컴퓨터 공학 개론
Lecture 2

2017

김태성

COMPUTERS

The Computer Revolution

- Progress in computer technology
  - Supported by advanced semiconductor technology

Year	1985	1989	1993	1997	1999	2000	2006	2008
CPU	80386	80486	Pentium	P II	P III	P 4	Core 2	Core i7
# Trans.	275K	1,200K	3,100K	7,500K	9,500K	42M	291M	781M

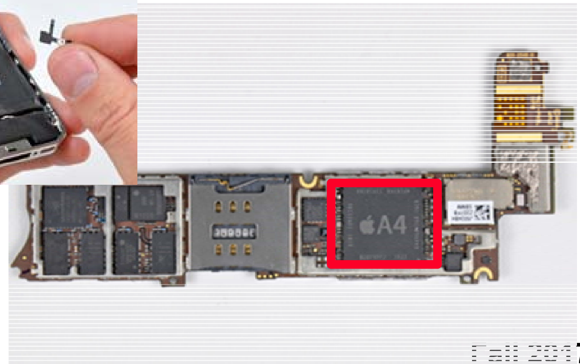
- Makes novel applications feasible
  - Computers in automobiles
  - Cell phones
  - Human genome project
  - Internet
  - AI
- Computers are pervasive

Classes of Computers

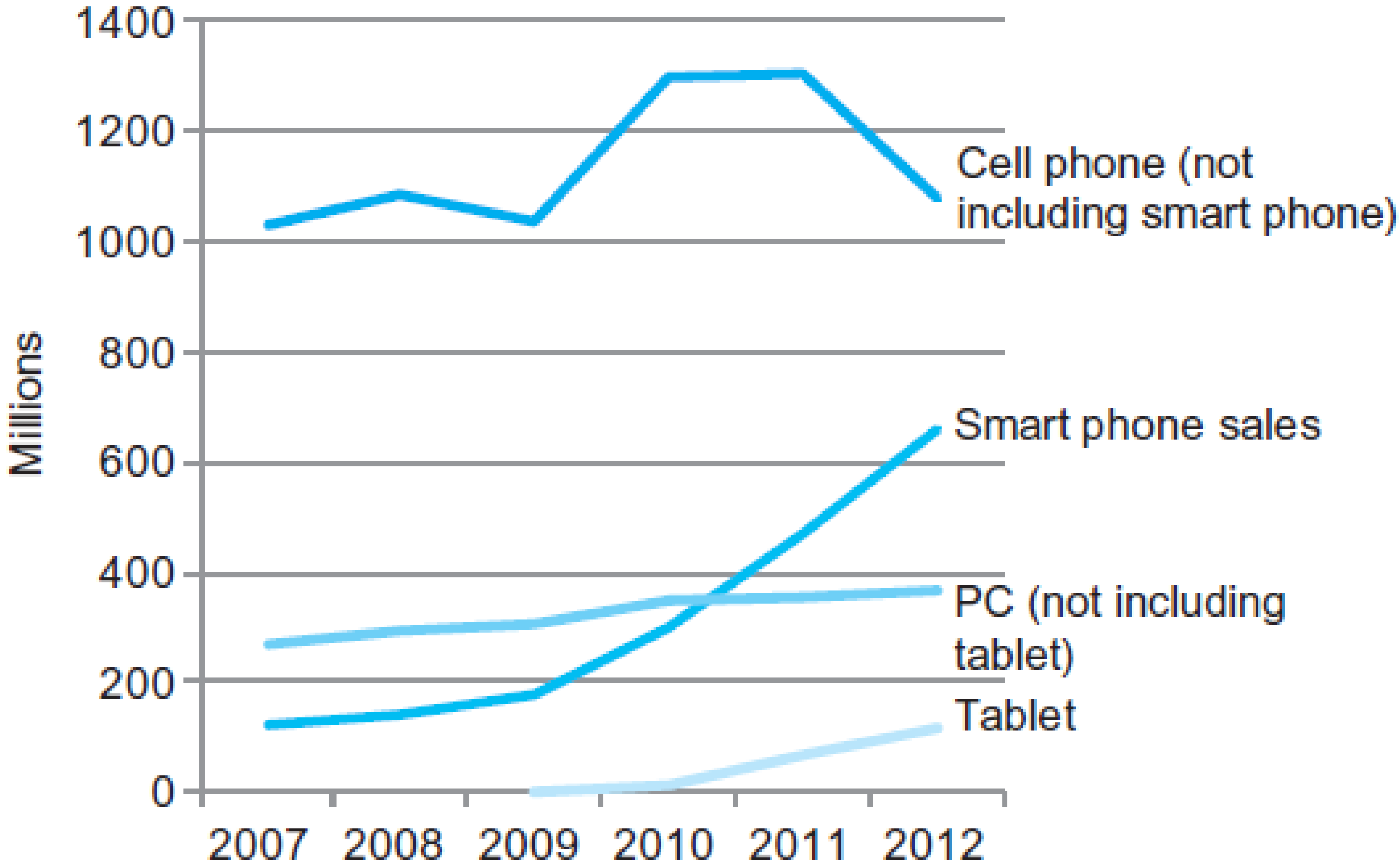
- Desktop computers
  - General purpose, variety of software
  - Subject to cost/performance tradeoff

