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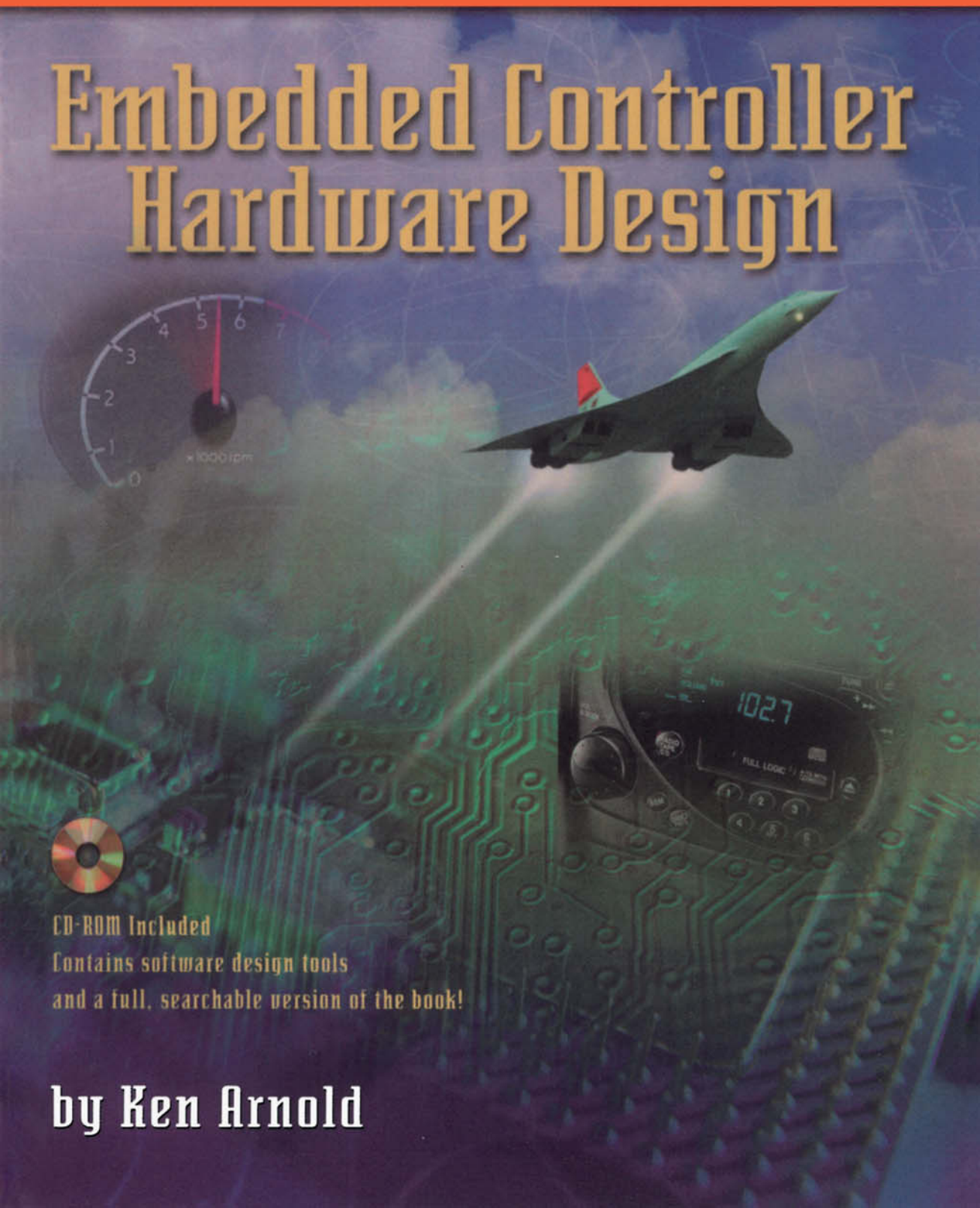
Embedded Controller Hardware Design



by Ken Arnold

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A Volume in the
Embedded Technology™ Series

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Dedication

This book is dedicated in memory of my father, Kenneth Owen Arnold, who always encouraged me to follow my dreams. When other adults discouraged me from entering the engineering field, he told me, "If you really like what you're doing and you're good at it, you will be successful." Nowadays I get paid to have fun doing things I'd do for free anyway, so that meets my definition of success! Thanks, Dad.

