Chapter One

Computer Evolution and Performance



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Target Group: 4th Year ECE Students

Material Primarily Adapted from the Works of W. Stallings

Topics

I. Organization and Architecture
II. Structure and Function of Computer
III. History of Computers
IV. Design for Performance
V. Performance Assessment

Architecture & Organization

- Architecture is those attributes visible to the programmer
  - Instruction set, number of bits used for data representation, I/O mechanisms, addressing techniques.
  - E.g. Is there a multiply instruction?

- Organization is how features are implemented
  - Control signals, I/O interfaces, memory technology.
  - E.g. Is there a hardware multiply unit or is it done by repeated addition?

Architecture & Organization

- All Intel x86 family share the same basic architecture
- The IBM System/370 family share the same basic architecture
- This gives code compatibility ... at least backwards.
- Organization differs within members of the same family,

E.g. floating point numerical co-processors with names like 8087, 80287 and 80387. With very few exceptions, the 80486 and subsequent x86 processors then integrated this x87 functionality on chip.

Structure & Function

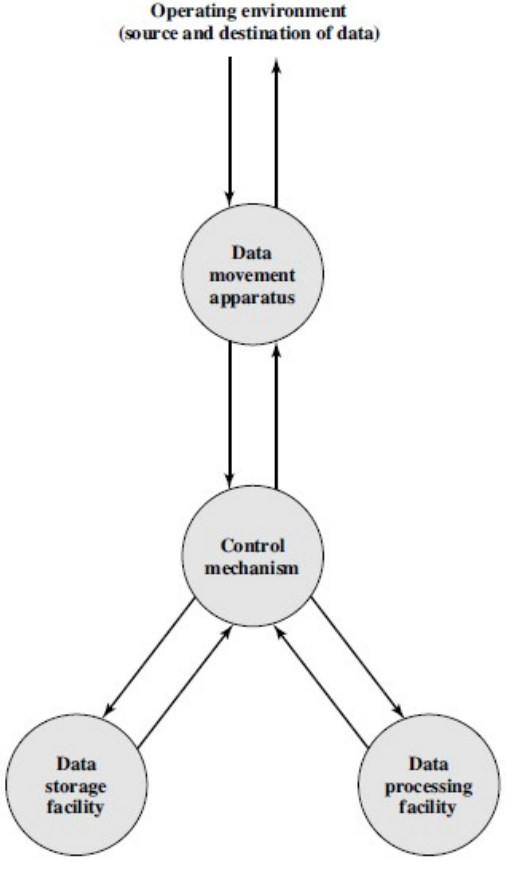
- Structure is the way in which components relate to each other
- Function is the operation of individual components as part of the structure

Functional Look of Computers

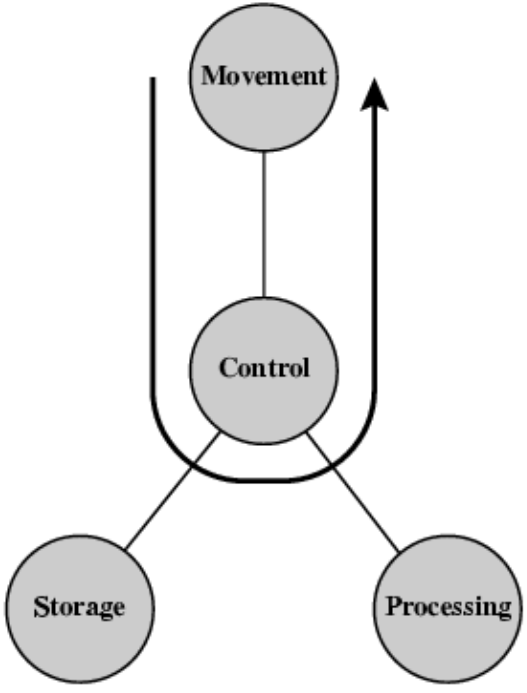
Function

General Computer Functions:

- Data processing
- Data storage
- Data movement
- Control



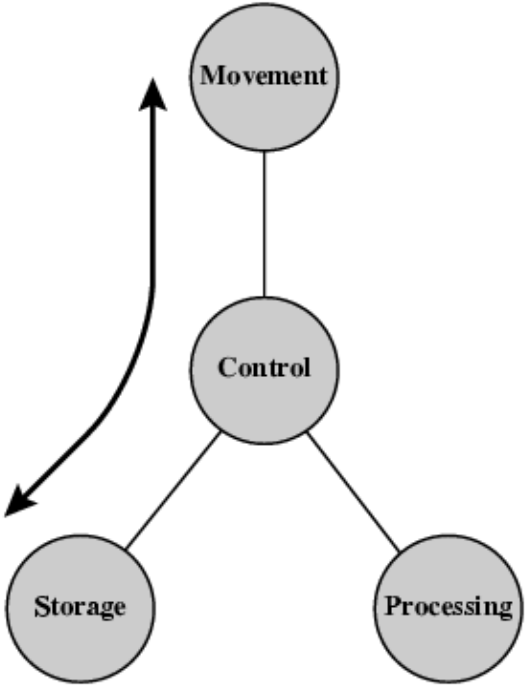
Data Movement I/O



I/O (peripherals directly attached), Communications/ Networking (communication lines)

