



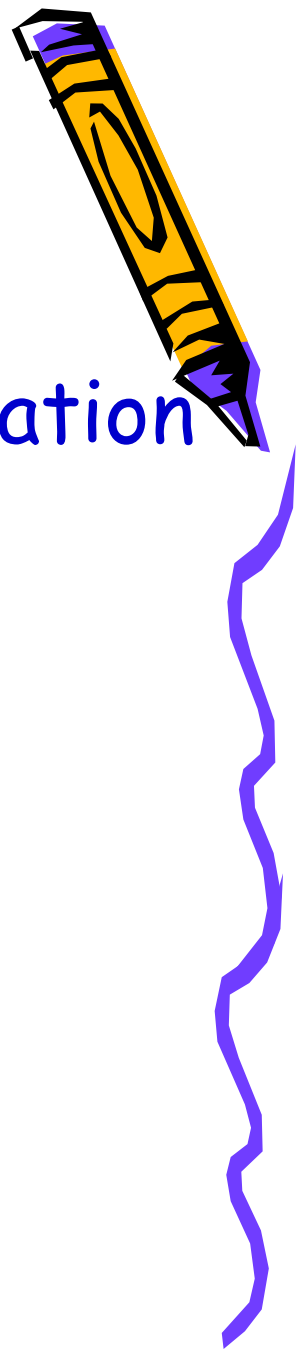
# Computer Architecture

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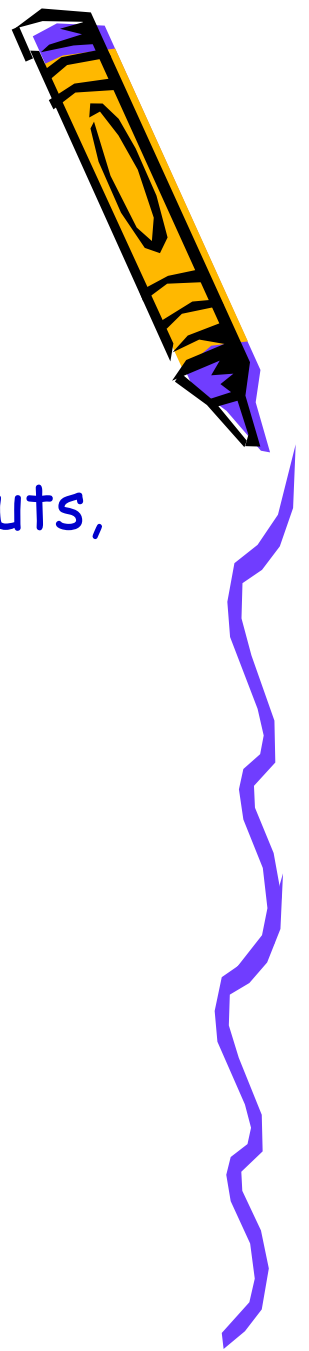


# Today's Topics

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



# Copyright Notice



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



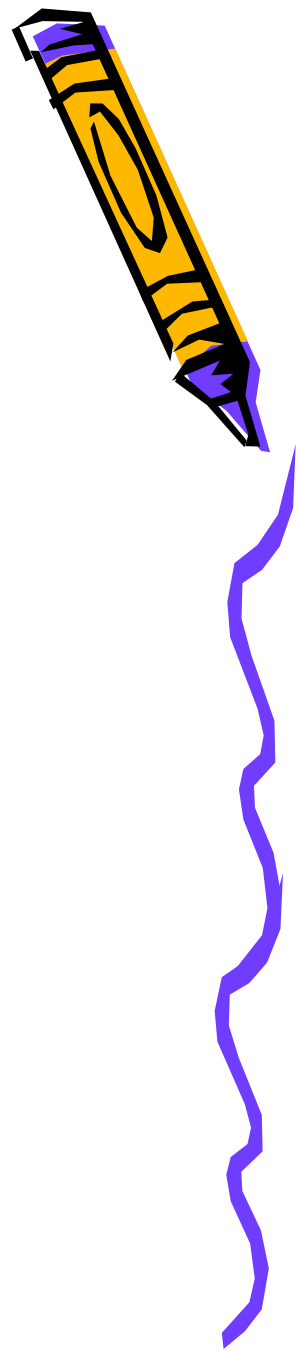
# Introduction



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



# Introduction (cont.)

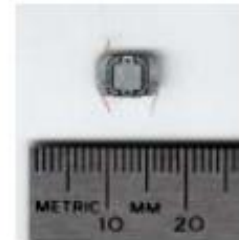


- Where are Computers?
  - PCs
  - Cars
  - Toys
  - Home appliances
    - Microwaves, refrigerators, TVs
  - In your pocket 😊
    - Cell phones, IPoDs, MP3 players
  - Or maybe in your shoes!!!



# Introduction (cont.)

- Where are Computers?



# Computer System



- A computer system consists of hardware and software 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.)

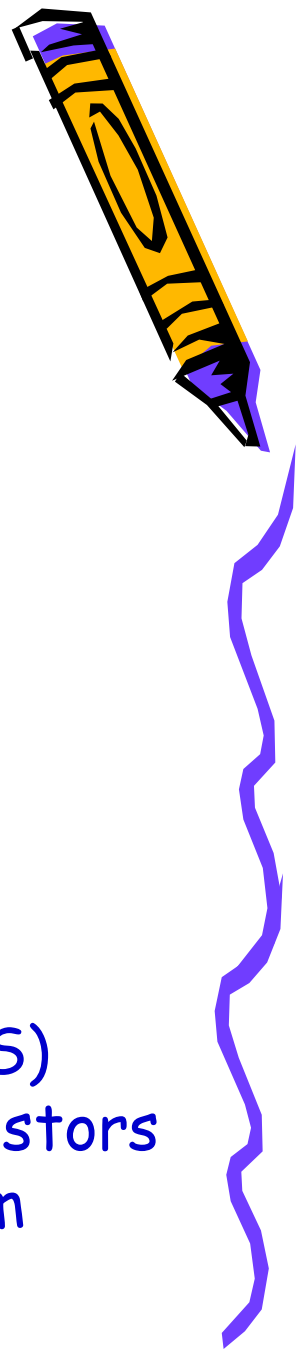


- Most complicated machines ever built on the earth
  - For example,
    - Dual-core Intel Itanium-2 9000 processor contains 1.72 billion transistors
    - Xilinx Virtex7: Over 6 billions transistors
    - A Boeing airplane has only 4 million parts
  - How can we comprehend these computer systems?
 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





# Computer System (cont.)



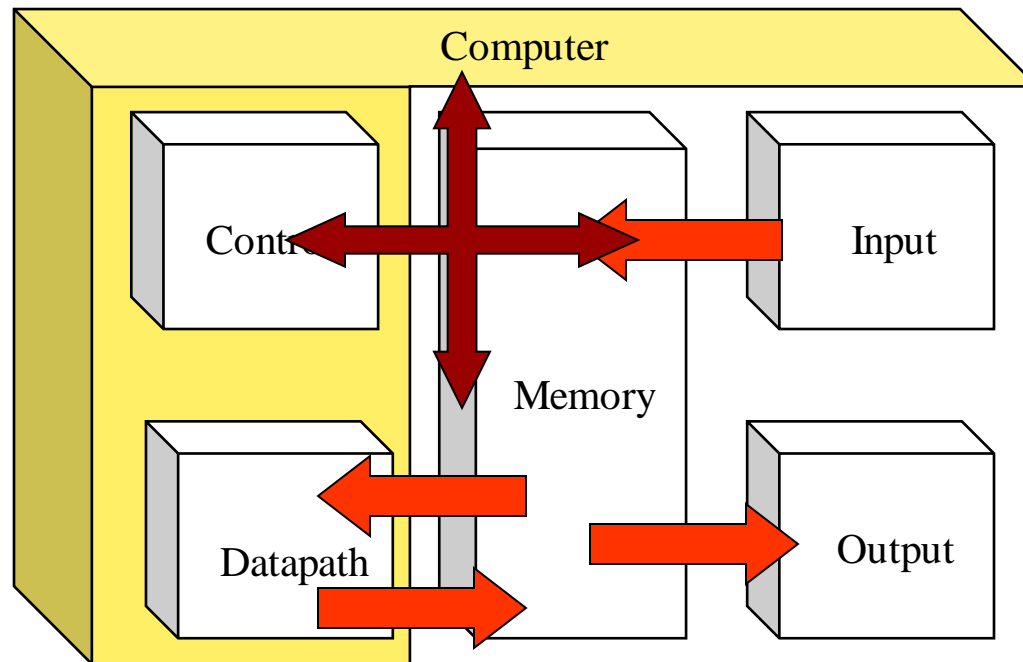
- Hierarchical Abstractions
  - Applications
  - Systems software
  - Assembly/machine language
  - Architectural issues
    - i.e., caches, virtual memory, pipelining
  - Boolean logic, 1s and 0s
    - Sequential logic, finite state machines
    - Combinational logic, arithmetic circuits
  - Transistors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



# Computer Organization

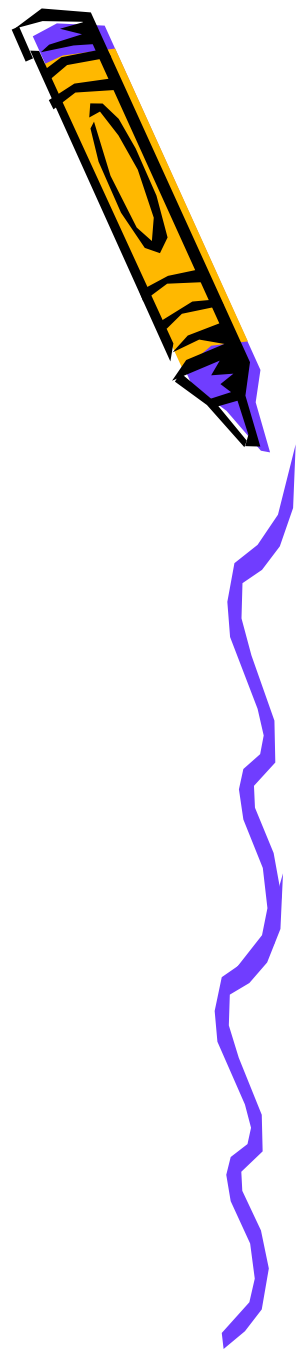


- Computer Components
  - Input, output, memory, control unit, & datapath



# 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



# Types of Computer Systems (cont.)



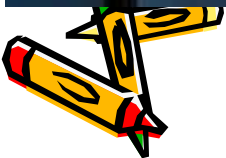
- Servers
  - High-end computing systems
    - Consists of several CPUs
  - Used by multiple users
  - Networked based
  - High capacity, performance, reliability
  - Range from small servers to building sized



