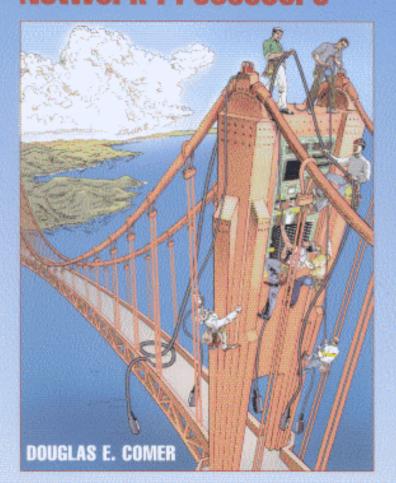
Network Systems Design Network Processors



Contents

Forew	Foreword	
Prefac	e	xxiii
Chapte	er 1 Introduction And Overview	1
1.1	Network Systems And The Internet 1	
1.2	Applications Vs. Infrastructure 1	
1.3	Network Systems Engineering 2	
1.4	Packet Processing 2	
1.5	Achieving High Speed 3	
1.6	Network Speed 3	
1.7	Hardware, Software, And Hybrids 4	
1.8	Scope And Organization Of The Text 5	
1.9	Summary 5	
Chapte	er 2 Basic Terminology And Example Systems	7
2.1	Introduction 7	
2.2	Networks And Packets 7	
2.3	Connection-Oriented And Connectionless Paradigms 8	
2.4	Digital Circuits 8	
2.5	LAN And WAN Classifications 9	
2.6	The Internet And Heterogeneity 9	
2.7	Example Network Systems 9	
2.8	Broadcast Domains 10	
2.9	The Two Key Systems Used In The Internet 11	
2.10	Other Systems Used In The Internet 12	
2.11	Monitoring And Control Systems 13	
2.12	Summary 13	

viii Contents

Chapte	r 3 Review Of Protocols And Packet Formats	15
3.1	Introduction 15	
3.2	Protocols And Layering 15	
3.3	Layers 1 And 2 (Physical And Network Interface) 17	
3.4	Layer 3 (Internet) 19	
3.5	Layer 4 (Transport) 20	
3.6	Protocol Port Numbers And Demultiplexing 23	
3.7	Encapsulation And Transmission 23	
3.8	Address Resolution Protocol 24	
3.9	Summary 24	
PART	I Traditional Protocol Processing Systems	
Chapte	r 4 Conventional Computer Hardware Architecture	29
4.1	Introduction 29	
4.2	A Conventional Computer System 29	
4.3	Network Interface Cards 30	
4.4	Definition Of A Bus 31	
4.5	The Bus Address Space 32	
4.6	The Fetch-Store Paradigm 33	
4.7	Network Interface Card Functionality 34	
4.8	NIC Optimizations For High Speed 34	
4.9	Onboard Address Recognition 35	
4.10	Onboard Packet Buffering 36	
4.11	Direct Memory Access 37	
4.12	Operation And Data Chaining 38	
4.13	Data Flow Diagram 39	
4.14	Promiscuous Mode 39	
4.15	Summary 40	
01	. 5. Boole Booket Duces of the Alexandrian And Bata Churching	40
Chapte	r 5 Basic Packet Processing: Algorithms And Data Structures	43
5.1	Introduction 43	
5.2	State Information and Resource Exhaustion 43	
5.3	Packet Buffer Allocation 44	
5.4	Packet Buffer Size And Copying 45	
5.5	Protocol Layering And Copying 45	
5.6	Heterogeneity And Network Byte Order 46	
<i>5.7</i>	Bridge Algorithm 47	

Contents ix

5.13	Table Lookup And Hashing 49 IP Datagram Fragmentation And Reassembly 50 IP Datagram Forwarding 56 IP Forwarding Algorithm 57 High-Speed IP Forwarding 57 TCP Connection Recognition Algorithm 59 TCP Splicing Algorithm 60 Summary 63	
Chapter	6 Packet Processing Functions	67
6.1	Introduction 67	
6.2	Packet Processing 68	
6.3	Address Lookup And Packet Forwarding 68	
6.4	Error Detection And Correction 69	
6.5	Fragmentation, Segmentation, And Reassembly 70	
6.6	Frame And Protocol Demultiplexing 70	
6.7	Packet Classification 71	
6.8	Queueing And Packet Discard 73	
6.9	Scheduling And Timing 75	
6.10	Security: Authentication And Privacy 76	
6.11	Traffic Measurement And Policing 76	
6.12	Traffic Shaping 77	
6.14	Summary 80	
Chapter	7 Protocol Software On A Conventional Processor	83
7.1	Introduction 83	
7.2	Implementation Of Packet Processing In An Application 83	
7.3	Fast Packet Processing In Software 84	
7.4	Embedded Systems 84	
7.5	Operating System Implementations 85	
7.6	Software Interrupts And Priorities 85	
7.7	Multiple Priorities And Kernel Threads 87	
7.8	Thread Synchronization 88	
7.9	Software For Layered Protocols 88	
7.10	Asynchronous Vs. Synchronous Programming 92	
7.11	Summary 93	