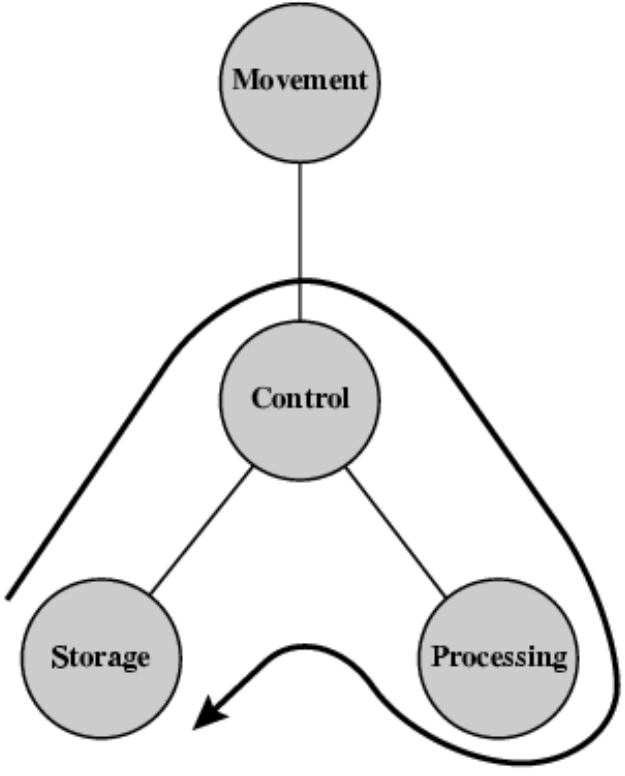
Camera attached to a PC, sending the frames to a window on the screen of the same PC.

Storage



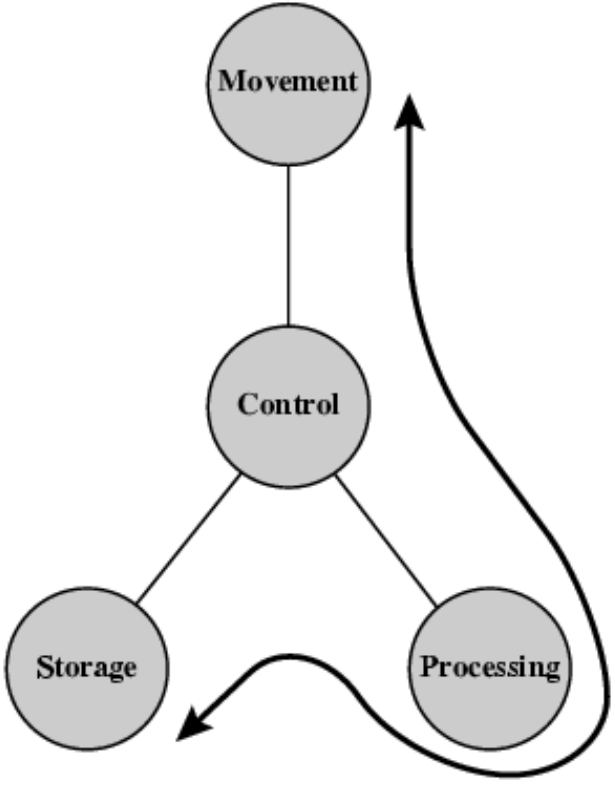
- Temperature Logger
- Uncompressed Audio Players

Processing from/to Storage



Any number-crunching application that takes data from memory and stores the result back in memory.

