

CONTENTS

VOLUME I

Control Systems, Robotics, and Automation	1
<i>Heinz Unbehauen, Control Engineering Division, Department of Electrical Engineering and Information Sciences, Ruhr University Bochum, Germany</i>	

1. Introduction
 - 1.1. What is a Dynamical System?
 - 1.2. Introductory Examples for Simple Closed-Loop Control Systems
 - 1.3. Block Diagram Representation
 - 1.4. Automatic and Manual Control
 - 1.5. Automation and Robotics
 - 1.6. Cybernetics
2. Feedforward and Feedback Control
 - 2.1. Feedforward or Open-Loop Control
 - 2.2. Feedback or Closed-Loop Control
 - 2.3. Some Simple Examples of Feedback Control Systems
 - 2.4. Elements of Feedback Control Systems
 - 2.5. Servomechanism, Regulator, and Process Control
 - 2.6. Continuous and Discontinuous Operation of Automatic Control Systems
3. Analysis and Design of Feedback Control Systems
 - 3.1. Describing the Dynamical Behavior of Systems
 - 3.2. Performance Objectives
 - 3.3. Controller Design
 - 3.4. Non-Standard Types of Control Systems
4. Higher-Level Control Systems
 - 4.1. Adaptive Control Systems
 - 4.2. Large-Scale Systems
 - 4.3. Control of Discrete-Event Systems and Hybrid Systems
 - 4.4. Supervisory Distributed Control Systems
 - 4.5. Fault Diagnosis and Fault-Tolerant Control Systems
5. Applications
 - 5.1. Control of Robot Manipulators
 - 5.2. Other Technical Applications
 - 5.3. Nontechnical Fields of Application
 - 5.4. Computational Tools for Application of Control Systems
6. History
7. Outlook on Some Trends in Future Research and Developments
8. Conclusions

Elements of Control Systems	77
<i>Ganti Prasada Rao, International Centre for Water and Energy Systems, Abu Dhabi, UAE</i>	

1. Introduction
2. System modeling
3. Mathematical models of dynamical systems
 - 3.1. Differential Equation Models for Lumped Parameter Systems in Continuous-time Domain
 - 3.2. State Space Description of Lumped Parameter Systems
 - 3.3. Time-invariant Linear Systems
 - 3.4. Discrete-time Systems or Sampled-Data Systems
 - 3.5. Block Diagram Representation and Simplification
 - 3.6. Distributed Parameter Systems
 - 3.7. Deterministic and Stochastic Systems
 - 3.8. Non-linear Models and Linearization

- 3.9. Causal and Non-causal Systems
- 3.10. Stable and Unstable Systems
- 3.11. Single-Input-Single-Output (SISO) and Multiple-Input-Multiple-Output (MIMO) Systems
- 4. Systems control
 - 4.1. Open-loop Control
 - 4.2. Feedback Control
 - 4.3. Closed-loop Behavior of Control Systems
 - 4.4. Control Strategies

Basic Elements of Control Systems**107**Ganti Prasada Rao, *International Centre for Water and Energy Systems, Abu Dhabi, UAE*

- 1. Dynamical Systems
- 2. Graphical Description of Systems
- 3. Open-loop Control and Closed-loop Control
- 4. Principal Functions of Control
- 5. The Basic Structure of Control Systems
- 6. Some Typical Examples of Control
 - 6.1. Voltage Control of a D.C. Generator
 - 6.2. Course Control of a Ship
 - 6.3. Liquid Level Control
 - 6.4. Control of a Heat Exchanger
- 7. A Brief Overview of the History of Control Systems

General Models of Dynamical Systems**128**Ganti Prasada Rao, *International Centre for Water and Energy Systems, Abu Dhabi, UAE*

