## CSE 466 – Software for Embedded Systems

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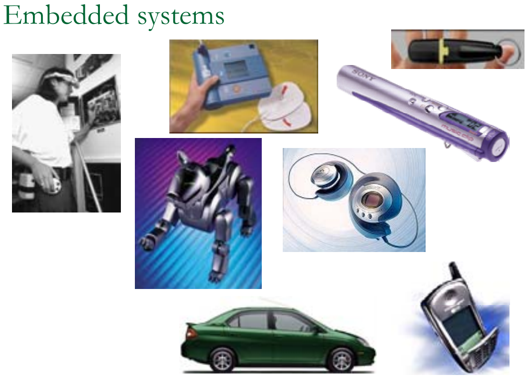
## CSE 466 – Software for Embedded Systems

- Class Meeting Times and Location:
  - Lectures: MGH 231, MWF 9:30-10:20
  - Lab: CSE 003, T – Section A, 2:30-5:20<br>Th – Section B, 2:30-5:20
- Exams
  - I: Friday, 5 Nov, MGH 231, 9:30-10:20
  - II: Friday, 10 Dec, MGH 231, 9:30-10:20
  - Final demo: Wednesday, 15 Dec, CSE Atrium, 8:30-10:20



## Embedded systems





## 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?

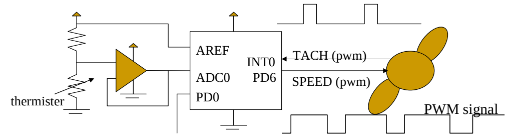
- Less emphasis on
  - Graphical user interface
  - Dynamic linking and loading
  - Virtual memory, protection modes
  - Disks and file systems
  - Processes
- More emphasis on
  - Real-time support, interrupts (very small OS, if we're lucky)
  - Tasks (threads)
  - Task communication primitives
  -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

## 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: FanPWM (periodic, hard constraint)**
count++;
if (count == 0) GP0 = 1;
if (count > Thi) GP0 = 0;
return;

**Task: TempControl (periodic, soft constraint)**
if (Temp > setpoint) Thi++;
if (Temp < setpoint) Thi--;
if (period<min || period>max) GP4 = 1;

**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**



## Class logistics – see course web

- http://www.cs.washington.edu/education/courses/cse466/04au/
- Class structure
- Business matters
- Grading
- Syllabus
- What we'll be doing



## Class structure

- Lecture
  - Closely linked to laboratory assignments
  - Cover main concepts, introduced laboratory problems
- Lab
  - Implementation of two projects
  - Lab reports due prior with 30 minutes of start of next lab section
- Exams
  - Two, based on lecture, lab, and reading
- Final demo
  - During scheduled final time – participation required
- Reading and source material
  - 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 ($24.75, 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% (5 Nov and 10 Dec)
  - Demo: 10%
  - Class Participation: 20%



## CSE466 Lab Projects

- Two multi-week projects
  - Four lab assignments each
  - Different lab partners
- First project
  - Familiarize with microcontroller
  - Learn how to interface various devices
  - Testing and debugging
  - Basic communication between chips and between chip and PC
- Second project
  - Wireless communication
  - Embedded operating system
  - Real-time issues
  - Testing and debugging
  - Emergent behavior of a collection of devices



## CSE466 Lab Projects (cont'd)

- Project 1 – USB device
  - Platform: ATmega16 AVR microcontroller
  - Accelerometer and push-button used to control a room light
  - Connects sensor and actuator to PC through USB port
  - ***Ball Lightning***
    - Roll a ball to control a light (dimmer)
    - Accelerometer senses movement of ball – tilting
    - Push button activates sensing
    - Eventually would be wireless USB device to home PC
    - One or more in each room



## 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
  - Emergent behavior between different nodes
  - ***Flock-II***
    - Install in Allen Center atrium for pleasing auditory display
    - Switch between bird songs, crickets, water sounds