Introduction & Syllabus

ECE 476 Advanced Embedded Systems

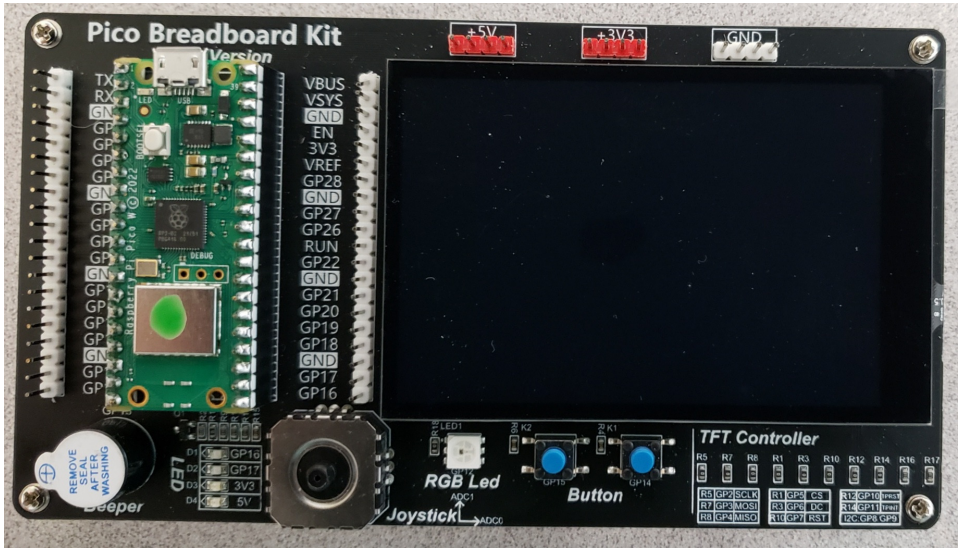
Jake Glower - Lecture #1

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

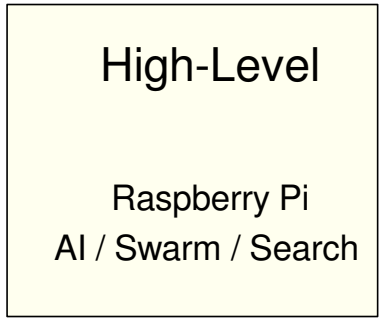
Senior-Level Course

- Students don't know what they don't know
- 35 lectures = 35 things you can do with a microcontroller

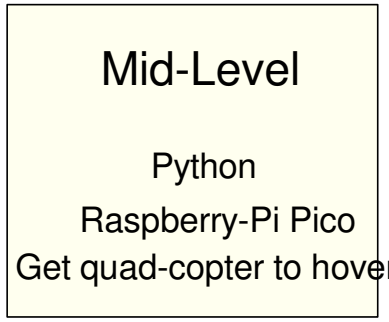
What is Advanced Embedded Systems?

Three programming levels:

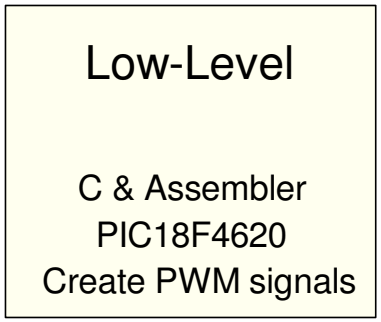
- Low-Level (ECE 376)
  - Focus on driver routines to access the hardware
  - Directly control registers, I/O pins
  - Assembler & C programming languages
  - example: how to generate a 100Hz, 30% duty cycle square wave
- Mid-Level (ECE 476)
  - Focus on more complicated programs
  - Use driver routines to access the hardware
  - Python programming language
  - example: Control the speed of a motor using PWM
- High-Level (CSCI 4xx)
  - Focus on more complicated programs
  - Use lower-level routines to do task
  - AI languages
  - example: Get quad-copters to swarm



NDSU CSCI 4xx



NDSU ECE 476



NDSU ECE 376

ECE 376 vs. ECE 476

ECE 376: Embedded Systems	ECE 476: Advanced Embedded
Low-Level Programming • Focus on driver routines • Access hardware • Setting control registers	Mid-Level Programming • Call driver routines • Focus on more complex tasks
Assembler & C • Fast • Access to hardware	Python • Slower • Easier to write and debug code
Microcontroller • PIC18F4620	Microcontroller • Raspberry Pi-Pico (RP2040)
I/O • Binary (LEDs) • LCD character display • Analog inputs	I/O • Serial port (SCI) • Graphics LCD display • Analog inputs (A/D) • Analog outputs (PWM)

Do I Need ECE 376 Embedded Systems?