- 1. Mathematical Models
- 2. Dynamic and Static Behavior of Systems
- 3. System Properties
 - 3.1. Linear and Non-linear Systems
 - 3.2. Lumped and Distributed Parameter Systems
 - 3.3. Time-varying and Time-invariant Systems
 - 3.4. Systems with Continuous or Intermittent Action
 - 3.5. Systems with Deterministic or Stochastic Properties
 - 3.6. Causal and Non-causal Systems
 - 3.7. Stable and Unstable systems
 - 3.8. SISO and MIMO Systems

Description of Continuous Linear Time-Invariant Systems in Time-Domain**143**Heinz Unbehauen, *Control Engineering Division, Department of Electrical Engineering and Information Sciences, Ruhr University Bochum, Germany*Ganti Prasada Rao, *International Centre for Water and Energy Systems, Abu Dhabi, UAE*

- 1. Description by differential equations
 - 1.1. Electrical Systems
 - 1.2. Mechanical Systems
 - 1.3. Thermal systems
- 2. System description with reference to special signals
 - 2.1. Step and Impulse Response Functions
 - 2.2. The Convolution Integral
- 3. System description in state space
 - 3.1. State Space Description for SISO Systems
 - 3.2. State Space Description for MIMO Systems

Description of Continuous Linear Time-Invariant Systems in Frequency Domain 164

Unbehauen H, *Control Engineering Division, Department of Electrical Engineering and Information Sciences, Ruhr University Bochum, Germany*

1. Laplace Transformation
2. Fourier Transformation
3. Transfer Function of a Dynamical System
 - 3.1. Definition
 - 3.2. Poles and Zeros of $G(s)$
 - 3.3. Transfer Functions of Interconnected Systems
 - 3.4. Relation between $G(s)$ and the State-Space Representation
 - 3.5. The Complex G-Plane
4. Frequency-Response of a Dynamical System
 - 4.1. Definition
 - 4.2. Polar Plot Representation
 - 4.3. Bode-Diagram Representation
5. The Most Common Dynamical Systems
 - 5.1. Element with P-Action (Proportional Action or Gain)
 - 5.2. Element with I-Action (Integration)
 - 5.3. Element with D-Action (Differentiation)
 - 5.4. Element with PT1-Action (First-Order Lag Element)
 - 5.5. Element with PT2-action (Second-Order Lag Element)
 - 5.6. Bandwidth of a Dynamic System
 - 5.7. Minimum and Non-minimum Phase Systems

Closed-loop Behaviour of Continuous Linear Time-Invariant Systems 190

Unbehauen H, *Control Engineering Division, Department of Electrical Engineering and Information Sciences, Ruhr University Bochum, Germany*

1. Dynamic behavior of the closed-loop Control system
2. Sensitivity of feedback control systems to parameter variations
3. Stability
4. Steady-state error
5. ID controller and other standard controller types
6. Behavior of Standard Controllers in Closed-Loop Operation.

Stability Concepts 207

Alexander B. Kurzhanski, *Faculty of Computational Mathematics and Cybernetics, Moscow State University, Russia*

Irina F. Sivergina, *Institute of Mathematics and Mechanics of Ural Department of Russian Academy of Science, Russia*

1. The Definition of Stability
 - 1.1. Introduction
 - 1.2. The Concept of Liapunov's Stability
 - 1.3. The Second (Direct) Method of Liapunov
 - 1.4. Sylvester's Criterion
 - 1.5. Stability of Linear Systems
 - 1.6. Simplest Types of Stable Equilibrium States
 - 1.7. Stability in the First Approximation
 - 1.8. Stability under Persistent Disturbances
 - 1.9. Further Liapunov-Related Types of Stability
2. Stability Criteria for Linear Time-Invariant Systems
 - 2.1. The Routh Hurwitz Stability Criterion
 - 2.2. The Hermite Stability Criterion
 - 2.3. Kharitonov's Criterion

- 2.4. Criterion of Leonhard-Mikhailov
- 2.5. The Nyquist Stability Criterion

Index	239
About EOLSS	245