Computer Science 703

# Advance Computer Architecture

2005 Semester 1

## Lecture Notes

## 12 Apr 06

## Computer Design Issues/Technology

**James Goodman**

Department of Computer Science

# Reference

Hennessy & Patterson, *Computer Architecture: A Quantitative Approach* (3rd Ed.), 2003, Chapter 1.

# Scaling of transistors, wires, & Power

- Feature size: minimum size of a transistor or wire in one dimension (today: 0.09 microns = 90 nm)
- Smaller features imply
  - lower voltage
  - increased speed
- But, wires do not scale! They get worse!

# Power

- Major limit today:
  - delivering clean voltage to the chip
  - dissipating heat generated
- Two kinds of power, both getting worse
  - static (leakage)
  - dynamic (switching)

# Integrated Circuit Economics

$$\textit{Die yield} = \textit{wafer yield} \times \left(1 + \frac{\textit{Defects per unit area} \times \textit{Die area}}{\alpha}\right)^{-\alpha}$$

For current CMOS, $\alpha \approx 4$

In practice, at cost-effective point,

$$\textit{Die cost} \approx (\textit{Die area})^2$$

# Cost vs. Price

- Price often (not always) tracks cost
- Learning curve for each new generation
  – Costs plummet as processes are tuned
  – Volume is critical
- Integrated circuits: good dies/wafer
  – Expensive, infrequent
  – Larger wafer increases potential number
  – Larger die-size reduces potential number

# Cost vs. Price (con’t)

- Hardware is different than software!
  – High development cost, but
  – Manufacturing and testing (direct costs) are per unit
- Gross margins: 10-45%
- Corporate goal: component that is
  – Unique
  – High-volume

# Rules of Thumb

- Every 3 years DRAMs increase in size by 4X. Gordon Moore
- Every 3 years transistor count on a chip increases 4X. Andy Glew
- Every 3 years chip speed increases by 2X. Andy Glew
- Every 10 years DRAMs get 30% faster. Andy Glew
- Every 3 years Disks increase in size by 2X. Andy Glew
- Every 10 years Disks get 30% faster. Andy Glew
- Programmers increase the size of programs 2X every year. Andy Glew
- 1Mb/s of I/O bandwidth is required per MIPS. Gene Amdahl
- Doubling volume reduces cost by 10% Gordon Bell

# Amdahl's Law

You need to go 100 km, ½ by auto and ½ walking

*Question: if you travel half way at 100km/hr and half way at 5km/hr, what is your average speed?*

*Answer:* $$\cancel{\frac{100+5}{2}=52.5km/hr}$$

*Question: How long does it take to get there?*

*Answer:* $$\frac{50km}{100km/hr}+\frac{50km}{5km/hr}=10.5hr$$

*Average speed:* $$\frac{100km}{10.5hours}=9.5km/hr$$

# Amdahl's Law

- Even if first half is done instantly, average is still only 10 km/hour!
- Amdahl's Law: the performance improvement to be gained from using some faster mode of execution is limited by the fraction of the time the faster mode can be used.

# Amdahl's Law

$$\text{Speedup} = \frac{\text{Performance for entire task using the enhancement when possible}}{\text{Performance for entire task without using the enhancement}}$$

*Alternatively,*

$$\text{Speedup} = \frac{\text{Execution time for entire task without using the enhancement}}{\text{Execution time for entire task using the enhancement when possible}}$$

# Clocks per Instruction (CPI)

Execution time = # instructions
× average # clocks/instruction
× clock period

What is "average # clocks/instruction"? CPI