- Server computers
  - Network based
  - High capacity, performance, reliability
  - Range from small servers to building sized

- Embedded computers
  - Hidden as components of systems
  - Stringent power/performance/cost constraints

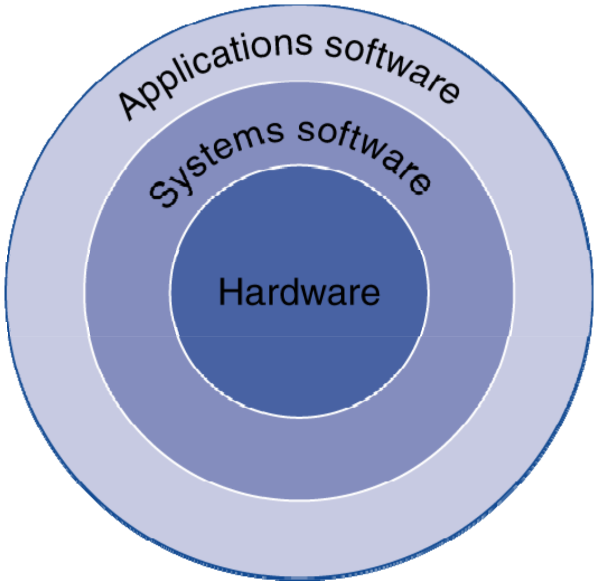


The Processor* Market



*processor: a core element of a computer that can execute computer programs

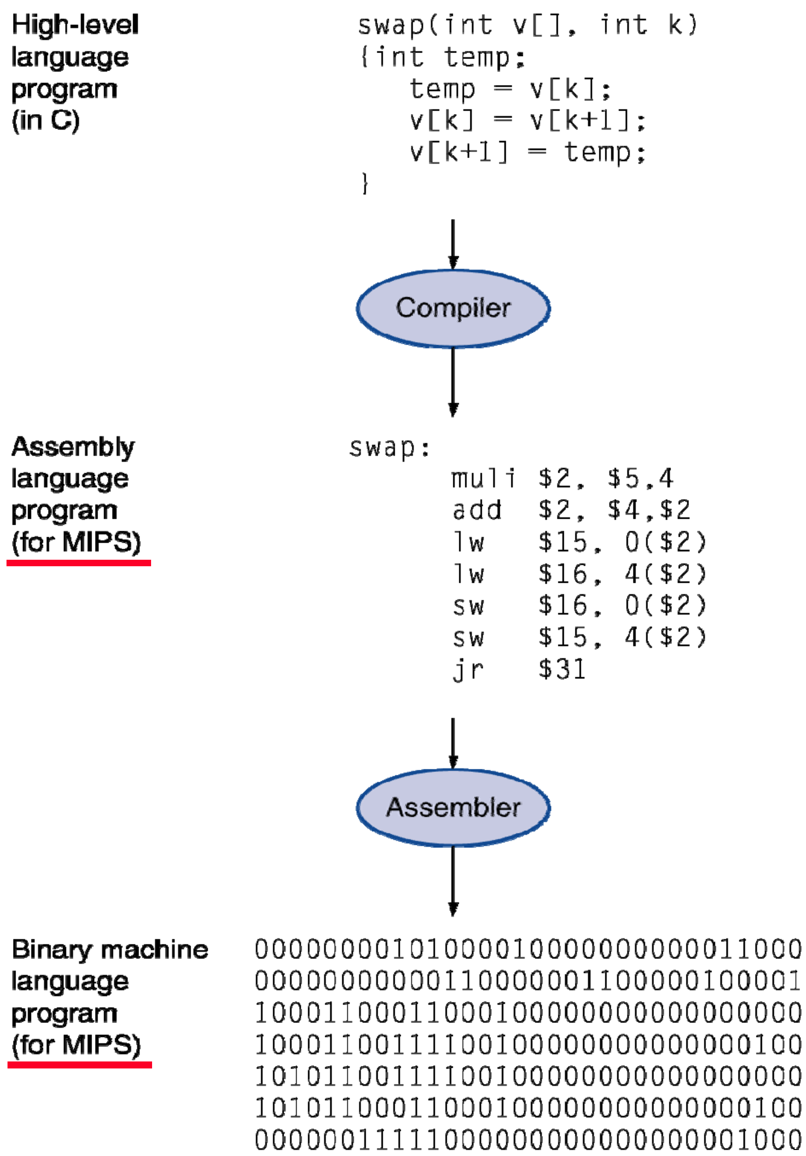
Below Your Program



- Application software
  - Written in high-level language
- System software
  - Compiler: translates high level language code(e.g. C) to machine code
  - Operating System: service code
    - Handling input/output
    - Managing memory and storage
    - Scheduling tasks & sharing resources
- Hardware
  - Processor, memory, I/O controllers

