BY BONNIE BAKER

Choosing antialiasing-filter amplifiers

When you digitize an analog signal, you use a lowpass filter to prevent aliasing errors from out-of-band noise. Doing so attenuates superimposed, high-frequency noise on the analog signal before it reaches the ADC. If the noise on the input signal is more than half the sampling frequency of the converter, the magnitude of that noise stays the same, but the frequency changes as it aliases back onto your signal of interest. You cannot use a digital filter to reduce in-band noise after digitizing the signal.

Selecting the correct operational amplifier for an active lowpass-filter circuit can appear overwhelming as you read an amplifier's data sheet and view all of the specifications.

Before selecting the amplifier, however, you need to determine the filter-cutoff frequency, f_{CUT} (or -3-dB frequency). You can use filter-design programs to determine the filter's capacitor and resistor values.

Next, you should initially consider only two important specifications when selecting an amplifier for your active lowpass filter: gain-bandwidth product and slew rate. In **Figure 1**, for Q_i of less than 1, the gain-bandwidth product of the amplifier, f_{AMP}, must be at least $100\times$ gain$\times f_{CUT}\times k_i$, where Q_i is the quality factor of the ith partial filter and k_i is the ratio of the partial-filter-corner frequency to the overall-filter-corner frequency. For Q_i greater than 1, $f_{AMP}=100\times$gain$\times(f_{CUT}/a_i)\times\sqrt{[(Q_i^2-0.5)/(Q_i^2-0.25)]}$, where a_i is the ith coefficient in the partial-filter-transfer function. The gain-bandwidth product of the operational amplifiers appears in the specification table of the respective product-data sheet.

You should also evaluate the effects of amplifier slew rate. Doing so ensures that your filter does not create signal distortions due to slew limitations. The slew rate depends on internal IC currents and capacitances. When you send large signals through the amplifier, internal currents charge these internal capacitors. The speed of this charging process depends on the amplifier's internal resistances, capacitances, and currents. To ensure that your active filter does not enter into a slew condition, you need to select an amplifier such that the slew rate$\geq(\pi V_{OUT\,P\text{-}P}f_{CUT})$, where $V_{OUT\,P\text{-}P}$ is the expected peak-to-peak output-voltage swing below your filter's cutoff frequency.

The most common topologies for active, second-order, lowpass filters are the noninverting Sallen-Key and the inverting multiple feedback (**Reference 1**). If you need a higher order filter, you can cascade both of these topologies (**Reference 2**).

When using the Sallen-Key circuit, input-common-mode-voltage range (V_{CMR}) and input bias current (I_B) can also affect you. In this configuration, V_{CMR} limits the range of your input signal. Additionally, the input bias current conducts through the external source resistance. The voltage drop that the input-bias-current error causes appears as an additional input-offset voltage. Also, be aware that this circuit has high-frequency feedthrough.**EDN**

REFERENCES

[1] Bishop, J, B Trump, and RM Stitt, "FilterPro MFB and Sallen-Key Low-Pass Filter Design Program," Texas Instruments application note SBFA-001A, November 2001, www.ti.com.

[2] Mancini, Ron, *Op Amps for Everyone*, ISBN-0-7506-7701-5, Elsevier-Newnes, April 2003.

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A FEW BUTTERWORTH-DESIGN CONSTANTS

FILTER ORDER	i	a_i	$k_i=f_{CUT-i}/f_{CUT}$	Q_i
4	1	1.8478	0.719	0.54
	2	0.7654	1.390	1.31
5	1	1	1	NA
	2	1.6180	0.859	0.62
	3	0.6180	1.448	1.62

Figure 1 You build a multi-order analog filter by cascading first- and second-order filters.