

Table of Contents

Foreword	xiii
Preface to the Third Edition	xv
Acknowledgements	xvii
1 Introduction.....	1
1.1 Goals of This Manual	2
1.1.1 Assumptions	3
1.1.2 Definitions	3
1.1.3 Virtual Socket Interface Alliance	4
1.2 Design for Reuse: The Challenge.....	4
1.2.1 Design for Use.....	5
1.2.2 Design for Reuse	5
1.3 The Emerging Business Model for Reuse.....	6
2 The System-on-Chip Design Process.....	9
2.1 A Canonical SoC Design.....	9
2.2 System Design Flow.....	11
2.2.1 Waterfall vs. Spiral	11
2.2.2 Top-Down vs. Bottom-Up	15
2.2.3 Construct by Correction	15
2.2.4 Summary.....	16

2.3	The Specification Problem	17
2.3.1	Specification Requirements	17
2.3.2	Types of Specifications	18
2.4	The System Design Process.....	19
3	System-Level Design Issues: Rules and Tools.....	23
3.1	The Standard Model	23
3.1.1	Soft IP vs. Hard IP	25
3.1.2	The Role of Full-Custom Design in Reuse.....	27
3.2	Design for Timing Closure: Logic Design Issues	28
3.2.1	Interfaces and Timing Closure.....	28
3.2.2	Synchronous vs. Asynchronous Design Style	33
3.2.3	Clocking	35
3.2.4	Reset	36
3.2.5	Timing Exceptions and Multicycle Paths	37
3.3	Design for Timing Closure: Physical Design Issues	38
3.3.1	Floorplanning	38
3.3.2	Synthesis Strategy and Timing Budgets	39
3.3.3	Hard Macros	39
3.3.4	Clock Distribution	40
3.4	Design for Verification: Verification Strategy	40
3.5	System Interconnect and On-Chip Buses	42
3.5.1	Basic Interface Issues	43
3.5.2	Tristate vs. Mux Buses	47
3.5.3	Synchronous Design of Buses.....	47
3.5.4	Summary.....	47
3.5.5	IP-to-IP Interfaces	48
3.6	Design for Bring-Up and Debug: On-Chip Debug Structures	51
3.7	Design for Low Power.....	52
3.7.1	Lowering the Supply Voltage	53
3.7.2	Reducing Capacitance and Switching Activity	54
3.7.3	Sizing and Other Synthesis Techniques	56
3.7.4	Summary.....	57
3.8	Design for Test: Manufacturing Test Strategies	57
3.8.1	System-Level Test Issues.....	57
3.8.2	Memory Test.....	58
3.8.3	Microprocessor Test	58
3.8.4	Other Macros	59
3.8.5	Logic BIST	59

- 3.9 Prerequisites for Reuse 60
 - 3.9.1 Libraries 60
 - 3.9.2 Physical Design Rules 61

- 4 The Macro Design Process63**
 - 4.1 Overview of IP Design 63
 - 4.1.1 Characteristics of Good IP..... 64
 - 4.1.2 Implementation and Verification IP..... 65
 - 4.1.3 Overview of Design Process..... 67
 - 4.2 Key Features 68
 - 4.3 Planning and Specification 69
 - 4.3.1 Functional Specification 69
 - 4.3.2 Verification Specification 71
 - 4.3.3 Packaging Specification 71
 - 4.3.4 Development Plan..... 71
 - 4.3.5 High-Level Models as Executable Specifications 72
 - 4.4 Macro Design and Verification..... 73
 - 4.4.1 Summary..... 77
 - 4.5 Soft Macro Productization 78
 - 4.5.1 Productization Process..... 78
 - 4.5.2 Activities and Tools 78

- 5 RTL Coding Guidelines.....81**
 - 5.1 Overview of the Coding Guidelines 81
 - 5.2 Basic Coding Practices 82
 - 5.2.1 General Naming Conventions..... 82
 - 5.2.2 Naming Conventions for VITAL Support 84
 - 5.2.3 State Variable Names..... 85
 - 5.2.4 Include Informational Headers in Source Files 85
 - 5.2.5 Use Comments..... 87
 - 5.2.6 Keep Commands on Separate Lines 87
 - 5.2.7 Line Length 87
 - 5.2.8 Indentation..... 88
 - 5.2.9 Do Not Use HDL Reserved Words..... 89
 - 5.2.10 Port Ordering 89
 - 5.2.11 Port Maps and Generic Maps 92
 - 5.2.12 VHDL Entity, Architecture, and Configuration Sections 93
 - 5.2.13 Use Functions 93
 - 5.2.14 Use Loops and Arrays 94
 - 5.2.15 Use Meaningful Labels..... 96

