Computer Architecture
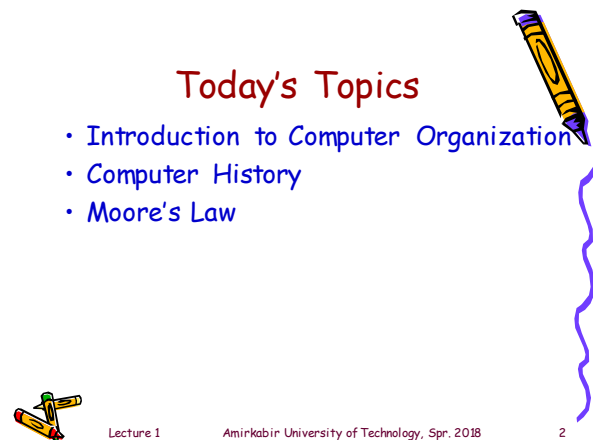
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Today's Topics

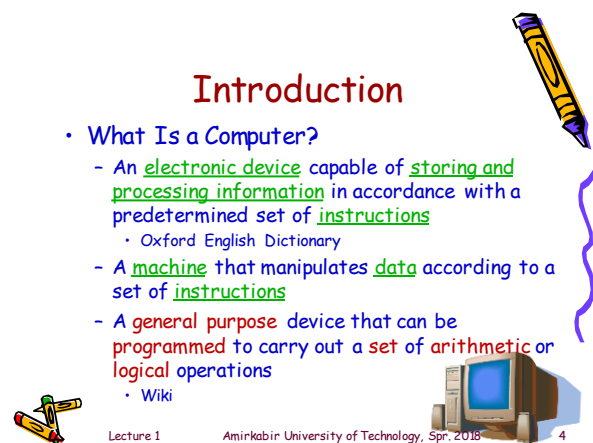- Introduction to Computer Organization
- Computer History
- Moore's Law

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- Lectures adopted from:
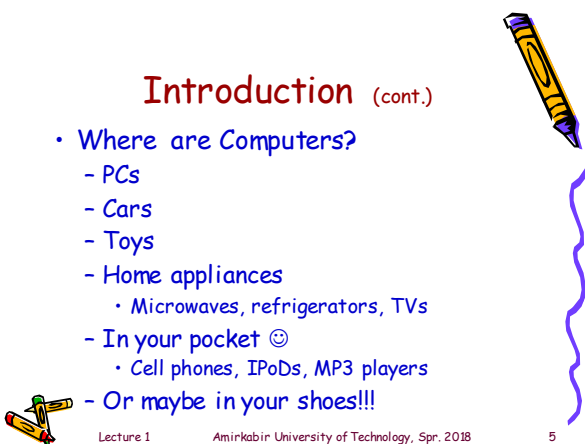 - "Computer Organization & Language" handouts, Dept. of CE, SUT, by Prof. H. Asadi, 2016.

Introduction

- What Is a Computer?
  - An <u>electronic device</u> capable of <u>storing and processing information</u> in accordance with a predetermined set of <u>instructions</u>
    - Oxford English Dictionary
  - A <u>machine</u> that manipulates <u>data</u> according to a set of <u>instructions</u>
  - A general purpose device that can be programmed to carry out a set of arithmetic or logical operations
    - Wiki

Introduction (cont.)

- Where are Computers?
  - PCs
  - Cars
  - Toys
  - Home appliances
    - Microwaves, refrigerators, TVs
  - In your pocket ☺
    - Cell phones, IPoDs, MP3 players
  - Or maybe in your shoes!!!

Introduction (cont.)

- Where are Computers?

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Computer System

- A computer system consists of <u>hardware</u> and <u>software</u> that are combined to provide a tool to solve problems (with best performance)
  - Hardware may include:
    - CPU, memory, disks, printers, screen, keyboard, mouse
    - Other peripherals
  - Software may include:
    - System software
      - A general environment to create specific applications
    - Application software
      - A tool to solve a specific problem

Computer System (cont.)

- Most complicated machines ever built on the earth
  - For example,
    - Dual-core Intel Itanium-2 9000 processor contains 1.72 billion transistors
    - Xilinx Virtex7: Over 6 billions transistors
    - A Boeing airplane has only 4 million parts
  - How can we comprehend these computer systems?
    - Using hierarchical abstraction levels

Computer System (cont.)

