CSE 466 – Software for Embedded Systems

- Instructor:
  - Gaetano Borriello
    - CSE 572, Hours: by app't
    - gaetano@cs.washington.edu
- Teaching Assistants:
  - Brain French
    - CSE 003, Hours TTh 2:30-5:30
    - bmf@cs.washington.edu
  - Chris Grand
    - bitabur@cs.washington.edu
    - CSE 003, Hours TTh 2:30-5:30

CSE 466 – Software for Embedded Systems

- Class Meeting Times and Location:
  - Lectures: EE1 037, MWF 12:30-1:20
  - Lab: CSE 003, T – Section A, 2:30-5:20
Th – Section B, 2:30-5:20
- Exams
  - Exam-I: Friday, 10 February, EE1 037, 12:30-1:20
  - Final demo: Friday, 10 March, CSE Atrium, 12:30-1:20
  - Exam-II: Thursday, 16 March, EE1 037, 8:30-10:20 (but only 1 hour)
- Evaluations
  - Wednesday, 8 March, EE1 037, 12:30-1:20

Embedded system – from the web

- Definitions
  - A device not independently programmable by the user.
  - Specialized computing devices that are not deployed as general purpose computers.
  - A specialized computer system which is dedicated to a specific task.
  - An embedded system is preprogrammed to perform a narrow range of functions with minimal end user or operator intervention.
- What it is made of
  - Embedded systems range in size from a single processing board to systems with operating systems.
  - A combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a dedicated function.
  - In some cases, embedded systems are part of a larger system or product, as is the case of an anti-lock braking system in a car.
  - A specialized computer system that is part of a larger system or machine.
  - Typically, an embedded system is housed on a single microprocessor board with the programs stored in ROM.
  - Some embedded systems include an operating system, but many are so small and specialized that the entire logic can be implemented as a single program.
- Examples
  - Virtually all appliances that have a digital interface -- watches, microwaves, VCRs, cars -- utilize embedded systems.
  - A computer system dedicated to controlling some non-computing hardware, like a washing machine, a car engine or a missile.
  - Examples of embedded systems are medical equipment and manufacturing equipment.
  - While most consumers aren't aware that they exist, they are extremely common, ranging from industrial systems to VCRs and many net devices.

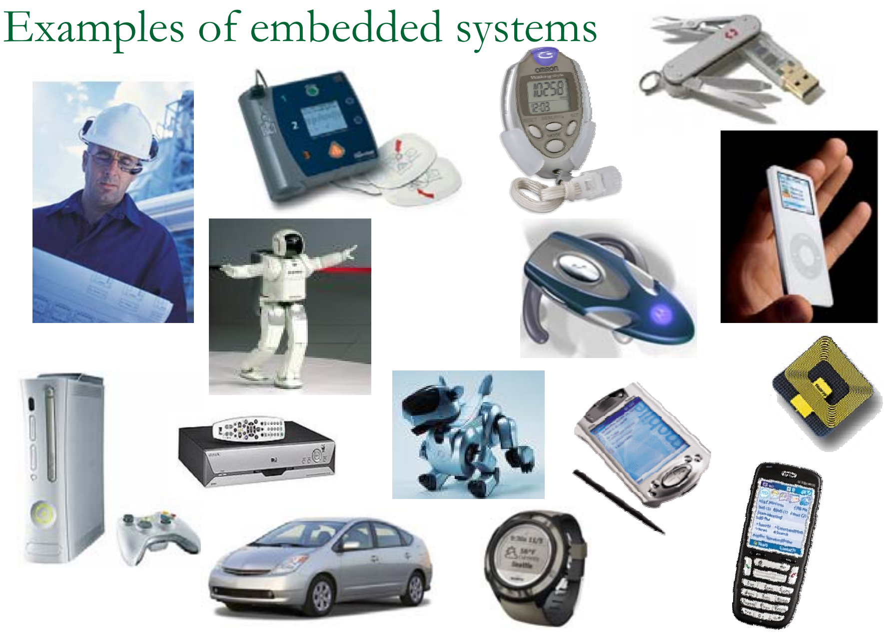
What is an embedded system?

- Different than a desktop system
  - Fixed or semi-fixed functionality (not user programmable)
  - Different human interfaces than screen, keyboard, mouse, audio
  - Usually has sensors and actuators for interface to physical world
  - May have stringent real-time requirements
- It may:
  - Replace discrete logic circuits
  - Replace analog circuits
  - Provide feature implementation path
  - Make maintenance easier
  - Protect intellectual property
  - Improve mechanical performance

What do these differences imply?

