# Contents

## Part I  Modelling, Calculation and Analogy: The Themes of Analogue Computing

1  **Introduction: Analogue Computers in the History of Computing**  
   1.1 Analogue Computers: Another Class of Computing Technology  
   1.2 Analogue Computer: A Challenge to Define  
   1.3 Analogue Computing as Modelling Technology  
   1.4 Structure of This Book  
      1.4.1 Part I: Modelling, Calculation and Analogy: The Themes of Analogue Computing  
      1.4.2 Part II: Analogue Computing in Use: A Selection of Contexts  

2  **A Multi-Stranded Chronology of Analogue Computing**  
   2.1 Two Meanings of Analogue: The Tension Between Analogy and Continuity  
   2.2 Towards a Chronology of Analogue Computing  
   2.3 First Thematic Time-Line—Mechanising the Calculus: The Story of Continuous Computing Technology  
      2.3.1 1814–1850: Towards the Mechanical Integrator: The Invention and Development of the Planimeter  
      2.3.2 1850–1876: Maxwell, Thomson and Kelvin: The Emergence of the Integrator as a Computing Component  
      2.3.3 1870–1900: The Age of the Continuous Calculating Machine  
      2.3.4 1880–1920: The Integrator Becomes an Embedded Component Initiating Associations Between Control and Calculation  
      2.3.5 1920–1946: The ‘Heyday’ of Analogue Computing?  
   2.4 Second Thematic Time-Line—From Analogy to Computation: the Development of Electrical Modelling  
      2.4.1 1845–1920: The Development of Analogy Methods  
      2.4.2 1920–1946: Pre-digital Analogue Modelling
2.5 Third Thematic Time-Line—Analogue Computing and the Entwining of Calculation and Modelling .......................... 47
  2.5.1 1940: The Emergence of Analogue Computing as a Technical Label and Class of Machine .......................... 47
  2.5.2 1945–1960: The Development and Stabilisation of Computer Technology ............................................ 49
  2.5.3 1950–1965: The Commercialisation of the Analogue Computer, and the Invention of Hybrid Computing ............ 53
  2.6 Conclusions ........................................................................................................................................ 54

3 Modelling Technology and the History of Analogue Computing ................................................................. 57
  3.1 Modelling: A Variety of Definitions and Associations .............................................................................. 58
  3.2 Modelling as a Meta-Narrative for the History of Computing ................................................................. 59
  3.3 Support for Thinking of the Computer as a Modelling Medium ............................................................... 61
    3.3.1 Theoretical Support for a Modelling Perspective ............................................................................... 63
    3.3.2 Historical Support for a Modelling Perspective ................................................................................ 67
  3.4 Analogue Computing as a Technology of Modelling ............................................................................... 69
  3.5 Conclusion ............................................................................................................................................ 71

4 Origins of Analogue: Conceptual Association and Entanglement ............................................................. 73
  4.1 The Establishment of ‘Forward Analogy’: Historical Influences from Electrical Theory ........................... 74
  4.2 Modelling with Electricity: Early Use of a Reverse Analogy .................................................................. 76
    4.2.1 Clifford Nickle and Vannevar Bush: Modelling with the Reverse Analogy ...................................... 78
    4.2.2 Establishing a Modelling Medium Based on the Reverse Analogy: The Work of Nickle and Doherty ........ 78
    4.2.3 Stabilising the Field: Bush’s Classification Schemes and Their Enrolling Function ............................ 81
    4.2.4 Positive Association with Computing and Computational Rhetoric ............................................... 83
  4.3 Formation of an Analogue User Culture ................................................................................................. 84
    4.3.1 George Philbrick and Lightning Empiricism: An Exemplar of Analogue Culture .............................. 86
  4.4 Simulation Culture and the Transition to Digital .................................................................................... 89
    4.4.1 Digital Languages for Simulating Analogue Computing ................................................................. 90
  4.5 Dis-enrollment of Analogue Computing and the Redefinition of Analogue Culture .............................. 91
  4.6 Conclusion ............................................................................................................................................ 93

Part II Analogue Computing in Use: A Selection of Contexts

5 Analogue Computers in British Higher Education .................................................................................. 97
  5.1 Calculation, Modelling, or Control: Three Different Uses, Three Different Histories ........................... 101
5.2 Analogue Research at Manchester: Networks, Tanks, and Hybrid Computing ........................................... 103
5.3 Analogue Research at Imperial College: Networks and Tanks as Engineering Tools ................................... 105
5.4 King’s College London: Analogue Computing at ‘Ultra-High Speed’ ........................................... 106
5.5 Analogue Computing at Birmingham ........................................... 111
5.6 Analogue Computing at the University of Bath: An Example of a Technical College .................................... 115
5.7 The Flowers Report and the Funding of Analogue Computing ........................................... 116
5.8 Conclusion ........................................... 119

6 Analogue Computers and Oil Reservoir Modelling ........................................... 123
6.1 Production Management and the Application of Analogue Computing ........................................... 124
6.1.1 Modelling Hydraulic Pressures with Electricity: William A. Bruce and the Carter Analyser ........................................... 125
6.1.2 Incorporating Repetitive Operation: The Reservoir Analysers Developed by the Sun Oil Company ........................................... 127
6.2 The Story of the BP Analogue Computer ........................................... 131
6.2.1 Outsourcing Development to EMI Electronics ........................................... 133
6.3 The BP Analyser in Use ........................................... 135
6.4 BP and the Analogue–Digital Debate ........................................... 136
6.4.1 Analogue–Digital Issues at the Local Level ........................................... 137
6.4.2 Analogue–Digital Issues at the Corporate Level ........................................... 138
6.5 Conclusion ........................................... 139

7 Analogue–Digital Decisions in British Aeronautical Research ........................................... 141
7.1 Analogue Computing for Aeronautics ........................................... 142
7.1.1 Soap Film Models as Analogue Computers ........................................... 143
7.1.2 The Electrolytic Tank as a Table-Top Wind Tunnel ........................................... 145
7.2 Aerodynamic Calculations, British Aircraft Designers and the ARC Computation Panel ........................................... 147
7.2.1 Tanks Versus Networks ........................................... 150
7.2.2 Deciding Between Analogue and Digital: The Case of Flutter ........................................... 151
7.3 Thirty Year Persistence: The Shortcomings of Digitalisation ........................................... 153
7.4 Conclusion ........................................... 155

8 The Analogue Dishpan: Physical Modelling Versus Numerical Calculation in Meteorology ........................................... 157
8.1 Computation and the History of Meteorology ........................................... 158
8.2 Non-digital Approaches to Meteorology ........................................... 160
8.3 Richardson’s Forecast Factory and His Suggested Analogue Alternative ........................................... 160
8.3.1 Richardson: Mathematician, Experimentalist, Quaker ........................................... 163
8.3.2 Richardson’s Rotating Fluid Experiment and the Tension Between Experiment and Mathematics ........................................... 165
8.4 Dave Fultz and the Experimental Tradition of Meteorology ... 169
8.5 Conclusion .................................................. 173

9 Conclusion .................................................. 177
9.1 Three Principal Conclusions .................................................. 178
  9.1.1 Multiple Perspectives of Use Informing Multiple Historical Trajectories .................. 179
  9.1.2 Classifications and Social Associations in the Construction and Deconstruction of Analogue Culture .................. 180
  9.1.3 Analogue–Digital Debates Were Application Based not Technologically Based .................. 181
9.2 Challenges for Future Scholarship in the History of Analogue Computing .................. 182
9.3 Concluding Remarks .................................................. 183

References .................................................. 185

Index .................................................. 207