# Contents


**1 Introduction** **1**

**2 Field Programmable Gate Array basics** **5**
2.1 Generic structure . . . 5
2.2 Typical applications . . . 10
2.3 Existing designs . . . 12
2.3.1 Related academic research . . . 12
2.3.2 Commercial FPGAs . . . 15
2.4 New approach in this thesis . . . 21

**3 Aspects of low power applications** **23**
3.1 Motivation . . . 23
3.2 Static power dissipation . . . 28
3.3 Dynamic power dissipation . . . 30
3.4 Leakage current suppression . . . 31

**4 Cryptography and its application** **35**
4.1 Basic principles . . . 35
4.2 Side channel attacks . . . 35
4.3 Power Analysis . . . 36
4.3.1 Simple Power Analysis . . . 36
4.3.2 Differential Power Analysis . . . 37
4.4 Countermeasures . . . 38

**5 Low-power configuration random access memory** **41**
5.1 Existing designs . . . 41
5.2 New low-power approach: LP 4T SRAM Cell . . . 61
5.2.1 Dual threshold CMOS . . . 62
5.2.2 Transistor stacking . . . 63
5.2.3 Dynamic voltage scaling . . . 67
5.3 Timing considerations . . . 72
5.4 Conclusion . . . 74

**6 Low-power data flip-flop** **77**
6.1 Basic considerations . . . 77
6.2 Selected legacy designs . . . 79
6.3 New power saving modifications . . . 89
6.3.1 Dual threshold CMOS . . . 93
6.3.2 Multi-oxide technology . . . 93

6.3.3 Clk- and power-gating . . . 93
6.3.4 Stacking . . . 94
6.4 Simulation results . . . 94
6.5 Conclusion . . . 102

**7 Low power tristate buffer** **105**
7.1 Basic considerations . . . 105
7.2 Legacy design . . . 108
7.3 New low-power approaches . . . 114
7.3.1 Power gating . . . 114
7.3.2 Leakage current reduction . . . 114
7.3.3 Subthreshold current reduction . . . 116
7.3.4 Multi supply voltage . . . 117
7.4 Low-power tristate buffer . . . 117
7.5 Simulation results . . . 137
7.6 Conclusion . . . 138

**8 Partial component integration** **141**
8.1 LUT design . . . 142
8.2 SLICE design . . . 157
8.3 GPIO design . . . 161
8.4 Conclusion . . . 164

**9 Summary / Outlook** **167**
9.1 Summary . . . 167
9.2 Outlook . . . 168

**A CRAM - Additional Figures and Simulation Results** **171**

**B D-FF - Additional Figures and Simulation Results** **175**

**C Tristate Buffers - Additional Simulation Results** **181**

**D Partial SLICE Integration - Additional Figures and Simulation Results** **189**

**List of figures** **191**

**Bibliography** **197**