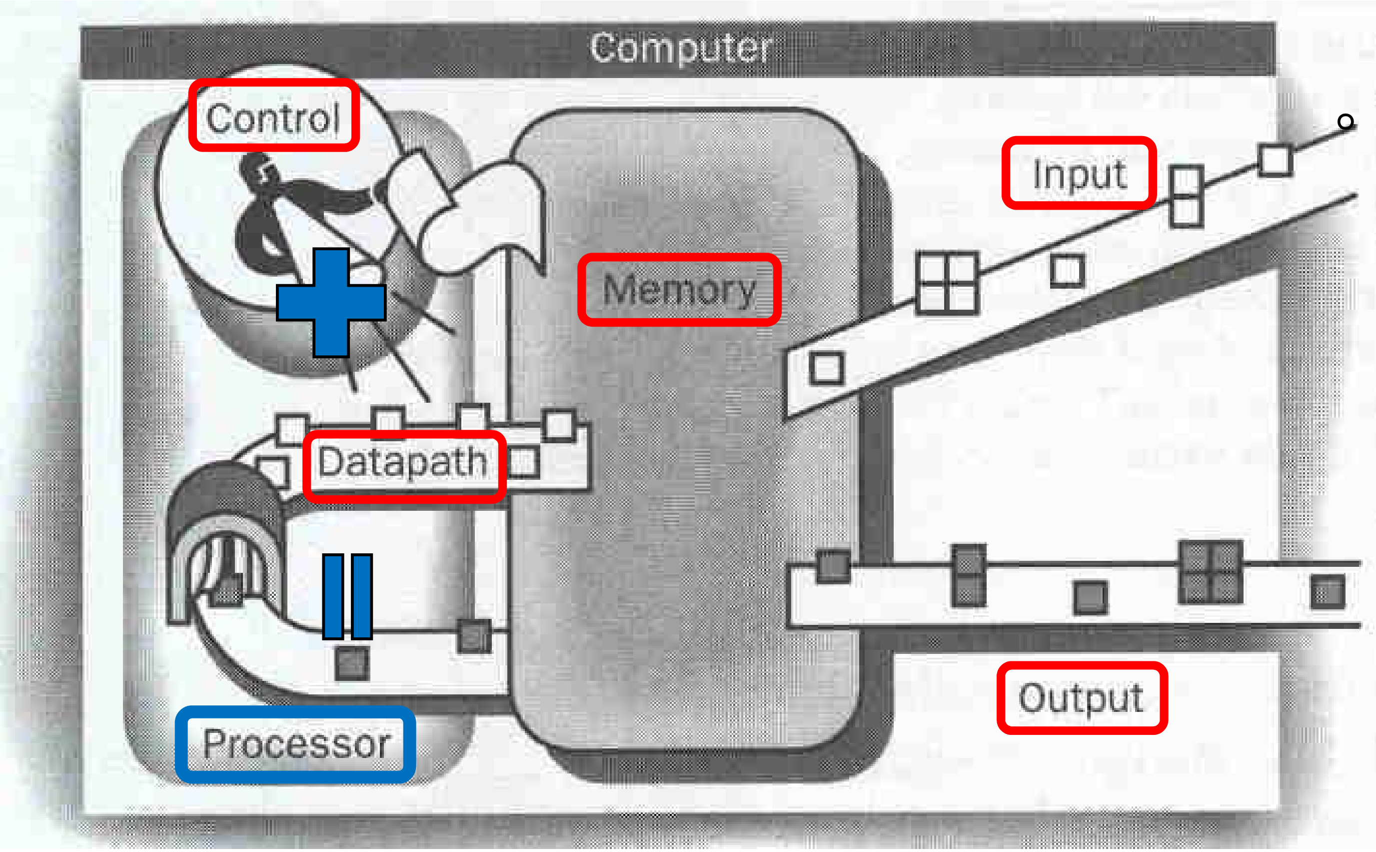
Levels of Program Code

- **High-level language**
  - **Level of abstraction closer to problem domain**
  - **Provides for productivity and portability**
- **Assembly language**
  - **Textual representation of instructions**
- **Hardware representation**
  - **Binary digits (bits)**
  - **Encoded instructions and data**