# Types of Computer Systems (cont.)



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





# Types of Computer Systems (cont.)



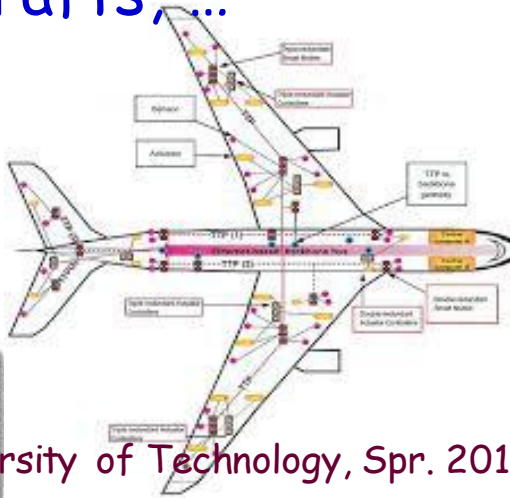
- Embedded Systems
  - A computer system designed to perform one or a few dedicated functions
    - Often with real-time, power, high reliability, low-cost, size/weight constraints
  - Hidden as components of systems



# Types of Computer Systems (cont.)

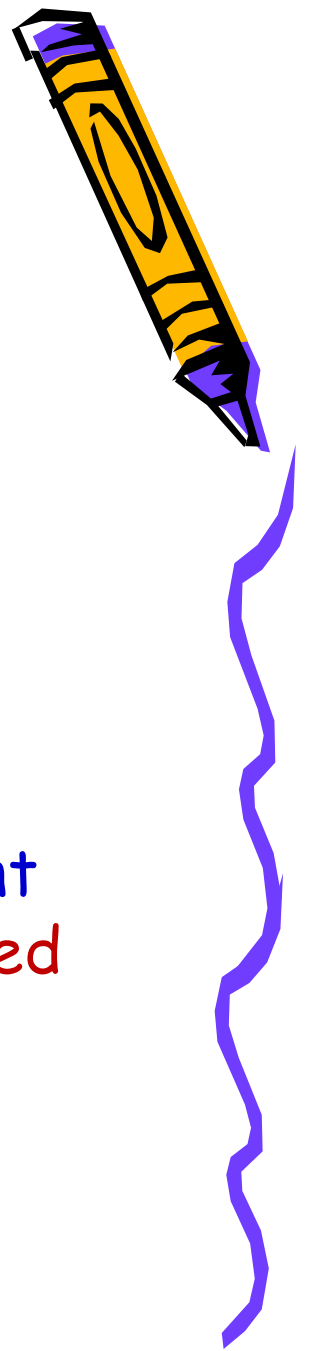


- Embedded Systems
  - Widest range of applications!
    - Telecommunications systems: routers, ...
    - Consumer electronics: cell phones, PDAs, MP3 players, digital cameras, printers, fax machines, ...
    - Transportation systems: cars (ABS, airbag controller, ...), aircrafts, ...
    - Medical equipment



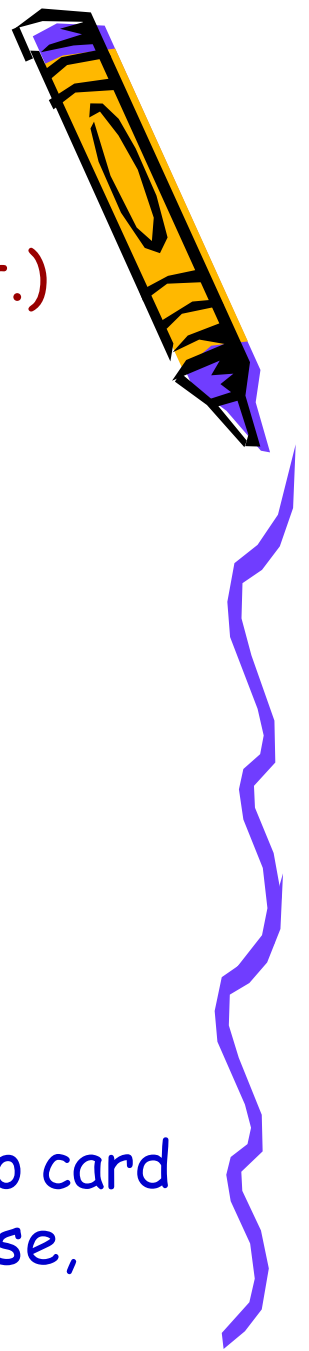


# Types of Computer Systems (cont.)



- 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**



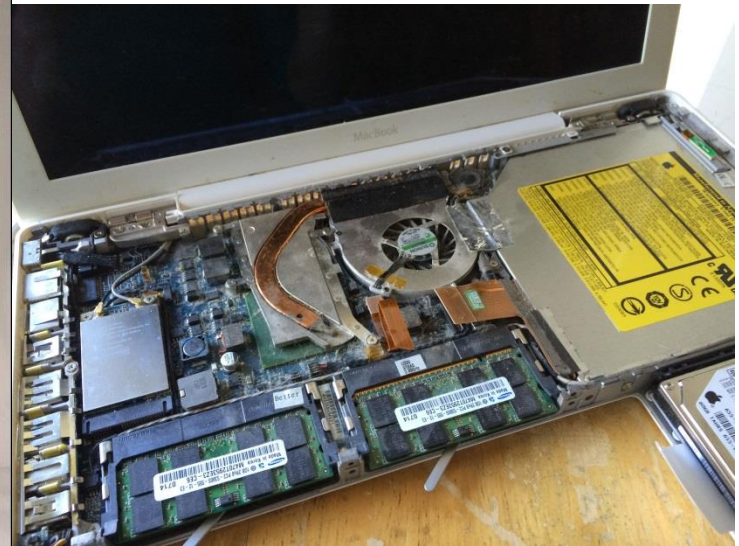
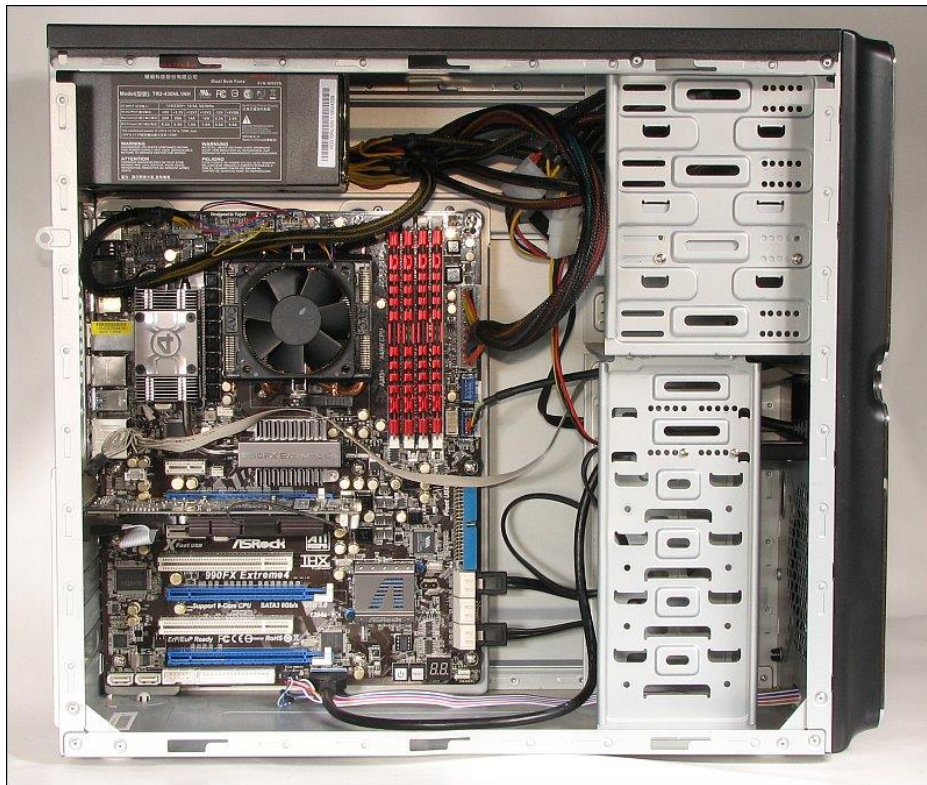


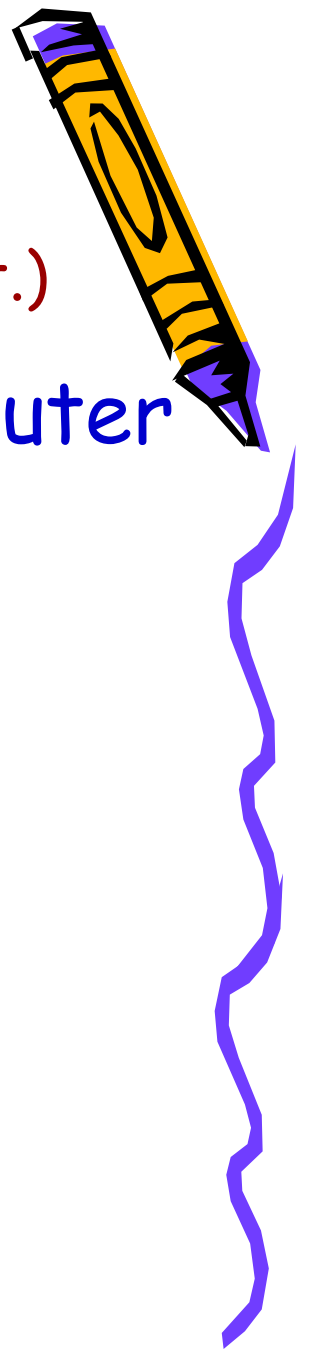
# Computer Organization (cont.)

