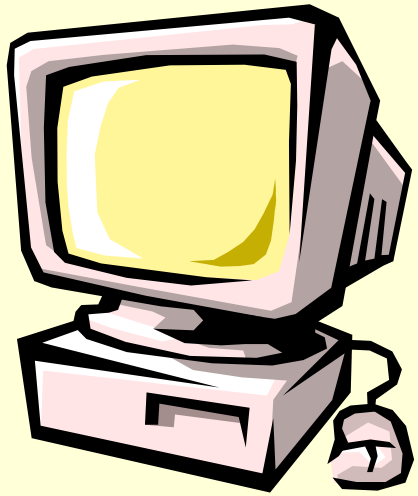


CSE 141-- Introduction to Computer Architecture

Larry Carter

What is Computer Architecture?

You should know meaning of all underlined words

- Instruction Set Architecture (ISA):
  - Anything a programmer needs to know to make an assembly-language program work correctly.
    - Instruction formats
    - What the instructions do
    - number and types of registers
    - addressing modes, exceptional conditions, ...
- Architecture (broader definition):
  - ISA + implementation
  - Structure, behavior and **performance** of computer systems (primarily hardware)

140 vs 141

CSE 140

- Hardware Designer
  - thinks about circuits, components, timing, functionality, ease of debugging

"construction engineer"

CSE 141

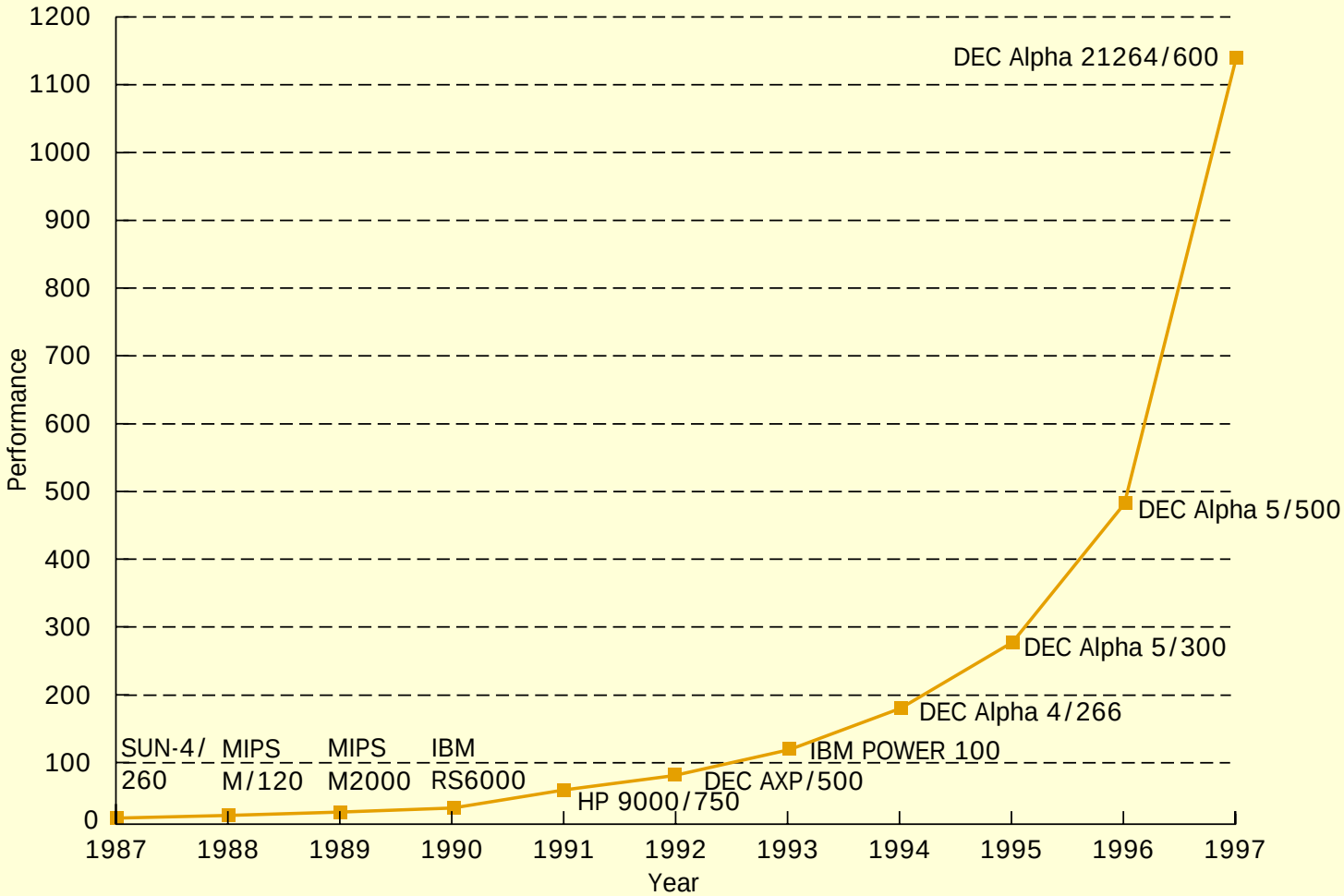
- Computer Architect
  - thinks about high-level components, how they fit together, how they work together to deliver performance.

