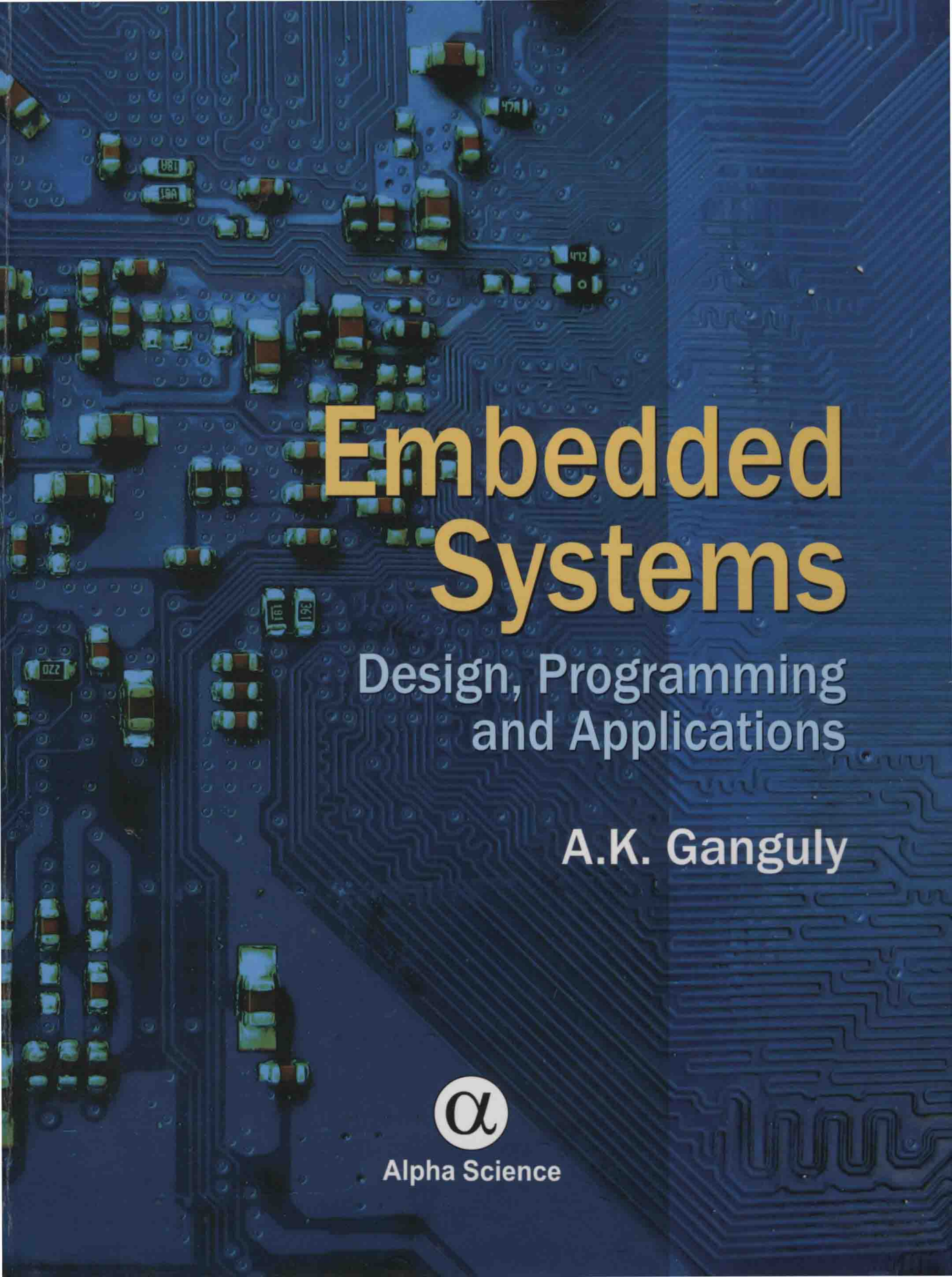

Embedded Systems

Design, Programming and Applications

A.K. Ganguly

Alpha Science

Embedded Systems

Design, Programming and Applications

Amar K. Ganguly

Alpha Science International Ltd.
Oxford, U.K.

Embedded Systems: *Design, Programming and Applications*
402 pgs. | 129 figs. | 43 tbls.

Amar K. Ganguly
Department of Electronics and Communication Engineering
Asansol Engineering College
Asansol

ALPHA SCIENCE INTERNATIONAL LTD.
7200 The Quorum, Oxford Business Park North
Garsington Road, Oxford OX4 2JZ, U.K.

www.alphasci.com

ISBN 978-1-84265-782-9

Printed in India

Embedded Systems

Design, Programming and Applications

In loving memory of my wife Mrs. Rina Ganguly

Acknowledgements

I would like to express our deep gratitude to Dr. B. K. Dey, Principal; Registrar; Advisor; Mr. T. K. Ghosh, Director; Mr. T. Singh, Director; Dr. M. G. Tiary, HOD, ECE Department; Asansol Engineering college for their constant encouragement and strong support in writing this book.