- 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, ...



# Computer Organization: Inside the Box

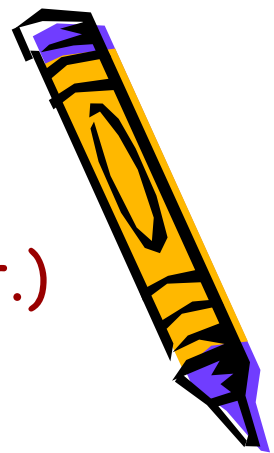




# Computer Organization (cont.)

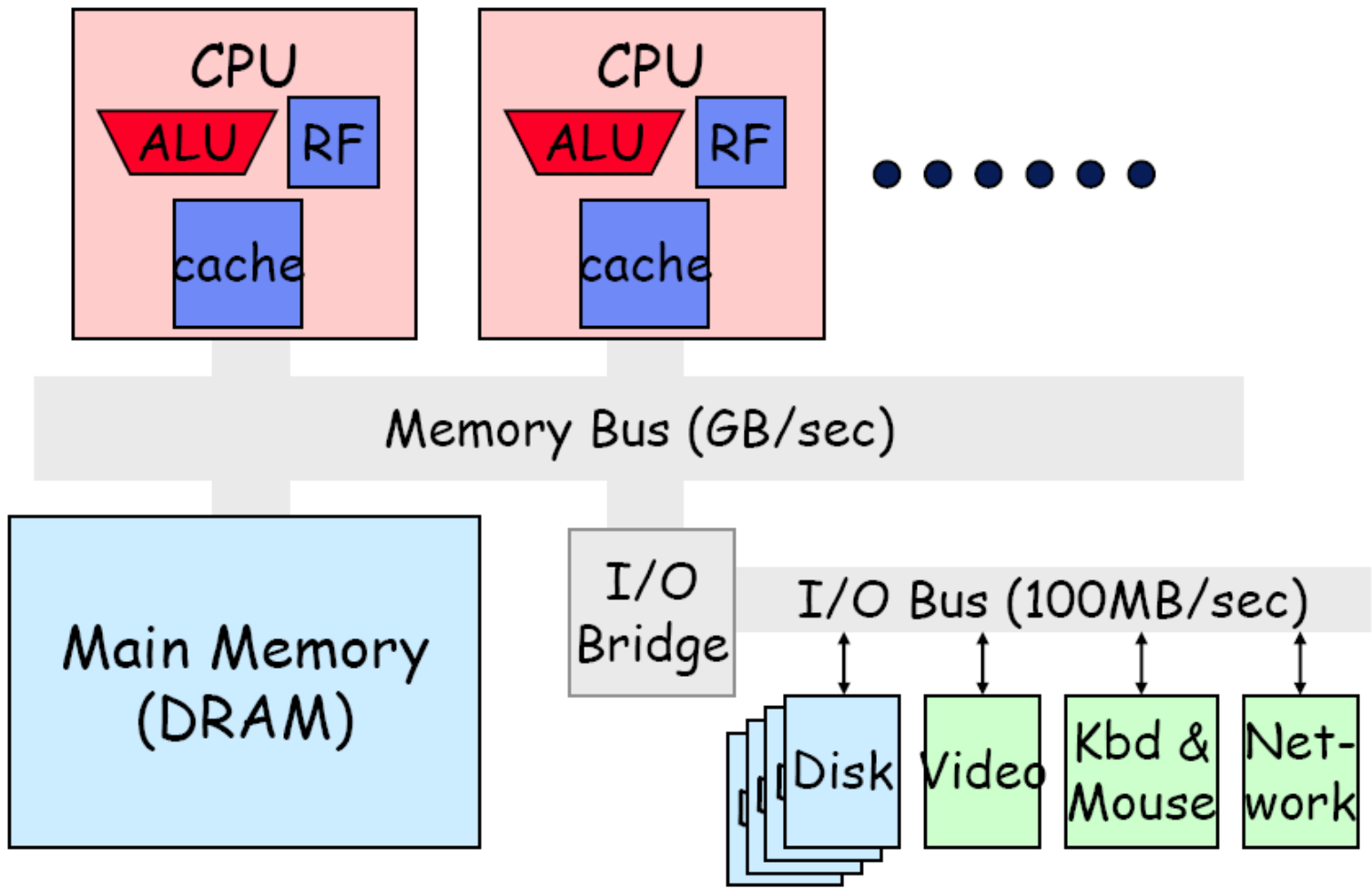
- Components of an Embedded Computer
  - Processor
  - Memory system
  - Power supply
  - Cooling system
  - Sensors
  - Converters (ADC, DAC)
  - Actuators





# Computer Organization (cont.)

- A Typical Computer Org.



