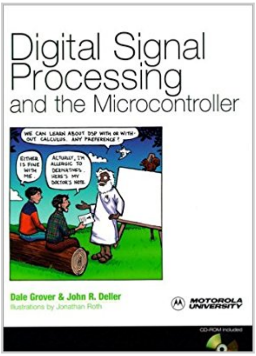
Digital Signal Processing and the Microcontroller

By Dale Grover, John Deller



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Digital signal processing (DSP) is often treated as a complicated, theoretical subject. This book takes a friendly, informal approach, stressing the practical information needed to not just understand, but use DSP on real hardware, including microcontrollers. It is aimed at readers who might not have an background in signal processing, and it does not assume mathematics beyond algebra and trigonometry. Topics include digital filters, the Fast Fourier Transform (FFT), and generating special signals and functions. Familiarity with programming microprocessors is assumed. The Motorola MC68HC16 is used as an example of a microcontroller with DSP-specific features, and complete assembly language programs show how DSP is implemented on a real processor. Numerous cartoon illustrations by Jonathan Roth.

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Editorial Review

From the Back Cover

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The friendly, intuitive approach to microcontroller-based DSP!

If you actually want to process signals — not just theorize about digital signal processing — this is the book for you. It's a friendly, informal guide to understanding — and implementing — digital signal processing with microcontrollers. You'll find enough theory to keep you on track (and a brief refresher on the basic math you'll need — with no calculus!) But the focus is on real-world applications, especially specifying, designing, and implementing digital filters, and using fast Fourier transform.

Coverage includes:

- The big picture: What DSP can and cannot do.
- Analog systems, signals and filters.
- Discrete-time signals and systems.
- FIR and IIR filters.
- Microcontroller filter implementation.
- Frequency analysis, correlation, sampling and signal synthesis.

Digital Signal Processing and the Microcontroller includes extensive examples and assembler code based on Motorola's powerful 16-bit M68HC16 microcontroller — and expert DSP insights you can use with any processor. Whether you have a formal electrical engineering background or not, it's all you need to get results with DSP fast.

The accompanying website contains extensive source code for the MC68HC16 microcontroller, including assembler code for DSP filters and other applications; a complete set of MC68HC16 documentation in PDF format; MATLAB m-files for selected examples, and more.

About the Author

DALE GROVER designs and programs embedded systems at Red Cedar Electronics, and has been involved since 1982 in research and development of devices to aid individuals with communication disabilities. His articles have appeared in Midnight Engineering and Communication Outlook.

JOHN R. (JACK) DELLER, JR., PhD., is Professor of Electrical Engineering at Michigan State University, where he coordinates Communications and Signal Processing Research Laboratories and the related curriculum. He is a Fellow of the IEEE and the lead author of the text Discrete-Time Processing of Speech Signals (Prentice Hall).

Preface

This book was written in the belief that VLSI design is system design. Designing fast inverters is fun, but designing a high-performance, cost- effective integrated circuit demands knowledge of all aspects of digital design, from application algorithms to fabrication and packaging. Carver Mead and Lynn Conway dubbed this approach the tall-thin designer approach. TodayÕs hot designer is a little fatter than his or her 1979 ancestor, since we now know a lot more about VLSI design than we did when Mead and Conway first spoke. But the same principle applies: you must be well-versed in both high-level and low-level design skills to make the most of your design opportunities.

Since VLSI has moved from an exotic, expensive curiosity to an everyday necessity, universities have refocused their VLSI design classes away from circuit design and toward advanced logic and system design. Studying VLSI design as a system design discipline requires such a class to consider a somewhat different set of areas than does the study of circuit design.

Topics such as ALU and multiplexer design or advanced clocking strategies used to be discussed using TTL and board-level components, with only occasional nods toward VLSI implementations of very large components. However, the push toward higher levels of integration means that most advanced logic design projects will be designed for integrated circuit implementation.

I have tried to include in this book the range of topics required to grow and train today's tall, moderately-chubby IC designer. Traditional logic design topics, such as adders and state machines, are balanced on the one hand by discussions of circuits and layout techniques and on the other hand by the architectural choices implied by scheduling and allocation.

Very large ICs are sufficiently complex that we can't tackle them using circuit design techniques alone; the top-notch designer must understand enough about architecture and logic design to know which parts of the circuit and layout require close attention. The integration of system-level design techniques, such as scheduling, with the more traditional logic design topics is essential for a full understanding of VLSI-size systems.

