BLM6112
Advanced Computer Architecture

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Course Details

- Course Code : **BLM6112**
- Course Name : **Advanced Computer Architecture**
- Credit : **3**
- Level : **Graduate**
- Schedule : **Wednesday 09:00-11:50**
- Course web page:
  http://www3.yildiz.edu.tr/~naydin/na_AcA.htm
- Instructors : **Nizamettin AYDIN**
  Room: D-128
  Email: naydin@yildiz.edu.tr, nizamettinaydin@gmail.com

Course Objective

- Learning properties of various computer architectures
- Learning about design (hardware) issues of high performance computing.

Course Content

- Revisison of Some Fundamental Concepts
- Computer System, Computer Evolution and Performance
- Cache, Cache Optimization, Virtual Memory
- Pipeline, Instruction-Level Parallelism, Data-Level Parallelism
- GPU Architectures, Thread-Level Parallelism, Multicore Processors.

Course Prerequisite

- Basic knowledge in
  - Computer organization
  - Digital circuit design
  - High-level language programming, e.g. C or Java
  - Assembly programming, e.g. Intelx86 or MC680xx.

Recommended Text(s)

- **Main textbook:**
  - **Computer Architecture: A Quantitative Approach, John L. Hennessy, David A. Patterson**
- Other recommended texts
  - Computer Organization and Architecture: Designing for Performance, William Stallings
  - Computer Organization and Design, David A. Patterson and John L. Hennessy
  - Computer System Architecture, M. Morris Mano
  - Logic and Computer Design Fundamentals, M. Morris Mano, Charles Kime
  - …

Course Outline

- Revision of Fundamental Concepts
- Fundamentals of Quantitative Design & Analysis (**Chapter 1**)
- Instruction Set Principals (**Appendix A**)
- Instruction Pipelining (**Appendix C**)
- Memory Hierarchy Design (**Appendix B & Chapter 2**)
- Instruction-Level Parallelism (**Chapter 3**)
- Data-Level Parallelism (**Chapter 4**)
- Thread-Level Parallelism (**Chapter 5**)

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Assesment

- Midterm : 30%
- Final : 40%
- Project : 15%
- Homework : 15%

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Rules of the Conduct

- No eating /drinking in class
  - *except water*
- Cell phones must be kept outside of class or switched-off during class
- No talking with your peers
- No late arrival or early leave to/from the lecture
- No web surfing and/or unrelated use of computers
  - when computers are used in class or lab

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Rules of the Conduct

- You are responsible for checking the class web page often for announcements.
  - http://www3.yildiz.edu.tr/~naydin/na_AcA.htm
- Academic dishonesty and cheating
  - will not be tolerated
  - will be dealt with according to university rules and regulations
    - http://www.yok.gov.tr/content/view/475/
    - Presenting any work that does not belong to you is also considered academic dishonesty.

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Electronics Systems

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The Computer Revolution

- Progress in computer technology
  - Underpinned by Moore's Law
- Makes novel applications feasible
  - Computers in automobiles
  - Cell phones
  - Human genome project
  - World Wide Web
  - Search Engines
- Computers are pervasive

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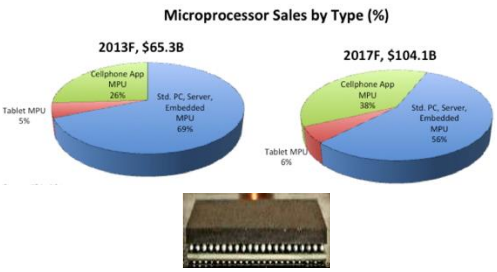
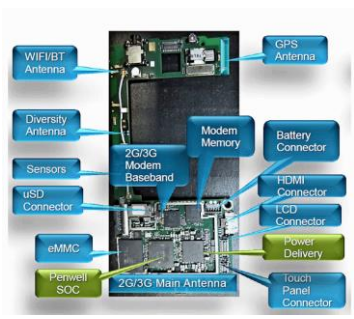
The Processor Market



Cell Phones!!