- Hierarchical Abstractions
  - Applications
  - Systems software
  - Assembly/machine language
  - Architectural issues
    - i.e., caches, virtual memory, pipelining
  - Boolean logic, 1s and 0s
    - Sequential logic, finite state machines
    - Combinational logic, arithmetic circuits
  - Transistors used to build logic gates (CMOS)
  - Semiconductors/silicon used to build transistors
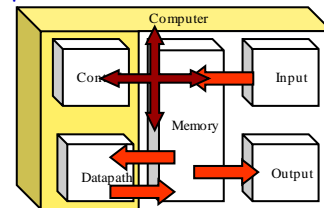 - Properties of atoms, electrons, and quantum dynamics

Computer Organization

- **Computer Components**
  - Input, output, memory, control unit, & datapath

Types of Computer Systems

- Desktops
- Servers
- Embedded Systems

Types of Computer Systems (cont.)

- Desktops
  - General purpose computers
  - Variety of software
  - Designed for use by individuals
    - PCs, Notebooks

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Types of Computer Systems (cont.)

- Servers
  - High-end computing systems
    - Consists of several CPUs
  - Used by multiple users
  - Networked based
  - High capacity, performance, reliability
  - Range from small servers to building sized

Types of Computer Systems (cont.)

- Servers
  - Supercomputers highest performance servers
    - Hundreds of CPUs, TBs of memory, PBs of storage

Types of Computer Systems (cont.)

- Embedded Systems
  - A computer system designed to perform one or a few dedicated functions
    - Often with real-time, power, high reliability, low-cost, size/weight constraints
  - Hidden as components of systems

Types of Computer Systems (cont.)

- Embedded Systems
  - Widest range of applications!
    - Telecommunications systems: routers, …
    - Consumer electronics: cell phones, PDAs, MP3 players, digital cameras, printers, fax machines, …
    - Transportation systems: cars (ABS, airbag controller, …), aircrafts, …
    - Medical equipment

Types of Computer Systems (cont.)

- Embedded Systems
  - Q1: Embedded systems are special-purpose designed; why?
    - To further reduce cost and power consumption
  - Q2: Is performance a major metric?
    - As long as we satisfy real-time constraint
    - Further performance increase not desired

Computer Organization (cont.)

- Components of a Desktop System
  - Processor
  - Memory system
  - Power supply
  - Cooling system
  - Motherboard
  - I/Os
    - Disk drive, network card (on-chip), video card (on-chip), keyboard, mouse, printer, mouse, camera, …

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Computer Organization: Inside the Box

Computer Organization (cont.)

- Components of an Embedded Computer
  - Processor
  - Memory system
  - Power supply
  - Cooling system
  - Sensors
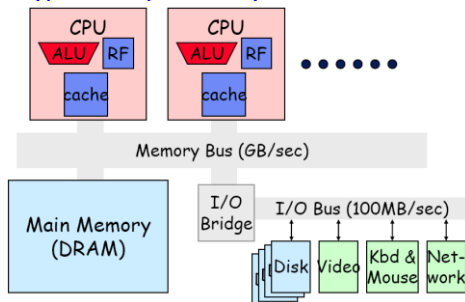 - Converters (ADC, DAC)
  - Actuators

Computer Organization (cont.)

- A Typical Computer Org.

Inside the Processor (CPU)

- Datapath
  - Performs operations on data
- Control
  - Sequences datapath and memory accesses
- Cache memory
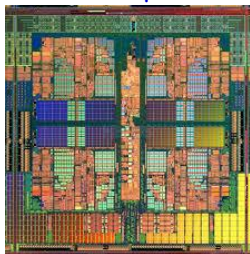 - Small fast SRAM memory for immediate access to data

Inside the Processor (CPU)

- AMD Barcelona: 4 processor cores

Computer Organization (cont.)

