Introduction & Syllabus

ECE 376 Embedded Systems

Jake Glower - Lecture #0

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

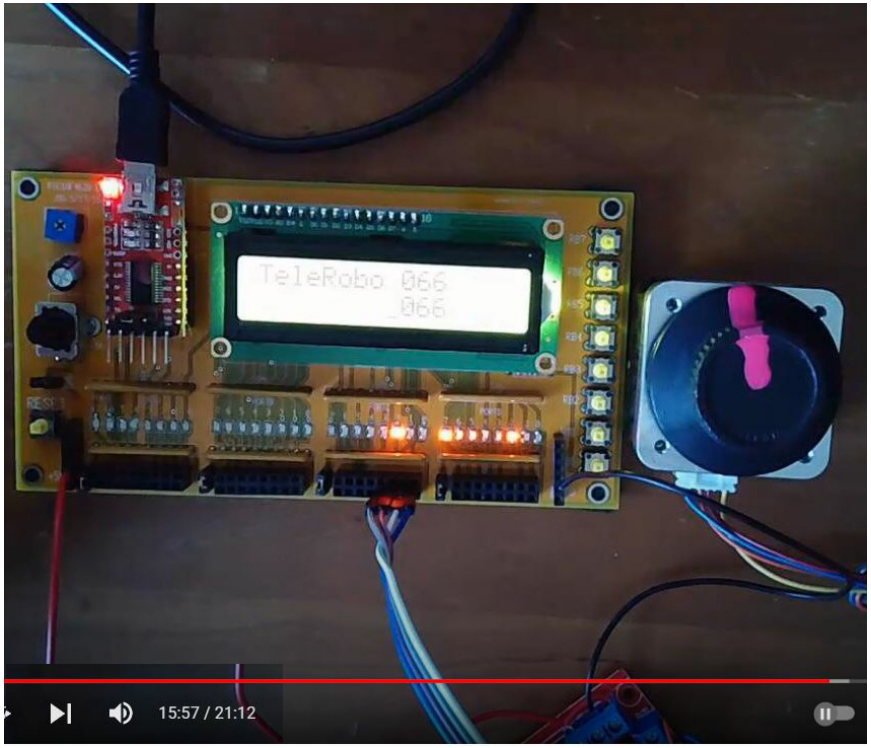
What Are Embedded Systems?

Electronics which includes a microcontroller

- Inputs: Sensors, what's happening?
- Outputs: Actuators: do something
- Microcontroller: Use software to control the outputs based upon the inputs

This is a fun course where you build, program, test, and demonstrate various devices

- Having a microcontroller allows you to much more than you could in other classes, much easier



Junior-Level Course

- Students don't know what they don't know
- 30 lectures = 30 things you can do with a microcontroller

Course Content (Week 1-4)

Binary Inputs

- 0V = logic 0, 5V = logic 1
- Converting switches, temperatures, etc. to 0V/5V

Binary Outputs

- Turn on/off lights, heaters
- Drive a speaker, motors

Assembler

- Low-level programming language
- Very fast, very powerful
- Very painful
- (How computers actually work)

	Date	Lecture
M	Aug 21	Holiday! -
W	Aug 23	Syllabus Slide #0
F	Aug 25	Architecture and Boolean Math Lecture #1
M	Aug 28	PIC Assembler Lecture #2
W	Aug 30	MPLAB8 & Flow Charts Lecture #3
F	Sep 1	Binary Inputs & Counters Lecture #4
M	Sep 4	Holiday! -
W	Sep 6	Binary Outputs & Timing Lecture #5
F	Sep 8	Binary Outputs: LEDs Lecture #6
M	Sep 11	AdaFruit: NeoPixels Lecture #7
W	Sep 13	Review -
F	Sep 15	Test #1: Assembler & Digital I/O

Course Content (Week 5-9)

C Programming

- Higher-level computer language
- Much easier than assembler (but slower)
- Allows for digital and analog I/O

Allows you to do more than you could with assembler

- Drive LCD displays
- Read keypads
- Drive stepper motors
- Read analog inputs (temperature, light, etc)
- Collect data

