

Contents

Preface xv

1. Introduction to Embedded Systems	1-34
1.1 Embedded System	1
1.2 Processor Embedded into a System	4
1.3 Embedded Hardware Units and Devices in a System	11
1.4 Embedded Software in a System and an Overview of Programming Languages	16
1.5 Introduction to Embedded-system design	21
1.6 Introduction to Embedded-system Architecture	22
1.7 Introduction to Embedded-system Model	23
1.8 Classification of Embedded Systems	25
1.9 Skills required for an Embedded-system Designer	26
1.10 Examples of the Embedded Systems	27
<i>Summary</i>	28
<i>Keywords</i>	29
<i>Review Questions</i>	33
<i>Practice Exercises</i>	34
2. Embedded Systems Design and Development Process	35-70
2.1 Embedded System-On-Chip (SoC) and Use of VLSI Circuit Design Technology	36
2.2 Complex Systems Design and Processors	40
2.3 Build Process for Embedded Systems	45
2.4 Design Process in Embedded System	45
2.5 Design Challenges in Embedded-System Design	50
2.6 Challenges in Embedded-System Design: Optimising the Design Metrics	51
2.7 Challenges and Issues Related to Embedded-Software Development	53
2.8 Hardware–Software Co-Design in an Embedded System	55
2.9 Embedded-System Design Technologies	57
2.10 Formalism of System Design	59
2.11 Design Process and Design Examples	59
<i>Summary</i>	67
<i>Keywords</i>	68
<i>Review Questions</i>	69
<i>Practice Exercises</i>	70

- 3. 8051, AVR and ARM Microcontrollers, Real-World Interfacing, and the Inputs and Outputs Using Buses** **71-109**
- 3.1 Introduction to Microcontrollers and Microprocessors 72
 - 3.2 Embedded Versus External Memory Devices 72
 - 3.3 Example of a Microcontroller–8051 Architecture 73
 - 3.4 ATMEL AVR Microcontrollers 82
 - 3.5 ARM Microcontrollers 84
 - 3.6 Computer-System Buses 85
 - 3.7 Real-World Interfacing 91
 - 3.8 I/O Performance 97
 - 3.9 I/O Buses 98
 - 3.10 Network-Oriented Bus Arbitration 101
 - 3.11 Buses 102
 - 3.12 Multilevel Buses 102
 - Summary* 105
 - Keywords* 105
 - Review Questions* 108
 - Practice Exercises* 109
- 4. Introduction to Advanced Architectures and Processor-Memory Organisations** **110-143**
- 4.1 Processor and Memory Organisation 110
 - 4.2 Introduction to Advanced Processor Architectures 114
 - 4.3 Processor Organisation 118
 - 4.4 Instruction-Level Parallelism 120
 - 4.5 Intel x86 Architecture (8086, 80386, 80486 and Pentium) 122
 - 4.6 ARM 124
 - 4.7 SHARC 126
 - 4.8 Memory Types and Addresses 127
 - 4.9 Memory Addresses 134
 - 4.10 Memory Hierarchy and Cache 135
 - 4.11 Performance Metrics 136
 - 4.12 Selection of Processor and Memory Devices 137
 - Summary* 139
 - Keywords* 139
 - Review Questions* 142
 - Practice Exercises* 142
- 5. I/O Devices, Communication Buses and Distributed Networked Embedded Architectures** **144-192**
- 5.1 I/O Types and Examples 145
 - 5.2 Serial Communication Devices 150
 - 5.3 Parallel Device Ports 159

- 5.4 Sophisticated Interfacing Features in Device Ports 163
- 5.5 Wireless Devices 164
- 5.6 Timer and Counting Devices 164
- 5.7 Distributed Network Embedded Systems Architecture 167
- 5.8 Serial Bus Communication Protocols 169
- 5.9 Parallel Bus Device Protocols—Parallel Communication
Network Using the ISA, PCI, PCI-X and Advanced Buses 175
- 5.10 Internet Enabled Systems—Network Protocols 178
- 5.11 Wireless and Mobile System Protocols 182
 - Summary* 186
 - Keywords* 187
 - Review Questions* 191
 - Practice Exercises* 191

