ET 438a
Automatic Control Systems Technology

Instructor: Dr. Carl Spezia, P.E.

Office: Engineering D110
Phone: 453-7839
E-mail: powerguy@siu.edu

Office Hours: 10:00 am - 10:50 am M-W-F
2:00 pm - 3:00 pm M-W-F
Or by appointment

Textbook: Introduction to Control System Technology, 7th Ed., Robert N. Bateson.

Reference: Process Control Instrumentation Technology, 5th Ed. Curtis D. Johnson.
Matlab Users Guide, Student Edition, Mathworks Inc.

Grading Scale:

100-90%	A
89-80%	B
79-70%	C
69-60%	D
59-below	F

Hour Exams (3 at 100 points each)	45%
Final Exam (200 points)	20%
Homework	5%
Lesson Quizzes (Desire To Learn D2L)	10%
Laboratory Experiments/Activities	20%
Total	100%

Note: the final exam is optional for all students that have a 90% or higher average on the hour exams, homework, and experiment/activities

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Course Policies

1. **Late Work and Makeup Exams**
   No make-up exams. All homework handed in at the beginning of the period it is due. No late homework accepted. Late lab grades will be reduced by 5% per working day starting from due date.
2. **Attendance Policies**
   Class attendance is required and attendance will be taken at the beginning of every period. Students are allowed **four** unexcused absences. Any further absences will reduce the TOTAL grade by 5% per day absent.
3. **Cell Phone/Electronic Device Usage**
   Cell phone usage during meeting periods is prohibited. Devices should be TURNED OFF prior to entering class. Other electronics devices (Tablets, iPads, Readers etc) are only allowed for academic/research purposes. No electronic devices other than calculators are allowed during exams. Those violating this policy are subject to disciplinary action under the Student Conduct Code. Follow this link to review this code: (http://policies.siuc.edu/policies/conduct.html)
   Nicotine Consumption
4. No use of electronic cigarettes during class.

Final Exam Scheduling Policy

The course final exam is comprehensive. The course instructor will give the exam during finals week at the time and place prescribed by the University in its final exam schedule. The final will take place in the normal lecture room.

Course Description and Prerequisites

This course covers the fundamental concepts and tools used to model and design continuous automatic control systems. Mathematical models for electric, hydraulic, and thermal process systems are examined. The Laplace transform, transfer function, block diagram and signal flow graph are applied to the modeled systems to determine the system response and design stable control systems. Computer implementations of graphical analysis and design techniques are covered. These methods include root locus, and frequency response methods. A laboratory demonstrates practical applications of measurement and control.

Prerequisite: Engineering Technology 304b or concurrent enrollment.

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Course Content Overview

This course is an introduction to the operation and design of continuous signal control systems. Continuous signals are also call analog signals. Analog signals are continuous functions of time. Sampled, also called digital, control uses signals that are a series of samples of continuous signals. This course will focus on the analog systems modeling and design.

The basic parts of an analog control system will be identified. Different methods for controlling a analog control system will be examined. The methods of representing physical systems as mathematical models will be covered. Once a real system is modeled, design techniques can be used to develop responsive, stable controls for the actual system.

A continuous control system uses some type of sensor to measure the process that requires control. This measurement is input to a controller that decides the amount of corrective action, if any, that must be applied to the process. The corrective action signal is transmitted to an actuator.

This device causes the changes in process. The effective design of these types of systems requires:

Measurement of the process variables
A mathematical model of the process
Selection and modeling of the controller
Determining combined controller and process response by using a
Analog electronic implementation of the controller design

This course will cover the concepts and tools that make these designs possible.

Course Objectives

At the end of this course, you will be able to**:**

1.) Identify the components of a typical single-input single-output automatic control system.
2.) Distinguish between an open-loop and a closed loop control system.
3.) Use analog OP AMP circuits to scale linear sensor signals.
4.) Develop and use mathematic models of simple mechanical, thermal, and electrical systems.

5.) Identify linear ordinary differential equations and explain how there solutions differ from algebraic equations.
6.) Use a differential equation to model dynamic response in a simple system.
7.) Use the Laplace transform to solve first and second order differential equations.
8.) Use transfer functions and signal flow block diagrams to represent control systems.
9.) Identify the three modes of analog control: proportional, derivative, and integral and explain how each impacts system performance.
10.) Develop analog circuits using OP AMP’s that realize the control modes.
11.) Identify stability conditions of an analog control system using the transfer function model.
12.) Identify the stability conditions of an analog control system using Bode plots. Use Nyquist plots to determine control system stability.
13.) Use the Routh-Hurwitz Criteria to identify stable control system operation.
14.) Design negative feedback control circuits for dc motor speed regulation using analog devices.

Others Helpful Information

All members of the faculty and staff of SIUC are here to help you as you begin this course and all others on your schedule this semester. Attached to this syllabus is a summary sheet that includes all the important dates and other valuable information to help you succeed during your academic career at SIUC. Please feel free to communicate with the course instructor and any other staff of the Department of Technology if you have any problems and concerns. Good luck this semester.

