You may also enjoy reading the following –

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### **[Understanding Time Shifting](#)**



### **[Tip to Find Feedback in a Circuit](#)**

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