

# Real Time Microcomputer Control of Industrial Processes

edited by  
SPYROS G. TZAFESTAS and J. K. PAL

**MICROPROCESSOR-BASED  
SYSTEMS ENGINEERING**

KLUWER ACADEMIC PUBLISHERS

2-670-8-1

2-670-8-1

# Real Time Microcomputer Control of Industrial Processes

*edited by*

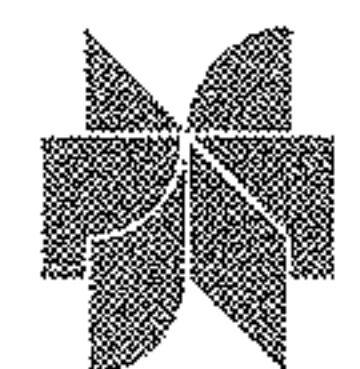
SPYROS G. TZAFESTAS

*Department of Electrical Engineering,  
National Technical University of Athens,  
Athens, Greece*

and

J. K. PAL

*Engineering Technology and Development Division  
Engineers India Limited,  
New Delhi, India*



KLUWER ACADEMIC PUBLISHERS

DORDRECHT / BOSTON / LONDON

## CONTENTS

Contributors . . . . .	v
Preface . . . . .	vii

### SECTION I METHODOLOGY: HARDWARE, SOFTWARE AND SYSTEMIC TOPICS

#### Chapter 1 MICROPROCESSORS - THE FIRST TWELVE YEARS *A. Gupta and Hoo-Min D. Toong*

1. Introduction . . . . .	3
2. 4-bit Microprocessors . . . . .	8
3. 8-bit Microprocessors . . . . .	9
4. 16-bit Microprocessors . . . . .	9
5. 32-bit Microprocessors . . . . .	19
6. System Issues . . . . .	32
7. Multiprocessor Capabilities . . . . .	36
8. Special-purpose Processors . . . . .	38
9. Conclusion . . . . .	39
Glossary . . . . .	39
References . . . . .	41

#### Chapter 2 INTRODUCTION TO REAL-TIME SYSTEM SOFTWARE *S. Dasgupta*

1. Introduction . . . . .	49
2. The Real-Time Program Environment . . . . .	50
3. Task Scheduling . . . . .	53
4. Memory Management . . . . .	61
5. The Input-Output Sub-Systems . . . . .	69
6. Programming Languages . . . . .	75
7. System Performance Monitoring . . . . .	78
References . . . . .	79

Chapter 3  
DIGITAL CONTROL ALGORITHMS  
*S.G. Tzafestas and J.K. Pal*

1. Introduction . . . . .	81
2. Process Model . . . . .	82
3. Process Control Strategies . . . . .	84
- Controllers for SISO Systems . . . . .	85
- Controllers for MIMO Systems. . . . .	107
- Autotuning . . . . .	128
- Expert Control . . . . .	129
References . . . . .	136

Chapter 4  
ESTIMATION AND SIGNAL PROCESSING ALGORITHMS  
*A.K. Mahalanabis*

1. Introduction . . . . .	139
2. Stochastic Signal Models . . . . .	140
3. The Kalman Filtering and Prediction Techniques . . . . .	145
4. Linear Prediction Based on the CARMA Model . . . . .	152
5. Sequential Parameter Estimation . . . . .	153
6. Adaptive Prediction . . . . .	156
References . . . . .	157

Chapter 5  
CONFIGURATION OF DISTRIBUTED CONTROL SYSTEMS  
*P. Purkayastha*

1. Introduction . . . . .	163
2. Control System Evolution . . . . .	164
3. Distributed Control System . . . . .	174
4. Criteria for System Segmentation . . . . .	176
5. Task Allocation in a Distributed Environment . . . . .	177
References . . . . .	185

Chapter 6  
MODELLING AND SIMULATION  
*J.K. Pal and S.G. Tzafestas*

1. Introduction . . . . .	187
2. Mathematical Modelling . . . . .	190
3. Validation of Models . . . . .	204
4. Solution Techniques . . . . .	208
5. Simulation Languages and Simulation Methodology . . . . .	210
6. Simulation Software for Industry . . . . .	215
7. Simulation Hardware . . . . .	222

8. Multiprocessors in Simulation . . . . .	223
9. Simulation of Digital Control System Performance . . . . .	227
10. The Future of Simulation . . . . .	230
References . . . . .	230
Appendix: Process Transient Analysis	
- An Industrial Case Study (T.Aio, M. Tanaka) . . . . .	234

## SECTION II REAL TIME APPLICATIONS

### Chapter 7

#### A LOW COST SELF-ADAPTIVE MICROPROCESSOR CONTROLLER: APPLICATION TO HEATING AND VENTILATION CONTROL

*R.M.C. De Keyser*

1. Introduction . . . . .	251
2. System Hardware . . . . .	252
3. System Software . . . . .	258
4. Applications . . . . .	268
5. Real Life Experiments . . . . .	272
6. Conclusions . . . . .	273
References . . . . .	273