8 Hardware Architectures For Protocol Processing	97
Introduction 97	
Network Systems Architecture 97	
The Traditional Software Router 98	
Aggregate Data Rate 99	
Aggregate Packet Rate 99	
Packet Rate And Software Router Feasibility 101	
Overcoming The Single CPU Bottleneck 103	
Fine-Grain Parallelism 104	
Symmetric Coarse-Grain Parallelism 104	
Asymmetric Coarse-Grain Parallelism 105	
Special-Purpose Coprocessors 105	
ASIC Coprocessor Implementation 106	
NICs With Onboard Processing 107	
Smart NICs With Onboard Stacks 108	
Cells And Connection-Oriented Addressing 108	
Data Pipelines 109	
Summary 111	
Introduction 115	
v v	
Fine-Grain Flow Creation 125	
Flow Forwarding In A Connection-Oriented Network 126	
•	
Connectionless Network Classification And Forwarding 126	
Connectionless Network Classification And Forwarding 126 Second Generation Network Systems 127	
	Network Systems Architecture 97 The Traditional Software Router 98 Aggregate Data Rate 99 Aggregate Packet Rate 99 Packet Rate And Software Router Feasibility 101 Overcoming The Single CPU Bottleneck 103 Fine-Grain Parallelism 104 Symmetric Coarse-Grain Parallelism 105 Special-Purpose Coprocessors 105 ASIC Coprocessor Implementation 106 NICS With Onboard Processing 107 Smart NICS With Onboard Stacks 108 Cells And Connection-Oriented Addressing 108 Data Pipelines 109 Summary 111 9 Classification And Forwarding Introduction 115 Inherent Limits Of Demultiplexing 115 Packet Classification 116 Software Implementation Of Classification 118 Software Classification Of Special-Purpose Hardware 119 Hardware Implementation Of Classification 119 Optimized Classification Of Multiple Rule Sets 120 Classification Of Variable-Size Headers 122 Hybrid Hardware/Software Classification 123 Dynamic Vs. Static Classification 124