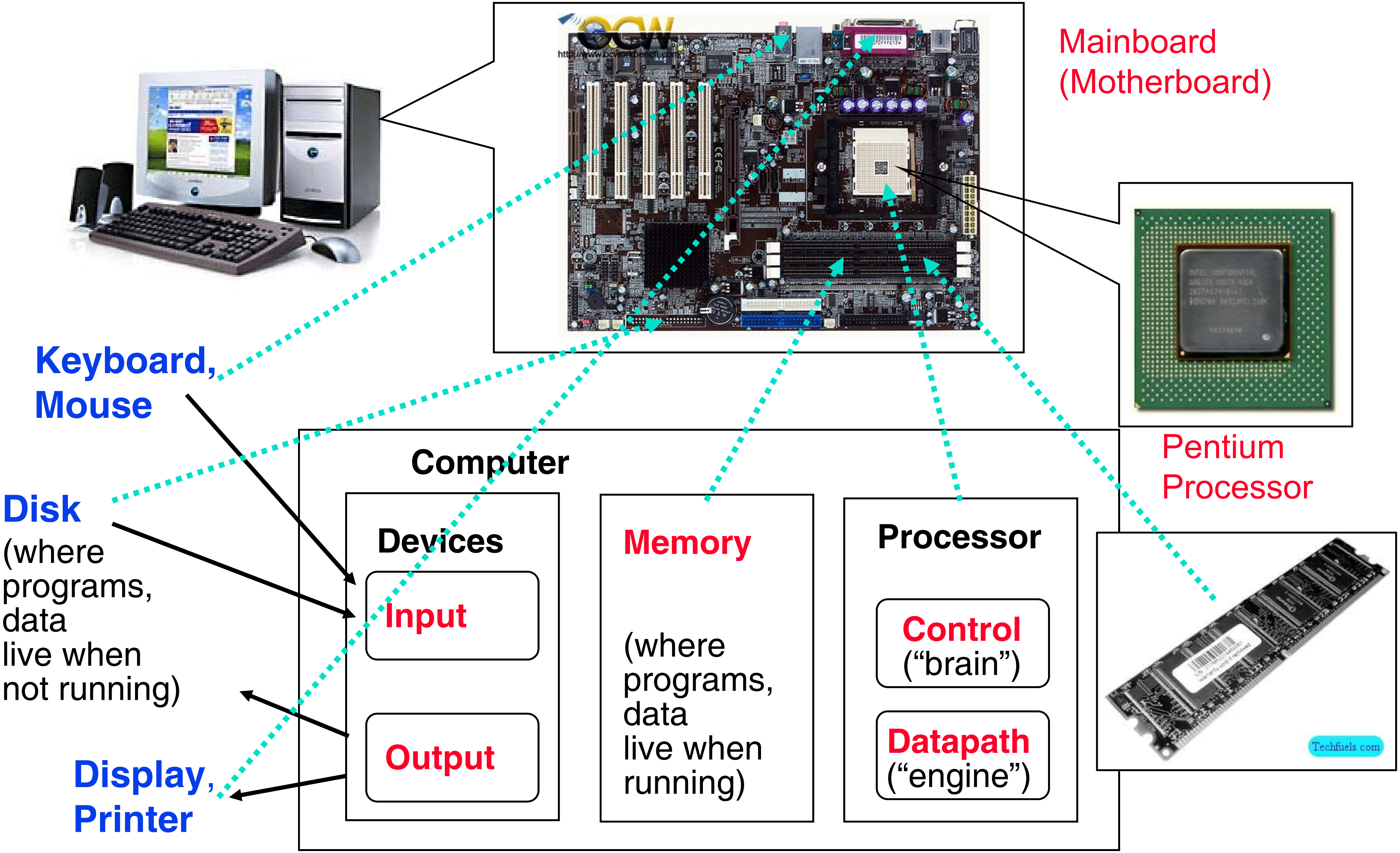
Components of a Computer

The BIG Picture



- Same components for all kinds of computer
  - Desktop, server, embedded
- Input/output includes
  - User-interface devices
    - Display, keyboard, mouse
  - Storage devices
    - Hard disk, CD/DVD, flash
  - Network adapters
    - For communicating with other computers

Components of a Typical Computer



Inside the Processor (CPU*)

