Csci136 Computer Architecture II
– Introduction

Xiuzhen Cheng
cheng@gwu.edu

Lecture Outline

- Administrivia – syllabus
- Introduction, Technology Trend

Administrivia – syllabus

Course Information
- 3 credits; CRN: 62513
- 11:10AM – 12:25PM, Tuesday & Thursday; PHIL 110
- http://www.seas.gwu.edu/~cheng/136

Instructor Information
- Xiuzhen Cheng, Academic Center, Room 716
  Tel: 202 994 9751   Fax: 202 994 4875
  cheng@gwu.edu
  Office hour: 1:00PM-3:00PM, Tue. & Thur.; or by appointment

Lab Sections
- Section 30: Tomp 405, Wed. 4:10PM – 6:00PM
- Section 31: Tomp 405, Wed. 10:00AM – 12:00PM
- Discussion on homework problems, projects, lectures, etc.
  Must attend one of them.

TA Information
- Fanchun Jin: jinfc@gwu.edu
  Office: Academic Center, Room 730
  Office hours: Mon, Thur. 4 – 6PM
- Fang Liu: fliu@gwu.edu
  Office: Academic Center, Room 710
  Office hours: ???

Textbook

Prerequisite
- Csci 135 or equivalent knowledge
- Programming ability in a higher-level language

Course Plan
- www.seas.gwu.edu/~cheng/136/agenda.html

Syllabus (Cont.)

- No midterm; 1 final. Final will cover all material.
- 5 quizzes, among which 4 will be counted in your final grades.
  - Open book, open notes
  - Graded by Instructors

More than 10 homework assignments. 3 projects.
- Will be graded by TA
  - 1: Merge Sort (7%); 2: Simple Calculator (6%); 3: Single Precision Floating Point Addition and Subtraction (7%)

Method of instruction: lecture and in-class discussion
Grading Policy
- Based on curve. You must pass final to pass the course
- Homework assignments: 20%
  - Projects: 20%
  - Quizzes: 30%
  - Final: 30%
- Make-up policy: NO

Lab plan:
www.seas.gwu.edu/~cheng/136/labPlan.html

Announcement Page
- Please visit routinely

Useful link page
- SPIM related pages

Questions?

Focus of the Course
- Focuses of this course:
  - How computers work
    - MIPS instruction set architecture, Assembly Programming
    - The implementation of MIPS instruction set architecture (a subset) – MIPS processor design
  - Issues affecting modern processors (caches, pipelines)
    - Pipelining – processor performance improvement
    - Memory system, I/O systems

Course Objective
- Objective of the course:
  - Help you become a better programmer!
  - Learn tools to solve problems
  - Study the interaction between hardware/software
  - Learn the design trade-offs that drive the performance of computer systems
- By the end of this semester, you will be able to understand...
  - How is high-level language translated to machine code?
  - How does the hardware execute the program?
  - What is the interface between hardware and software?
  - How does software instruct the hardware to perform the job?
  - What determines the performance and how to improve it?
  - ...
Anatomy: 5 components of any Computer

- Personal Computer
- Processor ("brain")
- Memory (where programs, data live when running)
- Devices Input
- Output
- Display, Printer

What is Computer Architecture

- Programmer’s view: a pleasant environment
- Operating system’s view: a set of resources (hw & sw)
- System architecture view: a set of components
- Compiler’s view: an instruction set architecture with OS help
- Microprocessor architecture view: a set of functional units
- VLSI designer’s view: a set of transistors implementing logic
- Mechanical engineer’s view: a heater!

For this course, computer architecture mainly refers to Instruction Set Architecture
- Programmer-visible. Serves as the boundary between the software and hardware.

Example Computer Architectures

- Accumulator architecture
  - 1 general purpose register called accumulator. Hold one source and the destination. The 2nd source is in memory
  - Eg. EDSAC (1949), Motorola 6800 (1974)
- Stack architecture: HP handheld calculator
  - Load-store register architecture – since 1980
  - Load data from memory to register, register-register operation
    - MIPS, SPARC, PowerPC, DEC Alpha
- Others:
  - Register-memory architecture: DEC VAX, Motorola 6800, etc
  - Memory-memory architecture: DEC VAX

Why Register Architecture Dominates?

- Mainly refers to General Purpose Register Architecture
  - A general purpose register can hold an address, an integer, an instruction, a floating point number, an integer, …
- Why General Purpose Register?
  - Registers are faster than memory
  - Registers are more efficient for a compiler to use than other forms of internal storage
  - Registers can be used to hold variables
- How many registers are sufficient?
  - Compiler requires at least 16
  - The more, the better? No! Why?
  - MIPS R3000 has 32 32-bit general purpose register

Overview of Physical Implementations

- The hardware out of which we make systems.
- Integrated Circuits (ICs)
  - Combinational logic circuits, memory elements, analog interfaces.
- Printed Circuits (PC) boards
  - Substrate for ICs and interconnection, distribution of CLK, Vdd, and GND signals, heat dissipation.
- Power Supplies
  - Converts line AC voltage to regulated DC low voltage levels.
- Chassis (rack, card case, …)
  - Holds boards, power supply, provides physical interface to user or other systems.
- Connectors and Cables.

