

FALL 2008

CSE 675.02:

Introduction to Computer Architecture

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Administrivia

- Course information is posted on the website:
www.cse.ohio-state.edu/~teodores

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Why learn Computer Architecture?

- CA is fundamental to Computer Science
 - Processor performance gains have been driving the field forward for 60 years!
- If you write software – need to be aware of your hardware platform
 - “Mega” supercomputer?
 - Desktop?
 - iPhone?
 - Solar-powered, earthquake detection sensor?
- If you want to learn about microprocessor design, this is the place to start!

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Historical Perspective

- ENIAC built in World War II was the first general purpose computer
 - Used for computing artillery firing tables
 - 80 feet long by 8.5 feet high and several feet wide
 - Each of the twenty 10 digit registers was 2 feet long
 - Used 18,000 vacuum tubes
 - Performed 1900 additions per second



–Since then:
Moore’s Law:
transistor capacity doubles every 18-24 months

Computer Architecture

- A modern meaning of the term *computer architecture* covers three aspects of computer design:
 - *instruction set architecture*,
 - *computer organization* and
 - *computer hardware*.
- *Instruction set architecture - ISA* refers to the actual programmer visible machine interface such as instruction set, registers, memory organization and exception (i.e. interrupt) handling.

One can think of a ISA as a hardware functionality of a given computer.

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Computer Organization and Hardware

- A *computer organization* and *computer hardware* are two components of the *implementation* of a machine.
- *Computer organization* includes the high-level aspects of a design, such as the memory system, the bus structure, and the design of the internal CPU (where arithmetic, logic, branching and data transfers are implemented).
- *Computer hardware* refers to the specifics of a machine, included the detailed logic design and the packaging technology of the machine.

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Tasks of Computer Architects

- **Computer architects** must design a computer to meet **functional requirements** as well as **cost, power, and performance** goals. Often, they also have to determine what the functional requirements are, which can be a major task. Once a set of functional requirements has been established, the architect must try to **optimize** the design.
- Here are three major application areas and their main requirements:
 - **Desktop computers**: focus on optimizing cost-performance as measured by a single user, with little regard for program size or power consumption,
 - **Server computers** – focus on availability, scalability, and throughput cost-performance,
 - **Embedded computers** – driven by price and often power issues, plus code size is important.

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Rapid Rate of Improvements

- Today, less than **one thousand dollars** purchases a personal computer that has more performance, more main memory, and more disk storage than a computer bought in 1980 for **one million dollars**.
- For many applications, the highest-performance microcomputers of today outperform the supercomputers of less than 10 years ago.
- This rapid rate of improvement has come from two forces:
 - **technology used to build computers** and
 - **innovations in computer design**.

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Technology Trends

- **Integrated circuit logic technology** – a growth in transistor count on chip of about 55% per year.
- **Semiconductor RAM** – density increases by 40% to 60% per year, while **access time** has improved very slowly, decreasing by about one-third in 10 years. Cost has decreased at rate about the rate at which density increases.
- **Magnetic disc technology** – disk density has been recently improving more than 100% per year, while prior to 1990 about 30% per year.
- **Network technology** – Latency and bandwidth are important, though recently bandwidth has been primary focus. Internet infrastructure in the U.S. has been doubling in bandwidth every year.

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Growth of Capacity per DRAM chip

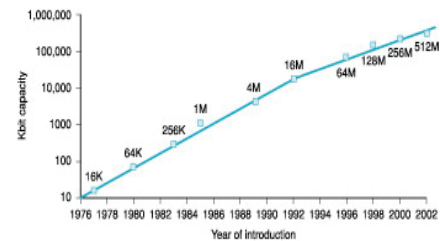


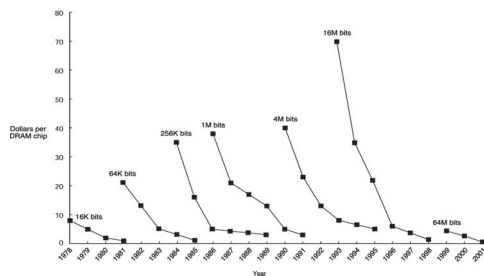
Figure 1.13

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Prices of Six Generations of DRAMs