° **Datapath: performs operations on data**

° **Control: sequences datapath, memory, ...**

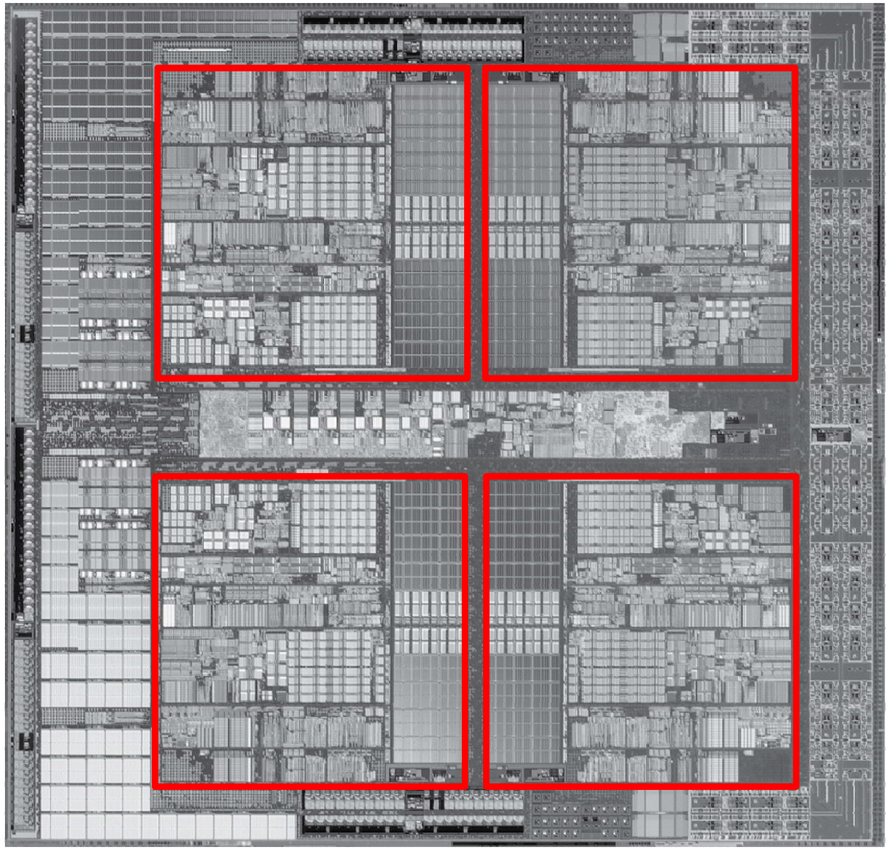
° **Cache memory**

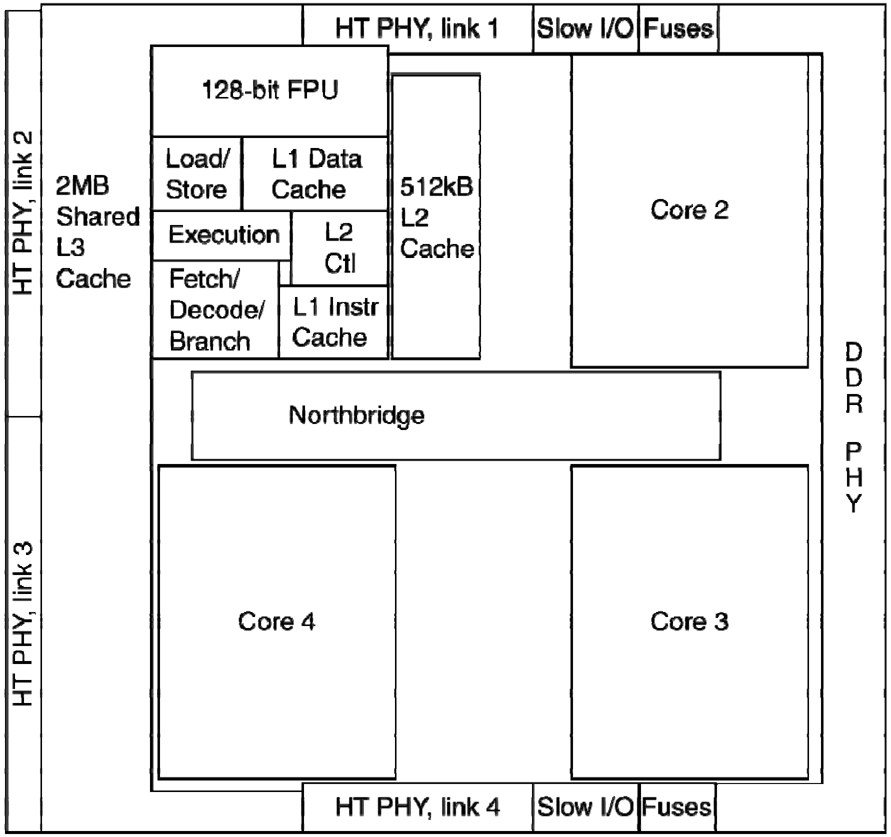
- **Small fast SRAM memory for immediate access to data**

CPU: Central Processing Unit

Inside the Processor

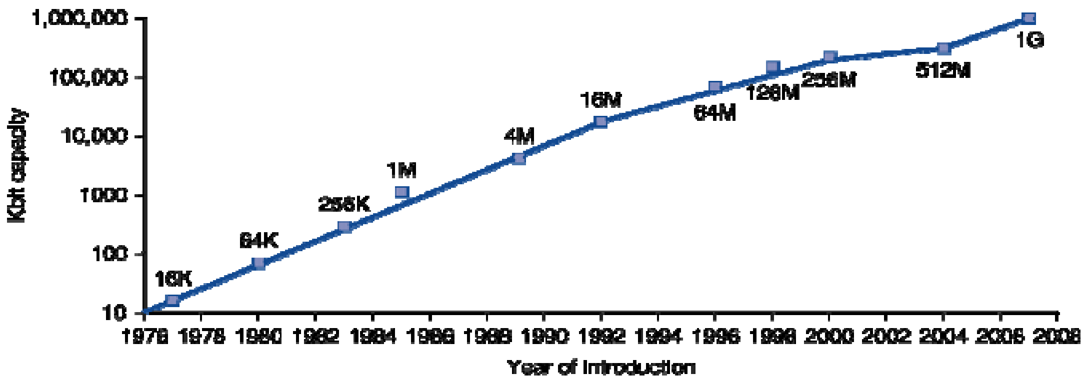
- AMD Barcelona: 4 processor cores





Technology Trends

- Electronics technology continues to evolve
  - Increased capacity and performance
  - Reduced cost



DRAM capacity

Year	Technology used in computers	Relative performance/unit cost
1951	Vacuum tube	1
1965	Transistor	35
1975	Integrated circuit	900
1995	Very large-scale integrated circuit	2,400,000
2013	Ultra large-scale integrated circuit	250,000,000,000

International System of Units (SI Units)

Prefix	Symbol for Prefix		Scientific Notation
exa	E	1 000 000 000 000 000 000	10^{18}
peta	P	1 000 000 000 000 000	10^{15}
tera	T	1 000 000 000 000	10^{12}
giga	G	1 000 000 000	10^{9}
mega	M	1 000 000	10^{6}
kilo	k	1 000	10^{3}
hecto	h	100	10^{2}
deka	da	10	10^{1}
----	--	1	10^{0}
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	µ	0.000 001	10^{-6}
nano	n	0.000 000 001	10^{-9}
pico	p	0.000 000 000 001	10^{-12}
femto	f	0.000 000 000 000 001	10^{-15}
atto	a	0.000 000 000 000 000 001	10^{-18}