ET 438a
Continuous and Digital Control Systems
Course Outline

<u>Introduction to Automatic Controls</u>	Johnson Handout
Process control principles	Sections 1.1 -1.4
Process control block diagrams	Sections 1.6 - 1-8
Evaluation of system performance	
Review of OP AMPs	Class notes
Scaling of sensor signals using OP AMPs	
Open loop systems	Bateson
Closed loop systems	Sections 1.1-1.4
<u>Modeling Physical Systems</u>	Bateson
Models of Mechanical Systems	Sections 3.1-3.3
Electrical	Sections 3.5-3.6
Liquid	
Thermal	
Mechanical	
<u>Proportional Control Mode</u>	Johnson Handout
Model of proportional control mode	Class notes
Proportional bandwidth	Bateman
Steady-state error of proportional control	pp. 467-473
Practical realization of proportional control	
	TEST 1
T<u>ransfer Function Models</u>	
Mathematical Models of Systems	Bateman
Self-regulating tanks	Chapter 4
Non-regulating tanks	
R-C circuits	
Liquid-filled Thermometers	
Control Valves	
Laplace Transforms	
Laplace transform pairs	
Laplace theorems	
Finding inverse Laplace transforms	

Transfer Function Models (cont.)	Section 1.12 Section 4.7 Section 10.3

Transfer Functions and Block Diagrams
    Finding transfer functions
    Block diagram simplifications
    Bode Plots of transfer functions
    DC motor block diagram
    Introduction to Matlab control toolbox
	Class handouts

	TEST 2

Control of Continuous Processes
    Modes of control
      Proportional
        Time and frequency response
        Transfer function
      Integral
        Time and frequency response
        Transfer function
      Derivative
        Time and frequency response
        Transfer function
      Proportional plus integral control
        Time and frequency response
        Transfer function
    Proportional Plus Derivative Control
        Time and frequency response
        Transfer function
    Proportional plus Integral Plus Derivative Control (PID)
        Time and frequency response
        Transfer function
    Practical Circuit realizations of control modes
	Section 13.1, Section 13.2
	pp. 467-486
	Section 13.3

Analysis and Design of Systems
Process characteristics
        Integral processes
        First order lag process
        Second order lag process
        Dead-time process
	Bateman
	Chapter 14

Methods of Analysis
    Bode plots of transfer functions
    Open-loop bode plots
	Bateman
	Chapter 15

Method of Analysis (cont.)	Class Handouts
Closed-loop bode plots	
Error ratio and deviation ratio	
Generating Bode plots with Matlab	Class notes
Bode stability criteria	
Nyquist stability criteria	
Routh-Hurwitz Criteria	
	Test 3
Course Review	**Final Exam**

ET 438a
Homework Listing

Assignments	Lesson Number	Problems
Book Chapter 1		
1	1	1.5a, 1.5b 1-15a, 1-15b. 1-15c Bateson
2	1	1-27, 1-28, 1-29 Bateson
3	2	1.1, hw1.wp5* Johnson/handout
4	2	1.17, 1.24, 1.28, 1.33 Johnson
5	3	op_hw1.wp5
6	3	averhw.wp5
7	4	hw38a3a.wp5
8	4	hw38-3.wp5
Book Chapter 3		
9	5	3.5, 3.6, 3.8 Bateson
10	6	3.9d, 3.10a-d Bateson
11	6	3.11a-c, 3.12a-c Bateson
12	7	3.20d-e, 3.22a Bateson
13	8	3.28 hw38-5.wp5
Book Chapter 4		
14	8	4.1, 4.3, 4.5 Bateson
15	8	hw38-4.wp5
16	10	4.6a, b, d, g, i, m Bateson
17	10	4.7a, c, e, g, j Bateson
18	10	4.8, 4.9, 4.11, 4.15 Bateson
19	10	hw38-6a (problem 1 only)
20	10	hw38-6a.wp5
21	11	hw38-7.wp5
22	12	hw38-8.wp5
23	14	4.16, 10.16, 4.21 Bateson
Book Chapter 13		
24	14	dcmtrhw.wp5
25	16	13.14, 13.18 Bateson
26	17	13.20, 13.23, 13.34 Use Matlab
27	17	13.30, 13.32 Bateson
28	17	hw38a-12.wp5
29	18	intpros.wp5

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*Homeworks listed in this format are on handouts.

Book Chapter 14	Lesson Number	Problems
30	20	hw38a-11.wp5
31	20	14.6, 14.26 Bateson
32	21	hw38a-13.wp5
33	23	bodeny.wp5
34	23	14.27, 14.28, 14.31 Bateson

CARL SPEZIA ← NAME

ET 332A ← Course

Homework 1 ← HW NUMBER

1.1 Sample Homework format

Always use engineering paper unless otherwise instructed

↑ included Problem numbers

Transcribe all Key values here with units

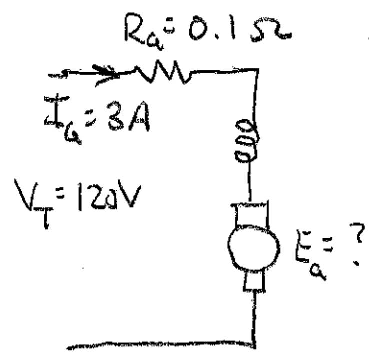
$R_1 = 10\ \Omega$

$V = 100\text{V}$

$I = 3\text{A}$

[Include sketches & Schematics with values if useful]

b.) ← label Subsections of problem



Include enough work so that grader can follow logic

Answers with no support or invalid support receive no credit

$E_a = V_T - I_a R_a$

$E_a = 120\text{V} - (3\text{A})(0.1\ \Omega)$ always include units

$\boxed{E_a = 119.7\text{V}}$

↑ Box final answer

Staple multiple pages. Unstapled work not accepted

Pencil is better than ink for problem solutions

Organize work in logical way. This helps graders follow work and promotes maximum points for partial credit.

