 By Bonnie Baker, Microchip Technology Inc

Three alternatives to your aliasing problems

So, you need a lowpass filter in your data-acquisition circuit. And you know it's not a good idea to implement this function after the ADC as a digital filter in your controller or processor. The best place for this filter is before your ADC, which makes it an analog option.

You can build analog filters using one of three basic approaches. The first and most fundamental approach is to design a passive filter using resistors and capacitors (**Figure 1a**). A second alternative is to design an active lowpass filter by using an operational amplifier, a few resistors, and a few capacitors (**Figure 1b**). A third and maybe more attractive option for digital designers is to use a switched-capacitor filter (**Figure 1c**).

The passive RC filter is inexpensive, and you can effectively use it with delta-sigma converters. A single-pole, lowpass filter is adequate for this type of converter because the device's sampling frequency is significantly higher than the data-throughput rate. The output impedance of a passive lowpass filter is relatively high compared with the active-filter or switched-capacitor realizations. For instance, a 1-kHz lowpass filter that uses a 0.1-μF capacitor in the design would require a 1.59-kΩ resistor to complete the implementation. This resistor's value could create an undesirable voltage drop or make impedance matching difficult. SAR (successive-approximation-register), pipeline, and flash converters require a higher order filter, leaving the approaches that **figures 1b** and **1c** illustrate.

The active lowpass filter looks complicated, but it is relatively easy to design if you use filter-design-tool software from operational-amplifier vendors. You can design a higher order filter if you cascade this circuit with itself. For example, you build a fourth-order filter using two cascaded circuits. The output impedance of this type of filter is very low. This low impedance essentially minimizes ADC input-impedance errors (**Reference 1**). The configuration in **Figure 1b** implements a gain of 1V/V. You can use other configurations to implement a negative gain (**Reference 2**). This filter's corner-frequency accuracy depends on the accuracy of the discrete resistors (R_2 and R_3) and capacitors (C_2 and C_3) and not on the amplifier. When you properly design it, this filter eliminates SAR-, pipeline-, and flash-converter-aliasing errors.

You can use the switched-capacitor filter as a third alternative when solving your filter challenges. The filter's corner frequency is a derivative of the input frequency (CLK_{IN}). For instance, a typical specification for this characteristic is $f_{CORNER}=f_{CLKIN}/100$. The lowpass filter's corner frequency is almost as accurate as your clock. Depending on the vendor, the device can contribute a ±0.3% error.

The switched-capacitor lowpass filter (IC_2) is an analog sampling system. Consequently, it requires external capacitors and resistors (lowpass filters) at the device's input and output. The input lowpass filter (R_4 and C_4) minimizes alias errors. The output lowpass filter (R_5 and C_5) smoothes the sampled analog-output signal. The accuracy of these external components does not affect the precision of the switched-capacitor filter. This filter is also less sensitive to temperature changes and aging.

Lowpass analog filters come in many flavors, from the passive RC filter, to the classical active filter and the switched-capacitor filter. The RC filter is less expensive than the alternatives, but it brings unwanted impedance-matching errors into the system. The active filter is easy to design because of software tools from vendors but depends on the accuracy of the external passive resistors and capacitors. And finally, the switched-capacitor lowpass filter easily connects to your microcontroller or processor, but it requires passive RC filters on the input and output.□

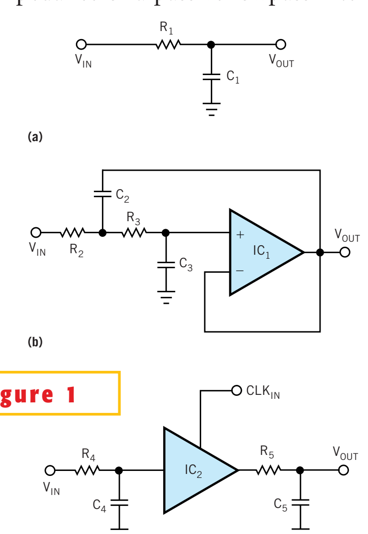

Figure 1

To build an analog filter, you can use an RC lowpass filter (a), an active lowpass filter (b), or a switched-capacitor lowpass filter (c).

References

1. Baker, Bonnie, "Solve high-source-impedance errors in firmware," *EDN*, Dec 26, 2002, pg 20.
2. Baker, Bonnie, "Anti-Aliasing, Analog Filters for Data Acquisition Systems," AN699, Microchip Technology.
3. Yager, Charles, and Carlos Laber, "Switched-Capacitor Filters Beat Active filters at their Own Game," TechOnLine, www.techonline.com/community/home/7534.

Bonnie Baker is the analog/mixed-signal-applications engineering manager for Microchip Technology's microperipherals division. You can reach her at Bonnie.Baker@microchip.com.