Not really

- Different processor
- Different language
- Different objectives

If you need a refresher

- Bison Academy
  - https://www.BisonAcademy.com/Index
- ECE 320 Electronics
  - https://www.BisonAcademy.com/ECE320/Index
- ECE 376 Embedded Systems
  - https://www.BisonAcademy.com/ECE376/Index

What's New: Processor

Raspberry Pi Pico W

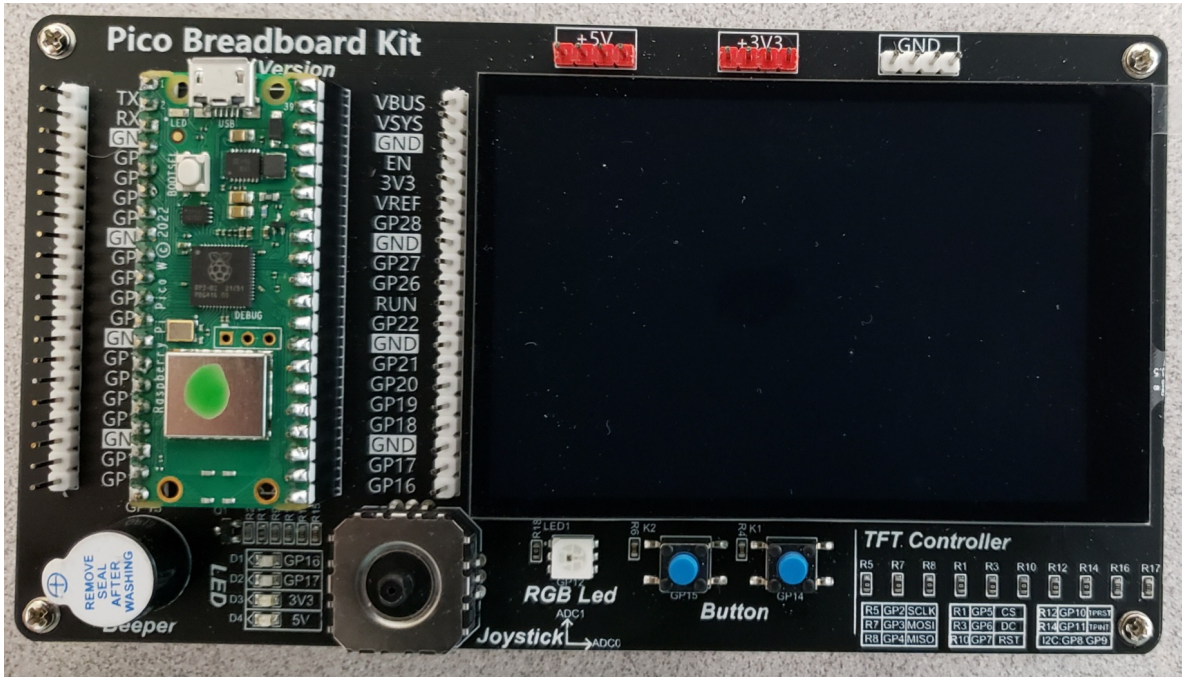
- $9 from Amazon
- $6 from Adafruit or the Pi-Shop

Features

- Dual ARM Cortex-M0+ @ 133MHz
- 2MB Flash
- 264kB on-chip SRAM in six independent banks
- 30 GPIO pins
  - 3.3V fixed
  - 12mA source/sink
- 4 x 12-bit, 500ksps A/D (3 external connections)
- 2 × UART, 2 × I2C, 2 × SPI, 16 × PWM channels
- 1 × Timer with 4 alarms, 1 × Real Time Counter
- 8 state machines total
- Bluetooth
- Wi-Fi

What's New: Development Board

- GeeekPi Pico Breadboard Kit Plus Version
- $32 from Amazon



Features:

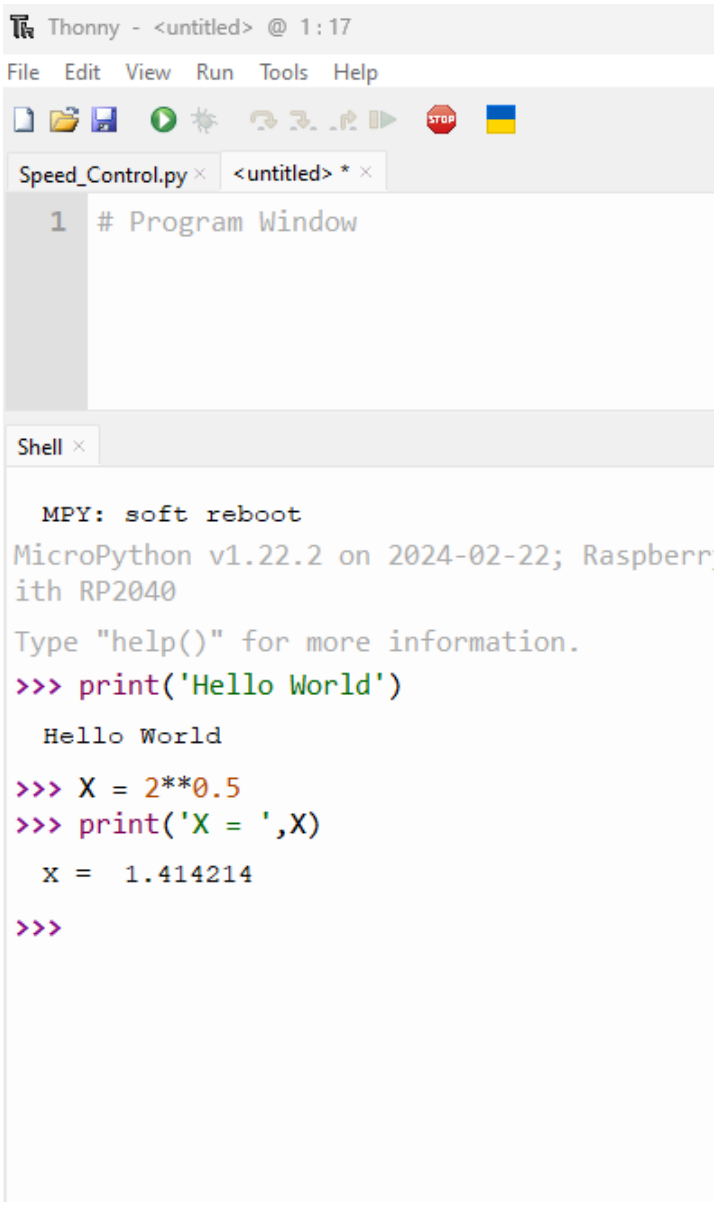
- I/O pins connected to headers
- 2 x Push Buttons
- 2 x LEDs
- 1 x Beeper
- XY joystick (analog inputs)
- RGB LED (NeoPixel)
- 320 x 480 graphics LCD
  - with touch-screen
- Total Current Draw:
  - 272mA when LCD is black
  - Pico-W = 20.7mA

What's New: Python

- Thonny programmer (free!)
- Windows compatible

Very similar to Matlab

- Similar syntax
- Works with complex numbers
- Easily read/write to console
- Interpritive language
  - Can test your code in the command window



Course Content

- Lectures 1-11
- Python Programming

How to read and write in Python

- Binary signals
- Analog signals
- Use of libraries

How to measure time

- and output frequencies

How to drive different motors

- motors with binary inputs
- motors with analog inputs

1	Introduction & Syllabus
2	Thonny & MicroPython
3	Loops & If-Statements
4	Subroutines
5	Binary Outputs
6	Binary Inputs
7	Serial I/O
8	Timing
9	Analog I/O
10	Motors with Binary Inputs
11	Motors with Analog Inputs
	Test #1

Course Content

- Lectures 12 - 24

Creating your own libraries

- LCD routines
- Matrix routines

Math & Random libraries

- What they include
- How to use their funcitons

Interrupts in Python

- Edge interrupts
- Timer interrupts

Controlling a DC motor

- Speed & angle control using interrupts

Reading Sensors

- Temperature, Current, Pulse, Wind, Pressure, etc.

