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Oversampled Pipeline A/D Converters with Mismatch Shaping

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In recent years, delta-sigma modulators and pipeline converters have been considered as possible realizations of analog-to-digital converters for wide-band signals. In comparing these converters, we recognize a few important attributes. Due to the wide bandwidth of the input signal and limited circuit speed, delta-sigma converters afford only low oversampling ratios, which makes high-resolution conversion extremely difficult. The low oversampling ratio generally nullifies the primary advantage of delta-sigma converters; the tolerance to component mismatches. In this regard, remaining potential advantages of delta-sigma converters over pipeline converters now only include ease of anti-alias filtering and low quantization noise. It must be noted that the ease of anti-aliasing is not inherent to delta-sigma modulation. Rather, it is associated with oversampling. Therefore, pipeline converters can experience the same benefit of easy anti-aliasing by simply operating the converter at higher sampling rate than the Nyquist rate, i.e., oversampling. As for quantization noise in pipeline converters, the quantization noise can be made smaller by adding more stages at the end of the pipeline. Since the last stages of the pipeline do not contribute much thermal noise, they can be made extremely small and low power. Therefore, the quantization noise itself can be made arbitrarily small with negligible increase of area and power. Certainly, doing so will not improve the accuracy or thermal noise. However, it is no different in delta-sigma converters with low oversampling ratio.

Based on the above observation, we can conclude that delta-sigma converters do not possess any fundamental advantage over pipeline converters for wide-band applications that necessitate low oversampling ratios. At this low oversampling ratio many delta-sigma converters are incapable of providing good enough performance. While there are a few examples of delta sigma converters with a low oversampling ratio, we believe that a more efficient approach would be to oversample a standard pipeline converter, and shape the distortion due to mismatch out of the signal band, where it will be removed by a subsequent digital filter. Since no attempt is made to shape the quantization noise, there are none of the concerns associated with delta-sigma converters with a low oversampling ratio.

A test chip was fabricated in a 0.35µm CMOS process to demonstrate a number of mismatch shaping concepts. A 77dB SFDR and 67dB SNDR is achieved at an oversampling ratio of 4 and a sampling rate of 60Msample/s. Mismatch shaping improves the converter SFDR by 12dB's and SFDR by 5dB's.