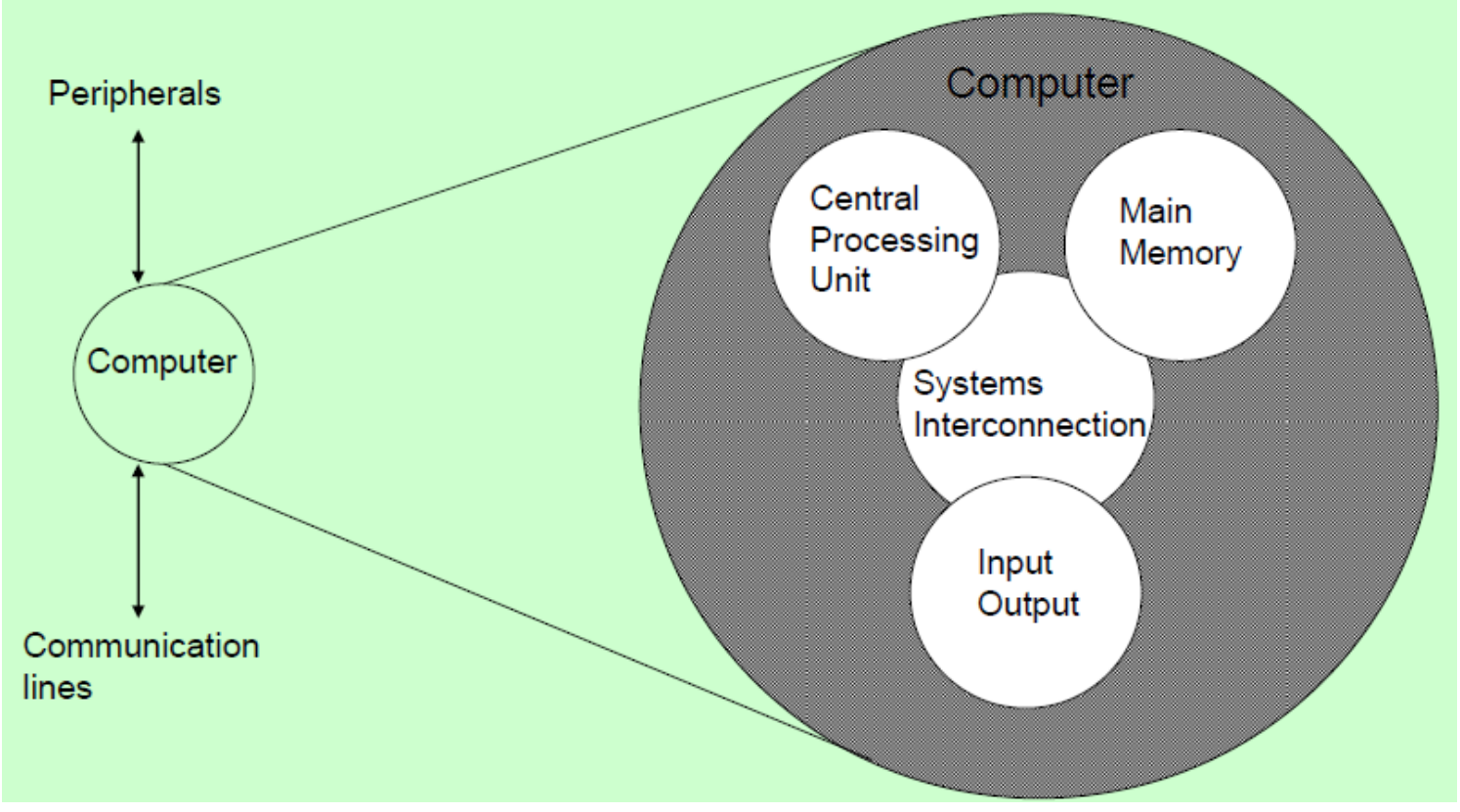
Processing from storage to I/O



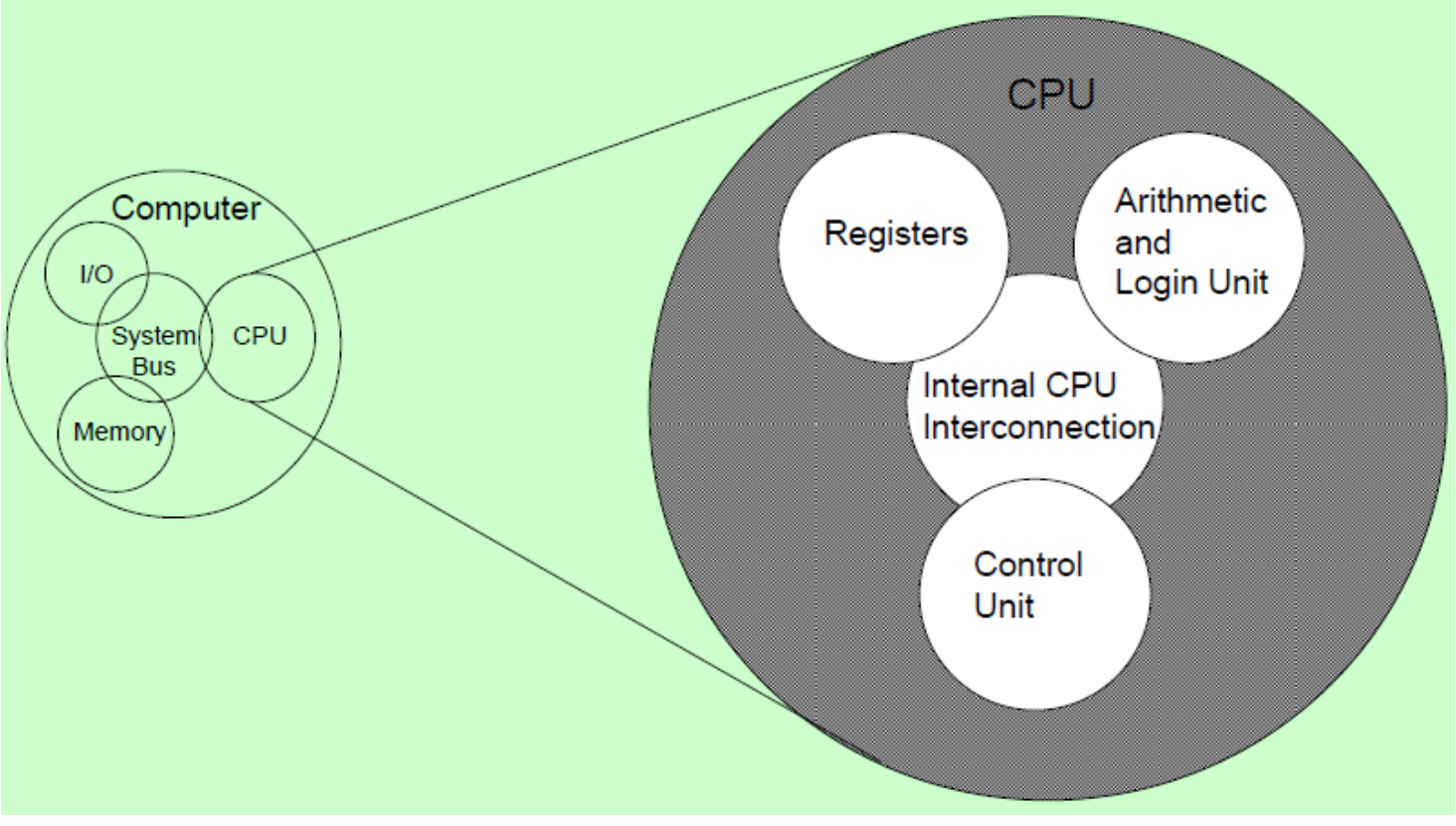
Receiving packets over a network interface, verifying their CRC, then storing them in memory.