5.3	Coding for Portability	97
5.3.1	Use Only IEEE Standard Types (VHDL).....	97
5.3.2	Do Not Use Hard-Coded Numeric Values.....	98
5.3.3	Packages (VHDL)	98
5.3.4	Constant Definition Files (Verilog)	98
5.3.5	Avoid Embedding Synthesis Commands	99
5.3.6	Use Technology-Independent Libraries.....	99
5.3.7	Coding For Translation	100
5.4	Guidelines for Clocks and Resets.....	101
5.4.1	Avoid Mixed Clock Edges.....	102
5.4.2	Avoid Clock Buffers	103
5.4.3	Avoid Gated Clocks	103
5.4.4	Avoid Internally Generated Clocks	104
5.4.5	Gated Clocks and Low-Power Designs	105
5.4.6	Avoid Internally Generated Resets	106
5.4.7	Reset Logic Function.....	107
5.4.8	Single-Bit Synchronizers.....	108
5.4.9	Multiple-Bit Synchronizers	108
5.5	Coding for Synthesis	108
5.5.1	Infer Registers	109
5.5.2	Avoid Latches	110
5.5.3	If you must use a latch.....	113
5.5.4	Avoid Combinational Feedback	113
5.5.5	Specify Complete Sensitivity Lists.....	114
5.5.6	Blocking and Nonblocking Assignments (Verilog).....	117
5.5.7	Signal vs. Variable Assignments (VHDL).....	119
5.5.8	Case Statements vs. if-then-else Statements	120
5.5.9	Coding Sequential Logic	122
5.5.10	Coding Critical Signals.....	124
5.5.11	Avoid Delay Times	124
5.5.12	Avoid full_case and parallel_case Pragmas.....	124
5.6	Partitioning for Synthesis	125
5.6.1	Register All Outputs	125
5.6.2	Locate Related Combinational Logic in a Single Module	126
5.6.3	Separate Modules That Have Different Design Goals	127
5.6.4	Asynchronous Logic.....	128
5.6.5	Arithmetic Operators: Merging Resources.....	128
5.6.6	Partitioning for Synthesis Runtime	130
5.6.7	Avoid Timing Exceptions	130
5.6.8	Eliminate Glue Logic at the Top Level.....	133
5.6.9	Chip-Level Partitioning	134

- 5.7 Designing with Memories 135
- 5.8 Code Profiling 136

- 6 Macro Synthesis Guidelines137**
 - 6.1 Overview of the Synthesis Problem 137
 - 6.2 Macro Synthesis Strategy 138
 - 6.2.1 Macro Timing Constraints 139
 - 6.2.2 Subblock Timing Constraints 139
 - 6.2.3 Synthesis in the Design Process 140
 - 6.2.4 Subblock Synthesis Process 141
 - 6.2.5 Macro Synthesis Process 141
 - 6.2.6 Wire Load Models 142
 - 6.2.7 Preserve Clock and Reset Networks 142
 - 6.2.8 Code Checking Before Synthesis 143
 - 6.2.9 Code Checking After Synthesis 143
 - 6.3 Physical Synthesis 144
 - 6.3.1 Classical Synthesis 144
 - 6.3.2 Physical Synthesis 145
 - 6.3.3 Physical Synthesis Deliverables 145
 - 6.4 RAM and Datapath Generators 145
 - 6.4.1 Memory Design 146
 - 6.4.2 RAM Generator Flow 147
 - 6.4.3 Datapath Design 148
 - 6.5 Coding Guidelines for Synthesis Scripts 150

- 7 Macro Verification Guidelines153**
 - 7.1 Overview of Macro Verification 153
 - 7.1.1 Verification Plan 154
 - 7.1.2 Verification Strategy 155
 - 7.2 Inspection as Verification 159
 - 7.3 Adversarial Testing 160
 - 7.4 Testbench Design 161
 - 7.4.1 Transaction-Based Verification 161
 - 7.4.2 Component-Based Verification 163
 - 7.4.3 Automated Response Checking 165
 - 7.4.4 Verification Suite Design 166
 - 7.5 Design of Verification Components 169
 - 7.5.1 Bus Functional Models 169
 - 7.5.2 Monitors 171

