CSE 466 – Software for Embedded Systems

- Instructor:
  - Joshua Smith
    - CSE 556, Office Hours: 11:20-12:30 p.m. Monday, or by appt
    - jrs@cs.washington.edu
  - Teaching Assistant:
    - Aaron Parks
    - anparks@uw.edu

CSE 466 – Software for Embedded Systems

- Class Meeting Times and Location:
  - Lectures: EEB 023, MWF 10:30-11:20
  - Lab: CSE 003, Tuesday 2:30-5:20
- Exams
  - Midterm: TBD
  - Final: TBD

CSE 466 – Software for Embedded Systems

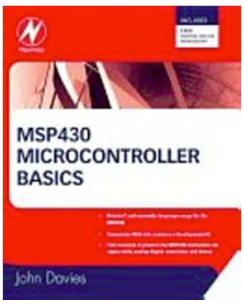
- Grading Policy
  - There will be two exams…dates will be on calendar
  - Lab reports: Demo usually required, sometimes questions
- Ratios:
  - Lab: 50%
  - Exams total: 20%
  - Homework: 10%
  - Class Participation: 20%

Textbook

MSP430 Microcontroller Basics

By John H. Davies

Newnes (2008) - Paperback - 668 pages - ISBN 0750682760



U Bookstore has it.

Also available from Amazon.

Class logistics – see course web

- http://www.cs.washington.edu/education/courses/cse466/11au/
  - Key information will be on course calendar
    - http://www.cs.washington.edu/education/courses/cse466/11au/calendar/calendar.html
- 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
  - 8 one week labs
  - Lab reports due prior to start of next lab section
- Project
  - 3 weeks
- HW
  - Occasional, as-needed
- Exams
  - Two, based on lecture, lab, and datasheet reading
  - Open datasheets, open notes
- Final demo
  - To be scheduled– participation required

Business Matters

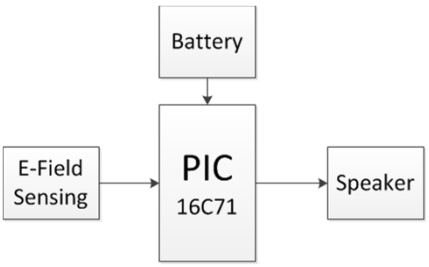
- Lecture slides will be on line after class (linked from calendar)
- You should already be on CSE466 mailing list, if you're registered…email me if you have not received any mail on the class mailing list

What is an embedded system?

- Let's proceed inductively…
  - with a bunch of (fun) examples

"Phone thing"

cf. iPhone that disables display when near your head!

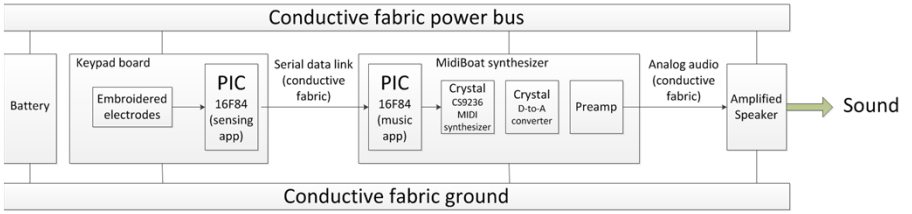


In this project, much of the sensing HW functionality was shifted to SW running on the microcontroller…"software radio sensing"

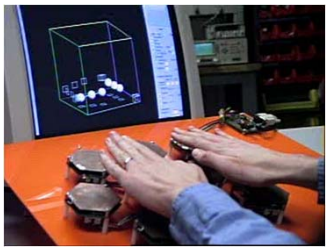
MIT Media Lab 1998

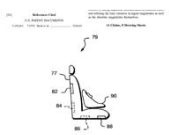
Musical jacket

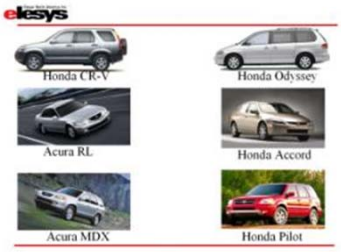
MIT Media Lab 1998
Maggie Orth, Rehmi Post,
Josh Strickon, Emily Cooper