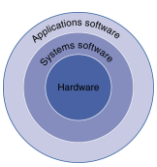
Cell Phones!!



Classes of Computers

- Desktop computers
  - General purpose, variety of software
  - Subject to cost/performance tradeoff
- Server computers
  - Network based
  - High capacity, performance, reliability
- Embedded computers
  - Hidden as components of systems
  - Stringent power/performance/cost constraints
- Supercomputers

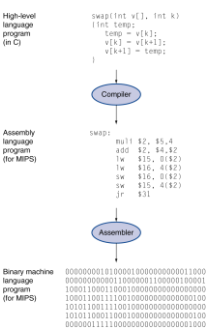
Below Your Program



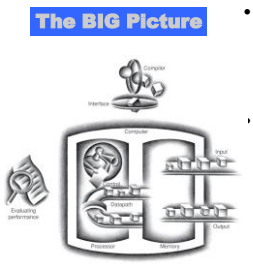
- Application software
  - Written in high-level language
- System software
  - Compiler: translates HLL code to machine code
  - Operating System: service code
    - Handling input/output
    - Managing memory and storage
    - Scheduling tasks & sharing resources
- Hardware
  - Processor, memory, I/O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



Below Your Program



- 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

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Networks

- Communication and resource sharing
- Local area network (LAN): Ethernet
  - Within a building
- Wide area network (WAN: the Internet
- Wireless network: WiFi, Bluetooth

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Networks

- Volatile main memory
  - Loses instructions and data when power off
- Non-volatile secondary memory
  - Magnetic disk
  - Flash memory
  - Optical disk (CDROM, DVD)

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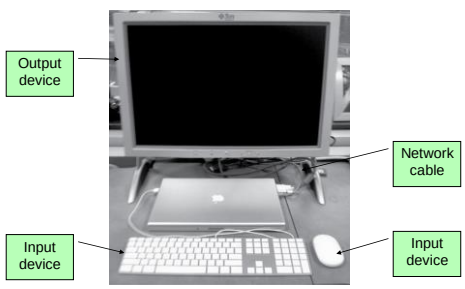
Anatomy of a Computer



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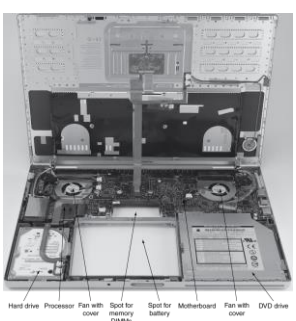
Opening the Box



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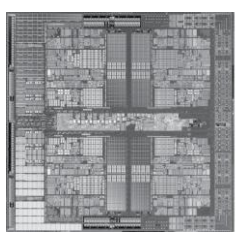
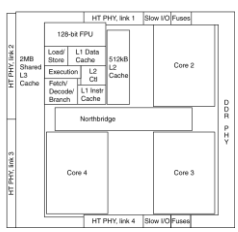
The Processor

- AMD Barcelona: 4 processor cores





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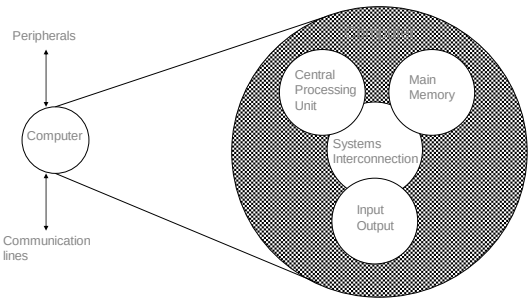
Inside the Computer



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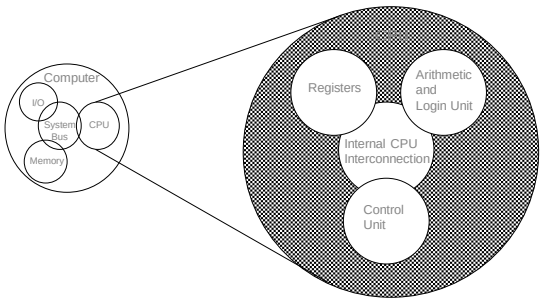
Inside the Processor (CPU)



