FILTER FACTS

INTRODUCTION

Over the years Allen Avionics has used its experience and knowledge to supply customers with a comprehensive catalog that is easy to use and filled with valuable information. By reading FILTER FACTS, you will gain a good general understanding of LC Filters and some of their applications. This should also help when you have a need for special or custom filter designs. Allen Avionics Engineering and Sales Staff will be glad to answer any questions that you may have regarding our filter products.

An LC Filter may be defined as a passive device consisting of capacitors and inductors in a particular array such that a group of specified frequencies pass with very little attenuation while the undesired frequencies are attenuated.

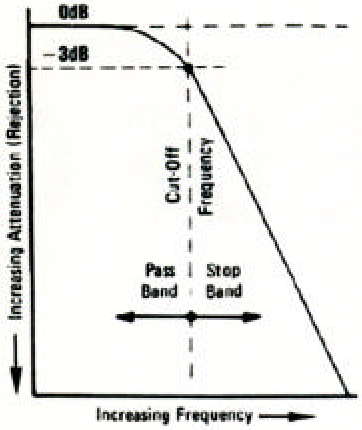
The four most common types of LC Filters (Lowpass, Highpass, Bandpass, Band Reject) are described in the following illustrations.

The ideal filter would be a device that exhibits no attenuation in the passband and infinite attenuation to all other frequencies. However, a filter with these characteristics cannot be manufactured. Allen Avionics uses state-of-the-art computer aided design and filter modeling to produce the highest quality LC Filters available.

The amplitude response of a filter from its passband to its reject band is defined by its shape factor. In this catalog, the Lowpass and Highpass Filters have their shape factors expressed as the ratio of the 20dB and 40dB frequencies to that of the 3dB frequency.

For example: a Lowpass Filter with its cutoff at 1MHz and its 20dB point at 1.60MHz has a ratio of 1.6 at 20dB. This can be found by dividing the 20dB frequency by the 3dB frequency i.e. (1.6MHz/1.0MHz) = 1.6.

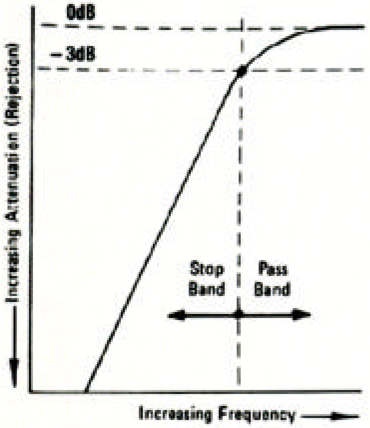
When a Highpass Filter is used, the ratio is expressed as a number less than one. The cutoff ratios of Lowpass and Highpass filters that Allen Avionics can manufacture are listed in the tabulated listings for Lowpass and Highpass filters starting on page 14.