M	Sep 18	C Programming with Mplab8 Lecture #8 C Programming with MplabX
W	Sep 20	C & LCD Displays Lecture #9
F	Sep 22	Keypads in C Lecture #10
M	Sep 25	Stepper Motors in C Lecture #11
W	Sep 27	NeoPixels and In-Line Assembly Lecture #12
F	Sep 29	A/D Converters Lecture #13
M	Oct 2	Data Collection & Calibration Lecutre #14
W	Oct 4	Statistics: Chi-Squared Test Lecture #15
F	Oct 6	Chi-Squared Examples Lecture 15b
M	Oct 9	Student t-Test with One Population Lecture #16
W	Oct 11	Student t-Test with Two Populations Lecture #16b
F	Oct 13	D/A Converters Lecture #17
M	Oct 16	Placing a PIC in stand-alone mode Low-Power Operation
W	Oct 18	Review -
F	Oct 20	Test #2: C Programming & Statistics

Course Content: Week 10-15

Interrupts

- Subroutines called by hardware
- Really confusing
- Really powerful

With interrupts, you can

- Measure time to 100ns (!)
- Control binary outputs to 100ns (!)
- React to rising / falling edges within 5us (!)
- Implement digital filters
- Read GPS sensors

M	Oct 23	Timer 2 Interrupts Lecture #18
W	Oct 25	Timer 2 Examples Lecture #19
F	Oct 27	Timer 0 Interrupts Lecture #20
M	Oct 30	Timer 0123 Interrupts Lecture #21
W	Nov 1	INT Interrupts Lecture #22
F	Nov 3	Timer 1 Capture Lecture #23
M	Nov 6	Timer 1 Compare Lecture #24
W	Nov 8	Filters in the s-Plane Lecture #26
F	Nov 10	Holiday! -
M	Nov 13	z-Transform Lecture #27
W	Nov 15	Filters in the z-Plane Lecture #28
F	Nov 17	FIR Filters Lecture #29
M	Nov 20	SCI and GPS Lecture #25
W	Nov 22	Holiday! -
F	Nov 24	Holiday! -

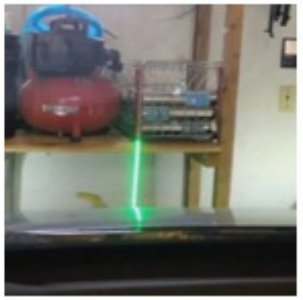
Course Content: Week 16

Term Projects

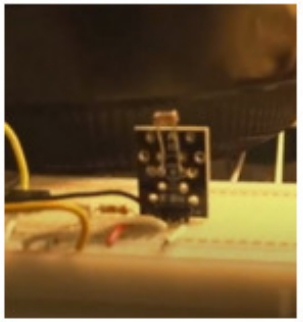
- Demonstrate your ability to build, test, and demo an embedded system
- Demonstrate your term project to the class
  - optional

Examples from previous semesters are linked under "Best of 376"

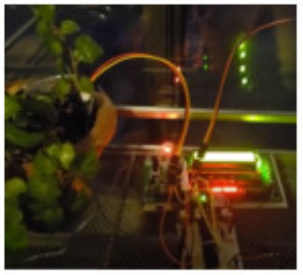
- YouTube videos



Car Parking Sensor
Spring 2020
An ultrasonic range sensor dete
bar graph. When you're close e



Refrigerator Data Logger
Spring 2020
A PIC mircocontroller along wit
the time that the door remains



Automated Watering System
Spring 2020
A PIC mircontroller monitors th
on to water the plants.

Course Information

Instructor:	Jake Glower
Class Times	Mo / We / Fr
Lab Times:	Open Lab
	ECE 211
Office Hours:	Tu/Th 11am - noon
	ECE 201 & Zoom
Text:	Bison Academy (free!)

