

CSE 141  
Introduction to Computer Architecture  
Fall 2005

Lecture 1  
Introduction

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## What is a Computer?

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- Components:
  - Input (mouse, keyboard)
  - Output (display, printer)
  - Memory (disk drives, DRAM, SRAM, CD)
  - Network
- Our primary focus: the processor (datapath and control)
  - Implemented using millions of transistors
  - Impossible to understand by looking at each transistor
- Rapidly changing field:
  - Vacuum tube → Transistor → IC → VLSI → SoC
- Interesting history:
  - Search “history of computer(s)” on the Web

## Architecture: Dictionary Definition

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- The art and science of designing and erecting buildings.
- A style and method of design and construction.
- Orderly arrangement of parts; structure.
- ...

## What is Computer Architecture?

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| <ul style="list-style-type: none"><li>● Hardware Designer<ul style="list-style-type: none"><li>– Thinks about circuits, components, timing, functionality, ease of debugging</li></ul></li></ul> | <ul style="list-style-type: none"><li>● Computer Architect<ul style="list-style-type: none"><li>– Thinks about high-level components, how they fit together, how they work together to deliver performance.</li></ul></li></ul> |
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“construction engineer”

“building architect”

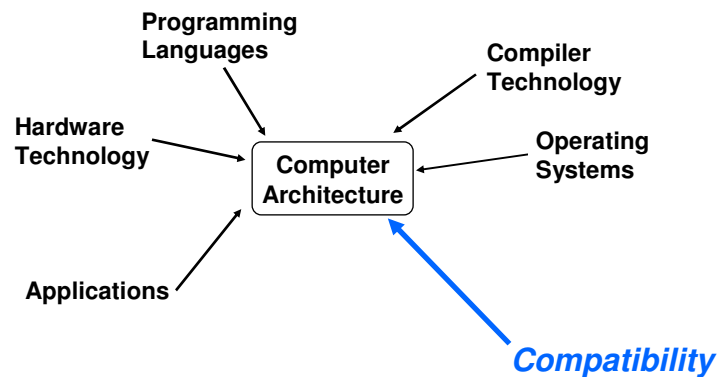
## The Challenge of Computer Architecture

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- 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 current generation of processors

## Forces on Computer Architecture

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## Evolution of Intel Processors\*

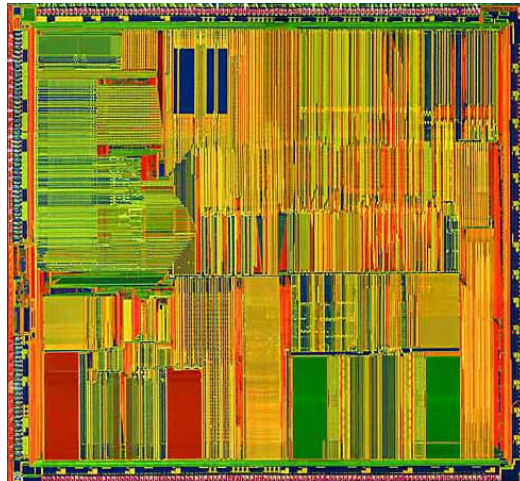
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Processor	Year of Introduction	# Transistors
4004	1971	2,250
8008	1972	2,500
8080	1974	5,000
8086	1978	29,000
286	1982	120,000
Intel i386	1985	275,000
Intel i486	1989	1,180,000
Intel Pentium	1993	3,100,000
Intel Pentium II	1997	7,500,000
Intel Pentium III	1999	24,000,000
Intel Pentium 4	2000	42,000,000
Intel Itanium	2002	220,000,000
Intel Itanium 2	2003	410,000,000

\*<http://www.intel.com/research/silicon/mooreslaw.htm>

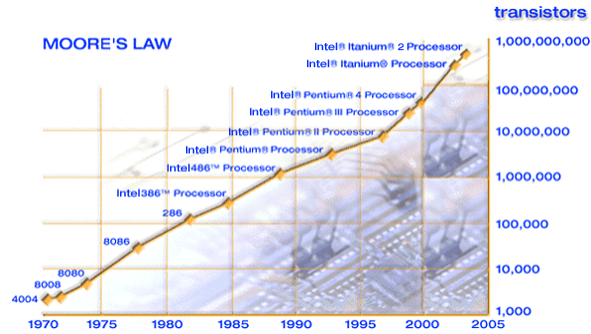
## Pentium 2 Photomicrograph\*

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\*<http://microscope.fsu.edu/chipshots/pentium/pent2large.html>

