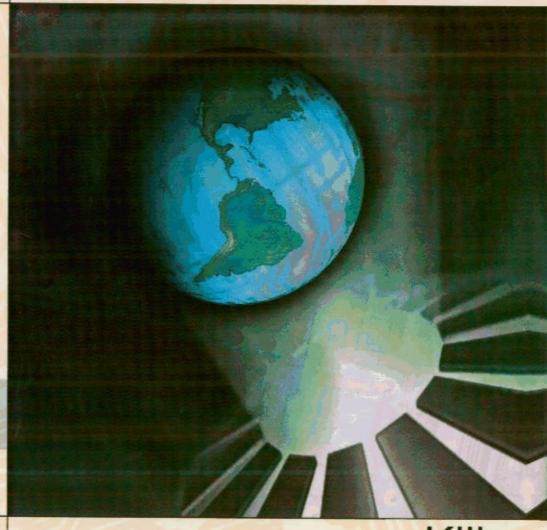
THOMSON DELMAR LEARNING

## Modern Control Technology



Kilian

3rd Edition

## Contents

Acknowledgments xv

Preface xi

			Conditioning 53
1	Introduction to Control Systems 1	3.1	Operational Amplifiers 54 Voltage Follower
1.1	Control Systems 2 Open-Loop Control Systems Closed-Loop Control Systems Transfer Functions		Inverting Amplifier Noninverting Amplifier Summing Amplifier
1.2 1.3	Analog and Digital Controllers 10 Classifications of Control Systems 11 Process Control		Differential and Instrumentation Amplifiers Integrators and Differentiators Active Filters Comparator
	Motion Control (Servomechanisms, Numerical Control, Robotics)	3.2	Special Interface Circuits 84 The Current Loop (Voltage-Current Conversion) Analog Switch Circuit
2	Introduction to Microprocessor-Based Control 23	3.3	Sample-and-Hold Circuit Signal Transmission 91 Earth Ground and Ground Loops
2.1	Introduction to Microprocessor System Hardware 25		Isolation Circuits Shielding
2.2 2.3	Introduction to Microprocessor Operation 28 Interfacing to a Microprocessor Controller 30 The Parallel Interface (DACs, ADCs)		Shield-Grounding Considerations Practical Wiring Considerations
2.4	The Serial Interface (RS232, Networking) Introduction to Controller Programming 41	4	Switches, Relays, and Power-Control
2.5	Microprocessor-Based Controllers 43		Semiconductors 107
	Single-Chip Microcomputers (Microcontrollers) Single-Board Computers Digital "Panel Mount" Controllers Programmable Logic Controllers	4.1	Switches 108 Toggle Switches Push-Button Switches Other Switch Types
	Personal Computers Used in Control Systems	4.2	Relays 114 Electromechanical Relays Solid-State Relays
		4.3	Power Transistors 118 Bipolar Junction Transistor Field Effect Transistor (FET)

3

Operational Amplifiers and Signal

Insulated Gate Bipolar Transistor (IGBT)

4.4	Silicon-Controlled Rectifiers 131	6	Sensors 209
4.5	Triacs 137		
4.6	Calculation of Delay and Conduction Periods  Trigger Devices 142  Unijunction Transistors	6.1	Position Sensors 210 Potentiometers Optical Rotary Encoders
	Programmable Unijunction Transistors		Linear Variable Differential Transformers
	Diac	6.2	Angular Velocity Sensors 229
5	Mechanical Systems 149	6.3	Velocity from Position Sensors Tachometers (Optical, Toothed-Rotor, Direct Current) Proximity Sensors 237
5.1	Behavior of Mechanical Components 150 Overview Friction Springs Mass and Inertia Basic Equations of Motion for Linear Systems	0.5	Limit Switches Optical Proximity Sensors Commercially Available Photoelectric Sensors Ultrasonic Proximity Sensors Inductive Proximity Sensors Hall-Effect Proximity Sensors
	Basic Equations of Motion for Rotational Systems Levers	6.4	Load and Force Sensors 247 Bonded-Wire Strain Gauges Semiconductor Force Sensors
5.2	Energy 170		Other Force Sensors
	Energy Conversion Heat Transfer	6.5	Pressure Sensors 255 Bourdon Tubes
5.3	Response of the Whole Mechanical System 176		Bellows Semiconductor Pressure Sensors
	Underdamped, Critically Damped, and Overdamped Mechanical Systems Mechanical Resonance	6.6	Temperature Sensors 256 Bimetallic Temperature Sensors Thermocouples
5.4	Gears 182 Spur Gears Using Gears to Change Speed		Resistance Temperature Detectors Thermistors Integrated-Circuit Temperature Sensors
	Using Gears to Transfer Power Long Gear Trains Worm Gears Harmonic Drive Differential Gears	6.7	Flow Sensors 267 Pressure-Based Flow Sensors Turbine Flow Sensors Ultrasonic Flowmeters Magnetic Flowmeters
5.5	Clutches and Brakes 196 Clutches Brakes	6.8	Liquid-Level Sensors 272 Discrete-Level Detectors Continuous-Level Detectors
5.6	Other Power-Transmitting Techniques 198 Belts Roller Chain	6.9	Vision Sensors and Systems 276 Commercially Available Vision Sensor Systems

