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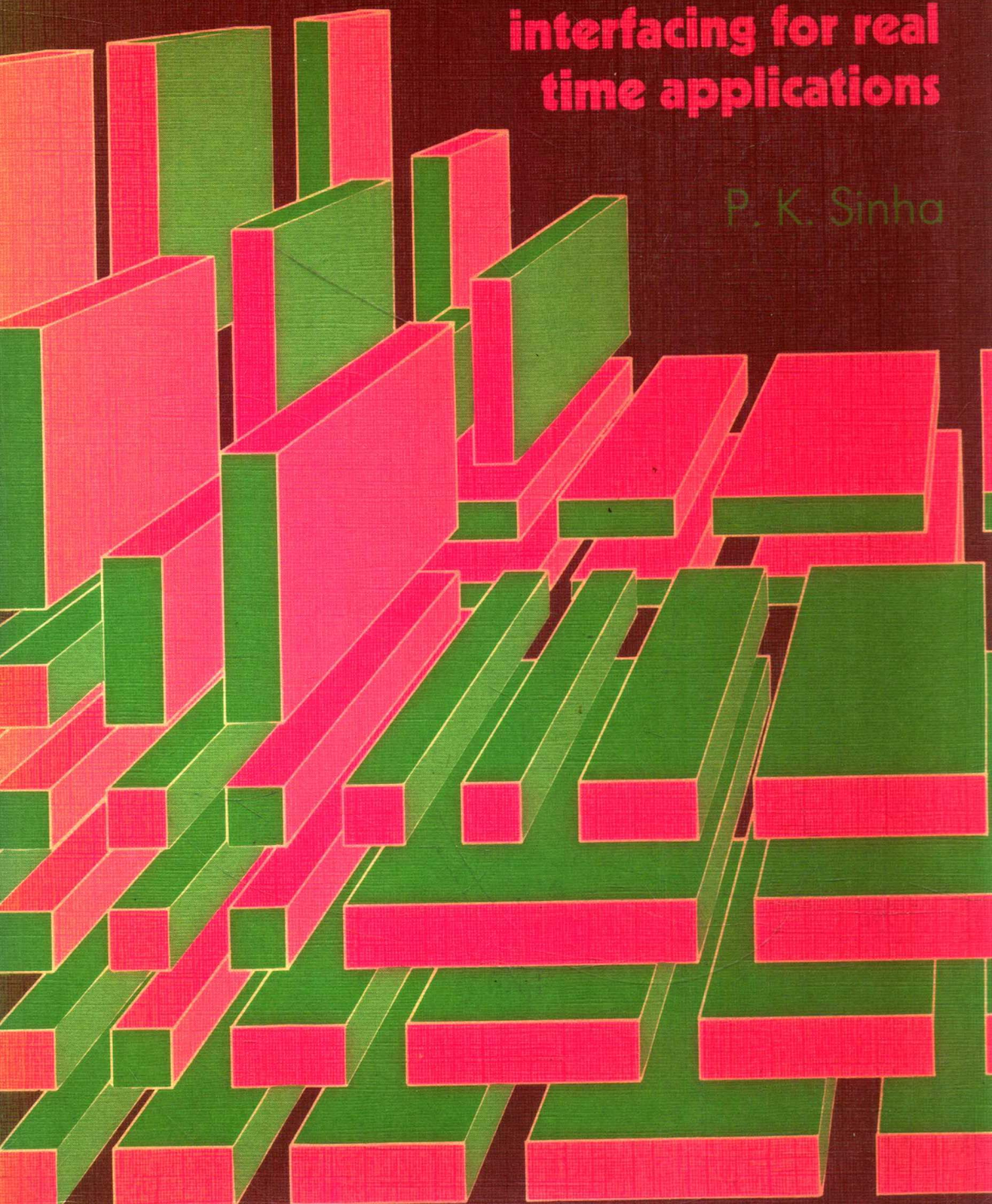
MICROPROCESSORS FOR ENGINEERS

interfacing for real time applications

P. K. Sinha



MICROPROCESSORS FOR ENGINEERS: Interfacing for Real Time Applications

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Microprocessors in place of analogue circuits as a controller in engineering still tend to be surrounded by a certain 'mystique' due to the emphasis on the software aspects of particular systems in most microcomputing books. This book, based on the author's experience of developing applications-oriented microprocessor courses, is a unified and valuable account of the hardware configuration, programming concepts, and the interfacing of microcomputers for real-time measurement and control applications.

The book has been carefully structured to encompass the essential aspects of microcomputer components, input-output data transfer concepts, interfacing circuit design, and the writing of control algorithms from a 'non-electric' engineering viewpoint. Numerous scientific applications are described, covering data conversion techniques, timing and sequencing, three term controller, stepper motor control, and open and closed-loop speed control of a d.c. motor.

