Preface

Embedded Systems serves as a textbook and start-up book for undergraduate and postgraduate computer science, information technology, electronics and communication engineering and software-training-institution students, and embedded-system-design professionals. It is written in an easy-to-understand and student-friendly manner, and includes several illustrative figures and examples, sample codes and system-design case studies.

Embedded system design needs a team of hardware as well software professionals. The book explains both hardware and software concepts, while keeping multidisciplinary UGs and PGs in mind as primary readers. The earlier two editions appear to have met this task successfully for UGs and PGs in the areas of Electronics, Computer Science and Engineering on one hand, and for training software and hardware professionals and designers of Embedded Systems on the other hand. Academia, as well industry in the fields such as VLSI and System-on-Chip Technology, Automobile and Vehicular Technology, Medical-electronics and Robotics, also found the book valuable for study by start-ups in design and research areas.

Response to earlier editions in India as well as abroad has been tremendous. A rough estimate is that 16, 00, 00 engineering and professional training students, and software and hardware professionals became first-time readers of this book in India alone in the last decade. Originally published in India, the book has now McGraw-Hill team translations published in China and South Korea, International Students' edition and McGraw-Hill USA editions published from Singapore and New York.

Presumption About Reader's Basic Academic Background

The author presumes the reader has undergone thorough courses and possesses basic intellectual and academic background in microprocessors, microcontrollers, computer architecture and organization, operating systems and programming skills in C/C++.

Need for a New Edition

The new edition gives added emphasis on Embedded Systems Design and Development Processes. The edition takes into account the UG and PG level syllabi requirements and changes in recent years in the Embedded Systems paper in Electronics and Communication Engineering, Electrical Engineering, Instrumentation and Control engineering, Computer Science and Engineering, Information Technology and Computer Applications.

Specific Improvements and What's New

The new edition includes several new topics in introductory chapters of the second edition. The important ones are four separate chapters on (1) Embedded Systems Design and Development Processes, (2) 8051, AVR and ARM Microcontrollers, Real-World Interfacing, and the Inputs and Outputs Using

Buses, (3) Introduction to Advanced Architectures and Processor-Memory Organisations, and (4) I/O Devices, Communication Buses and Distributed Networked Embedded Architectures.

Further, since the previous edition, the author has been interacting with a number of young teachers, and has been receiving feedback from teachers and students almost at regular intervals. Chapters of the new edition have also been reviewed by some young, forthright and dedicated engineering college teachers. It is hoped that this edition takes care of most of their valuable suggestions and criticism.

Valuable Additions for Academia and Researchers

System-on-Chip designs, advanced architectures of computing systems, distributed networked embedded architectures and vehicular technology are new areas of interest for academia and researchers in Embedded Systems. The new edition incorporates these as valuable additions.

Book's Main Strength

The book's unique strength lies in that it explains both hardware and software concepts without over-emphasising on the microcontroller or DSP based circuits or VLSI circuits as embedded systems or over-emphasis on programming languages and OS.

Readers will find presentation and description of the following topics unique: bus arbitration, I/O devices, interfacing, communication buses, distributed networked embedded architectures, interrupts, exceptions and signals, context switching, program models, processes, threads and tasks, inter-process synchronization, real-time operating system functions and case studies presented following established software engineering practices. Instructors will find the presentation made highly interesting for the students, due to a unique common example taken in the chapters—the *Automatic Chocolate Vending Machine* software and hardware architecture and design.

Guidelines for Readers

Suggested roadmap for various disciplines of UG, PG and Professional Training Students is given in Appendix A.

The new edition of the book is expected to find greater favour internationally than the second edition and is meant to serve as a textbook as well as start-up book for the following readers:

1. Undergraduate and postgraduate computer science, information technology, electronics and communication, instrumentation and control engineering,
2. Software and Embedded System professional training programs, and
3. Design professionals, academia and researchers in areas of system-on-chip designs, advanced architectures of computing systems, distributed networked embedded architectures and vehicular technology, the new areas of interest for academia and researchers in Embedded Systems.

