Introduction & Syllabus

ECE 461/661 Controls Systems

Jake Glower - Lecture #0

Please visit Bison Academy for corresponding
lecture notes, homework sets, and solutions

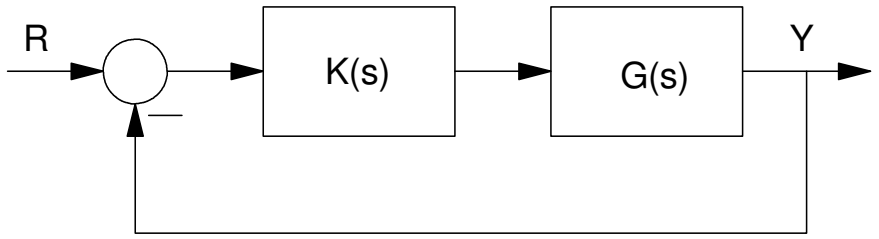
What Are Controls Systems?

Process Control

- Think a car wash
- Turn on / off pumps & valves
- Keep track of times and counts
- Often implmented using PLC's

Applied Math

- Control of dynamic systems using feedback
- Force the output to track a set point
- Improve the response of a system
- Stabilize an unstable system



What is Feedback?

Make the input a function of the output

- Which is a funciton of the input

All important

- Can improve the response of dynamic system
- Can stabilize an unstable system

How the world works

- Fed Reserve: Adjust interest rates and money supply to control inflation
- Riding a Bike: Adjust your weight and heading to remain upright
- Cruise Control: Adjust the fuel to an engine to maintain speed
- Thermostat: Adjust the heat to a room to maintain temperature

Course Content:

- Week 1-5

Review of Signals & Systems

- LaPlace Trasform review
- 1st & 2nd Order Approximations

Ladder Logic

- Graphical programming language
- Used in PLCs

System Modeling

- RLC circuits
- Mass-spring systems
- Rotational systems
- DC servo motors

Test #1

- In-person on on BlackBoard

Lecture
Holiday 1947th Anniversary of Mt. Vesuvius
Syllabus Slides #0
LaPlace Transforms Slides #10
Intro to Ladder Logic PLC Lecture #1
1st and 2nd Order Approximations Slides #11
Block Diagrams Slides #12
Holiday Labor Day
State-Space and Canonical Forms Slides #13
Electrical Circuits: Heat Equation Slides #14
Code Composer Workbench PLC Lecture #2
Mass Spring Systems: Wave Equation Slides #15
Rotational Systems & Gears Slides #16
PLCs and State Transition Logic PLC Lecture #3
Modeling a DC Servo Motor Slides #17
Test #1

Course Content:

- Week 6-10

PLC Blocks

- Timer blocks
- Counter blocks
- Analog inputs

Feedback Control

- Root locus techniques
- Sketching a root locus
- Compensator design using root-locus techniques
  - Gain compensation
  - Lead compensation
  - PID compensation

Test #2

- In-person and online

Timer Blocks PLC Lecture #4
Error Constants Slides #18
Routh Criteria Slides #19
Counter Blocks PLC Lecture #5
Sketching a Root Locus Plot Slides #20
Root Locus with Complex Poles Slides #21
For-Next Loops, If-Then Statements PLC Lecture #6
Gain Compensation Slides #22
Lead Compensation Slides #23
Analog Inputs & Comparitors PLC Lecture #7
PID Compensation Slides #24
Meeting Design Specs Slides #26
Systems with Delays Slides #27
Unstable Poles and Multi-Loop Feedback Slides #28
Test #2

Course Content

- Weeks 11-15

PLC Programming

- Structured Text Programs
- Programming in Pascal

Digital Control

- z-Transforms
- Design of descrete-time compensators

Frequency Domain Techniques

- Bode plots
- Design of feedback controls in the frequency domain

Test #3

- In-Person or Online

Structured Text (ST) Programs PLC Lecture #8
z-transform Slides #29
s to z Conversion Slides #30
Root Locus in the z-Domain Slides #31
Holiday Veterans Day
Digital PID Control Slides #32
Meeting Design Specs in the z-plane Slides #33
Bode Plots Slides #35
Nichols Charts and Gain Compensation Slides #36
Gain and Lead Compensation with Bode Plots Slides #37
Holiday Thanksgiving
Holiday Thanksgiving
Lag Compensators Slides #38
Meeting Design Specifications Slides #39
Test #3

Course Information

Instructor:	Jake Glower
Office:	Offerdahl Hall 244M
Class Times	MWF 10am
	Dolve 118
Lab Times:	Open Labs
	PLCs available for checkout
	PLC Fiddle also works
Textbook	Bison Academy

Alternate Textbooks (edition doesn't matter)

- Control System Design: Bernard Friedland
- Linear System Theory and Design, Chi-Tsong Chen
- Linear Systems, Thomas Kalith
- Schaum's Outline on Controls Systems

Bulletin Description:

- Analysis and design of control systems. Controller design to meet time and frequency specifications. Three 50-min lectures and one 2-hour lab per week. Prereq: ECE 343.