The author maintains throughout an emphasis on interface design and the formulation of real-time control algorithms, providing a systematic evaluation of the data processing and software concepts in numerous practical engineering situations. He covers an important area of microcomputer applications with a level of rigour and scope beyond most available texts, co-ordinating much diverse material, previously only available in journal literature, into a single book.

Readership: Electrical and electronics engineers, civil and mechanical engineers. All engineering students, both electrical and from other disciplines. Applied mathematicians, computing scientists.

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To my parents

PREFACE

Despite the presence of numerous books on microprocessors, the mystique of using microprocessors as a controller in place of analogue circuits remains. This is due mainly to the fact that most books on "micros" tend to emphasise the software aspects of a particular system while most books on computer-controlled systems cover the mathematical details of digital control systems. Very few books convey the extent of background knowledge needed to design even the simplest system required for on-line control of electro-mechanical devices. The family of books which cover some aspects of "applications" using personal computers are aimed at the hobby market rather than the engineering designer. This book has been formatted to bridge the gap between programming techniques and the engineering aspects of interfacing and data transfer between a microprocessor and the real world.

This book is based on my experience in developing a number of applications orientated microprocessor courses for undergraduates and practising engineers. Although some knowledge of analogue circuits is assumed, the contents of the book have been selected to cover the essential elements of designing a microprocessor-based engineering system from a 'non-electronic' engineer's viewpoint. Since such designs need a wider knowledge which goes beyond the skill of program writing, a number of topics covering the details of

real-time data transfer, data conversion and timing problems as well as project development have been described. Because of the constraints of data format and different processing requirements, generalized description of interfacing techniques for microprocessor-controlled systems is difficult. Programming and interfacing for a selection of signal processing and control application have been described in detail to provide a framework for the practical design of microprocessor-controlled engineering systems.

One of the main problems of writing an introductory book on the applications of microprocessors for real-time control is the choice of the processor. Although 16-bit processors and associated support devices are available, the system complexity as well as the configurations of data and address buses are too complex for the designer not familiar with the detail circuits and input-output lines of microprocessors. For this reason I have chosen to describe the programming principles, data conversion techniques and interfacing circuits with reference to an 8-bit processor. Of the several 8-bit processors, Intel 8080A, Z80, M6800 and R6500 are most common and well supported. Although there are differences in architectural features amongst these processors, they have similar functional properties with 8080A/Z80 and 6800/6500 having many common operational features. Although a wide variety of microcomputer systems based on these devices is available, the R6500 family is believed to be one of the most successful processors; it is used by several personal computer manufacturers, including Commodore, Apple, Acorn, and a large number of equipment manufacturers. Because of the wide variety of support-chips as well as the ease of programming for real-time control, the R6502 variant of the 6500 family has been referred throughout this book. Programming techniques and interfacing details have been given with reference to one processor to avoid the ambiguity usually associated with any general description of real-time control algorithms. The programs described in this

book have been developed on the Rockwell-Advanced Interactive Computer (AIM-65) and the Apple-II microcomputer, both based on the R6502 processor. These single-board computers are ideally suited for relatively simple engineering control applications. The contents of the book have been selected to

- highlight the hardware configuration of microcomputers and input-output devices with particular reference to real-time data transfer,
- provide an introduction to the basic rules of programming in assembly language for real-time applications,
- outline some of the fundamental aspects of designing interfacing circuitry for the processing of time-varying signals,
- present detailed descriptions of the various stages of designing and constructing a number of real-time control systems using single-board microcomputers.

The emphasis of the book is on synthesis rather than any particular area of a microprocessor-based system design. In view of this, there is more emphasis on the interfacing, analysis and applications with relatively little material on the "abstract" software details of microcomputer programming.

Although many of the topics described here are treated elsewhere, the material in this book has been structured to provide a systematic progression from the fundamental concepts of data processing to the design of microprocessor-based systems. Chapters 1-4 describe the hardware aspects of microprocessors and microcomputers with particular reference to their configurations for real-time applications. A short introduction to programming in assembly language is given in Chapter 5. The main features of BASIC are described in the Appendix and are referred to in Chapter 5. The basic principles of interfacing as well as the main features of using microprocessors for real-time control are covered in Chapters 6-10. A large portion of these chapters deal with specific applications with

particular reference to software/hardware design to meet the required objectives.

The book is suitable for applications orientated microprocessor courses for undergraduates in electrical, electronics, mechanical, computer-systems and control engineering in the universities and polytechnics. For the practising engineer, the book provides an introduction to the hardware configuration, programming concepts and interface design principles in the context of a number of typical measurement and control applications.