LOWPASS

PASSES LOW FREQUENCIES

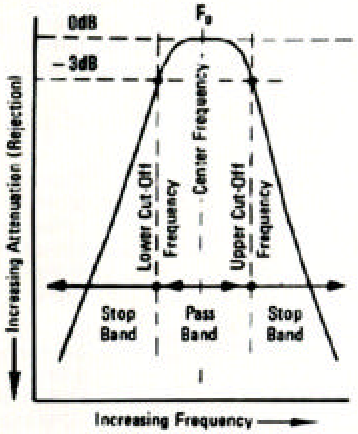
REJECTS HIGH FREQUENCIES



HIGHPASS

PASSES HIGH FREQUENCIES

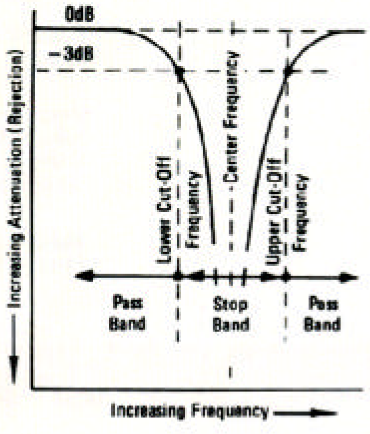
REJECTS LOW FREQUENCIES



BANDPASS

PASSES A BAND OF FREQUENCIES

REJECTS BOTH HIGHER AND LOWER FREQUENCIES



BAND REJECT

REJECTS A BAND OF FREQUENCIES

PASSES BOTH HIGHER AND LOWER FREQUENCIES

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The shape factors for the Bandpass Filters listed on pages 22-25 and the Band Reject Filters on page 29 can be determined by dividing the frequency difference between the 20dB points or the 40dB points (rejection bandwidth) by the frequency difference between the 3dB points (passband). The specified upper and lower 3, 20 or 40dB points should be geometrically symmetrical to the center frequency. The relationship of the band edges (F_1 & F_2) to the center frequency (F_0) in a filter that has geometric symmetry is defined as $F_0 = \sqrt{F_1 \times F_2}$.

The Linear Phase Flat Delay Bandpass Filters on page 26 through 28 have arithmetic symmetry to the center frequency. This type of symmetry is defined by $F_0 = \frac{1}{2}(F_1 + F_2)$. This type of filter will always have at least one half of the passband on either side of the center frequency.

In this filter catalog, all the lowpass and bandpass shape factors will result in a number greater than one, while the shape factors in the highpass and band reject filters will be less than one. In all cases, however, the shape factor improves as the number approaches one.

As the shape factor requirement for a particular filter approaches one, the necessary number and quality factor of its capacitors and inductors increases. Extensive experience and knowledge of components, along with the ultimate in computer aided design and computer controlled test equipment, are required to manufacture LC Filters that exhibit these very low shape factors. Allen Avionics offers a wide range of shape factors for each of the Lowpass, Highpass, Bandpass and Band Reject type of filter. By taking advantage of the tables of shape factors for each filter type, you can pick just the right amount of filtering to do your job. Buying more filter than you need can cost a lot.

The characteristics that the Lowpass, Highpass, Bandpass or Band Reject Filters exhibit are determined by the type of design as well as the number of elements. The Butterworth, Chebyshev, Elliptical, Bessel, Gaussian and the Transitional Gaussian are the best known and most useful designs that are currently used in the filter industry.

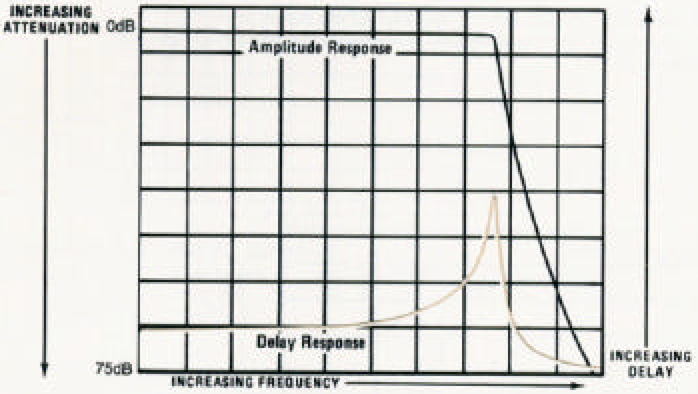

FIGURE-A TYPICAL LOWPASS
Amplitude and delay response of typical Lowpass Filter. Note the rapid change in the delay response as the cut-off frequency (3dB) is approached. If this type of delay distortion is unacceptable, see figure C or D.