7	Direct Current Motors 287	9	Alternating Current Motors 363
7.1 7.2	Theory of Operation 288 Wound-Field DC Motors 293 Series-Wound Motors Shunt-Wound Motors Compound Motors	9.1	AC Power 364 Background Single-Phase AC Three-Phase AC Electrical Safety
7.3	Permanent-Magnet Motors 298  Relationship Between Torque and Speed  Circuit Model of the PM Motor (Optional)	9.2	Ground-Fault Interrupters Induction Motors 371 Theory of Operation
7.4	DC Motor-Control Circuits 306 DC Motor Control Using an Analog Drive Reversing the PM Motor DC Motor Control Using Pulse-Width		Single-Phase Motors Three-Phase Motors Split-Phase Control Motors AC Servomotors
	Modulation PWM Control Circuits DC Motor Control for Larger Motors Braking the DC Motor	9,3	Synchronous Motors 385 Theory of Operation Power-Factor Correction and Synchronous Motors
7.5	A Comprehensive Application Using a Small	9.4	Small Synchronous Motors Universal Motors 388
7.6	DC Motor 322 Brushless DC Motors 326	9.5	AC Motor Control 388 Start-Stop Control
8	Stepper Motors 331		Jogging Reduced-Voltage Starting
8.1	Permanent-Magnet Stepper Motors 332 Effect of Load on Stepper Motors Modes of Operation Excitation Modes for PM Stepper Motors (Two- Phase (Bipolar) Stepper Motors, Four-Phase (Unipolar) Stepper Motors, Available PM Stepper Motors)		Variable-Speed Control of AC Motors Variable-Frequency (V/Hz) Drives Vector Drives
		10	Actuators: Electric, Hydraulic, and Pneumatic 401
8.2 8.3 8.4	Variable-Reluctance Stepper Motors 344 Hybrid Stepper Motors 346 Stepper Motor Control Circuits 348	10.1	Electric Linear Actuators 402 Leadscrew Linear Actuators Solenoids Electric Linear Motors
	Controlling the Two-Phase Stepper Motor Controlling the Four-Phase Stepper Motor Microstepping Improving Torque at Higher Stepping Rates	10.2	Hydraulic Systems 411 Basic Principles of Hydraulics Hydraulic Pumps
8.5	Stepper Motor Application: Positioning a Disk Drive Head 356		Hydraulic Actuators Pressure-Control Valves Accumulators Directional Control Valves
		10.3	Pneumatic Systems 422 Compressors, Dryers, and Tanks Pressure Regulators Pneumatic Control Valves Pneumatic Actuators
		10.4	Flow-Control Valves 429

Introduction PLC Hardware PLC Setup Procedure PLC Operation

11	Feedback Control Principles 433	Ladd	nming the PLC 507 er Diagram Programming		
11.1 11.2 11.3	Performance Criteria 436 On-Off Controllers 437 Two-Point Control Three-Position Control Proportional Control 439 The Steady-State-Error Problem	Time Cour Sequ Usin Adva	Bit Instructions Timers Counters Sequencers Using a PLC as a Two-Point Controller Advanced Instructions PID Instruction		
	The Gravity Problem Bias Analog Proportional Controllers	Othe 12.4 Program	r PLC Programming Languages mmable Logic Controllers and rks 525		
11.4 11.5	Integral Control 450 Derivative Control 454		Controllers 529		
11.6 11.7 11.8 11.9	Proportional + Integral + Derivative  Control 455  Analog PID Controllers Digital PID Controllers Stability Tuning the PID Controller Sampling Rate Autotuning  Cascade Control 473 PIP Controllers 473  Fuzzy Logic Controllers 474 Introduction Example of a One-Input System	Appendix A Appendix B	Thermocouple Tables for Type J (°F and °C) 539  The Getting Started Guide for APS, Chapter 2—Control Basics (tutorial on using the file system, addressing and ladder logic for the Allen-Bradley SLC 500 and MicroLogix 1000 PLCs) 544  Getting Results with RS Logix 500, Chapters 1 and 5 (instructions for using Windows-based ladder logic		
12	Example of a Two-Input System Closing Thoughts  Relay Logic, Programmable Logic Controllers, and Motion Controllers 489	- Appendix C Appendix D	programming for Allen-Bradley SLC 500 and MicroLogix 1000 PLCs) 550 Glossary 573 Answers to Odd-Numbered Exercises 597		
		Index 621			
	Relay Logic Control 490 Relay Logic Ladder Diagrams Timers, Counters, and Sequencers Programmable Logic Controllers 498				
12.2	Programmable Logic Controllers 498				