BY JOSHUA ISRAELSOHN, CONTRIBUTING TECHNICAL EDITOR

The secret, nonspectral lives of analog-input filters

Analog-filter designs manage an uncommonly large number of core parameters compared with designs of other analog-circuit-block types. First, the application usually suggests the overall spectral shape or passband type—lowpass, highpass, bandpass, or band-reject.

Given a shape, the next consideration is usually that of the filter's corner frequency or frequencies. In peak and notch filters, the center frequency and a bandwidth often replace the corner-frequency specifications. Many applications traditionally express bandwidth in terms of Q—a reciprocal measure of bandwidth numerically related to the center frequency.

> **Your filter design must accommodate its client's input characteristics to minimize the parasitic interactions between the two.**

The parameters thus far describe ideal filters. Real implementations exhibit nonideal traits, some of which specific designs can influence. Examples include nonzero passband ripple and finite transition-band slope. Your application's requirements of these parameters inform the filter's complex-plane geometry, often selecting among, but not necessarily limited to, the classical shapes of Butterworth, Bessel, and Chebyshev. These choices optimize various time- or frequency-domain filter characteristics, including spectral flatness, phase coherence, and transition-band steepness near the corner frequency. Other parameters of concern to some applications include insertion loss and stopband ripple.

Once you've worked through all of these issues, you're on to implementation-circuit topology, component selection, and a brief, heartfelt declaration of victory. Well … that is, as long as your filter feeds a TILC (time-invariant linear circuit)—the kind of circuit to which all of your early circuit-analysis training applies. Alas, in the case of input filters, the next stage is nowadays often a multiplexer or a digitizer—usually an ADC—and these are *not* TILCs.

Many ADC ICs provide buffered inputs, which integrate an operational amplifier or a differential amplifier between the input pin or pins and the digitizer circuitry. Multiplexers and unbuffered ADCs, by contrast, bring your source signal directly to a switching input. When using these devices, your filter design must accommodate its client's input characteristics to minimize the parasitic interactions between the two.

These interactions share a common trait: They derive from charge quanta that input-circuit switching devices inject. This charge injection manifests itself as current impulses that reflect in the filter's output impedance and result in an error voltage.

This simplest input filter is a passive-RC arrangement. The charge—the time integral of the current impulse—adds to the charge on the filter's capacitor and creates an error voltage, $dV=dQ/C$, where dQ is the injected charge and C is the capacitance. Assuming a high-impedance input stage, such as a noninverting buffer amplifier following an input multiplexer, the error voltage can decay only by leaking the excess charge into the signal source through the filter's resistance. The charge quantum and the filter capacitance determine the peak-error voltage. The filter's time constant determines the error-voltage-recovery dynamic.

Active filters with RC-output stages, including many filters with odd numbers of poles, behave like passive-RC sections. Active filters with op-amp outputs exhibit a different behavior in which the amplifier's dynamic output impedance determines the peak-error voltage and the amplifier's loop characteristics determine the error-voltage-recovery dynamic.

Joshua Israelsohn is a co-founder of JAS Technical Media, where he manages the company's technical-communication services practice. You can find his contact information at www.jas-technicalmedia.com.

⊞ Go to www.edn.com/080724ji and click on Feedback Loop to post a comment on this column.

⊞ www.edn.com/analogdomain