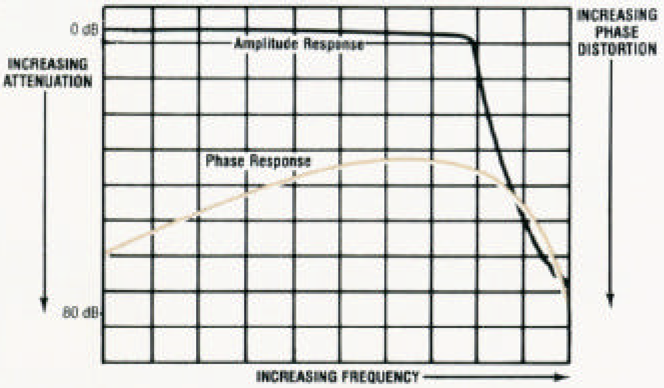

FIGURE-B LOWPASS WITH PHASE PLOT
Amplitude and phase response of typical Lowpass Filter (same filter as in A). Note that the phase deviation from a straight line is equivalent to the variation in delay in plot A.

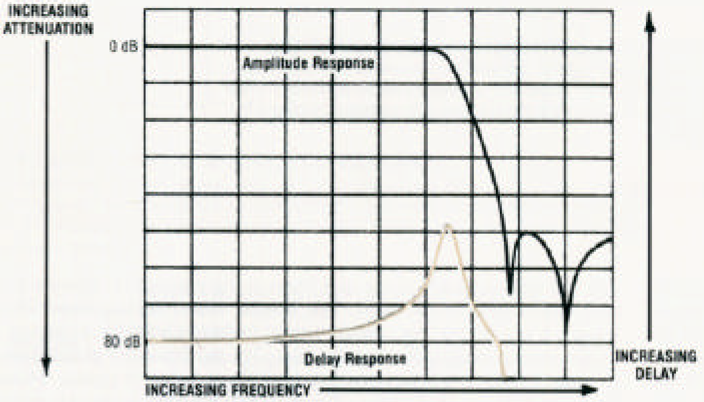

FIGURE-C TYPICAL ELLIPTIC LOWPASS
Amplitude and delay response of typical Elliptic Lowpass Filter. Note the rapid change in the delay response as the cut-off frequency (3dB) is approached. Also note the large ripples in reject band. The minimum attenuation in the reject band can be controlled by the filter design and can be specified when ordering custom designs.

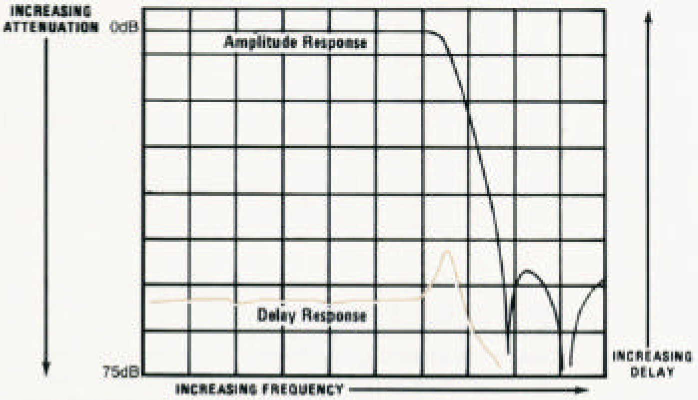

FIGURE-D DELAY EQUALIZED LOWPASS
Amplitude and delay response of NTSC Delay Equalized Lowpass Filter. The above illustrates the excellent delay response of this filter over 91% of its passband. Also note the very rapid attenuation that the filter exhibits after it reaches its 3dB cut-off frequency.

The Butterworth design is characterized by a ripple-free passband as well as a smooth stop band. Increased attenuation is achieved as the frequencies get further from the passband. For a given shape factor, this design requires more components than the Chebyshev or Elliptic types but the required quality factor of its components is not as high. When a Butterworth filter is specified for a filter application, the additional sections needed to meet a given shape factor will increase over other filter types and can result in increased size and cost.