I am deeply indebted to Professor Alok K. Das and Professor P. Banerjee, Electronics and Telecommunication Engineering Department, Jadavpur University; Prof. Anish Dev, Applied Physics Department, Calcutta University; Dr. S. Kundu, HOD, CSE Department, West Bengal University of Technology; for their constructive suggestions directly or indirectly to improve the book. I am also grateful to Prof. A. K. Aditya, Director NSHM, Durgapur and Dr. Krishnendu Chakraborty, Principal, Kalyani Govt. Engineering College; Mr. Subhashish Maitra, Kalyani Govt. Engineering College; for many constructive suggestions for improving the book.

I wish to thank post graduate students of Asansol Engineering College for finding solutions of problems related to the subject included in this book. We also wish to thank Mr. Manik Bhoumik, Asst. Professor, NIT Agartala and Aparna Bhoumik for their encouragement and strong support in writing this book. I am deeply indebted to my wife Mrs. R. Ganguly and my daughter Suparna Bhattacharya for their constant encouragement in writing this book.

I am indebted to Mr. Bidyut Patra, Head Librarian, Asansol Engineering College for issuing valuable books and journals related to the subject content of this book.

I am grateful to the reviewers of this book for providing their valuable time to review this book. I wish to thank Mr. N. K. Mehra, Publisher and Managing Director, Narosa Publishing House Private Limited for constant encouragement and strong support in writing this book. I am very much grateful to him for taking entire responsibility of publication of this book.

I obtained valuable comments from outstanding professionals directly involved in teaching this subject and also engaged in research and development works in educational institutions and industries on this subject. I am really grateful to them. I also expressed my deep gratitude to the

authors of numerous papers, articles and books which I have referenced. I also thank my friends and my family for inspiring me in writing this book.

It is needless to say that without all the above help and support, the writing and publication of this book would not have been possible.

Amar K. Ganguly

Preface

Now-a-days embedded systems are used in our daily life. Embedded systems are used in toys, video games, automatic chocolate-vending machines, mobile phones, smart cards, ATM, network systems and so on. Initially, embedded systems were designed using first generation microprocessor like 8085. Using this microprocessor, the embedded systems had limited applications. Embedded computing system design is a useful skill for many types of product. Automobiles, personal digital assistants (PDAs), and even household appliances make extensive use of embedded systems.

Now an Embedded system consists of computer hardware with embedded software which is a dedicated system for applications. It is a hardware platform with microprocessor or microcontroller and input/output devices which support required tasks and implement software that perform the required processing. Designers in many fields must be able to identify where microprocessors can be used, design a hardware platform with I/O devices that can support the required tasks, and implement software that perform the required processing. A microprocessor is a single chip CPU. VLSI technology has allowed us to put a complete CPU on a single chip. Scientists realized that a general purpose computer programmed properly could implement the required function, and that the computer on a chip could then be reprogrammed for use in other products as well. Since integrated circuit design was an expensive and time consuming process, the ability to reuse the hardware design by changing the software was a breakthrough. Automobile designers started making use of the microprocessor soon after single chip CPUs became available. Microprocessors and microcontrollers are available in different levels of sophistications.

A microcontroller is a true computer on a chip. It is a general purpose microprocessor with inbuilt RAM, ROM, I/O ports, and timers. A microcontroller has a CPU in addition to a fixed amount of RAM, ROM, I/O ports, and a timer all on a single chip. It is used to read data, perform limited calculations on that data, and control the interfaced devices based on those calculations. The microcontroller stores the program in ROM inbuilt in the microcontroller. Therefore, microcontroller is a single chip microprocessor system which consists of CPU, RAM, ROM serial and parallel I/O ports, timers and interrupts. Following additional circuits are added to microcontrollers to perform some special functions. These circuits are analog to digital converters (ADC), Counter

arrays, Watchdog timers (WDT), Pulse Width Modulation (PWM) circuit, Universal Synchronous and Asynchronous Receiver Transmitter (USART) circuit, Phase Locked Loop (PLL) circuit External bus controllers. For this reason, the microcontrollers are suitable processor for embedded systems.

Embedded systems contain processing cores that are typically either microcontrollers or digital signal processors (DSP). The key characteristic, however, is being dedicated to handle a particular task. They may require very powerful processors and extensive communication. Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance. Physically, embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights, factory controllers, or the systems controlling nuclear power plants. Complexity varies from low, with a single microcontroller chip, to very high with multiple units, peripherals and networks mounted inside a large chassis or enclosure.

This book is about embedded system design and their applications. The organizations of the chapters are described here. The definition of embedded systems, categories of embedded systems, requirement of embedded systems, embedded hardware unit, embedded software units, embedded software and applications of embedded system are described in Chapter 1.

In Chapter 2 all most all embedded processors and characteristics of embedded processor are described. Microcontrollers and classification of microcontrollers are also shown in this chapter. Architecture of digital signal processor (DSP) and its application is described here.

