



ACM MONOGRAPH SERIES

**Foundations of  
Microprogramming**  
ARCHITECTURE, SOFTWARE,  
AND APPLICATIONS

Ashok K. Agrawala  
Tomlinson G. Rauscher

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# Foundations of Microprogramming

ARCHITECTURE, SOFTWARE,  
and APPLICATIONS

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E7952198



Academic Press, Inc.

NEW YORK SAN FRANCISCO LONDON 1976

*A Subsidiary of Harcourt Brace Jovanovich, Publishers*

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ACADEMIC PRESS, INC.

111 Fifth Avenue, New York, New York 10003

*United Kingdom Edition published by*

ACADEMIC PRESS, INC. (LONDON) LTD.

24/28 Oval Road, London NW1

**Library of Congress Cataloging in Publication Data**

Agrawala, Ashok K

Foundations of microprogramming

(ACM monograph series)

Bibliography: p.

1. Microprogramming. I. Rauscher, Tomlinson G., joint  
author. II. Title. III. Series: Association for  
Computing Machinery. ACM monograph series.

QA76.6.A35

001.6'42

75-37656

ISBN 0-12-045150-6

PRINTED IN THE UNITED STATES OF AMERICA

# Foundations of Microprogramming

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## ACM MONOGRAPH SERIES

*Published under the auspices of the Association for  
Computing Machinery Inc.*

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*Editor* ROBERT L. ASHENHURST *The University of Chicago*

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*In preparation*

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Stroud), 1962

*To*  
*Radhika and Suki*

## Preface

The purpose of this book is to define, describe, and illustrate the foundations and current trends in microprogramming. Because the emergence of *user* microprogrammable computers is responsible for significant activity in this field, the book covers this topic extensively. The level of presentation highlights the architectural, software, and applications aspects of microprogramming without becoming mired in intricate details. Descriptions of current developments are intended to provide examples, illustrate capabilities, and show alternatives with the expectation that they will provoke thought, provide insight, and indicate directions for new developments.

Microprogramming is receiving new interest with the development of fast writable memories for microprogram residence, and the subsequent marketing of several user microprogrammable computers. Whereas previous developments of read-only memories provided manufacturers with the capability to microprogram machine language instruction sets, recent developments have facilitated new techniques, implementations, and applications for users.

The book is intended for a wide audience and can be used in a variety of ways. Chapter 1 introduces microprogramming concepts. This chapter presents background material, develops a general definition of microprogramming and its characteristics, provides an easy to understand example, and compares microprogramming with programming and microprocessors. An elementary understanding of machine languages and computers is helpful in reading the chapter. In describing the fundamental concepts of microprogramming, Chapter 1 presents microprogramming from a slightly different but more general viewpoint than the classical approach. The sections on programming, microprogrammability, and microprocessors should provide some new insights as all these subjects are seldom considered in microprogramming presentations.

Microprogramming has borrowed heavily from the areas of computer architecture and software, and should be regarded as another level in a system hierarchy. There is little underlying theory to microprogramming but there are basic con-

## PREFACE

cepts; these concepts are described in Chapter 2 on architectural characteristics and in Chapter 3 on microprogramming languages and support software. For those new in the field these chapters define the characteristics that will be illustrated by the developments described in Chapters 4-7. Although the principles discussed in Chapters 2 and 3 should be well known to those familiar with microprogramming, they are often confused in the literature. Thus Chapters 2 and 3 separate and clarify the issues involved in microprogramming architecture and software. The student and practitioner should be well aware of the distinction and interrelationships among these concepts.

Chapters 4-7 present contemporary developments of user microprogrammable computer systems and microprogramming languages. The computers are primarily commercially available systems, and many are fairly inexpensive. The computers are described through the characteristics discussed in earlier chapters using the terminology developed in those chapters. The architecture diagrams have generally been drawn in the same format; common components have been placed in the same relative locations for each machine. These diagrams show the logical structure of the computers; we are not overly concerned with the engineering aspects of these designs. An attempt has been made to avoid a favored treatment of any machine. Our biases are reserved for the last chapter of the book.

In reading the machine descriptions, an interesting exercise is to determine the characteristics that a machine demonstrates well, or the degree to which various characteristics are in evidence. Example microprograms have been included for most of the computers and have been explained carefully in an effort to illustrate current microprogramming characteristics. Whereas the manufacturers of most of the computers discussed agree with our descriptions, the descriptions are not to be construed as operating specifications nor as commitments to specifications. Although software developments have been largely experimental, the same comments apply.