The Chebyshev design is characterized by a predetermined amount of passband ripple. The stop band exhibits smooth roll-off and infinite attenuation is approached as the frequency increases. This design requires less components than the Butterworth to realize a given shape factor. Reductions in cost and size can be realized with this type of filter over the Butterworth even though the quality factor demanded of its components is much greater. (See Fig. A and B.)

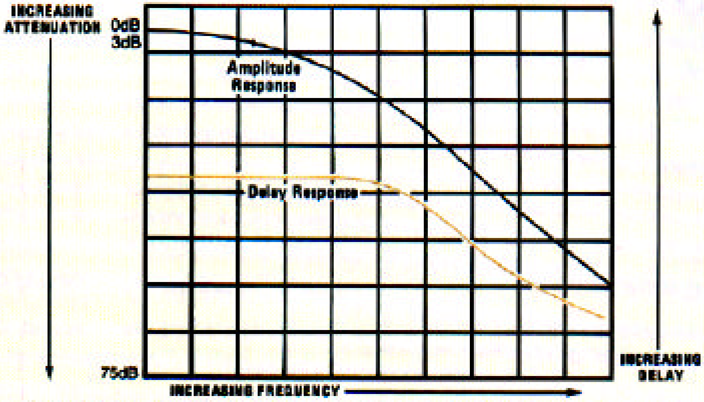

FIGURE-E AMPLITUDE & DELAY RESPONSE OF A BESSEL FILTER

Note the exceptional delay flatness that extends well beyond the cut-off frequency. The relatively poor attenuation characteristics of this filter is the penalty for this exceptional delay response.

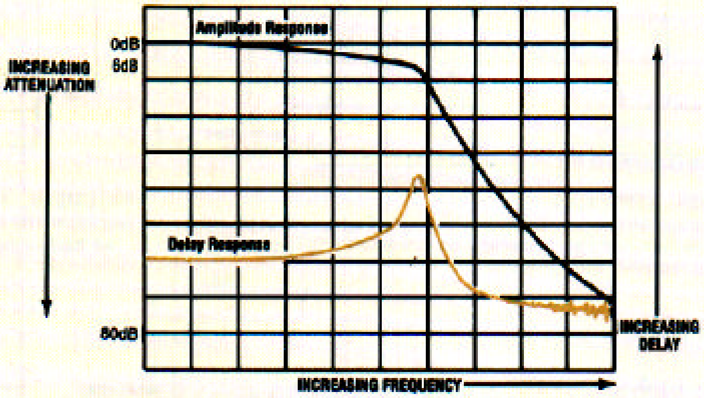

FIGURE-F TYPICAL TRANSITIONAL GAUSSIAN LOWPASS

Amplitude and delay response of typical Transitional Gaussian Lowpass Filter. Note the sharper cut-off of this filter along with increased delay distortion. This filter is a good compromise between the Bessel and the standard lowpass for both amplitude and delay.

The Elliptic design is also noted for a predetermined amount of passband ripple along with ripple in the stop band. See fig.C. While this design requires less components than the Butterworth or Chebyshev to realize a given shape factor, the quality factor required of its components is much higher than that of other filter types. This results in a reduced useful frequency range and can increase cost. Using this filter type, Allen Avionics has been able to achieve stop band ratios of less than 1.012 at 40dB. For example, a lowpass filter with its 3dB cutoff frequency at 10,000Hz would have its 40dB point at 10,120Hz.

The amplitude, delay and phase response of the Bessel and Gaussian designs are very similar to each other. Both filter types have excellent flat delay characteristics in the passband when they are used for lowpass or narrow band bandpass. In the wide band bandpass, special designs must be used to keep the delay flat over the passband. Their shape factors are extremely poor (2 to 1 at 13dB) and for this reason their usefulness is somewhat limited. If better shape factors are needed with constant delay distortion in the passband, delay equalized filters have to be used. The Bessel filters are represented by curves A, B and C on the Linear Phase Lowpass page of this catalog. A much more desirable and useful design is the Transitional Gaussian. Curves D, E and F are representative of these types of Linear Phase Lowpass Filters. Linear Phase Filters of this type are extremely popular because of their cost/performance ratio.

