ABE 460 – Sensors & Process Control

Fall 2018

Instructor: Gabe Wilfong (gwilfong@purdue.edu)
Office: LILY 3-119
Office Hours: Before/after each lecture, by appointment, Mon 10:30 – 11:45a, Tues 1 – 2:30p

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Office Hours:	Wed 11:30a – 12:30p LILY 2-118 By appointment	By appointment LILY 2-118

Class Schedule:

Lecture -	M W	9:30 - 10:20am	Room – WALC B093
Lab -	M	1:30 - 3:20pm	Room – SC 179
	W	3:30 - 5:20 pm	Room – SC 179

Catalog Description

Introduction to modeling and evaluating dynamic systems and their responses with particular emphasis on sensors and controls used in agricultural, biological, and food applications. Classical controller design is presented, including root locus and Bode domain design approaches; along with ladder logic and programmable logic control. Laboratory exercises and projects provide hands-on opportunities for simulation, design, and testing of process control systems.

Prerequisite(s)

A course in differential equations. Authorized equivalent courses or consent of instructor may be used in satisfying course pre- and co-requisites.

Textbook and/or other recommended material

Lumkes, J., *Control Strategies for Dynamic Systems, Design and Implementation*, Course Pack
Lumkes, J., ABE 460 Lecture Notes, Course Pack

Course Learning Objectives:

Upon Successful completion of the course, students will be able to:

1. Model dynamic systems and processes using differential equations (SO-1)
2. Convert between time responses and 1st and 2nd order differential equations for dynamic systems (SO-1)
3. Develop TFs and Block diagrams representing the dynamics of systems (SO-1)
4. Design and simulate feedback control systems (SO-1)
5. Design and tune PID control systems (SO-1)
6. Evaluate control system performance using root locus and bode plots to (SO-1)
7. Program and implement ladder logic on a programmable logic controller (SO-6)
8. Simulate, design, and test a laboratory process control system (SO-1, SO-6)

*ABET Criterion 3 student outcome mapping shown in parenthesis

Course Topics/Practices:

- Introduction to control systems
- Modeling and simulation of dynamic systems
- Laplace transforms and block diagrams
- Step responses of first and second order systems
- Analysis of dynamic systems in the frequency domain
- Simulating dynamic control systems using Matlab/Simulink
- Characteristics of feedback control systems
- Design, simulation, and tuning of PID controllers
- Sampling and aliasing effects of digital systems
- Actuators and sensors for analog control systems
- Digital control systems
- Actuators and sensors for digital control systems
- Programmable logic controllers

Lab Topics/Practices:

- Modeling of dynamic systems
- Simulation of dynamic systems
- System Identification
- Instrumentation and sensors
- Sampling and Aliasing effects
- Ladder logic and PLC programming
- Process control design project using PLCs

Course Overview

This course is designed to be an introduction to programmable controllers and control system design. Since this is most likely your first course in the control area, much of the material will be very different than previous courses. However, in order to understand and reliably design control systems, a strong background in control theory, differential equations and modeling is a must. We will spend some time reviewing "dynamic system modeling." We will cover basic principles of feedback control from both a design and analysis point of view. Then we'll spend some time learning the terminology and hardware required for control systems, including sensors and PLC's. Since this course is, in most cases, your only exposure to control, we will attempt to concisely cover a variety of topics. My goal is that, if given a good overview, you can fill in the details, where needed, through self-study of the numerous texts on control.

Reading Assignments

Chapters and handouts to be read are listed on the course outline following each major topic. It is expected that this reading will be completed prior to the class period in which it is covered. Lectures will not always be a review of the reading. Lecture material will be intended to supplement the text with examples or more detailed discussion. The reading material codes are as follows:

CSDS—*Control Strategies for Dynamic Systems* by Lumkes
Handouts—Appropriate paragraphs and outlines which have been assembled to aid your learning. These will be handed out in class.

It is recommended that questions over the reading material be brought up during class. This will become part of the discussion for the day.

Class Attendance

Lecture attendance: During lecture each week, there will be time allotted for in-class problem solving. A portion of the overall course grade will come from the completion and participation of these in-class problems. If you must miss lecture due to interviews, travel, etc., please talk with the instructor prior to your absence in order to obtain approval.

Laboratory attendance: Persons missing these sessions will have difficulty completing the labs unless prior arrangements are made for extenuating circumstances. It is your responsibility to obtain material covered during your absence. I will be glad to provide handouts but not lecture notes if missed.

Exams and Assignments

There will be two exams over the material as noted, tentatively scheduled for the eighth and final exam weeks. If you miss an exam without either a certified medical excuse or prior instructor approval, you will receive a zero on that test or final exam. Tests missed with approval will be individually discussed.

There will be required homework assignments. **Late homework assignments will not be accepted and will receive no credit**. All work must be shown on your homework to receive full credit. Copying of homework or other academic misconduct will result in a failing course grade.

