

CONTENTS

PREFACE xiii

1 INTRODUCTION 1

- 1-1 Magnitude Function, 3
- 1-2 Phase and Group Delay Functions, 9
- 1-3 Design Procedure, 12
- References and Further Reading, 13
- Problems, 13

2 BUILDING BLOCKS 17

- 2-1 Representation, 18
- 2-2 Circuit Components, 19
 - 2-2-1 *Basic building blocks*, 20
 - 2-2-2 *Secondary building blocks*, 23
- References and Further Reading, 39
- Problems, 39

3 PROPERTIES OF NETWORK FUNCTIONS 51

- 3-1 Polynomials of a Complex Variable, 51
- 3-2 Network Function, 54
 - 3-2-1 Hilbert transform, 55
 - 3-2-2 Even and odd parts, 61
 - 3-2-3 Phase and magnitude functions, 65
- References and Further Reading, 69
- Problems, 69

4 POSITIVE REAL FUNCTIONS AND PASSIVITY 73

- 4-1 Hurwitz Polynomial, 76
- 4-2 Positive Real (PR) Functions, 84
- 4-3 Passivity, 89
 - References and Further Reading, 90
 - Problems, 90

5 PROPERTIES AND REALIZATIONS OF LOSSLESS DRIVING-POINT FUNCTIONS 97

- 5-1 Properties of Lossless DP Functions, 98
- 5-2 Realization of Lossless DP Functions, 102
 - 5-2-1 Foster's realization methods, 103
 - 5-2-2 Cauer's realization methods, 107
- 5-3 Concluding Remarks, 120
 - References and Further Reading, 121
 - Problems, 122

6 PROPERTIES AND REALIZATIONS OF PASSIVE RC DRIVING-POINT FUNCTIONS 127

- 6-1 Properties of RC DP Impedance Functions, 128
- 6-2 Properties of RC DP Admittance Functions, 133
- 6-3 Example of Foster's Realization Methods, 137
- 6-4 Cauer's Realization Methods, 139
 - 6-4-1 Cauer's first form, 139
 - 6-4-2 Cauer's second form, 146
- 6-5 Concluding Remarks, 152
 - References and Further Reading, 155
 - Problems, 155

7 PASSIVE REALIZATION OF TRANSFER FUNCTIONS 162

- 7-1 Ladder Networks, 163
 - 7-1-1 *RC ladder networks*, 163
 - 7-1-2 *LC ladder networks*, 175
 - 7-1-3 *Alternative considerations*, 181
- 7-2 Lattice Networks, 186
- 7-3 Darlington Methods, 189
 - 7-3-1 *Lossless network with single termination*, 191
 - 7-3-2 *Lossless two-port terminated at both ends*, 199
- 7-4 Concluding Remarks, 211
 - References and Further Reading, 213
 - Problems, 214

8 FILTER APPROXIMATION 220

- 8-1 The Butterworth Approximation, 225
 - 8-1-1 *Basic properties*, 226
 - 8-1-2 *Transfer function*, 231
 - 8-1-3 *Circuit realization*, 236
- 8-2 The Chebyshev Approximation, 241
 - 8-2-1 *Chebyshev polynomials*, 243
 - 8-2-2 *Chebyshev filters*, 244
 - 8-2-3 *Transfer function*, 247
 - 8-2-4 *Circuit realization*, 261
 - 8-2-5 *Examples*, 263
 - 8-2-6 *Elliptic filters*, 264
- 8-3 The Bessel Approximation, 266
 - 8-3-1 *Transfer function* 267
 - 8-3-2 *Design and realization*, 272
 - 8-3-3 *Transitional filters*, 275
- 8-4 Basic Frequency and Network Transformations, 276
 - 8-4-1 *Low-pass to low-pass transformation*, 277
 - 8-4-2 *Low-pass to bandpass transformation*, 281
 - 8-4-3 *Low-pass to band-reject transformation*, 287
 - 8-4-4 *Low-pass to high-pass transformation*, 291
 - 8-4-5 *Impedance scaling*, 293
 - 8-4-6 *Examples*, 295
- 8-5 All-Pass Filters, 298
 - References and Further Reading, 300
 - Appendix to Chapter 8, 300
 - Problems, 311

9 SENSITIVITY 321

- 9-1 Pole and Zero Sensitivities, 322
 - 9-1-1 *Computation techniques, 322*
 - 9-1-2 *Some general results, 330*
- 9-2 Network Function Sensitivities, 332
 - 9-2-1 *Some general results, 333*
- 9-3 Second-Order Filter Sensitivities, 335
 - References and Further Reading, 337
 - Problems, 338

10 ACTIVE FILTERS 343

- 10-1 Direct Realization Approach, 345
 - 10-1-1 *Direct realization via passive circuits, 345*
 - 10-1-2 *Direct realization with RC 2-ports—Kuh's method, 353*
 - 10-1-3 *Direct realization with RC 1-ports, 359*
 - 10-1-4 *Direct realization via state-variable technique, 370*
- 10-2 Cascade Realization Approach, 373
 - 10-2-1 *Single amplifier biquad, 376*
 - 10-2-2 *Multiple amplifier biquad, 394*
 - 10-2-3 *Complementary circuit configurations, 411*
 - 10-2-4 *Pole-zero pair selection, 415*
 - 10-2-5 *Pole sensitivity considerations, 416*
- 10-3 Nonideal Operational Amplifier Consideration, 418
 - 10-3-1 *Inverting voltage-gain amplifier, 419*
 - 10-3-2 *Noninverting voltage-gain amplifier, 423*
 - 10-3-3 *Integrator, 425*
 - 10-3-4 *Friend's bandpass filter section, 429*
- 10-4 Active Circuits without Capacitors, 433
 - 10-4-1 *A high-Q high-frequency band pass active R biquad circuit, 434*
 - 10-4-2 *An active R biquad circuit, 436*
 - References and Further Reading, 446
 - Problems, 449

11 INTRODUCTION TO DIGITAL FILTERS 462

- 11-1 Digital Signals and Systems, 463
- 11-2 Z-Transform, 472
 - 11-2-1 *Properties of z-transform, 476*
 - 11-2-2 *Inverse Z-transform, 479*
- 11-3 Fourier Transform, 485
 - 11-3-1 *Sampling theorem, 489*
- 11-4 Discrete Fourier Transform, 494
- 11-5 Basic Building-Block Considerations, 500
- 11-6 Stability Considerations, 504
- 11-7 A Simple Digital-Filter Example, 507
- 11-8 Analysis of Digital Filters, 509
 - References and Further Reading, 511
 - Problems, 513

12 DESIGN OF DIGITAL FILTERS 518

- 12-1 Design of IIR Digital Filters, 523
 - 12-1-1 *Numerical integration techniques, 525*
 - 12-1-2 *Impulse invariant transformation, 530*
 - 12-1-3 *Bilinear Transformation, 543*
 - 12-1-4 *Frequency transformations, 552*
 - 12-1-5 *Design of all-pass digital filters, 561*
- 12-2 Design of FIR Digital Filter, 564
 - 12-2-1 *Frequency sampling method, 567*
 - 12-2-2 *The method of windowing, 569*
 - 12-2-3 *Some comments on FIR digital filters, 572*
 - References and Further Reading, 573
 - Problems, 574

13 REALIZATION OF DIGITAL FILTERS 581

- 13-1 Realization of IIR Digital Filters, 581
 - 13-1-1 *Direct realization, 582*
 - 13-1-2 *Indirect realization, 607*
- 13-2 Realization of FIR Digital Filters, 615
 - References and Further Reading, 619
 - Problems, 620