ECE 3510

Introduction to Feedback Systems
Spring 2024 Class Syllabus

Instructor: Arn Stolp
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Phone: U of U: 581-4205
Cell: (801) 783-6589 **<u>Always</u> TEXT FIRST & start text with "ECE 3510"**. This is the best way to contact me.
E-mail: arnstolp@ece.utah.edu. I rarely check my e-mail, so text me if you send me email that I need to read. Subject should start with "ECE 3510". DO NOT use other email addresses or Canvas messaging.
Office hours: My "office hours" will likely be problem sessions. Otherwise it's catch me if you can. To increase your chances, talk to me after class. I'm usually around between 12:20 a.m. & 3 p.m. M,W & F. If I'm not in my office, check the lab.
DO NOT send messages via Canvas. I don't have the time to monitor them.

Web Site: http://www.ece.utah.edu/~ece3510/

Required books and lab supplies:
Textbooks: *Foundations of Control Engineering*, by Marc Bodson, available free at http://www.ece.utah.edu/~bodson/ifs/
Control Systems Engineering, 3rd , 4th or 5th ed. by Norman S. Nise
Calculator that easily handles complex-number arithmetic.
Ring binder for the Bodson text and additional materials to be handed out in class.
Lab notebook (bound or spiral) and standard ECE lab supplies

Prerequisites: C- or better in ECE 2240 or 2260, Full major status

Introduction:

When you're walking down the sidewalk, how do you actually stay on the sidewalk? "Duh, I watch where I'm going", you say. Well, that's feedback. You use your vision to detect which way the sidewalk leads as well as which way you are moving and adjust your direction to minimize the difference between the two. The sidewalk direction is the input, you are the system, and your movement direction is the output. Detecting your direction and using that information to adjust your direction is feedback.

Your body uses feedback control systems to automatically regulate your internal temperature, heart-rate, blood sugar, etc. etc.. Without feedback systems you'd be dead by this afternoon! Feedback is important stuff! Any system that uses a sensor to regulate or control what the sensor is measuring is a feedback system. Engineers use this concept extensively.

This class will introduce you to some of the basics of feedback and control systems and the math used to analyze, design, and stabilize these systems.

I teach concepts and the use of those concepts to solve problems, not formulas and memorization. The hands-down easiest way get a good grade in this class is to *learn* those concepts.

This class consists of:

Lectures: M, W & F 10:45 -12:05 am. WEB 2230

Lectures set the direction and tone of the class and cover more than the written material. You will be held accountable for everything discussed in the lectures, so your attendance is important.

Supplemental Example / Problem Sessions: time and place to br determined

We cover a lot of material in this class and there is rarely enough lecture time to cover everything in the reading assignments, to work as many examples as most students would like, or to answer your questions in detail. These supplemental sessions will make the class much easier to follow with less outside reading and study time.

Textbook:

The main textbook was written by Dr. Marc Bodson, who taught this class for many years. The secondary textbook is an older edition of a popular control-systems textbook which you will have to buy on-line.

Handouts:

There will be a number of handouts for, homework, labs, notes, etc.. I may hand these out before class or may have to download them from the class web site; http://www.ece.utah.edu/~ece3510/.

Homework, homework, and more homework: 14%

I will assign a lot of homework, it will be your main study tool. As such, I'll give you all the numeric answers so that you can check your work immediately. In fact, you'll have to self-correct your homework. If you can't get the answer, check the web site for corrections, study some more, come to the problem session, or ask for help, or see the posted solutions (outside my office). Sometimes I even post solutions before the homework is due. So, you might ask, "Why is it handed in and 'graded'?". Well, to answer a question with a question, "Would you even do it otherwise?"

Your homework should be neat and clear and show all your work. For most problems the grader will simply check to see that you've done it and that your paper shows the necessary work to get the answer. Only a few problems will be checked in greater detail. You may collaborate with others to learn how to do the homework, but will need to hand in your own work. Copying or allowing another student to copy your work is considered cheating.

You will probably learn more from doing the homework than any other part of this class. If you thoroughly understand the homework, you will know what the class is about, and the exams should give you no trouble.

You will need to scan your homework, create a .pdf file, and turn that in on canvas by 11:59 pm of the due date. Solutions will be posted in my office window. Most graded material will be returned on Canvas.

