

CPL  
998

# Digital Circuit Testing and Testability

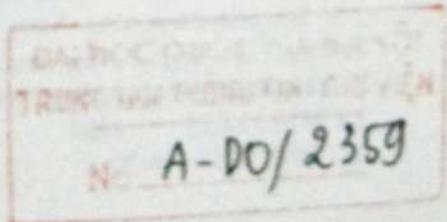
*Parag K. Lala*

Electrical Engineering Department  
North Carolina Agricultural and Technical State University  
Greensboro, North Carolina



ACADEMIC PRESS

San Diego London Boston  
New York Sydney Tokyo Toronto



# Contents

## Preface

xi

<b>Chapter 1</b>	Faults in Digital Circuits	1
1.1	Failures and Faults	1
1.2	Modeling of Faults	1
1.2.1	Stuck-At Faults	2
1.2.2	Bridging Faults	5
1.2.3	Breaks and Transistor Stuck-On/Open Faults in CMOS	10
1.2.4	Delay Faults	13
1.3	Temporary Faults	14
	References	17
<b>Chapter 2</b>	Test Generation for Combinational Logic Circuits	20
2.1	Fault Diagnosis of Digital Circuits	20
2.2	Test Generation Techniques for Combinational Circuits	21
2.2.1	One-Dimensional Path Sensitization	21
2.2.2	Boolean Difference	23
2.2.3	D-Algorithm	29
2.2.4	PODEM (Path-Oriented Decision-Making)	38
2.2.5	FAN (Fanout-Oriented Test Generation)	47
2.2.6	Delay Fault Detection	48
2.3	Detection of Multiple Faults in Combinational Logic Circuits	50
	References	52

<b>Chapter 3 Testable Combinational Logic Circuit Design</b>	55
3.1 The Reed-Muller Expansion Technique	55
3.2 Three-Level OR-AND-OR Design	58
3.3 Automatic Synthesis of Testable Logic	58
3.4 Testable Design of Multilevel Combinational Circuits	60
3.4.1 Single Cube Extraction	63
3.4.2 Double Cube Divisor	64
3.4.3 Extraction of a Double Cube Divisor and Its Complement	64
3.5 Synthesis of Random Pattern Testable Combinational Circuits	65
3.6 Path Delay Fault Testable Combinational Logic Design	70
3.7 Testable PLA Design	73
References	74
	77
<b>Chapter 4 Test Generation for Sequential Circuits</b>	79
4.1 Testing of Sequential Circuits as Iterative Combinational Circuits	79
4.2 State Table Verification	81
4.3 Test Generation Based on Circuit Structure	87
4.4 Functional Fault Models	92
4.5 Test Generation Based on Functional Fault Models	94
References	100
	100
<b>Chapter 5 Design of Testable Sequential Circuits</b>	101
5.1 Controllability and Observability	101
5.2 Ad Hoc Design Rules for Improving Testability	103
5.3 Design of Diagnosable Sequential Circuits	107
5.4 The Scan-Path Technique for Testable Sequential Circuit Design	110
5.5 Level-Sensitive Scan Design (LSSD)	114
5.5.1 Clocked Hazard-Free Latches	114
5.5.2 LSSD Design Rules	116
5.5.3 Advantages of the LSSD Technique	121
5.6 Random Access Scan Technique	122
5.7 Partial Scan	125
5.8 Testable Sequential Circuit Design Using Nonscan Techniques	127
5.9 CrossCheck	130
5.10 Boundary Scan	133
References	138
	138
<b>Chapter 6 Built-In Self Test</b>	140
6.1 Test Pattern Generation for BIST	141
6.1.1 Exhaustive Testing	141
6.1.2 Pseudo-Exhaustive Pattern Generation	143

6.1.3	Pseudo-Random Pattern Generator	
6.1.4	Deterministic Testing	150
6.2	Output Response Analysis	153
6.2.1	Transition Count	153
6.2.2	Syndrome Checking	153
6.2.3	Signature Analysis	154
6.3	Circular BIST	155
6.4	BIST Architectures	159
6.4.1	BILBO (Built-In Logic Block Observer)	162
6.4.2	STUMPS (Self-Testing Using an MISR and Parallel Shift Register Sequence Generator)	162
6.4.3	LOCST (LSSD On-Chip Self-Test)	163
	References	165
		166
<b>Chapter 7 Testable Memory Design</b>		169
7.1	RAM Fault Models	169
7.2	Test Algorithms for RAMs	172
7.2.1	GALPAT (Galloping 0s and 1s)	172
7.2.2	Walking 0s and 1s	173
7.2.3	March Test	173
7.2.4	Checkerboard Test	174
7.3	Detection of Pattern-Sensitive Faults	174
7.4	BIST Techniques for RAM Chips	179
7.5	Test Generation and BIST for Embedded RAMs	184
	References	191
<b>Appendix Markov Models</b>		193
<b>Index</b>		195