Course Objectives:

By the end of the semester, students should:

- Determine the differential equation which describes electrical circuits, mass spring systems, and rotational systems
- Determine the transfer function of a system from its differential equation
- Determine how a given system will behave by inspection based upon its dominant poles
- Determine how a feedback control system will behave as the feedback gain changes using root locus techniques,
- Design single-loop feedback control systems for a dynamic system using root locus and frequency domain techniques

Bison Academy

- www.BisonAcademy.com
- Where to access lecture notes, homework sets, etc. for ECE 461/661

BISON ACADEMY

ECE LABS

Advising Info
ECE Lab Supplies (new)
ECE 111: Intro to ECE
ECE 206: Circuits I
ECE 311: Circuits II
ECE 320: Digital Electronics
ECE 321: Analog Electronics
ECE 331: Energy Conversion
ECE 341: Random Processes
ECE 343: Signals and Systems
ECE 376: Embedded Systems
ECE 461: Controls Systems

Bison Academy: Syllabus

- Daily material (lecture topic in pdf format)
- Recorded lectures (YouTube)
- Sample Code (from lecture notes)
- Homework assignments

ECE 461/661: Controls Systems

Syllabus - HW & Solutions - Resources - Comments

	Date	Lecture	Videos and Code YouTube PlayList	Handouts	Homework
M	Aug 21	*Holiday!*	Download Matlab (link here) VisSim (link here)		HW #1
W	Aug 23	Syllabus Slides #0 Intro to Ladder Logic	0: Syllabus 1 Intro to PLCs		
F	Aug 25	Code Composer Workbench PLCs and State Transition Logic	2 Logic with PLCs 3 State Transition Logic		
M	Aug 28	Timer Blocks Counter Blocks	4 Timers 5 Counters		HW #2
W	Aug 30	For-Next Loops, If-Then Statements Analog Inputs & Comparitors			
F	Sep 1	Structured Text (ST) Programs	6 ST Intro 7 ST Counters 8 ST Timers		

Bison Academy: HW & Solutions

Homework Assignments & Solutions from previous semesters

Tests and Solutions from Previous Semesters

- Good resource if you want sample problems to work on
- YouTube recordings where I go over each homework set

ECE 461: Controls Systems

Homework and Solutions

Syllabus - HW & Solutions - Resources - Comments

Fall 2022	Fall 2021	Fall 2020	Fall 2019
H1: Ladder Logic	1: Ladder Logic	1: PLC Ladder Logic Solution #1	1: PLC Ladder Logic Solution #1
2: Timers & Counters	2: Timers & Counters	2: PLC Timers & Counters	2: PLC Counters and Timers Solution #2
3: Structured Text	3: LaPlace Transforms Solution #3	3: PLC Loops Solution #3	3: PLC Loops and Analog
4: LaPlace Transforms Solution #4 (pdf) Solution #4 (YouTube)	4: State-Space Solution #4 HW #4 (YouTube)	4: Block Diagrams Solution #4	4: Block Diag & State Space Solution #4
5: State Space Solution #5 (pdf) Solution #5 (YouTube)	5: System Modeling Solution #5 HW #5 (YouTube)	5: Modeling Solution #5	5: Heat & Wave Eq Solution #5

Hy-Flex Model for ECE 461/661

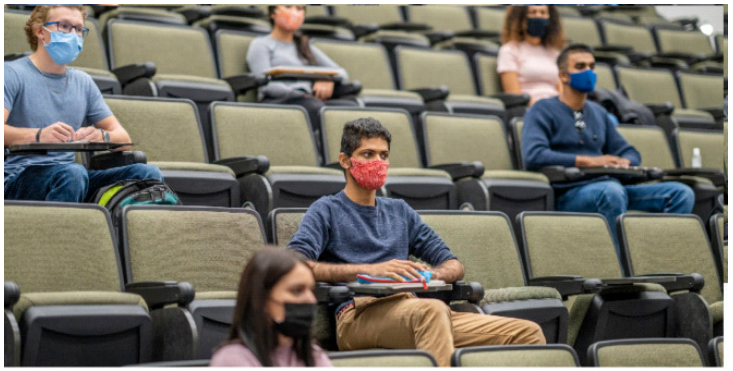
Students are welcome to take this course however they like:

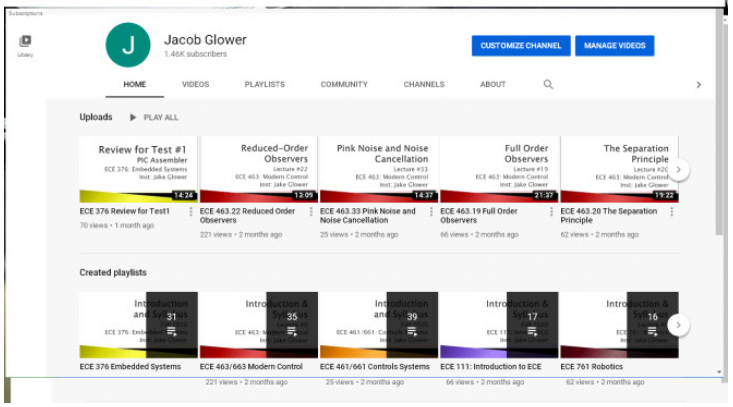
- In-Person:
- Live-Stream: on Zoom
- On-Line: YouTube recordings of lectures

There is plenty of room, so you are welcome to attend each day however you like

- Whatever fits your schedule

Everyone is welcome to use the on-line resources on Bison Academy.





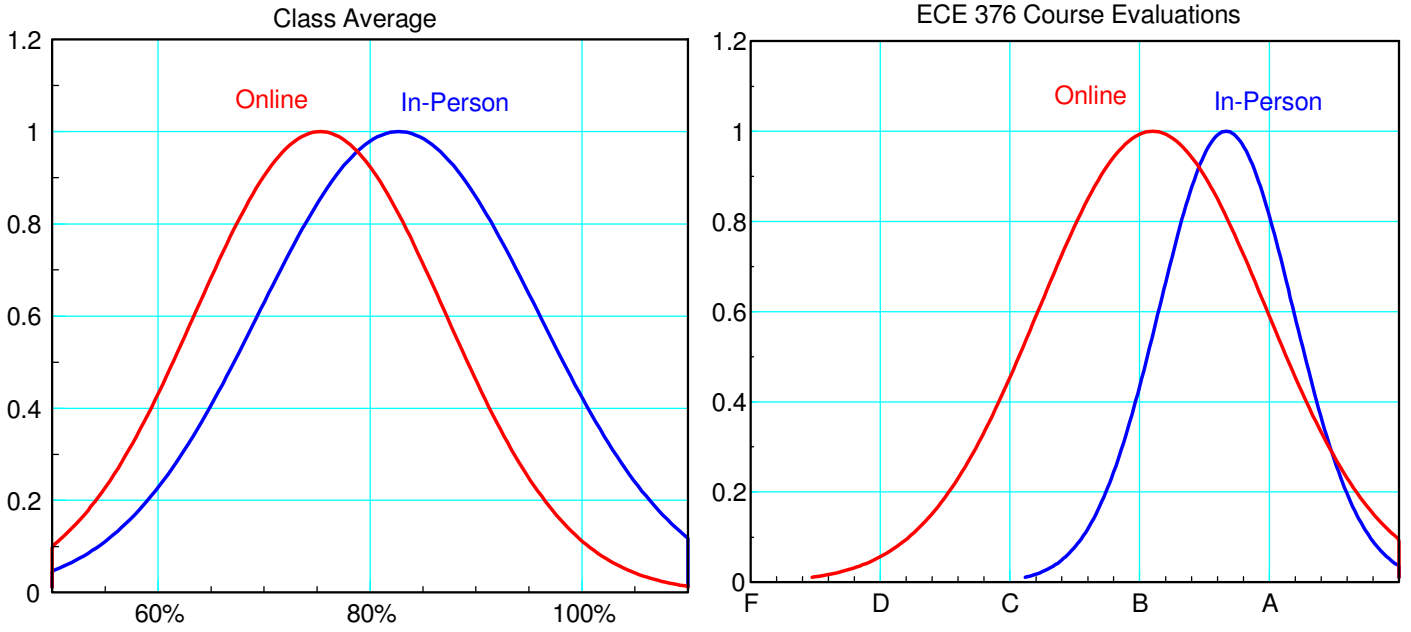
In-Person vs. Online

In-person appears to be better than online.