Contents xi

Chapter	10 Switching Fabrics	133
10.1	Introduction 133	
10.2	Bandwidth Of An Internal Fast Path 133	
10.3	The Switching Fabric Concept 134	
10.4	Synchronous And Asynchronous Fabrics 135	
10.5	A Taxonomy Of Switching Fabric Architectures 136	
10.6	Dedicated Internal Paths And Port Contention 136	
10.7	Crossbar Architecture 137	
10.8	Basic Queueing 139	
10.9	Time Division Solutions: Sharing Data Paths 141	
10.10	Shared Bus Architecture 141	
10.11	Other Shared Medium Architectures 142	
10.12	Shared Memory Architecture 143	
10.13	Multistage Fabrics 144	
10.14	Banyan Architecture 145	
10.15	Scaling A Banyan Switch 146	
10.16	Commercial Technologies 148	
10.17	Summary 148	
	·	
PART	II Network Processor Technology r 11 Network Processors: Motivation And Purpose	153
PART Chapter	II Network Processor Technology r11 Network Processors: Motivation And Purpose	150
PART Chapte	II Network Processor Technology r11 Network Processors: Motivation And Purpose Introduction 153	153
PART Chapter	II Network Processor Technology r 11 Network Processors: Motivation And Purpose Introduction 153 The CPU In A Second Generation Architecture 153	153
PART Chapter 11.1 11.2 11.3	Il Network Processor Technology r 11 Network Processors: Motivation And Purpose Introduction 153 The CPU In A Second Generation Architecture 153 Third Generation Network Systems 154	153
PART Chapter 11.1 11.2 11.3 11.4	Il Network Processor Technology r 11 Network Processors: Motivation And Purpose Introduction 153 The CPU In A Second Generation Architecture 153 Third Generation Network Systems 154 The Motivation For Embedded Processors 155	153
PART Chapter 11.1 11.2 11.3 11.4 11.5	Il Network Processor Technology r 11 Network Processors: Motivation And Purpose Introduction 153 The CPU In A Second Generation Architecture 153 Third Generation Network Systems 154 The Motivation For Embedded Processors 155 RISC vs. CISC 155	153
PART Chaptel 11.1 11.2 11.3 11.4 11.5 11.6	Il Network Processor Technology 11 Network Processors: Motivation And Purpose Introduction 153 The CPU In A Second Generation Architecture 153 Third Generation Network Systems 154 The Motivation For Embedded Processors 155 RISC vs. CISC 155 The Need For Custom Silicon 156	153
PART Chapter 11.1 11.2 11.3 11.4 11.5 11.6 11.7	Il Network Processor Technology 11 Network Processors: Motivation And Purpose Introduction 153 The CPU In A Second Generation Architecture 153 Third Generation Network Systems 154 The Motivation For Embedded Processors 155 RISC vs. CISC 155 The Need For Custom Silicon 156 Definition Of A Network Processor 157	
PART Chapter 11.1 11.2 11.3 11.4 11.5 11.6 11.7 11.8	Il Network Processor Technology 11 Network Processors: Motivation And Purpose Introduction 153 The CPU In A Second Generation Architecture 153 Third Generation Network Systems 154 The Motivation For Embedded Processors 155 RISC vs. CISC 155 The Need For Custom Silicon 156 Definition Of A Network Processor 157 A Fundamental Idea: Flexibility Through Programmability 1	15 3
PART Chapter 11.1 11.2 11.3 11.4 11.5 11.6 11.7 11.8 11.9	Il Network Processor Technology 11 Network Processors: Motivation And Purpose Introduction 153 The CPU In A Second Generation Architecture 153 Third Generation Network Systems 154 The Motivation For Embedded Processors 155 RISC vs. CISC 155 The Need For Custom Silicon 156 Definition Of A Network Processor 157 A Fundamental Idea: Flexibility Through Programmability 1 Instruction Set 159	
PART Chaptel 11.1 11.2 11.3 11.4 11.5 11.6 11.7 11.8 11.9 11.10	Il Network Processor Technology 11 Network Processors: Motivation And Purpose Introduction 153 The CPU In A Second Generation Architecture 153 Third Generation Network Systems 154 The Motivation For Embedded Processors 155 RISC vs. CISC 155 The Need For Custom Silicon 156 Definition Of A Network Processor 157 A Fundamental Idea: Flexibility Through Programmability Instruction Set 159 Scalability With Parallelism And Pipelining 159	
PART Chaptel 11.1 11.2 11.3 11.4 11.5 11.6 11.7 11.8 11.9 11.10 11.11	Il Network Processor Technology 11 Network Processors: Motivation And Purpose Introduction 153 The CPU In A Second Generation Architecture 153 Third Generation Network Systems 154 The Motivation For Embedded Processors 155 RISC vs. CISC 155 The Need For Custom Silicon 156 Definition Of A Network Processor 157 A Fundamental Idea: Flexibility Through Programmability Instruction Set 159 Scalability With Parallelism And Pipelining 159 The Costs And Benefits Of Network Processors 160	
PART Chapter 11.1 11.2 11.3 11.4 11.5 11.6 11.7 11.8 11.9 11.10 11.11 11.12	Il Network Processor Technology 11 Network Processors: Motivation And Purpose Introduction 153 The CPU In A Second Generation Architecture 153 Third Generation Network Systems 154 The Motivation For Embedded Processors 155 RISC vs. CISC 155 The Need For Custom Silicon 156 Definition Of A Network Processor 157 A Fundamental Idea: Flexibility Through Programmability 1 Instruction Set 159 Scalability With Parallelism And Pipelining 159 The Costs And Benefits Of Network Processors 160 Network Processors And The Economics Of Success 161	
PART Chapter 11.1 11.2 11.3 11.4 11.5 11.6 11.7 11.8 11.9 11.10 11.11 11.12 11.13	Il Network Processor Technology 11 Network Processors: Motivation And Purpose Introduction 153 The CPU In A Second Generation Architecture 153 Third Generation Network Systems 154 The Motivation For Embedded Processors 155 RISC vs. CISC 155 The Need For Custom Silicon 156 Definition Of A Network Processor 157 A Fundamental Idea: Flexibility Through Programmability Instruction Set 159 Scalability With Parallelism And Pipelining 159 The Costs And Benefits Of Network Processors 160	