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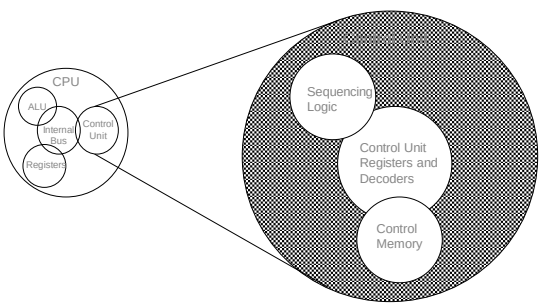
Inside the Control Unit



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Technology Trends

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

Year	Technology	Relative performance/cost
1951	Vacuum tube	1
1965	Transistor	35
1975	Integrated circuit (IC)	900
1995	Very large scale IC (VLSI)	2,400,000
2005	Ultra large scale IC	6,200,000,000

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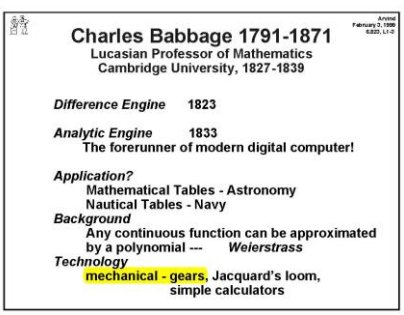

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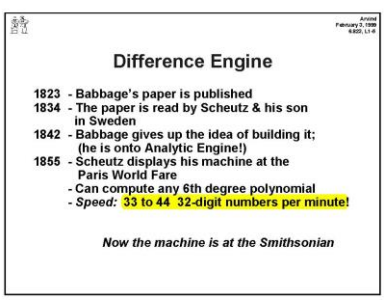

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Linear Equation Solver

John Atanasoff, Iowa State University

1930's: Atanasoff built the Linear Equation Solver.
It had 300 tubes!

Application:
Linear and Integral differential equations

Background:
Vannevar Bush's Differential Analyzer
--- *an analog computer*

Technology:
Tubes and Electromechanical relays

Atanasoff decided that the correct mode of computation was by electronic digital means.

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ENIAC and EDVAC

The first conception of a *stored program computer*

ENIAC 1946, 48
EDVAC 1948 *concept only*

Players brought together by the WW-2 effort
- Eckert & Mauchley, University of Pennsylvania
- John von Neumann, Princeton University

Application:
Ballistic calculations
angle = f (location, tail wind, cross wind,
air density, temperature, weight of shell,
propellant charge, ...)

Technology:
tubes, relays, electromechanical delays,
mercury delay lines,...

Developed the concept of *stored program computer*
⇒ *program can be manipulated as data*

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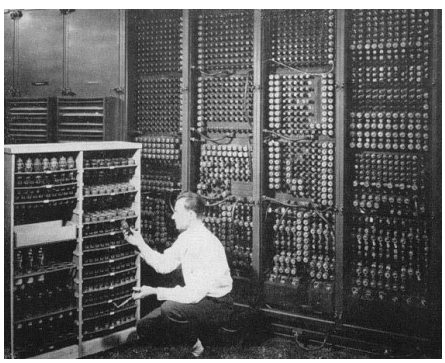
Eniac



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Eniac (find the OS?)

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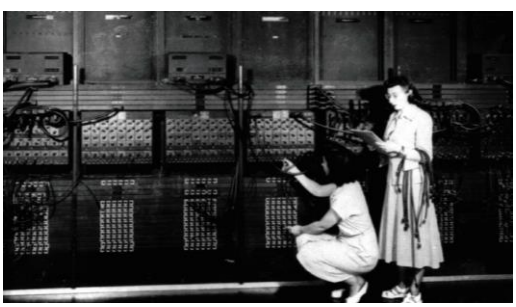
Eniac (find the Programmer?)