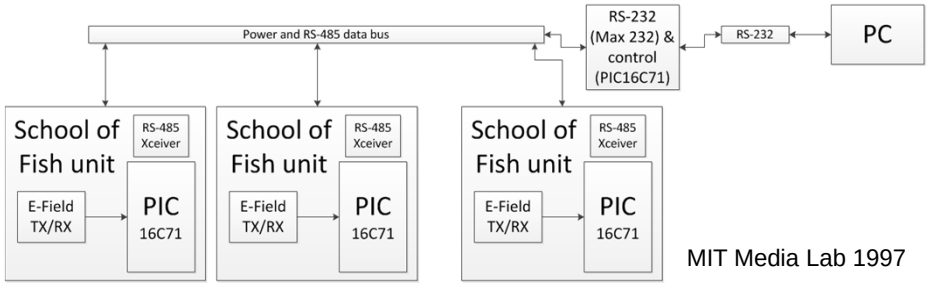


School of Fish



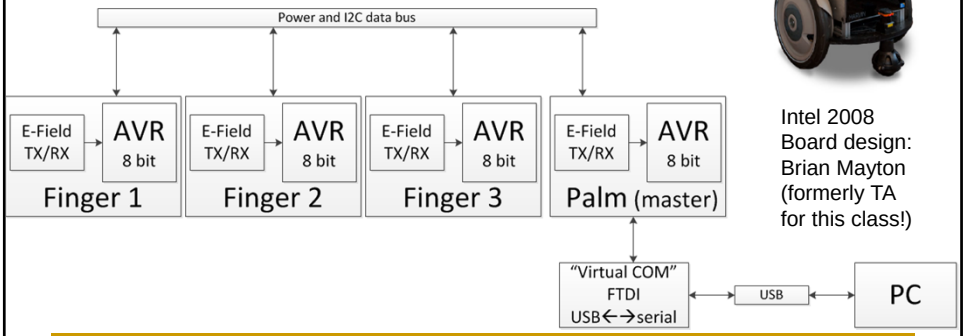






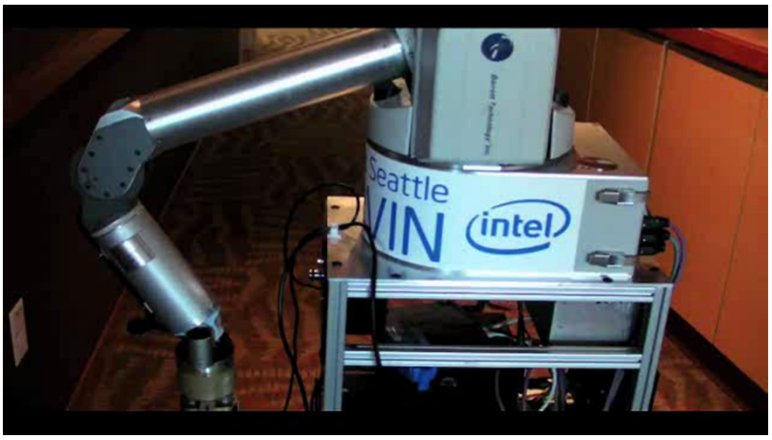
MIT Media Lab 1997

EF Sensing Robot Hand



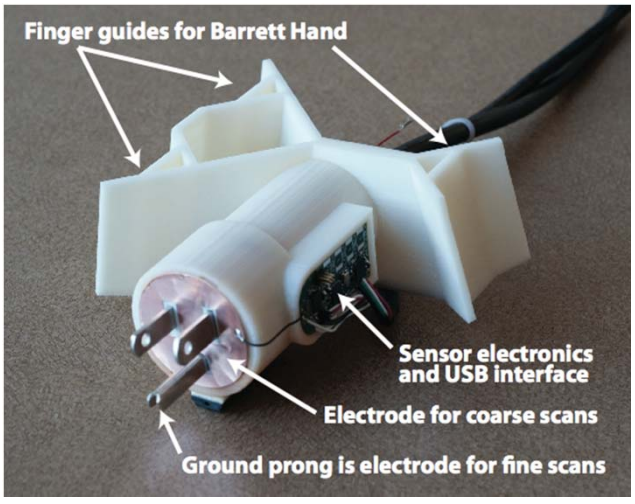
Intel 2008 Board design: Brian Mayton (formerly TA for this class!)

Marvin finds its food by "smell"!



Robot, Feed Thyself: Plugging In to Unmodified Electrical Outlets by Sensing Emitted AC Electric Fields, ICRA-2010.
B. Mayton, L. LeGrand, J.R. Smith

The E-Field-Sensing Plug



James Youngquist (taking this class!) did a rev 2 of this!

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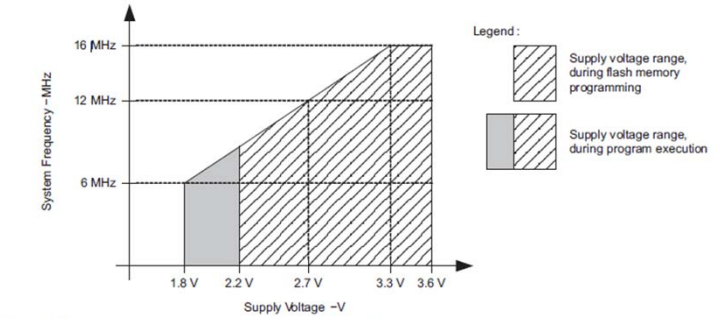
