TOPICS IN DIGITAL SIGNAL PROCESSING

Digital Signal Processing with the TMS320C25

RULPH CHASSAING
DARRELL W. HORNING

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Rulph Chassaing
Darrell W. Horning

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C. S. BURRUS and T. W. PARKS: *DFT/FFT AND CONVOLUTION ALGORITHMS: THEORY AND IMPLEMENTATION*

JOHN R. TREICHLER, C. RICHARD JOHNSON, Jr., and MICHAEL G. LARIMORE: *THEORY AND DESIGN OF ADAPTIVE FILTERS*

T. W. PARKS and C. S. BURRUS: *DIGITAL FILTER DESIGN*

RULPH CHASSAING and DARRELL W. HORNING: *DIGITAL SIGNAL PROCESSING WITH THE TMS320C25*

Digital Signal Processing with the TMS320C25

To Our Families
Linda, Amber, Otis, Alice, Andrew, and Chloe

Preface

Digital signal processors, made possible through advances in integrated circuits, have added a new element to the environment of digital signal processing (DSP). With this new technology, a student can appreciate the concepts of digital signal processing through real-time implementation of experiments and projects.

This book was developed out of a digital signal processing course and a senior project course taught at Roger Williams College, as well as a digital signal processing laboratory course taught at the University of Bridgeport. The background assumed is an electrical engineering systems course and a knowledge of assembly language programming. Each chapter begins with a theoretical discussion, followed by representative examples. Thirty examples, many with program solution, are included throughout the book; and a variety of students' projects are described in Chapter 9.

This text is intended primarily for senior and first-year graduate students in electrical and computer engineering and as a tutorial for the practicing engineer.

In Chapter 1 we introduce the software development tools. These tools are demonstrated through short programming examples. Chapter 2 covers the architecture and the instruction set of the TMS320C25. Structures and special instructions that are useful in DSP are included. Chapter 3 focuses on input and output (I/O) methods. Two I/O alternatives are presented: The analog interface board (AIB) and the analog interface chip (AIC).

In Chapter 4 we introduce the Z-transform. A digital oscillator example is implemented and can be useful for later experiments and projects. Finite impulse response (FIR) filters are discussed in Chapter 5. Several window functions to improve the characteristics of FIR filters are demonstrated. In Chapter 6 we discuss infinite impulse response (IIR) filters illustrating different structures. The effect of quantization on IIR filters is examined. Two software design tools are covered in conjunction with FIR and IIR filters.

Chapter 7 includes both the decimation-in-time and the decimation-in-frequency fast Fourier transform (FFT). Special instructions for the implementation of the FFT are covered. In Chapter 8 we introduce an intuitive approach to adaptive filtering using the linear combiner structure and the least mean squared (LMS) algorithm. Laboratory examples demonstrate the usefulness of the adaptive approach. Chapter 9 covers a variety of projects, including multirate filtering, modulation techniques, and the FFT. This chapter can be used as a source of experiments, projects, and applications.

We feel that the principles of digital signal processing can best be mastered through interaction in a laboratory setting, with real-time algorithm implementations. This interaction can serve to enhance and enrich a student's understanding of DSP.

This book can be used in a variety of ways, such as:

1 For a senior or first-year graduate project course, using Chapters 1 to 7 (Chapter 3 partially) to provide general background, and selected materials from Chapters 8 and 9.
2 For a DSP lab course, covering Chapters 1 to 6 (Chapter 3 partially) and selected materials from Chapters 8 and 9. The beginning of the semester can be devoted to short experiments and miniprojects and the remainder of the semester used for a final project.

We would like to thank all our digital signal processing students who have made our project- and laboratory-oriented courses very rewarding; in particular, Peter Martin, for his work on adaptive filtering with the AIC, and Ken Zemlok for his work on the additional AIB channel. The suggestions made by Dr. Kun-Shan Lin of Texas Instruments and Dr. David P. Morgan of Sanders Assoc. are appreciated. The authors would like to acknowledge the National Science Foundation's equipment support through grants CSI-8851272, CSI-8650204, and USE-8851147 and the support of the Roger Williams College Research Foundation. A special thanks to Carol Reineke for typing the manuscript.

Bristol, Rhode Island
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RULPH CHASSAING
DARRELL W. HORNING

List of Examples and Exercises

Exercise

Contents

1

A Digital Signal Processing Development System

CONCEPTS AND PROCEDURES

- *Use of the Software Development System (SWDS), commands and menus*
- *Creation, assembly, and execution of a TMS320C25 program*
- *Use of the debugging tools such as modify memory and single step*

In this chapter we introduce the use of development tools for real-time signal processing. Those tools include an SWDS, based on the second-generation TMS320C25 digital signal processor, an analog interface board (AIB) and an analog interface chip (AIC). In this chapter we show how to create a source file as well as an object file that can be downloaded into the SWDS and executed. A short example program (LOOP) illustrates how an input signal is brought through the A/D unit into the processor and then sent out to the D/A unit and output filter, where it is reconstructed.

1.1 INTRODUCTION

Signal processing can be split into two areas: nonreal-time signal processing and real-time signal processing. *Real-time processing* means that the processing must keep pace with some external event; *nonreal-time processing* has no such timing constraint. For signal processing, the external event to keep pace with is usually the analog input. This book and digital signal processing (DSP) processors such as the TMS320 family are concerned primarily with real-time signal processing.

The processing speed is often the paramount consideration in choosing design primitives for DSP applications. Figure 1.1 gives a general picture of the relative speeds of various primitives. In progressing from left to right on the diagram, the speed increases, as does the design difficulty. The degree of parallel processing also increases from left to right. On the far right is the fastest technology, fiber optic