Bulletin Description:

- The use of microcontrollers for data acquisition and device control. Includes assembly language and high-level programming, serial and parallel I/O, timers and interface design. 3 lectures, 1 two-hour laboratory. Prereq: ECE 173, ECE 275, EE 206. F, S

Course Objectives:

By the end of the semester, students should:

- Be able to solder a circuit board,
- Be able interface a microcontroller to binary inputs and outputs,
- Be able to interface a microcontroller to analog inputs and outputs,
- Be able to control these inputs and outputs using programs written in assembler and C, and
- Be able to use interrupts to control the precise timing of a microcontroller, precise to 100ns

Bison Academy

- www.BisonAcademy.com
- Where to access lecture notes, homework sets, etc. for ECE 376

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 376: Embedded Systems

Syllabus - HW & Solutions - Best of 376 - Lab Kits - Resources - Comments

	Date	Lecture	Videos YouTube PlayList	Sample Code	Homework
M	Aug 21	Holiday!	Photo of EVB Soldering you PCB	Install Matlab	HW #1
W	Aug 23	Syllabus Slide #0	0 Syllabus	FTDI Driver FTDI Driver (exe)	
F	Aug 25	Architecture and Boolean Math Lecture #1	1 Architecture	**Assembler (handout)**	
M	Aug 28	PIC Assembler Lecture #2	2 Assembler	**Assembler Code (handout)** 1234.asm Add Subtract.asm	HW #2
W	Aug 30	MPLAB8 & Flow Charts Lecture #3	3 MPLAB8	CountRB0.asm Random.asm BootLoader.zip	
F	Sep 1	Binary Inputs & Counters Lecture #4	4 Binary Inputs	Up.asm UpDown.asm HungryHungryHippo.asm	

Bison Academy: Homework and Solutions

Homework Assignments & Solutions from previous semesters

Tests and Solutions from Previous Semesters

- Good resource if you want sample problems to work on
- Code is usually removed (use sample code from the Syllabus as a starting point)

Fall 2021	Spring 2021	Fall 2020	Spring 2020	Fall 2019
1: PIC Background Solution #1 (pdf) Solution #1 (YouTube)	1: PIC Background Solution #1	1: PIC Background Solution #1 (pdf) Solution #1 (YouTube)	1: PIC Background Solution #1	1: PIC Background Solution #1
2: PIC Assembler Solution #2 (pdf) Solution #2 (YouTube)	2: PIC Assembler Solution #2	2: PIC Assembler Solution #2 (pdf) Solution #2 (YouTube)	2: Assembler Solution #2	2: Assembler Solution #2
3: Binary I/O Solution #3 (pdf)	3: Binary I/O Solution #3	3: Binary I/O Solution #3	3: Binary I/O Solution #3	3: Binary I/O Solution #3
Test #1 Test #1 Solution (pdf) Test #1 Solution (YouTube)	Test #1 Test #1 Solution	Test #1 Test #1 Solutions	Test #1 Test#1 Solution	Test #1 Test #1 Solution
4: C-Coding Solution #4 (pdf) Solution #4 (YouTube)	4: C Coding Solution #4	4: C Coding Solution #4	4: C Coding Solution #4	4: C Coding Solution #4

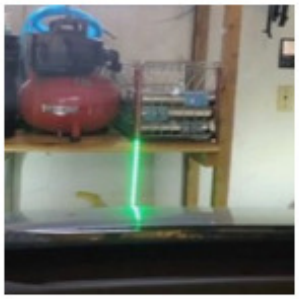
Bison Academy: Best of 376

Most homework sets have four parts

- Requirements
- Hardware & Software
- Testing
- Validation & Demonstration

YouTube videos work well for validating and demonstrating your code works.

- The better videos are shared under "Best of 376" (with student permission)
- Good recruiting tool for ECE
- Good way to demonstrate your skills to future employers



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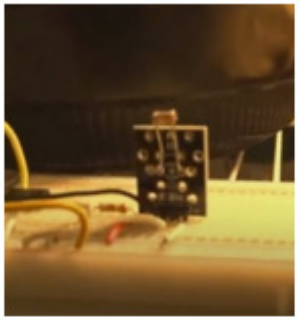

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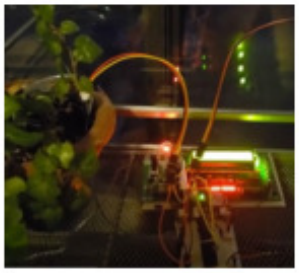

Automated Watering System
Spring 2020
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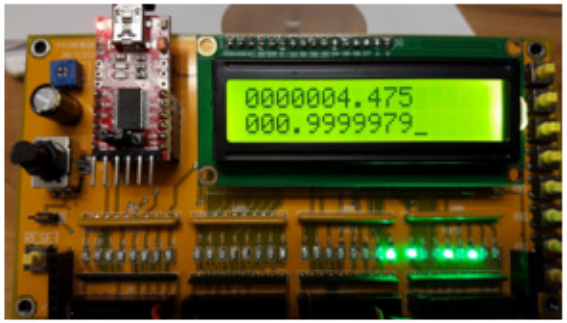
Lab Kits

One lab kit is required for each student

- $65 from SWE (check or cash)
- Pick up in ECE 201

Allows you to test your code in hardware

- Course is a lot more fun if you can see your program working
- You learn by doing: about the only way to understand the concepts in this course is to write and debug the code yourself.



