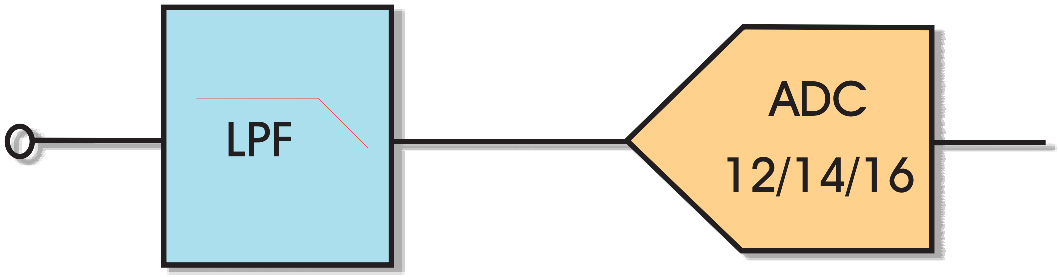
Summary

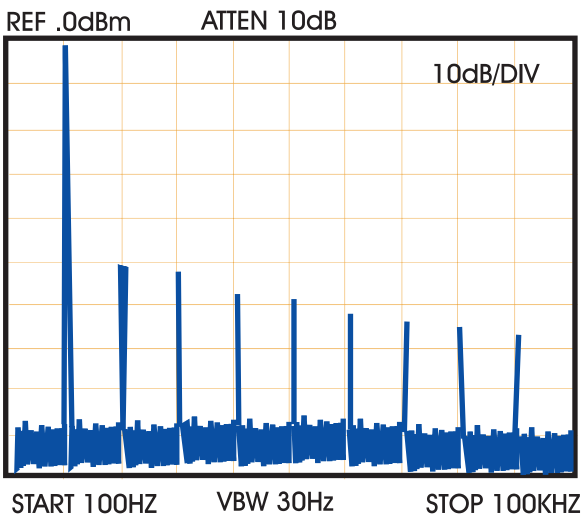
The Nyquist criterion dictates that all signals must be bandlimited to less than half the sampling rate of the sampling system. Many signals already have a limited spectrum, so this is not a problem. However, for broad spectrum signals, an analog lowpass filter must be placed before the data acquisition system.

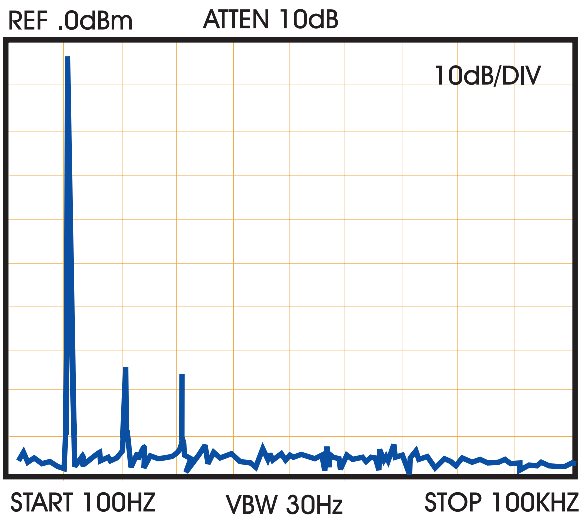
The minimum attenuation of this filter at the aliasing frequency depend on the number of bits of the ADC.

Butterworth, Cauer, Bessel ?



Frequency Spectra





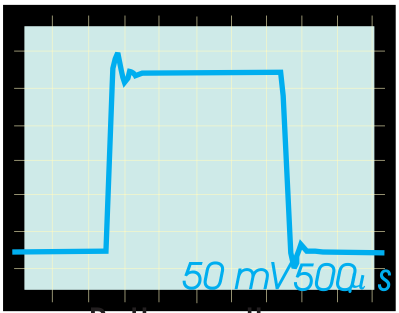
To illustrate the need for a filter preceeding an A/D converter these two input signals were used.

On the left, the generator has an output which is rich in harmonic content as can be seen by one output of the spectrum analyzer.

The spectrum shown on the righ is the same signal which has been filtered by a fourth order Butterworth 10KHz low pass filter.

Among the types of filters more commonly used for anti-alias purposes are **Cauer** (Elliptic) filters, **Bessel** filters, and **Butterworth** filters. No filter is perfect, and different types of filters are imperfect in different ways. The optimum filter type for an application depends on which kinds of imperfections are most easily tolerated. Examples of imperfections include phase non-linearity, gain error, passband ripple and droop, and wideband noise.