Use lecture examples as guides for proper layout

ET 438a
Laboratory Experiments

1.) **Analog Sensor Signal Conditioning**
Use analog OP AMP circuits to scale the output of a sensor to signal levels commonly found in practical control systems. To use OP AMP analog circuits to combine several simulated sensor inputs according to a predefined input signal formula. Produce an error signal using an OP AMP differential amplifier.
(3 periods)

2.) **Proportional Control Action**
Construct a proportional controller using OP AMP circuits and measure its steady state and transient response. View the response of a first order process to proportional control action.
(3 periods)

3.) **Introduction to Control System Modeling with Matlab/Simulink**
This laboratory introduces the Matlab/Simulink programming and numerical simulation software. Learn how to generate frequency response and time plot common to control systems analysis and design. These include Bode plots and unit step response. Create basic open loop and closed loop block diagram systems using Simulink and find their response using numerical methods that plot the response as graphs.
(1 period)

4.) **Modeling Control Systems Using Matlab/Simulink**
This lab uses Matlab/Simulink software to model an antenna positioning system. Students develop the transfer function blocks from component parameters and construct the block diagram in Simulink. Observe the results of step input changes and external disturbances on the control performance using various types of control action.
(1 period)

5.) **Motor-Generator Speed Control Using Proportional and Proportional/Integral Controllers**
Design and test a feedback control system that regulates the speed of a motor generator system. A dc tachogenerator measures the speed of the motor-generator system. Build a proportional controller using OP AMPs to control the smotor speed as the generator load changes. Design a proportional-integral controller using OP AMPs. Compare the performance of the two systems.
(4 periods)

ET 438A
Lab Report Grading and Attendance Policies

Grading

The following table shows the point distribution and items that will be graded in the ET 438A lab report. If all listed items are included and correct then the maximum grade is received.

Late labs will have the point totals reduced by 5 pts per working day. After one week, late labs will not be accepted.

Attendance

Students are expected to be seated in the lab at the scheduled starting time. An attendance sheet will be circulated at the beginning of the lab period. Everyone is responsible for signing this sheet. Anyone failing the sign the sheet will be counted absent. The lab and lecture absences are combined for the course total. The fifth unexcused absence will result in overall grade reduction. The T.A. will be available outside the lab period to sign off on results if necessary.

Item	Points	Comments
Title page	2 pts	Title page must follow the given format exactly to receive credit. See the example attached example. Other examples are available from Lab T.A.
Table of Contents/Equipment List	2 pts	Table of contents should be numbered correctly to match the pages in the report. The equipment list should include the manufacturer, model number, and SIU number of the instruments used. No parts list is necessary.
Experimental Objective	6 pts	The purpose for conducting this experiment and designing the circuits must be identified. Use the lab handout as a guide.
Theory of Operation and Discussion of Design.	30 pts	This section should include the background theory for the experimental circuit operation. It should also discuss supporting theoretical topics that explain what should happen in the system or circuit design. When a circuit design is required in a lab, it should be explained in detail with the function of each stage and its supporting components given. A schematic of the overall design should be provided in this section. All passive components (resistors, capacitor, potentiometers etc) should have values and identifiers. (R_1 C_2 e.g.) All active components, IC, transistors, and diodes, must be labeled also. The power supply values must be given. The schematic should have a figure number or page number depending on its size. Refer to the schematic when explaining the design of the circuit.
Discussion of Design/Results	30 pts	This section contains the collected experimental data and results that demonstrate the performance of the designed circuit or system. The readings and observations made in the performance of the lab should be included here. All measurements must be clearly organized into tables. Each table must have a table number and title. Refer to the table number when explaining the results of the experiment (See table 1 e.g.). Use Excel to create tables and do repeated calculations. Sample calculations should be included in the appendix. This section should address errors that may occur in the lab. Compare and contrast the measurements with the theory of operation. Read the lab carefully for other required discussion points. Example: what was the effect of increasing controller gain on system performance.
Conclusion	20 pts	The conclusion should summarize the overall operation of the system or design presented in the lab. It should highlight trends and relationships between variables. This section should only be 1 or 2 paragraphs long (100-200 words)
Appendix	10 pts	This section should have a separator page with the word Appendix centered between top and bottom margins. It should include, at the minimum, the signed data sheets from the lab. Also included in the section are sample calculations and other formulas necessary for the completion of the lab design. The first page of the appendix should have a consecutive page number.