Instructions for how to build your circuit board

- Text File
- YouTube Video
- Photo of what's inside the box
- Photo of Finished Board

What to do if your board quits working:

About a third of the boards will quit working

- Usually this is a bad solder connection
- Eventually, the solder oxidizes an creates an open-circuit
- If you flex your board and the LEDs turn on then off - that's a sign of a bad solder joint

If this happens to you, please see the instructor (Jake Glower).

- I can usually fix the problem in 10-20 minutes.
- I also have spare boards we can swap
  - Take a board - leave a board

The course is a lot more fun if your board works

- It also helps with completing the homework assignments.

Hy-Flex Model for ECE 376

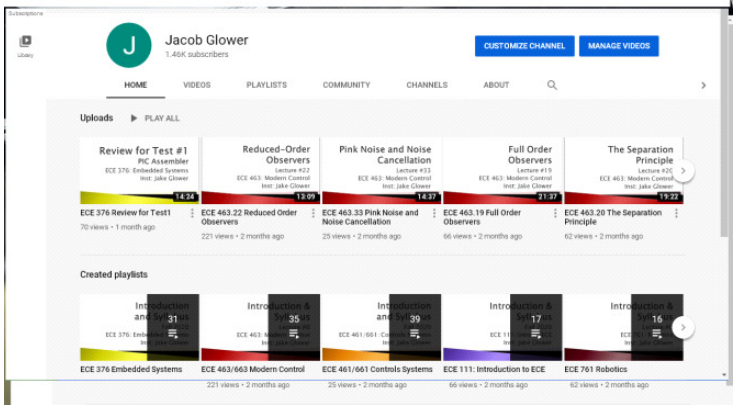
Students are welcome to take this course however they like:

- 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.