Roadmap for Various Courses

Learned professors and syllabi designers are the best judges. From the author's experience, the roadmap shown in the figure in Appendix A can be adapted by various disciplines of UG, PG and professional training students.

Salient Features

- Thorough explanation of embedded hardware architecture, design process and approaches, interfacing techniques, buses and protocols, hardware and software interrupts, embedded software programming, modeling of programs, interprocess synchronisation and real-time operating systems
- Comprehensive explanation with examples for learning the widely used RTOSes—µCOS-II, VxWorks, Windows CE, OSEK and real-time Linux
- Facilitates an insight into the fundamental aspects that form the basis of hardware and software designing of embedded systems
- Case studies of systems for automatic chocolate-vending machine, digital camera, TCP/IP stack creation, robot orchestra, automatic cruise control, smart card and SMS keying in mobile phone explain modeling of programs and software engineering practices for system design
- Each chapter starts with recall of salient topics and gives the learning objectives.
- Sample codes
- Detailed selected bibliography of books, journal references and important web links at the end of the book to facilitate building a startup library for references and further studies in embedded systems
- Incorporates pedagogical features such as a large number of examples, sample codes and case studies, demonstrations of software engineering practice of UML model design and diagrams, how to design and program a system, and end-chapter glossary of important terms, review questions and practice exercises

  - Illustrations: 250
  - Examples: 215
  - Review Questions: 265
  - Practice Exercises: 200

Chapter Organization

Organization of the chapters in the new edition is as follows:

Chapter 1 gives a detailed introduction to embedded systems. The chapter introduces the hardware units, the embedded ROM image of the system and application software. It also introduces languages used to develop the embedded software, embedded system design, architecture and models. It also gives a broad classification of the systems and requirement of skills for system development while providing a number of applications.

Chapter 2 introduces the designing of an embedded system on SoC (System on Chip) and use of VLSI circuit-design technology, AISC, IP cores, microprocessors, ASIPs, microcontrollers, DSPs and multiprocessors in complex systems. The chapter gives concepts of the design process, design metrics, abstraction, challenges and issues in the embedded-system design. It introduces system design technologies and formalism. Three design examples of embedded hardware and software are given at the end.

Chapter 3 explains features of the 8051 architecture and introduces processing instructions, memory, ports, counters/timers, serial input-output (IO) and interrupt handler units. It also introduces ATMEL AVR® and ARM® microcontrollers. The chapter describes the interfacing of system memory and IO buses in a computing system. It describes how the buses interface memory devices, real-world devices and components. It illustrates bus architectures, bus performance and input-output performance, multilevel bus architecture and methods of bus-arbitration in a computer system. It introduces network-oriented bus arbitration in a network of distributed devices and controllers.

Chapter 4 enables readers to learn about advanced structural units in a processor that enhances the processing power in an embedded system. The readers will learn concepts of instruction-level parallelism, pipelining, superscalar processing and cache units, and the x86, ARM and SHARC architectures. They will also learn about memory devices. This chapter explains performance metrics for measuring performance of the processor. It lists the processor and memory selection methods for a given embedded system.

Chapter 5 describes the devices: parallel and serial port devices, timing devices, devices for asynchronous, iso-synchronous and asynchronous communications and important buses for networking these. Also described are distributed network architectures and networks of the embedded systems using the I^2C, CAN, USB, advanced serial high-speed buses, ISA, PCI, PCI-X and advanced parallel high-speed buses. The chapter describes Internet-enabled embedded devices and their network protocols. It also introduces wireless protocols for mobile and wireless networks of embedded devices.

Chapter 6 describes the concepts of hardware and software interrupts, and data transfer from ports and devices using interrupt servicing and handling mechanism, essential for an embedded-system designer. It explains the concepts of context, the periods for context-switching, interrupt latencies and deadlines. The chapter explains DMA method of data transfer and introduces device drivers with examples.

Chapter 7 explains the programming concepts and embedded-system programming in embedded C/C++/Java. Object-oriented programming concepts in C++ and Java are also described in this chapter.

