Frequency dithering enhances high-performance ADCs

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Since the late 1970s, designers have successfully improved the effective resolution and spurious performance of A/D converters by adding dither—uncorrelated noise—to a converter's input and then using DSP techniques to average out noise from the converted data. The most common dithering method adds random-amplitude noise to an A/D converter's input signal. Although this method works, the added noise includes large random peak values. To keep the A/D converter's input out of the saturation region, a designer must know both the peak signal and the peak dither levels. Even briefly saturating the A/D converter adds more nonlinearities than dither can remove.

Another approach adds a dithered-frequency, constant-amplitude signal. **Figure 1** shows one possible implementation featuring a Linear LTC1799 programmable oscillator, IC_2, that's operated in a VCO (voltage-controlled-oscillator) mode in which an applied voltage modulates the center frequency. You can set the LTC1799's center frequency at 1 kHz to 33 MHz, making it a suitable dither generator for many currently available A/D converters. Because the LTC1799's output comprises a square wave, its peak output amplitude is well-defined.

You can set the random-dither center frequency either below or above the signal frequency of interest. For conversion of a narrowband intermediate frequency, either location may work well. For an A/D converter that must operate to dc, the only useful location is above the signal frequency of interest. One approach places the dither frequency at one-half of the sampling or the Nyquist frequency. When you place it there, the random noise typically doesn't interfere with the desired signal, and any aliasing that occurs only folds the random frequency noise around itself and not into the desired signal band.

The circuit in **Figure 1** operates with a 20-MHz sampling A/D converter and generates random noise around a center frequency of 10 MHz. You can use any of a number of techniques to generate the random noise, including dig-

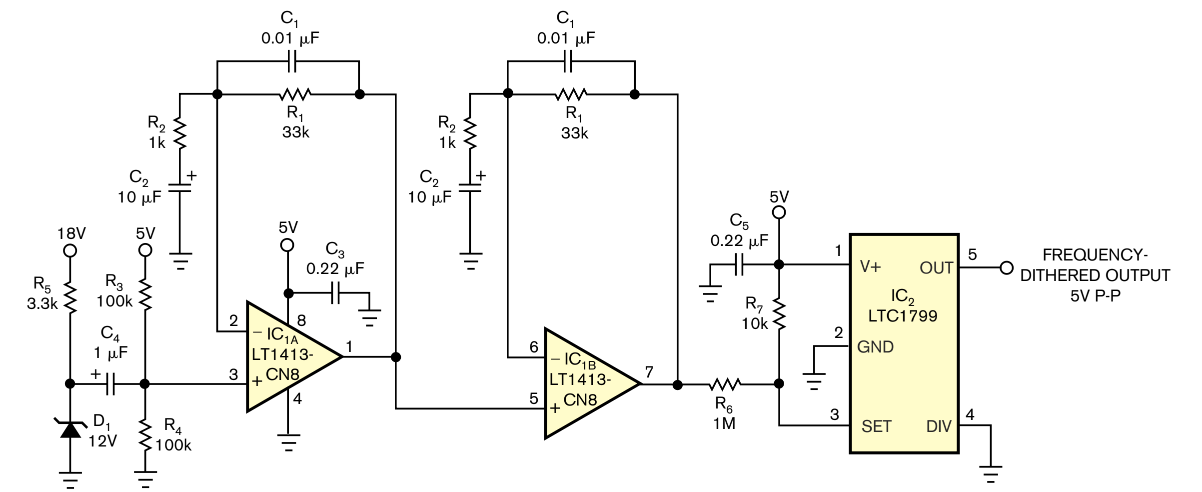

Figure 1 A zener diode, two stages of amplification, and an FM voltage-controlled oscillator form a constant-amplitude dither generator.

ital shift registers and semiconductor junctions biased into the breakdown range. In this design, a 12V zener diode, D_1, generates the noise, which a two-stage amplifier amplifies and frequency-shapes. If necessary, you can further shape the noise distribution by using more complex active-filter sections, IC_{1A} and IC_{1B}. After filtering, the noise modulates the LTC1799. Make sure that the LTC1799's power-supply voltage is pure dc and free of ripple, because power-supply noise produces nonrandom AM sidebands.

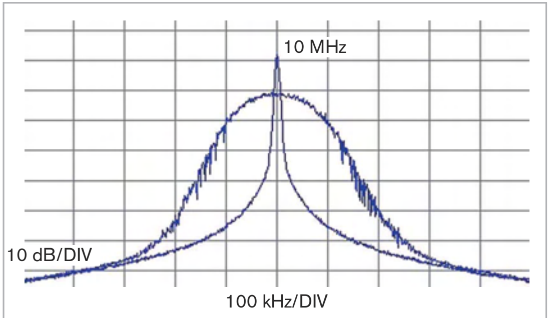

Figure 2 The broad bell-shaped curve shows a random-frequency-dithered spectrum superimposed onto the LTC1799's unmodulated, 10-MHz output.

Figure 2 shows an amplitude-versus-frequency plot of the frequency-limited spectrum that the design in **Figure 1** produces. Depending on the circuit's configuration, you can apply the dither to the A/D converter using a small coupling capacitor or a more complex active summing circuit. Although zener-diode noise generators offer theoretical simplicity, they behave poorly in production environments because their noise outputs can vary greatly. Even among diodes from the same manufacturing batch, you can observe popcorn noise, unevenly distributed noise histograms, amplitude shifts, and frequency-weighted noise. In a high-volume application, well-specified noise diodes, such as those from Micronetics (www.micronetics.com), may prove more cost-effective than zener diodes.

Once you select a noise diode, you can select amplification-stage gains such that clipping of noise peaks isn't evident at the circuit's output. If your application requires it, you can alter the amplifiers' frequency responses to alter the noise spectrum. Finally, adjust the LTC1799's frequency-setting resistors, R_6 and R_7, so that the noise-spectrum display resembles that in **Figure 2**. Any clipping along the amplifier path tends to add peaks to the edges of the spectrum, which indicates amplitude clipping and reduction of the noise's random characteristics.

You can add a filter between the noise output and the A/D converter's summing input to limit inband noise or remove any periodic modulation that power-supply ripple introduces. In a modern, high-performance A/D converter, even a small amount of periodic noise can manifest itself as a −80-dBc (decibels-below-carrier) spurious response. **EDN**