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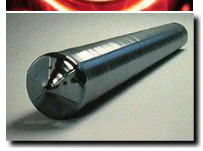
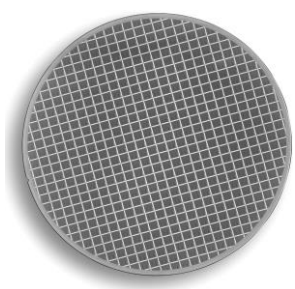
Integrated Circuits: wafer (564 dies)

Drawing single-crystal
Si ingot from furnace….



Then, slice into wafers and pattern it…



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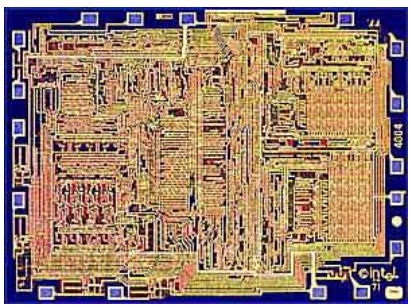
In the beginning Intel 4004 (4-bit)



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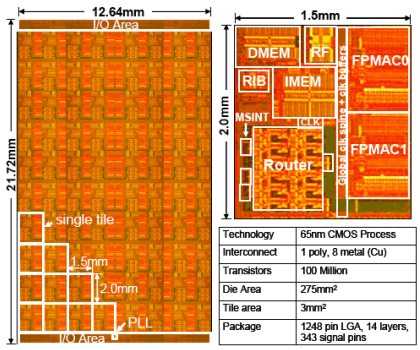
Intel 8080 (8-bit)



Technology	65nm CMOS Process
Interconnect	1 poly, 8 metal (Cu)
Transistors	100 Million
Die Area	275mm²
Tile area	3mm²
Package	1248 pin LGA, 14 layers, 343 signal pins

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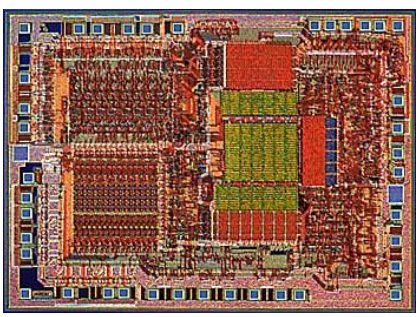
Intel 8086 (16-bit)



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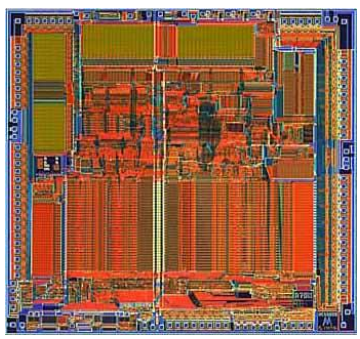
Motorola 68000 (32-bit)



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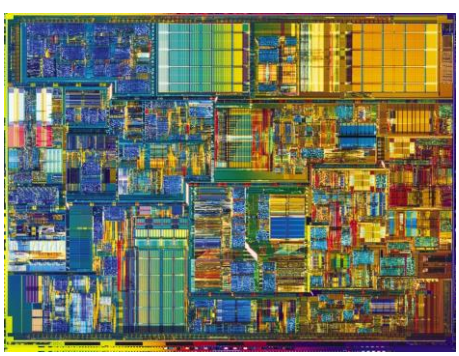
Pentium 4 (64-bit)