### Chapter 8

#### SELF-ADAPTIVE MULTI-MICROPROCESSOR CONTROL OF CUTTER SUCTION DREDGING SHIPS

*R.M.C. De Keyser and J.L.S. Van Ostaeyen*

1. Introduction . . . . .	275
2. Cutter Suction Dredgers. . . . .	276
3. Modelling and Identification. . . . .	280
4. Multiprocessor Simulator . . . . .	290
5. Adaptive Control . . . . .	295
6. Conclusions . . . . .	307
Acknowledgements . . . . .	307
References . . . . .	308

### Chapter 9

#### ADVANCED CONTROL IN THERMAL POWER PLANTS

*M. Uchida*

1. Introduction . . . . .	311
2. Present Status of Automation in Thermal Power Plants . . . . .	312
3. Advanced Technique for the Improvement of Dynamic Performance . . . . .	320
4. Advanced Technique for Maintenance and Operation . . . . .	323
5. Some Experiments of Actual Plant Control . . . . .	330

6. Future of Advanced Control System . . . . . 332  
 References . . . . . 335

Chapter 10  
 STATUS REPORT ON REAL-TIME CONTROL  
 IN INDUSTRIES: ELECTRIC POWER SYSTEMS  
*H. Nakamura*

1. Introduction . . . . . 337  
 2. Power System Control Concept . . . . . 339  
 3. Control System Configuration . . . . . 341  
 4. Theory and Practice of On-line Automatic Control . . . . . 347  
 5. Security Control in Abnormal Operating Conditions . . . . . 354  
 6. Closing Remarks . . . . . 361  
 References . . . . . 362

Chapter 11  
 STATUS REPORT ON REAL TIME CONTROL  
 IN STEEL INDUSTRY  
*K. Saito*

1. Introduction . . . . . 363  
 2. Control System Configuration . . . . . 364  
 3. Microprocessor Based Fully Digitized Speed Control  
 for Motor Drives . . . . . 371  
 4. Advanced Control System and its Application . . . . . 382  
 5. Conclusions . . . . . 394  
 References . . . . . 394

Chapter 12  
 PROCESS MONITORING AND CONTROL  
 OF GAS PIPELINE NETWORKS  
*G. Lappus and G. Schmidt*

1. Introduction . . . . . 397  
 2. High Pressure Gas Transmission Networks . . . . . 398  
 3. SCADA and Telemetry System . . . . . 401  
 4. Basic Process Monitoring and Control Functions . . . . . 404  
 5. Advanced Dispatching Support . . . . . 406  
 6. Simulation . . . . . 408  
 7. State Estimation . . . . . 412  
 8. Fault Detection and Diagnosis . . . . . 420  
 9. Model Parameter Estimation . . . . . 424  
 10. Load Prediction. . . . . 425  
 11. Optimal Network Control . . . . . 425  
 12. Outlook to Knowledge-Based Process Monitoring and Control. . . 428  
 References . . . . . 430

Chapter 13  
 REAL TIME COMPUTER CONTROL OF CEMENT INDUSTRY  
*S. Kawai and Y. Koike*

1. Introduction . . . . .	435
2. Cement Manufacturing Equipment . . . . .	436
3. Control System in Cement Factory . . . . .	438
4. Optimal Temperature Control of Kiln by AR Model . . . . .	448
5. RAM Material Blending Control with Statistical Modification . . . . .	461
6. CRT Display Applications . . . . .	464
7. Electric Power Demand Control . . . . .	470
8. Autotuning and Adaptation of PID Control Parameters . . . . .	472
9. Conclusion . . . . .	479
References . . . . .	480

Chapter 14  
 CURRENT STATUS OF MICROCOMPUTER APPLICATIONS  
 ON RAILWAY TRANSPORTATION SYSTEMS  
*H. Ihara and M. Nohmi*

1. Introduction . . . . .	481
2. Total System . . . . .	482
3. Ground System . . . . .	483
4. On-Board System . . . . .	491
5. Maintenance Support System . . . . .	504
References . . . . .	508

AUTHOR INDEX . . . . .	509
SUBJECT INDEX . . . . .	511

# Real Time Microcomputer Control of Industrial Processes

edited by

**SPYROS G. TZAFESTAS and J. K. PAL**

The introduction of the microprocessor in computer and systems engineering has motivated the development of many new concepts and has simplified the design of many modern industrial systems. During the first decade of their life, microprocessors have shown a tremendous evolution in all possible directions (technology, power, functionality, I/O handling, etc). Of course putting the microprocessors and their associated devices to work in properly operating systems is a complex and difficult task requiring great skill in the blending and integrating of hardware, software and systemic components.

This book provides a good coverage of modern industrial applications of microprocessor-based real time control, together with latest advanced methodological issues. It is appropriate for the senior undergraduate and the postgraduate student, but it is mainly intended for the researcher or professional who wants to see how microcomputer-based control was applied in specific modern-life processes. It reflects the experience and background of twenty experts working in academia and industry. All chapters contain sufficient background material for independent reading. The reader can find advanced methodological concepts and techniques, in addition to the various practical implementation issues presented in the application chapters.