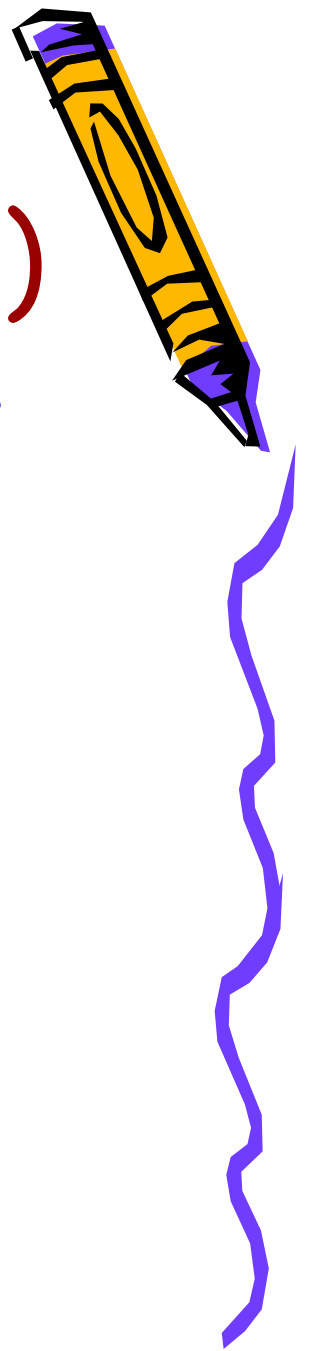


# Inside the Processor (CPU)

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

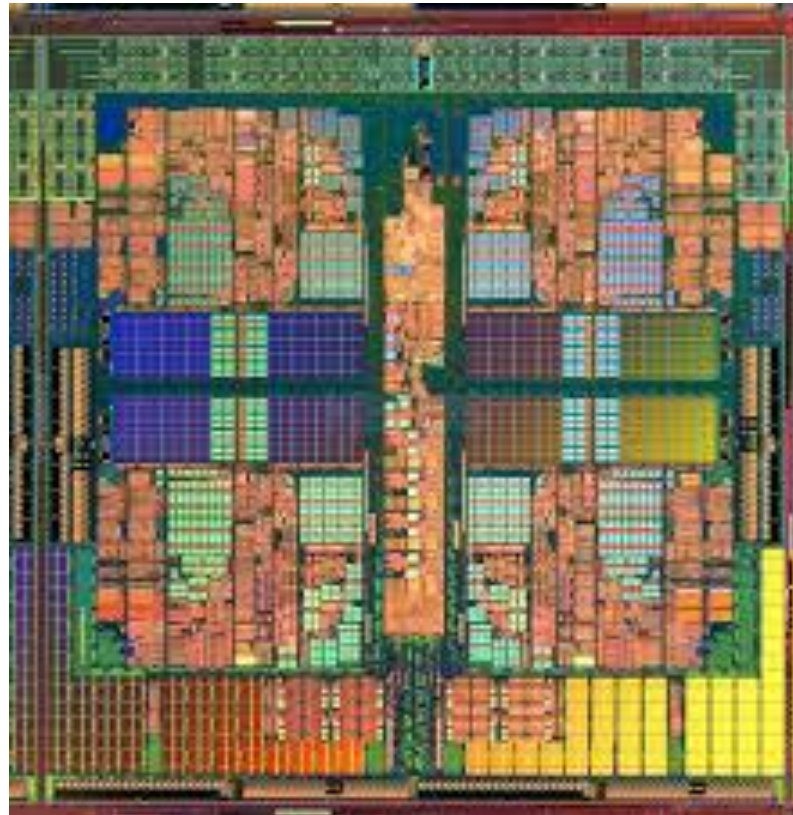


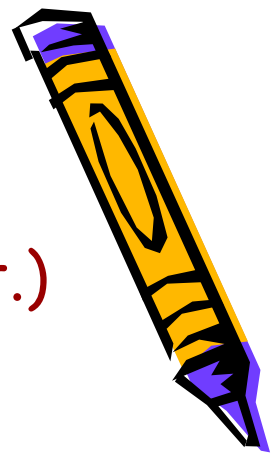




# Inside the Processor (CPU)

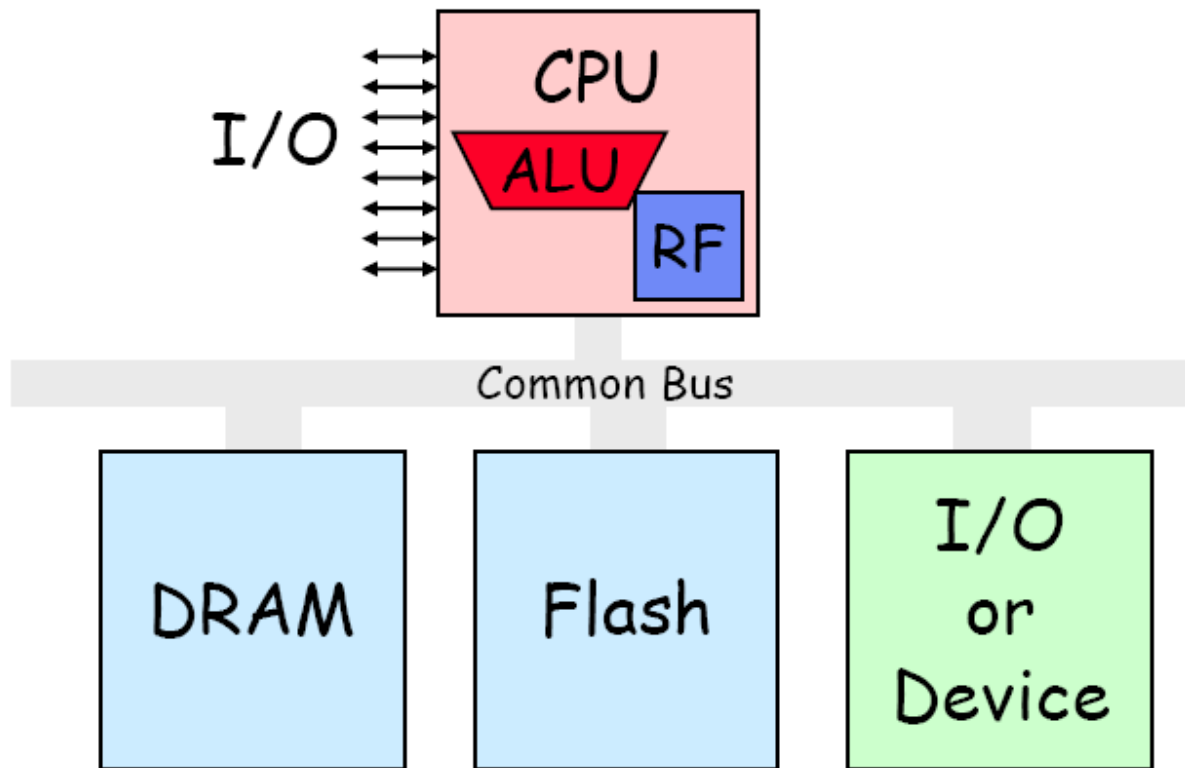
- AMD Barcelona: 4 processor cores





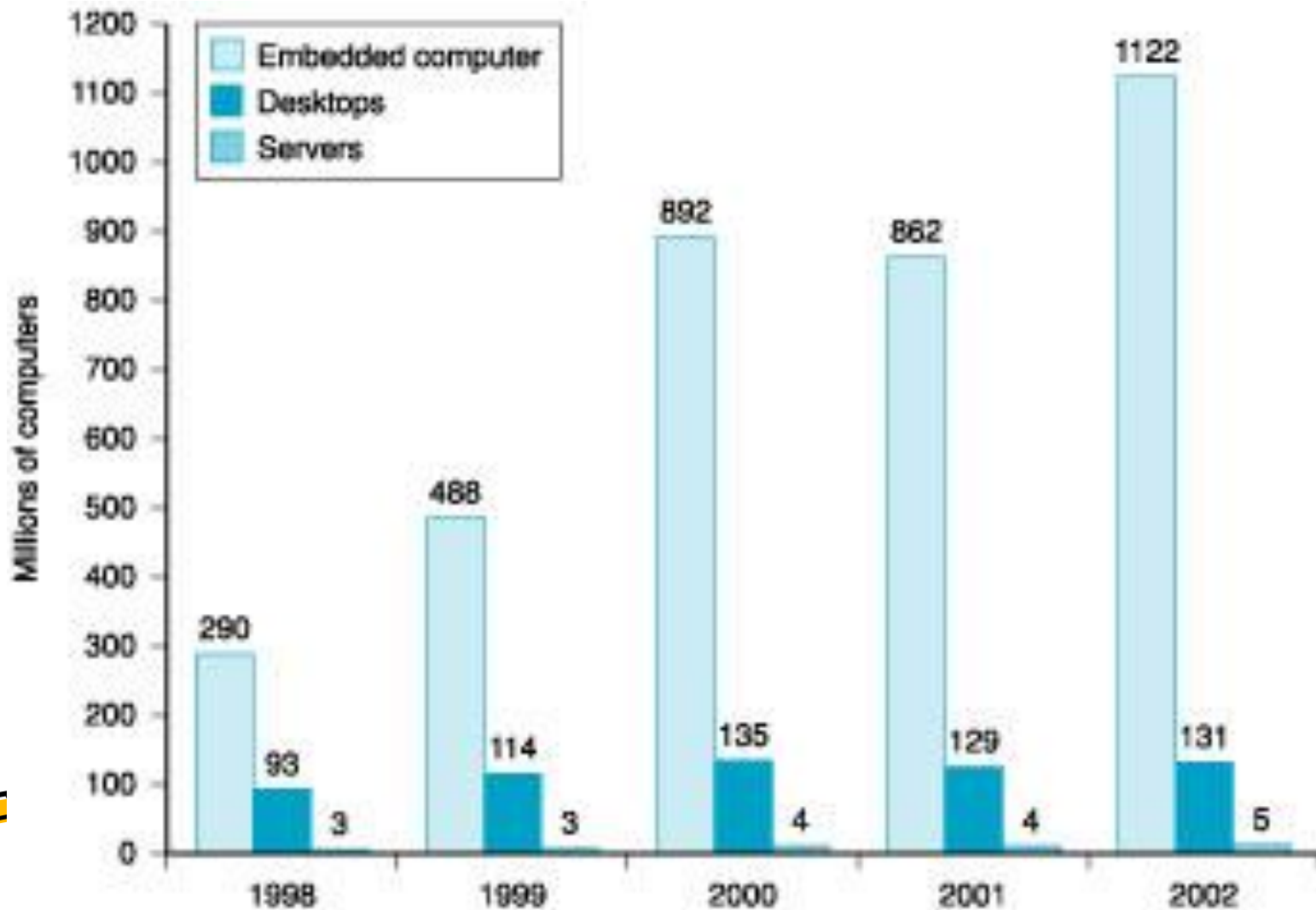
# Computer Organization (cont.)

