

# Contents

- 1 Signals and Systems . . . . . 1**
  - 1.1 Signals . . . . . 2
    - 1.1.1 Various Types of Signal . . . . . 2
    - 1.1.2 Continuous/Discrete-Time Signals . . . . . 2
    - 1.1.3 Analog Frequency and Digital Frequency . . . . . 6
    - 1.1.4 Properties of the Unit Impulse Function  
and Unit Sample Sequence . . . . . 8
    - 1.1.5 Several Models for the Unit Impulse Function . . . . . 11
  - 1.2 Systems . . . . . 12
    - 1.2.1 Linear System and Superposition Principle . . . . . 13
    - 1.2.2 Time/Shift-Invariant System . . . . . 14
    - 1.2.3 Input-Output Relationship of Linear  
Time-Invariant (LTI) System . . . . . 15
    - 1.2.4 Impulse Response and System (Transfer) Function . . . . . 17
    - 1.2.5 Step Response, Pulse Response, and Impulse Response . . . . 18
    - 1.2.6 Sinusoidal Steady-State Response  
and Frequency Response . . . . . 19
    - 1.2.7 Continuous/Discrete-Time Convolution . . . . . 22
    - 1.2.8 Bounded-Input Bounded-Output (BIBO) Stability . . . . . 29
    - 1.2.9 Causality . . . . . 30
    - 1.2.10 Invertibility . . . . . 30
  - 1.3 Systems Described by Differential/Difference Equations . . . . . 31
    - 1.3.1 Differential/Difference Equation and System Function . . . . . 31
    - 1.3.2 Block Diagrams and Signal Flow Graphs . . . . . 32
    - 1.3.3 General Gain Formula – Mason’s Formula . . . . . 34
    - 1.3.4 State Diagrams . . . . . 35
  - 1.4 Deconvolution and Correlation . . . . . 38
    - 1.4.1 Discrete-Time Deconvolution . . . . . 38
    - 1.4.2 Continuous/Discrete-Time Correlation . . . . . 39
  - 1.5 Summary . . . . . 45
    - Problems . . . . . 45

<b>2</b>	<b>Continuous-Time Fourier Analysis</b>	61
2.1	Continuous-Time Fourier Series (CTFS) of Periodic Signals	62
2.1.1	Definition and Convergence Conditions of CTFS Representation	62
2.1.2	Examples of CTFS Representation	65
2.1.3	Physical Meaning of CTFS Coefficients – Spectrum	70
2.2	Continuous-Time Fourier Transform of Aperiodic Signals	73
2.3	(Generalized) Fourier Transform of Periodic Signals	77
2.4	Examples of the Continuous-Time Fourier Transform	78
2.5	Properties of the Continuous-Time Fourier Transform	86
2.5.1	Linearity	86
2.5.2	(Conjugate) Symmetry	86
2.5.3	Time/Frequency Shifting (Real/Complex Translation)	88
2.5.4	Duality	88
2.5.5	Real Convolution	89
2.5.6	Complex Convolution (Modulation/Windowing)	90
2.5.7	Time Differential/Integration – Frequency Multiplication/Division	94
2.5.8	Frequency Differentiation – Time Multiplication	95
2.5.9	Time and Frequency Scaling	95
2.5.10	Parseval's Relation (Rayleigh Theorem)	96
2.6	Polar Representation and Graphical Plot of CTFT	96
2.6.1	Linear Phase	97
2.6.2	Bode Plot	97
2.7	Summary	98
	Problems	99
<b>3</b>	<b>Discrete-Time Fourier Analysis</b>	129
3.1	Discrete-Time Fourier Transform (DTFT)	130
3.1.1	Definition and Convergence Conditions of DTFT Representation	130
3.1.2	Examples of DTFT Analysis	132
3.1.3	DTFT of Periodic Sequences	136
3.2	Properties of the Discrete-Time Fourier Transform	138
3.2.1	Periodicity	138
3.2.2	Linearity	138
3.2.3	(Conjugate) Symmetry	138
3.2.4	Time/Frequency Shifting (Real/Complex Translation)	139
3.2.5	Real Convolution	139
3.2.6	Complex Convolution (Modulation/Windowing)	139
3.2.7	Differencing and Summation in Time	143
3.2.8	Frequency Differentiation	143
3.2.9	Time and Frequency Scaling	143
3.2.10	Parseval's Relation (Rayleigh Theorem)	144