- A Typical Embedded Computer
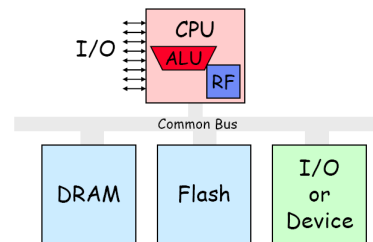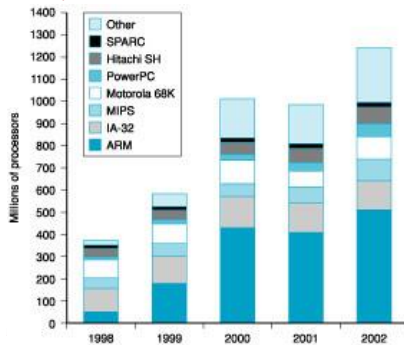
Market: Application
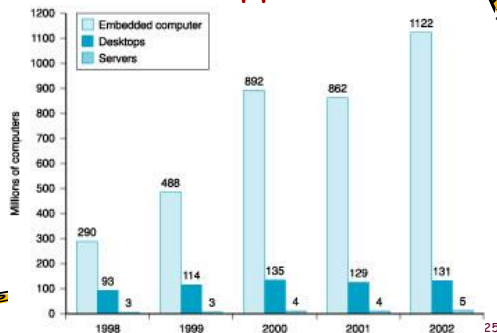
Market: Application (cont.)
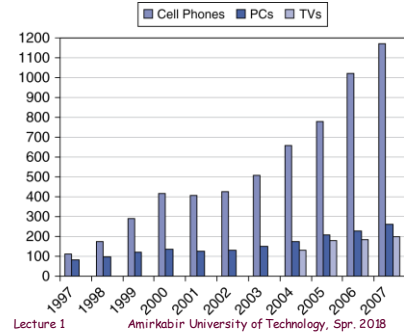
Market: CPU Brand

Computer History

- Non-Electronic Computing Machines
  - Abacus
  - Punch machine
  - Difference engine
  - Analytical engine
- Electro-Mechanical Computers
- Electronic Computers

Computer History (cont.)

- Non-Electronic Computing Machines

Computer History (cont.)

- Non-Electronic Computing Machines
  - "Program" on punch cards
  - "Input" & "Output" on punch cards, too!

Computer History (cont.)

- Non-Electronic Computing Machines
  - Difference engine, 1823
    - Evaluated polynomial functions using additions
    - By Charles Babbage
    - Special-purpose computer
    - Built by George & Edward Shuetz in 1855
    - Read more on Wiki
      - http://en.wikipedia.org/wiki/Difference_engine

Computer History (cont.)

- Non-Electronic Computing Machines
  - Analytical engine, 1833
    - A general purpose computer
    - Programmed by punch cards
    - Never completed
    - Would have been 30 by 10 m
    - Read more on Wiki
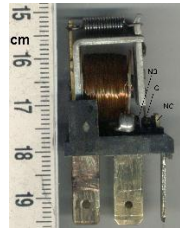   - http://en.wikipedia.org/wiki/Analytical_engine

Computer History (cont.)

- ElectroMechanical Computing Machines
  - Early 1900s
  - Switches, relays

Computer History (cont.)

- Electronic Computers
  - 1st generation: vacuum tubes
    - 1945-1955
  - 2nd generation: BJT transistors
    - 1955-1965
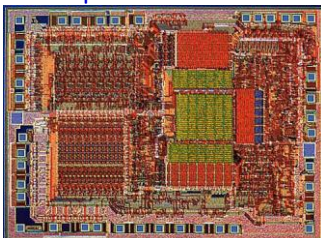 - 3rd generation: integrated circuits
    - 1965-1974

Computer History (cont.)

- 3rd generation: integrated circuits
  - 8085 Microprocessor

6450 Transistors

Computer History (cont.)

- Electronic Computers
  - 4th generation: VLSI
    - 1974-1989
  - 5th generation: ULSI
    - 1990-present

Motorola MC68040

Pentium III

Computer History (cont.)

- Electronic Computing Machines
  - ENIAC, 1946
    - By Eckert & Mauchly, UPENN
    - 1st programmable electronic digital computer
    - 18,000 vacuum tubes
    - 30 ton, 80 by 8.5 feet
    - 1900 additions per second
    - Programmed by 3000 switches
    - Used Von Neumann stored program model
    - Read more on Wiki:
      - http://en.wikipedia.org/wiki/ENIAC

Computer History (cont.)

- Electronic Computing Machines
  - UNIVAC, 1951
    - First commercial computer
    - Contract price: $400K, total price: $1M
    - Sold 48 copies
  - IBM 701, 1952
    - Leased at 12K per month
    - Shipped 19 copies
  - IBM 650, 1953
    - Mass produced, 2000 copies!
    - $200K ~ $400K

Computer History (cont.)