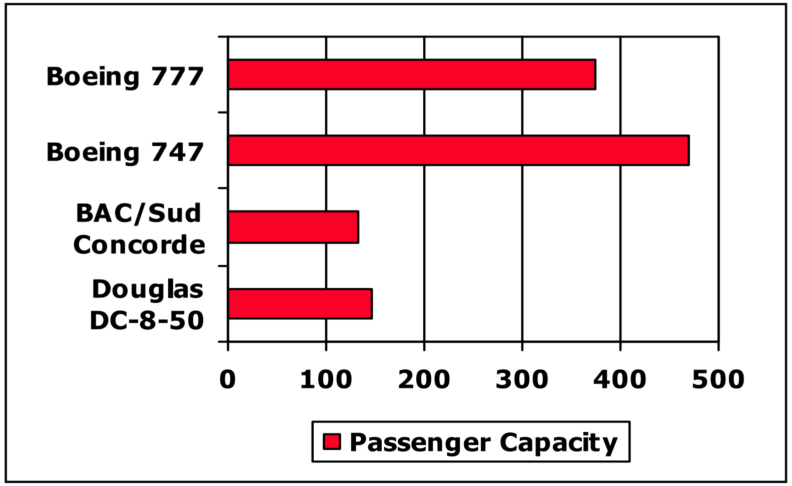
PERFORMANCE

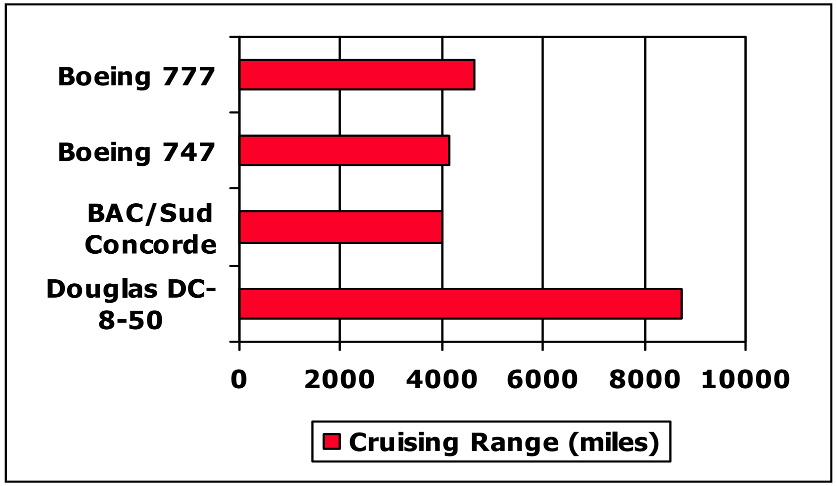
Whose Performance Is Better?

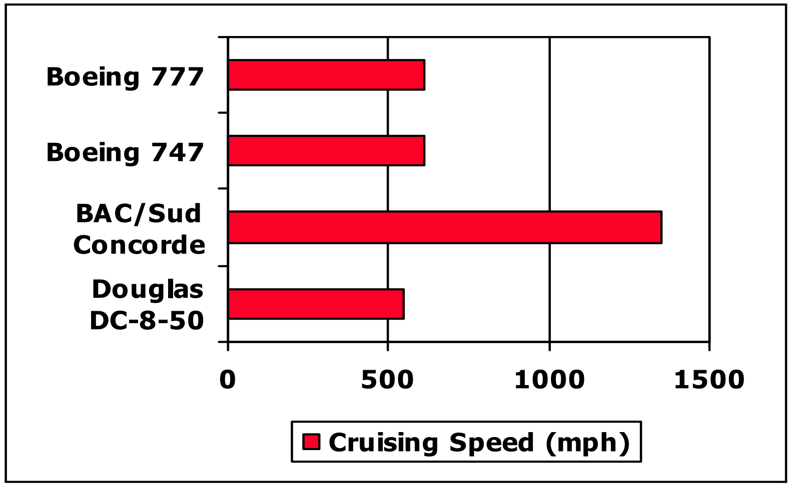
Whose Performance Is Better?

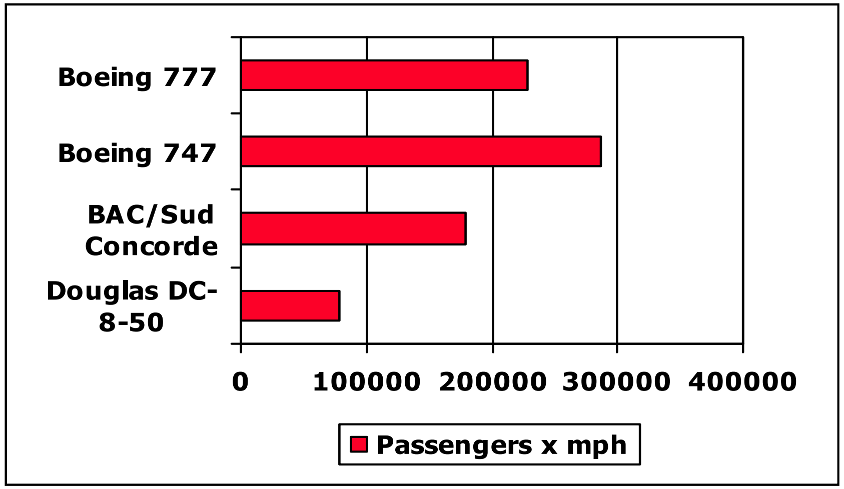
Defining Performance

° **Which airplane has the best performance?**









Response Time and Throughput

- Response time
  - How long it takes to do a task
- Throughput
  - Total work done per unit time
    - e.g., tasks/transactions/… per hour
- How are response time and throughput affected by
  - Replacing the processor with a faster version?
  - Adding more processors?
- We'll focus on response time for now…

