

Contents

1	Models and Experiments	1
1.1	Hierarchy of Systems	2
1.2	The Bottom Layer—Control and Measurement	2
1.3	Models of Physical Reality	3
1.3.1	Models Based on First Principles	3
1.3.2	Models Based on Statistical Inference	6
1.4	Models of Computation	7
1.4.1	Finite State Machines	7
1.4.2	Signal and Data Flow—Block Diagrams	9
1.5	Structural Models	10
1.6	Bibliographic Notes	10
1.7	Exercises	10
	References	11
2	Tools—Mainly Mathematics	13
2.1	Complex Numbers	13
2.2	Line and Surface Integrals	14
2.3	Discrete-Time Signals and Systems	15
2.3.1	Linear Time-Invariant Systems	16
2.3.2	Impulse Response and Convolution	17
2.3.3	Circular Convolution	17
2.4	Continuous-Time Signals and Systems	18
2.4.1	Linear Time-Invariant Systems	19
2.4.2	Impulse Response and Convolution	20
2.4.3	Circular Convolution	20
2.5	The Four Fourier Transforms	20
2.5.1	Periodic Continuous-Time Signals— The Fourier Series	21
2.5.2	Periodic Discrete-Time Signals—the Discrete Fourier Transform	23

2.5.3	Discrete-Time Signals—The Discrete-Time Fourier Transform	24
2.5.4	Continuous-Time Signals—The Continuous-Time Fourier Transform	27
2.6	Noise	29
2.7	The Z-Transform	30
2.7.1	Stability of Linear Time-Invariant Discrete-Time Systems	31
2.8	The Two-Sided Laplace Transform	32
2.8.1	Stability of Linear Time-Invariant Continuous-Time Systems	34
2.9	Differential Equations, State-Space Models	35
2.9.1	The Harmonic Oscillator	36
2.9.2	The Pendulum	40
2.10	Feedback Control	41
2.11	Instrumentation for Producing and Measuring Signals	45
2.11.1	The Function Generator	45
2.11.2	The Oscilloscope	46
2.12	Bibliographical Notes	48
2.13	Exercises	48
2.14	Lab Exercise	49
	References	49
3	Voltage, Current, Basic Components	51
3.1	Electric Charge, Voltage, and Current	51
3.1.1	The Electric and the Magnetic Field	52
3.1.2	Electric Circuits	53
3.1.3	The Kirchhoff Voltage Law and the Kirchhoff Current Law	54
3.2	Electric Power	55
3.3	Resistors	56
3.4	Current and Voltage Sources	57
3.4.1	Equivalent Circuits	59
3.4.2	Voltage Dividers	59
3.5	Voltage, Current, and Resistance Measurements	60
3.6	Capacitors	64
3.6.1	Energy Stored in a Capacitor	65
3.7	Inductors	66
3.7.1	Energy Stored in an Inductor	67
3.8	RLC Circuits	67
3.9	Alternating Current Circuits	69
3.10	Three-Phase Circuits	73

3.11	Bibliographical Notes	73
3.12	Exercises	73
3.13	Lab Exercises	75
	References	75
4	Digital Electronics	77
4.1	Inputs	77
4.2	Outputs	78
4.2.1	The Nine Logic Values	78
4.3	Combinatoric Logic	79
4.4	Sequential Logic	81
4.4.1	Flip-Flops and Metastability	82
4.4.2	Synchronous Logic	82
4.4.3	State Machines	83
4.4.4	Transparent Latch	84
4.5	Clock Domains	87
4.6	Digital Building Blocks	88
4.7	Realization of Logic Circuits	89
4.8	Support Circuits	90
4.9	Analog Aspects of Fast Logic	90
4.10	Bibliographic Notes	92
4.11	Exercises	92
4.12	Lab Exercises	93
	References	93
5	Programmable Devices—Software and Hardware	95
5.1	Challenges Particular to Embedded Systems Development	95
5.1.1	Time	96
5.1.2	Reliability	96
5.1.3	Safety	96
5.1.4	Power	96
5.2	The Event Triggered Architecture	97
5.2.1	Implementing Event Triggered Systems	99
5.2.2	Keeping Time in Event-Triggered Architectures	102
5.3	The Time Triggered Architecture	104
5.3.1	Maintaining a Common Sense of Time	105
5.3.2	Implementing Time Triggered Systems	106
5.4	The Polling Architecture	106
5.5	Hardware Organization	107
5.6	Peripherals	108
5.6.1	General Purpose Input and Output	108
5.6.2	Counters and Timers	108
5.6.3	Analog Data Acquisition	109