Structural Look of Computers

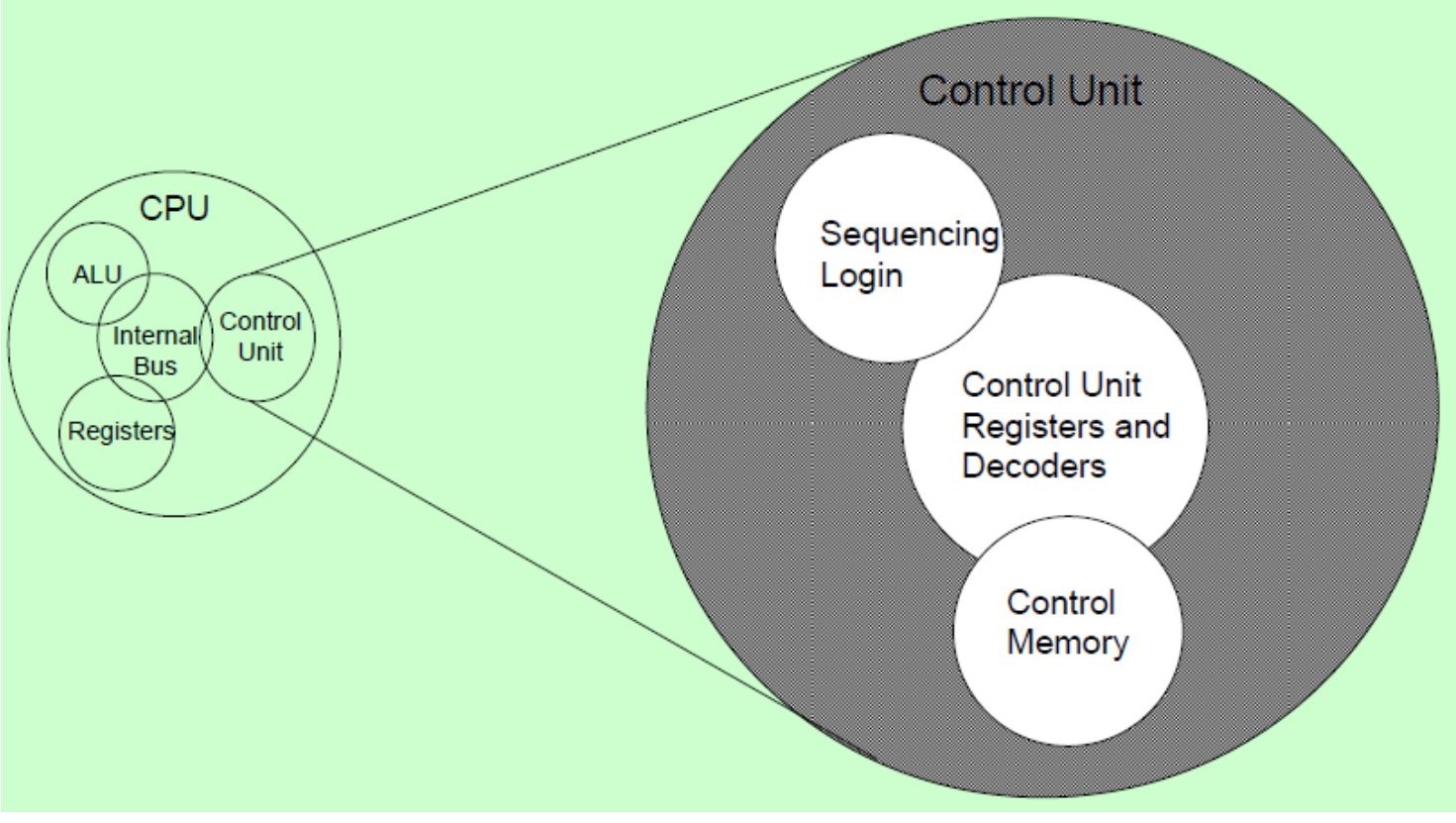
Structure - Top Level



Structure - The CPU



Structure -The Control Unit



Computer Evolution and Performance

- First Generation of (ENIAC, von Neumann, UNIVAC)
- Second Generation (Age of Transistors)
- Third Generation (ICs)
- Later Generations

ENIAC

- Electronic Numerical Integrator And Computer
- Eckert and Mauchly
- University of Pennsylvania
- Trajectory tables for weapons
- Started 1943
- Finished 1946
- Too late for war effort
- Used until 1955

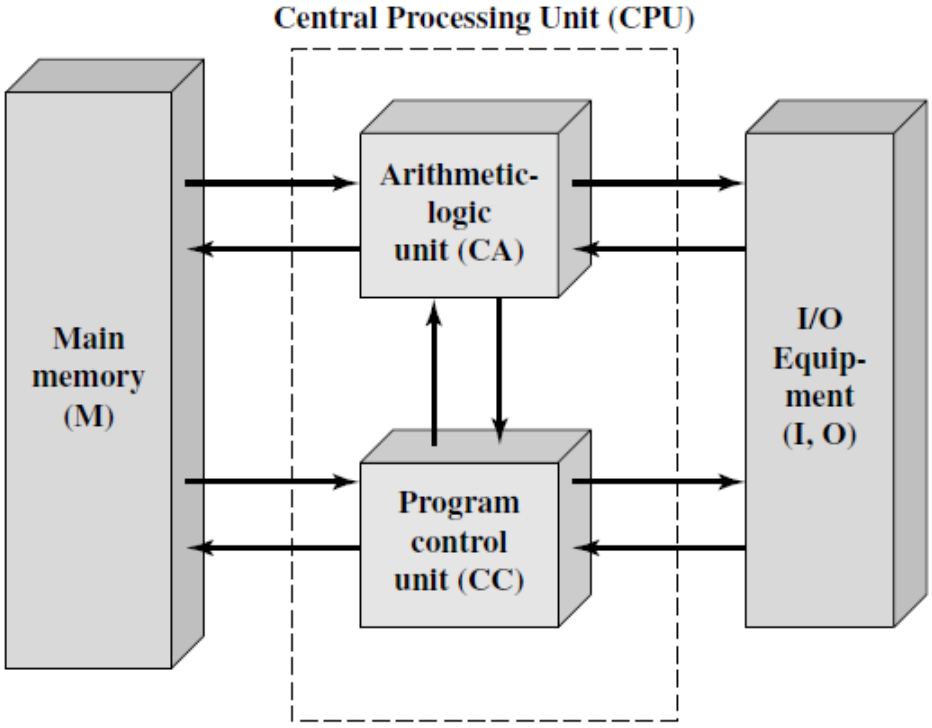
ENIAC

- Decimal (not binary)
- 20 accumulators of 10 digits
- Programmed manually by switches
- 18,000 vacuum tubes
- 30 tons
- 15, 000 square feet
- 140 kW power consumption
- 5,000 additions per second