MSP430 Voltage-Frequency scaling

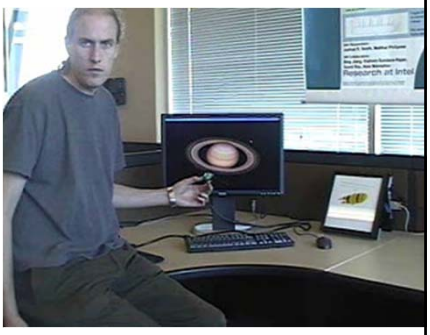


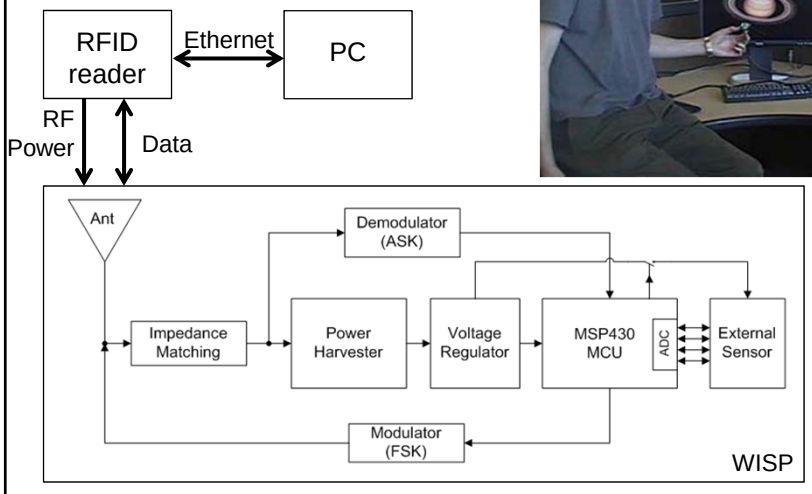
Note: Minimum processor frequency is defined by system clock. Flash program or erase operations require a minimum V_{CC} of 2.2 V.

Figure 1. Safe Operating Area

WISP:

Wireless Identification and Sensing Platform





Digital logic of RFID tag shifted to SW… another SW defined radio. For low power operation, micro sleeps most of the time. More power ➔ more updates / s

Board design: Alanson Sample, Dan Yeager

Embedded SW: Polly Powledge

Solar WISP

Figure 9. Passive solar antenna-based data logger on a parcel.