3.3	Polar Representation and Graphical Plot of DTFT .....	144
3.4	Discrete Fourier Transform (DFT) .....	147
3.4.1	Properties of the DFT .....	149
3.4.2	Linear Convolution with DFT .....	152
3.4.3	DFT for Noncausal or Infinite-Duration Sequence .....	155
3.5	Relationship Among CTFS, CTFT, DTFT, and DFT .....	160
3.5.1	Relationship Between CTFS and DFT/DFS .....	160
3.5.2	Relationship Between CTFT and DTFT .....	161
3.5.3	Relationship Among CTFS, CTFT, DTFT, and DFT/DFS ..	162
3.6	Fast Fourier Transform (FFT) .....	164
3.6.1	Decimation-in-Time (DIT) FFT .....	165
3.6.2	Decimation-in-Frequency (DIF) FFT .....	168
3.6.3	Computation of IDFT Using FFT Algorithm .....	169
3.7	Interpretation of DFT Results .....	170
3.8	Effects of Signal Operations on DFT Spectrum .....	178
3.9	Short-Time Fourier Transform – Spectrogram .....	180
3.10	Summary .....	182
	Problems .....	182
<b>4</b>	<b>The <math>z</math>-Transform .....</b>	<b>207</b>
4.1	Definition of the $z$ -Transform .....	208
4.2	Properties of the $z$ -Transform .....	213
4.2.1	Linearity .....	213
4.2.2	Time Shifting – Real Translation .....	214
4.2.3	Frequency Shifting – Complex Translation .....	215
4.2.4	Time Reversal .....	215
4.2.5	Real Convolution .....	215
4.2.6	Complex Convolution .....	216
4.2.7	Complex Differentiation .....	216
4.2.8	Partial Differentiation .....	217
4.2.9	Initial Value Theorem .....	217
4.2.10	Final Value Theorem .....	218
4.3	The Inverse $z$ -Transform .....	218
4.3.1	Inverse $z$ -Transform by Partial Fraction Expansion .....	219
4.3.2	Inverse $z$ -Transform by Long Division .....	223
4.4	Analysis of LTI Systems Using the $z$ -Transform .....	224
4.5	Geometric Evaluation of the $z$ -Transform .....	231
4.6	The $z$ -Transform of Symmetric Sequences .....	236
4.6.1	Symmetric Sequences .....	236
4.6.2	Anti-Symmetric Sequences .....	237
4.7	Summary .....	240
	Problems .....	240

<b>5</b>	<b>Sampling and Reconstruction</b>	<b>249</b>
5.1	Digital-to-Analog (DA) Conversion[J-1]	250
5.2	Analog-to-Digital (AD) Conversion[G-1, J-2, W-2]	251
5.2.1	Counter (Stair-Step) Ramp ADC	251
5.2.2	Tracking ADC	252
5.2.3	Successive Approximation ADC	253
5.2.4	Dual-Ramp ADC	254
5.2.5	Parallel (Flash) ADC	256
5.3	Sampling	257
5.3.1	Sampling Theorem	257
5.3.2	Anti-Aliasing and Anti-Imaging Filters	262
5.4	Reconstruction and Interpolation	263
5.4.1	Shannon Reconstruction	263
5.4.2	DFS Reconstruction	265
5.4.3	Practical Reconstruction	267
5.4.4	Discrete-Time Interpolation	269
5.5	Sample-and-Hold (S/H) Operation	272
5.6	Summary	272
	Problems	273
<b>6</b>	<b>Continuous-Time Systems and Discrete-Time Systems</b>	<b>277</b>
6.1	Concept of Discrete-Time Equivalent	277
6.2	Input-Invariant Transformation	280
6.2.1	Impulse-Invariant Transformation	281
6.2.2	Step-Invariant Transformation	282
6.3	Various Discretization Methods [P-1]	284
6.3.1	Backward Difference Rule on Numerical Differentiation	284
6.3.2	Forward Difference Rule on Numerical Differentiation	286
6.3.3	Left-Side (Rectangular) Rule on Numerical Integration	287
6.3.4	Right-Side (Rectangular) Rule on Numerical Integration	288
6.3.5	Bilinear Transformation (BLT) – Trapezoidal Rule on Numerical Integration	288
6.3.6	Pole-Zero Mapping – Matched $z$ -Transform [F-1]	292
6.3.7	Transport Delay – Dead Time	293
6.4	Time and Frequency Responses of Discrete-Time Equivalents	293
6.5	Relationship Between $s$ -Plane Poles and $z$ -Plane Poles	295
6.6	The Starred Transform and Pulse Transfer Function	297
6.6.1	The Starred Transform	297
6.6.2	The Pulse Transfer Function	298
6.6.3	Transfer Function of Cascaded Sampled-Data System	299
6.6.4	Transfer Function of System in A/D- $G[z]$ -D/A Structure	300
	Problems	301

