

COMPUTER PROCESS CONTROL

Option for the

B.Sc. Degree Program in Chemical Engineering

UNIVERSITY OF ALBERTA

Department of Chemical and Materials Engineering

April/06
[RKW]

UNIVERSITY OF ALBERTA

FIRST YEAR ENGINEERING

TERM 1

CHEM 103 (Introductory University Chemistry I)

ENGG 100 (Orientation to the Engineering Profession I)

ENGG 130 (Engineering Mechanics)

MATH 100 (Calculus I)

PHYS 130 (Wave Motion, Optics and Sound)

COMPLEMENTARY STUDIES ELECTIVE

TERM 2

CHEM 105 (Introductory University Chemistry II)

ENGG 101 (Orientation to the Engineering Profession II)

ENCMP 100 (Computer Programming for Engineers)

EN PH 131 (Mechanics)

MATH 101 (Calculus II)

MATH 102 (Applied Linear Algebra)

UNIVERSITY OF ALBERTA

COMPUTER PROCESS CONTROL OPTION

for the

B.Sc. degree in CHEMICAL ENGINEERING

TERM "3"

CHEM 261 (ORGANIC CHEMISTRY I)

CME 200 (INTRODUCTION TO CHEMICAL AND MATERIALS ENGINEERING)

E E 240 (ELECTRICAL CIRCUITS-I)

E E 280 (INTRODUCTION TO DIGITAL LOGIC DESIGN)

ENGG 299 (ORIENTATION TO COOPERATIVE EDUCATION)

MAT E 252 (MATERIALS SCIENCE-II)

MATH 209 (CALCULUS III)

COMPLEMENTARY STUDIES ELECTIVE

TERM "4"

CH E 243 (ENGINEERING THERMODYNAMICS)

CHE 265 (PROCESS ANALYSIS)

ENGL 199 (ESSENTIALS OF WRITING FOR ENGINEERING STUDENTS)

MATH 201 (DIFFERENTIAL EQUATIONS)

STAT 235 (INTRODUCTORY STATISTICS FOR ENGINEERING)

COMPLEMENTARY STUDIES ELECTIVE

UNIVERSITY OF ALBERTA
COMPUTER PROCESS CONTROL OPTION

for the

B.Sc. degree in CHEMICAL ENGINEERING

TERM “5”

CH E 312 (FLUID MECHANICS)

CH E 343 (CHEMICAL ENGINEERING
THERMODYNAMICS)

CH E 351 (CHEMICAL ENGINEERING
LABORATORY)

CH E 374 (COMPUTATIONAL METHODS
IN ENGINEERING)

CHE 446 (PROCESS DYNAMICS AND CONTROL)

IMPACT OF TECHNOLOGY ON SOCIETY
ELECTIVE

TERM “6”

CH E 314 (HEAT TRANSFER)

CH E 318 (MASS TRANSFER)

CHE 345 (CHEMICAL REACTOR ANALYSIS I)

CHE 358 (PROCESS DATA ANALYSIS)

ENGG 310 (ENGINEERING ECONOMY)

or
ENGG 401 (FUNDAMENTALS OF ENGINEERING
MANAGEMENT)

UNIVERSITY OF ALBERTA
COMPUTER PROCESS CONTROL OPTION

for the

B.Sc. degree in CHEMICAL ENGINEERING

TERM "7"

CME 481 (COLLOQUIUM I)

CH E 416 (EQUILIBRIUM STAGE PROCESSES)

CH E 464 (CHEMICAL ENGINEERING DESIGN I)

CH E 572 (MODELLING PROCESS DYNAMICS)

TECHNICAL ELECTIVE

TECHNICAL ELECTIVE

TERM "8"

CME 483 (COLLOQUIUM II)

CH E 454 (CHEMICAL ENGINEERING PROJECT LABORATORY)

CH E 465 (CHEMICAL ENGINEERING DESIGN II)

CH E 573 (DIGITAL SIGNAL PROCESSING FOR FOR CHEMICAL ENGINEERS)

CH E 576 (INTERMEDIATE PROCESS CONTROL)

ENGG 400 (THE PRACTICE OF THE ENGINEERING PROFESSION)

COMPUTER PROCESS CONTROL OPTION COURSES
[other than Department courses]

TERM 3

EE 240 - Electrical Circuits I (3-1s-3/2)

Circuit element definitions. Circuit laws: KVL, KCL, Ohm's. Resistive voltage and current dividers. Basic loop and nodal analysis. Dependent sources. Circuit theorems: linearity, superposition, maximum power transfer, Thevenin, Norton. Time domain behavior of inductance and capacitance, energy storage. Sinusoidal signals. complex numbers, phasor and impedance concepts. Magnetically coupled networks. Single phase power and power factor.