Chapter 8 describes the concepts of event polling, sequential, state machine and concurrent-processing programming models. The uses of data flow and control data flow graphs are explained. Program models during real-time programming and uses of FSM are described. How do we model multiprocessors, and schedule and synchronize the processing of instructions on these? This chapter enables a reader to know the answers to this question. This chapter also gives the basics of UML modelling using diagrams.

Chapter 9 covers the most important aspect of real-time programming, namely, the concept of the processes, tasks and threads and inter-process communications. It describes the use of semaphores. This chapter explains thoroughly the use of signals, mutex, message queues, mailboxes, pipes, virtual (logical) sockets and remote procedure calls.

Chapter 10 describes RTOS concepts, and the kernel functions. It explains the process, memory, devices, files and IO subsystem management functions. The OS controls the interrupt-handling mechanism, and thus execution of interrupt service routines (ISRs) and ISTs (interrupt service threads). RTOS provides for synchronisation of the ISRs, ISTs and processes, tasks and threads. RTOS enables hard real-time and soft real-time operations and provides for asynchronous IOs. The chapter describes scheduling of multiple tasks in an RTOS environment.

Chapter 11 introduces Unix-based real-time operating systems: PSoS, VRTX, QNX and VxWorks. The chapter describes two most important RTOS tools, C/OS-II and VxWorks, in detail with coding examples of the use of OS functions in these RTOSes.

Chapter 12 describes the POSIX compliant systems and Linux based RTOSes: Real-Time Linux, Embedding Linux and RT Linux. It describes Windows as a real-time operating system, handheld and automobile real-time systems, Windows CE and Windows 8 Embedded. It also introduces OSEK—an operating system for automobile applications.

Chapter 13 describes seven case studies of programming with RTOS. These are automatic chocolate-vending machine system, digital camera, TCP/IP network system, communication between master robots and slave robots, adaptive cruise control system in a car, access control and card-host communication tasks in a smart card, and coding example using state machine concept for keying in an SMS text in a mobile device.

Chapter 14 details the software tools, source-code engineering tool, integrated development environment, and the use of two development platforms: host and target machines. It discusses the issues in embedded system development that need to be addressed by any development team. These are independent software–hardware design, hardware–software co-design, choosing the right processor, allocation of memory addresses, devices and bus, and porting issues of OS/RTOS.

Chapter 15 describes how to test the system codes on a host system as the host system has application-development tools, large memory and windows or powerful GUIs. It explains simulation on the host by the following: target processor or microcontroller, peripherals, devices and network interfaces. It introduces laboratory tools, in-circuit emulator and monitor, which help in hardware development of a target system and test and debug the target system software in the target environment.

Online Learning Center

The Web has become the best companion of teachers and students. We need the Web as much as we need food and water daily. The new edition has a number of additions in the Web supplement accompanying this book available at http://www.mhhe.com/kamal/emb3 Readers of embedded system design are expected to refer to the Web supplement topics in full. The link has the following and will be periodically updated:

For Instructors

- Solution Guide to Review Questions and Practice Exercises (Updated)
- Suggested Laboratory Experiments
- Chapterwise PowerPoint slides with diagrams and notes for effective presentation

For Students

- Chapter on ‘Software Engineering Practices in Embedded System Process’
- Multiple-Choice Questions (Updated)
- Additional details of all the Case Studies in the book

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Invitation for Feedback

The author expects that students and professionals will love this new edition too and the book will let students hone their problem-solving and system design skills using modeling practices and learn more key concepts in the embedded hardware architecture, interfaces, buses, software programming design and RTOSes.

Although much care has been taken to ensure an error-free text, some errors may have crept in. The author shall be grateful for pointing these out to him. The feedback on content of the book as well as online PPTs and other reading Web supplement material at the McGraw Hill site from readers, particularly students, teachers, scholars, and professionals, will be highly appreciated through *Query* or *Contact Me* links at the author's website at http://www.mhhe.com/kamal/emb3

Raj Kamal

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