Von Neumann/ Turing

- Stored Program concept
- **Main memory storing programs and data**
- ALU operating on binary data
- Control unit interpreting instructions from memory and executing
- Input and output equipment operated by control unit
- Princeton Institute for Advanced Studies (**IAS**) computer
- Completed 1952

Structure of Von Neumann



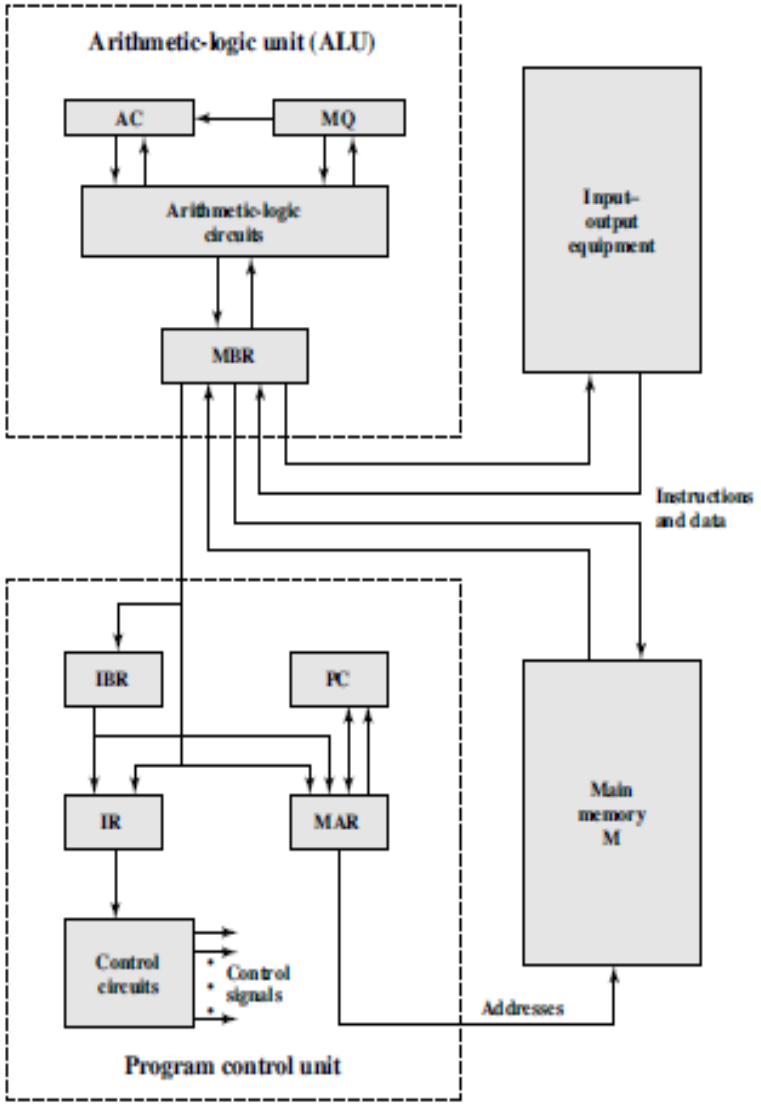
IAS Details

- 1000 x 40 bit words, each word representing
- One 40-bit binary number
- Two 20-bit instructions:
  - 8 bits opcode
  - 12 bits address

