CSE 474 – Introduction to Embedded Systems

- Instructor:
  - Bruce Hemingway
    - CSE 464, Office Hours: 11:00-12:00 p.m., Tuesday, Thursday
    - or whenever the door is open
    - bruceh@cs.washington.edu
  - Teaching Assistants:
  - Cody Ohlsen, Kendall Lowrey and Ying-Chao (Tony) Tung

CSE 474 – Software for Embedded Systems

- Class Meeting Times and Location:
  - Lectures: EEB 037, TTh 2:30-4:20
  - Labs: EEB 345,   24/7 access
- Exams
  - Midterm: Tuesday, Feb. 7, EEB 037, 2:30-4:20
  - Final: Tuesday, March 14, 2017, 430-620 pm, EEB 037

CSE 474 – Software for Embedded Systems

- Grading Policy
  - There will be two exams, as shown on the class schedule.
  - Lab reports: Demo usually required, sometimes questions

- Ratios:
  - Lab: 40%
  - Exams total: 40%
  - Class Participation: 20%

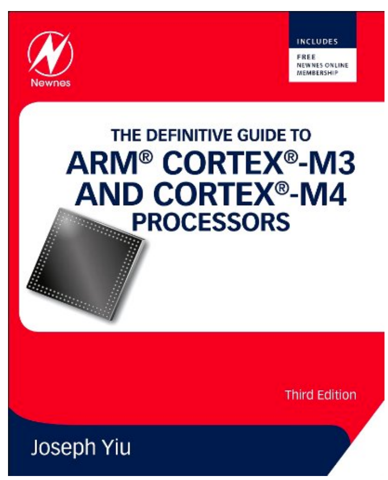
Recommended Textbook (not required):

The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors, Third Edition

By Joseph Yiu

Newnes; 3 edition (November 1, 2013)

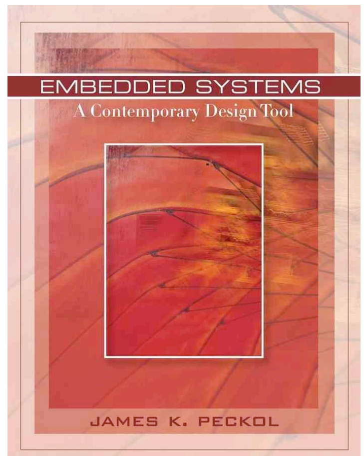
U Bookstore doesn't have it.



Other Textbook (not required):

- **Embedded Systems: A Contemporary Design Tool Paperback – 2009**
- by James K Peckol

U Bookstore has used hardback.



Embedded systems

Embedded systems

What are Embedded Systems?

- Anything that uses a microprocessor but isn't a general-purpose computer

– Smartphones
– Set-top boxes
– Televisions
– Video Games
– Refrigerators
– Cars
– Planes
– Elevators
– Remote Controls
– Alarm Systems

• The user “sees” a smart (special-purpose) system as opposed to the computer inside the system
  • “how does it do that?”
  • “it has a computer inside it!”
  • “oh! BTW, it does not or cannot run Windows or MacOS!”

– the end-user typically does not or cannot modify or upgrade the internals

What Are You Going to Learn?

- **Hardware**
  - I/O, memory, busses, devices, control logic, interfacing hardware to software
- **Software**
  - Lots of C and assembly, device drivers, low level real-time issues, scheduling,
  - Concurrency: interrupts
- **Software/Hardware interactions**
  - Where is the best place to put functionality hardware or software?
  - What are the costs:
    - performance,
    - memory requirements (RAM and/or FLASH ROM)
- **Integration of hardware and software courses**
  - Programming, logic design, architecture,
  - Algorithms, mathematics and *common sense*

Where Could *You* End Up?