"building architect"

The Challenge of Computer Architecture

- The industry changes faster than any other.
- The ground rules change every year.
  - new problems
  - new opportunities
  - different tradeoffs
- It's all about making programs run faster than the next guy's machine.

Performance Trends



What we'll study

- Internal organization of computers
- How it affects performance
- Vocabulary
- Clever ideas
- Historical perspective
- Architectural trends and tradeoffs
- Value of abstraction and standards

Meta subjects

- Algebra (word problems, logarithms, ...)
- Numeracy
- Economics & business
- Common sense
- Bright ideas vs. good ideas vs. successful ideas

Administrivia

- Instructor -- Larry Carter
  - Office hours (4101 APM)
    - Monday & Friday 10 - 11
    - Wednesday 3-4
  - carter@cs.ucsd.edu
- TAs:
  - Vineet Kumar (vineet@cs) Mon 6:30-7:30, Thurs 5:30-6:30
  - Rakesh Kumar (rakumar@cs) Tues, 10-12
  - Greg Chun (gchun@cs), Mon 2:30- 3:30 and Wed, 11-12
- Section meeting
  - 2:30 Fridays, CSB 001
  - We can set up a second section if desired

More administrivia

- Tests & homework:
  - 3 30-minute quizzes (4th, 7th, and 10th Wednesday)
  - 4 graded homeworks (relatively short)
  - Ungraded homeworks
    - discussed in sections
    - good practice for quizzes
- Grading:
  - Best 2 quizzes – 20% each
    - worst quiz score ignored (I may use in borderline decisions)
    - NO MAKEUP QUIZZES!
  - Graded homeworks – 5% each
  - Final – 40%

More administrivia

- Integrity
  - Ungraded homework: you are encouraged to work with others.
  - Graded homework: to be done entirely by yourself.
    - If you need clarification or a hint, ask me or a TA.
    - I will persecute violators to my fullest ability!
  - Quizzes & final. Closed book, but you may bring in one HANDWRITTEN page of notes. No calculators.
- Relationship with 141L
  - Dean Tullsen & I will coordinate material.
  - TA's are (to some extent) working on both courses.
  - 141L is a LOT of work. (But it's a good course!)

Website

- www.cs.ucsd.edu/classes/wi02/cse141
- Assignments, late-breaking news, etc.
- *May* have these slides before class
  - but perhaps not until after class.

Textbook

- Patterson & Hennessy, second edition of *"Computer Organization, the Hardware/Software Interface"*
  - Exceptionally good book. We'll read most of it.
    - Published 1997 (Pentium Pro was latest Intel processor)
  - Patterson is professor at Berkeley;
    - lead RISC project (foundation of SPARC processor)
    - lead RAID (redundant array of inexpensive disks) project
  - Hennessy is professor at Stanford
    - now Dean of Engineering
    - co-founded of MIPS Computer Systems
  - Note: same authors wrote the graduate textbook, "Computer Architecture, A Quantitative Approach".