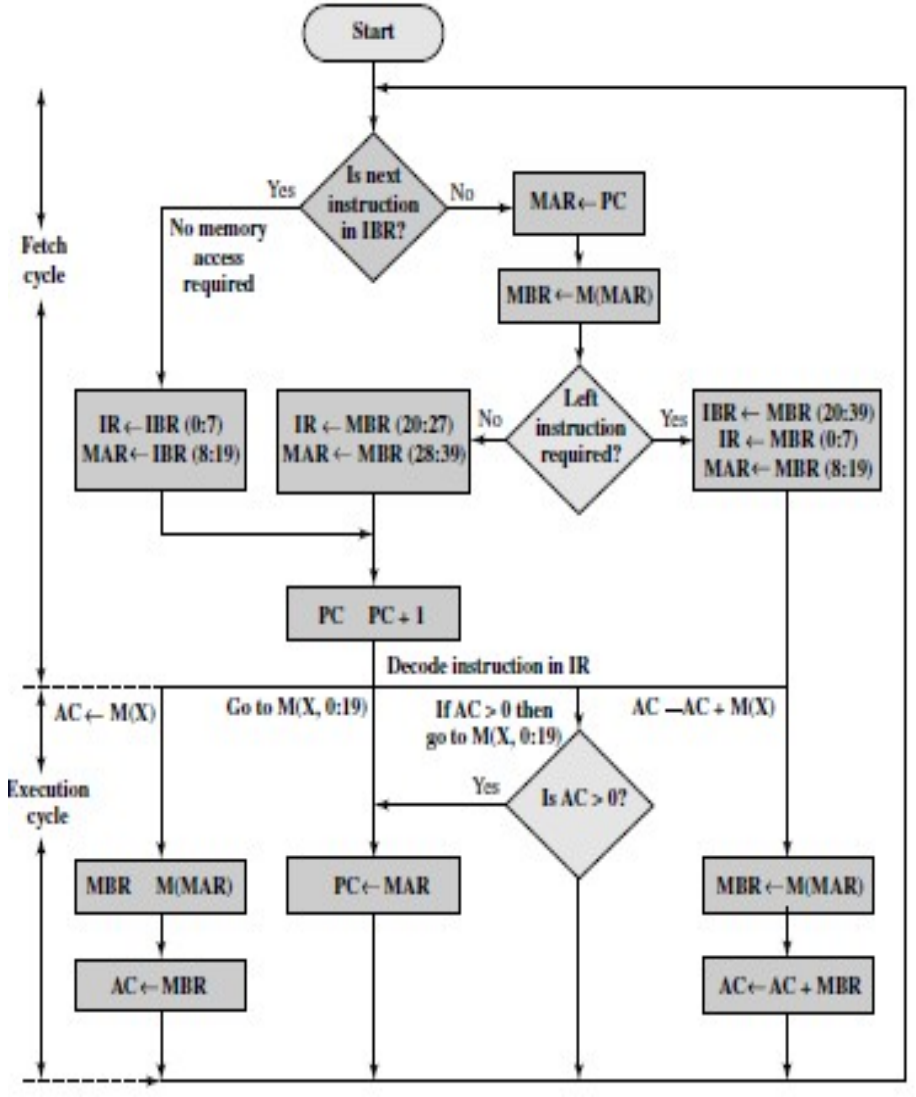
Set of registers (storage in CPU)

- Memory Buffer Register
- Memory Address Register
- Instruction Register
- Instruction Buffer Register
- Program Counter
- Accumulator
- Multiplier Quotient

Extended Structure of IAS



Partial Flow Chart



Commercial Computers

- 1947 – Eckert-Mauchly Computer Corporation
- **UNIVAC I** (Universal Automatic Computer)
- US Bureau of Census 1950 calculations
- Became part of Sperry-Rand Corporation
- Late 1950s -UNIVAC II
  - Faster
  - More memory

IBM

- Punched-card processing equipment
- 1953 -the 701
  - IBM’s first stored program computer
  - Scientific calculations
- 1955 -the 702
  - Business applications
- Lead to 700/7000 series

Second generation of computers Transistors

- Replaced vacuum tubes
- Smaller
- Cheaper
- Less heat dissipation
- Solid State device
- Made from Silicon (Sand)
- Invented 1947 at Bell Labs by William Shockley et al.

Transistor Based Computers

- NCR & RCA produced small transistor machines
- IBM 7000
- DEC (Digital Equipment Corporation) was founded in 957
  - Produced PDP-1 in the same year

Transistor Based Computers

Model Number	First Delivery	CPU Tech-nology	Memory Tech-nology	Cycle Time (μs)	Memory Size (K)	Number of Opcodes	Number of Index Registers	Hardwired Floating-Point	I/O Overlap (Chan-nels)	Instruc-tion Fetch Overlap	Speed (relative to 701)
701	1952	Vacuum tubes	Electrostatic tubes	30	2–4	24	0	no	no	no	1
704	1955	Vacuum tubes	Core	12	4–32	80	3	yes	no	no	2.5
709	1958	Vacuum tubes	Core	12	32	140	3	yes	yes	no	4
7090	1960	Transistor	Core	2.18	32	169	3	yes	yes	no	25
7094 I	1962	Transistor	Core	2	32	185	7	yes (double precision)	yes	yes	30
7094 II	1964	Transistor	Core	1.4	32	185	7	yes (double precision)	yes	yes	50