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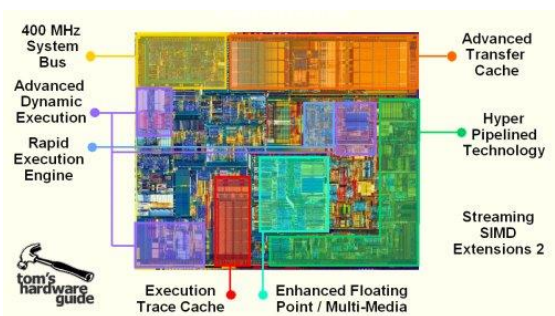
Pentium 4 chip breakdown



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Intel Microprocessor Evolution

	Year/Month	Clock =1/tc.	Transistors.	Micras
I4004	1971/11	108 KHz.	2300	10
I8080	1974/04	2 MHz.	6000	6
I8086	1978/06	10 MHz.	29000	3
I80286	1982/02	12 MHz.	0.13 m.	1.50
I486DX	1989/04	25 MHz.	1.2 m.	1
Intel DX2	1992/03	100 MHz.	1.6 m.	0.8
Pentium	1993/03	60 MHz.	3.1 m.	0.8
Pentium Pro	1995/11	200 MHz.	5.5 m.	0.35
Pentium II	1998/	450 MHz.	7.5 m.	0.25
Pentium III	2000/01	1000 MHz.	28 m.	0.18
P4	2000/09	1400 MHz.	42 m.	0.18

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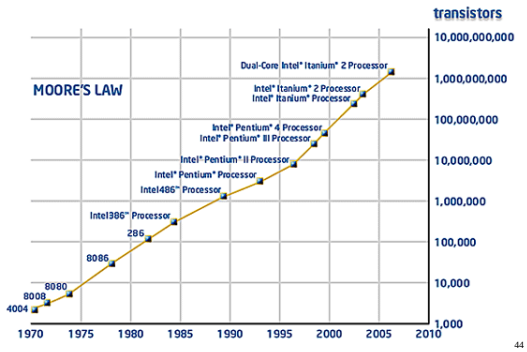
Technology Trends



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Intel IA-64 / Itanium

Explicit Parallel Instruction Computer

- IA-64
- Implementations: Merced (2001), McKinley (2002), Montecite (2 core, 2006), Tukwila (4-core 2009), Poulson (Q4, 2009, 8-core)
- Architecture is now called Itanium

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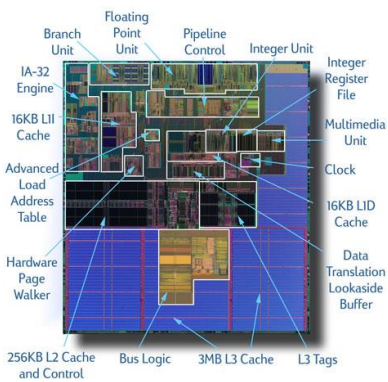

McKinley microprocessor (2002)

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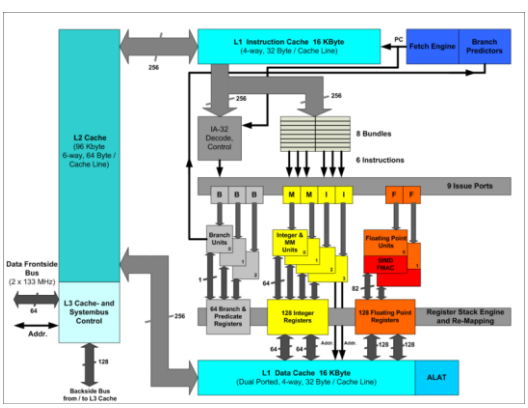

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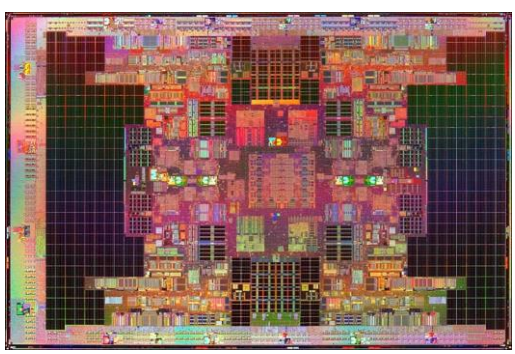
Tukwila 4 core Itanium, 2009