Approximate Course Outline

Weeks 1-3: Chapters 1-4 + some math

- Performance and Performance Metrics
- Instruction Set Architectures

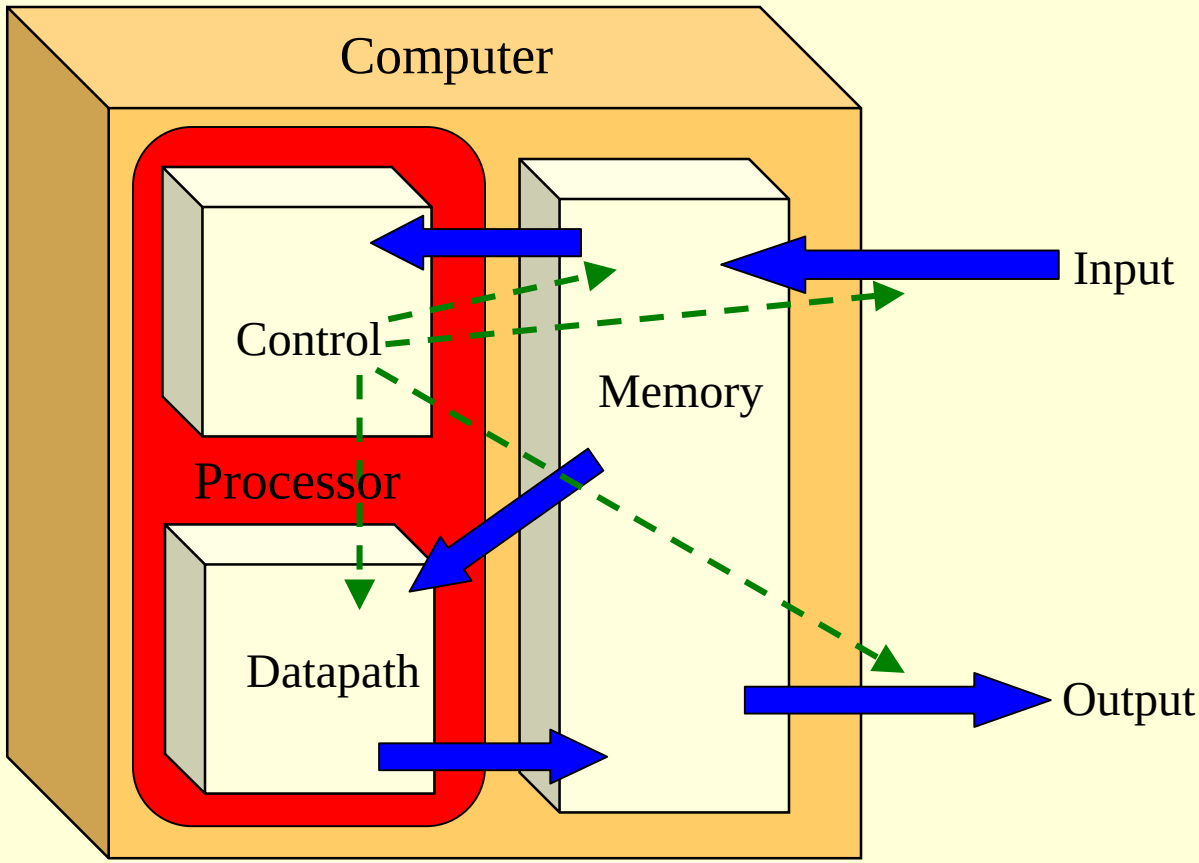
Weeks 4-6: Chapters 5-6:

- Three implementations of basic MIPS instructions
  - Single-cycle, Multiple-cycle, Pipelined implementation

Weeks 7-10:

- The Memory/Cache Hierarchy
- Superscalars, parallel machines, ... (as time allows)

The five classic components of computers



Output devices

- Display (aka Monitor)
  - CRT (cathode ray tube)
  - LCD (liquid crystal diode)
    - lighter, thinner, uses less power
  - Typical size: ”1 million *pixels* (picture element).
  - 8 to 24 bits per pixel
- Printer
  - Ink jet: cheaper
  - Laser: faster

aka = “also known as”

“”means “about”. Numbers like this are useful for “back of the envelope” estimates.

