

---

# Contents

<b>1</b>	<b>Introduction to Systems</b>	<b>1</b>
1.1	Study of Systems	1
1.2	Standard Forms of System Description	9
1.2.1	Input-Output Description	9
1.2.2	State-Variable Description	11
1.3	Controllability, Observability, and Identifiability	17
1.4	Analytical Solutions of Linear Systems Models	23
1.4.1	Solution of State Equations Using the Laplace Transform	25
1.4.2	Eigenvalues of the Linear Vector-Equation Systems	27
1.5	Steady-State Errors of Systems	29
1.6	Case Study in Systems Stability Analysis	31
1.7	Exercises	34
	References	34
<b>2</b>	<b>Introduction to Embedded Computing Systems</b>	<b>37</b>
2.1	Embedded Computing Systems	37
2.2	Hardware Architectures of Embedded Computing Systems	41
2.2.1	Programmable Logic Devices	44
2.2.2	Field-Programmable Gate Arrays	46
2.3	Design Metrics	52
2.4	Embedded Control Systems	56
2.4.1	Control	56
2.4.2	Feedback Control	57
2.4.3	Feedback Components of Embedded Control Systems	62
2.5	Hardware-Software Codesign	69
2.6	Case Study: FPGA-Based CPU Core	73
2.7	Exercises	78
	References and Further Reading	79
<b>3</b>	<b>Introduction to Cyber-Physical Systems</b>	<b>81</b>
3.1	Cyber-Physical Systems	81
3.2	Cyber-Physical Systems Design Recommendations	88

3.3	Cyber-Physical System Requirements . . . . .	94
3.3.1	Requirements Engineering . . . . .	95
3.3.2	Interoperability . . . . .	96
3.3.3	Real-Time Systems . . . . .	97
3.3.4	GPU Computing . . . . .	98
3.4	Cyber-Physical Systems Applications . . . . .	99
3.4.1	Communication . . . . .	102
3.4.2	Consumer Interaction . . . . .	103
3.4.3	Energy . . . . .	104
3.4.4	Infrastructure . . . . .	107
3.4.5	Health Care . . . . .	110
3.4.6	Manufacturing . . . . .	114
3.4.7	Military . . . . .	117
3.4.8	Robotics . . . . .	118
3.4.9	Transportation . . . . .	120
3.5	Smart Cities and the Internet of Everything . . . . .	123
3.6	Case Study: Cyber-Physical Vehicle Tracking System . . . . .	127
3.6.1	Vehicle Tracking System . . . . .	127
3.6.2	RFID-Based Vehicle Tracking System . . . . .	129
3.6.3	Requirements Analysis . . . . .	130
3.6.4	Further Research . . . . .	133
3.7	Exercises . . . . .	133
	References . . . . .	134
<b>4</b>	<b>Introduction to the Internet of Things . . . . .</b>	<b>141</b>
4.1	The Internet of Things . . . . .	141
4.2	Radio Frequency Identification Technology . . . . .	145
4.3	Wireless Sensor Networks Technology . . . . .	151
4.3.1	Sensor Technology . . . . .	152
4.3.2	Sensor Networks . . . . .	154
4.3.3	Wireless Sensor Networks . . . . .	158
4.4	Powerline Communication . . . . .	162
4.4.1	Internet of Things and Powerline Communication . . . . .	164
4.4.2	Smart Grid . . . . .	166
4.4.3	Smart Home Energy Management . . . . .	169
4.5	RFID Applications . . . . .	170
4.6	Case Study: Luggage Tracking System . . . . .	174
4.7	Exercises . . . . .	181
	References . . . . .	182
<b>5</b>	<b>Ubiquitous Computing . . . . .</b>	<b>185</b>
5.1	Ubiquitous Computing History to Date . . . . .	185
5.2	Ubiquitous Computing Fundamentals . . . . .	189
5.2.1	Learning in the Ubiquitous Space . . . . .	191
5.2.2	Smart Home and Powerline Communication . . . . .	196