xii Contents

Chapter	12 The Complexity Of Network Processor Design	165
12.1	Introduction 165	
12.2	Network Processor Functionality 165	
12.3	Packet Processing Functions 166	
12.4	Ingress And Egress Processing 167	
12,5	Parallel And Distributed Architecture 170	
12.6	The Architectural Roles Of Network Processors 171	
12.7	Consequences For Each Architectural Role 171	
12.8	Macroscopic Data Pipelining And Heterogeneity 173	
12.9	Network Processor Design And Software Emulation 173	
12.10	Summary 174	
Chapter	13 Network Processor Architectures	177
13.1	Introduction 177	
13.2	Architectural Variety 177	
13.3	Primary Architectural Characteristics 178	
13.4	Architecture, Packet Flow, And Clock Rates 186	
13.5	Software Architecture 189	
13.6	Assigning Functionality To The Processor Hierarchy 189	
13.7	Summary 191	
Chapter	14 Issues in Scaling A Network Processor	195
14.1	Introduction 195	
14.2	The Processing Hierarchy And Scaling 195	
14.3	Scaling By Making Processors Faster 196	
14.4	Scaling By Increasing The Number of Processors 196	
14.5	Scaling By Increasing Processor Types 197	
14.6	Scaling A Memory Hierarchy 198	
14.7	Scaling By Increasing Memory Size 200	
14.8	Scaling By Increasing Memory Bandwidth 200	
14.9	Scaling By Increasing Types Of Memory 201	
	Scaling By Adding Memory Caches 202	
	Scaling With Content Addressable Memory 203	
	Using CAM for Packet Classification 205	
	Other Limitations On Scale 207	
	Software Scalability 208	
	Bottlenecks And Scale 209	
14.10	Summary 209	

Contents xiii

Chapter	15 Examples Of Commercial Network Processors	213
15.1	Introduction 213	
15.2	An Explosion Of Commercial Products 213	
15.3	A Selection of Products 214	
15.4	Multi-Chip Pipeline (Agere) 214	
15.5	Augmented RISC Processor (Alchemy) 218	
15.6	Embedded Processor Plus Coprocessors (AMCC) 219	
15.7	Pipeline Of Homogeneous Processors (Cisco) 221	
	Configurable Instruction Set Processors (Cognigine) 222	
	Pipeline Of Heterogeneous Processors (EZchip) 223	
	Extensive And Diverse Processors (IBM) 225	
	Flexible RISC Plus Coprocessors (Motorola) 227	
15.12	Summary 231	
Chapter	16 Languages Used For Classification	233
16.1	Introduction 233	
16.2	Optimized Classification 233	
16.3	Imperative And Declarative Paradigms 234	
16.4	A Programming Language For Classification 235	
16.5	Automated Translation 235	
16.6	Language Features That Aid Programming 236	
16.7	The Relationship Between Language And Hardware 236	
16.8	Efficiency And Execution Speed 237	
	Commercial Classification Languages 238	
	Intel's Network Classification Language (NCL) 238	
	An Example Of NCL Code 239	
	NCL Intrinsic Functions 242	
	Predicates 243	
	Conditional Rule Execution 243	
	Incremental Protocol Definition 244	
	NCL Set Facility 245	
	Other NCL Features 246	
	Agere's Functional Programming Language (FPL) 247	
	Two Pass Processing 247	
	Designating The First And Second Pass 249	
	Using Patterns For Conditionals 249	
	Symbolic Constants 251	
	Example FPL Code For Second Pass Processing 251	
	Sequential Pattern Matching Paradigm 252	
	Tree Functions And The BITS Default 254	
10.26	Return Values 254	