Midterms: (300 exam pts) 43.75%

You will take three 50-minute midterms throughout the semester. They will cover material up to the time of the test. All exams are closed book, closed notes, no phones, tablets or computers allowed. These exams will usually be in two parts, a no calculator, no reference material part where I ask for items that you should have committed to memory, and a part with *some* reference material where I will ask you to solve problems that may require your calculator. This part is designed to see if you learned concepts and problem solving strategies and whether you can work with them, sometimes in new and different ways. Don't try to memorize specific problems. Exams also cover what you learn in the labs. Exams will be returned in class. If you miss class, come to my office.

Final: Monday, 4/29/24 10:30 - 12:30 pm (180 exam pts) 26.25%

The final will be comprehensive with greater emphasis on the most recent material. It may also be in two parts. There will be a zoom review session. Listen for details in class.

Labs: MEB 2365 begin Mon., 1/22/24 16%

Lab will be held every week, beginning the second week and including the last week of class. Many of the subjects covered in lab aren't covered anywhere else in class, so make sure you pay attention and read the lab instructions. You will have to keep a laboratory notebook as a requirement of the lab. Your lab TA will either collect and grade these notebooks or ask you to scan them and submit on canvas.

Labs are **not optional.** For each lab that you miss or fail (< 60% score), your final grade will suffer a **half letter drop** (5% of possible points). Be sure to make-up any labs you miss or fail.

Grades:

Homework:	14%
Labs:	16%
Exams:	70%
Total:	100%
Failed lab:	-5%
Cheating:	-100%

% of total	Grade
> 93	A
90-93	A-
87-90	B+
83-87	B
80-83	B-
77-80	C+
73-77	C
70-73	C-
67-70	D+
63-67	D
60-63	D-
< 60	E

If you want any deviations from the normal requirements, you will need to see me before the work would normally be due and get an agreement *in writing*. You'll need to turn in your copy of the agreement with your final, so I'll remember to grade you properly.

Disclaimer:

All information provided here is subject to change due to external factors or unintended typos or errors.

ECE 3510

A. Stolp

Tentative

01/06/24

Spring 2024 COURSE SCHEDULE

Week		Date	lect	Topics	Books: Bodson	Books: Nise
1	M	01/08	1	Syllabus, etc. Servo, Introduction to Feedback Systems, Block diagrams	Ch.1	Ch.1
	W	01/10	2	Transfer functions and signals, The Laplace transform of signals	2.1	2.1
	F	01/12	3	The Laplace transform, Relationship between pole locations and signal shapes	2.1	2.2
2	M	01/15		Martin Luther King Day		
	W	01/17	4	Inverse of Laplace transforms using partial fraction expansions	2.2	2.2
	F	01/19	5	Inverse Laplace, Properties of signals (bounded, converge)	2.3	2.2
3	M	01/22	6	Transfer functions, Interconnected systems, Feedback system	3.1	2.3, 5.1-2
	W	01/24	7	Systems, Circuits, BIBO stability	3.1 - 2	2.4
	F	01/26	8	Responses to impulse and step inputs, 1st & 2nd order	3.3	4.1 - 4
4	M	01/29	9	Responses to step inputs, % overshoot, effect of zeros	3.3	4.5 - 7
	W	01/31	10	Responses to sinusoidal inputs, sinusoidal steady-state	3.4	4.1 - 8
	F	02/02	11	Effect of initial conditions, State-space advantages	3.5-6,	Ch.3
5	M	02/05	12	Electrical analogies of mechanical systems	notes	2.5 - 9
	W	02/07		Exam 1		
	F	02/09	13	Electrical analogies of mechanical systems	notes	2.5 - 9
6	M	02/12	14	Stability and Performance of Control Systems	4.1 - 3	6.1
	W	02/14	15	Steady-state error and integral control	4.1 - 5	Ch. 7,
	F	02/16	16	Routh-Hurwitz stability test	4.5.1	6.2
7	M	02/19		Presidents Day		
	W	02/21	17	Root-locus introduction, main rules, RL1	4.6.1	8.1 - 4
	F	02/23	18	Root-locus main rules, examples		
8	M	02/26	19	Root-locus additional rules, examples	4.6.2	8.1 - 4
	W	02/28	20	Root-locus additional rules, examples	4.6.3	8.5 - 7
	F	03/01	21	Root-locus design, PI, Lag, PD, Lead, Example 1	notes	9.1- 4
	S	02/26		Spring Break		
	Su	03/05				