- Electronic Computing Machines
  - CDC Computers
    - VAX
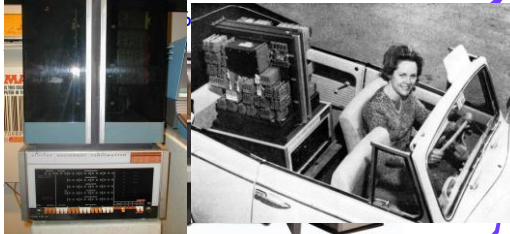
Computer History (cont.)

- Electronic Computing Machines

Xerox Alto, 1973
Early PC with mouse and GUI

Computer History (cont.)

- Technology Advances

Year	Technology Used in Computers	Relative Performance per unit cost
~1950	Vacuum tube	1
1960s	Transistor	35
1975	Integrated circuit	900
1995	Very large scale integrated circuit	2,400,000
2005	Ultra large scale integrated circuit	6,200,000,000
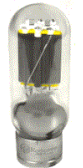
Computer History (cont.)

- Electronic Computing Machines
  - Read more on Wiki
    - http://en.wikipedia.org/wiki/Computer
    - http://en.wikipedia.org/wiki/History_of_computing_hardware
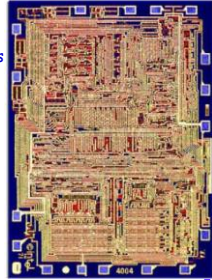
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Computer History (cont.)

- CPU History
  - Intel 4004,
    - 1st single chip CPU in textbooks
    - 1970
    - 4-bit processor
    - 2,300 transistors
    - 16-pin DIP package
    - About 100 kHz
    - 100K OPs per second
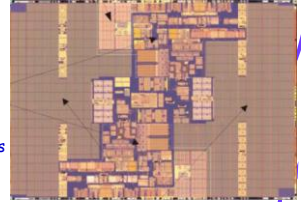   - More info at Intel website
      - www.intel.com/museum

Computer History (cont.)

- CPU History
  - Intel Itanium
    - Montecito
    - 2004
    - 64-bit processor
    - 1.7 billion transistors
    - 1.7 GHz
    - Issue up to 8 instructions per cycle
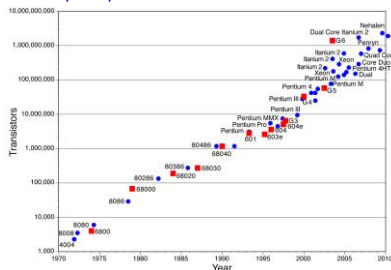   - 26 MB of cache memory

Moore's Law

- **What happened from 1970 to 2004?**
  - Transistor count doubles every 24-month
    - Some say every 18-month

Moore's Law (cont.)

- **Who's Moore?**
  - Gordon Moore a co-founder of Intel Corp.
- **Corollaries of Moore's Law**
  - Performance of computers doubles every two-year
    - Per unit cost
  - Power consumption doubles every 18 months
    - Per unit area
  - Hard disk capacity doubles every 24 months
  - RAM storage capacity doubles every 24 months
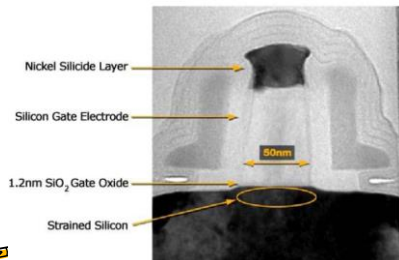 - Capital cost of a semiconductor fab doubles every 24 months
- More on Moore's Law on Wiki

Moore's Law (cont.)

- **End of Moore's Law?**

Nickel Silicide Layer

Silicon Gate Electrode

50nm

1.2nm SiO$_2$ Gate Oxide

Strained Silicon

Moore's Law (cont.)

- **End of Moore's Law?**
  - Transistor physical dimensions
    - Gate oxide thickness
  - Power wall
    - Amount of power consumed per inch square

Moore's Law (cont.)

- End of Moore's Law?
  - Future of VLSI technology is unknown
    - Probably no more scaling after 2015
- Possible Solutions
  - Parallel & distributed processing
  - Reconfigurable hardware computing
  - Non-silicon technologies
    - Nano-technologies
      - Carbon nano-tubes, molecular switches
    - Biological computers
      - DNA self-assembly
    - Quantum computing

What We Learned So Far?

- Computer Organization
- Types of Computers
- Computer History
- CPU History
- Moore's Law