I have described design process in embedded system, Challenges in embedded system design, formalization of system design, design examples in Chapter 3. An embedded system is characterized by real time and multi-rate operations in which the system works, reacts to events, interrupts and schedules the system's functioning in real-time. It controls latencies to meet deadlines. In this chapter latencies are describe elaborately. Microprocessor is the main part of a Real-Time Embedded System (RTES). Microprocessor selection process for embedded systems is discussed here. Now-a-days embedded systems are designed on a single silicon chip using VLSI technology. This chip is known as System on Chips (SoC). SoC is designed on a single silicon chip that has all necessary analog and digital circuits, microprocessor and software. The basic components of SoC are also described here.

In Chapter 4, interrupt types and how microprocessor responds to these interrupts in variety of applications are described. Interrupt vector table and its initialization and method of writing interrupt service procedure are described here. Programmable interrupt controller (8259A) is also required for interrupt applications. For this reason, block diagram and operation of 8259 for interruption of execution of normal program are also described. The necessary instructions for operation of 8259 are discussed elaborately in this chapter. Programmable timer/counter 8254 is also required for interrupt applications. For this reason, the operation of 8254 for interruption of execution of normal program is described here. The necessary instructions to initialize programmable timer/counter 8254 for a specified applications is discussed elaborately in this chapter. The available interrupt of microcontroller 8051 also described here.

Interfacing is a way to communicate and transfer information in either way without ending into deadlocks. It is process of effective communication in real time which involves addressing, arbitration and protocols. In Chapter 5 the interfacing of embedded microprocessor with real world is described. An interfacing circuit consists of decoders and demultiplexers and is designed according to the available control signals and timing plan of bus signals. The circuit connects all the units like processors, memory I/O bus bridge controller and I/O devices through the system buses and I/O buses. I/O bus bridge controller may be a part of the glue interfacing circuit used in the system. It is also used in Programmable Logic Device (PLD), Generic Array Logic (GAL) and FPGA. These logic circuits are also described in this chapter.

Data transmission is an important task of embedded system. For this reason, synchronous or asynchronous, serial or parallel data transmission is described in Chapter 6. EIA standard RS-232C and modem are also described here. Universal asynchronous receiver transmitter (UART - 8250) and Universal synchronous asynchronous receiver transmitter (USART-8251) are also described in this chapter.

The activities of embedded systems are taken care of by the Real-Time Operating System software stored on the non-volatile memory of the RTES. This software design of embedded system is described in Chapter 7. Program design of embedded system is simplified by program modeling. The models of software design process of embedded system are discussed in this chapter. Software is required for device drivers and device management in an operating system because an embedded system is designed to do multiple functions. For this reason device management software and device driver software are described in this chapter. This chapter also includes different software tools for designing embedded systems. In this chapter, software design methodology is described elaborately. Use of assembly level language, high level language C, object-oriented language C++ and JAVA are also discussed for embedded software design.

A process is an instance of a computer program that is being executed. It contains the program code and its current activity. Inter-process communication is described in Chapter 8. Multitasking, multiprogramming processes, threads and tasks are described here. Use of dynamic data exchange, Primary process states and additional process states are discussed in this chapter. Use of a file mapping, mail slot, pipes, remote procedure call, windows sockets for inter-process communication (IPC) are described here. Communication message-based inter-process communication, semaphores, mutex and real-time kernel; IPC using shared memory and queues are described in this chapter.

Real-time is a quantitative notion of time. Real-time is measured using a physical (real) clock. In Chapter 9, the real-time operating system is discussed. In this chapter, a basic conceptual understanding of the underlying hardware of a real-time system is described. Types of real-time tasks are described here elaborately. Real-time and embedded computing applications in the first two computing era were restricted to a few specialized applications such as space and defense. Now the use of computer systems based on real-time and embedded technologies has already touched every facet of our life. Real-time and embedded computing applications in the first two computing era were restricted to a few specialized applications such as space and defense. Now the use of computer systems based on real-time and embedded technologies has already touched every facet of our life. In this chapter, applications of real-time systems are discussed. Safety and reliability

of an embedded system is described here. Real-time tasks and real-time operating system are also discussed here.

Embedded system testing services help fulfill customers' demand for innovative, higher-performing products while addressing safety-critical issues, time-to-market and cost pressures. The value of embedded systems constitutes the software that runs them. Testing and debugging embedded systems is described in Chapter 10. Simulator software also simulates hardware units. A simulator is always independent of a particular targeted system. Simulator is very much useful during the development phase of application software for the system. For this reason, simulator is described in this chapter. Faults in embedded system are discussed here. Finally, dataflow analysis and testing tools are discussed at the end of this chapter.

Ninety three references of books journals and websites are included in this book. The readers may take help of these references for further higher studies in embedded systems.

This book is a well structured book on embedded system. It has systematic coverage and logical sequence of all topics of embedded system. Maximum effort has been given to provide correct information codes and tools. Readers are requested to point out error to the author, if any in this book.

Amar K. Ganguly

E-mail: amarganguly@rediffmail.com

Contents