

## Part I Introduction and Background

<b>1 Introduction</b> .....	3
1.1 Quantum Mechanics and Quantum Logic.....	4
1.2 Quantum Computation and Circuit Design.....	6
1.3 Topics Covered in This Book.....	9
<b>2 Background</b> .....	11
2.1 Boolean Logic.....	11
2.2 Quantum Logic.....	13
2.2.1 Qubits and Measurement.....	14
2.2.2 Quantum Operations.....	15
2.3 Quantum Circuits and Gate Libraries.....	17

## Part II Representation of Quantum Functionality

<b>3 Challenges and Initial Approaches</b> .....	23
3.1 From Conventional to Quantum Logic.....	23
3.2 Decision Diagrams for Quantum Logic.....	26
3.2.1 Basic Concepts: Binary Decision Diagrams (BDDs).....	26
3.2.2 Still Boolean: Quantum Decision Diagrams (QDDs).....	29
3.2.3 Characteristic Functions: QuIDDs and XQDDs.....	31
<b>4 Quantum Multiple-Valued Decision Diagrams</b> .....	35
4.1 Basic Concepts.....	36
4.2 Formal Definition.....	40
4.3 Canonicity.....	42
4.4 Construction and Manipulation.....	43
4.4.1 Normalization.....	43
4.4.2 Matrix Operations.....	45
4.4.3 Construction.....	47

4.5	Changing the Variable Order .....	51
4.5.1	Shared Vertices and Skipped Variables.....	51
4.5.2	Local Modifications and Vertex Weights .....	53
4.5.3	Variable Interchange Scheme for QMDDs .....	54
4.6	Efficiency of QMDDs.....	56
<b>5</b>	<b>Discussion and Outlook.....</b>	<b>59</b>
 <b>Part III Design of Quantum Logic</b>		
<b>6</b>	<b>Challenges and Initial Approaches.....</b>	<b>67</b>
6.1	Design Challenges .....	68
6.2	Initial Synthesis Approaches.....	71
6.2.1	Synthesis of Boolean Components .....	72
6.2.2	Synthesis of Arbitrary Quantum Functionality .....	74
<b>7</b>	<b>Synthesis of Quantum Circuits.....</b>	<b>79</b>
7.1	Synthesis of Boolean Components .....	79
7.1.1	Embedding: Handling Irreversible Function Descriptions .....	80
7.1.2	Construction of QMDDs for Boolean Functions.....	82
7.1.3	QMDD-Based Synthesis of Reversible Circuits .....	86
7.2	Synthesis of Clifford Group Operations .....	89
7.2.1	Main Concepts of the Synthesis Approach .....	90
7.2.2	Algorithm .....	93
7.2.3	Theoretical Analysis .....	98
7.2.4	Experimental Results.....	102
7.3	Conclusions .....	104
<b>8</b>	<b>Correctness of Multiple-Valued Implementations .....</b>	<b>107</b>
8.1	Multi-level Quantum Systems.....	108
8.2	Equivalence Checking in Multi-level Quantum Systems.....	110
8.2.1	Functional Equivalence for Quantum Operations .....	111
8.2.2	Proposed Equivalence Checking Scheme .....	112
8.2.3	Implementation Using QMDDs.....	114
8.3	Experimental Results .....	116
8.4	Conclusions .....	117
<b>9</b>	<b>Discussion and Outlook.....</b>	<b>119</b>
<b>References .....</b>		<b>121</b>