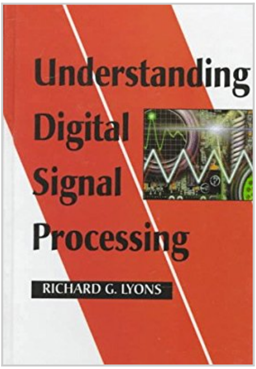

Understanding Digital Signal Processing

By Richard G. Lyons

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Editorial Review

From the Inside Flap
Learning Digital Signal Processing

Learning the fundamentals, and how to speak the language, of digital signal processing does not require profound analytical skills or an extensive background in mathematics. All you need is a little experience with elementary algebra, knowledge of what a sinewave is, this book, and enthusiasm. This may sound hard to believe, particularly if you've just flipped through the pages of this book and seen figures and equations that appear rather complicated. The content here, you say, looks suspiciously like the material in technical journals and textbooks, material that is difficult to understand. Well, this is not just another book on digital signal processing.

This book's goal is to gently provide explanation followed by illustration, not so that you may understand the material, but that you must understand the material "Here we have the opportunity of expounding more clearly what has already been said" (Rene Descartes).

Remember the first time you saw two people playing chess? The game probably appeared to be mysterious and confusing. As you now know, no individual chess move is complicated. Given a little patience, the various chess moves are easy to learn. The game's complexity comes from deciding what combinations of moves to make and when to make them. So it is with understanding digital signal processing. First we learn the fundamental rules and processes and, then, practice using them in combination.

If learning digital signal processing is so easy, then why does the subject have the reputation of being difficult to understand? The answer lies partially in how the material is typically presented in the literature. It's difficult to convey technical information, with its mathematical subtleties, in written form. It's one thing to write equations, but it's another matter altogether to explain what those equations really mean from a practical standpoint, and that's the goal of this book.

Too often, written explanation of digital signal processing theory appears in one of two forms: either mathematical miracles occur and you are simply given a short and sweet equation without further explanation, or you are engulfed in a flood of complex variable equations and phrases such as "it is obvious that," "such that W(f) is greater than or equal to 0 å f," and "with judicious application of the homogeneity property." Authors usually do provide the needed information, but, too often, the reader must grab a pick and shovel, put on a miner's helmet, and try to dig the information out of a mountain of mathematical expressions. (This book presents the results of several fruitful mining expeditions.) How many times have you followed the derivation of an equation, after which the author states that he or she is going to illustrate that equation with a physical example-and this turns out to be another equation? Although mathematics is necessary to describe digital signal processing, I've tried to avoid overwhelming the reader because a recipe for technical writing that's too rich in equations is hard for the beginner to digest.

The intent of this book is expressed in a popular quote from E. B. White in the introduction of his Elements of Style (New York: Macmillan Publishing, 1959):

Will (Strunk) felt that the reader was in serious trouble most of the time, a man floundering in a swamp, and that it was the duty of anyone attempting to write English to drain the swamp quickly and get his man up on dry ground, or at least throw him a rope.

I've attempted to avoid the traditional instructor-student relationship, but, rather, to make reading this book like talking to a friend while walking in the park. I've used just enough mathematics to develop a fundamental understanding of the theory, and, then, illustrate that theory with examples.

The Journey

Learning digital signal processing is not something you accomplish; it's a journey you take. When you gain an understanding of some topic, questions arise that cause you to investigate some other facet of digital signal processing. Armed with more knowledge, you're likely to begin exploring further aspects of digital signal processing much like those shown in the following diagram. This book is your tour guide during the first steps of your journey.

You don't need a computer to learn the material in this book, but it would help. Digital signal processing software allows the beginner to verify signal processing theory through trial and error. "One must learn by doing the thing; for though you think you know it, you have no certainty until you try it" (Sophocles). In particular, software routines that plot signal data, perform the fast Fourier transform, and analyze digital filters would be very useful.

As you go through the material in this book, don't be discouraged if your understanding comes slowly. As the Greek mathematician Menaechmus curtly remarked to Alexander the Great, when asked for a quick explanation of mathematics, "There is no royal road to mathematics." Menaechmus was confident in telling Alexander that the only way to learn mathematics is through careful study. The same applies to digital signal processing. Also, don't worry if you have to read some of the material twice. While the concepts in this book are not as complicated as quantum physics, as mysterious as the lyrics of the song "Louie Louie," or as puzzling as the assembly instructions of a metal shed, they do get a little involved. They deserve your attention and thought. So go slow and read the material twice if you have to; you'll be glad you did. If you show persistence, to quote a phrase from Susan B. Anthony, "Failure is impossible."