12	LCD Graphic Display
13	Fun with LCD Graphics
28	Touch Screens
14	Math and Random Library
15	Matrix Library
16	Edge Interrupts
17	Timer Interrupts
18	Speed Control of a DC Motor
19	Angle Control of a DC Motor
20	Text Files
21	Temperature Sensors
22	Current & Heart Rate Sensors
23	Wind, Pressure, Humidity Sensors
24	Acceleration & Light Sensors
	Test #2

Course Content

- Lectures 25- 34

SCI & GPS

- Reading GPS sensors

NeoPixels and State Machines

- Pretty lights

I/O with Bluetooth

- send / receive data to your cell phone

WiFi in AP Mode

- set up a stand-alone WiFi network
- send / receive data

WiFi in Client Mode

- join an existing WiFi network
- send / receive data

25	SCI & GPS
26	NeoPixels
27	State Machines
28	Bluetooth
29	Bluetooth (cont'd)
30	Wi-Fi in AP Mode
31	WiFi & AP Tags
32	WiFi in Client Mode
33	WiFi & Client Tags
	Test #3

Course Information

Instructor:	Jake Glower
Office:	Offerdahl Hall, 244M
Class Times	MWF 11am
	Dolve 118
Lab Times:	Open Lab
Office Hours:	MWF noon - 2pm
	Tu/Th 11am - 4pm
	Whenever I'm in my office
Text:	Bison Academy (free!)
	W3Schools

Bulletin Description:

- Specification, design, development, and rest of modern embedded systems using a high-level programming language. Prereq: ECE 376. F, S

Course Objectives:

By the end of the semester, students should:

- Be able to interface a microcontroller to binary inputs and outputs,
- Be able to interface a microcontroller to analog inputs and outputs,
- Be able to use a graphics display touch-screen for I/O,
- Be able to send/receive data to your cell phone using Bluetooth,
- Be able to access a WiFi network using a microcontroller, and
- Be able to do all of this using Python

Bison Academy

- www.BisonAcademy.com
- Where to access lecture notes, homework sets, etc. for ECE 476

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 476: Advanced Embedded Systems

Syllabus: Fall 2024

Syllabus - HW & Solutions - Resources - Comments

	Date	Topic	Recorded Lecture *YouTube PlayList*	Code *Used in lecture*	Homework
M	Aug 26	Holiday			HW #1
W	Aug 28	1Introduction & Syllabus Slides #1	Video #1		
F	Aug 30	2 Thonny & MicroPython Slides #2	Video #2		
M	Sep 2	Holiday			HW #2
W	Sep 4	3 Loops & if-Statements Slides #3	Video #3	03 Timer2 Interrupts 03 For Loops 03 While Loops 03 d4 + d6	
F	Sep 6	4 Subroutines Slides #4	Video #4	04 Resistors 04 Convolution with Dice 04 Convolution with Polynomials	

Bison Academy: Homework and Solutions

Homework Assignments & Solutions from previous semesters

- Once the course runs for more than one semester

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)

ECE 476 Advanced Embedded Systems

Homework and Solutions

Syllabus - HW & Solutions - Resources - Comments

Fa25	Sp25	Fall 2024
1: Python Solution #1 (pdf) Solution #1 (YouTube)	1: Python Solution #1 (pdf) Solution #1 (YouTube)	1: Python Solution #1 (pdf) Solution #1 (YouTube)
2: Loops & Subroutines Solution #2 (pdf) Solution #2 (YouTube)	2: Loops & Subroutines Solution #2 (pdf) Solution #2 (YouTube)	2: Loops & Subroutines Solution #2 (pdf) Solution #2 (YouTube)
3: Binary I/O Solution #3 (pdf) Solution #3 (YouTube)	3: Binary I/O Solution #3 (pdf) Solution #3 (YouTube)	3: Binary I/O Solution #3 (pdf) Solution #3 (YouTube)

Bison Academy: Best of 476

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 476" (with student permission)
- Good recruiting tool for ECE
- Good way to demonstrate your skills to future employers

Lunar Lander Game
Spring 2024
Showing off the graphic
your lunar module on th
ECE 476.