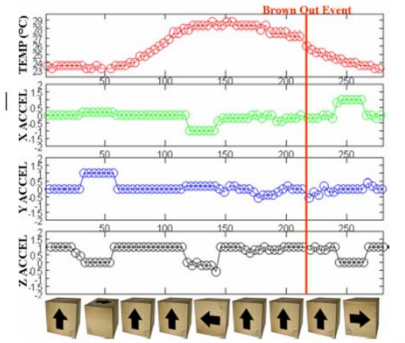


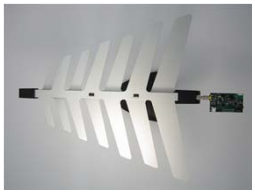
Figure 11. Temperature and orientation data recorded by the solar-enhanced RFID platform during a simulated parcel shipment.

Micro logs data, uploads it once it reaches a reader

Photovoltaic Enhanced UHF RFID Tag Antennas for Dual Purpose Energy Harvesting
Alanson Sample, Jeffrey Braun, Aaron Parks, Joshua R. Smith
IEEE RFID 2011

HW: Jeff Braun & Alanson Sample
SW: Aaron Parks (our TA!)

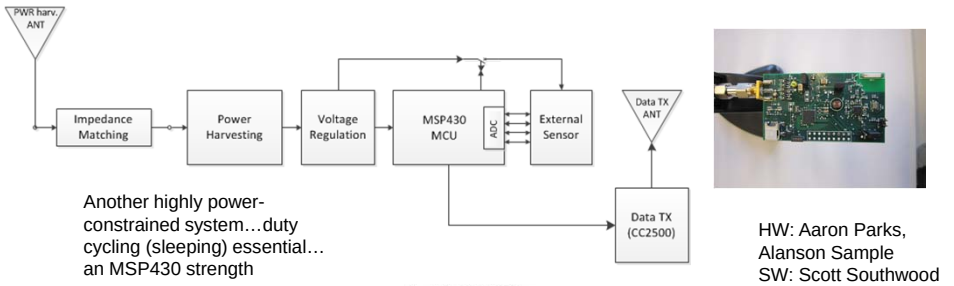
WARP: Wireless Ambient Radio Power



- KING-TV
- Channel 48: 674MHz – 680MHz
- 960kW
- 4.1km
- 5dBi log periodic antenna
- Front end 30MHz BW
- Open circuit: 5V
- 8kOhm load➔ 0.7V ➔ 60uW
- Friis formula predicts 280uW

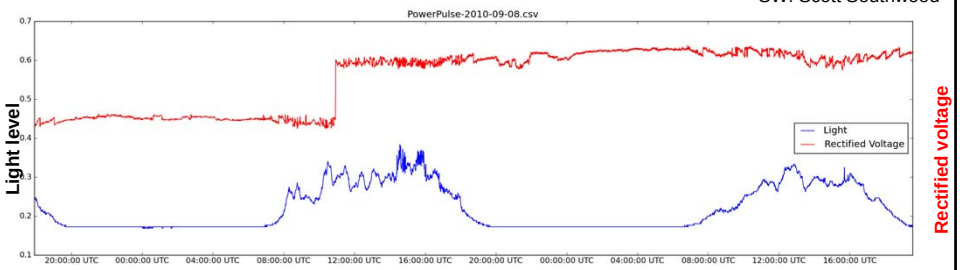
Experimental results with two wireless power transfer systems
A.P. Sample and J.R. Smith
Proceedings RAWCON 2009