In an effort to systematically cover all the problems encountered while designing digital systems in VLSI, I have organized the material in this book relatively bottom-up, from fabrication to architecture. Though I am a strong fan of top-down design, the technological limitations which drive architecture are best learned starting with fabrication and layout. You can't expect to fully appreciate all the nuances of why a particular design step is formulated in a certain way until you have complete d a chip design yourself, but referring to the steps as you proceed on your own chip design should help guide you. As a result of the bottom-up organization, some topics may be broken up in unexpected ways. For example, placement and routing are not treated as a single subject, but separately at each level of abstraction: transistor, cell, and floor plan. In many instances I purposely tried to juxtapose topics in unexpected ways to encourage new ways of thinking about their interrelationships. This book is designed to emphasize several topics that are essential to the practice of VLSI design as a system design discipline:

- A systematic design methodology reaching from circuits to architecture. Modern logic design includes more than the traditional topics of adder design and two-level minimization — register-transfer design, scheduling, and allocation are all essential tools for the design of complex digital systems. Circuit and layout design tell us which logic and architectural designs make the most sense for CMOS VLSI.
- Emphasis on top-down design starting from high-level models.

  While no high-performance chip can be designed completely top-down, it is excellent discipline to start from a complete (hopefully executable) description of what the chip is to do; a number of experts estimate that half the application-specific ICs designed execute their delivery tests but don't work in their target system because the designer didn't work from a complete specification.

- Testing and design-for-testability.

  Today's customers demand both high quality and short design turnaround. Every designer must understand how chips are tested and what makes them hard to test. Relatively small changes to the architecture can make a chip drastically easier to test, while a poorly designed architecture cannot be adequately tested by even the best testing engineer.

- Design algorithms.

  We must use analysis and synthesis tools to design almost any type of chip: large chips, to be able to complete them at all; relatively small ASICs, to meet performance and time-to-market goals. Making the best use of those tools requires understanding how the tools work and exactly what design problem they are intended to solve.

The design methodologies described in this book make heavy use of computer- aided design (CAD) tools of all varieties: synthesis and analysis; layout, circuit, logic, and architecture design. CAD is more than a collection of programs. CAD is a way of thinking, a way of life, like Zen. CAD's greatest contribution to design is breaking the process up into manageable steps. That is a conceptual advance you can apply with no computer in sight. A designer can — and should — formulate a narrow problem and apply well-understood methods to solve that problem. Whether the designer uses CAD tools or solves the problem by hand is much less important than the fact that the chip design isn't a jumble of vaguely competing concerns but a well-understood set of tasks.

I have explicitly avoided talking about the operation of particular CAD tools. Different people have different tools available to them and a textbook should not be a userÕs guide. More importantly, the details of how a particular program works are a diversion — what counts is the underlying problem formulations used to define the problem and the algorithms used to solve them. Many CAD algorithms are relatively intuitive and I have tried to walk through examples to show how you can think like a CAD algorithm. Some of the less intuitive CAD algorithms have been relegated to a separate chapter; understanding these algorithms helps explain what the tool does, but isnÕt directly important to manual design.

Both the practicing professional and the advanced undergraduate or graduate student should benefit from this book. Students will probably undertake their most complex logic design project to date in a VLSI class. For a student, the most rewarding aspect of a VLSI design class is to put together previously-learned basics on circuit, logic, and architecture design to understand the tradeoffs between the different levels of abstraction. Professionals who either practice VLSI design or develop VLSI CAD tools can use this book to brush up on parts of the design process with which they have less-frequent involvement. Doing a truly good job of each step of design requires a solid understanding of the big picture.

A number of people have improved this book through their criticism. The students of COS/ELE 420 at Princeton University have been both patient and enthusiastic. Profs. C.K. Cheng, Andrea La Paugh, Miriam Leeser, and John “Wild Man” Nestor all used d rafts in their classes and gave me valuable feedback. Profs. Giovanni De Micheli, Steven Johnson, Sharad Malik, Robert Rutenbar, and James Sturm also gave me detailed and important advice after struggling through early drafts. Profs. Malik and Niraj Jha also patiently answered my questions about the literature. Any errors in this book are, of course, my own.

Thanks to Dr. Mark Pinto and David Boulin of AT&T for the transistor cross section photo and to Chong Hao and Dr. Michael Tong of AT&T for the ASIC photo. Dr. Robert Mathews, formerly of Stanford University and now of Performance Processors, indoctrinated me in pedagogical methods for VLSI design from an impressionable age. John Redford of DEC supplied many of the colorful terms in the lexicon.

Wayne Wolf Princeton, New Jersey

Users Review

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Justin Campbell:

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