Integrated Circuits (2003 state-of-the-art)

- Primarily Crystalline Silicon
  - 1mm - 25mm on a side
  - 2003 - feature size ~ 0.13µm = 0.13 x 10^-6 m
  - 100 - 400M transistors
  - 25 - 100M "logic gates"
  - 3 - 10 conductive layers
- "CMOS" (complementary metal oxide semiconductor) - most common.

- Package provides:
  - Spreading of chip-level signal paths to board-level
  - Heat dissipation.
  - Ceramic or plastic with gold wires.
Printed Circuit Boards

- fiberglass or ceramic
- 1-20 conductive layers
- 1-20in on a side
- IC packages are soldered down.

Technology Trends: Memory Capacity (Single-Chip DRAM)

<table>
<thead>
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<th>year</th>
<th>size (Mbit)</th>
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<tbody>
<tr>
<td>1980</td>
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<tr>
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<td>1989</td>
<td>4</td>
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<tr>
<td>1992</td>
<td>16</td>
</tr>
<tr>
<td>1996</td>
<td>64</td>
</tr>
<tr>
<td>1998</td>
<td>128</td>
</tr>
<tr>
<td>2000</td>
<td>256</td>
</tr>
<tr>
<td>2002</td>
<td>512</td>
</tr>
</tbody>
</table>

- Now 1.4X/yr, or 2X every 2 years.
- 8000X since 1980!

Technology Trends: Microprocessor Complexity

- Itanium 2: 410 Million
- Athlon (K7): 22 Million
- Alpha 21264: 15 million
- Pentium Pro: 5.5 million
- PowerPC 620: 6.9 million
- Alpha 21164: ± 3 million
- Sparc Ultra: ± 3 million

2X transistors/Chip Every 1.5 years

Called "Moore’s Law"

Technology Trends: Processor Performance

- Intel P4 2000 MHz (Fall 2001)
- DEC Alpha 21264/600
- DEC Alpha 5/900
- DEC Alpha 5/300
- IBM POWER 100

We’ll talk about processor performance later on...

Computer Technology - Dramatic Change!

- Memory
  - DRAM capacity: 2x / 2 years (since '96); 64x size improvement in last decade.
- Processor
  - Speed 2x / 1.5 years (since ’85); 100X performance in last decade.
- Disk
  - Capacity: 2x / 1 year (since ’97) 250X size in last decade.

State-of-the-art PC when you graduate:
(at least…)
- Processor clock speed: 5000 MegaHertz
  (5.0 GigaHertz)
- Memory capacity: 4000 MegaBytes
  (4.0 GigaBytes)
- Disk capacity: 2000 GigaBytes
  (2.0 TeraBytes)
- New units! Mega => Giga, Giga => Tera

(Kilo, Mega, Giga, Tera, Peta, Exa, Zetta, Yotta = 10^24)

Come up with a clever mnemonic, fame!
**Technology in the News**

- **BIG**
  - LaCie the first to offer consumer-level 1.6 Terabyte disk!
  - $2,200
  - Weighs 11 pounds!
  - 5 1/4" form-factor
- **SMALL**
  - Pretec is soon offering a 12GB CompactFlash card
  - Size of a silver dollar
  - Cost? > New Honda!
  - Fast
  - Samsung 256 Mbit XDR DRAM

**So What You Will Learn?**

- Learn some of the big ideas in CS & engineering:
  - 5 Classic components of a Computer
  - Data can be anything (integers, floating point, characters): a program determines what it is
  - Stored program concept: instructions just data
  - Principle of Locality, exploited via a memory hierarchy (cache)
  - Greater performance by exploiting parallelism
  - Principle of abstraction, used to build systems as layers
  - Compilation v. interpretation thru system layers
  - Principles/Pitfalls of Performance Measurement
  - Assembly Language Programming
    - This is a skill you will pick up
  - Hardware design
    - We think of hardware at the abstract level, with only a little bit of physical logic to give things perspective

**Summary**

- Continued rapid improvement in computing
  - 2X every 2.0 years in memory size;
    - every 1.5 years in processor speed;
    - every 1.0 year in disk capacity;
  - Moore's Law enables processor
    - (2X transistors/chip ~1.5 yrs)
- 5 classic components of all computers
  - Control Datapath Memory Input Output

**Homework and Questions**

- Homework #1:
  - Readings: Chapter 1
  - Problems: 1.1-1.28, 1.29-1.45, 1.46, 1.51-1.52, 1.54-1.55

Questions?