E E 280 - Introduction to Digital Logic Design (3-0-3/2)

Boolean algebra, truth tables, Karnaugh maps. Switching devices and their symbology with an introduction to NAND and NOR logic. Number systems, codes, minimization procedures, synthesis of combinational networks. Synchronous sequential circuits, flip-flops, counters. Arithmetic circuits. Introduction to computer-aided design and simulation tools for digital design and implementation

TERM 7 ELECTIVES (select two, one of engineering science/design content)

EE 250 - Electrical Circuits-II (3-1s-3/2)

Forced and natural time domain response of RL, RC, and RLC circuits using the differential equation approach. The s-plane and poles and zeros. Forced and natural response of circuits using complex frequency analysis. Mutual inductance and the ideal transformer. Two-port networks and the y,z,h and ABCD parameters. Reciprocal networks. Introduction to the ideal operational amplifier.

E E 380 - Introduction to Microprocessors (3-0-3/2)

Microcomputer architecture, assembly language programming, sub-routine handling, memory and input/output system and interrupt concepts.

E E 390 - Introduction to Communication Systems (3-0-3/2)

Basics of analog communication: amplitude, angle, and analog pulse modulation; modulators and demodulators; frequency multiplexing. Basics of digital communication: sampling, quantization, pulse code modulation, time division multiplexing, binary signal formats.

CMPE 210 - Principles of Software Implementation (3-0-3)

Guidelines for good programming style: information hiding, coupling and cohesion, high-quality routines, modularity, usage of variables, fundamental and complex data types, conditionals, control loops, quality attributes, inspection and unit testing. Introduction to Personal Software Process (PSP) for improvement of software development on a personal level: measurement of the process performance, analysis of process measurements, adjustments and improvements of the process. Prerequisite: ENCMP 100. Corequisite: CMPUT 115.

CMPE 402 - C/C++ Programming for Engineers (3-0-3/2)

Introduction to the C/C++ programming language and object-oriented software design. Models of software development. Fundamental principles of software engineering. Procedure-oriented versus object-oriented software design. Built-in and user-defined data types. Abstract data types and objects. Basic control structures and input/output in C/C++. Functions, parameter passing mechanisms, and function overloading. Arrays and pointers. Classes and data abstraction. Operator overloading. Class hierarchies, inheritance, virtual functions, and polymorphism. Function and class templates. Exception handling. Generic programming and the C++ Standard Template Library. Prerequisite: ENCMP 100 or equivalent. Note: Only one of the following courses may be taken for credit: CMPE 210, 402, CMPUT 201

CMPUT115 - Programming with Data Structures (3-0-3)

A study of dynamic data structures (e.g., sets, lists, stacks, queues, dictionaries) and their associated algorithms (e.g., traversal, sorting, searching, element addition and removal) using Java. An introduction to recursive references and algorithms and to more advanced programming language techniques including inheritance and exceptions. Prerequisite: CMPUT 102 or CMPUT 114 or equivalent.

CMPUT 201 - Practical Programming Methodology (3-0-3)

Introduction to the principles, methods, tools, and practices of the professional programmer. The lectures focus on the fundamental principles of software engineering based on abstract data types and their implementations. The laboratories offer an intensive apprenticeship to the aspiring software developer. Students use C and C++ and software development tools of the UNIX environment. Prerequisite: CMPUT 115

UNIVERSITY OF ALBERTA

Department of Chemical and Materials Engineering

Ch E 446: Process Dynamics and Control

COURSE OUTLINE

1. Introduction to Process Control
 - Motivation with an example
 - Definition of feedback and feedforward control
 - Dynamics models of physical systems
2. Mathematical Preliminaries
 - Linearization and Taylor's series expansion
 - Deviation or perturbation variables
 - Laplace transforms
 - Properties of Laplace transforms
3. Dynamic Behaviour of (mostly) 1st and 2nd Order Systems
 - First-order systems
 - Second-order systems
 - Time-delays
 - Dynamics of higher-order systems
 - System identification and development of empirical models from step-response data
4. Analysis and Design of Feedback Control Systems
 - Introduction to the concept of feedback control systems
 - Control system Instrumentation
 - Open loop and closed loop systems
 - Transfer functions
 - Block diagrams
 - Design of a PID controller and controller tuning techniques
 - Stability of control systems
 - Routh test for stability
 - Introduction to root locus techniques (optional if time permits)
 - Nyquist plots, Bode plots and frequency response analysis
 - Feedback control using a digital computer
5. Advanced Process Control Techniques
 - Ratio and cascade control
 - Feedforward control
 - Time delay compensation techniques
 - Statistical quality control

