
Contents

Preface	ix
Chapter 1. Introduction, Generalities, Definitions of Systems	1
1.1. Introduction	1
1.2. Signals and communication systems	2
1.3. Signals and systems representation	5
1.3.1. Signal	5
1.3.2. Functional space L_2	6
1.3.3. Dirac distribution	8
1.4. Convolution and composition products – notions of filtering	10
1.4.1. Convolution or composition product	10
1.4.2. System	11
1.5. Transmission systems and filters	12
1.5.1. Convolution and filtering	13
1.6. Deterministic signals – random signals – analog signals	15
1.6.1. Definitions	15
1.6.2. Some deterministic analog signals	16
1.6.3. Representation and modeling of signals and systems	20
1.6.4. Phase–plane representation	23
1.6.5. Dynamic system	26
1.7. Comprehension and application exercises	28
Chapter 2. Transforms: Time – Frequency – Scale	31
2.1. Fourier series applied to periodic functions	31
2.1.1. Fourier series	31
2.1.2. Spectral representation (frequency domain)	33
2.1.3. Properties of Fourier series	34
2.1.4. Some examples	35

2.2. FT applied to non-periodic functions	36
2.3. Necessary conditions for the Fourier integral	38
2.3.1. Definition	38
2.3.2. Necessary condition	38
2.4. FT properties	39
2.4.1. Properties	39
2.4.2. Properties of the FT	39
2.4.3. Plancherel theorem and convolution product	40
2.5. Fourier series and FT	41
2.6. Elementary signals and their transforms	43
2.7. Laplace transform	46
2.7.1. Definition	46
2.7.2. Properties	49
2.7.3. Examples of the use of the unilateral LT	50
2.7.4. Transfer function	52
2.8. FT and LT	53
2.9. Application exercises	54
Chapter 3. Spectral Study of Signals	59
3.1. Power and signals energy	59
3.1.1. Power and energy of random signals	59
3.2. Autocorrelation and intercorrelation	61
3.2.1. Autocorrelation and cross-correlation in the time domain	61
3.2.2. A few examples of applications in steady state	64
3.2.3. Powers in variable state	65
3.3. Mathematical application of the correlation and autocorrelation functions	66
3.3.1. Duration of a signal and its spectrum width	68
3.3.2. Finite or zero average power signals	72
3.3.3. Application for linear filtering	74
3.4. A few application exercises	75
Chapter 4. Representation of Discrete (Sampled) Systems	81
4.1. Shannon and sampling, discretization methods, interpolation, sample and hold circuits	81
4.1.1. Sampling and interpolation	81
4.2. Z-transform – representation of discrete (sampled) systems	89
4.2.1. Definition – convergence and residue	89
4.2.2. Inverse Z-transform	91
4.2.3. Properties of the Fourier transform	96
4.2.4. Representation and modeling of signals and discrete systems	99
4.2.5. Transfer function in Z and representation in the frequency domain	102

4.2.6. Z-domain transform, Fourier transform and Laplace transform	104
4.3. A few application exercises	105
Chapter 5. Representation of Signals and Systems	123
5.1. Introduction to modeling	123
5.1.1. Signal representation using polynomial equations	127
5.1.2. Representation of signals and systems by differential equations . .	127
5.2. Representation using system state equations	128
5.2.1. State variables and state representation definition	128
5.2.2. State–space representation for discrete linear systems	134
5.3. Transfer functions	135
5.3.1. Transfer function: external representation	135
5.3.2. Transfer function and state–space representation shift	135
5.3.3. Properties of transfer functions	138
5.3.4. Associations of functional diagrams	142
5.4. Change in representation and canonical forms	142
5.4.1. Controllable canonical form	143
5.4.2. Controllable canonical form	145
5.4.3. Observability canonical form	145
5.4.4. Observable canonical form	146
5.4.5. Diagonal canonical form	149
5.4.6. Change in state-space representations and change in basis	150
5.4.7. Examples of systems to be modeled: the inverse pendulum	152
5.4.8. System phase–plane representation	155
5.5. Some application exercises	160
Chapter 6. Dynamic Responses and System Performance	173
6.1. Introduction to linear time-invariant systems	173
6.2. Transition matrix of an LTI system	173
6.2.1. Transition matrix	173
6.3. Evolution equation of an LTI system	174
6.3.1. State evolution equation	174
6.3.2. Transition matrix computation	176
6.4. Time response to the excitation of continuous linear systems	177
6.4.1. System response	177
6.4.2. Solution the state equation	178
6.4.3. Role of eigenvalues of the evolution matrix A within the system dynamics	181
6.5. Sampling and discretization of continuous systems	182
6.5.1. Choice of the sampling period (Shannon) and integration methods .	182
6.5.2. Euler's method	182
6.5.3. Order n Runge–Kutta method	183
6.5.4. Method using the state transition matrix with zeroth-order holder .	184

6.5.5. Evolution equation for a time-invariant discrete system (DTI)	185
6.6. Some temporal responses	186
6.6.1. Response to an impulse excitation	187
6.6.2. Response to step excitation	187
6.7. Transfer function frequency responses	193
6.7.1. Bode plot	193
6.7.2. Nyquist plot	195
6.7.3. Black–Nichols plot	197
6.8. Parametric identification	198
6.8.1. Identification by analogy	199
6.8.2. Parameters identification: examples of systems	201
6.8.3. Strejc method (minimal dephasing)	203
6.9. Dynamics of linear systems	204
6.9.1. Link between frequency domain and time domain	204
6.10. System performance and accuracy	205
6.10.1. Damping factor of a system	205
6.10.2. System speed and transient	205
6.10.3. System static error, speed, sensitivity to noise and accuracy	205
6.10.4. Conclusion	208
6.11. Some application exercises	208
Chapter 7. System Stability and Robustness Analysis Methods	227
7.1. Introduction	227
7.2. Definitions related with the stability of a dynamic system	228
7.2.1. Equilibrium state of a system	229
7.2.2. Stable system: bounded input bounded output	229
7.3. Stability criteria	230
7.3.1. Routh criterion and stability algebraic criterion	230
7.3.2. Jury criterion and discrete system example	235
7.4. Some application exercises	242
7.4.1. Exercises: circle criterion, causes of instability and practical cases	242
Bibliography	257
Index	263