Design Automation for Field-coupled Nanotechnologies

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Dedicated to the loving memory of
Barbara Walter (1932–2019)

Thank you, Grandma. Yours, Marcel.

Preface

Since the invention of integrated digital circuits, which heralded the beginning of the information age, their fabrication capabilities underwent rapid progress. Considering their transistor density doubled every few years since the 1960s, the physical limits of miniaturization will soon be reached. Consequently, novel paradigms are needed to enable computation-intensive future-oriented technologies such as artificial intelligence, autonomous driving, and immersive virtual reality.

Field-coupled nanocomputing (FCN) is a class of post-CMOS emerging integrated circuit technologies that includes contestants with enhancements in terms of energy dissipation and feature size. Certain implementations indicate the possibility to realize molecular-sized elementary devices with ultra-low energy dissipation or clock frequencies in the terahertz range.

Despite their promising characteristics, sophisticated automatic design methods are yet to be established. Due to the peculiarity and specificity of the FCN technologies' design constraints, conventional physical design algorithms cannot be applied. In other words, design automation for an entire class of highly promising nanotechnologies that could potentially enable a future of powerful and green computational devices is still in its infancy.

This book considers the main tasks in the area of design automation for FCN technologies that must be proficiently understood to enable large-scale composition of elementary building blocks to obtain correct systems from given function specifications. To this end, a holistic design flow is presented that covers

- Exact and scalable placement and routing
- One-pass logic synthesis
- Novel clocking mechanisms for data synchronization
- Formal verification for obtained circuit layouts

Additionally, theoretical groundwork is presented that lays the foundation for any algorithmic consideration in the future. Furthermore, an open-source and publicly available FCN design framework called *fiction*, which contains implementations of all discussed techniques, is presented.

The presented approaches address obstacles that have existed since the conceptualization of the FCN paradigm and could not be resolved since then. Thereby, this book substantially advances the state of the art in design automation for FCN technologies.

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Furthermore, our gratitude extends to all the researchers currently utilizing the *fiction* framework in their work. It is an honor to assist in the extension of the domain of field-coupled nanotechnologies.

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Contents

1 Introduction 1

2 Preliminaries 7
2.1 Logic Representations 7
2.1.1 Boolean Functions 7
2.1.2 Truth Tables 9
2.1.3 Logic Networks 10
2.2 Satisfiability Solvers 13
2.2.1 Boolean Satisfiability (SAT) 14
2.2.2 Satisfiability Modulo Theories (SMT) 15
2.3 Field-coupled Nanocomputing (FCN) 19
2.3.1 Cells 20
2.3.2 Gates 21
2.3.3 Clocking 25
2.3.4 Circuit Layouts 30

3 Theoretical Groundwork 37
3.1 FCN Placement and Routing Problem Definition 38
3.2 Intractability Proofs for FCN Placement and Routing 39
3.3 Summary and Future Work 44

4 Exact Placement and Routing 47
4.1 General Idea 48
4.2 Formulation as an SMT Problem 49
4.2.1 Global Synchronization 54
4.2.2 Predefined Clocking Schemes 55
4.2.3 Wire Crossings 56
4.2.4 Border I/O Pins 58
4.2.5 Secondary Optimization Criteria 59
4.3 Incremental and Parallel Solving 61
4.3.1 Incremental Solving 61
4.3.2 Parallel Solving 66

4.4 Experimental Results 69
4.4.1 Implementation and Setup 69
4.4.2 Quality Comparison Against State-of-the-Art Algorithms .. 70
4.4.3 Design Space Exploration 73
4.4.4 Benefit of Incremental Solving 74
4.5 Summary and Future Work 77

5 Scalable Placement and Routing 79
5.1 The Impact of Logic Network Preprocessing 80
5.2 Relation to Orthogonal Graph Drawing 83
5.3 Addressing FCN Design Constraints 85
5.4 Resulting Algorithm 88
5.5 Experimental Results 92
5.5.1 Implementation and Setup 92
5.5.2 Scalability Comparison Against State-of-the-Art Algorithms 92
5.6 Summary and Future Work 96

6 One-Pass Synthesis 99
6.1 Shortcomings of Two-Step Physical Design 100
6.2 General Idea 102
6.3 Formulation as a SAT Problem 103
6.4 Experimental Results 107
6.4.1 Implementation and Setup 107
6.4.2 Quality Comparison Against Placement and Routing 108
6.4.3 Generating a Design Library 110
6.4.4 Further Benefits of the One-pass Scheme 112
6.5 Summary and Future Work 113

7 Exploiting Clocks for Synchronization 115
7.1 Global Synchronization Revisited 116
7.1.1 Combinational Circuits 116
7.1.2 Sequential Circuits 119
7.2 Synchronization Elements 121
7.2.1 Basic Latch 121
7.2.2 D Latch 124
7.3 Experimental Results 126
7.3.1 Implementation and Setup 127
7.3.2 Relieving Global Synchronization 129
7.3.3 Adapting Conventional Methods to FCN 131
7.4 Summary and Future Work 133

8 Formal Verification 135
8.1 Problem Discussion and General Idea 136
8.2 Verification Approach 138
8.2.1 Miter Structure 138
8.2.2 Enforcing Proper Synchronization 139

8.2.3 Resulting Equivalence Checking Process 143
8.3 Experimental Results 145
8.3.1 Implementation and Setup 145
8.3.2 Validation of Physical Design Algorithms 145
8.4 Summary and Future Work 148

9 *fiction*: A Holistic Open-Source Framework 151
9.1 Related Work on FCN Design Tools 152
9.1.1 QCADesigner 152
9.1.2 ToPoliNano and MagCAD 152
9.1.3 NMLSim 153
9.1.4 Ropper 154
9.1.5 SiQAD 154
9.2 The User's Perspective 155
9.2.1 The Command-Line Interface 155
9.2.2 Specifications to Be Realized 157
9.2.3 Physical Design 158
9.2.4 Validation and Verification 160
9.2.5 Scripting for Experimental Evaluations 162
9.2.6 Full User Documentation 163
9.3 The Developer's Perspective 173
9.3.1 Third-Party Libraries 174
9.3.2 Architecture and Data Types 177
9.3.3 Implementing a Naive Placer 180
9.4 Summary and Future Work 182

10 Summary and Conclusions 185

References 187