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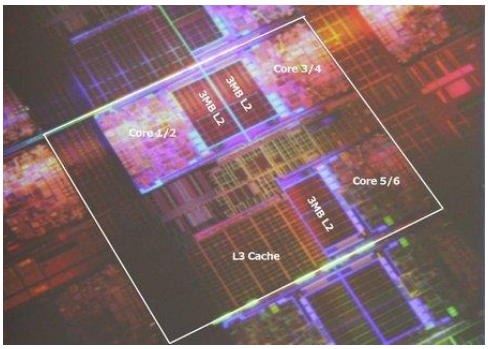
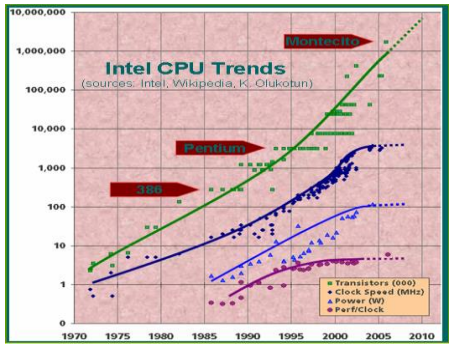
Intel Dunnington 6-core



How further?



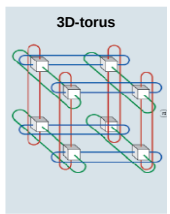
Supercomputers

- IBM cluster
- 6480 nodes with
  - Dual core Opteron 1.8 GHz
  - 2 * PowerXCell 8i 3.2 GHz (12.8 GFlops)
- Infiniband connection fabric (16 Gbit/s per link)
  - FAT tree interconnect
- 100 Tbyte DRAM memory
- 216 I/O nodes
- **2.35 MW** power
- MPI programming
- Size: 296 racks, **550 m²** *This is huge !!*

BlueGene/L IBM

- Based on ASIC with PowerPC 440, 700 Mhz, each 2.8 GFlops
- 105,496 nodes
- 3D Torus interconnect for p2p communication + Collective network

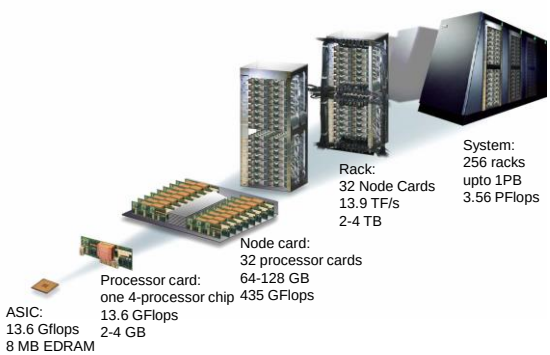
rack



Complete system

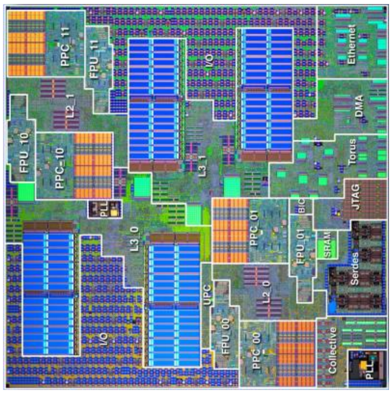
Data Center (IBM)

2009: BlueGene/P



BlueGene/P ASIC

- 208M trans
- 850 MHz
- 16W
- 90nm



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BlueGene/L Node board

- 16 cards with 2 ASICs each
- 8 GB
- 180 Gflop

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BlueGene/P node card

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BlueGene/P rack

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Can we match the human brain ???