- A Typical Embedded Computer

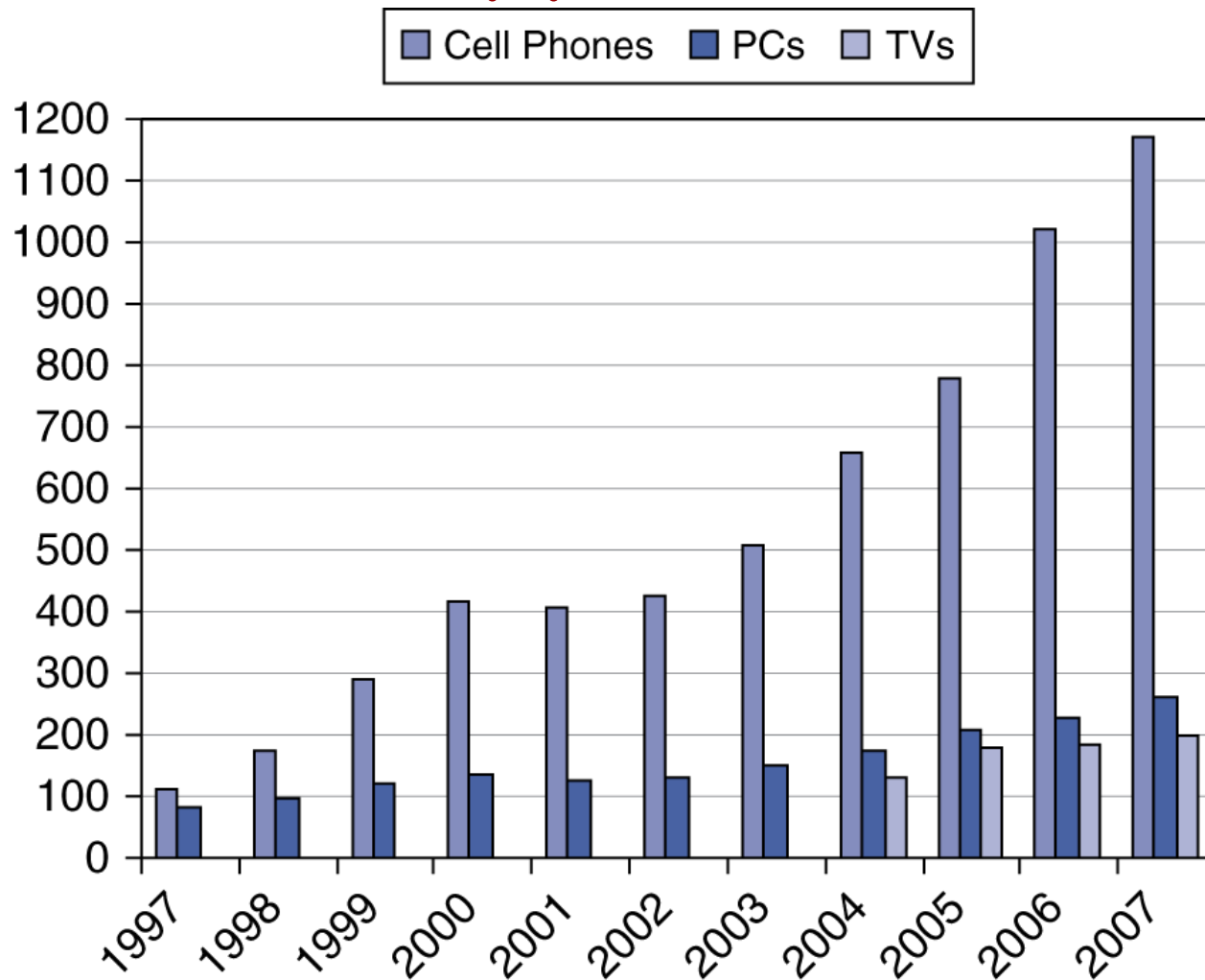




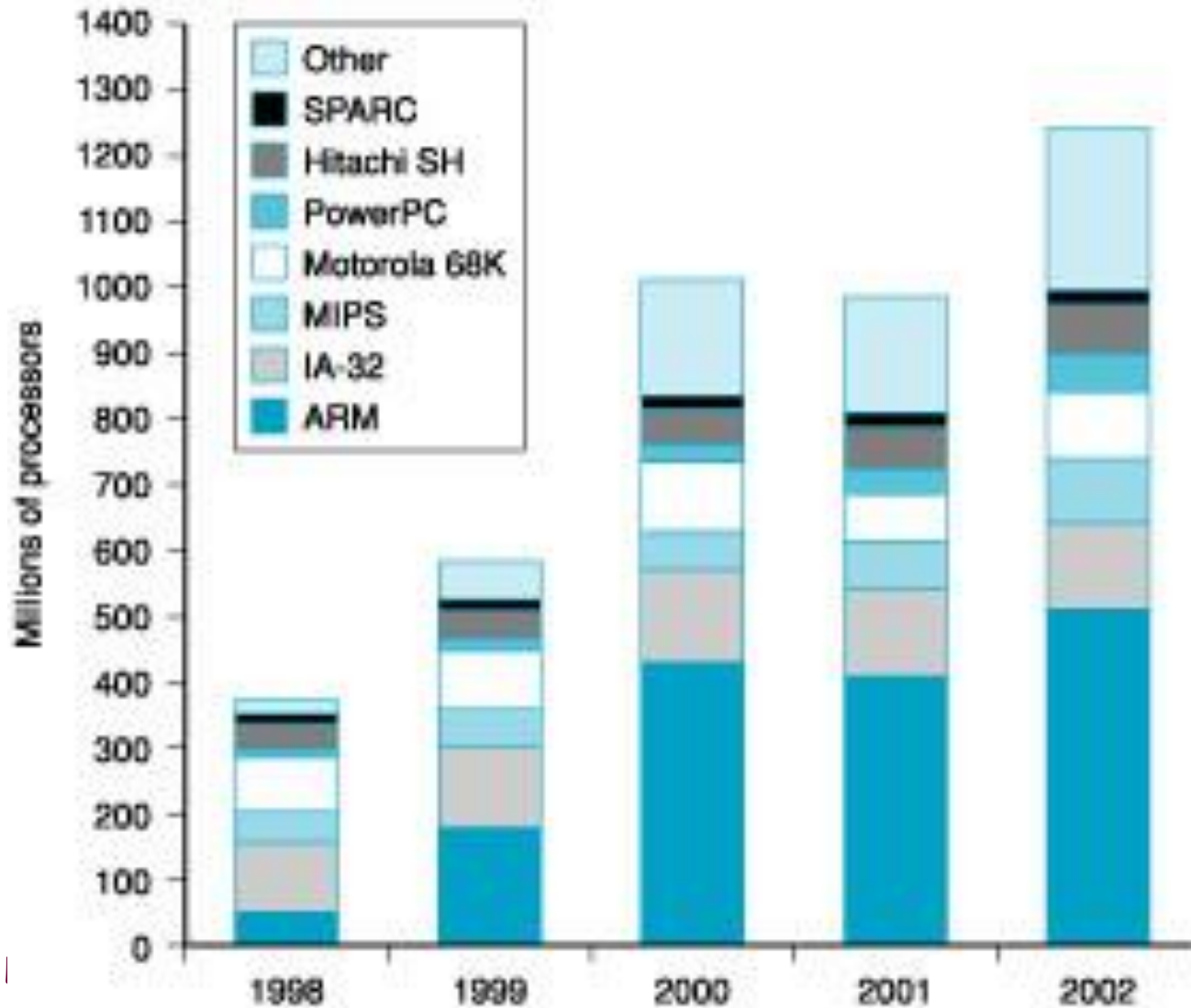
# Market: Application



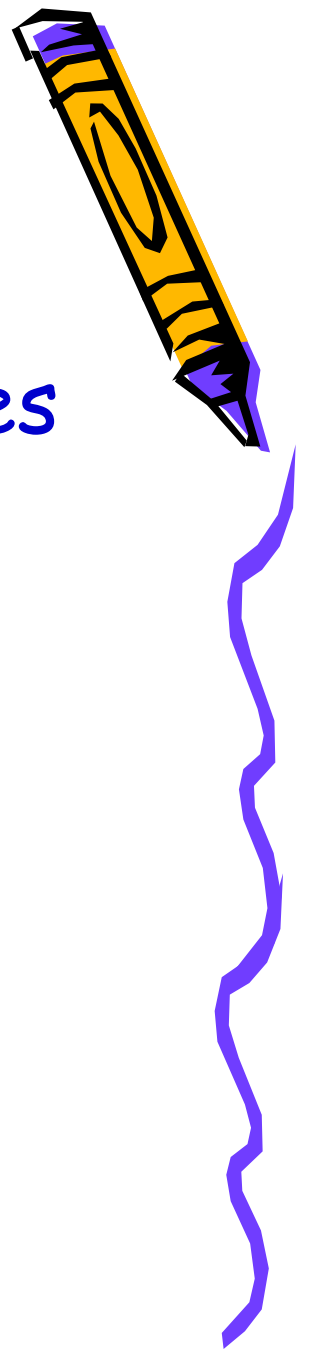
# Market: Application (cont.)



# Market: CPU Brand



# Computer History

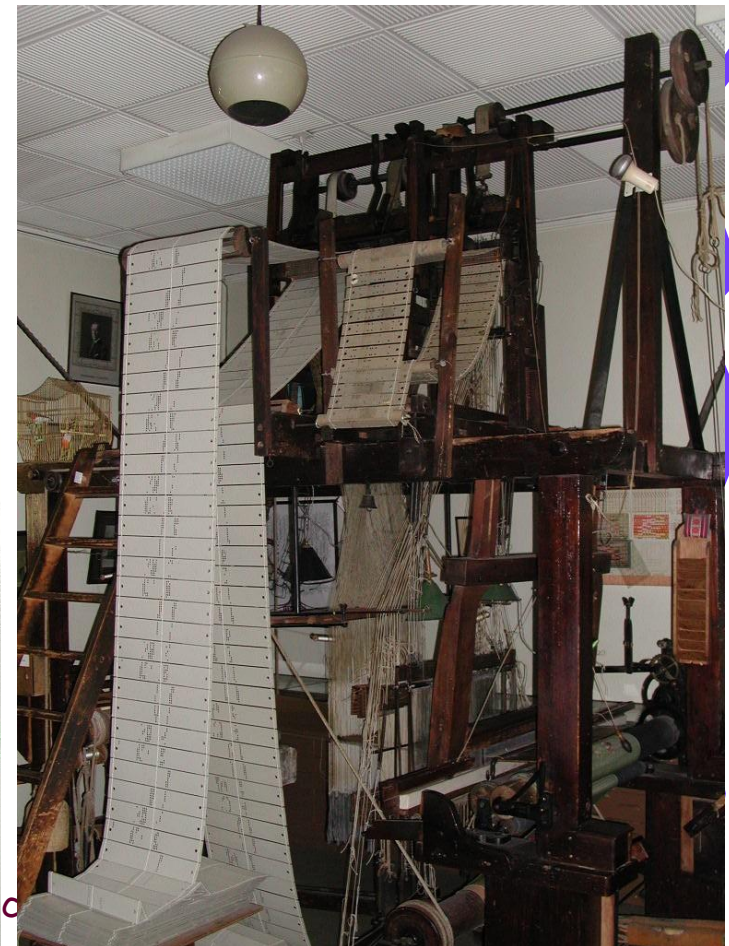


- Non-Electronic Computing Machines
  - Abacus
  - Punch machine
  - Difference engine
  - Analytical engine
- Electro-Mechanical Computers
- Electronic Computers



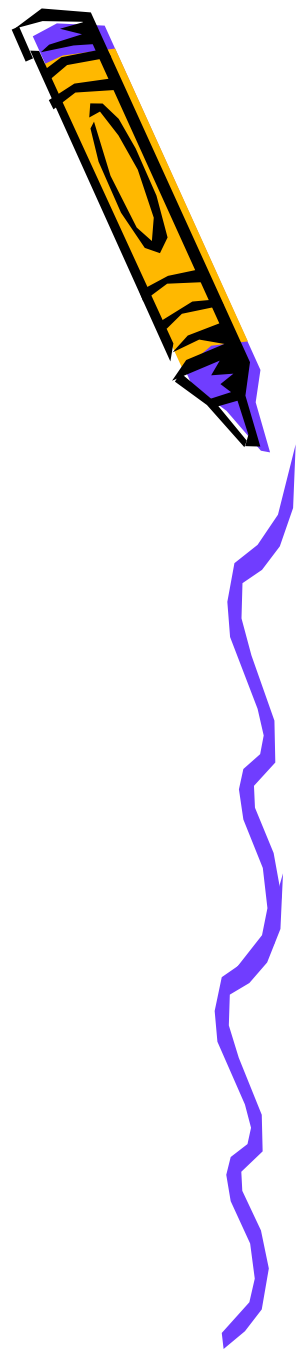
# Computer History (cont.)

- Non-Electronic Computing Machines



# Computer History (cont.)

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





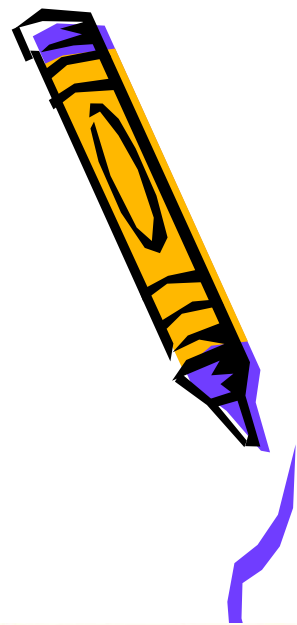
# Computer History (cont.)