Disks & Tape

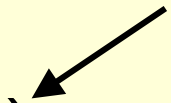
Also considered I/O devices

Fine print: portion of disk used as "virtual memory" could be called "memory".

- Hard disks (magnetic surface on metal)
  - Very slow access time (~ 5 ms)
  - Getting inexpensive *very* fast
- Floppy disks (magnetic surface on mylar)
  - Cheap and convenient
- CD's (compact disks) – optical
  - Even cheaper
  - Slow (or impossible) to write
- Magnetic tape – a dying technology (?)

"secondary storage"

"tertiary storage"



Memory

- SRAM (static random access memory)
  - very fast: ~ 1 ns access time
- DRAM (dynamic random access memory)
  - very dense (1 transistor per bit)
  - low power
  - ~ 30 ns access time
    - slow compared to SRAM
    - but over 100,000 times faster than disk access
- SDRAM (synchronous DRAM)
  - DRAM, but improved speed for getting a block of data
- VRAM (Video RAM)
  - SDRAM with extra port for streaming data to display

Why care about power consumption?

- California's energy crisis??
  - Not really
- Heat is hard to get rid of!
  - Workstation processor might use 70 Watts
  - Limits how densely components can be packaged
- Battery power is limited!
  - Embedded processors in portable devices

Typical home computer

	Power Mac 8500 (1996)	Power Mac G4 (2001)
Price:	$4000	$1700
Speed:	120 MHz	733 MHz
Memory:	16 MB DRAM	128 MB SDRAM
Disc:	1 GB	40 GB
Video RAM:	2 MB	32 MB
Extras:	10Mbit Ethernet, 4x CD ROM, ...	1 Gbit Ethernet, 32x CD R/W, ...

5 years → < 1/2 the price, 5-10 times better

A Quote from Robert Cringely

"If the automobile had followed the same development at the computer, a Rolls-Royce would today cost $100, get a million miles per gallon, and explode once a year killing everyone inside."

Who needs all this computation?

Back Of The Envelope Estimate (BOTEE®): what's needed for full-screen animation?

- Bandwidth (Bytes/sec) to monitor
- Bandwidth to disk (assuming MPEG compression)
- Processing power
- Disk capacity

(Worked out in class, if time permits)

Computer of the day

Historical perspective: last minutes of class

Computers:
4000 BC to 1940's

Input: ears
Output: mouth
Memory: paper
Datapath: eye-brain-pencil
Control: brain

- "Computer" was once a job title.
- Often assisted by mechanical devices (abacus, calculators ...)
- "Roman numeral" architecture (I, II, III, IV, V, ..., X, L, C, D, M)
  - Addition is pretty easy
- "Arabic numbers" architecture (..., -1, 0, 1, 2, ..., 10, 11, ...)
  - Easier multiplication
  - Much better for large numbers

Concluding Remarks

- Some things that I want you to get out of today's (and future) class:
  - Vocabulary
  - Approximate characteristics of current computers and components
  - Ability to make estimates
  - Awe at how quickly computer industry evolves

Reading Assignment

- Read Chapter 1
- Skim Chapter 3
  - Particularly "Hardware/Software Interface", and sections 3.12 – 3.16 .
  - Brings together issues from languages, compilers, operating systems, and architecture.
  - You already know assembly-language programming (??).
  - We'll go over details of relevant MIPS instructions later.
- Think about implications of, and reasons for, ISA choices.
- See website for homework problems (posted Weds).