Most of the laboratory exercises will require a written lab report. In general, I am looking for a brief review of the lab procedures/setup, along with key data and analyses in graphical form (if possible), and a discussion of the results and their significance (i.e., *did you learn something from the exercise, or just blindly follow the procedures?*). Each lab handout will specify what needs to be included within the lab report. Lab reports are due one week after the completion of the lab. **Late assignments will receive no credit.**

Grading Procedure

A midterm exam and a final exam will be administered. Your grade for the course will be comprised of the following:

Lab exercises	40 %	Midterm Exam	20 %
Homework	5 %	Final Exam	30 %
Participation	5 %		

The final grades for the course will be based solely on your performance in this class. You are welcome to stop in my office any time during the semester to discuss your grades. The following performances will guarantee such grades:

Grade	GPA Value	Numerical Range
A	4.0	93 - 100
A-	3.7	90.0 - 92.9
B+	3.3	87.0 - 89.9
B	3.0	83.0 - 86.9
B-	2.7	80.0 - 82.9
C+	2.3	77.0 - 79.9
C	2.0	73.0 – 76.9

Grade	GPA Value	Numerical Range
C+	2.3	77.0 - 79.9
C	2.0	73.0 – 76.9
C-	1.7	70.0 – 72.9
D+	1.3	67.0 – 69.9
D	1.0	63.0 – 66.9
D-	0.7	60.0 – 62.9
F	0.0	< 60.0

Purdue Honors Pledge: "As a boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue." Web link

Tips for Success (in this course)

1. Read through the material **before** class.
2. Write down questions when reading/studying. Ask these questions in class.
3. Ask questions in class as soon as you feel confused.
4. Do the homework problems. Homework is due by chapter, one week after the lectures are finished for the chapter. Do not wait until the last week but instead work the problems as the material is covered in lecture.
5. Ask questions in class if you think others are confused.
6. Think about lab exercises. Your main concern with lab exercises should not be to simply get the assignment completed, but to understand the concepts. The labs are designed help you visualize and/or implement the principles discussed in lecture.

Safety Considerations:

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances. Here are ways to get information about changes in this course. Blackboard Vista web page, my email address: lumkes@purdue.edu, and my office phone: 494-1173.

If the fire alarm is activated as a result of a fire or explosion, the building must be evacuated immediately. Proceed to the nearest stairway, then to the nearest building exit doors and finally to the Emergency Assembly Area which is located on the Agricultural Mall directly in the front (north side) of the Food Science Building. Building occupants are required by law to evacuate the building when the fire alarm sounds.

In the event of a tornado or the sounding of the county tornado sirens, all ABE occupants should proceed to room 106A or 106B (main floor south of the hallway where the coke machines are located). This procedure may also be necessary if there are other emergencies that make it unsafe to be outside, such as release of a harmful or irritating gas outside of the building.

Laboratories: The name of the staff member with overall responsibility for the laboratory is posted near the entrance door along with the name of the faculty member(s) associated with work in the room and other staff emergency contacts. Each laboratory has a **purple notebook** containing important information. It contains Material Safety Data Sheets (MSDS's) describing chemicals that are located in the laboratory, information on hazards associated with their use and safe handling procedures. The **purple notebook** should be located **near the laboratory entrance door**. This notebook should also contain the ABE Building Emergency Plan. There should also be a "Hazard Assessment" that identifies potential hazards such as chemicals, electrical connections or flammable liquids that may be located in the laboratory area. A copy of the Hazard Assessment and the ABE Building Emergency Plan can be found in the **purple notebook**.

CAPS Information: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at (765)494-6995 and http://www.purdue.edu/caps/ during and after hours, on weekends and holidays, or through its counselors physically located in the Purdue University Student Health Center (PUSH) during business hours.

Weekly Syllabus for Lecture and Lab

Wk	Dates	Chapter	Topics
1	8/20 & 8/22	1, 2	Course Overview, Introduction to Control Systems Lab: Introduction to Process Control and Simulink
2	8/27 & 8/29	2	Modeling and system dynamics Lab: Digital and Analog Sensors; A/D conversion
3*	9/5	3	Analysis methods for dynamic systems Lab: NO LAB
4	9/10 & 9/12	3	Analysis methods for dynamic systems Lab: Liquid Level Model Development Part 1
5	9/17 & 9/19	3	Analysis methods for dynamic systems Lab: Liquid Level Model Development Part 2
6	9/24 & 9/26	3	Analysis methods for dynamic systems Lab: Liquid Level Control with Digital Controller
7	10/1 & 10/3	4	Analog control system performance Lab: Process Identification and Empirical Modeling
8*	10/10	4	Analog control system performance Lab: NO LAB
9	10/15 & 10/17	4	Analog control system performance Lab: Liquid Level Implementation and Validation
10	10/22 & 10/24	4	Analog control system performance Lab: Liquid Level Implementation and Validation
11	10/29 & 10/31	5	Analog control system design Lab: Toaster PLC Project
12	11/5 & 11/7	5	Analog control system design Lab: Toaster PLC Project
13	11/12 & 11/14	5	Analog control system design Lab: Toaster PLC Project
14*	11/19	5	Analog control system design Lab: NO LAB
15	11/26 & 11/28	6 or 8/9	Analog control system components Lab: Toaster PLC Project
16	12/3 & 12/5	10 or 8/9	Digital control system components Lab: Toaster PLC Project
17	12/11-12/16		Final Exams

*Irregular Schedule due to holidays or October Break.

Homework Assignments (due a week after the chapter is finished)
Chapter 2: 4, 6, 15, 16, 17, 22, 25, 29
Chapter 3: 2, 3, 8, 12, 13, 14, 18, 22, 25, 27
Chapter 4: 5, 7, 14, 15, 18, 21 (a&b)
Chapter 5: 8, 9, 13, 14, 19, 20, 21, 22

Homework assignments are to be turned in at the beginning of lecture (9:30 am).