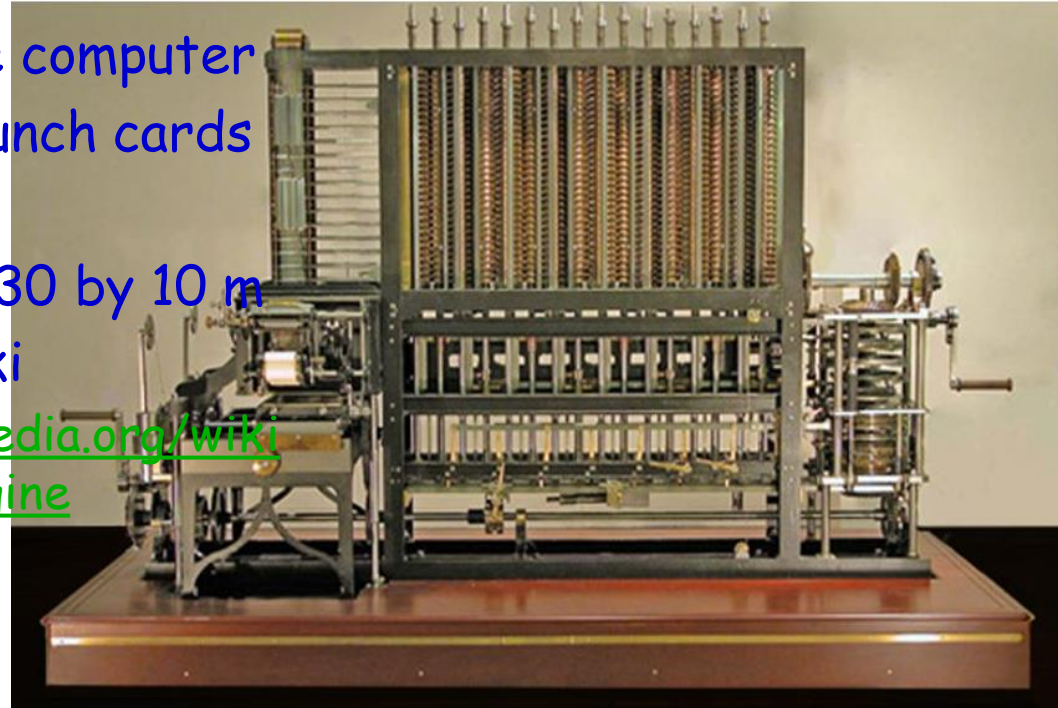
- Non-Electronic Computing Machines
  - Difference engine, 1823
    - Evaluated polynomial functions using additions
    - By Charles Babbage
    - Special-purpose computer
    - Built by George & Edward Shuetz in 1855
    - Read more on Wiki
      - [http://en.wikipedia.org/wiki/Difference\\_engine](http://en.wikipedia.org/wiki/Difference_engine)



# Computer History (cont.)



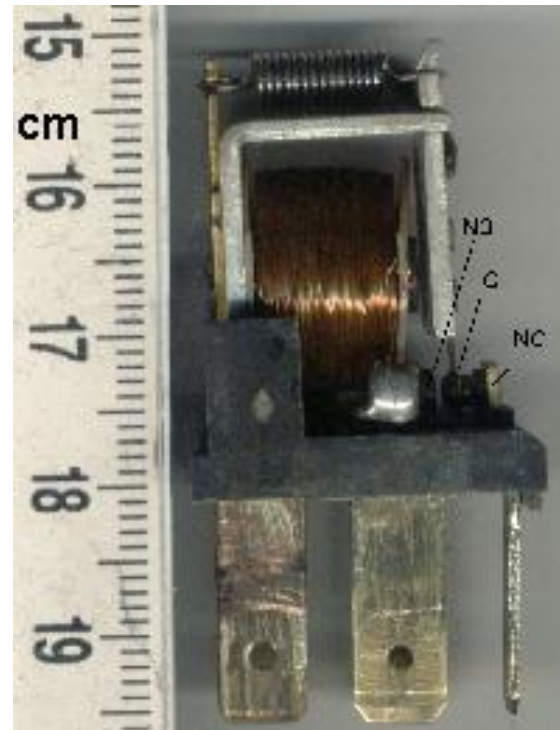
- Non-Electronic Computing Machines
  - Analytical engine, 1833
    - A general purpose computer
    - Programmed by punch cards
    - Never completed
    - Would have been 30 by 10 m
    - Read more on Wiki
      - [http://en.wikipedia.org/wiki/Analytical\\_engine](http://en.wikipedia.org/wiki/Analytical_engine)





# Computer History (cont.)

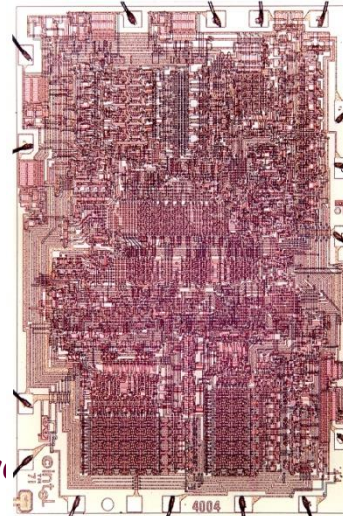
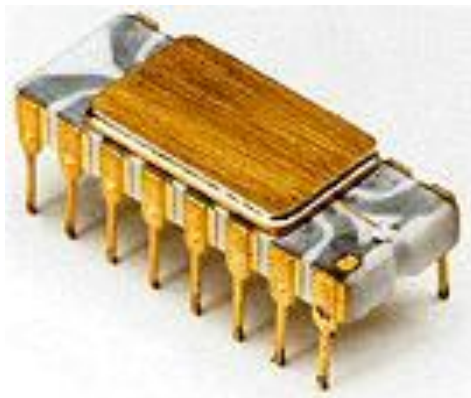
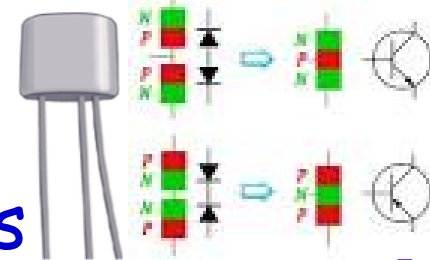
- ElectroMechanical Computing Machines
  - Early 1900s
  - Switches, relays



# Computer History (cont.)

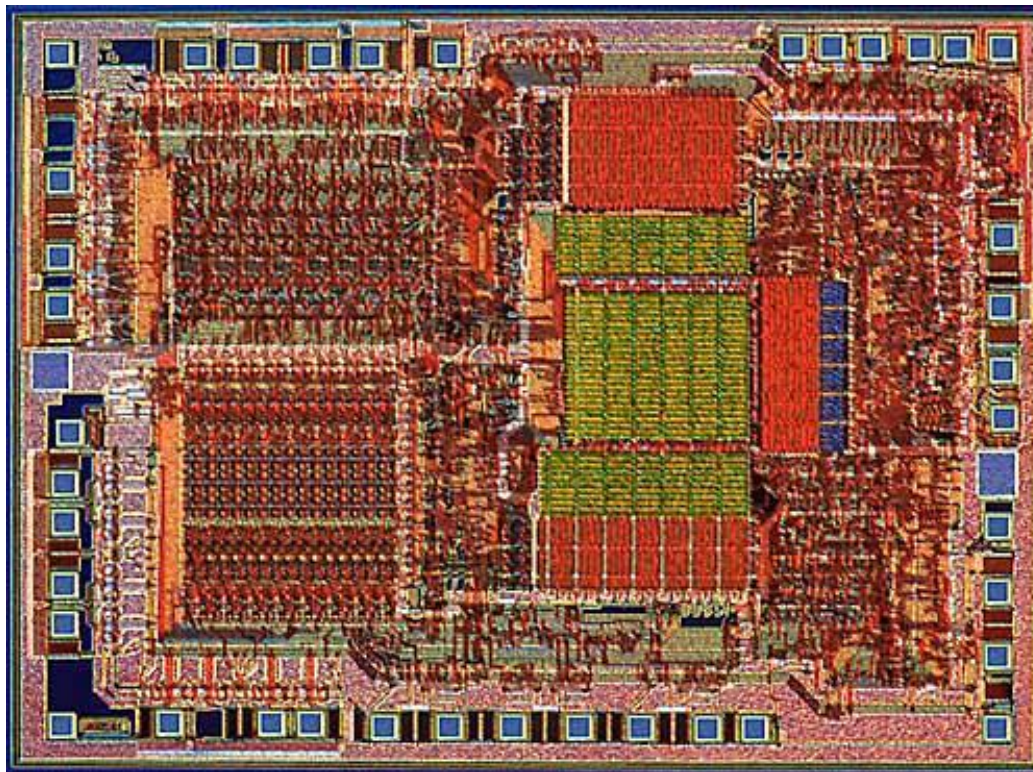
- Electronic Computers

- 1<sup>st</sup> generation: vacuum tubes
  - 1945-1955
- 2<sup>nd</sup> generation: BJT transistors
  - 1955-1965
- 3<sup>rd</sup> generation: integrated circuits
  - 1965-1974



# Computer History (cont.)

- 3<sup>rd</sup> generation: integrated circuits
  - 8085 Microprocessor



**6450  
Transistors**



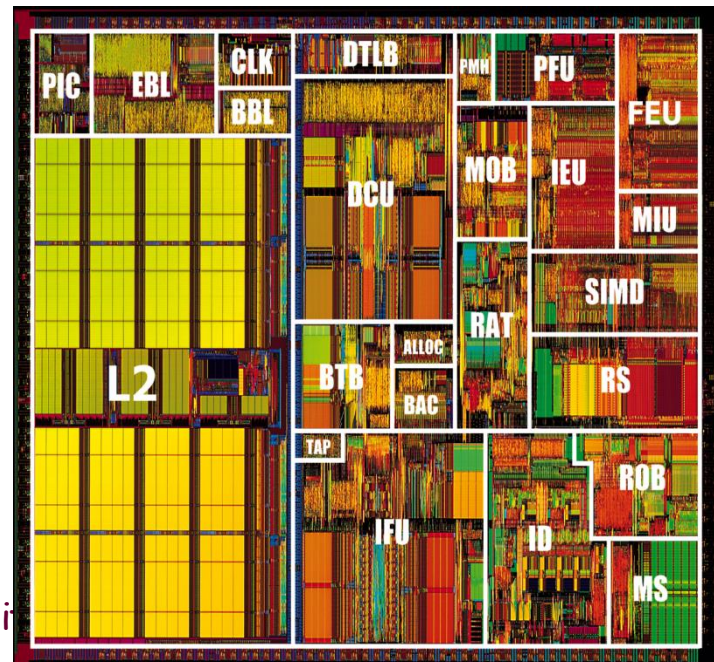
# Computer History (cont.)