- Automotive systems
  - perhaps designing and developing "drive-by-wire" systems
  - -- self-driving vehicles
- Telecommunications
- Consumer electronics
  - cellular phones, MP3 devices, integrated cellular/tablet/kitchen sink
  - Set-top boxes and HDTV
  - Home appliances
  - Internet appliances
    - your washer will be on the internet more than you are!
- Defense and weapon systems
- Process control
  - gasoline processing, chemical refinement
- Automated manufacturing
  - Supervisory Control and Data Acquisition (SCADA)
- Space applications
  - Satellite communications

Goals of the Course

- **High-Level Goals**

1. Understand the scientific principles and concepts behind embedded systems, and
2. Obtain hands-on experience in programming embedded systems.

By the end of the course, you should be able to

• Understand the "big ideas" in embedded systems

• Obtain direct hands-on experience on both hardware and software elements commonly used in embedded system design.

• Understand the basics of embedded system application concepts such as signal processing and feedback control

• Understand, and be able to discuss and communicate intelligently about

– embedded processor architecture and programming

– I/O and device driver interfaces to embedded processors with networks, multimedia cards and disk drives

– OS primitives for concurrency, timeouts, scheduling, communication and synchronization

The Big Ideas

•HW/SW Boundary

• Non processor centric view of architecture

• Bowels of the operating software

– specifically, basic real-time operation with interrupts

– Concurrency

• Real-world design

– performance vs. cost tradeoffs

• Analyzability

– how do you “know” that your drive-by-wire system will function correctly?

• Application-level techniques

– signal processing, control theory

– semaphores, locks, atomic sections

What is an Embedded System?

- Computer purchased as part of some *other* piece of equipment
  - Typically dedicated software (may be user customizable)
  - Often replaces previously electromechanical components
  - Often no “real” keyboard
  - Often limited display or no general purpose display device
- But, every system is unique there are always exceptions

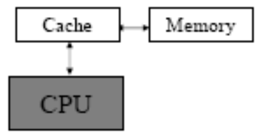
CPU: An All-Too-Common View of Computing

- Measured by:
  - Performance

CPU

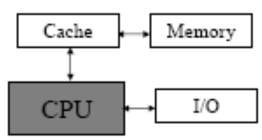
An Advanced Computer Engineer's View

- Measured by: Performance
    - Compilers matter too...



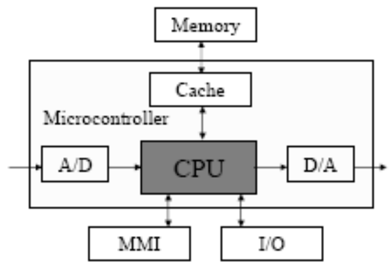
An Enlightened Computer Engineer's View

- Measured by: Performance, Cost
  Compilers & OS matters



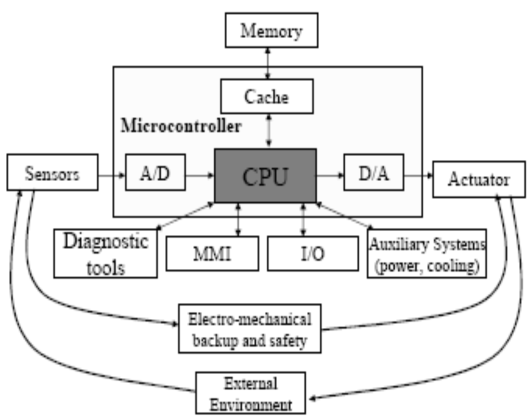
An Embedded Computer Designer's View

- Measured by: Cost, I/O connections, Memory Size, Performance



An Embedded Control System Designer's View

- Measured by:
  Cost, Time to market, Cost, Functionality, Cost & Cost.



A Customer View

– Reduced Cost
– Increased Functionality
– Improved Performance
– Increased Overall Dependability

Why Are Embedded Systems Different?