Relative Performance

- **Define "Performance = 1/Execution Time"**
- **"X is n time faster than Y"**

$$\text{Performance}_X / \text{Performance}_Y = \text{Execution time}_Y / \text{Execution time}_X = n$$

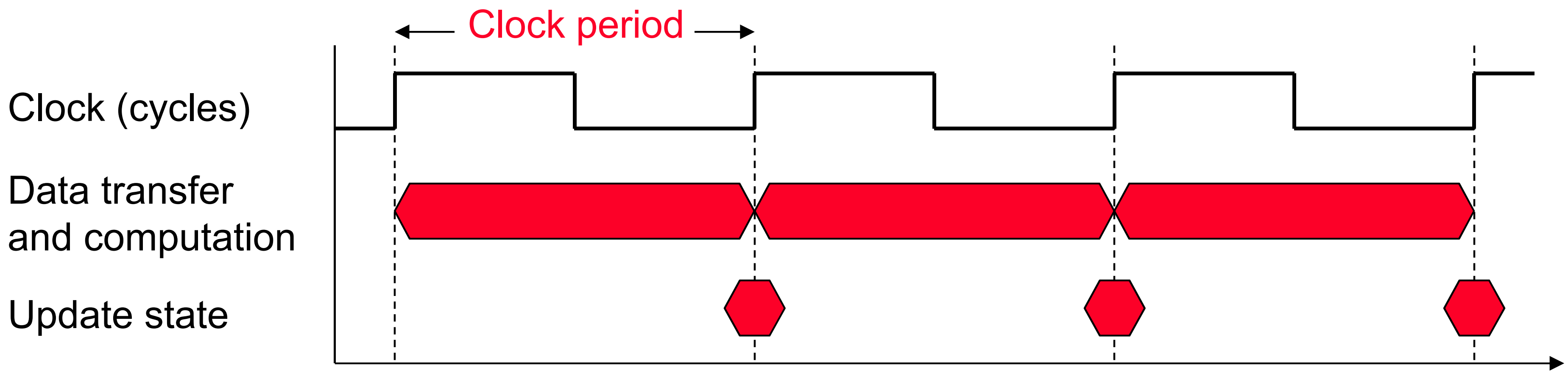
- Example: time taken to run a program
  - 10s on A, 15s on B
  - Execution Time$_B$ / Execution Time$_A$ = 15s / 10s = 1.5
  - So, A is 1.5 times faster than B

Measuring Execution Time

- Elapsed time
  - Total response time, including all aspects
    - Processing, I/O, OS overhead, idle time
  - Determines system performance
- CPU time
  - Time spent processing a given job
    - Discounts I/O time, other jobs' shares
  - Comprises user CPU time and system CPU time
  - Different programs are affected differently by CPU and system performance

CPU Clocking

- Operation of digital hardware governed by a constant-rate clock



- Clock period: duration of a clock cycle
  - e.g. **250 ps** = 0.25 ns = 250×10^{-12} s
- Clock frequency (rate): cycles per second (= $\frac{1}{clock\ period}$)
  - e.g. $\frac{1}{250\ ps}$ = 4.0×10^{9} Hz = **4.0 GHz** = 4000 MHz

CPU Clocking

삼성전자 아티브북9 Plus NT940X3G-K64 HIT 9

인텔 / 코어i5-4세대 / i5-4200U (1.6 GHz) / LED백라이트 / 터치스크린 / 33.78cm(13.3인치) / 3200x1800 / 128GB(SSD) / 4GB / DDR3L / ODD 옵션(선택) / 윈도8.1 / 인텔 / HD 4400 / 시스템 메모리 공유 / 1.39Kg / 탈착 불가능 / 4cell / 1Gbps 유선랜 / 802.11 a/b/g/n 무선랜 / WiDi / 블루투스 4.0 / HDMI / D-SUB / 웹캠 / USB 2.0 / USB 3.0 / 멀티 리더기 / 블록 키보드 / 키보드 라이트 / 색상: 블랙 / 미니 VGA, 마이크로 HDMI

상품비교

판매몰 : 153 등록월 : 2013.10 상품의견 : 11

관련기사 삼성 노트북과 올인원PC에 돌비 디지털 플러스 적용

판매조건	판매몰	최저가	묶음상품
단품	153	1,504,000원	가격비교 관심상품
필수옵션 선택 추가금결제	59	1,542,610원	가격비교 관심상품

