8.1 Introduction

In this chapter noise-shaping techniques to improve the dynamic range of a system will be described. Noise-shaping can be very useful when speed can be exchanged with accuracy. The quantization errors in a noise-shaping system are removed from the signal band of interest. Mostly the suppressed quantization errors appear enlarged as out-of-band noise in the system. With a simple filter these errors are removed. An increased dynamic range of the coder is obtained. In digital systems word length can intelligently be reduced using a noise-shaping operation without losing dynamic range significantly. An ultimate in bit reduction is obtained when the noise-shaping operation reduces the number of bits to 1. Examples of such an operation is sigma-delta analog-to-digital conversion or noise-shaping digital-to-analog conversion based on single-bit word-lengths. The advantage of a 1-bit converter is the extreme linearity of such a device. A very good differential linearity is obtained with these converters. The most important design criteria for these converters will be given. At the moment the dynamic range of a system must be enlarged, but the maximum clock rate of the system cannot be increased because of technology limitations, then a multi-bit digital-to-analog converter can be used in the feedback loop. At that moment, however, the linearity of the digital-to-analog converter determines the linearity and the distortion in the system. To overcome this problem Dynamic Element Matching or Continuous Current Calibration techniques can be used to obtain the extreme linearity of the D/A converter without
needing extra trimming steps. In the stability analysis of the noise-shaping coders the root-locus method can be successfully applied. A model for the quantizer will be introduced using a gain AND a phase uncertainty. This model shows good prediction of idle patterns and predicts the limits of stability of a higher order coder very well comparable to practical simulations. Examples for first-, second-, and third-order coders will be treated. A coder is said to be stable when idling occurs at the highest possible frequency. In this case a maximum of oversampling ratio is obtained resulting in a maximum dynamic range. Mostly an idle pattern having a frequency around half the sampling frequency gives the best result. However, instability of a coder results in limit cycles that can not be influenced by the input signal and remain disturbing the coder even when the input signal is removed. This is the main cause of instability in an oversampling converter. Idle patterns at other frequencies depending on the input signal randomly generated are also allowed. In this case the quantization errors are randomized and appear as noise. Examples of designed 16- to 24-bits digital-to-analog converters will be shown [100, 93, 94]. Furthermore a combination of the analog output filter with the digital-to-analog converter will be described. This results in a completely integrated oversampling digital-to-analog converter system needing no external analog filtering or no accuracy with respect to analog on chip filtering. Furthermore non-filtered multi-bit converters using a randomized Dynamic Element Matching algorithm will be shown.

8.2 Digital oversampling filtering

In this section an example of oversampling and noise-shaping to increase the dynamic range of a digital-to-analog converter including a combined digital and analog output filtering will be described. With oversampling the dynamic range is increased as has been shown in one of the beginning chapters. However, the linearity of the converter must be in accordance with the extended resolution obtained by oversampling. Noise-shaping is a technique for increasing the resolution of a converter by using quantization error feedback. The basic idea behind noise shaping is to exchange resolution in time for resolution in amplitude. Many times more speed is available than is required by the signal bandwidth. At that moment oversampling is used, while a combination with error feedback in a noise-shaper increases the resolution of the overall converter. The concept of oversampling and noise-shaping will be explained using a practical example of an audio digital-to-analog converter.