Coming Attractions

Chapter 1 of this book begins by establishing the notation used throughout the remainder of our study. In that chapter, we introduce the concept of discrete signal sequences, show how they relate to continuous signals, and illustrate how those sequences can be depicted in both the time and frequency domains. In addition, Chapter 1 defines the operational symbols we'll use to build our signal processing system block diagrams. We conclude that chapter with a brief introduction to the idea of linear systems and see why linearity enables us to use a number of powerful mathematical tools in our analysis.

Chapter 2 introduces the most frequently misunderstood process in digital signal processing, periodic sampling. Although it's straightforward to grasp the concept of sampling a continuous signal, there are mathematical subtleties in the process that require thoughtful attention. Beginning gradually with simple examples of low-pass sampling and progressing to the interesting subject of bandpass sampling, Chapter 2 explains and quantifies the frequency-domain ambiguity (aliasing) associated with these important topics. The discussion there highlights the power and pitfalls of periodic sampling.

Chapter 3 is devoted to one of the foremost topics in digital signal processing, the discrete Fourier transform (DFT). Coverage begins with detailed examples illustrating the important properties of the DFT and how to interpret DFT spectral results, progresses to the topic of windows used to reduce DFT leakage, and discusses the processing gain afforded by the DFT. The chapter concludes with a detailed discussion of the various forms of the transform of rectangular functions that the beginner is likely to encounter in the literature. That last topic is included there to clarify and illustrate the DFT of both real and complex sinusoids.Chapter 4 covers the innovation that made the most profound impact on the field of digital signal processing, the fast

Fourier transform (FFT). There we show the relationship of the popular radix-2 FFT to the DFT, quantify the powerful processing advantages gained by using the FFT, demonstrate why the FFT functions as it does, and present various FFT implementation structures. Chapter 4 also includes a list of recommendations to help us when we use the FFT in practice.

Chapter 5 ushers in the subject of digital filtering. Beginning with a simple low-pass finite impulse response (FIR) filter example, we carefully progress through the analysis of that filter's frequency-domain magnitude and phase response. Next we learn how window functions affect and can be used to design FIR filters. The methods for converting low-pass FIR filter designs to bandpass and highpass digital filters are presented, and the popular Remez Exchange (Parks McClellan) FIR filter design technique is introduced and illustrated by example. In that chapter we acquaint the reader with, and take the mystery out of, the process called convolution. Proceeding through several simple convolution examples, we conclude Chapter 5 with a discussion of the powerful convolution theorem and show why it's so useful as a qualitative tool in understanding digital signal processing.

Chapter 6 introduces a second class of digital filters, infinite impulse response (IIR) filters. In discussing several methods for the design of IIR filters, the reader is introduced to the powerful digital signal processing analysis tool called the z-transform.

From the Back Cover

The author covers the essential mathematics by explaining the meaning and significance of the key DSP equations. Comprehensive in scope, and gentle in approach, the book will help you achieve a thorough grasp of the basics and move gradually to more sophisticated DSP concepts and applications.

The book begins with a complete explanation of the often misunderstood topic of periodic sampling. The introduction to the important discrete Fourier transform, and its fast Fourier transform (FFT) implementation, is the most lucid and illuminating explanation available anywhere. You will also find extensive information on both finite impulse response (FIR) and infinite impulse response (IIR) digital filters, as well as coverage of the benefits of signal averaging. In addition, the book demystifies the abstruse topics of the Convolution theorem and complex signals. The practical uses of various binary number formats are also carefully described and compared. Finally, a collection of tricks-of-the-trade used by professionals to make DSP algorithms more efficient will help you apply DSP concepts successfully.

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About the Author
Richard G. Lyons is a Systems Engineer with the Systems Integration Group at TRW, Inc. He has been involved with the design and testing of digital signal processing systems for the past fifteen years. He is the author of numerous articles on the topic and is a member of the IEEE and Eta Kappa Nu, the electrical engineering honor society.

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Users Review

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Jerry Brock:

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