Preface

Analog Delta Sigma Modulators (ADSM) have been extensively analyzed and used in the context of analog-to-digital conversion; however, less attention has been paid to Digital Delta Sigma Modulators (DDSM) which are commonly used in digital-to-analog conversion and fractional-N frequency synthesis. Motivated by this fact, combined with their widespread use in wireless transceivers, we aim to demystify an important aspect of some popular DDSM structures, namely the existence of spurious tones due to the inherent periodicity of signals in DDSMs with constant inputs. The architectures under investigation include Multi-stAge noise SHaping (MASH), Single Quantizer (SQ) and Error Feedback (EF) DDSMs.

A DDSM is a finite state machine (FSM); it is implemented using finite precision arithmetic units and the number of available states is finite. A deterministic FSM has a deterministic rule for transitioning from each state to the next. If the input is constant, the most complex behavior the DDSM can exhibit is a trajectory that visits each state once before repeating; in fact, the output must always be constant or periodic. Therefore, the DDSM always produces a periodic output signal (a cycle) when the input is constant. Furthermore, the quantization error signal (commonly called the quantization noise) is also periodic in this case.

When the length of the cycle is short, the average power of the quantization noise in the DDSM is spread over a small number of discrete tones. According to Parseval's relation, the shorter the cycle length is, the fewer tones there are, and consequently the higher the power per tone. Undesirable tones of this type in DDSMs are called spurious tones or spurs. If the cycle length is sufficiently large and the quantization noise samples between cycles are sufficiently randomized, the shaped output quantization noise spectrum becomes indistinguishable in practice from a continuous spectrum.

There are two classes of techniques for maximizing cycle lengths in DDSMs: "stochastic" and deterministic. The "stochastic" approach to maximizing cycle lengths is to use a pseudo-random dither sequence to disrupt periodic cycles. Dithering breaks up the cycles and increases the effective cycle length, resulting in smooth noise-shaped spectra. While the "stochastic" solution increases the cycle length, as required, it inherently adds noise to the spectrum; care must be taken to minimize the effects of this additional noise. By contrast, the objective of deterministic approaches is to guarantee maximum cycle lengths by design, without the need for an external dithering signal. In this book, we focus primarily on deterministic techniques.

In Chapter 1, we explain briefly the concept of noise shaping in delta-sigma (DS) modulators. Then, we explain the problem which we address. The main contributions of the book are summarized at the end of this chapter.

In Chapter 2, we describe delta-sigma modulation (DSM) and provide an overview of two applications for DDSMs, namely digital-to-analog converters and fractional-N frequency synthesizers.

In Chapter 3, we review popular dithering techniques. Then, considering deterministic techniques, we provide an overview of some deterministic techniques for maximizing cycle lengths and we provide mathematical proofs concerning these.

In Chapters 4 and 5, we describe a deterministic technique for maximizing cycle lengths in MASH, SQ and EFM DDSMs.

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