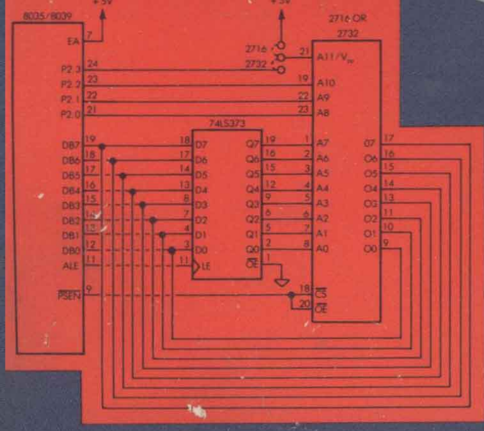
SYBEX

Mastering Digital Device Control

William G. Houghton



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Mastering
Digital Device Control

For
Ernie, Bill, and Stan,
Elainna and Barbara,
Fay and Lee

ACKNOWLEDGMENTS

Writing a book is an extremely personal experience. Early on, I began to realize that it is also an enormous task and that the end result would not be just the product of my own efforts, but the combination of the unselfish contributions of many other individuals. Some of these contributions are simply the encouragement of family members and personal friends, others the teachings of instructors in formal education, others the sharing of knowledge and personal experience given willingly by colleagues.

As I am an engineer by day, this book was necessarily written at night. Writing a book under such circumstances placed a large burden on my family, with all members sacrificing. My wife, Elainna, has had to endure this process as well as I, taking on many of my responsibilities around the home so that I could devote my time to this project. Without her encouragement and support, this book might not have ever been completed. She has been there to experience both the joys and the fears.

Without the thoughtfulness of David Graves this book would not have been started. David, a personal friend, invited me to join him for lunch with Dr. R. S. Langer and Carole Alden of SYBEX. It was at that lunch meeting that the idea for this book was conceived. Dr. Rodnay Zaks of SYBEX suggested the focus on applications that became the theme of this work.

I owe a large debt of gratitude to my teachers at Napa College, Ernie Abbott, Billy J. Williams, and the late Stan Casassa. I feel fortunate to have attended Napa College, as many of my skills today have been made possible by the efforts of these three individuals. Stan, incidentally, was also a personal friend. Those of us who knew him miss him greatly.

Much of the material that is in this book is the result of my professional experiences at Intel, OKI, and Signetics, as well as various assignments as a private consultant. At Intel I learned a lot from Tom Voll and Tom Rossi. Tom Voll is an excellent theorist. Tom Rossi is an expert at reducing theory to practice. The world needs both types. Roger Lynn (of OKI) is one of the finest engineers I have ever met. I owe a large part of my professional development, and many thanks, to him. Many of the display devices in Chapter 11 were first introduced to me by Roger.

Much of my business sense was cultivated by Doug McCown of Multimek. Doug is able to teach engineers the practical aspects of taking a product to the production phase. For designers these are valuable lessons that, unfortunately, are not taught in school.

Several people have made direct contributions to this book. Employees of the manufacturers of the chips used as examples were kind enough to provide data sheets, user's manuals, and application notes, and to answer questions about the features and applications of their company's products. I do not know most of their names, but nevertheless I am grateful for their assistance. Two whose names I do know are Robin Jigour of ICT and Dave Roush of OKI.

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INTRODUCTION

Why This Book

Many books have been written about microprocessors; far fewer have been written about microcontrollers. Most, if not all of these, are concerned with the specific capabilities and features of an individual chip or members of a specific family of related chips. In essence, they are an extension of the ideas presented in the manufacturers' data sheets, with very little information to show *how* to make the microcontroller do what you want it to.

Mastering Digital Device Control does not just describe single-chip microcontrollers; it also explains their application. It details how to use microcontrollers and how to interface them to additional circuitry to perform real functions and provide solutions to design problems. Using numerous examples, the book brings out the capabilities, constraints, and trade-offs that the designer encounters when implementing a variety of microcontroller systems. The reader will come away from the book with a solid, practical mastery of the fundamentals of microcontroller system design and applications.

Who This Book Is For

This book is intended for the engineer or technician who needs to design with microcontroller-based systems and who might not have previous experience in designing with these devices. It assumes that the reader is familiar with at least the basic concept of a microprocessor and possesses a basic understanding of digital logic elements such as gates, flip-flops, buffers, and inverters. This book's broad range of topics should prove useful to more experienced designers as well.

Mastering Digital Device Control is also intended to appeal to electronics hobbyists, who have had an important influence on the electronics industry. Most of the really good engineers and technicians I have known had hobby interests in electronics prior to their formal education in the field. Many still pursue their hobby in addition to their professional careers.

Organization of This Book

Chapter 1 introduces the basic concepts of a microcontroller and how such a device differs from its earlier relative, the microprocessor. Chapter 1 also briefly reviews the basic features of three popular microcontrollers—the 8048, 8051, and 6805.