- Less emphasis on
  - Graphical user interface
  - Dynamic linking and loading
  - Virtual memory, protection modes
  - Disks and file systems
  - Processes
- More emphasis on
  - Real-time support, interrupts (very small OS, if we're lucky)
  - Tasks (threads)
  - Task communication primitives
  - General-purpose input/output
  - Analog-digital/digital-analog converters
  - Timers
  - Event capture
  - Pulse-width modulation
  - Built-in communication protocols

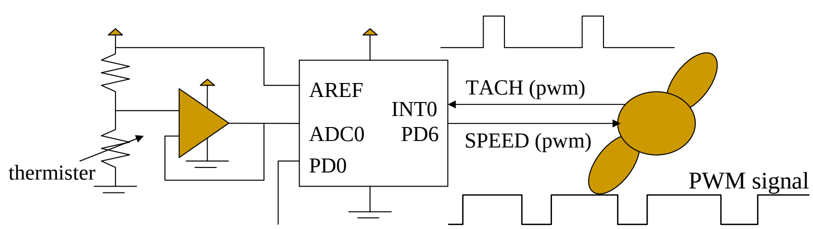
Examples of embedded systems



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

Example: a temperature controller



Task: Tachometer (external interrupt)
now = getTime();
period = then - now; //overflow?
then = now;
return;

Task: FanPWM (periodic, hard constraint)
count++;
if (count == 0) PD6 = 1;
if (count > Thi) PD6 = 0;
return;

Task: TempControl (periodic, soft constraint)
if (Temp > setpoint) Thi++;
if (Temp < setpoint) Thi--;
if (period<min || period>max) PD0 = 1;

Task: Main
Thi = 0;
setup timer for 1ms interrupt;
setup timer for 100ms interrupt;
while (1) ;

Capacity

- Assume:
  - 8 MHz processor @ one instruction/cycle
  - Assume fan runs between 30Hz and 60Hz
  - Assume 256ms period on speed control PWM, with 1ms resolution.
- What percent of the the available cycles are used for the temperature controller?
  - [total instructions in one second] / (8MInstr/sec)
- How much RAM do you need?
- How much ROM?

Resource analysis of temp controller

Task: Tachometer (external interrupt)

```
now = getTime();
period = then - now; //overflow?
then = now;
return;
```

Task: TempControl (periodic, soft constraint)

```
if  (Temp > setpoint) Thi++;
if  (Temp < setpoint) Thi--;
if  (period<min || period>max) GP4 = 1;
```

Task: FanPWM (periodic, hard constraint)

```
count++;
if (count == 0) GP0 = 1;
if (count > Thi) GP0 = 0;
return;
```

Task: Main

```
Thi = 0;
setup timer for 1ms interrupt;
setup timer for 100ms interrupt;
while (1) ;
```

Task	ROM	RAM	Instructions/Sec
Tach	~4	2 (period, then)	4 * 60 = 240
FanPWM	~8	1 (count)	8 * 1000 = 8000
TempControl	~10	1 (THI)	10 * 2 = 20

Total Instructions/Sec = 8260, at 8MIPS, that's only 0.1% utilization!
Other resources? local variables, stack

What Are You Going to Learn?

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

What are you going to learn? (cont'd)

- Understanding of basic microcontroller architecture
- Understanding of interfacing techniques
- Appreciation of power management methods
- Understanding of basic communication protocols
- Facility with a complete set of tools for design/debug
- Experience implementing some real systems

Class logistics – see course web

- http://www.cs.washington.edu/466
  - expands to http://www.cs.washington.edu/education/courses/cse466/06wi/
- Class structure
- Business matters
- Grading
- Syllabus
- What we'll be doing

Class structure

- Lecture (25)
  - Closely linked to laboratory assignments
  - Cover main concepts, introduced laboratory problems
- Lab (8)
  - Implementation of two projects
  - Lab reports due prior with 30 minutes of start of next lab section
- Exams (2)
  - Based on lectures, labs, and reading assignments
- Final demo (1)
  - During scheduled final time – participation required
- Reading and source material (lots)
  - Some assigned, most you'll find on your own

Business Matters

- Lecture slides will be on line after class (links in several places)
- Get the CoursePak for CSE466 ($33.50, Communications B-042)
- Bring a $200 personal check to the first lab to check out a kit
- Random lab partner assignments, changed mid-quarter
- Sign up for CSE466 mailing list

Grading

- Lab reports:
  - Demonstration(s) required
  - Brief answers to questions embedded in assignment
  - Sometimes hand-in code
  - Do with your partner
- Distribution:
  - Labs: 40%
  - Exams: 30% (10 Feb and 10 Mar – both Fridays)
  - Demo: 15%
  - Class Participation: 15%

CSE466 Lab Projects

- Two multi-week projects
  - Four lab assignments each
  - Different lab partners
- First project
  - Familiarize with microcontroller
  - Learn how to interface devices to it
  - Test and debug
  - Basic communication between chips and between chip and PC
- Second project
  - Wireless communication
  - Embedded operating system
  - Real-time issues
  - Test and debug
  - Coordinated behavior among many devices

CSE466 Lab Projects (cont'd)

- Project 1 – USB device
  - Platform: ATmega16 AVR microcontroller
  - Accelerometer and multi-color LED used to select a color
  - Connects sensor and actuator to PC through USB port
  - ***Color Selector***
    - Tilt accelerometer to move cursor on a color map
    - Send selected color back to device
    - Pulse-width modulation of multi-color LED to reproduce color
    - Eventually would be wireless USB device to home PC to control room lighting

CSE466 Lab Projects (cont'd)

- Project 2 – Ad hoc wireless network ("flock")
  - Platform: UC Berkeley wireless sensor nodes (UCB "motes")
  - Sound generation coordinated with neighbors and time of day
  - Coordinated behavior between different nodes
  - ***Flock-IV – the deployment***
    - Install in Allen Center atrium for pleasing auditory display
    - Focus on ease of installation and command/control
    - Switch between bird songs, crickets, water sounds