- Electronic Computers
  - 4<sup>th</sup> generation: VLSI
    - 1974-1989
  - 5<sup>th</sup> generation: ULSI
    - 1990-present

Motorola  
MC68040



Pentium III



# Computer History (cont.)



- Electronic Computing Machines

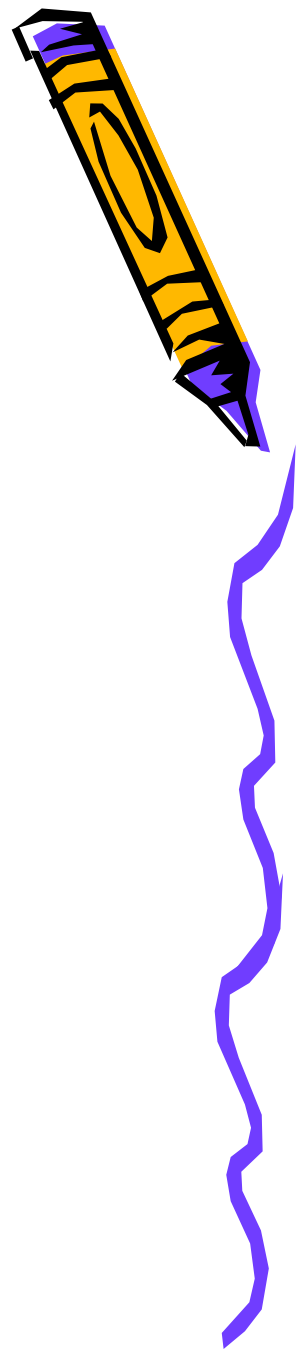
- ENIAC, 1946

- By Eckert & Mauchly, UPENN
    - 1<sup>st</sup> 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



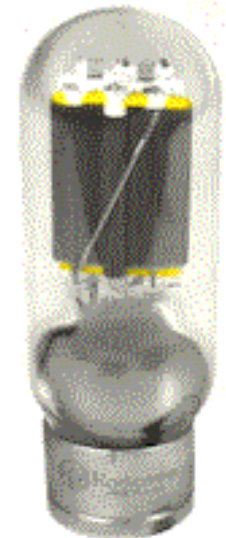
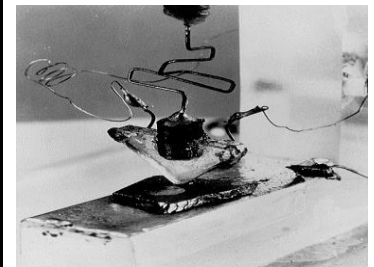
Xerox Alto, 1973  
Early PC with mouse and GUI



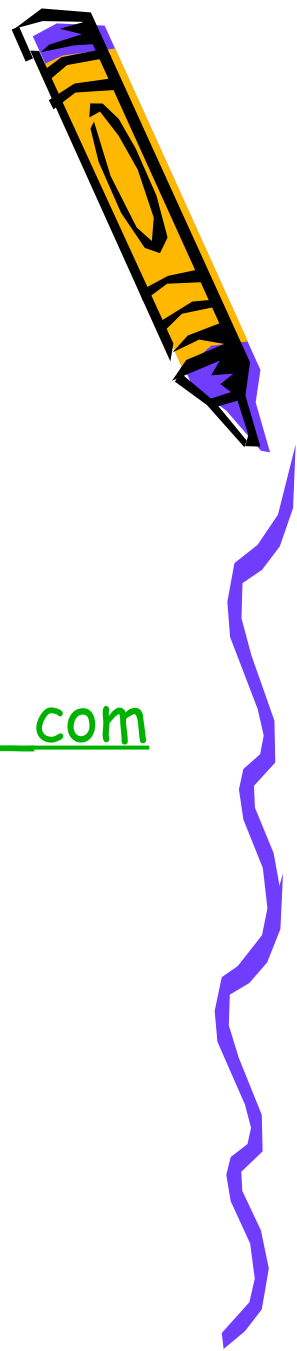
# Computer History (cont.)

- 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.)



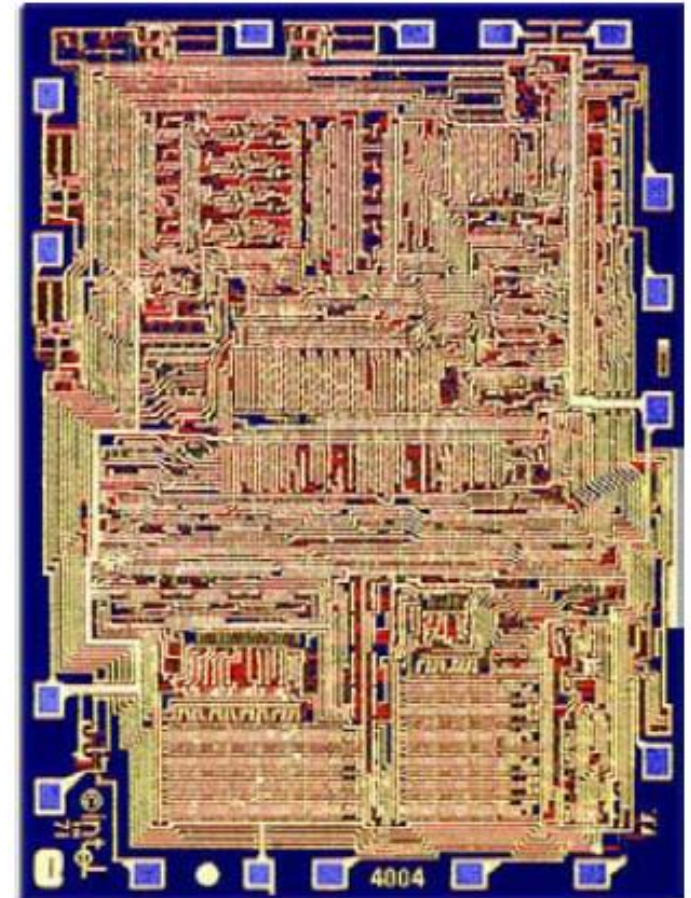
- Electronic Computing Machines
  - Read more on Wiki
    - <http://en.wikipedia.org/wiki/Computer>
    - [http://en.wikipedia.org/wiki/History\\_of\\_computing\\_hardware](http://en.wikipedia.org/wiki/History_of_computing_hardware)



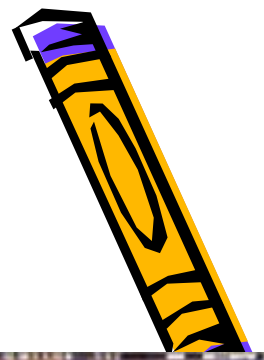
# Computer History (cont.)



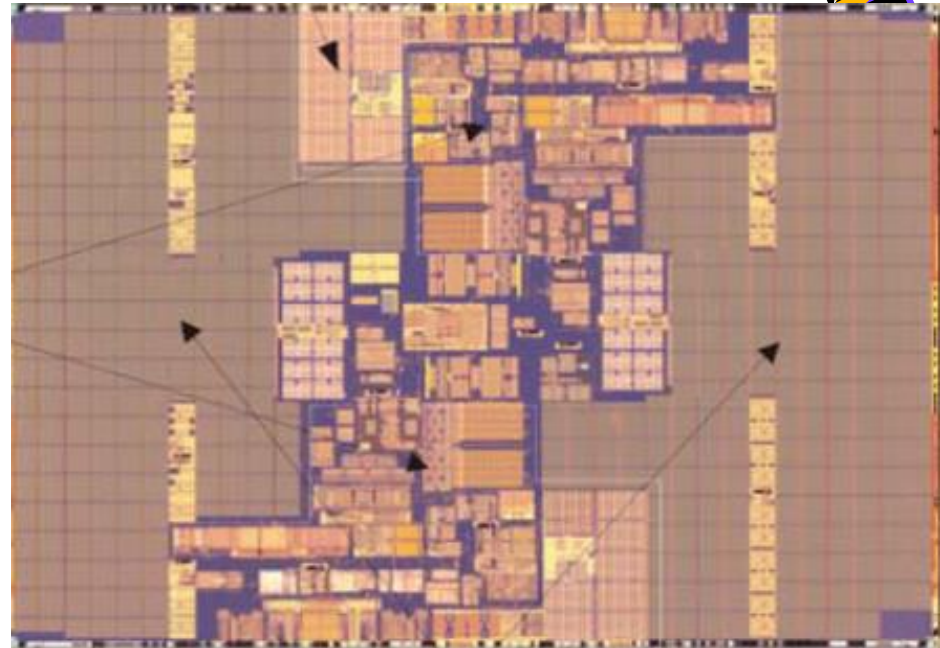
- CPU History
  - Intel 4004,
    - 1<sup>st</sup> single chip CPU in textbooks
    - 1970
    - 4-bit processor
    - 2,300 transistors
    - 16-pin DIP package
    - About 100 kHz
    - 100K OPs per second
    - More info at Intel website
      - [www.intel.com/museum](http://www.intel.com/museum)