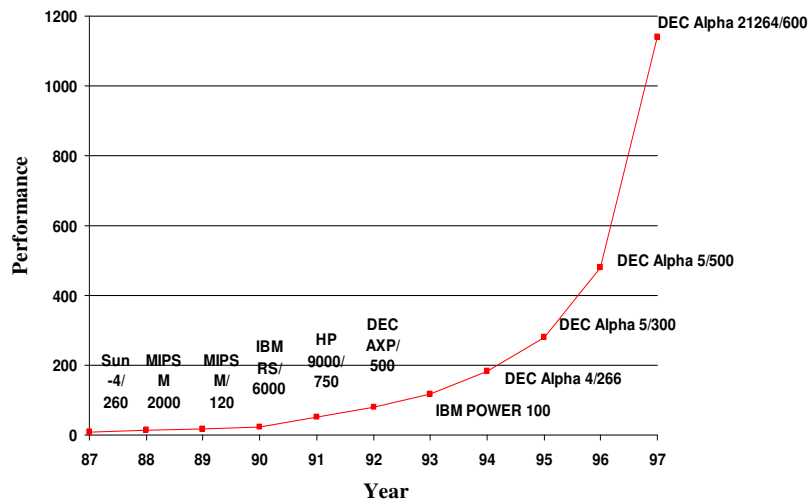
# Moore's Law\*



- Gordon Moore made the observation in 1965, four years after planar integrated circuit was discovered.
- The “law” states that transistor density doubles every ~18 months

\*<http://www.intel.com/research/silicon/mooreslaw.htm>

# Processor Performance



## World's Fastest Computer

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- BlueGene
  - Performance
    - Unit is TeraFlop: Trillion Floating Point Operations Per Second
    - 136 TeraFlops Max
    - 183 TeraFlops Peak
  - 65,536 PowerPC Processors (700 MHz, 2.8 GF)
  - Manufactured by IBM
  - Installed at Department of Defense
  - Linux Operating System
- See: [top500.org](http://top500.org) for a list of top 500 computers

## Computer Architecture's Changing Definition

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- 1950s to 1960s Computer Architecture
  - Computer Arithmetic
- 1970s to mid 1980s Computer Architecture
  - Instruction Set Design, especially ISA appropriate for compilers
- 1990s Computer Architecture
  - Design of CPU, memory system, I/O system, Multiprocessors
  - Instruction level Parallelism
- 2000s Computer Architecture
  - System-on-a-chip (SoC)

## Processors are everywhere!

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- PC, Workstation
- Cell Phone
- DVD Player
- Digital Camera
- Car
- Watch
- Pacemaker
- “Pill Camera”
- ...

## Commercial Processor Architectures

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- Embedded Processors
  - ARM, MIPS, PowerPC, ARC, ...
- PC/Workstation Processors
  - Intel x86, Sun SPARC, IBM/Motorola PowerPC, ...
- Super Computer
  - IBM PowerPC, Intel Itanium, NEC,...

## Why do you care about architecture?

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- If you become a SW designer
  - Understand architecture to better utilize it
  - What are performance bottlenecks & who will fix them?
- If you become a HW designer
  - You may implement a processor architecture in your career
- If you become a System designer
  - You may make HW and SW partition decision
- You may have to make purchasing decisions
  - Buy from vendor A or B? Why?
- Everything amounts to cost/benefit tradeoff!
  - What are the techniques for making such tradeoffs?

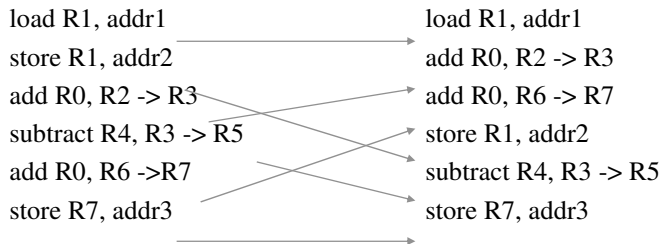
## Which is faster?