Acknowledgment

This book is a direct result of contributions from many of the students I have been fortunate enough to have in my embedded computer engineering courses at the University of California—San Diego extension. They have provided a valuable form of feedback by sharing their notes and pointing out weaknesses in the text and in-class presentations. Some sections of this text were also provided by David Fern and Steven Tietsworth.

I would also like to thank my family for supporting me and, Mary, Nikki, Kenny, Daniel, Amy, and Annie for being patient and helping out when I needed it!

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Preface

During the early years of microprocessors, there were few engineers with education and experience in the applications of microprocessor technology. Now that microprocessors and microcontrollers have become pervasive in so many devices, the ability to use them has become almost a requirement for many technical people.

Today the microprocessor and the microcontroller have become two of the most powerful tools available to the scientist and engineer. Microcontrollers have been embedded in so many products that it is easy to overlook the fact that they greatly outnumber personal computers. Millions of PCs are shipped each year, but *billions* of microcontrollers ship annually. While a great deal of attention is given to personal computers, the vast majority of new designs are for embedded applications. For every PC designer, there are thousands of designers using microcontrollers in embedded applications. The number of embedded designs is growing quickly. The purpose of this book is to give the reader the basic design and analysis skills to design reliable microcontroller or microprocessor based systems. The emphasis in this book is on the practical aspects of interfacing the processor to memory and I/O devices, and the basics of interfacing such a device to the outside world.

A major goal of this book is to show how to make devices that are inherently reliable by design. While a lot of attention has been given to "quality improvement," the majority of the emphasis has been placed on the processes that occur *after* the design of a product is complete. Design deficiencies are a significant problem, and can be exceedingly difficult to identify in the field. These types of quality problems can be addressed in the design phase with relatively little effort, and with far less expense than will be incurred later in the process. Unfortunately, there are many hardware designers and organizations that, for various reasons, do not understand the significance and expense of an unreliable design. The design methodology presented in this text is intended to address this problem.

Learning to design and develop a microcontroller system without any practical hands-on experience is a bit like trying to learn to ride a bike from reading book. Thus, another goal is to provide a practical example of a complete working product. What appears easy on paper may prove extremely difficult without some real world experience and some potentially painful crashes. In order to do it right, it's best to examine and use a real design. On the other hand, the current state of the technology (surface mounted packaging, etc.) can make the practical side problematic. In order to address this problem, a special educational System Development Kit is available to accompany this book (8031SDK). All the documentation to construct an SDK is available on the companion CD-ROM. This info, along with updated information and application examples, is also available on the web site for this book: http://www.hte.com/echdbook. All the information needed to build the SDK is available there, as well as information on how to order the SDK assembled and tested.

While searching for an appropriate text for one of the courses I teach in embedded computer engineering, I was unable to locate a book that covered the topic adequately. An earlier version of this book was written to accompany that course and has since evolved into what you see here. The course is offered at the University of California, San Diego Extended Studies, and is titled "Embedded Controller Hardware Design." The same courses may also be taken in an on-line format using the Internet, and can be found at http://www.hte.com/uconline/ecd The goals of the course and the book are very much the same: to describe the *right way* to design embedded systems.

While no prior knowledge of microcontrollers or microprocessors is required, the reader should already be familiar with basic electronics, logic, and basic computer organization. Chapter one is intended as a review of those basic concepts. Next there is a general overview of microcontroller architecture, and a specific microcontroller chip architecture, the 8051 family, is intro-

duced and detailed. The 8051 was chosen because it can be interfaced to external memory, has simple timing specs, is widely used and available from a number of manufacturers. The concepts of worst-case design and analysis are described, along with techniques for hardware interfacing. A good embedded design requires familiarity with the underlying memory technology, including ROM, SRAM, EPROM, Flash EPROM, EEPROM storage mechanisms and devices. The processor bus interface is then covered in general form, along with an introduction to the 8051's bus interface. Most embedded designs can also benefit from the use of user programmable logic devices (PLD). This subject is too complex for in-depth coverage here, so PLD technology is covered from a relatively high level. The central theme of designing an embedded system that can be proven to be reliable is illustrated with a simple embedded controller. The iterative nature of the design process is shown by example, and several design alternatives are evaluated. With the central part of the design completed, the remaining chapters cover the various types of I/O interfaces, bus operations, and a collection of information that is seldom included in the usual sources, but is often handed down from one engineer to another.

I hope that you will find this book to be useful, and welcome any observations and contributions you may have. If you should find any errors in the text, or if you know of some good embedded design resources, please feel free to contact me directly by e-mail: ken.arnold@ieee.org