The communications industry has a high demand for Linear Phase Flat Delay Bandpass Filters. Allen Avionics has developed a series of synthesized bandpass designs which have exceptional flat delay characteristics. The advantage of this design over that of a delay equalized bandpass filter is that it utilizes less components. This results in economy, reliability and generally smaller sizes. Because of our computer modeling capabilities, fast deliveries (about one week) are achieved. They are available with center frequencies ranging from 1KHz to 80MHz and bandwidths from 2% to 50%. Filters of this type are tabulated on pages 26 and 27 of this catalog.

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Many LC Filter designs that involve extremely sharp cut-offs cannot be synthesized. With this in mind, Allen Avionics utilizes a special computer aided design program that transforms this type of filter into a flat delay device. By utilizing the proper delay sections, it is practical in many cases to achieve a delay flatness of less than 3% of the nominal delay over the passband. A group of these very unusual Sharp Cut-off Lowpass Delay Equalized Filters are offered by Allen Avionics on pages 16 and 17. These filters have never been tabulated by anyone before and their excellent specifications make them very desirable for use as Anti-Aliasing filters in A/D or D/A digital systems. Four shape factors are offered in this series. Each one is designed to offer the best in cut-off and delay flatness.

After learning about the different types of filters, you have to know the important information that has to be specified when you order a custom filter. Allen Avionics provides an easy to use, step by step filter order/specification form with our catalog that will guide you in the design of a custom filter. The form covers all the filter types and allows you to match your needs with our products. All the parameters like cut-off, shape factor, impedance, size and termination type are easily defined. If your requirements cannot be met with the order form and the standard filter tabulations on the filter catalog pages, our technical sales staff is ready to assist you.

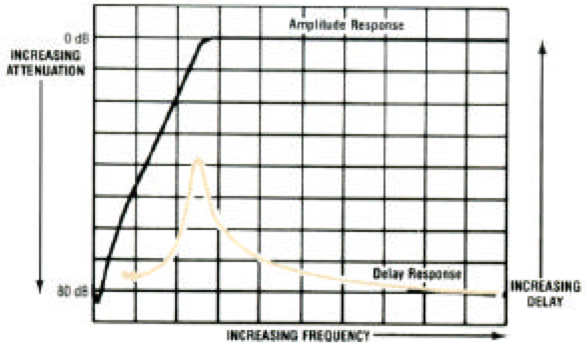

FIGURE-G TYPICAL HIGHPASS
Amplitude and delay response of typical Highpass Filter. Note the sharp cut-off with the accompanied delay plot. This filter can be delay equalized over a specified part of its bandwidth.

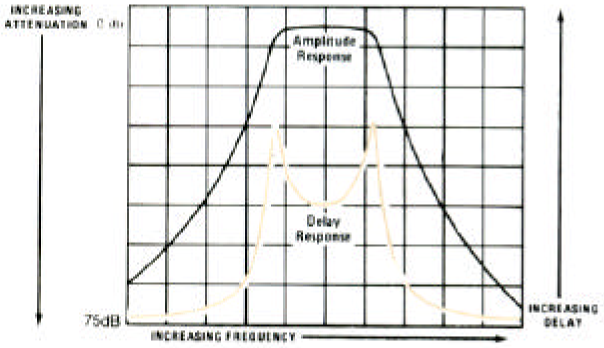

FIGURE-H TYPICAL BANDPASS
Amplitude and delay response of typical Bandpass Filter. The delay plot shows a rapid change in delay as the frequencies approach the edges of the passband. If improved delay response is required, then see Figures I, J or K.