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```
for (i=0; i<N; i=i+1)
  for (j=0; j<N; j=j+1) {
    r = 0;
    for (k=0; k<N; k=k+1)
      r = r + y[i][k] * z[k][j];
    x[i][j] = r;
  }
```

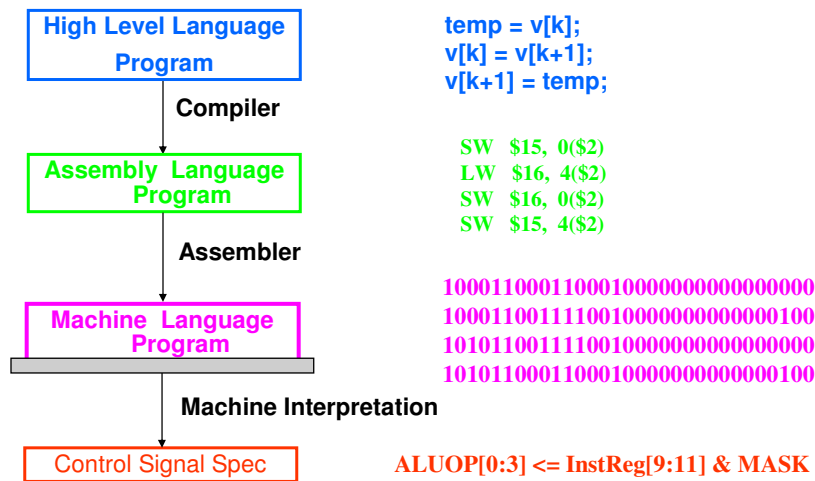
```
for (jj=0; jj<N; jj=jj+B)
  for (kk=0; kk<N; kk=kk+B)
    for (i=0; i<N; i=i+1) {
      for (j=jj; j<min(jj+B-1,N); j=j+1)
        r = 0;
      for (k=kk; k<min(kk+B-1,N); k=k+1)
        r = r + y[i][k] * z[k][j];
      x[i][j] = x[i][j] + r;
    }
```

## Which is faster?

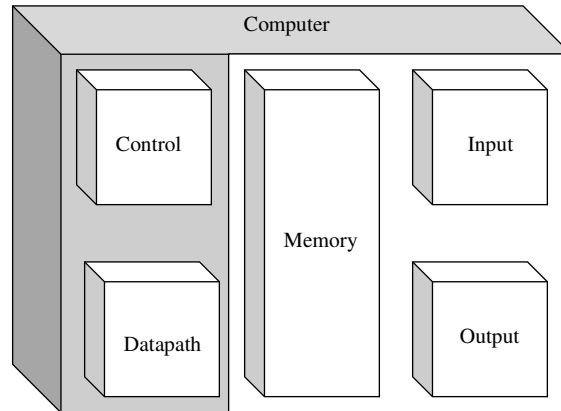


## Levels of Abstraction

- Delving into the depths reveals more information
- An abstraction omits unneeded detail, helps us cope with complexity

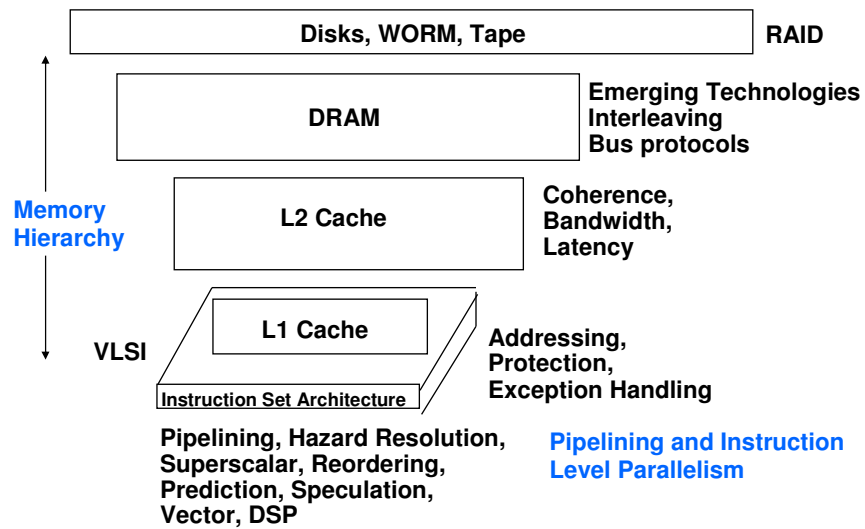


## The five classic components of computers



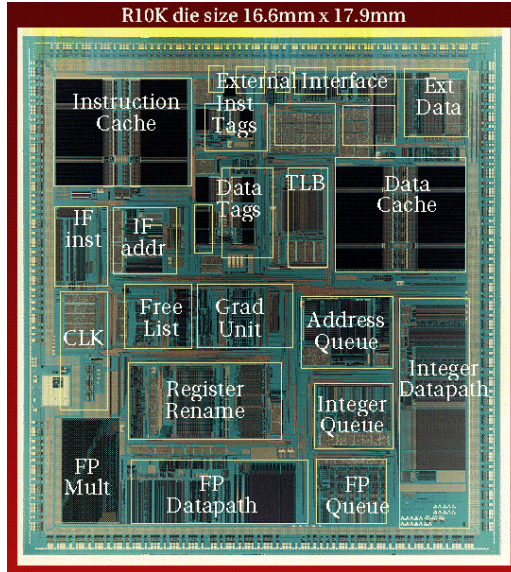
## Computer Architecture Topics

### Input/Output and Storage



## MIPS R10000 CPU

R10K die size 16.6mm x 17.9mm



### What you can expect to get out of this class

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- Understand fundamental concepts in computer architecture
- Understand impact on application performance
- Evaluate architectural descriptions of processors
- Gain experience designing a working CPU completely from scratch
- Learn techniques used to evaluate advanced architecture design

## Course Outline

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- Instruction Set Architecture
- Computer Arithmetic and Number System
- Computer System Performance and Performance Metrics
- CPU Architecture
- Pipelining
- Memory Hierarchy and Caches
- Virtual Memory

## Course Schedule

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Lecture #	Date	Day	Lecture Topic	Quiz Topic	Homework Due
1	9/26	Monday	Introduction, Ch. 1	-	-
2	9/28	Wednesday	ISA, Ch. 2	-	-
3	10/3	Monday	Performance, Ch. 3	ISA	#1
4	10/5	Wednesday	Arithmetic, Ch. 4	-	-
5	10/10	Monday	Arithmetic, Ch. 4	Performance	#2
6	10/12	Wednesday	Single cycle CPU, Ch. 5	-	-
7	10/17	Monday	Single cycle CPU, Ch. 5	Arithmetic	#3
8	10/19	Wednesday	Multi-cycle CPU, Ch. 5	-	-
9	10/24	Monday	Multi-cycle CPU, Ch. 5	Single Cycle CPU	#4
10	10/26	Wednesday	Review for the Midterm	-	-