Where's My Cat?
Summer 2024
Use a GPS sensor to det
your car or cat. Part of l

GPS Speedometer
Summer 2024
Measure the speed of yo
200 pixel numbers. Par

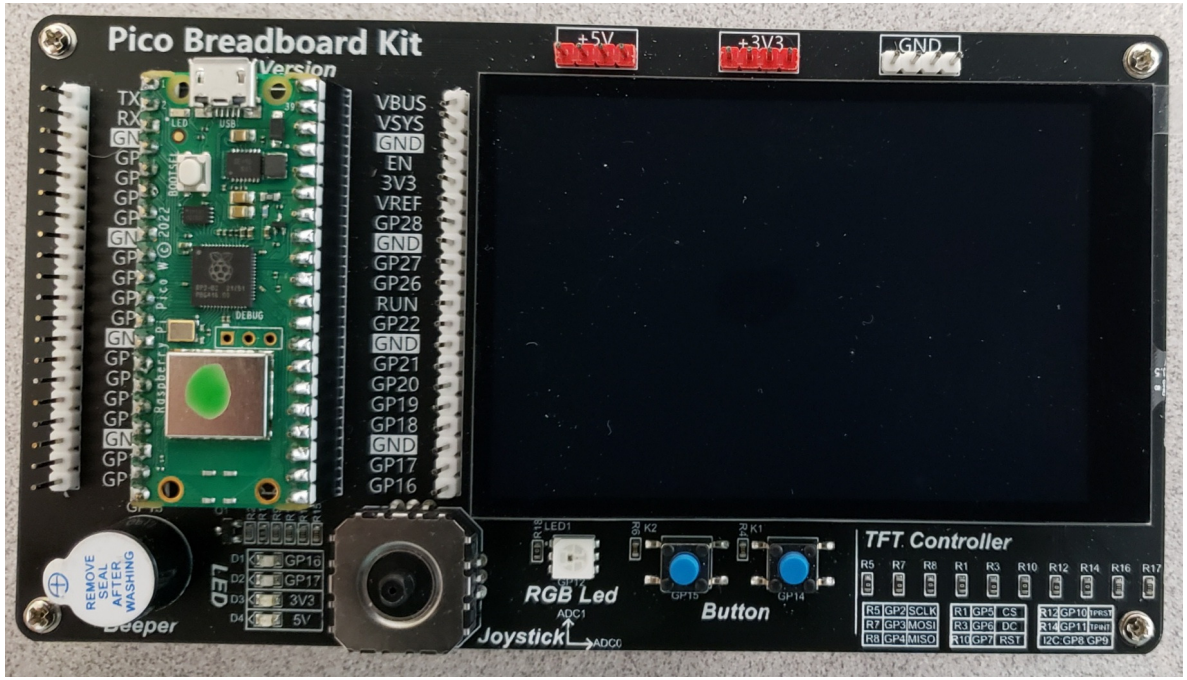
How Fast Can I Run?
Fall 2024
Use a GPS module to re
three recorded speeds

Lab Kits

- GeeekPi Pico Breadboard Kit Plus Version
- Motors, sensors, lights, etc.
- $65 (cash of check - pick up in my office)

Makes the class a lot more fun

- And understandable



Hy-Flex Model for ECE 476

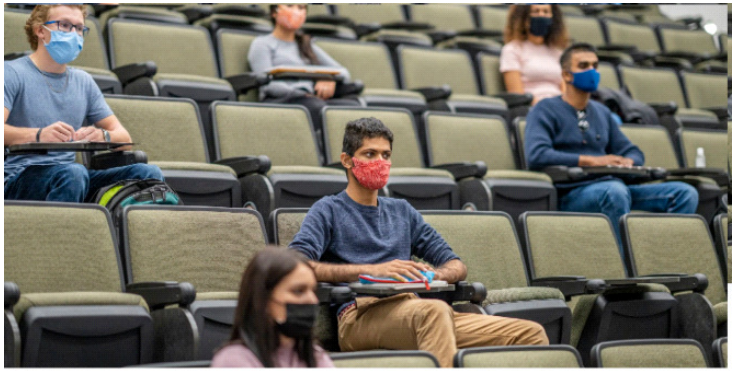
Students are welcome to take this course however they like:

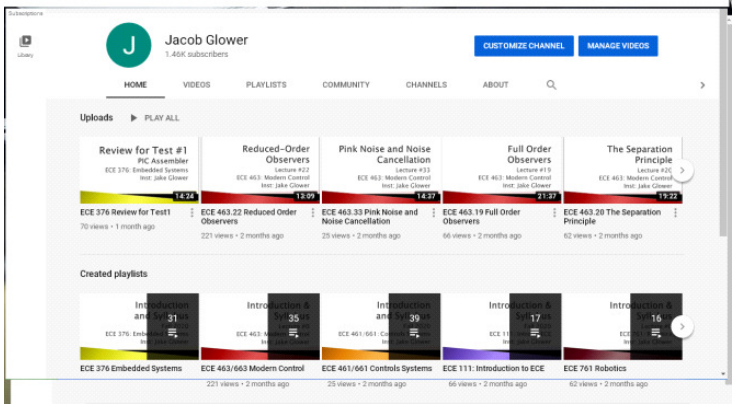
- In-Person:
- Live-Stream: on Zoom
- On-Line: YouTube recordings of lectures

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.





Evaluation Procedures and Grading Criteria

Grades will be the average of the following:

Midterms (x3)	Homework	Final Exam
75%	25%	none

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.

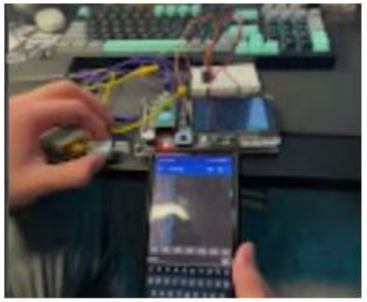
Homework & Lab Projects

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



Bluetooth Motor Speed Control

Fall 2024

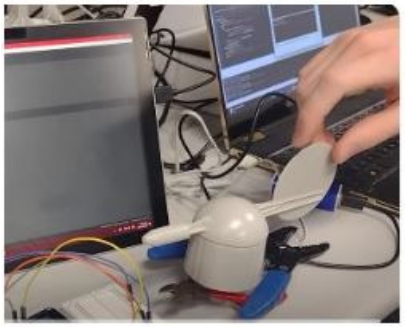
Using a cell phone, control the spe

Weather Station Web Page

Fall 2024

Set up a WiFi link with a Pi-Pico. D

BME280 sensor.



Wind Direction & Display

Fall 2024

Interface a wind-direction sensor t

Open-Ended Assignments

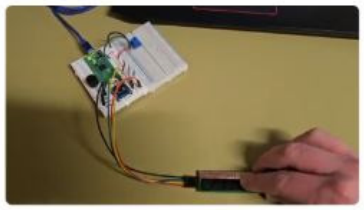
Most homework sets are open-ended:

- 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:

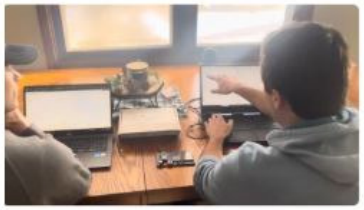
- Requirements What your device does
- Hardware & Software: Schematics & Code
- Test & Validation: Data to verify your design works (voltages, frequencies...)
- Demonstration: In-person or YouTube

This allows you to tailor your homework to your own interests



MIDI Keypad
Fall 204
Build a circuit for a piano

Sunrise Alarm Clock
Fall 2024
Drive a strip of NeoPixel L



Quiz Game Controller
Fall 2024
Use a Pi-Pico to run a gam

Pulse Sensor & Display
Summer 2024
Measure your pulse and di
476

Use of AI & ChatGPT

- AI exists. ChatGPT exists.

Both can be useful

- Learn new commands
- Learn new programming tricks

Please do *not* turn in code written by either.

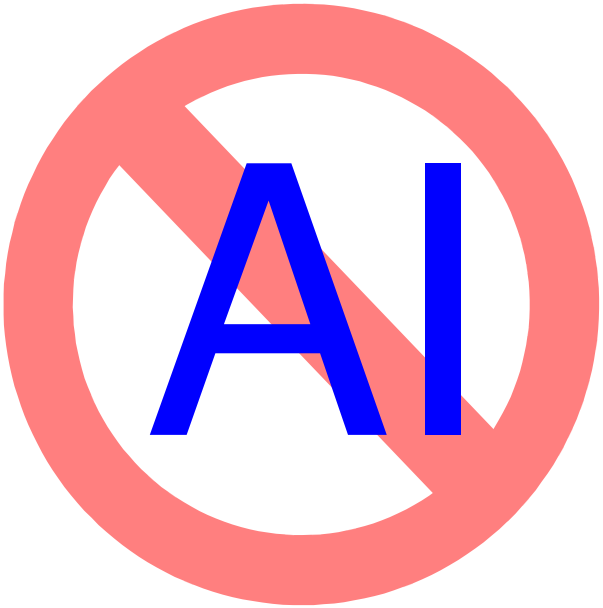
- AI and ChatGPT don't think
- They just copy code they find on the web