- Course evaluations were 1 letter grade higher for students who took the course in-person
- Grades were 7% higher on average for students who took the course in-person

Regardless, it's your choice how you take the course

- It can change on a daily basis



Homework Sets

Homework sets are due on the following Monday

- Wednesday if Monday is a holiday
- Except for the PLC assignments: Due after you get a chance to use a PLC

Copy and paste Matlab code and images as needed

- Hard Copy
- pdf file
- Word file
- jpg images

Submit

- Hard copy (in class)
- Submit on BlackBoard
- email (jacob.glower@ndsu.edu)

b) Check your answers using the 3rd order model and Ma

```
>> G = zpk([],[-15,-1+j*4,-1-j*4],300)

          300
----------------------
(s+15) (s^2 + 2s + 17)

>> DC = evalfr(G,0)

DC = 1.1765

>> t = [0:0.01:6]';
>> y = step(G,t);
>> plot(t,y);
>> xlabel('Time (seconds');

>> max(y) / DC

ans =    1.4380
```

System actually has 43.8% overshoot

- 45.59% calculated

Labs

PLC Labs

- Part of each homework set
- Ten Allen Bradley Micro810 PLC's are avilable for checkout
  - Please return at the end of the semester
- PLC Fiddle can also be used (www.plcfiddle.com)

Feedback Controls Labs

- Verify your paper design works in practice (in simulation)

To simulate the dynamics of your closed-loop system, you can use:

- Matlab: Write Matlab code to simulate the dynamics of a closed-loop system
- Simulink: Part of the Matlab tool suite
- CircuitLab: CircuitLab does everything...

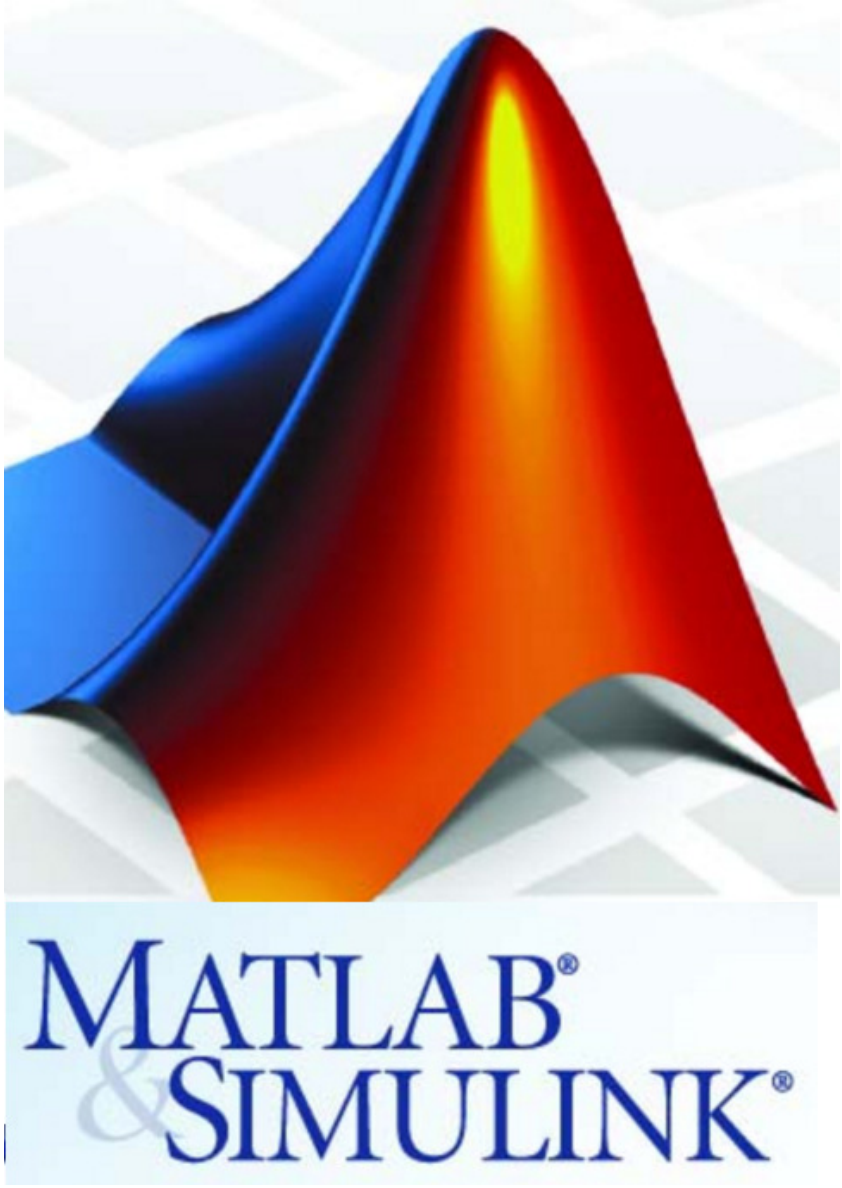
Required Student Resources:

Calculator capable of complex numbers

- Matlab works
  - Free for NDSU students
- Free42
  - HP42: best calculator every made
  - free app on your cell phone
- HP35S
  - Physical RPN calculator
  - $159 on Amazon
- Other
  - TI84 Plus
  - Your pick

Matlab

- Free for NDSU students
- Register using your NDSU email
- student.name@ndsu.edu



Evaluation Procedures and Grading Criteria

Grades will be the average of the following:

Midterms (x3)	Homework	Final Exam
50%	17%	33%

Grades are rounded to the nearest 1%, with your final grade being

F	D	C	B	A
59% or less	60% - 69%	70% - 79%	80% - 89%	90% or more

Use of AI & ChatGPT

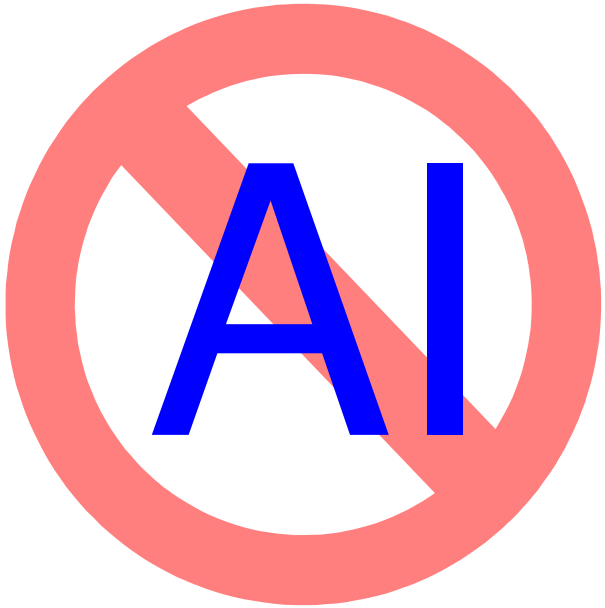
AI exists. ChatGPT exists.

- Both can be useful.
- Learn new Matlab commands
- Learn new programming techniques

Please do *not* turn in ChatGPT or AI solutions

- Both are easy to spot:
  - If you know what you're doing, most homework problems take just a few Matlab commands to complete.
  - ChatGPT, in contrast, tends to give long elaborate solutions with fancy formatted output using commands I've never seen before.
  - ChatGPT also tends to give solutions that are pure nonsense

If you turn in a solution that shows you don't understand what you're doing, I'll grade accordingly.



Legal Stuff:

Attendance: According to NDSU Policy 333 (www.ndsu.edu/fileadmin/policy/333.pdf), attendance in classes is expected. Students are responsible for the material covered in class and in assignments regardless of their attendance. Note that all lecture notes, homework sets, and solutions are available on-line at www.BisonAcademy.com

Students with Special Needs: Any students with disabilities or other special needs, who need special accommodations in this course, are invited to share these concerns or requests with the instructor and contact the Disability Services Office (www.ndsu.edu/disabilityservices) as soon as possible.

Academic Honesty: The academic community is operated on the basis of honesty, integrity, and fair play. NDSU Policy 335: Code of Academic Responsibility and Conduct applies to cases in which cheating, plagiarism, or other academic misconduct have occurred in an instructional context. Students found guilty of academic misconduct are subject to penalties, up to and possibly including suspension and/or expulsion. Student academic misconduct records are maintained by the Office of Registration and Records. Informational resources about academic honesty for students and instructional staff members can be found at www.ndsu.edu/academichonesty.

Academic Honesty Defined: All written and oral presentations must "respect the intellectual rights of others. Statements lifted verbatim from publications must be cited as quotations. Ideas, summaries or paraphrased material, and other information taken from the literature must be properly referenced" (Guidelines for the Presentation of Disquisitions, NDSU Graduate School).

ECE Honor Code: On my honor I will not give nor receive unauthorized assistance in completing assignments and work submitted for review or assessment. I have to complete all my work with complete integrity.

Veterans and Student Soldiers: Veterans and student soldiers with special circumstances or who are activated are encouraged to notify the instructor in advance.