An Introduction to Digital Delta Sigma Modulators and MASH Equations

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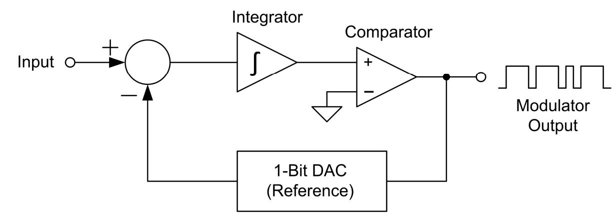
Abstract

The first step in understanding what DDSMs are is understanding what DSMs are in general. A delta-sigma modulator is an electronic circuit used to convert analog signals into digital data. It works by taking small samples and comparing them to the previous samples to determine the difference. The modulator then transforms this rate of change into a series of digital bits. By integrating the differences between these consecutive samples over time and feeding this information back into the system, the modulator can reduce quantization errors and noise. This results in high-resolution digital output. This process has many useful applications such as analog-to-digital conversion, audio processing, telecommunications, and more.

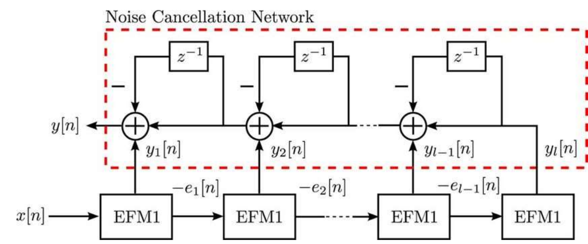
There are two types of delta-sigma modulators: analog and digital. Both oversample analog signals to achieve high-resolution digital conversion through feedback. However, they differ in signal processing. Analog delta-sigma modulators operate solely in the analog domain, while digital ones convert signals into digital early in the process. Digital delta-sigma modulators output digital bits representing the processed signal. We focus on digital delta-sigma modulators (DDSMs) widely used in digital-to-analog conversions and fractional N-frequency synthesis. DDSMs exhibit spurious tones due to signal periodicity with constant inputs. These unwanted tones, caused by system imperfections, degrade performance and reliability. Minimizing them involves deterministic methods, maximizing cycle lengths without external noise signals (dithers), eliminating the need for intentional noise addition.

MASH equations, short for Multi-Stage Noise Shaping equations, are vital mathematical tools for designing digital delta-sigma modulators with multiple stages. They characterize noise transfer and behavior across different levels. Once grasping the concepts of DSMs and DDSMs, students can seamlessly delve into how MASH equations predict outputs across different feedback loop orders.

Relevant Figures



Block diagram of 1-bit delta-sigma modulator



Block diagram of a MASH DDSM comprising first order error feedback modulators

Conclusion

Navigating through the inner workings of delta-sigma modulators has proven to be a challenging endeavor given my limited prior knowledge in the field. However, this exploration has undoubtedly expanded my understanding in this complex domain, and I feel that I have learned a lot.

References and Acknowledgements

Kaveh Hosseini and Michael Peter Kennedy (2011). DDSM and Applications, Conventional Techniques for Maximizing Cycle Lengths, *Minimizing Spurious Tones in Digital Delta-Sigma Modulators* (pp. 7-90).

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