Contents

1 INTRODUCTION 1
  1.1 Background ......................................................... 1
  1.2 Motivation ........................................................ 3
  1.3 Problem Definition ............................................... 5
  1.4 Research Methodology and Results ............................... 6
  1.5 Organization of Thesis .......................................... 7

2 LITERATURE SURVEY 10
  2.1 Degrees of Freedom in Low Power CMOS Design ............... 10
  2.2 Low Power Themes ............................................... 11
  2.3 Introduction to Energy Recovery Adiabatic Logic ............ 15
    2.3.1 Energy Dissipation in Conventional CMOS .................. 16
    2.3.2 Energy Recovery Principle .................................. 17
    2.3.3 Adiabatic Logic Circuit .................................... 18
  2.4 Energy Recovery Adiabatic Logic Styles ....................... 20
  2.5 Adiabatic Circuits .............................................. 29
  2.6 Towards Research Objectives .................................... 32

3 DESIGN OF ADIABATIC CIRCUIT 34
  3.1 Introduction ..................................................... 34
  3.2 Designing Adiabatic Circuit .................................... 35
  3.3 Summary ......................................................... 57

4 PERFORMANCE EVALUATION OF SELECTED QUASI-ADIABATIC
   LOGIC STYLES 59
  4.1 Introduction ...................................................... 59
    4.1.1 Selecting Quasi-adiabatic Logic Styles for Comparative
          Study .......................................................... 60
    4.1.2 Selection of 2:1 MUX as a Benchmark Circuit ............ 61
  4.2 Implementation and Testing of 2:1 MUX Quasi-adiabatic Circuits 62
    4.2.1 Important Design and Test Considerations ................ 62
4.2.2 Implementation and Testing ........................................ 64
4.3 Performance Evaluation of CAL, PAL, IPGL and CMOS ........ 86
  4.3.1 Comparison of Energy Dissipation ........................... 86
  4.3.2 Comparison of Delay ........................................... 90
4.4 Conclusions and Remarks ........................................... 91
5 PROPOSED NEW QUASI-ADIABATIC LOGIC STYLE ................. 94
  5.1 Design of a New Quasi-adiabatic Logic Style .................. 95
    5.1.1 PAL2NSM (PAL2N with Stand-by-Mode) .................... 95
    5.1.2 Use of T-gate ................................................ 103
    5.1.3 Comparison of PAL2NSM with Others ....................... 103
    5.1.4 Effect of Stand-by Time and Frequency on Energy Dissipa-
            tion ...................................................... 122
    5.1.5 Implementing a Boolean Expression ......................... 122
    5.1.6 Conclusions ................................................ 125
  5.2 Detail Comparison with CMOS ..................................... 126
    5.2.1 Data Activity Rates of CMOS and PAL2NSM ................ 126
    5.2.2 Comparison of Energy Dissipations of Power-optimized
            CMOS and PAL2NSM ....................................... 127
    5.2.3 Comparison of Energy Dissipations of CMOS Operated at
            its Maximum Frequency and PAL2NSM Operated at its
            Maximum Frequency ...................................... 130
  5.3 Designing Cell Library and TYPICAL.LIB ......................... 132
    5.3.1 Simulation Results and Observation Tables ................ 136
    5.3.2 Sample LUT for AND Gate .................................. 138
    5.3.3 Remarks and Future Scope ................................ 139
  5.4 Robustness Testing of PAL2NSM .................................. 140
    5.4.1 Effect of Parasitic on the Energy Dissipation and Delay . 140
    5.4.2 Harmonics Generated by the Circuit ....................... 142
    5.4.3 Noise Analysis ............................................. 142
    5.4.4 Jitter Analysis ............................................ 144
  5.5 Final Conclusions ............................................... 151
6 RESEARCH CONTRIBUTIONS IN QUASI-ADIABATIC CIRCUIT
   THEORY ................................................................. 154
  6.1 Leakage Power Reduction in Quasi-adiabatic Circuit .......... 154
    6.1.1 Control Circuits for Switching Purpose .................... 158
    6.1.2 Conclusions and Remarks ................................... 160
  6.2 Partially Reversible Boundary Circuit Between Quasi-adiabatic
       and CMOS ....................................................... 161
    6.2.1 Design of Boundary Circuit ................................. 162