A significant portion of the book is based on original design work, but many fundamental topics described here are based on published books and papers, manufacturers' data sheets and reference manuals. I am grateful to Rockwell International (Semiconductor Products Division) for their permission to use material from the manuals and application notes of the R6500 processors and related products. I have attempted to include my other sources, except product literature, in the reference.

I appreciate the assistance of many of my students, in particular Dean Claxton, Brent Crouch, Stanley Chia, Lzun Ho, William Liu, Ken Kan, Simon Pawlowski, Allen Martin, Michael Miller and Andrew Stubley, in the development of some of the topics covered in this book. I am grateful to many colleagues in the UK and abroad for their active support in the running of a number of very successful short-courses based on the experiments described here. I would like to thank the University of Warwick for the provision of facilities during the development of these courses and during the writing of this book. A visiting fellowship at the National Central University (under the auspices of the National Science Council, Republic of China) during the final stages of preparation of this book is gratefully acknowledged. Finally I thank my wife for her support during this rather long project.

P. K. Sinha

September 1985

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– by P.K. SINHA –

CHAPTER

ONE

INTRODUCTION

A microcomputer operates more or less in the same fashion as the conventional digital computers providing similar processing power and input/output capabilities. However, microcomputers differ from their mainframe counterparts in one important respect – the unit which provides the processing power to the microcomputer is the least expensive component, and consequently for the purpose of costing, the processing element may be treated like other peripherals.

The schematic of a mainframe computer is shown in Fig. 1.1a, where the interface consists of circuits to connect the operator and external world (environment) to the internal electronic world of the computer. Viewed from the environment the mainframe is rigid, in that its internal structure is inaccessible to the operator. The structure of a basic microcomputer (Fig. 1.1b) is very similar to a mainframe, except that the user has access to the input/output terminals of each of the functional blocks of the system. Compared to a mainframe computer, the microcomputer is neither a general purpose machine nor can it provide the speed and accuracy needed in many large computing tasks. However, when the cost of a microcomputer (Fig. 1.1c) is taken into account, the microcomputer is well ahead of its older counterparts.

All microcomputers are built around similar basic components

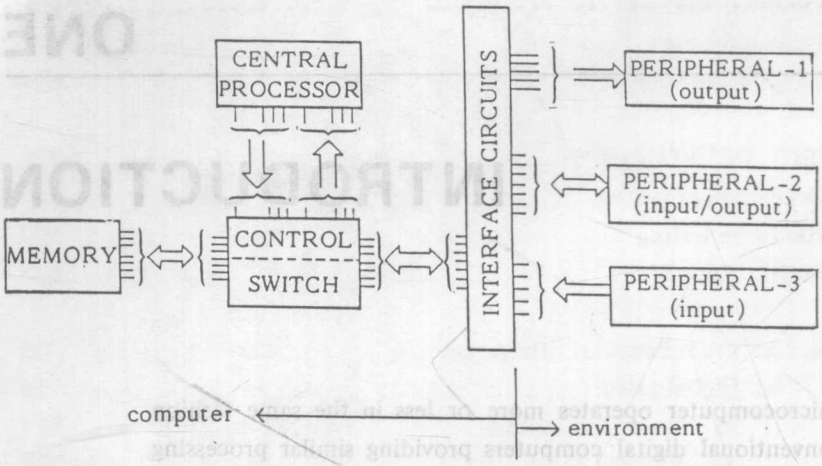

Fig. 1.1a Schematic of a mainframe computer. Access to any section of the computer is through the peripherals and interface circuitry.

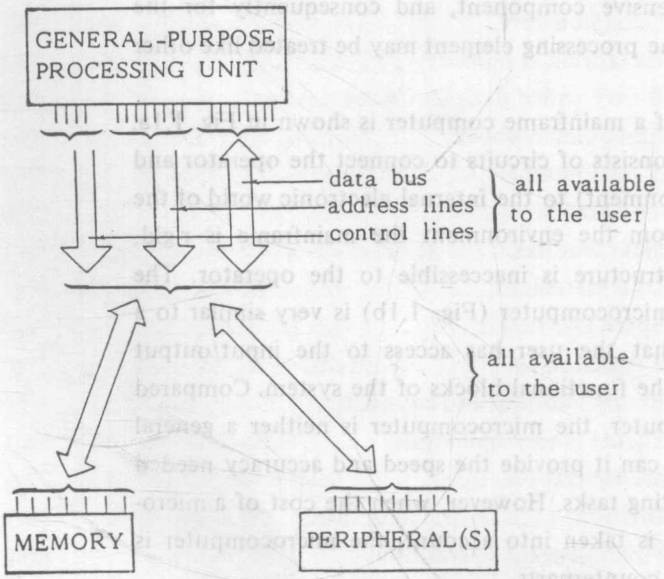

Fig. 1.1b Schematic of a microcomputer.