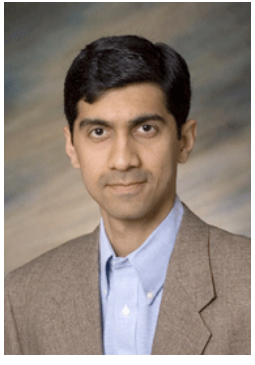
Spring 2022
ECE568: Embedded Systems
Lecture #1: Course Logistics

Vijay Raghunathan
School of ECE, Purdue University
vr@purdue.edu

Course Basics and Staff

- Class Location and Time: WANG 2579, Tue. and Thu. (1:30pm - 2:45pm)



- Instructor: Prof. Vijay Raghunathan
  - Email: vr@purdue.edu
  - Webpage: https://engineering.purdue.edu/~vr
  - Office location: MSEE 224
  - Office hours: By appointment, for now
- Research Interests: Hardware and software architectures for embedded systems, Internet-of-Things (IoT), and system-on-chip design, with an emphasis on low power design, micro-scale energy harvesting, and reliable system design
- Teaching Assistant(s): To be announced

Embedded System (from Wikipedia)

- (What?) An embedded system is a computer system that
  - is designed to do one or a few dedicated/specific things
  - often has real-time computing constraints
  - is embedded as part of a complete device often including mechanical parts (car, airplanes, satellites, etc.) not electronic in nature
  - interacts with external physical world (eyes and ears to the physical world; sensors sense signals and manipulate/inference data, translate back to physical world)

Performance Time becomes an important characteristics for embedded system (i.e, response time : car brakes)

- By contrast, general-purpose computers are designed to be flexible and to meet a wide range of end-user needs
  - As we will see, the distinction is not always sharp; really a continuum

- (Why?) Embedded systems are all around us, particularly as previously dumb engineered systems are made "intelligent" or "smart" via adoption of information technology driven control
  - appliances, cars, traffic systems, factories, aircrafts, electrical grid, buildings (most of these are not single systems, but contain multiple systems.)

- (Challenge?) As we will soon see, embedded systems have unique and tight constraints on both hardware and software
  - Real-time, power/energy constraints, cost, extreme conditions, poor user interfaces

Main Course Goals

- To learn about the fundamental technology enablers and trends that have led to the proliferation of embedded systems and the rise of the Internet of Things
  How did we get to this point in the rise of Embedded Systems?
- To review how embedded platforms are designed, how their hardware components work and interface to each other
- To learn about various software architectures used in embedded systems and when each of these should be considered for use (How does software differ from general-purpose computing systems?)
- To learn advanced design techniques for optimizing performance, power consumption, reliability, and security in embedded systems (ability to design it well given sets of constraints)
- To gain hands-on knowledge and experience with programming and debugging embedded platforms
  (build simple embedded systems; mostly focus on embedded software, but also on hardware)
- To design and implement distributed applications for networked embedded systems
  (LITERALLY EVERYTHING IS NETWORK THESE DAYS (i.e., WiFi))
- To gain experience in reading embedded systems technical literature such as component data-sheets and product manuals

Prerequisites and Expectations

- **Prerequisites:** Background Knowledge and Skills
  - Good programming skills and exposure to the inner workings of a microcontroller
  - Would help, but not necessary: Some knowledge of computer networks

  For Labs, we will use microPython! Have some exposure to inner workings of a microcontroller (interrupt, digital gates, bus, instruction pipeline)
- **Expectations:** Initiative and Independence
  - Not a spoon-fed course! You are graduate students and expected to be independent and show initiative
  - Very hands on course and topic; you will learn by doing
  - Willingness to work hard and address (often open-ended) problems that require thinking, web research, use of debugging tools, hands-on design, and experimentation
  - Particularly important because of high enrollment and limited TA support
  - High ethical standards: Plagiarism and copying will have a zero-tolerance policy

- Many of you will directly use the material learned here in your jobs. Please focus on learning and understanding the material well

Accessing Course Materials

- Course webpage
  - Brightspace: https://purdue.brightspace.com/d2l/login
  - All course material will be posted on the webpage (lecture slides, reading material, labs, homework, additional resources, etc.)
  - The material is for your use only and not to be shared with anyone outside the course. By accessing the material, you agree that you will not distribute or share the material with anyone outside this class, either now or in the future. Do not upload or post the material anywhere else.
- All submissions (homework, code, project report, *etc.*) will be handled through Brightspace
- Piazza (http://piazza.com) for class discussions

Grading Components

- Lab Assignments and Project (50%)
  - Three to five lab assignments using off-the-shelf embedded development kits
- Paper Summaries and Review Article (25%)
  - Write short reviews/critiques of selected papers and an overview of a specific topic
- Exam (25%)
  - One late midterm exam, held in April (date TBA). No final exam!
- Bonus credit (Δ%)
  - Labs, etc.

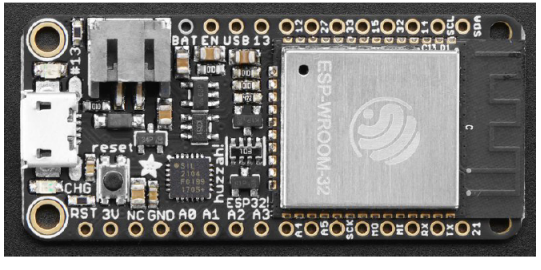
- I reserve the right to make minor changes to this policy
  - For example, depending on how fast we move through the material
  - Depending on how the pandemic situation evolves

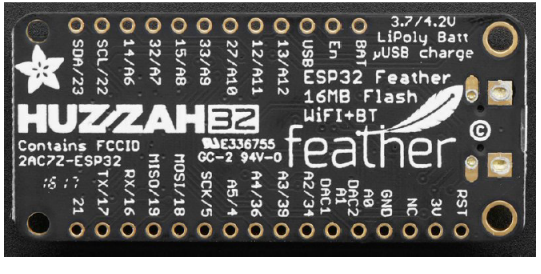
Lab Assignments

Company: Ada Fruit

- To gain hands-on embedded systems experience, you will write software using a state-of-the-art embedded platform
- The assignments will require a significant amount of time investment to understand the embedded platform
- The labs are based on the **ESP32 Feather board** and Micropython (smaller version of Python programming language).

