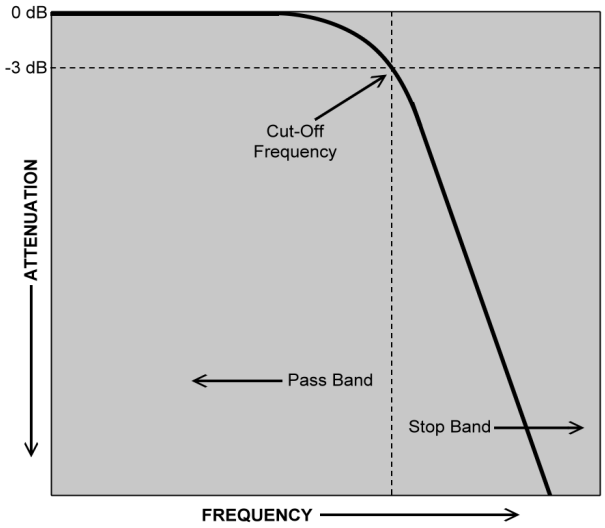
InnowaveRF, LLC has the knowledge and experience in designing a variety of lumped element filters that are used to satisfy filter requirements from 20Hz to 5GHz. These kinds of filters are also called LC Filters since it consists of discrete elements such as Inductors (L) and Capacitors (C) that are soldered on to a substrate to realize different types of characteristic response. These inductors and capacitors are arranged such that a range of specified frequencies (known as the pass band) passes through with minimal attenuation and rest of the frequencies (known as the reject band / stop band) is attenuated heavily.

Lumped element filters can be classified into these four basic categories:

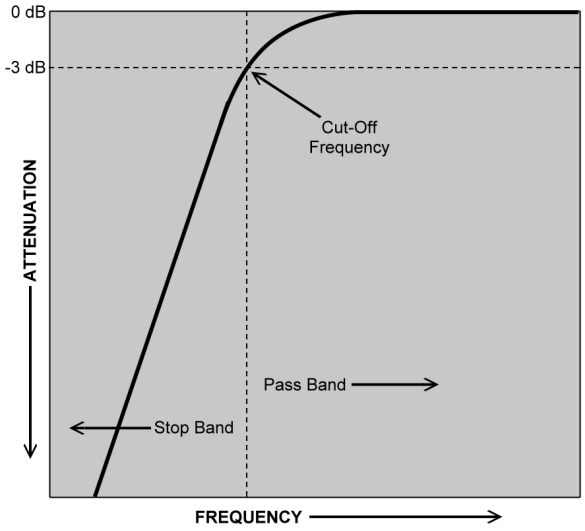
Lowpass Filters:

Passes low frequencies, rejects high frequencies



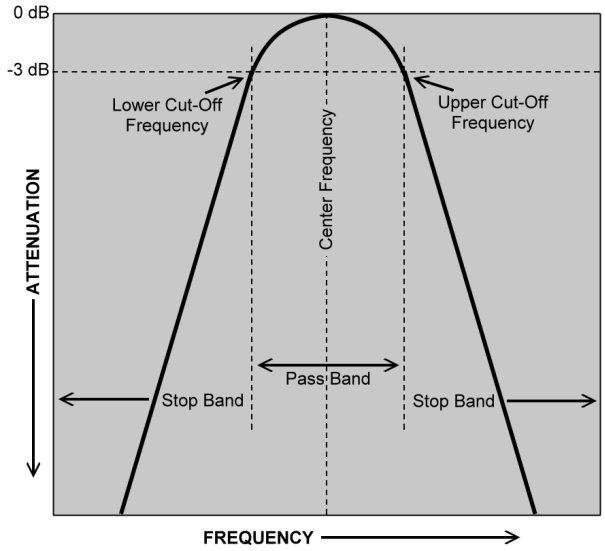
Highpass Filters:

Passes high frequencies, rejects low frequencies



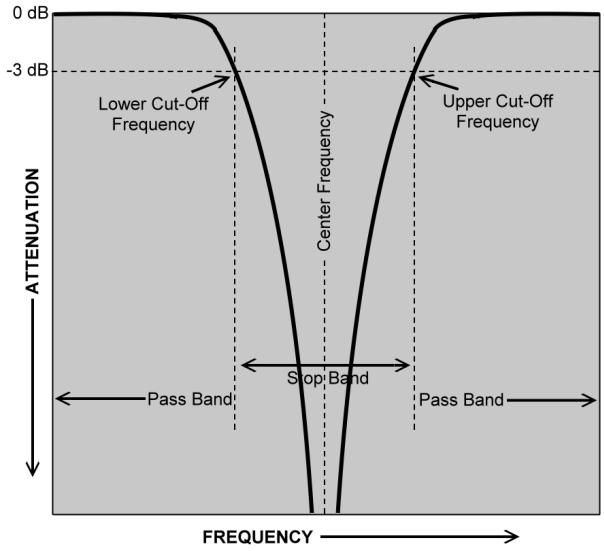
Bandpass Filters:

Passes a band of frequencies centered on a center frequency, rejects both higher and lower frequencies



Bandstop / Band Reject Filters:

Rejects a band of frequencies centered on a center frequency, passes both higher and lower frequencies



Filter Basics

Ideal filter will have zero attenuation in the pass band and infinite attenuation in the stop band. However, such a filter cannot be manufactured practically. Using the best design and modeling technique and state-of-the-art CAD solutions, *InnowaveRF* manufactures filters that have an unloaded Q as high as 400. Along the band edges, the pass band of the filter gets rounded off and then starts the roll-off into the reject band. The response of the filter from its pass band to its reject band is called the shape factor of the filter. The sharper the roll-off of the filter, the higher is the order of the filters, which in turn means more elements.

Picking the correct order of the filter is very important. It is redundant to use more elements in the filter, if the required response can be achieved with a lesser number of elements. Having more elements will not only cost more, but will also increase the insertion loss of the filter in the pass band. Specifying your requirements to *InnowaveRF* engineering team, and we will suggest you the ideal number of elements needed to achieve your specifications.

Apart form the amplitude response of the filter, other important characteristics such as the delay response and the phase response are also critical in some of the applications. Different filter designs have different response characteristics and are chosen to meet varied requirements. Listed below the different filter designs and their characteristics:

1. **Butterworth Design:** A ripple free pass band and a smooth stop band characterize this design. Increased attenuation is achieved as you move away higher in frequency. The downside for this design is that it uses more components than Chebyshev or Elliptical designs, which makes it less economical in applications that does not require a ripple free pass band. Since the roll off is smooth id does not require quality factor of its components to be high.
2. **Chebyshev Design:** A predetermined amount of pass band ripple is used to design filters that meet chebyshev characteristics. The roll off and the stop band is smooth and approaches infinity as the frequency moves away from the band edges. It requires less number of elements to achieve similar shape factor as compared to a Butterworth design. Therefore it is more economical and hence used more commonly used in filter designs. A good quality factor is required for such filters, typically a Q of 250 for inductors and 500 for capacitors.
3. **Elliptical Design:** This also requires a predetermined amount of pass band ripple along with stop band ripple. Although these use the least amount of elements required in achieving a desired shape factor compared to Checbyshev or Butterworth designs, the quality factor required for the elements are very high. As a result, the dynamic range of frequency elliptical filters can be used are limited by the elements' Q. These filters are ideal for applications that require a very sharp roll off. Roll off ratio as lower than 1.01 at 40dB can be achieved using this.
4. **Bessel Design:** Bessel filters are a kind of linear filters with maximally flat group delay and hence maximally linear phase response. For lowpass and narrow bandpass filter designs, the delay is flat through out the pass band, but for wider band pass filters, special designs are used to achieve the group delay flatness. The downside of this is that the roll off is horrible with ratio of 2 at 13dB and has a very poor VSWR.
5. **Gaussian Design:** The step and impulse response of a Gaussian filter has ZERO overshoot while minimizing the rise and fall time. The delay response in almost similar to that of Bessel filter, except that it has a bump at the center frequency. The cutoff frequency for Gaussian is usually specified as the 6dB cutoff or 12dB cutoff.

There is really no right or wrong way to design a filter. The type and kind of filters are designed based on the specifications and applications in which they are used. *InnowaveRF*'s engineering team will be happy to assist you in finding the best solution for your requirements. Please don't hesitate in giving us a call at 914-230-4060 or email us at sales@innowaverf.com.