WARP Wireless Weather Station Data



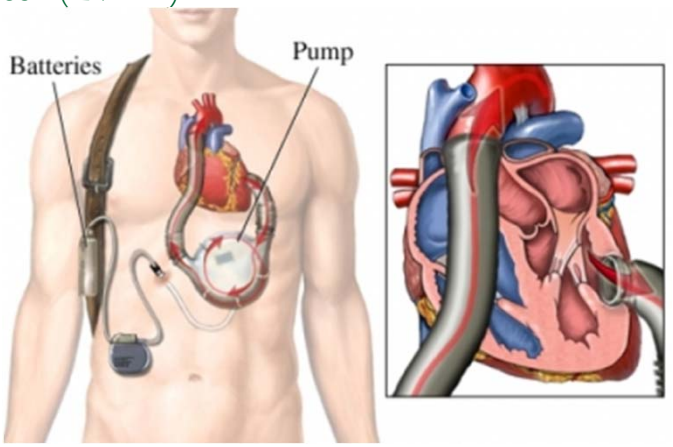
Another highly power-constrained system…duty cycling (sleeping) essential… an MSP430 strength

HW: Aaron Parks, Alanson Sample
SW: Scott Southwood

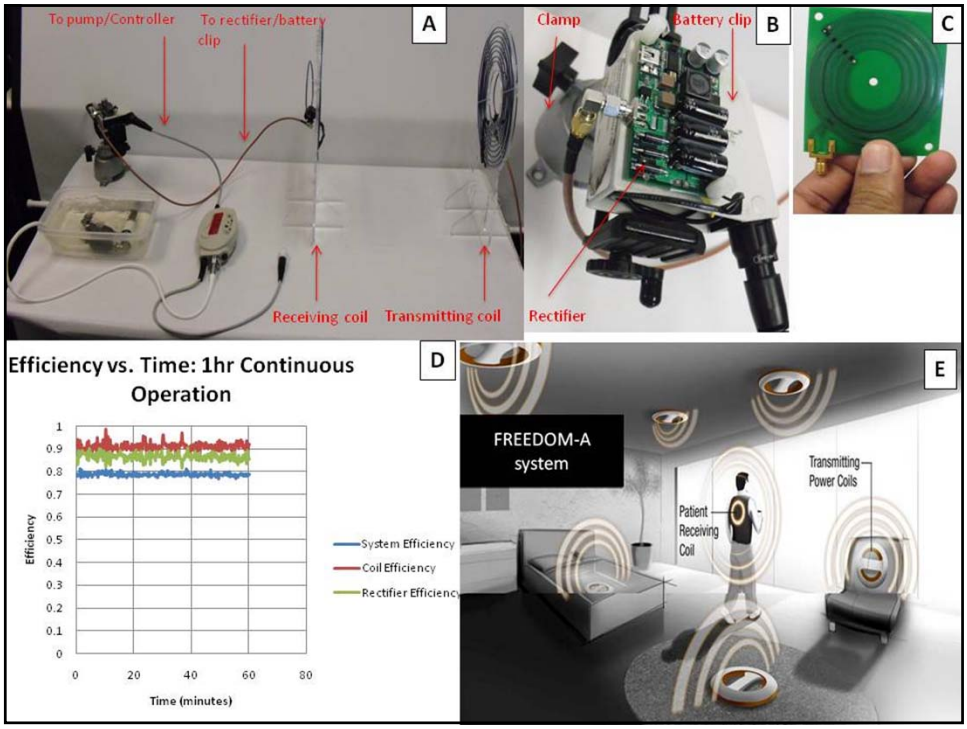


8pm Sept 8, 2010 **8am** **8pm Sept 9** **8am** **4pm**

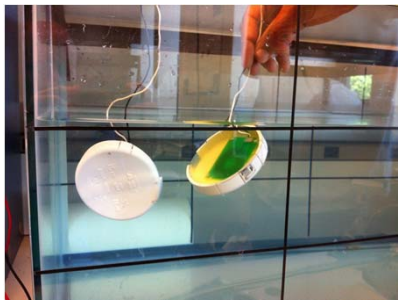
WREL for wireless power of "left ventricular assist device" (LVAD)