ECE 3510 Spring 2024 Course Schedule p2

Week		Date	lect	Topics	Books Bodson	Nise
9	M	03/11	22	Root-locus design, PID, Lag - lead, Catchup and Review	4.6.5	9.1- 4
	W	03/13		Exam 2		
	F	03/15	23	Feedback design for phase-locked loops, discussion of PLL lab	4.7, not	notes
10	M	03/18	24	Variations of Root Locus	notes	notes
	W	03/20	25	Pole dominance, Physical realization,	notes	9.6
	F	03/22	26	PID tuning and Relay logic	notes	notes
11	M	03/25	27	Ladder Logic & Programmable Logic Controllers (PLCs)	notes	notes
	W	03/27	28	Frequency-Domain, Bode plots, basic examples	5.1	10.1 - 2
	F	03/29	29	Bode Plots complex poles & zeros, ζ, ω_n	5.1	10.2
12	M	04/01	30	Bode Plots to Transfer functions	5.1	10.13
	W	04/03		Exam 3		
	F	04/05	31	Bode Plots to Transfer functions, Gain and phase margins	5.3	10.7,12
13	M	04/08	32	Relation to transient response, Frequency-Domain Design, Z_{in}, Z_{out}	5.2 - 3	10.8
	W	04/10	33	Amplifier Feedback & freq response, Op Amp compensation	notes	notes
	F	04/12	34	Discrete-time Signals and Systems	6.1	13.1 - 2
14	M	04/15	35	The z-transform and properties	6.1	13.3
	W	04/17	36	Properties of the z-transform	6.2 - 3	13.3
	Th	04/18		ME Design Day, Union Build.		
	F	04/19	37	Inverse z-transform	6.3	13.3
15	M	04/22	38	Digital control	Ch.7	Ch.13
	T	04/23		Last Day of Classes		
	W	04/24		Reading Day		
	Th	04/25		Finals		
	Su	04/28		ECE 3510 Review		
16	M	04/29		3510 Final 10:30 AM		
	Th	05/02		Freedom		

ECE 3510 Spring Semester, 2024 01/06/24

Week	Month	Mon	Tue	Wed	Thur	Fri
1	Jan	8 L1 Syllabus, etc. Servo, Introduction to Feedback Systems, Block diagrams	9	10 L2 Transfer functions and signals, The Laplace transform of signals	11	12 L3 The Laplace transform, Relationship between pole locations and signal shapes
2		15 Martin Luther King Day	16	17 L4 Inverse of Laplace transforms using partial fraction expansions	18	19 L5 Inverse Laplace, Properties of signals (bounded, converge)
3		22 L6 Transfer functions, Interconnected systems, Feedback system	23	24 L7 Systems, Circuits, BIBO stability	25	26 L8 Responses to impulse and step inputs, 1st & 2nd order
4		29 L9 Responses to step inputs, % overshoot, effect of zeros	30	31 L10 Responses to sinusoidal inputs, sinusoidal steady-state	1	2 L11 Effect of initial conditions, State-space advantages
5	Feb	5 L12 Electrical analogies of mechanical systems	6	7 Exam 1	8	9 L13 Electrical analogies of mechanical systems
6		12 L14 Stability and Performance of Control Systems	13	14 L15 Steady-state error and integral control	15	16 L16 Routh-Hurwitz stability test
7		19 Presidents Day	20	21 L17 Root-locus introduction, main rules, RL1	22	23 L18 Root-locus main rules, examples
8		26 L19 Root-locus additional rules, examples	27	28 L20 Root-locus additional rules, examples	29	1 L21 Root-locus design, PI, Lag, PD, Lead, Example 1
	Mar	4 Spring Break	5	6	7	8
9		11 L22 Root-locus design, PID, Lag - lead, Catchup and Review	12	13 Exam 2	14	15 L23 Feedback design for phase-locked loops, discussion of PLL lab
10		18 L24 Variations of Root Locus	19	20 L25 Pole dominance, Physical realization,	21	22 L26 PID tuning and Relay logic
11		25 L27 Ladder Logic & Programmable Logic Controllers (PLCs)	26	27 L28 Frequency-Domain, Bode plots, basic examples	28	29 L29 Bode Plots complex poles & zeros, damping fact., nat. freq.
12	April	1 L30 Bode Plots to Transfer functions	2	3 Exam 3	4	5 L31 Bode Plots to Transfer functions, Gain and phase margins
13		8 L32 Relation to transient response, Frequency-Domain Design, Zin, Zout	9	10 L33 Amplifier Feedback & freq response, Op Amp compensation	11	12 L34 Discrete-time Signals and Systems
14		15 L35 The z-transform and properties	16	17 L36 Properties of the z-transform	18 ME Design Day, Union Build.	19 L37 Inverse z-transform
15		22 L38 Digital control	23 Last Day of Classes	24 Reading Day	25	26 Finals
16	May	29 3510 Final 10:30 AM	30	1	2 Freedom	3