A number of applications of microprogramming are described in Chapter 8, which surveys practical applications that are in wide use and also applications investigated primarily as research projects but which may come into common use in the future. Chapters 4-8 present a significant accumulation of information on the current state of microprogramming, and should serve as a handy reference to computer professionals.

The annotated bibliography at the end of each chapter should be helpful in further exploring the ideas presented in the book.

In Chapter 9 we try to provide a perspective on microprogramming systems by summarizing past, present, and future trends.

We believe the book is well suited for a short seminar on microprogramming or as an introduction to microprogramming in a course on computer architecture. This book could also serve as a primary text for a graduate course on micropro-



## PREFACE

gramming. In that case the bibliographies serve as a guide to topics to be studied in more detail.

This book evolved from work begun early in 1973. An early short report which summarized some parts of this work was published in the *IEEE Transactions on Computers* in August 1974.\* This book, which incorporates many new developments, is a significantly expanded and updated report on this work.

\*A.K. Agrawala and T.G. Rauscher, *Microprogramming: perspective and status*, *IEEE Trans. on Comp.*, Vol. C-23, No. 8, Aug. 1974, pp. 817-837.

## Acknowledgments

The assistance of many people helped make this book possible. We are especially grateful to those who provided information on computers and micro-programming languages: Mr. Ron Compton and Mr. Norman Compton, Standard Logic Inc.; Dr. Wayne Wilner, Burroughs Corporation; Mr. Han Park and Mr. Bill Dallenbach, Hewlett-Packard Company; Mr. Richard Caveny, Digital Scientific Corporation; Mr. W. David Elliott, Naval Research Laboratory; Mr. Paul Anagnostopoulos, Brown University; Mr. Frank Ferraro, INTERDATA Incorporated; Mr. Cliff Roebuck, Microdata Corporation; Mr. Ken Omohundro, California Data Processors; Mr. Steven Andleman and Mr. James Coffey, PRIME Computer Inc.; Mr. Bob Mahoney, Mr. Ed O'Neil, and Mr. Angus McLagan, Varian Data Machines; Mr. Jack Lynch and Dr. Earl Reigel, Burroughs Corporation; Mr. Joel Herbsman and Dr. John Hale, NANODATA Corporation; Mr. William Lidinsky, Argonne National Laboratory; Dr. Bruce Shriver, Dr. Ted Lewis, Mr. L. Phillip Caillouet, Jr., Mr. Allan Lang, and Mr. Les Waguespack, University of Southwestern Louisiana; Dr. Richard Eckhouse, Jr., Digital Equipment Corporation; Mr. Clinton W. Parker II, University of Maryland. The photograph in Figure 1.2-2 is courtesy of Hewlett-Packard. The Association for Computing Machinery and The Institute of Electrical and Electronics Engineers graciously permitted reproduction of several figures from their publications.

Finally, we would like to thank our colleagues in the Department of Computer Science and the Computer Science Center of the University of Maryland for their encouragement and support during this work.

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## CHAPTER 1

## INTRODUCTION TO MICROPROGRAMMING CONCEPTS

## 1.1 Basic Computer Organization

A digital computer is functionally organized into the four basic sections shown in Figure 1.1-1. The input/output (I/O) section maintains communication between the computer and its environment. It accepts information from devices (card readers, teletypes, tape drives, etc.) and converts it to a form

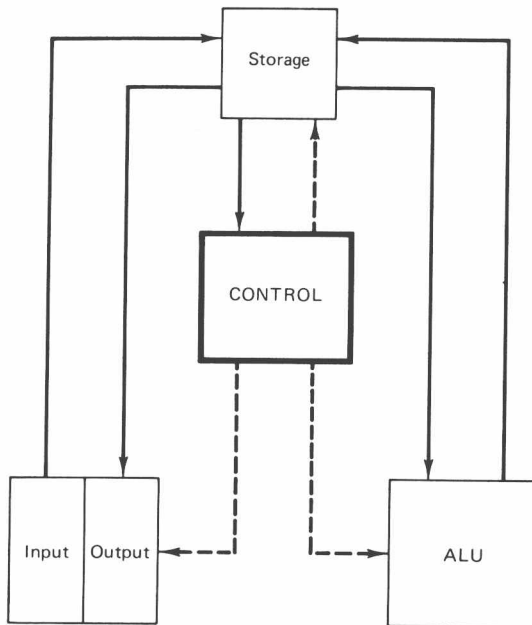


Figure 1.1-1. Functional organization of a digital computer;  
solid line, data; dashed line, control information.