Four General Categories of Embedded Systems

- General Computing
  - Applications *similar* to desktop computing, but in an embedded package
  - Video games, settop boxes, wearable computers, automatic tellers
  - Tablets, Phablets
- Control Systems
  - Closed loop feedback control of real time system
  - Vehicle engines, chemical processes, nuclear power, flight control
- Signal Processing
  - Computations involving large data streams
  - Radar, Sonar, video compression
- Communication & Networking
  - Switching and information transmission
  - Telephone system, Internet
  - Wireless everything

Typical Embedded System Constraints

- Small Size, Low Weight
  - Handheld electronics
  - Transportation applications weight costs money
- Low Power
  - Battery power for 8+ hours (laptops often last only 2 hours)
  - Limited cooling may limit power even if AC power available
- Harsh environment
  - Heat, vibration, shock
  - Power fluctuations, RF interference, lightning
  - Water, corrosion, physical abuse

- Safety critical operation
  - Must function correctly
  - Must not function incorrectly
- Extreme cost sensitivity
  - $.05 adds up over 1,000,000 units

Embedded System Design World-View

A complex set of tradeoffs:

- Optimize for ***more than just speed***
- Consider ***more than just the computer***
- Take into account ***more than just initial product design***

Multi-Discipline		**MultiPhase**		**MultiObjective**
• Electronic Hardware • Software • Mechanical Hardware • Control Algorithms • Humans • Society/Institutions	**X**	• Requirements • Design • Manufacturing • Deployment • Logistics • Retirement	**X**	• Dependability • Affordability • Safety • Security • Scalability • Timeliness

Embedded System Designer Skill Set

- Appreciation for multidisciplinary nature of design
  - Both hardware & software skills
  - Understanding of engineering beyond digital logic
  - Ability to take a project from specification through production
- Communication & teamwork skills
  - Work with other disciplines, manufacturing, marketing
  - Work with customers to understand the real problem being solved
  - Make a good presentation; even better write ``trade rag" articles
- And, by the way, technical skills too...
  - Low-level: Microcontrollers, FPGA/ASIC, assembly language, A/D, D/A
  - High-level: Object oriented Design, C/C++, Real Time Operating Systems
  - Meta-level: Creative solutions to highly constrained problems
  - Likely in the future: **U**nified **M**odeling **L**anguage, embedded networks

Class logistics – see course web

- https://courses.cs.washington.edu/courses/cse474/17wi/
- Class structure
- Business matters
- Grading
- Syllabus
- What we'll be doing

Class structure

- Lecture
  - Closely linked to laboratory assignments
  - Cover main concepts, introduce laboratory problems
- Lab
  - Work leading to implementation of a final project
  - Lab reports due by end of week
- Exams
  - Two, based on lecture, lab, and datasheet reading
  - **Open datasheets, open notes**
- Final demo
  - During last class time – participation required

Business Matters

- Lecture notes will be on line after class (links on Calendar page)
- You pick lab partner assignments, or we will
- Sign up for CSE474 mailing list