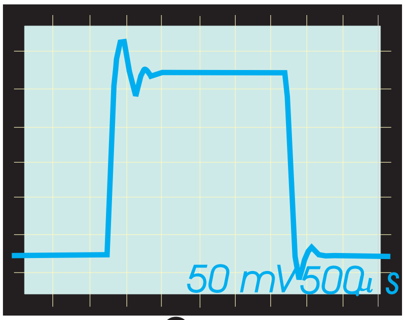
STEP RESPONSE OF FIFTH ORDER LOW PASS FILTER



Butterworth

Butterworth

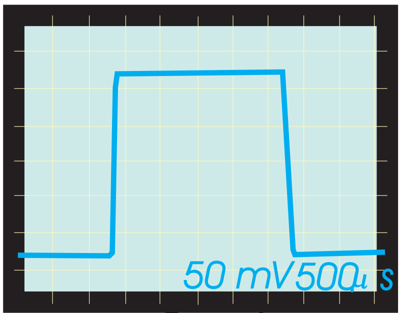
The moderate overshoot and ringing of the Butterworth may be acceptable.



Cauer

Cauer

The ringing in the Cauer make it useless in most step or impulse applications.



Bessel

Bessel

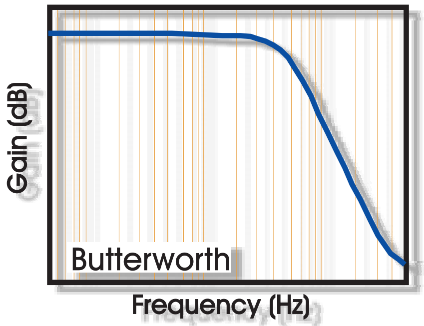
The Bessel exhibits the best pulse response of the types discussed.

An extremely and cutoff-frequency rolloff makes Cauer filters ideally suited for most anti-alias applications. Cauer filters also have good passband flatness and low wideband noise. But, their non-uniform group delay can cause some overshoot or ringing in time-domain plots if the input signal has sharp transitions. Bessel filters, on the order hand, have a uniform group delay with no ringing or overshoot.
They are best suited for time-domain anti-alias applications requiring minimum distortion of rapid slope changes. Butterworth filters are useful when maximum passband flatness is critical.

Both Bessel filters and Butterworth filters have a gentler cutoff slope as compared to the Cauer.

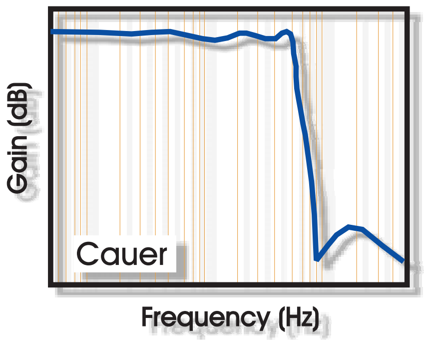
BODE PLOTS OF VARIOUS FILTER TYPES

Shown here are bode plots for various filter type implementations of 5 KHz low pass filters :



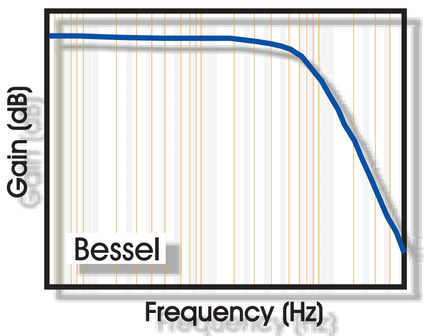
Butterworth

Shows its flat pass band response (the most flat of all types discussed here) and fairly steep rate of attenuation in the transition band. Butterworth filters are the most commonly used filter in anti-aliasing and noise.



Cauer

Shows the pass band ripple but extremely steep rate of attenuation in the transition band. Ideally suited for most anti-aliasing applications with SHANNON.



Bessel

Characterized by its fairly flat pass band gain and slow initial rate of attenuation. In closed-loop systems and signal reconstruction applications phase distorsion can often be more important than pure roll off rate. In these application the Bessel filter is a better choice.

Before purchasing an acquisition board with a filter :

- I choose the type of filter
  - --> The **Butterworth** filter is used in most cases — $Fe > 4\ F_{max}\ signal$
  - --> Where the acquisition frequency is low compared to the bandwidth being analyzed the **Cauer** filter is the best choice — $Fe \simeq 2\ F_{max}\ signal$
  - --> Where it is mandatory to maintain the shape of the signal in transient analysis, the **Bessel** filter is recommended, where Fe >> Fsignal — $Fe \gg F_{max}\ signal$
- It is advised that cutoff frequencies be programmable (versus the acquisition
- It will be very helpful to display the signal before converting it, by means of a
- In correlation measurements, each channel must feature the same cutoff frequency in order to maintain the same propagation time
- In my measurement chain, the amplitude and phase shift between each channel must be as low as possible
- I choose those boards whose type of conversion does not involve a specific transfer function (systematically avoid sign a delta types ADCs)

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