삼성전자 아티브북9 Lite NT905S3G-K1BP

AMD / Customized QuadCore (1.4GHz) / LED백라이트 / 눈부심방지 / 33.78cm(13.3인치) / 1366x768 / 128GB(SSD) / 4GB / DDR3L / ODD 옵션(선택) / 윈도8.1 / AMD(ATI) / 라데온 HD8250 / 시스템 메모리 공유 / 1.44Kg / 2cell / 1Gbps 유선랜 / 802.11 b/g/n 무선랜 / 블루투스 4.0 / HDMI / D-SUB / 웹캠 / USB 2.0 / USB 3.0 / 멀티 리더기 / 블록 키보드 / LAN, VGA 어댑터 필요

상품비교

판매몰 : 201 등록월 : 2013.12 상품의견 : 1

관련기사 삼성 노트북과 올인원PC에 돌비 디지털 플러스 적용

판매조건	판매몰	최저가	묶음상품
단품	201	730,000원	가격비교 관심상품
필수옵션 선택 추가금결제	39	705,620원 676,800원	가격비교 관심상품

CPU Clocking

Comparison of Specifications

Samsung Galaxy S II (Galaxy S2) vs iPhone 4

Design	**Samsung Galaxy S II (Galaxy S2)**	**iPhone 4**
Form Factor	Candy bar	Candy bar
Keyboard	Virtual QWERTY with Swype	Virtual Full QWERTY
Dimension	125.30 x 66.10 x 8.49 mm,	115.2 x 58.6 x 9.3 mm
Weight	116 g	137 g
Body Color	Black	White, Black
Display	**Samsung Galaxy S II (Galaxy S2)**	**iPhone 4**
Size	4.3 inches	3.5 inches
Resolution	WVGA, 800×480 pixels	960 x 640
Features	16M color	16M color, Oleophobic coated, scratch resistance
Sensors	Image stabilization, Accelerator Sensor, Proximity Sensor, Digital Compass, Gyrometer	Three axis gyro, Accelerometor, Proximity sensor, Ambient light sensor
Operating System	**Samsung Galaxy S II (Galaxy S2)**	**iPhone 4**
Platform	Android 2.3 (Gingerbread)	Apple iOS 4.2.1 (upgradeable to iOS 4.3.4)
UI	TouchWiz 4.0, Personalizable UI	Apple
Browser	Android WebKit, full HTML	Safari
Java/Adobe Flash	Adobe Flash 10.1	JavaScript
Processor	**Samsung Galaxy S II (Galaxy S2)**	**iPhone 4**
Model	Samsung Exynos, ARMv7 Dual-core Application processor	Apple A4
Speed	1.2 GHz Dualcore	1 GHz
Memory	**Samsung Galaxy S II (Galaxy S2)**	**iPhone 4**
RAM	1 GB	512 MB
Included	16 GB/32 GB	16 GB/32 GB
Expansion	Up to 32GB with microSD card	No card Slot

CPU Time

$$\text{CPU Time} = \text{CPU Clock Cycles} \times \text{Clock Cycle Time}$$
$$= \frac{\text{CPU Clock Cycles}}{\text{Clock Rate}}$$

° **Performance improved by**

- **Reducing number of clock cycles**
- **Increasing clock rate**
- **Hardware designer must often trade off clock rate against cycle count**

CPU Time Example

- Computer A: 2 GHz clock, 10 sec CPU time
- Designing Computer B
  - Aim for 6 sec CPU time
  - Can do faster clock, but causes 1.2 × clock cycles
- How fast must Computer B clock be?

$$\text{Clock Rate}_B = \frac{\text{Clock Cycles}_B}{\text{CPU Time}_B} = \frac{1.2 \times \text{Clock Cycles}_A}{6s}$$

$$\text{Clock Cycles}_A = \text{CPU Time}_A \times \text{Clock Rate}_A$$

$$= 10s \times 2\text{GHz} = 20 \times 10^9$$

$$\text{Clock Rate}_B = \frac{1.2 \times 20 \times 10^9}{6s} = \frac{24 \times 10^9}{6s} = 4\text{GHz}$$

Instruction Count and CPI

$$\text{Clock Cycles} = \text{Instruction Count} \times \text{Cycles per Instruction}$$

$$\text{CPU Time} = \text{Instruction Count} \times \text{CPI} \times \text{Clock Cycle Time}$$

$$= \frac{\text{Instruction Count} \times \text{CPI}}{\text{Clock Rate}}$$

- **Instruction Count for a program**
  - **Determined by program, ISA* and compiler**
- **Cycles per instruction (CPI)**
  - **Determined by CPU hardware**
  - **If different instructions have different CPI**
    - ☞ **Average CPI affected by instruction mix**

ISA: Instruction Set Architecture

CPI Example

- Computer A: Cycle Time = 250ps, CPI = 2.0
- Computer B: Cycle Time = 500ps, CPI = 1.2
- Same ISA
- Which is faster, and by how much?

$$\text{CPU Time}_A = \text{Instruction Count} \times \text{CPI}_A \times \text{Cycle Time}_A$$
$$= I \times 2.0 \times 250\text{ps} = I \times 500\text{ps}$$

A is faster…

$$\text{CPU Time}_B = \text{Instruction Count} \times \text{CPI}_B \times \text{Cycle Time}_B$$
$$= I \times 1.2 \times 500\text{ps} = I \times 600\text{ps}$$

$$\frac{\text{CPU Time}_B}{\text{CPU Time}_A} = \frac{I \times 600\text{ps}}{I \times 500\text{ps}} = 1.2$$

…by this much