xiv Contents

16.28 16.29	Passing Information To The Routing Engine 254 Access To Built-in And External Functions 255 Other FPL Features 255 Summary 257	
Chapter	17 Design Tradeoffs And Consequences	261
17.1	Introduction 261	
17.2	Low Development Cost Vs. Performance 261	
17.3	Programmability Vs. Processing Speed 262	
17.4	Performance: Packet Rate, Data Rate, And Bursts 262	
	Speed Vs. Functionality 263	
	Per-Interface Rate Vs. Aggregate Data Rate 263	
17.7	Network Processor Speed Vs. Bandwidth 263	
17.8	Coprocessor Design: Lookaside Vs. Flow-Through 264	
	Pipelining: Uniform Vs. Synchronized 264	
	Explicit Parallelism Vs. Cost And Programmability 264	
	Parallelism: Scale Vs. Packet Ordering 265	
	Parallelism: Speed Vs. Stateful Classification 265	
	Memory: Speed Vs. Programmability 265	
	I/O Performance Vs. Pin Count 266	
	Programming Languages: A Three-Way Tradeoff 266	
	Multithreading: Throughput Vs. Programmability 266	
	Traffic Management Vs. Blind Forwarding At Low Cost 267	
	Generality Vs. Specific Architectural Role 267	
	Memory Type: Special-Purpose Vs. General-Purpose 267	
	Backward Compatibility Vs. Architectural Advances 268	
	Parallelism Vs. Pipelining 268	
17.22	Summary 269	
PART	III Example Network Processor	
Chapte	18 Overview Of The Intel Network Processor	273
18.1	Introduction 273	
18.2	Intel Terminology 273	
	IXA: Internet Exchange Architecture 274	
	IXP: Internet Exchange Processor 274	
	Basic IXP1200 Features 275	
18.6	External Connections 275	
18.7	Internal Components 278	
18.8	IXP1200 Processor Hierarchy 279	

Contents xv

18.9	IXP1200 Memory Hierarchy 281	
	Word And Longword Addressing 283	
	An Example Of Underlying Complexity 283	
18.12	Other Hardware Facilities 285	
18.13	Summary 285	
	·	
Chante	r 19 Embedded RISC Processor (StrongARM Core)	289
Onapte	To Embedded Hoo Frocesor (orongamin ooro)	200
19.1	Introduction 289	
19.2	Purpose Of An Embedded Processor 289	
19.3	StrongARM Architecture 291	
19.4	RISC Instruction Set And Registers 291	
19.5	StrongARM Memory Architecture 292	
19.6	StrongARM Memory Map 293	
19.7	Virtual Address Space And Memory Management 294	
19.8	Shared Memory And Address Translation 294	
19.9	Internal Peripheral Units 295	
19.10	Other I/O 296	
19.11	User And Kernel Mode Operation 296	
19.12	Coprocessor 15 297	
19.13	Summary 297	
Chapte	r 20 Packet Processor Hardware (Microengines And FBI)	301
20.1	Introduction 301	
20.2	The Purpose Of Microengines 301	
20.3	Microengine Architecture 302	
20.4	The Concept Of Microsequencing 302	
	Microengine Instruction Set 303	
	Separate Memory Address Spaces 305	
	Execution Pipeline 305	
	The Concept Of Instruction Stalls 307	
	Conditional Branching And Pipeline Abort 308	
	Memory Access Delay 308	
	Hardware Threads And Context Switching 309	
	Microengine Instruction Store 311	
	Microengine Hardware Registers 312	
	General-Purpose Registers 312	
	Transfer Registers 314	
	Local Control And Status Registers (CSRs) 315	
	Inter-Processor Communication 315	
	FBI Unit 316	
20.10	12.000	

xvi Contents

	20.19	Transmit And Receive FIFOs 317	
	20.20	FBI Architecture And Push/Pull Engines 317	
	20.21	Scratchpad Memory 318	
	20.22	Hash Unit 319	
	20.23	Configuration, Control, and Status Registers 321	
	20.24	Summary 321	
С	hapter	21 Reference System And Software Development Kit (Bridal	325
		Vell, SDK)	
	21.1	Introduction 325	
	21.2	Reference Systems 325	
	21.3	The Intel Reference System 326	
	21.4	Host Operating System Choices 328	
	21.5	Operating System Used On The StrongARM 328	
	21.6	External File Access And Storage 329	
	21.7	PCI Ethernet Emulation 330	
		Bootstrapping The Reference Hardware 330	
		Running Software 331	
		System Reboot 332	
		Alternative Cross-Development Software 332	
	21.12	Summary 332	
_			
C	napte	r 22 Programming Model (ACE)	335
	22.1	Introduction 335	
	22.2	The ACE Abstraction 335	
	22.3	ACE Definitions And Terminology 336	
	22.4	Four Conceptual Parts Of An ACE 336	
		Output Targets And Late Binding 337	
	22.6	An Example Of ACE Interconnection 337	
	22.7	Division Of An ACE Into Core And Microblock 338	
		Microblock Groups 339	
		Replicated Microblock Groups 340	
	22.10	Microblock Structure 340	
		The Dispatch Loop 341	
		Dispatch Loop Calling Conventions 342	
		Packet Queues 343	
		Exceptions 344	
		Crosscalls 345	
		Application Programs Outside The ACE Model 346	
	22 17	Summary 346	