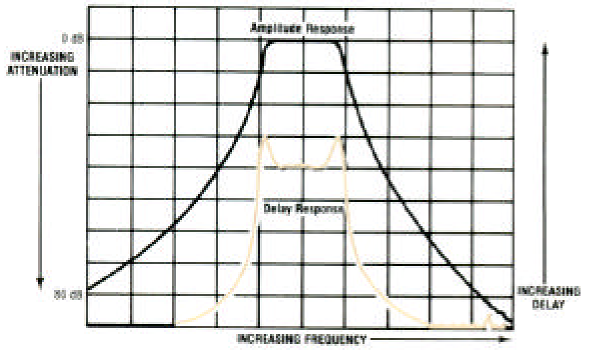

FIGURE-I DELAY EQUALIZED BANDPASS
Amplitude and delay response of Delay Equalized Bandpass Filter. Note the improved delay response over most of the passband. It is generally very costly and impractical to extend the delay flatness to the 3dB points. If this is required, see Figures J or K.

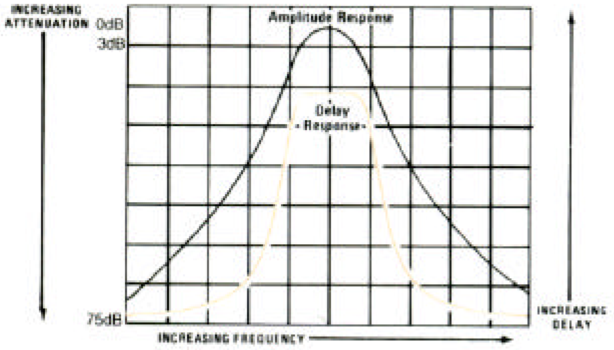

FIGURE-J GAUSSIAN LINEAR PHASE BANDPASS FILTER
Amplitude and delay response of Linear Phase Bandpass Filter. Allen Avionics synthesized Linear Phase Flat Delay Filters are extremely popular and display outstanding delay characteristics right to the 3dB bandwidths.

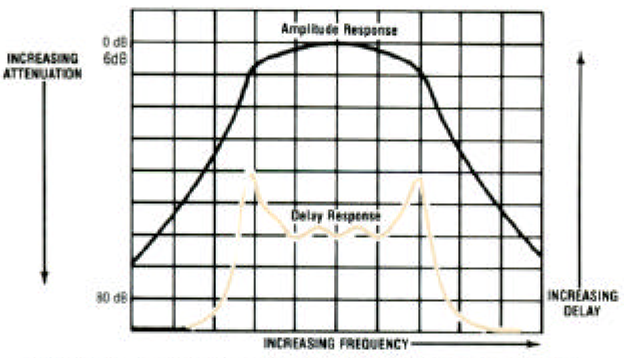

FIGURE-K TRANSITIONAL GAUSSIAN LINEAR PHASE BANDPASS FILTER
Amplitude and delay response of Transitional Gaussian Bandpass. Note that the amplitude and delay response are compromised due to the increase in roll-off with this type of filter. This filter is a good choice when one can tolerate some delay distortion from the 3dB to 6dB bandwidth.

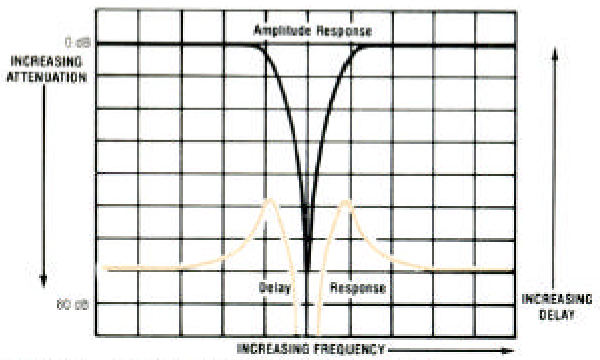

FIGURE-L TYPICAL BAND REJECT FILTER
Amplitude and delay response of a Band Reject Filter. Note the high delay distortion at the notch-band edges where the amplitude response falls off 3dB.