6. Device Drivers and Interrupts Service Mechanism

193-226

- 6.1 Port for Device Access without Interrupts Servicing
Mechanism Using Programmed I/O 193
- 6.2 Interrupt-driven Input and Output 199
- 6.3 Interrupt Service Routine Concept 201
- 6.4 Interrupt Sources 202
- 6.5 Hardware Interrupts 203
- 6.6 Software Interrupts 204
- 6.7 Interrupt-servicing Mechanism 207
- 6.8 Multiple Interrupts 211
- 6.9 Interrupt Service Threads as Second-Level Interrupt Handlers 213
- 6.10 Context and the Periods for Context Switching 214
- 6.11 Interrupt Latency 214
- 6.12 Interrupt-Service Deadline 216
- 6.13 Classification of Processors' Interrupt-Service Mechanism from
Context-Saving Angle 217
- 6.14 Direct Memory Access Driven I/O 217
- 6.15 Device Driver Programming 220
 - Summary* 223
 - Keywords* 224
 - Review Questions* 226
 - Practice Exercises* 226

7. Programming Concepts and Embedded Programming in C, C++ and Java 227-262

- 7.1 Programming in Assembly Language (ALP) and in
High-Level Language 'C' 228
- 7.2 'C' Program Elements: Header and Source Files and
Preprocessor Directives 229



7.3	Program Elements: Macros and Functions	231
7.4	Program Elements: Data Types, Data Structures, Modifiers, Statements, Loops and Pointers	233
7.5	Use of Loops, Infinite Loops and Conditions	241
7.6	Use of Function Calls	245
7.7	Multiple Function Calls in Cyclic Order	246
7.8	Function Pointers and Function Queues	247
7.9	Queuing of Functions on Interrupts and Interrupt-Service-Routine Queues	248
7.10	Embedded C and C++: Overview of Additional Features	250
7.11	Objected-Oriented Programming	254
7.12	Embedded Programming in C++	254
7.13	Optimisation of Codes and Memory Needs in Embedded C++ Programs to Eliminate the Disadvantages	255
7.14	Embedded Programming in Java	256
	<i>Summary</i>	258
	<i>Keywords</i>	259
	<i>Review Questions</i>	262
	<i>Practice Exercises</i>	262
8.	Program Modeling Concepts	263-289
8.1	Program Models	264
8.2	Data-Flow Graph-Based Program Models	268
8.3	State-Machine Programming Models for Event-Controlled Programs	272
8.4	Modeling of Multiprocessor Systems	278
8.5	UML Modeling	282
	<i>Summary</i>	287
	<i>Keywords</i>	287
	<i>Review Questions</i>	288
	<i>Practice Exercises</i>	288
9.	Real Time Operating Systems– I: Processes, Tasks and Threads and their Synchronization Using Inter-process Communication	290-331
9.1	Multiple Processes in an Application	291
9.2	Multiple Threads in an Application	293
9.3	Tasks	294
9.4	Task and Thread States	295
9.5	Tasks and Data	297
9.6	Clear-cut Distinction between Function, ISR, IST and Task by their Characteristics	299
9.7	Inter-process Communication and Synchronisation	300
9.8	Signals	301

- 9.9 Concept of Semaphores 303
- 9.10 Disabling and Enabling Functions 314
- 9.11 Shared Data Problem 315
- 9.12 Queues and Mailboxes 318
- 9.13 Pipe and Socket Functions 323
- 9.14 Remote Procedure Call Functions 328
 - Summary* 328
 - Keywords* 329
 - Review Questions* 330
 - Practice Exercises* 331