---

5.2.3	Core Properties of Ubiquitous Computing . . . . .	200
5.2.4	Ubiquitous Computing Formalisms for Use Cases . . . . .	203
5.3	Smart Devices: Components and Services . . . . .	204
5.4	Tagging, Sensing, and Controlling . . . . .	208
5.4.1	Tagging . . . . .	209
5.4.2	Sensing . . . . .	211
5.4.3	Controlling . . . . .	216
5.5	Autonomous Systems in Ubiquitous Computing . . . . .	222
5.6	Case Study: Robot Manipulator . . . . .	225
5.7	Exercises . . . . .	230
	References . . . . .	232
<b>6</b>	<b>Systems and Software Engineering . . . . .</b>	<b>235</b>
6.1	Introduction to Systems Engineering . . . . .	235
6.1.1	Systems Engineering Standard ISO/IEC 15288 . . . . .	239
6.1.2	Top-Down Approach to Systems Engineering . . . . .	251
6.1.3	Open Engineering Platform for Autonomous Mechatronic Automation . . . . .	255
6.2	Design Challenges in Cyber-Physical Systems . . . . .	256
6.2.1	Requirements Definition and Management Using Cradle® . . . . .	260
6.2.2	Requirements Definition and Management Activities . . . . .	262
6.2.3	INCOSE Systems Engineering Handbook (v.3.2.2) Traceability . . . . .	277
6.3	Introduction to Software Engineering . . . . .	278
6.3.1	V-Model . . . . .	285
6.3.2	Agile Software Development Methodology . . . . .	287
6.3.3	Comparison of the V-Model and the Agile Software Development Methodology . . . . .	289
6.4	Requirements in Software Design in Cyber-Physical Systems . . . . .	290
6.5	Maritime Area Case Studies . . . . .	295
6.5.1	Tracking and Monitoring Containers at Ports and on Ships . . . . .	296
6.5.2	Tracking and Monitoring Containers Transported from the Sea Gate Port to a Dry Port . . . . .	297
6.6	Exercises . . . . .	301
	References . . . . .	303
<b>7</b>	<b>Digital Manufacturing/Industry 4.0 . . . . .</b>	<b>307</b>
7.1	Introduction to Manufacturing . . . . .	307
7.1.1	Smart and Agile Manufacturing . . . . .	312
7.1.2	Smart Factory . . . . .	316
7.1.3	Industry 4.0 . . . . .	324
7.2	Individualized Production . . . . .	328
7.3	Networked Manufacturing-Integrated Industry . . . . .	330
7.4	Open and Closed Manufacturing Lines . . . . .	334

7.5	Cybersecurity in Digital Manufacturing/Industry 4.0 . . . . .	336
7.6	Case Studies in Digital Manufacturing/Industry 4.0 . . . . .	341
7.6.1	Digital Manufacturing/Industry 4.0: The Hannover Centre for Production Engineering (PZH) Approach . . . . .	341
7.6.2	Digital Manufacturing/Industry 4.0: The Steel Industry Approach . . . . .	348
7.6.3	Digital Manufacturing/Industry 4.0: The Bosch Software Innovations Approach . . . . .	354
7.6.4	Digital Manufacturing/Industry 4.0: The Insurance Business Approach . . . . .	360
7.6.5	Digital Manufacturing/Industry 4.0: The German Industry 4.0 Working Group Approach . . . . .	365
7.6.6	Digital Manufacturing/Industry 4.0: The US Digital Manufacturing and Design Innovation Institute Approach . . . . .	369
7.7	Exercises . . . . .	372
	References . . . . .	373
<b>8</b>	<b>Social Impact on Work Lives of the Future . . . . .</b>	<b>377</b>
8.1	Introduction . . . . .	377
8.2	Economic, Social, and Organizational Challenges . . . . .	380
8.3	Changing Demand in the World of Work . . . . .	381
8.4	Greater Product Individualization and Shifting Factors of Global Influence . . . . .	385
8.5	Exercises . . . . .	388
	References . . . . .	389
	<b>Glossary . . . . .</b>	<b>391</b>
	<b>Index . . . . .</b>	<b>405</b>

Guide to Computing Fundamentals in Cyber-Physical  
Systems

Concepts, Design Methods, and Applications

Möller, D.P.F.

2016, XVII, 422 p. 130 illus., Hardcover

ISBN: 978-3-319-25176-9