	<b>10/31</b>	<b>Monday</b>	<b>Mid-term Exam</b>	-	-
11	11/2	Wednesday	Exceptions, Ch. 5 and Pipelining, Ch. 6	-	-
12	11/7	Monday	Pipelining, Ch. 6	-	-
13	11/9	Wednesday	Data and control hazards, Ch. 6	-	-
14	11/14	Monday	Data and control hazards, Ch. 6	Pipeline Hazards	#5
15	11/16	Wednesday	Memory & cache design, Ch. 7	-	-
16	11/21	Monday	Memory & cache design, Ch. 7	Cache	#6
17	11/23	Wednesday	Virtual Memory & cache design, Ch. 7	-	-
18	11/28	Monday	Course Review	-	-
	?	?	<b>Final Exam</b>		

## Course Work and Grading

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- **Course Work**
  - Weekly homework assignments
    - No late assignments accepted
    - No re-grading of homework or quizzes
- **Grading**
  - 10% homework (Total 6 Homeworks)
    - Lowest homework score will be dropped
  - 25% weekly quizzes (10 minutes, Total 6 Quizzes)
    - Lowest quiz score will be dropped
  - 25% midterm
  - 40% final (which will cover the whole quarter)
  - Tests & Quizzes
    - Closed books, no notes and no calculators!

## Quiz, Tests: What to expect?

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- **Material in the Text Book**
- **Material covered during lectures**
- **Material covered by homework assignments**

## Academic Honesty

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- Academic dishonesty will be taken seriously. If you are caught cheating, it will have serious consequences, including failing grade on the course. You will be reported to UCSD's Judicial Affairs Committee.
- The following is not permitted in this course:
  - Looking/copying a completed homework of another student.
  - Referring or copying solutions to homework from a solution manual or solutions from any source, including WWW.
  - Referring to any reference material or someone else's solution during a quiz or a test.
- See <http://www.cse.ucsd.edu/classes/fa05/cse141/General.htm>

## Announcements

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- **Discussion Sections for 141:**
  - Led by Leo Porter
- **Reading Assignment:**
  - Chapter 1: Computer Abstractions and Technology
    - Sections 1.1 - 1.6
- **Homework: None**
- **Quiz: Mon. 10/3/05**
  - **Topic:** Instructions: Language of the Computer (Chapter 2)