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Digital Signal Computers and Processors

Andres C. Salazar

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Edited by
Andres C. Salazar

Member, Technical Staff
Bell Laboratories

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Introduction

Digital signal processing has now become an established field, and its importance as a method of manipulating waveforms grows daily as the new technology in circuitry evolves. Electronic technology, with the advances in integrated circuits with respect to lower price, increased speed and reliability, and enhanced capability, has made practical the processing in real time of signals whose spectra exceed the voice bandwidth. Applications of digital signal processing techniques to digital communications, radar, sonar, geological sensory systems, and speech signal analysis and synthesis are now commonplace. The publication of two IEEE Press volumes on digital signal processing by the IEEE Acoustics, Speech, and Signal Processing Society represents, in a way, the proliferation of interest and attention being given by researchers and applications and development engineers to these techniques.

In the past, new digital methods for processing waveforms were implemented on large, expensive general-purpose machines where virtually unlimited memory, processing capability, and time were available readily. Real-time implementation of these techniques was more a theoretical concept than a reality for all except a few basic and simple algorithms. As electronic technology matured and more became known about the limitations of digital signal processing, machines which were stand-alone, operating in real time, and implemented a digital signal processing technique became known as "digital signal processors." At first, these machines ranged in size from a room-full of equipment such as the FDP (at M.I.T. Lincoln Laboratories) which was general purpose in nature to nothing more than a rack which contained a programmable second-order section.

The role of computer architecture became increasingly important as more complicated applications were considered for digital signal processors. Speed, complexity, power consumption, computing capability, and cost were all factors to be considered in the design of these machines. It has been only in the last few years that the technology in integrated circuits has made feasible and viable the consideration of these machines for a myriad of applications. The advent of the general availability and large variety of low power Schottky devices and high-speed ALU chips, including the new bipolar microprocessor families, has generated an enormous amount of interest in the digital implementation in real time of many algorithms previously considered too costly. The burgeoning low-speed MOS microprocessor system market which, at present, by and large is dedicated to control and bookkeeping applications is starting to move towards higher speeds and more arithmetic capability. The multiply operation was long considered a costly, bulky, cumbersome, and time-consuming element. Again, new LSI bipolar technology has now produced single chip 8×8, 12×12, and 16×16 bit multipliers with less than 200 ns typical execution time. These chips are available now, and future improvements will likely include reduction in power consumption, higher reliability, and reduction in cost. An element which was somewhat expensive for many years was the A/D converter with reasonable conversion time. Developments in the last three years have also drastically reduced the price of this key element in a digital signal processor.

Memory elements, whether random access or read only, had been of medium density and cost. New production methods, especially in MOS technology, have permitted increased density, cost reduction, speed enhancement, and in general have contributed to the overall reduction in parts count, power consumption, and component cost required for implementing digital signal processors.

The architecture of the digital signal processor has traditionally depended on the application one has in mind for the machine. However, it is likely that with the advent of new cheap key elements, machine architecture will become more general purpose in nature. As a natural consequence to this trend, a digital signal processor, possibly with a switch-selectable sampling rate and easier memory and program control, will be offered on the market. It may be possible that the microcomputer revolution, which has recently come to encompass the fast minicomputer market, will spread to the digital signal processor field. As yet, micro- and minicomputer system manufacturers have provided only medium-speed hardware multipliers as additional peripherals, and have done little to modify architecture or software features in order to facilitate high-speed convolution, FFT's, or filtering. It is only when both hardware and software implementations of digital signal processing techniques are taken into account that a serious and viable digital signal processor product can be put on the market. An important consideration in working with a digital signal processor is the construction of a flexible and user-oriented interface or support system. This system permits the user to create, edit, assemble, load, probe, and monitor the program execution in the processor.

It is unfortunate that no software papers could be included in this volume. The few that were suggested to me considered general-purpose computers and were not involved with digital signal processing at all. Many workers in the digital signal processing field, including the Editor, consider themselves primarily "software types" with, of course, a serious interest in implementation and hardware. It is a curious phenomenon that the circuit design aspect of the machine evokes the most interest and generally gets the larger share of the patent and publishing limelight. Experience in software implementation of digital signal processing algorithms gives one a better perspective as to the advantages and disadvantages of a particular machine architecture. The vertical or horizontal microprogramming word organization, the number and sizes of memory registers, instructional branching, and looping capability are all machine features which can be better evaluated from a programmer's point of view. Management of the machine's resources in implementing an algorithm requires a considerable amount of planning and insight into both machine capability and algorithm understanding. Programming also inevitably requires careful manipulation of the signal data in order to minimize roundoff noise, aliasing, overflow, and other impairments peculiar to digital signal processing. We hope to see more papers in this field solicited and published in the future.

This volume is intended to serve as a reference source for those engineers and scientists who have determined that digital signal processing techniques can prove useful in their projects and are convinced that real-time execution is imperative for handling the signal data base. This book also serves as a companion volume to the two previous IEEE Press collections, entitled *Digital Signal Processing and Selected Papers in Digital Signal Processing II*, both compiled and sponsored by members of the Digital Signal Processing Committee of the IEEE ASSP Society. The present volume is co-sponsored by the Computer and ASSP Societies of the IEEE since the elements and the architecture of digital signal processors are unmistakably computer-like, and much of the literature on high-speed processors can be found in the former Society's TRANSACTIONS. The application and purpose of the machine is digital signal processing, and it is this field which is of great interest to ASSP TRANSACTIONS readers.

The present reprint collection is organized into four parts, the first of which is an overview of general-purpose processors either custom-built or commercially available. In Part II five articles are reprinted which stress architectural points about such processors. Part III consists of four sections: A. Computing Units, B. FFT Computing, C. Multiply Configurations, and D. A/D or D/A Conversion. These sections include papers which have dealt with individual elements of a digital signal processor. It has been breakthroughs or improvements of these elements which have played a key role in the real-time implementation of digital signal processing. In Part IV we have chosen five papers which are more specialized in nature in that they discuss a specific application of digital signal processors. The highly disparate field of application illustrates just how widespread the interest in such machines is at present.

It should be mentioned at this point that a large number of papers were considered for inclusion in this volume. Some papers, although they ordinarily would have been included here, were left out because they had been reproduced in one of the two above-mentioned IEEE Press volumes.

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