6. Case Studies

- An overview of control methods used in the control of common process units such as: boilers, distillation columns *etc.*

Recommended Text:

Seborg, D.E., Edgar, T.F. and D.C. Mellichamp, "Process Dynamics and Control", 2nd Edition, John Wiley & Sons, 2003

Supplementary References:

Ogunnaike, B. A. and Ray, W.H., Process Dynamics, Modeling, and Control, Oxford University Press, 1994

Nise, N.S., Control Systems Engineering, 4th Edition, John Wiley & Sons, 2004

Dorf, R.C., and Bishop, R. H., Modern Control Systems, 9th Edition, Addison-Wesley, 2001

Software:

The main software platform used for this course will be MATLAB and SIMULINK, including the Control System Toolbox. Students will learn the use of this software by illustrative examples and laboratory problem solving sessions.

Laboratory:

Hands-on experimental laboratories will complement the lectures to illustrate the basic concepts of feedback control and controller design techniques.

UNIVERSITY OF ALBERTA

Department of Chemical and Materials Engineering

Ch E 572: Modelling Process Dynamics

COURSE OUTLINE

1. Introduction
 - Process modelling: scope and applications
 - Basics of process modeling
 - Types of models
2. First Principles Modelling
 - Procedure
 - Balance equations
 - Constitutive relationships
 - Numerical solutions
3. State Space Models
 - State space representation
 - Linearization
 - Linear state space models and solutions
 - Stability analysis and degrees of freedom
4. Transfer Function Models
 - Review of Laplace transforms
 - Transfer functions
 - Behaviour of first, second and higher-order model transfer functions
 - Conversion between state space models and transfer function models
5. Discrete Models
 - Discretization of state space models
 - Solutions to discrete state space models
 - Relationship between discrete-time state space and transfer function models
 - Connection between continuous time and discrete time domains
6. Frequency Response Functions
 - Review of Fourier transforms
 - Frequency domain transfer functions
 - Bode and phase plots
 - Low and high pass filters
 - Lead-lag systems

7. System Identification

- Introduction
- Black-box and gray-box models
- Notion of parametric and non-parametric models
- Notions of plant and noise models
- Random signals
- The linear least squares problem
- Input design and excitation

8. Non-Parametric Models

- Impulse response
- Step response models
- Time-delay estimation using correlation analysis
- Frequency response models
- Empirical transfer function estimation and spectral analysis models
- Estimation of noise spectrum

9. Parametric Models

- Linear least squares problem re-visited
- ARX, ARMAX, OE and BJ models
- Estimation of ARX models
- Estimation principles

10. Time Series Models

- AR and ARMA processes
- Autocorrelation function (ACF) and partial autocorrelation function (PACF)
- Estimation of noise models using ACF and PACFs

11. System Identification Procedure

- Estimation of ARMAX models
- Model structure validation and residual analysis
- Model simulation and prediction
- Output error (OE) models
- Identification starting with an OE structure

12. Data Pre-Processing and Filtering

- Removal of trends
- Outlier detection and removal
- Missing data
- Filtering of input-output data
- Role of filtering in system identification

Recommended Text:

Bequette, W.B., Process Dynamics - Modeling, Analysis and Simulation, Prentice Hall, 1998

Supplementary References:

Basmadjian, D., The Art of Modeling in Science and Engineering, Chapman & Hall, 1999

Denn, M.M., Process Modeling, Longman, 1984

Felder, R.M. and R. Rousseau, Elementary Principles of Chemical Processes, Wiley, 1986

Luyben, W.L., Process Modeling, Simulation and Control for Chemical Engineers, McGraw-Hill, 1990

Ljung, L., T. Glad, Modeling of Dynamic Systems, Prentice-Hall, 1994

Soderstrom, T. and P. Stoica, System Identification, Prentice-Hall, 1989

Box, G.E.P. and G.M. Jenkins, Time Series Analysis: Forecasting and Control, Holden-Day, 1994.

Software

The MATLAB software will be used in this course, including its System Identification Toolbox. The MAPLE software, a powerful computational program for performing analytical and numerical computations, is also used. The power of MAPLE lies in its capability to handle symbolic computations. The Symbolic Math Toolbox of MATLAB can also be used to perform symbolic computations.