10. Real Time Operating Systems II: Basic Functions of OS and RTOS 332-365

- 10.1 Operating System Services 333
- 10.2 Process Management 335
- 10.3 Timer Functions 335
- 10.4 Event Functions 337
- 10.5 Memory Management 338
- 10.6 Device, File, and I/O Subsystems Management 339
- 10.7 Interrupt Routines in RTOS Environment and Handling of Interrupt-Source Calls 344
- 10.8 Introduction to Real-Time Operating Systems 347
- 10.9 Basic Design Using a Real-Time Operating System 348
- 10.10 RTOS Task-Scheduling Models 356
- 10.11 OS Security Issues 357
- 10.12 OS Standards: POSIX 358
- 10.13 RTOS Interrupt Latency and Response Times of the Tasks as Performance Metrics 360
- 10.14 OS Performance Guidelines 361
- 10.15 Middleware: Meaning and Examples 361
- 10.16 Application-layer Software: Meanings and Examples 362
 - Summary* 362
 - Keywords* 363
 - Review Questions* 364
 - Practice Exercises* 364

11. Real-time Operating System Programming: MicroC/OS-II and VxWorks 366-424

- 11.1 Real-Time Operating Systems (RTOSes) 367
- 11.2 μ C/OS-II (MUCOS) 370
- 11.3 Introduction to Unix-based Real-time Operating Systems 399
- 11.4 RTOS VxWorks 400
 - Summary* 421

Keywords 422
Review Questions 424
Practice Exercises 424

- 12. Real-Time Linux, Windows CE, OSEK, Handheld Devices and Automotives Operating Systems** **425-460**
- 12.1 POSIX Compliant Operating Systems 426
 12.2 Real-Time Linux Operating systems 426
 12.3 Windows CE 436
 12.4 OSEK 451
 Summary 454
 Keywords 456
 Review Questions 459
 Practice Exercises 459
- 13. Design Examples and Case Studies of Program-Modeling and Programming with RTOS** **461-519**
- 13.1 Case Study of Coding for an Automatic Chocolate Vending Machine using MUCOS RTOS 462
 13.2 Case Study of Digital Camera 471
 13.3 Application to Communication—Network Router for IP Packets 477
 13.4 Embedded Systems in Robotics: Case Study of Orchestra Playing Robots 484
 13.5 RTOS for Control Systems 491
 13.6 Case Study of an Embedded System for an Adaptive Cruise Control (ACC) System in a Car 492
 13.7 General Language Characteristics, Features of MISRA-C for Embedded Programming in Automobiles 499
 13.8 Case Study of an Embedded System for a Smart Card, Access Control Systems (Smart Cards, RFIDs, Fingerscan) 500
 13.9 Case Study of a Mobile-Phone Software for Key Inputs 505
 Summary 514
 Keywords 515
 Review Questions 518
 Practice Exercises 519
- 14. Embedded Software Development Process and Tools** **520-546**
- 14.1 Introduction to Embedded Software-Development Process and Tools 520
 14.2 Host and Target Machines 525
 14.3 Linking and Locating Software 527
 14.4 Getting Embedded Software into the Target System 532

- 14.5 Issues in Hardware Software Design and Co-Design 533
- 14.6 Program-Level Performance Analysis and Performance Modeling 541
- 14.7 Performance and Performance Accelerators 542
 - Summary* 543
 - Keywords* 543
 - Review Questions* 545
 - Practice Exercises* 546

15. Testing, Simulation, and Debugging Techniques and Tools

547-564

- 15.1 Integration and Testing of Embedded Hardware 548
- 15.2 Testing Methods 550
- 15.3 Debugging Techniques 553
- 15.4 Laboratory Tools and Target Hardware Debugging 557
 - Summary* 563
 - Keywords* 563
 - Review Questions* 564
 - Practice Exercises* 564

Appendix A 565**Appendix B** 567**Index** 573