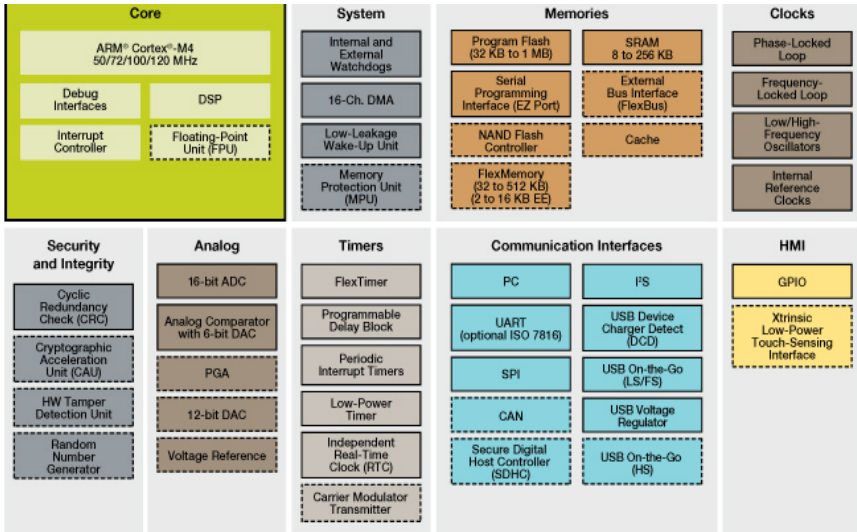
Grading

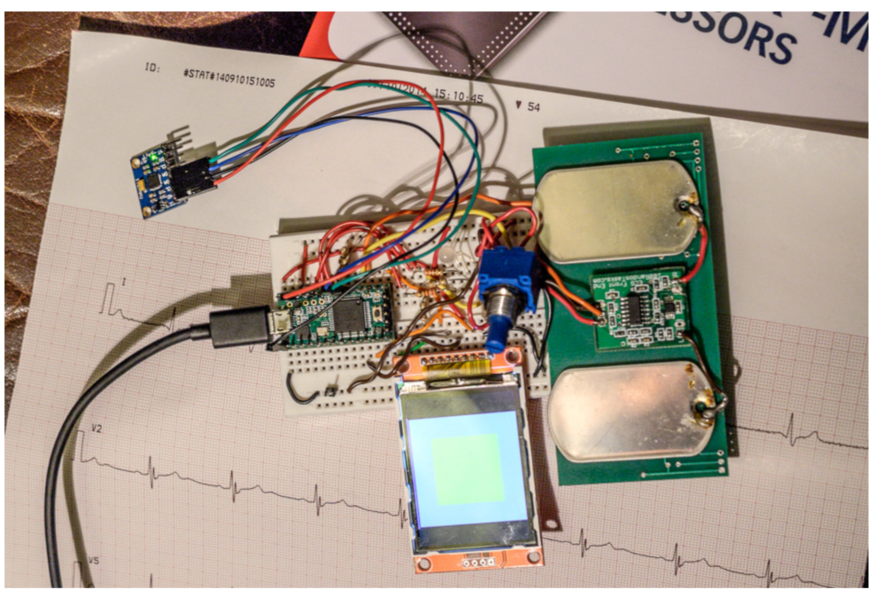
- Lab reports:
  - Demonstration(s) required
  - Brief answers to questions embedded in assignment
  - Sometimes hand-in code
  - Do with your partner
  - Both build hardware
- Distribution:
  - Labs: 40%
  - Exams: 40%
  - Class Participation: 20%

CSE466 Lab Content

- Arm Cortex M4 processor
  - Begin with basics and build
  - Do with your lab partner
  - You can work off-site
- Resources
  - Freescale Arm Processor
  - 320x240 Color LCD display
  - Switch, potentiometer
  - Accelerometer with gyroscope
  - Tri-color LED, NeoPixels, Bluetooth BLE
  - Learn how to interface various devices
- Final project
  - Heart-rate monitor– a mini ECG
  - LCD display of heart trace
  - Measure heart rate, basic arhythmia detection

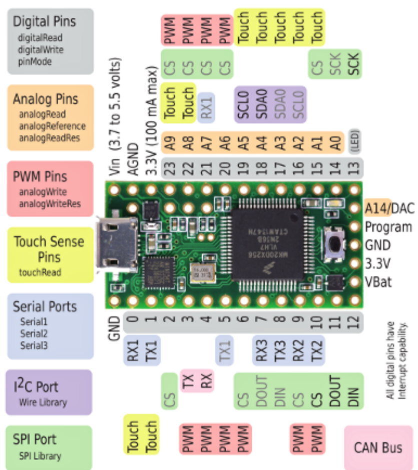
Freescale MK20DX256VLH7 processor





CSE466 Labs

- Final Project – Using the Teensy 3.1
- Build a Heart Rate Monitor



Assignment for Thursday:

- Review the K20 Sub-Family Reference Manual

MK20DX256 Manual (8.0M PDF), for Teensy 3.1 (This manual has all the useful programing info)

  - *Chapter 2: Introduction and Functional Modules*

Download here:

https://courses.cs.washington.edu/courses/cse474/17wi/pdfs/K20P64M72SF1RM.pdf

(link is on the Resources page...)