UNIVERSITY OF ALBERTA

Department of Chemical and Materials Engineering

Ch E 573: Digital Signal Processing for Process Engineers

COURSE CONTENT

1. Introduction to Signal Processing
 - Scope and applications
 - Course objectives
 - Elements of signal processing
 - Classification of signals
 - Review of complex numbers
2. Sampling and Aliasing
 - Introduction to sampling
 - Continuous time sinusoidal signal
 - Concept of aliasing
 - Sampling theorem
 - Quantization and coding
 - Digital to analog conversion
3. Discrete-Time Systems and the z-Transform
 - Mathematical representation of discrete-time signals and systems
 - Elementary discrete-time signals
 - Classification of discrete-time systems
 - Convolution sum and properties
 - Impulse and step response
 - Causality and stability
 - The z-transform: definition and properties
 - Applications of the z-transform to linear time invariant systems
4. Correlation and Covariance Analysis
 - Covariance and correlation: definitions, properties and calculations
 - Application of correlation analysis in process control
 - Identification of periodic signals
 - Time delay and impulse response estimation.
5. Fourier Series and Transforms
 - Introduction to spectrum
 - Fourier series
 - Power spectrum
 - Magnitude and phase spectra

- Applications of power spectrum
 - Fourier transforms and their properties
 - Discrete Fourier transform
 - Periodogram.
6. Frequency Response of Discrete-Time Systems
- The frequency response function
 - Response to periodic and aperiodic input signals
 - Input-output covariance functions and spectra
7. Filtering and Design of Filters
- Introduction to filtering
 - Low, high and band-pass filters
 - Median filter
 - EWMA filter
 - Filter specifications
 - Design of FIR and IIR filters

Recommended Text: McClellan, J., Schafer, R. and M.Yoder, Signal Processing First, Pearson-Prentice Hall, 2003,

Supplementary References:

S. W. Smith. The Scientist and Engineer's Guide to Digital Signal Processing, California Technical Publishing, 1997

J.G. Proakis and D.G. Manolakis, Digital Signal Processing: Principles, Algorithms and Applications, 3/e, Prentice Hall, 1996

S.Mitra, Digital Signal Processing: A Computer-Based Approach, 2e with DSP Laboratory using MATLAB, McGraw-Hill, 2001

A.V. Oppenheim and R.W. Schafer, Digital Signal Processing, Prentice Hall, 1975

B. Porat, A Course in Digital Signal Processing, John Wiley and Sons, New York, 1996

UNIVERSITY OF ALBERTA

Department of Chemical and Materials Engineering

Ch E 576: Intermediate Process Control

COURSE CONTENT

1. Introduction to Discrete-Time Systems
 - Introduction to computer process control systems
 - Sampling and signal reconstruction
 - Conversion of continuous time to discrete-time models
 - Finite difference method
 - Exact discretization method
 - Discrete-time response of dynamic systems
 - The backshift operator and transfer functions
 - Partial fraction expansion
 - Discrete-time response of transfer functions
 - Stability analysis
 - Initial and final value theorems
 - Physical realizability
 - Minimum phase and non-minimum phase
 - Development of closed-loop transfer functions
2. Design of Digital Control in the Continuous Time Domain
 - Continuous time PID and conversion to discrete-time PID
 - State space representation of process models
 - Transformation between state space model and transfer function models
 - Controllability
 - Pole placement
 - Optimal linear quadratic control
 - Control of inverse pendulum problem
3. Direct Synthesis of Digital Controllers
 - Perfect control
 - Effect of time delay and basic internal model control
 - Role of filter and robust control
 - Controller ringing
 - Effect of non-minimum phase systems
4. Advanced Multivariable Model Predictive Control
 - Discrete convolution models
 - Matrix forms for predictive models
 - Optimal predictions
 - Unconstrained and constrained model predictive control
 - Tuning and implementation issues
 - Other advanced model predictive control systems

References:

D.E. Seborg, T.F. Edgar and D.A. Mellichamp, Process Dynamics and Control, 2nd edition. John Wiley & Sons, 2003

B.A. Ogunnaike and W.H. Ray, Process Dynamics Modeling and Control, Oxford University Press, 1994

K.J. Astrom and B. Wittenmark, Computer Controlled Systems: Theory and Design, 3rd Ed, Prentice-Hall, 1997

G.C. Goodwin, S.F. Graebe, and M.E. Salgado, Control System Design, Prentice Hall, New Jersey, 2001

B. Huang, Ch E 576 lecture notes (available on the U of A course web)