ECE 3510 Spring Semester, 2024

ECE 3510 Spring Semester 2024 Likely HW Due-Dates (canvas date will overide)

01/06/24

Week	Month	Mon	Tue	Wed	Thur	Fri	Sat
1	Jan	8	9	10	11	12 Hw1 Identify Feedback Systems	13
2		15 Martin Luther King Day	16	17 Hw2 Laplace	18	19 Hw3A Inverse Laplace	20
3		22	23 Hw3B Inverse Laplace	24	25	26 Hw4 Systems & Transfer functions	27
4		29	30	31 Hw5 Circuits -> H(s), Step response	1	2	3 Hw6 Review of Steady-State AC
5	Feb	5	6 Hw7 Sinusoidal Resp., Init. Cond., State Space	7 Exam 1	8	9	10 Hw8 Electrical Analogies of Mech. Linear
6		12	13	14 Hw9 Electrical Analogies of Mech. Trans. Rot. & Fluids	15	16	17 Hw10 Control System Characteristics
7		19 Presidents Day	20	21 RL1 Root Locus by Hand	22	23	24 RL2 Basic rules
8		26	27 RL3 Additional rules	28	29	1	2 RL4 Departure Angles etc.
	Mar	4 Spring Break	5	6	7	8	9
9		11	12 RL5 MATLAB SISO tool	13 Exam 2	14	15	16 RL6 Root Locus Design
10		18 RL7 Root Locus Design	19	20	21	22 RL8 Unconventional Root Locus Plots	23
11		25 RL9 Physical Realization	26	27 FC1 PID tuning	28	29	30 FC2 Programmable Logic Controller, Ladder Logic
12	April	1 BP1 Bode Plots, simple & w/complex poles & zeros	2	3 Exam 3	4	5	6 BP2 Bode Plots to Transfer functions, GM,PM,DM
13		8	9 BP3 Bode GM, PM, DM, Bode Design	10	11	12	13 AF1 Amplifier Feedback, Zin, Zout
14		15 AF2 Amplifier Feedback	16	17	18 ME Design Day, Union Build.	19 Z1 z-transforms	20 DD Design day
15		22 Z2 Inverse z-transforms	23 Z3 Digital Control	24 Reading Day	25	26 Finals	27
16	May	29 3510 Final 10:30 AM	30	1	2 Freedom	3	4

ECE 3510 Spring Semester 2024 Likely HW Due-Dates (canvas date will overide)

ECE 3510 Spring Semester, 2024 Labs

01/06/24

Week	Month	Mon	Tue	Wed	Thur	Fri
1	Jan	8	9	10	11	12
2		15 Martin Luther King Day	16	17	18	19
3		22 Lab 1 Crude Servo System	23	24	25	26
4		29 Lab 2 Intro to dSpace Using a First - Order System	30	31	1	2
5	Feb	5 Lab 3 Second-Order System	6	7 Exam 1	8	9
6		12 Lab 4 DC Motor Characteristics	13	14	15	16
7		19 Presidents Day	20	21	22	23
8		26 Lab 5a Velocity PI Control & Steady-State error	27	28	29	1
	Mar	4 Spring Break	5	6	7	8
9		11 Lab 5b PID Control	12	13 Exam 2	14	15
10		18 Lab 6 PLL Basic	19	20	21	22
11		25 Lab 7 PLL Advanced	26	27	28	29
12	April	1 Lab 8 Ball & Beam	2	3 Exam 3	4	5
13		8 Lab 9 Inverted Pendulum	9	10	11	12
14		15 Lab 10 Flexible Beam	16	17	18 ME Design Day, Union Build.	19
15		22 Makeup	23	24 Reading Day	25	26 Finals
16	May	29 3510 Final 10:30 AM	30	1	2 Freedom	3

ECE 3510 Spring Semester, 2024 Labs

MERRILL ENGINEERING BUILDING (BLDG. 064)

SECOND FLOOR PLAN