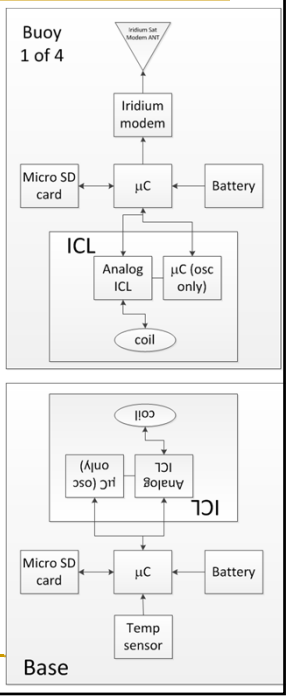


Implanted (in-body) devices an important emerging category of embedded
No labs on this this year



Underwater Thermal Vent Data Logger with Inductively Coupled Link (ICL)





Observations:

1. This embedded system contains many sub-systems:
   ICL, modem, microSD card
2. The oscillator in the ICL could be implemented with 2 transistors instead of a µC…nowadays your board may be smaller, cheaper, and more flexible if you throw in a 50,000 transistor µC instead…the package is much bigger than the transistors…that is why more functionality is shifting from HW to SW

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So what is an embedded system?

So what is an embedded system?

- High end
  - With operating system, display?, floating point unit?
  - Examples
    - Embedded computer w/ Linux…e.g., the robots in previous slides
      - The robots actually use ordinary servers…but no display, mouse, keyboard
    - Mobile platforms: e.g. your iPhone, etc
    - Friendly Arm platform used in previous offerings of this course
- Low end: no operating system
  - NO OS, no / limited display, no FPU
  - Examples
    - WISP, WARP sensor, robot finger sensor, "smart plug," etc

In this offering of 466, we will focus on the low end: embedded systems with no OS, no display, no floating point unit

Specifically, systems built around the TI-MSP430 microcontroller

So what is an embedded system?

- For the user
  - Constrained UI --- often no (big) display or input devices
  - May be a part of something else, e.g.
    - Computer input device
    - Car subsystem
    - Stereo, TV, remote control
    - Implanted device---part of user's body!
- For the developer (you!)
  - Constrained UI ➔ harder to debug
  - Good idea to design for testing / debugging
  - Often uses a microcontroller instead of microprocessor
  - Often closely coupled to the physical world
    - Analog to digital conversion, sensors, etc
  - Often power constrained
  - May prefer discrete or fixed-point algorithms since no FPU
    - Low end micros are like computers of yore, so old-school algorithms are sometimes useful

What do these differences imply?

- Less emphasis on
  - Graphical user interface
  - Dynamic linking and loading
  - Virtual memory, protection modes
  - Disks and file systems
  - Processes
  - Floating point computation
  - Computation speed
- More emphasis on
  - Real-time support, interrupts (no OS, in this offering of 466!)
  - Communication primitives
  - General-purpose input/output
  - Analog-digital/digital-analog conversion
  - Timers / Event capture / Pulse-width modulation
  - Built-in communication protocols
  - Discrete or fixed point computation
  - Computation efficiency

What is an embedded system? (cont'd)

- Figures of merit for embedded systems
  - Reliability – it should never crash
  - Safety – controls things that move and can harm/kill a person
  - Power consumption – may run on limited power supply
  - Cost – engineering cost, manufacturing cost, schedule tradeoffs
  - Product life cycle – maintainability, upgradeability, serviceability
  - Performance – real-time requirements, power budget

CSE466 Labs and Project

NB: subject to change!

- 1: Blinker (MSP430 intro)
- 2: Assembly and PWM
- 3: E-Field Sensing
- 4: Wireless communication fundamentals
- 5: Radio networks w/ SimpliciTI
- 6: Motor control & energy awareness
- 7: Sensing
- Project: blimp!
  - Wireless network communication & control of blimp
  - Will draw on many of the previous labs

End of lecture 1

- This week only…*Friday lecture canceled*

- Reading for Friday: Chapters 1,2,3
- Reading for Monday: Chapters 4,8