<b>7</b>	<b>Analog and Digital Filters</b>	307
7.1	Analog Filter Design	307
7.2	Digital Filter Design	320
7.2.1	IIR Filter Design	321
7.2.2	FIR Filter Design	331
7.2.3	Filter Structure and System Model Available in MATLAB	345
7.2.4	Importing/Exporting a Filter Design	348
7.3	How to Use SPTool	350
	Problems	357
<b>8</b>	<b>State Space Analysis of LTI Systems</b>	361
8.1	State Space Description – State and Output Equations	362
8.2	Solution of LTI State Equation	364
8.2.1	State Transition Matrix	364
8.2.2	Transformed Solution	365
8.2.3	Recursive Solution	368
8.3	Transfer Function and Characteristic Equation	368
8.3.1	Transfer Function	368
8.3.2	Characteristic Equation and Roots	369
8.4	Discretization of Continuous-Time State Equation	370
8.4.1	State Equation Without Time Delay	370
8.4.2	State Equation with Time Delay	374
8.5	Various State Space Description – Similarity Transformation	376
8.6	Summary	379
	Problems	379
<b>A</b>	<b>The Laplace Transform</b>	385
A.1	Definition of the Laplace Transform	385
A.2	Examples of the Laplace Transform	385
A.2.1	Laplace Transform of the Unit Step Function	385
A.2.2	Laplace Transform of the Unit Impulse Function	386
A.2.3	Laplace Transform of the Ramp Function	387
A.2.4	Laplace Transform of the Exponential Function	387
A.2.5	Laplace Transform of the Complex Exponential Function	387
A.3	Properties of the Laplace Transform	387
A.3.1	Linearity	388
A.3.2	Time Differentiation	388
A.3.3	Time Integration	388
A.3.4	Time Shifting – Real Translation	389
A.3.5	Frequency Shifting – Complex Translation	389
A.3.6	Real Convolution	389
A.3.7	Partial Differentiation	390
A.3.8	Complex Differentiation	390
A.3.9	Initial Value Theorem	391

A.3.10 Final Value Theorem . . . . .	391
A.4 Inverse Laplace Transform . . . . .	392
A.5 Using the Laplace Transform to Solve Differential Equations . . . . .	394
<b>B Tables of Various Transforms . . . . .</b>	<b>399</b>
<b>C Operations on Complex Numbers, Vectors, and Matrices . . . . .</b>	<b>409</b>
C.1 Complex Addition . . . . .	409
C.2 Complex Multiplication . . . . .	409
C.3 Complex Division . . . . .	409
C.4 Conversion Between Rectangular Form and Polar/Exponential Form	409
C.5 Operations on Complex Numbers Using MATLAB . . . . .	410
C.6 Matrix Addition and Subtraction[Y-1] . . . . .	410
C.7 Matrix Multiplication . . . . .	411
C.8 Determinant . . . . .	411
C.9 Eigenvalues and Eigenvectors of a Matrix <sup>1</sup> . . . . .	412
C.10 Inverse Matrix . . . . .	412
C.11 Symmetric/Hermitian Matrix . . . . .	413
C.12 Orthogonal/Unitary Matrix . . . . .	413
C.13 Permutation Matrix . . . . .	414
C.14 Rank . . . . .	414
C.15 Row Space and Null Space . . . . .	414
C.16 Row Echelon Form . . . . .	414
C.17 Positive Definiteness . . . . .	415
C.18 Scalar(Dot) Product and Vector(Cross) Product . . . . .	416
C.19 Matrix Inversion Lemma . . . . .	416
C.20 Differentiation w.r.t. a Vector . . . . .	416
<b>D Useful Formulas . . . . .</b>	<b>419</b>
<b>E MATLAB . . . . .</b>	<b>421</b>
E.1 Convolution and Deconvolution . . . . .	423
E.2 Correlation . . . . .	424
E.3 CTFS (Continuous-Time Fourier Series) . . . . .	425
E.4 DTFT (Discrete-Time Fourier Transform) . . . . .	425
E.5 DFS/DFT (Discrete Fourier Series/Transform) . . . . .	425
E.6 FFT (Fast Fourier Transform) . . . . .	426
E.7 Windowing . . . . .	427
E.8 Spectrogram (FFT with Sliding Window) . . . . .	427
E.9 Power Spectrum . . . . .	429
E.10 Impulse and Step Responses . . . . .	430
E.11 Frequency Response . . . . .	433
E.12 Filtering . . . . .	434
E.13 Filter Design . . . . .	436

E.13.1	Analog Filter Design .....	436
E.13.2	Digital Filter Design – IIR (Infinite-duration Impulse Response) Filter .....	437
E.13.3	Digital Filter Design – FIR (Finite-duration Impulse Response) Filter .....	438
E.14	Filter Discretization .....	441
E.15	Construction of Filters in Various Structures Using dfilt() .....	443
E.16	System Identification from Impulse/Frequency Response .....	447
E.17	Partial Fraction Expansion and (Inverse) Laplace/z-Transform .....	449
E.18	Decimation, Interpolation, and Resampling .....	450
E.19	Waveform Generation .....	452
E.20	Input/Output through File .....	452
<b>F</b>	<b>Simulink® .....</b>	<b>453</b>
<b>Index</b> .....		<b>461</b>
<b>Index for MATLAB routines</b> .....		<b>467</b>
<b>Index for Examples</b> .....		<b>471</b>
<b>Index for Remarks</b> .....		<b>473</b>



<http://www.springer.com/978-3-540-92953-6>

Signals and Systems with MATLAB

Yang, W.Y.

2009, XV, 474 p., Hardcover

ISBN: 978-3-540-92953-6