# Computer History (cont.)

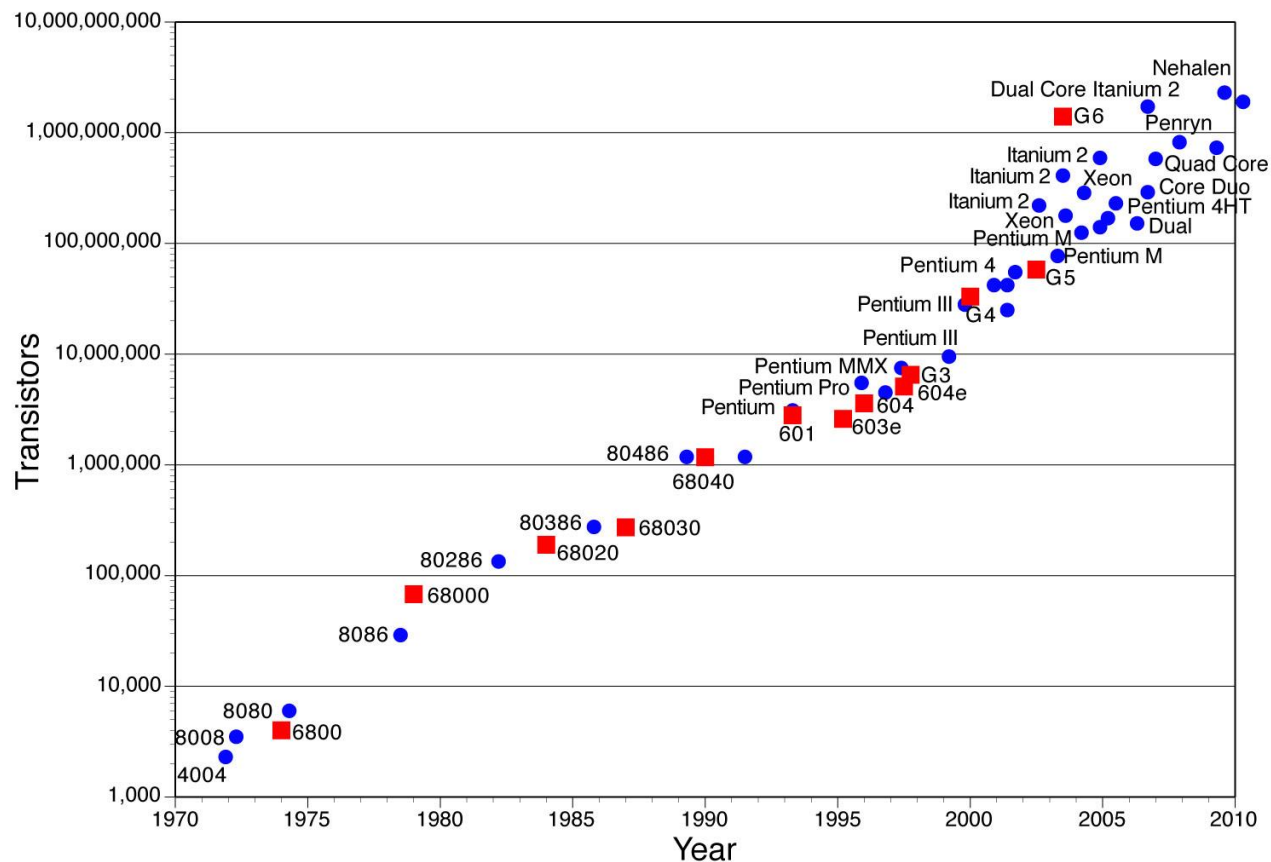


- CPU History
  - Intel Itanium
    - Montecito
    - 2004
    - 64-bit processor
    - 1.7 billion transistors
    - 1.7 GHz
    - Issue up to 8 instructions per cycle
    - 26 MB of cache memory

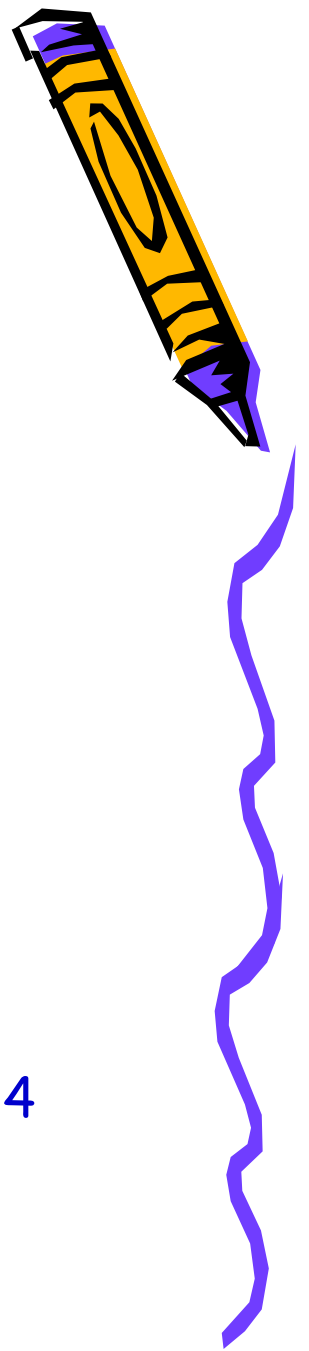


# Moore's Law

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



# Moore's Law (cont.)



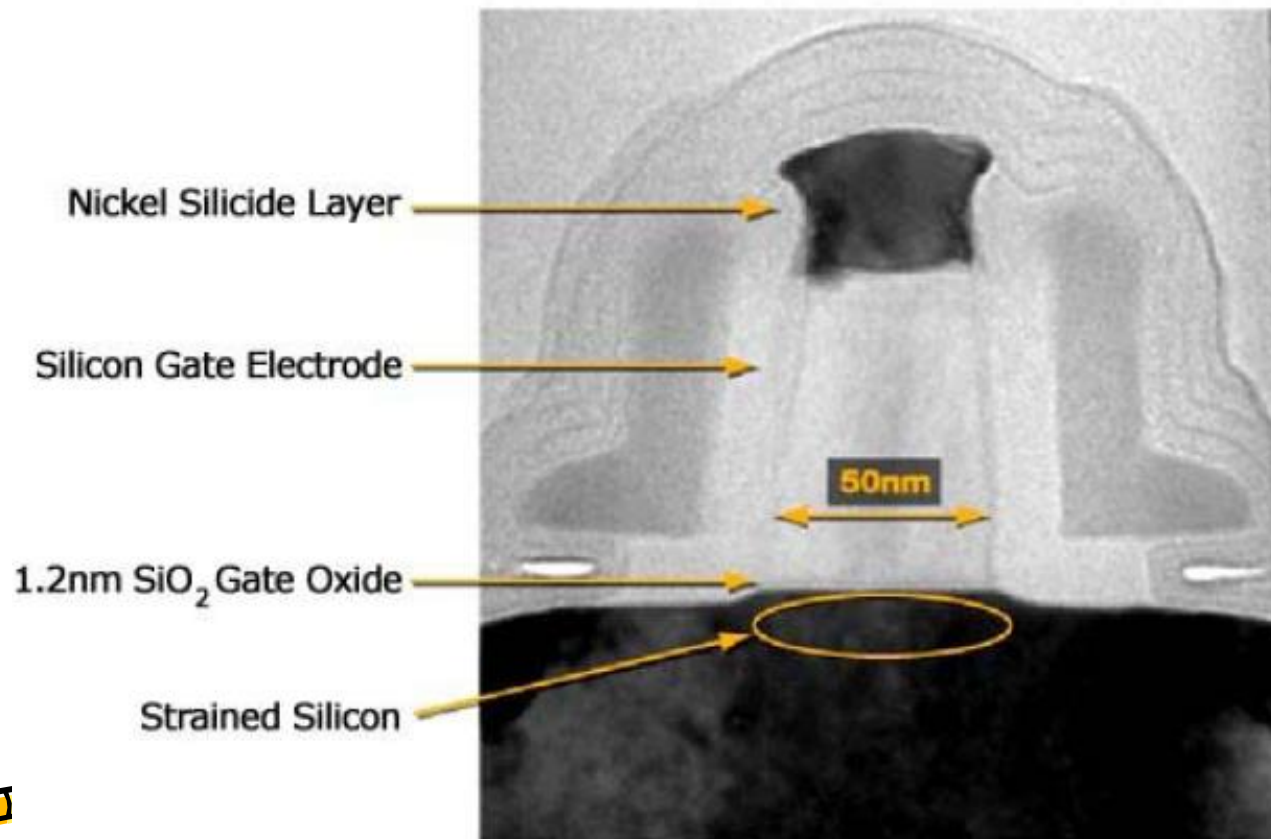
- Who's Moore?
  - Gordon Moore a co-founder of Intel Corp.
- Corollaries of Moore's Law
  - Performance of computers doubles every two-year
    - Per unit cost
  - Power consumption doubles every 18 months
    - Per unit area
  - Hard disk capacity doubles every 24 months
  - RAM storage capacity doubles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



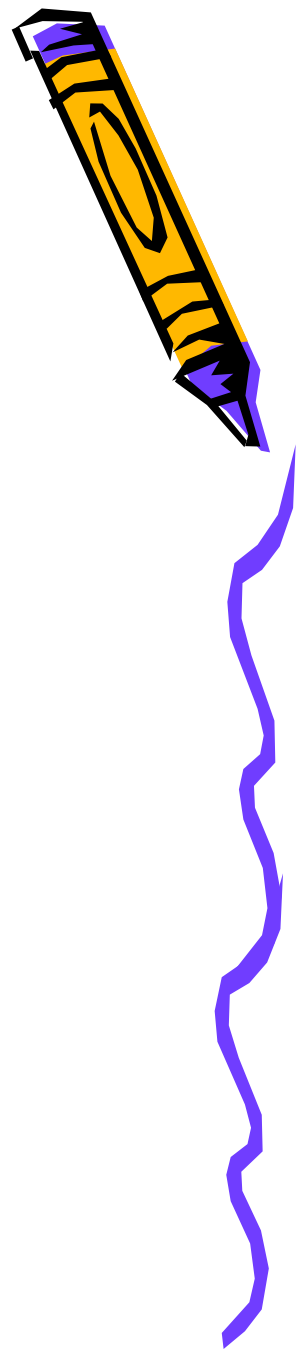
# Moore's Law (cont.)



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



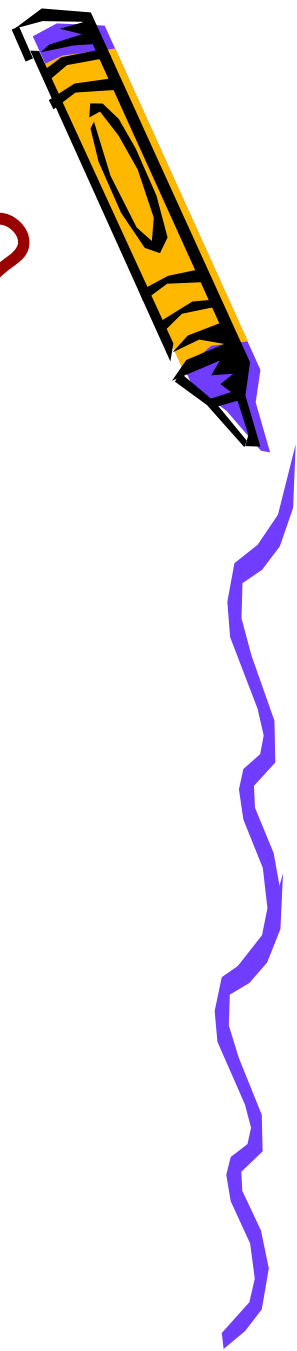
# Moore's Law (cont.)



- 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