Chapter 2 discusses the role of external program memory storage in microcontroller systems and how to add these memory chips to a design. Because the interface to these chips requires the designer to forfeit the use of some of the system's I/O ports, Chapter 2 also examines methods that can be used to recover these lost functions with some additional hardware.

Chapter 3 examines the use of external data memories in microcontroller systems. Like the program memories in Chapter 2, these memories also require that some of the port pins be forfeited. These lost I/O functions can be regained using techniques similar to those shown in Chapter 2. Chapter 3 also introduces the idea of serially interfaced data memory devices, which use fewer I/O ports to interface but which require more processing time to access. Several types of serial memory chips are used as examples.

Chapter 4 presents various methods of I/O expansion techniques that can be used when the system designer needs more I/O resources than the microcontroller has available. Both parallel and serial interfaces are described, building on the concepts introduced with memory devices in Chapters 2 and 3.

Chapter 5 discusses the use and application of system interrupts. Many designers seem to have difficulty implementing interrupts. However, once they are understood, interrupts can be valuable tools for achieving the goals of the system design. In this chapter we examine what interrupts are, what types exist, and how the microcontroller can handle them. We discuss in detail the interrupt structures of the 8048, 8051, and 6805 microcontrollers.

One of the microcontroller's significant advantages over its microprocessor counterparts is its ability to manipulate single bits of I/O ports and internal registers. Chapter 6 discusses this topic in detail.

Chapter 7 examines the role and use of clock sources external to the microcontroller. These clock sources are used to drive the oscillator pins of the microcontroller, as external timers, and in some cases as a reference to the AC power line.

Chapter 8 looks at the role of the RS-232 interface in the design of single-chip microcontroller applications. Such an interface allows the microcontroller to communicate with various computer peripherals such as printers, terminals, or other computer systems. Chapter 8 discusses the benefits of both hardware and software UARTs as they apply to microcontroller systems, and it provides examples of simple line drivers and receivers that can be used to fulfill the electrical requirements of an RS-232 interface.

Chapter 9 examines some of the many peripheral chips that have been designed to provide useful features to microprocessor-based systems. After reviewing the requirements of the interfaces to these chips, the reader will learn how a microcontroller can be used to create a custom peripheral chip by interfacing the microcontroller as a peripheral device to a microprocessor.

Chapter 10 introduces the concept of keypad scanning, a useful way to detect the open or closed status of a large number of switch contacts. The shortcomings of this technique are also discussed, including ghosting effects and switch bounce.

Chapter 11 examines the role of display devices such as light emitting diodes (LED), vacuum fluorescent (VF) displays, and liquid crystal displays (LCD). Included are both segmented and dot matrix displays, along with the unique requirements of each of these displays and their associated interfaces. Also included are examples of display driver chips that can simplify the design.

Chapter 12 discusses the role of lookup tables in the design of microcontroller systems. While basically a software solution to a design problem, lookup tables can have considerable influence on the hardware elements of the design. Also included in this chapter is a discussion of situations when a lookup table might not be the best solution.

Chapter 13 shows how a microcontroller system can be used to control an AC power source. The control of relays, opto-isolators, SCRs, and triacs is included, along with the application of zero-crossing detector circuits for minimizing noise generated when switching power to AC loads.

Chapter 14 shows how to use the microcontroller to measure and control the characteristics of analog sources through the use of analog-to-digital converters, digital-to-analog converters, and voltage-to-frequency converters.

Chapter 15 concludes the text with an example application—an EPROM programmer that is capable of programming many of the popular EPROM varieties. This design uses many of the techniques of microcontroller system interfacing introduced throughout the book, including an RS-232 interface to a host computer, external program and data memory expansion, lookup tables, digital-to-analog conversion, and more.

Appendix A contains the software drivers used with the EPROM programmer example shown in Chapter 15.

Appendix B provides the addresses of the manufacturers of the various chips discussed throughout this book. The addresses shown are the corporate headquarters of these firms in the United States. Many of these manufacturers have either local sales offices or representatives located in major cities throughout the world.

Throughout this book a few conventions are used. Unless stated otherwise, positive logic is used. Single bits of a given I/O port are expressed in the form

P*x.y*

where P*x* is the port name and *y* is the bit position in that port. This nomenclature is often used with the 8051 family of devices. For example, P3.2 refers to bit 2 of port 3. This terminology has been used for consistency throughout the book even though the manufacturer's data sheets might not use this method. In general, the book uses terminology common to the industry.

The EPROM Programmer Described in This Book

At the time of this writing, the author is arranging to make the EPROM programmer described in Chapter 15 and Appendix A available to interested readers at a reasonable cost. Several additions to the software drivers are also planned, including support for EPROM-based microcontrollers. For current availability and pricing information, please send a self-addressed stamped envelope to the author at North Valley Designs, P.O. Box 32899, San Jose, CA 95152.

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