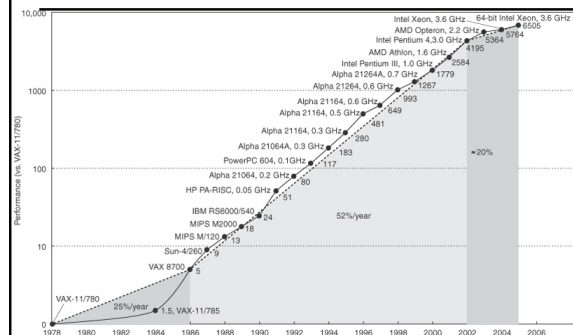


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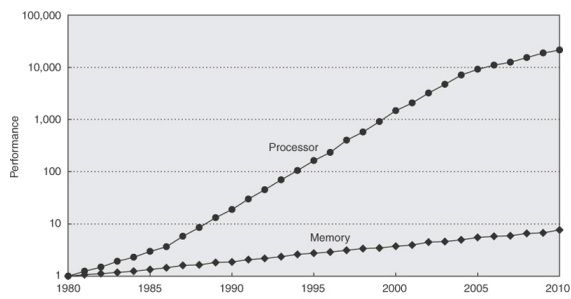
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Growth in Microprocessor Performance



Growth in Performance of RAM & CPU



Mismatch between CPU performance growth and memory performance growth!!

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Approaches to Instruction Set Architecture

- For many years the interaction between ISA and implementations was believed to be small, and implementation issues were not a major focus in designing instruction set architecture.
- In the 1980's, it becomes clear that both the difficulty of designing processors and performance inefficiency of processors could be increased by instruction set architecture complications.
- Two main approaches of ISA:
 - RISC (Reduced Instruction Set Computer) architecture
 - CISC (Complex Instruction Set Computer) architecture.

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RISC Architecture

RISC – Reduced Instruction Set Computer

RISC architecture goals are ease of implementation (with emphasis on concepts such as advanced pipelining) and reliance on highly optimized compilers.

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RISC ISA Characteristics

- All instructions on data apply to data in registers and typically change the entire register;
- The only instructions that affect memory are load and store instructions that move data from memory to a register or to memory from a register, respectively;
- A small number of memory addressing modes;
- The instruction formats are few in number with all instructions typically being one size;
- Large number of registers;

These simple properties lead to dramatic simplifications in the implementation of advanced pipelining techniques, which is why RISC architecture instruction sets were designed this way.

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CISC Architecture

CISC – Complex (and Powerful) Instruction Set Computer
CISC goals, such as simple compilers and high code density, led to the powerful instructions, powerful addressing modes and efficient instruction encoding.

VAX processor was a good example of CISC architecture. For example: accounting for all addressing modes and limiting to byte, word (16 bits) and long (32 bits), there are more than 30,000 versions of integer add in VAX.

Question: What is today the main example of CISC architecture processor?

Answer: **Intel IA-32 processors** (found in over 90% desktop computers).

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Intel IA-32 Processors

- Intel IA-32 processors, from 80386 processor in early 80's to the Core 2 Duo today are of CISC architecture. All Intel IA-32 processors are having as a core the identical instruction set architecture designed in early 1980's.
- The improvements in technology have allowed the latest Intel IA-32 processors (of CISC architecture) to continue improve performance.
- Since 1995, Pentium processors consist of a front end CISC processor and a RISC-style processor.
- The front end processor fetches and decodes Intel IA-32 complex instructions and maps them into microinstructions. A microinstruction is a simple instruction used in sequence to implement a more complex instruction and microinstructions look very much as RISC instructions.
- Then, the RISC-style processor executes microinstructions.

What Is This Course About?

In this course we are going to learn basic principles of processor and memory design using functionality of [MIPS processor](#), i.e. we shall design processor-memory system with [\(a subset of\) MIPS instruction set architecture](#).

What does **MIPS** stand for?

Answer: **M**icroprocessor without **I**nterlocked **P**ipeline **S**tages.
MIPS processor is one of the first RISC processors.

[Reading Assignment: Chapter 1](#)