Fixed-Point Signal Processing

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Wayne T. Padgett and David V. Anderson
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Fixed-Point Signal Processing

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SYNTHESIS LECTURES ON SIGNAL PROCESSING #9

ABSTRACT

This book is intended to fill the gap between the “ideal precision” digital signal processing (DSP) that is widely taught, and the limited precision implementation skills that are commonly required in fixed–point processors and field programmable gate arrays (FPGAs). These skills are often neglected at the university level, particularly for undergraduates. We have attempted to create a resource both for a DSP elective course, and for the practicing engineer with a need to understand fixed–point implementation. Although we assume a background in DSP, Chapter 2 contains a review of basic theory, and Chapter 3 reviews random processes to support the noise model of quantization error. Chapter 4 details the binary arithmetic that underlies fixed–point processors, and then introduces fractional format for binary numbers. Chapter 5 covers the noise model for quantization error and the effects of coefficient quantization in filters. Because of the numerical sensitivity of IIR filters, they are used extensively as an example system in both Chapters 5 and 6. Fortunately, the principles of dealing with limited precision can be applied to a wide variety of numerically sensitive systems, not just IIR filters. Chapter 6 discusses the problems of product roundoff error, and various methods of scaling to avoid overflow. Chapter 7 discusses limit cycle effects and a few common methods for minimizing them.

There are a number of simple exercises integrated into the text to allow you to test your understanding. Answers to the exercises are included in the footnotes. A number of Matlab examples are provided in the text. They generally assume access to the Fixed–Point Toolbox. If you lack access to this software, consider either purchasing or requesting an evaluation license from The Mathworks. The code listed in the text and other helpful Matlab code is also available at `http://www.morganclaypool.com/page/padgett` and `http://www.rose-hulman.edu/~padgett/fpsp`. You will also find Matlab exercises designed to demonstrate each of the four types of error discussed in Chapters 5 and 6. Simulink examples are also provided on the web site.

KEYWORDS

binary arithmetic, clipping, coefficient quantization, digital signal processing (DSP), field programmable gate array (FPGA), fixed–point, IIR filter, limit cycles, Matlab, numerical sensitivity, overflow, $Q15$, quantization error, quantization noise, roundoff noise, saturation, scaling, second order sections (SOS), signal to noise ratio (SNR), Simulink, uniform noise, wrapping

Contents

Notes

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PERMISSIONS

Figure 5.8 is adapted from [26]. Permission is pending.
Figures 5.14 through 5.19 are adapted from [23]. Permission is pending.

PRELIMINARY

This is a preliminary version of this book.

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