CMSC 611
Spring 2000

Prof. Ethan L. Miller (elm@csee.umbc.edu)

Welcome to CMSC 611!

- Instructor: Professor Ethan Miller (`elm@csee.umbc.edu`)
- TA: Joy Su (`xsu1@umbc.edu`)
- Text: *Computer Architecture: A Quantitative Approach* (Hennessy and Patterson)
- Supplementary reading material: available online
- Course web pages
  - `http://www.csee.umbc.edu/courses/graduate/611/Spring00/`
  - Students are required to read Web pages regularly
  - Assignments & announcements will be on the Web
  - Class slides will be on the Web (available only within the `umbc.edu` domain)

Why take this course?

- Introduction to many of the methods used by designers to implement
  - General purpose processors
  - Memory systems
  - I/O systems
  - Multiprocessors
- Introduction to methods of analyzing CPU performance

More reasons to take this course

- Exposure to many characteristics of today's architectures
  - CISC: Pentium/Merced, 680x0
  - RISC: PowerPC, DEC Alpha, Sun SPARC, HP PA-RISC, MIPS, …
- Learn how to do graduate research in computer systems
- It's required….

Course mechanics

- Semester long project (40% of grade)
  - Work in groups of 3-4 students
  - Grade based on technical content & presentation
- Homework every 1-2 weeks (total 20% of grade)
- Exams
  - Midterm (15% of final grade)
  - Final exam (20% of final grade)
- Class participation: 5% of grade
- Project & both exams ***required*** to pass the class

Projects

- Done in groups of 3-4 people
- Many topics available
  - Pick one that the whole group is interested in
    - Work-related?
    - Issue of current relevance
  - Do something different from what everyone else is doing
- Meet project milestones throughout the semester
- Make a presentation on the project to the class
- Hand in a paper on the project

Course summary

- Measuring performance & cost
- Instruction sets
- Improving CPU performance
  - Dynamic instruction scheduling & instruction-level ||ism
  - Branch prediction
- Vector processors
- Memory hierarchies
- Storage systems
- Multiprocessors

What is computer architecture?

- Answer: the design of computer systems
- What must a computer system provide?
  - Application support
  - Software compatibility
  - OS requirements
  - Standards
- Computer system designer must take into account
  - Cost & performance
  - Design complexity
  - reliability and fault tolerance

Trends in hardware

- IC technology
  - Transistor density improves about 50% per year
  - 60% - 80% increase per year of transistors per chip
- Memory (RAM)
  - Density increases at around 60%/year
  - Cycle time decreases around 30% in ten years.
  - Bandwidth proportional to cycle time and data width

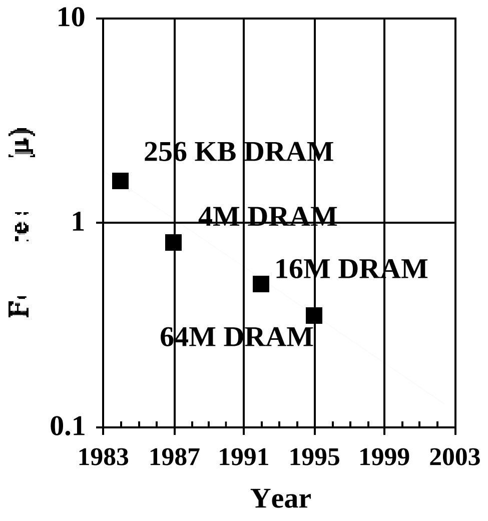
Moore's Law

- Gordon Moore (Intel Chairman, 1965) said "# of transistors in an IC will double every 18 months"
- Accurate for last 20 years; will it hold for the next 15 years?
  - Physics : lithographic limits
  - Economics: Design and test complexity, fabrication costs

	1995 (350 nm)	**1998 (250 nm)**	**2001 (180 nm)**	**2004 (130 nm)**	**2007 (100 nm)**	**2010 (80 nm)**
DRAM (bits)	64M	256M	1G	4G	16G	64G
MPU transistors / cm^2	4M	7M	13M	25M	50M	90M
DRAM chip size (mm^2)	190	280	420	640	960	1400
MPU chip size (mm^2)	250	300	360	430	520	620

Moore’s Law (2)

- Minimum transistor feature size must decrease by a factor of 0.7 every three years
- Where is the lower limit for feature size?



Moore’s Second Law

- Moore’s Second Law:
  The cost of building a semiconductor fab is doubling every three to four years.
- In 1995, approximately 50 fabs in operation worldwide
  - Another 50 in some state of completion
  - Current cost > $1 billion
- Physical Limits
  - “In 2010, we will run into the physical limitation of having a fraction of an electron show up at a gate to switch the state of the transistor” (Joel Birnbaum, HP senior president of R&D)

More trends in hardware

- Disk technology
  - Storage density increases around 50% per year
  - Rotation speed increases slowly
  - Bandwidth proportional to square root of density; increases around 25% per year
  - Access time (seek) drops around 30% in ten years
- Systems must take trends into account
  - Moving targets!
  - Optimal system today may not be optimal tomorrow

Trends in cost

- Learning curve : products drop in cost over time
  - Minor improvements in design & manufacturing
  - Amortization of startup costs (R&D, etc.)
- Volume decreases per-unit cost
  - Fixed costs amortized over more units
  - May have more competitors to help keep prices down
  - Commodities: standardized components available from many vendors
    - Little or no profit margin for commodities
    - Often *much* less expensive than low-volume components
- Relative prices of components can change...

Where does the money go?

- Component costs: raw material costs.
- Direct costs: costs incurred to actually make a single item (usually 20% to 40% of component costs)
- Gross margin: overhead not associated with a single item — R&D, plant equipment, profit, taxes, etc. (typically 20% to 55% of average selling price)
- Average selling price: direct cost + gross margin.
- List price: ASP + reseller’s margin

Design tradeoff examples

- Designing for low cost
  - Make choices that minimize cost no matter what
  - Design for ease of manufacture as well as low component cost
- Designing for high performance
  - Spend more money on R&D
  - Worry less about how much it costs to manufacture
- Designing for good cost/performance
  - Use more expensive parts if they have “bang for the buck”
  - Control costs, but not if they lower performance
- Cray vs. desktop workstation vs. Palm III