Contents xvii

Chapter	23 ACE Run-Time Structure And StrongARM Facilities	349
23.1	Introduction 349	
23.2	StrongARM Responsibilities 349	
23.3	Principle Run-Time Components 350	
23.4	Core Components Of ACEs 350	
23.5	Object Management System (OMS) 351	
23.6	Resource Manager 352	
23.7	Operating System Specific Library (OSSL) 352	
23.8	Action Services Library 353	
23.9	Automated Microengine Assignment 353	
23.10	ACE Program Structure 354	
23.11	ACE Main Program And Event Loop 354	
	ACE Event Loop And Blocking 355	
23.13	Asynchronous Programming Paradigm And Callbacks 356	
23.14	Asynchronous Execution And Mutual Exclusion 358	
23.15	Memory Allocation 359	
	Loading And Starting An ACE (ixstart) 360	
23.17	ACE Data Allocation And Initialization 361	
23.18	Crosscalls 362	
23.19	Crosscall Declaration Using IDL 363	
23.20	Communication Access Process (CAP) 364	
23.21	Timer Management 364	
	NCL Classification, Actions, And Default 366	
23.23	Summary 367	
Chapte	r 24 Microengine Programming I	37
24.1	Introduction 371	
24.2	Intel's Microengine Assembler 371	
24.3		
	Example Operand Syntax 373	
24.5	Symbolic Register Names And Allocation 376	
	Register Types And Syntax 377	
	Local Register Scope, Nesting, And Shadowing 378	
24.8	Register Assignments And Conflicts 379	
	The Macro Preprocessor 380	
	Macro Definition 380	
	Repeated Generation Of A Code Segment 382	
	Structured Programming Directives 383	
	Instructions That Can Cause A Context Switch 385	
	Indirect Reference 386	
24.15	External Transfers 387	

	Library Macros And Transfer Register Allocation 388 Summary 389	
Chapter	25 Microengine Programming II	393
25.1	Introduction 393	
25.2	Specialized Memory Operations 393	
25.3	Buffer Pool Manipulation 394	
25.4	Processor Coordination Via Bit Testing 394	
25.5	Atomic Memory Increment 395	
25.6	Processor Coordination Via Memory Locking 396	
25.7	Control And Status Registers 397	
25.8	Intel Dispatch Loop Macros 399	
25.9	Packet Queues And Selection 400	
25.10	Accessing Fields In A Packet Header 401	
25.11	Initialization Required For Dispatch Loop Macros 402	
25.12	Packet I/O And The Concept Of Mpackets 404	
	Packet Input Without Interrupts 405	
25.14	Ingress Packet Transfer 406	
25.15	Packet Egress 406	
25.16	Other I/O Details 408	
25.17	Summary 408	
Chapter	26 An Example ACE	411
26. I	Introduction 411	
26.2	An Example Bump-In-The-Wire 411	
26.3	Wwbump Design 412	
26.4	Header Files 413	
26.5	Microcode For Packet Classification And Processing 415	
26.6	Microcode For The Dispatch Loop 419	
<i>26</i> , <i>7</i>	Code For Core Component (Exception Handler) 422	
	ACE Structure 423	
	Code To Initialize And Finalize The Wwbump ACE 423	
	An Example Crosscall 426	
	Code For A Crosscall Function 430	
	System Configuration 432	
	A Potential Bottleneck In The Wwbump Design 437	
26.14	Summary 437	

Contents xix

Chapter 27 Intel's Second Generation Processors	441
27.1 Introduction 441	
27.2 Use Of Dual Chips For Higher Data Rates 441	
27.3 General Characteristics 442	
27.4 Memory Hierarchy 443	
27.5 External Connections And Buses 443	
27.6 Flow Control Bus 443	
27.7 Media Or Switch Fabric Interface 444	
27.8 Internal Architecture 445	
27.9 Physical Network Interfaces And Multiplexing 446	
27.10 Microengine Enhancements 446	
27.11 Support For Software Pipelining 447	
27.12 The IXP2800 447	
27.13 Summary 448	
Appendix 1 Glossary Of Terms And Abbreviations	449
Bibliography	
Index	501