CONTENTS

Preface *page* xi

1 Introduction 1
1.1 What is computer architecture? 2
1.2 Components of a parallel architecture 5
1.3 Parallelism in architectures 13
1.4 Performance 17
1.5 Technological challenges 26
Exercises 30

2 Impact of technology 36
2.1 Chapter overview 36
2.2 Basic laws of electricity 37
2.3 The MOSFET transistor and CMOS inverter 39
2.4 Technology scaling 43
2.5 Power and energy 45
2.6 Reliability 54
Exercises 71

3 Processor microarchitecture 74
3.1 Chapter overview 74
3.2 Instruction set architecture 75
3.3 Statically scheduled pipelines 91
3.4 Dynamically scheduled pipelines 111
3.5 VLIW microarchitectures 140
3.6 EPIC microarchitectures 157
3.7 Vector microarchitectures 158
Exercises 165

4 Memory hierarchies 193
4.1 Chapter overview 193
4.2 The pyramid of memory levels 194
4.3 Cache hierarchy 198
4.4 Virtual memory 212
Exercises 224

5 Multiprocessor systems 232
5.1 Chapter overview 232
5.2 Parallel-programming model abstractions 233
5.3 Message-passing multiprocessor systems 239
5.4 Bus-based shared-memory systems 246
5.5 Scalable shared-memory systems 276
5.6 Cache-only shared-memory systems 293
Exercises 298

6 Interconnection networks 309
6.1 Chapter overview 309
6.2 Design space of interconnection networks 311
6.3 Switching strategies 319
6.4 Topologies 322
6.5 Routing techniques 330
6.6 Switch architecture 337
Exercises 339

7 Coherence, synchronization, and memory consistency 342
7.1 Chapter overview 342
7.2 Background 344
7.3 Coherence and store atomicity 350
7.4 Sequential consistency 375
7.5 Synchronization 388
7.6 Relaxed memory-consistency models 398
7.7 Speculative violations of memory orders 411
Exercises 415

8 Chip multiprocessors 425
8.1 Chapter overview 425
8.2 Rationale behind CMPs 426
8.3 Core multi-threading 429
8.4 Chip multiprocessor architectures 446
8.5 Programming models 459
Exercises 482

9 Quantitative evaluations 488
9.1 Chapter overview 488
9.2 Taxonomy of simulators 490
9.3 Integrating simulators 498
9.4 Multiprocessor simulators 500

9.5 Power and thermal simulations 508
9.6 Workload sampling 510
9.7 Workload characterization 514
Exercises 516

Index 521