That doesn't work in this course.

- ChatGPT mashes up code from different processors
- ChatGPT doesn't know the EVB used in this class

ChatGPT code is usually partly correct, partly nonsense

- If you turn in a solution that's nonsense, I'll grade accordingly.
- It also won't work



Homework Demonstrations

Most homework includes a demosntration

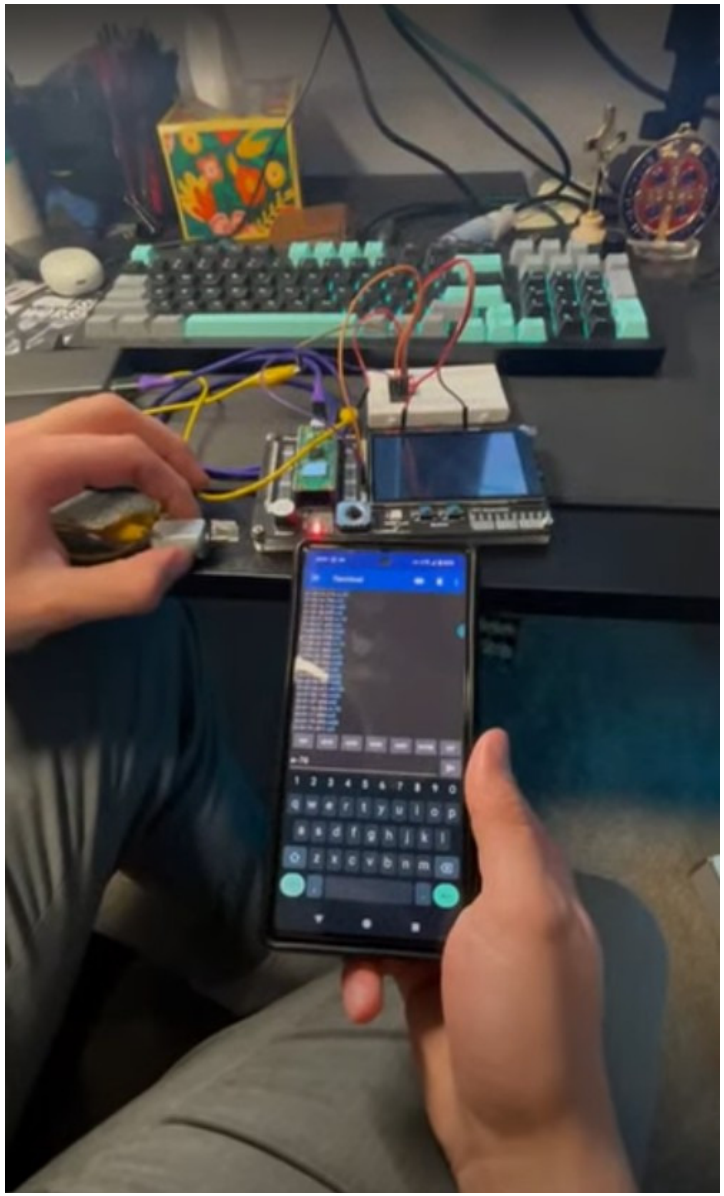
- In-person demonstration
- Demonstrate over Zoom
- Take a short video
  - Post the video on BlackBoard
  - Post the video on YouTube and include a link

Partly, this is anti-AI

- In order to get your code and hardware to work, you kind of have to understand how it works.

Partly, this makes the course more fun

- You go into engineering to build things.
- This course lets you do that.
- It also makes grading a lot more fun



Legal Stuff:

Attendance: According to NDSU Policy 333, attendance in classes is expected. How you attend is up to you (in-person, live-stream, online). 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.