5.6.4	Waveform Generation	109
5.6.5	Communication	110
5.7	Memory.	112
5.7.1	Volatile Memory	113
5.7.2	Memory Hierarchy	117
5.7.3	Nonvolatile Memory	118
5.8	Embedded Microprocessors	120
5.9	Digital Signal Processors	122
5.9.1	The SHARC [®] Family of Digital Signal Processors . . .	123
5.9.2	Case Study—Fast Fourier Transform.	127
5.10	Programmable Logic	140
5.10.1	Case Study—Rotary Encoder Interface	141
5.11	Tools.	144
5.11.1	Cross Compiler and Linker	144
5.11.2	Debugger and In-Circuit Emulator	144
5.11.3	Logic Design Tools.	145
5.12	Bibliographic Notes	145
5.13	Exercises	146
5.14	Lab Exercises.	146
	References.	146
6	Analog Circuits—Signal Conditioning and Conversion	149
6.1	Sampled Data Systems	149
6.2	Analog Filters	151
6.2.1	Filter Characteristics	152
6.3	Sampling and Reconstruction	156
6.3.1	Sampling Real-Valued Signals	158
6.4	Antialiasing and Reconstruction Filters	159
6.5	Analog-to-Digital Converters	160
6.5.1	Single-Shot Conversion	161
6.5.2	Periodic Conversion	162
6.5.3	Effects of Sampling Clock Uncertainty	162
6.6	Digital-to-Analog Converters	163
6.7	Analog Building Blocks.	164
6.7.1	Operational Amplifiers	165
6.7.2	Voltage References	171
6.7.3	Comparators.	171
6.8	Discrete Active Elements.	172
6.8.1	Diodes.	172
6.8.2	Transistors	175
6.9	Bibliographic Notes	178
6.10	Exercises	178
	References.	179

7	Energy Conversion—Power Supplies	181
7.1	Linear Regulators	181
7.2	Switchmode Converters	183
7.2.1	Step-Down Converters	184
7.2.2	Step-Up Converters	187
7.2.3	SEPIC Converters	189
7.2.4	Buck-Boost Converters	191
7.2.5	Ćuk Converters	193
7.2.6	Flyback Converters	195
7.2.7	Control of Switchmode Converters	198
7.2.8	Components for Switchmode Converters	200
7.3	Constant Current Supply for LED Illumination	202
7.4	Bibliographic Notes	203
7.5	Exercises	204
7.6	Lab Exercises	205
	References	205
8	Energy Conversion—Motor Control	207
8.1	Magnetism	207
8.1.1	Magnetically Soft Materials	209
8.1.2	Magnetic Circuits	209
8.1.3	Magnetically Hard Materials	210
8.2	The Permanent Magnet Synchronous Machine	211
8.2.1	Sine-Distributed Windings	212
8.2.2	Space Vectors	215
8.2.3	A Model of the Permanent Magnet Synchronous Machine	217
8.3	Open Loop Operation	221
8.4	Torque Control	225
8.5	Speed Control	226
8.6	Sensorless Operation	227
8.7	Delta and Wye Connection	229
8.8	Implementation of Field-Oriented Motor Control	229
8.8.1	Synthesizing Three Phase Voltages	231
8.9	A Low-Voltage Power Stage	234
8.10	Bibliographical Notes	237
8.11	Exercises	238
	References	238
9	Data Recovery from Noise—Lock-In Detection	241
9.1	Operational Principle	242
9.2	Square-Wave Reference	244
9.3	External Reference	245
9.4	Implementation	247

9.5	Signal Conditioning for Strain Gauges.	249
9.6	Simultaneous Measurements.	253
9.6.1	Sinusoidal References	254
9.6.2	Square-Wave References	256
9.7	A Moisture Sensor	257
9.8	Bibliographical Notes	262
9.9	Lab Exercises.	263
	References.	263
10	Short-Range Radar.	265
10.1	The Unmodulated Continuous-Wave Radar	265
10.1.1	The Doppler Shift.	265
10.1.2	Separating the Doppler Shift from the Carrier.	266
10.1.3	Down-Conversion of the Doppler Shift	267
10.1.4	Extracting Speed Information	268
10.1.5	Spectral Leakage	271
10.2	The Frequency-Modulated Continuous-Wave Radar	271
10.3	Implementation of a Continuous-Wave Radar.	272
10.3.1	Overview.	272
10.3.2	The Analog and High-Frequency Signal Path.	273
10.3.3	The Digital Signal Processor and its Support Circuits	274
10.3.4	The Digital-to-Analog Converter.	276
10.3.5	The Analog-to-Digital Converter.	277
10.3.6	The Communication Interface.	278
10.3.7	The Power Supplies	279
10.3.8	Software	280
10.4	Sample Measurements.	283
10.5	Bibliographic Notes	283
10.6	Lab Exercises.	283
	References.	283
11	Infrared Spectrometry	285
11.1	Light Waves	285
11.1.1	Coherence	286
11.1.2	Intensity	287
11.1.3	Refraction	287
11.1.4	Reflection	289
11.2	Spectrometer Types.	289
11.2.1	Diffraction Instruments	289
11.2.2	Fourier Transform Instruments	289

11.3	The Michelson Interferometer	290
11.3.1	Monochromatic Light	291
11.3.2	White Light	293
11.3.3	Imperfections in the Optics	293
11.4	Design of a Fourier Transform Spectrometer	294
11.4.1	Recording the Interferograms	296
11.4.2	Measuring the Mirror Movement	296
11.4.3	Demodulating the White-Light Interferogram	299
11.4.4	Phase Correction and Computation of Spectra	300
11.4.5	The Reference Laser	304
11.4.6	Detector Cooling	304
11.4.7	Driving the Movable Mirror	304
11.4.8	Optical Setup	305
11.4.9	Automation of Measurement Processes	306
11.5	Bibliographical Notes	306
	References.	308
	Appendix A: Block Diagrams.	311
	Appendix B: Circuit Diagrams.	315
	Appendix C: The One-Sided Laplace Transform.	319
	Appendix D: Answers to Selected Exercises	321
	Index	339

Engineering Embedded Systems

Physics, Programs, Circuits

Hintenaus, P.

2015, XXI, 345 p. 307 illus., 83 illus. in color., Hardcover

ISBN: 978-3-319-10679-3