7.5.3	Device Models	171
7.5.4	Verification Component Usage.....	172
7.6	Getting to 100%.....	172
7.6.1	Functional and Code Coverage.....	172
7.6.2	Prototyping	172
7.6.3	Limited Production	173
7.6.4	Property Checking	173
7.6.5	Code Coverage Analysis	174
7.7	Timing Verification.....	177
8	Developing Hard Macros.....	179
8.1	Overview	179
8.1.1	Why and When to Use Hard Macros.....	180
8.1.2	Design Process for Hard vs. Soft Macros.....	181
8.2	Design Issues for Hard Macros	181
8.2.1	Full-Custom Design.....	181
8.2.2	Interface Design.....	182
8.2.3	Design For Test.....	183
8.2.4	Clock.....	184
8.2.5	Aspect Ratio	185
8.2.6	Porosity	186
8.2.7	Pin Placement and Layout.....	187
8.2.8	Power Distribution.....	187
8.2.9	Antenna Checking	188
8.3	The Hard Macro Design Process	190
8.4	Productization of Hard Macros	190
8.4.1	Physical Design	190
8.4.2	Verification	193
8.5	Model Development for Hard Macros.....	194
8.5.1	Functional Models	194
8.5.2	Timing Models	199
8.5.3	Power Models	200
8.5.4	Test Models	201
8.5.5	Physical Models.....	204
8.6	Porting Hard Macros	204
9	Macro Deployment: Packaging for Reuse	207
9.1	Delivering the Complete Product	207
9.1.1	Soft Macro Deliverables	208

- 9.1.2 Hard Macro Deliverables..... 210
- 9.1.3 Software..... 212
- 9.1.4 The Design Archive..... 213
- 9.2 Contents of the User Guide 214

10 System Integration with Reusable Macros217

- 10.1 Integration Overview 217
- 10.2 Integrating Macros into an SoC Design 218
 - 10.2.1 Problems in Integrating IP..... 218
 - 10.2.2 Strategies for Managing Interfacing Issues 219
 - 10.2.3 Interfacing Hard Macros to the Rest of the Design 220
- 10.3 Selecting IP..... 221
 - 10.3.1 Hard Macro Selection..... 221
 - 10.3.2 Soft Macro Selection 221
 - 10.3.3 Soft Macro Installation..... 222
 - 10.3.4 Soft Macro Configuration..... 223
 - 10.3.5 Synthesis of Soft Macros..... 223
- 10.4 Integrating Memories 223
- 10.5 Physical Design 224
 - 10.5.1 Design Planning and Synthesis 226
 - 10.5.2 Physical Placement..... 230
 - 10.5.3 Timing Closure 234
 - 10.5.4 Verifying the Physical Design 237
 - 10.5.5 Summary..... 238

11 System-Level Verification Issues.....239

- 11.1 The Importance of Verification 239
- 11.2 The Verification Strategy..... 240
- 11.3 Interface Verification 241
 - 11.3.1 Transaction Verification..... 241
 - 11.3.2 Data or Behavioral Verification 242
 - 11.3.3 Standardized Interfaces 244
- 11.4 Functional Verification 244
- 11.5 Random Testing..... 247
- 11.6 Application-Based Verification 249
 - 11.6.1 Software-Driven Application Testbench 250
 - 11.6.2 Rapid Prototyping for Testing 251

11.7 Gate-Level Verification	253
11.7.1 Sign-Off Simulation	253
11.7.2 Formal Verification	254
11.7.3 Gate-Level Simulation with Full Timing	255
11.8 Specialized Hardware for System Verification	256
11.8.1 Accelerated Verification Overview	258
11.8.2 RTL Acceleration	259
11.8.3 Software Driven Verification	260
11.8.4 Traditional In-Circuit Verification	260
11.8.5 Design Guidelines for Emulation	261
11.8.6 Testbenches for Emulation	261
12 Data and Project Management	265
12.1 Data Management	265
12.1.1 Revision Control Systems	265
12.1.2 Bug Tracking	267
12.1.3 Regression Testing	267
12.1.4 Managing Multiple Sites	267
12.1.5 Archiving	268
12.2 Project Management	269
12.2.1 Development Process	269
12.2.2 Functional Specification	269
12.2.3 Project Plan	270
13 Implementing Reuse-Based SoC Designs	271
13.1 Alcatel	272
13.2 Atmel	274
13.3 Infineon Technologies	276
13.4 LSI Logic	278
13.5 Philips Semiconductor	280
13.6 STMicroelectronics	282
13.7 Conclusion	284
Bibliography	285
Index	287