- Performance = 100 Billion (10^11) Neurons * 1000 (10^3) Connections/Neuron * 200 (2 * 10^2) Calculations Per Second Per Connection = 2 * 10^16 Calculations Per Second
- Memory = 100 Billion (10^11) Neurons * 1000 (10^3) Connections/Neuron * 10 bytes (information about connection strength and adress of output neuron, type of synapse) = 10^15 bytes = 1 PB = 1000 TB
- ***How far off are we?***

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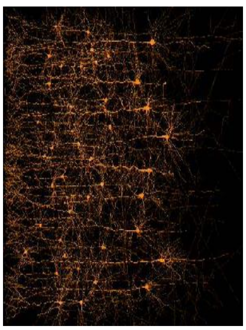
Blue brain research



- Software replica of a column of the neocortex
  - 85% of brains total mass
  - required for language, learning, memory and complex thought
  - the essential first step to simulating the whole brain
- Next: include circuitry from other brain regions and eventually the whole brain.

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Incredible Computer Ads!

System Industries: "80 MB for under $12,000" (1977)

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RAM Card!

Cromemco: "The New 16K RAM card..." (circa 1977)

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HD Monitor!

RadioShack: **Issac Assimov** featuring a color computer (1982)

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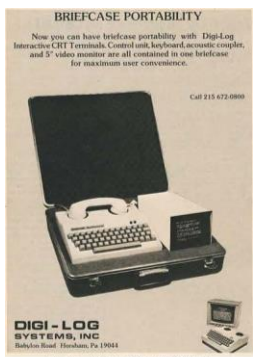
Mobile Phone!!



Digi-Log: "Briefcase Portability" (1976)

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Mobile Phones!!

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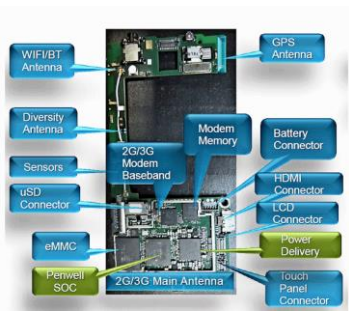
Mobile Phones!!



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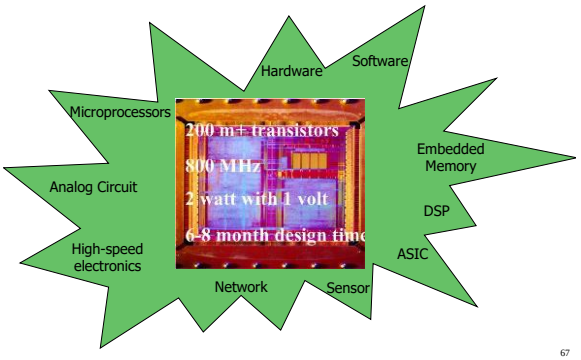
System-on-Chip (SOC)



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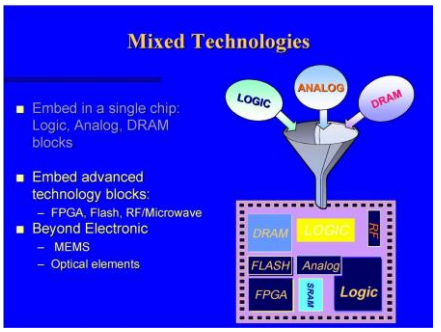
System-on-Chip (SOC)



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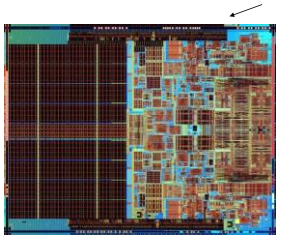
At The End

What you should have understood after taking BLM6112



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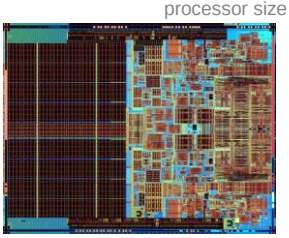
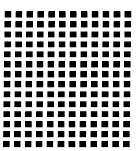
At The End

The actual processor size





The technology behind multiprocessor chips

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Thank You and Good Luck!

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