Powerful microcontroller





MCU	**Dual Core Tensilica LX6 microcontroller**
802.11 b/g/n Wi-Fi	**HT40**
Bluetooth	**Classic and BLE 4.2**
Typical Frequency	**240 MHz**
SRAM	**520 KB**
Flash	**4 MB**
GPIO	**28**
Software PWM	**Available on all GPIO pins**
SPI/I2C/UART	**3/2/2**
ADC	**12 channels**
DAC	**2 channels**
Touch Sensor	**10 capacitive interface**
Hall effect sensor	**Present**

Possible switch to a new platform

Cost of either board is ~$20-23, good availability on DigiKey

Paper Reading

- I will regularly assign research papers for required reading
- Write a 1 page review of the paper using a provided template
- Pay attention to spelling, grammar, and writing style
- Your review must cover many of the following aspects:
  - Summarize the main contributions of each paper
  - Identify the key ideas behind the contributions
  - Point out any weaknesses that you can think of
  - Propose ways to improve/extend/build on the work
  - Compare/contrast (if appropriate) the papers with any other approaches that you are aware of for solving the same problem

Textbooks

- I will not follow any specific textbook because there is no single textbook that satisfactorily covers all the topics in this course

- A few recent books are given below (only for your reference):
  - *Introduction to Embedded Systems - A Cyber-Physical Systems Approach*, Lee and Seshia, http://LeeSeshia.org, 2010 (free PDF of the book is available at their website)
  - *An Embedded Software Primer*, David E. Simon, Addison-Wesley Professional, 1999
  - *Embedded System Design*, Peter Marwedel, Springer, 2011
  - *Embedded Systems Building Blocks: Complete And Ready To Use Modules In C*, Jean Labrosse, 1999
  - *uC/OS-III, The Real-Time Kernel*, Jean Labrosse, 2009
  - *Programming Embedded Systems: With C and GNU Development Tools*, Michael Barr and Anthony Massa, 2006
  - …
  - many others (search Amazon for "embedded systems")

Additional Reading Material

- Will hand out a set of papers as reading material for each topic
  - Mostly easy to read general articles and overview papers, often providing a complementary perspective on the material presented in class
  - Will provide either a link to the paper or the PDF itself on the webpage
  -

Web Resources

- Embedded.com: http://www.embedded.com/
  - Embedded Systems Programming magazine

- EE Times Magazine: http://www.eetimes.com/
- Linux Gizmos: http://www.linuxgizmos.com
- Circuit Cellar: http://www.circuitcellar.com/
- The Ganssle Group: http://www.ganssle.com/
- Wikipedia!

Conferences and Journals

- Conferences and Workshops related to embedded systems
  - Embedded Systems Week (http://www.esweek.org),
  - Cyber-Physical Systems Week (http://www.cpsweek.org),
  - ACM SenSys, ACM Mobisys, ACM Ubicomp, ACM/IEEE DAC, IEEE RTSS

- Journals and Magazines covering research on embedded systems
  - ACM Transactions on Embedded Computing Systems
  - IEEE Embedded Systems Letters
  - ACM Transactions on Sensor Networks
  - ACM Transactions on Design Automation of Electronic Systems
  - IEEE Transactions on VLSI Design
  - IEEE Design and Test of Computers
  - Many others…

Makeup and Substitute Classes

- I will miss a couple of classes due to unavoidable meeting conflicts
  - Will provide makeup videos if that is the case

- Spring is the time when a lot of interesting seminars happen on campus (and remotely). We might also substitute a couple of classes with (virtual) attendance at ECE or CS seminars that are related to embedded systems

Reading List for Lecture #2

- Next class (Lecture 2): Introduction to embedded systems, examples, key design issues, hardware-software design flow, technology enablers

- Reading List
  - Wikipedia articles on Embedded Systems, Internet of Things, and Cyber Physical Systems
    - http://en.wikipedia.org/wiki/Embedded_system
    - https://en.wikipedia.org/wiki/Internet_of_Things
    - http://en.wikipedia.org/wiki/Cyber-physical_system
  - David Blaza, "Shifting Sands: Trends in Embedded Systems Design," available at http://www.embedded.com/design/embedded/4372666/Shifting-sands–Trends-in-embedded-systems-design

HW1: Due by 11:59pm on Jan. 16

- Goal: To test drive the Brightspace submission system
- Create a PDF document named hw1_*yourlogin**.pdf which has:
  - Your photograph and name
  - What is your interest in taking this course? Is there something specific you would like to get out of the course
  - One fun fact about you (hobby, passion, accomplishment, funny incident, …)
  - Think of one real-world scenario or problem that you think a connected embedded system can help solve. Don't worry about how to build the system, just describe what you think the system should/will do and how it would help solve the problem. A good start would be to think of simple situations in your everyday life where you have often thought that technology might help or improve convenience (i.e., where you have thought… "wouldn't it be cool to have a little gadget that does this?")
  - [*Since my login is "vr", my filename would be "hw1_vr.pdf"]