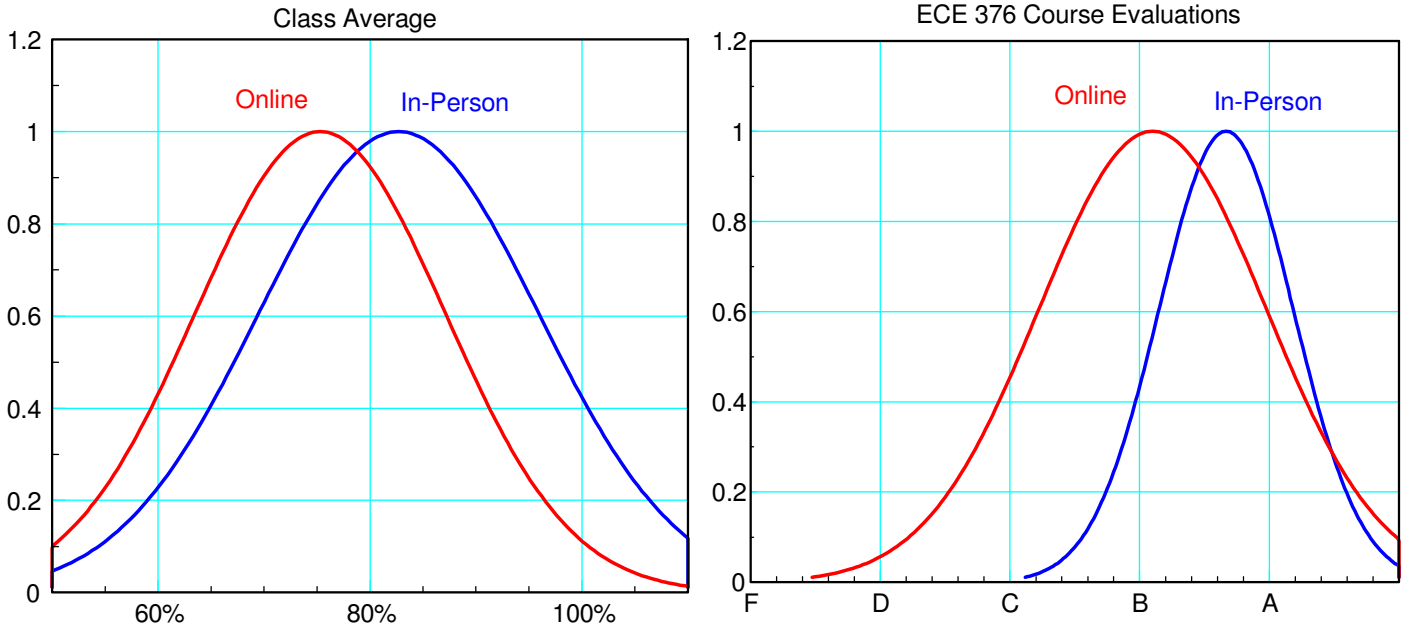
In-Person vs. Online

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



Evaluation Procedures and Grading Criteria

Grades will be the average of the following:

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

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

How to Get an A or B:

Keep up and do the homework.

- This class involves programming and interfacing hardware to your computer board.
- The only way I know to understand this interaction is to do it yourself.
- Sort of like weight lifting: watching someone else lift weights isn't the same as doing it yourself

Grades in this class are often bimodal:

- People who did the homework themselves tend to get either an A or a B.
- People who did not do the homework or copied tend to struggle to get a D.

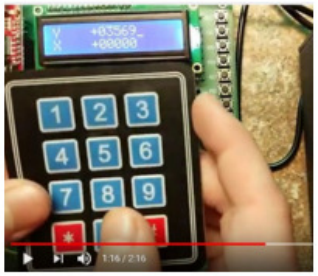
Homework & Lab Projects

Groups of 1 or 2 allowed

- Only one homework set per group

Exams serve as a check that you're doing the homework

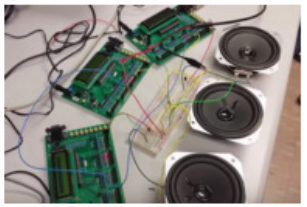
- If you do the homework, exams should be straight forward
- If you're giving moral support or copying code you found online, you'll probably struggle



Security Passcode Systems

Spring 2019

Using a numeric keypad, a passcoc buzzer sounds.



Mission Impossible Theme

Fall 2015

Using three PIC microcontrollers, th separate speakers.

ECE 376 Term Project: Padlock Solver

Padlock Solver

Spring 2014

This embedded system will determi motor turns the lock and goes thro tests the combination and a force s combination)

Open-Ended Assignments

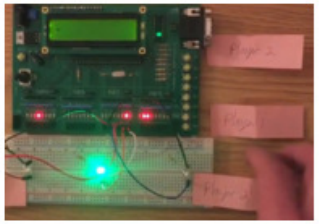
Most homework sets are open-ended:

- You are free to specify what it is you're going to build and program
- Subject to it including things that we're covering that week, such as stepper motors

Each write-up includes four sections:

- Requirements What your device does
- Hardware & Software: Schematics & Code
- Test & Validation: Data to verify your design works (voltages, frequencies...)
- Demonstration: In-person or YouTube

This allows you to tailor your homework to your own interests



Reaction Test Game

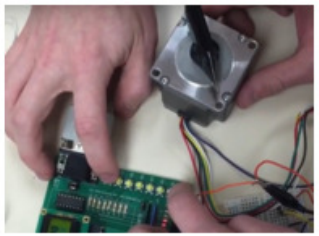
Spring 2016

A game is set up using a PIC proc
seconds later, a light turns on. Bc
- the fastest player wins. The time
LCD screen.

Scooby Doo Theme using Timer

Spring 2017

The theme from Scooby Doo is pl
each note and Timer2 sets the du



Stepper Motor Tennis Game

Spring 2016

A game is programmed where tw
the stepper motor reaches your s
miss, you suffer humiliation. Time

Legal Stuff:

Attendance: According to NDSU Policy 333, attendance in classes is expected. How you attend is up to you: in-person, live-stream, or watching YouTube videos. 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.