Improve Group Delay Response In The Anti-Aliasing Filter

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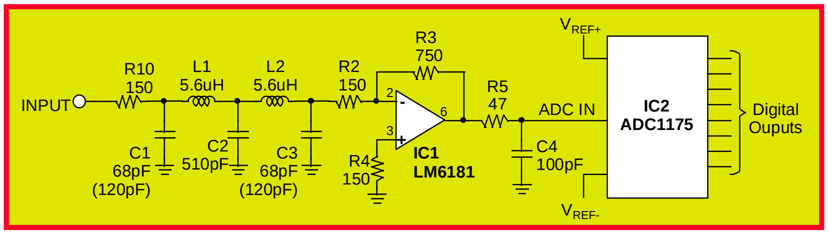
You can dramatically improve the group delay performance of a video digitizer by using the anti-aliasing filter shown ***(Fig. 1)*** instead of a Butterworth anti-aliasing filter.



1. The group delay of this 5-pole anti-aliasing filter were improved by modifying the values of the input and output capacitors. Output filter R4C4 helps to isolate the filter amp while improving phase margins.

To accurately sample a signal and eliminate aliasing, you must reduce undesired signals at the quantizer input to acceptable levels. To reduce energy at frequencies greater than those desired at the ADC input, it's common to employ an anti-aliasing filter in the analog signal path prior to quantization. For NTSC (National Television Standards Committee--used in the United States and Japan) and PAL (Phase Alternate Line--used in much of Europe) video systems, the filter cutoff frequencies are about 4 to 6.5 MHz, depending upon the video system.

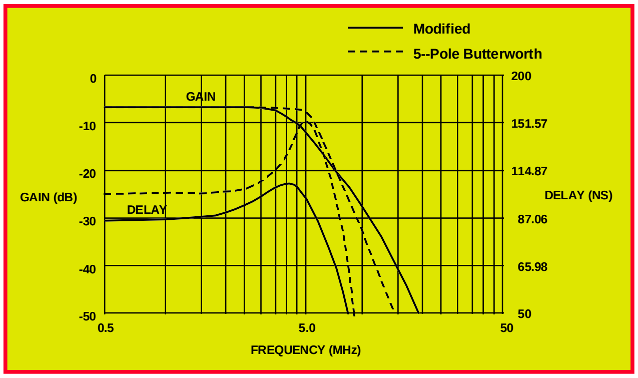
Practical filter design requires a compromise between gain flatness in the passband and stopband slope. To overcome these limitations, the sampling rate is often four or more times the highest frequency of interest. For example, in NTSC systems with a color subcarrier of 3.58 MHz, it's conventional to use a sampling rate of 14.318 Msamples/s.

The choice of filter to be used depends upon which characteristics must be maintained and those that can be somewhat compromised. Chebyshev and elliptic filters feature very steep stopband slopes, but also have a very nonlinear phase response. For video systems, this nonlinear phase response is catastrophic because phase and frequency, as well as amplitude, provide critical information.

The Butterworth filter has been widely used as the anti-aliasing filter in video systems because of its flat passband response and relative insensitivity to component tolerance. The Butterworth design, however, exhibits more group delay near cutoff than most video systems can accept.

A 5-pole filter with a Butterworth-like amplitude response and reduced phase lag near the 4-MHz cutoff is shown in **Figure 1**. If you modify the Butterworth filter so that capacitors C1 and C3 are about half of the "ideal" value, you can get a modified phase response that improves group delay and transient response. R1 and R2 are termination resistors for the filter. The sum of the driving source impedance and R1 should be 150Ω. The Butterworth capacitor values for C1 and C3 are shown in parentheses for comparison.

The plots of Figure 2 demonstrate the resulting gain and phase response of this 5-pole filter, compared with that of a 5-pole Butterworth filter. Note that the stopband slope of the modified filter is not as steep as that of the Butterworth filter, but the phase delay near cutoff is significantly reduced. Some of the stopband slope steepness in the amplitude response is sacrificed to achieve less group delay. The reduced steepness of this slope is not a problem since the sampling rate is four times the maximum frequency of interest, allowing enough attenuation of energy at half the clock rate to avoid aliasing problems. The reduced group delay reduces ringing in the step response of the system.



2. Comparing the modified filter response with that of a normal Butterworth filter shows significantly improved group delay response with little sacrifice in gain roll-off.

This circuit was developed for use in an ADC1175 signal conditioning circuit. The ADC1175 is an inexpensive, low-power 20-Msamples/s analog-to-digital converter with superior dynamic performance characteristics.

Video ADCs tend to have input current transients that can upset the driving amplifier, causing it to distort the driving signal as it attempts to counteract the transient load current. R5 and C4 isolate the amplifier's output from the current transients at the input to the ADC, maintaining signal fidelity. This RC also adds a small phase lag that improves the phase margin of the video driver.