Third Generation of Computers: ICs

- A computer is made up of gates, memory cells and interconnections.
- All these can be manufactured either separately (discrete components) or on the same piece of semiconductor (a.k.a. silicon wafer)

Generation of Computers

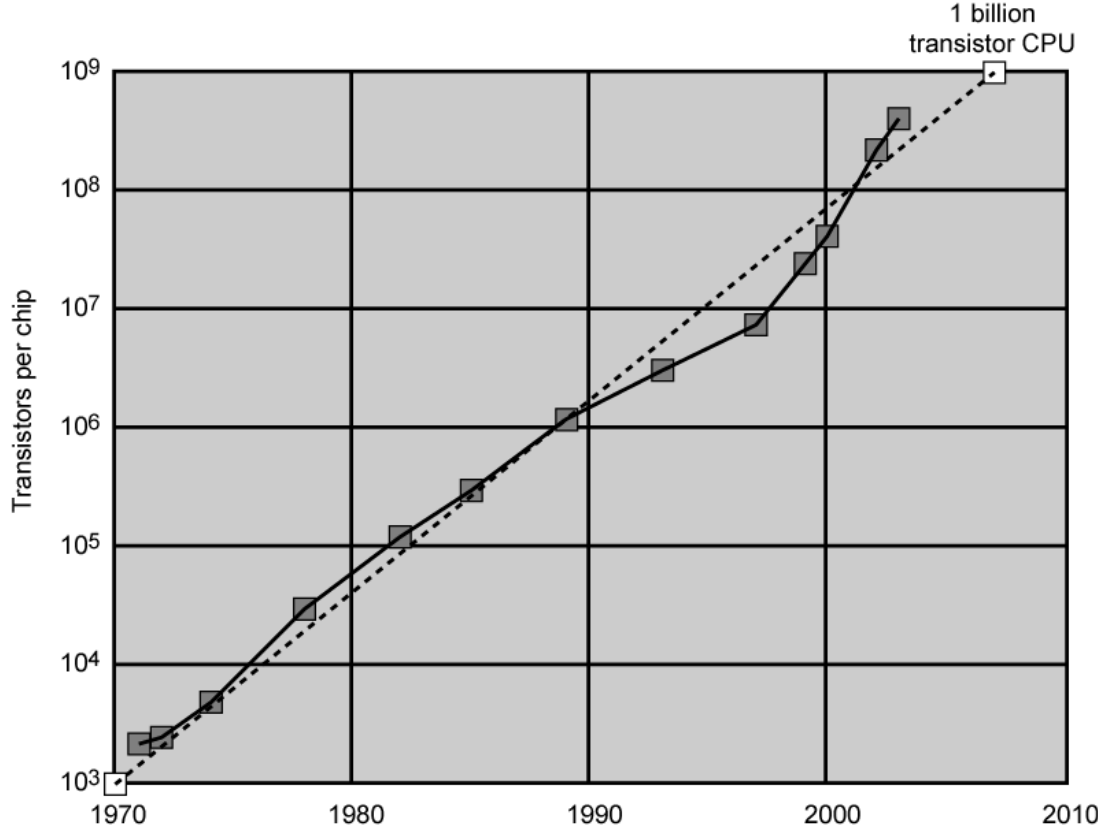
- Vacuum tube -1946-1957
- Transistor -1958-1964
- Small scale integration -1965 on
  - Up to 100 devices on a chip
- Medium scale integration -to 1971
  - 100-3,000 devices on a chip
- Large scale integration -1971-1977
  - 3,000 -100,000 devices on a chip
- Very large scale integration -1978 -1991
  - 100,000 -100,000,000 devices on a chip
- Ultra large scale integration –1991 -
  - Over 100,000,000 devices on a chip

Moore’s Law

- Increased density of components on chip
- Gordon Moore –co-founder of Intel
- Number of transistors on a chip will double every year
- Since 1970’s development has slowed a little

  —Number of transistors doubles every 18 months
- Cost of a chip has remained almost unchanged
- Higher packing density means shorter electrical paths, giving higher performance
- Smaller size gives increased flexibility
- Reduced power and cooling requirements
- Fewer interconnections increases reliability

Growth in CPU Transistor Count



IBM 360 series

- 1964
- Replaced (& not compatible with) 7000 series
- First planned —family of computers
  - —Similar or identical instruction sets
  - —Similar or identical O/S
  - —Increasing speed
  - —Increasing number of I/O ports (i.e. more terminals)
  - —Increased memory size
  - —Increased cost
- Multiplexed switch structure

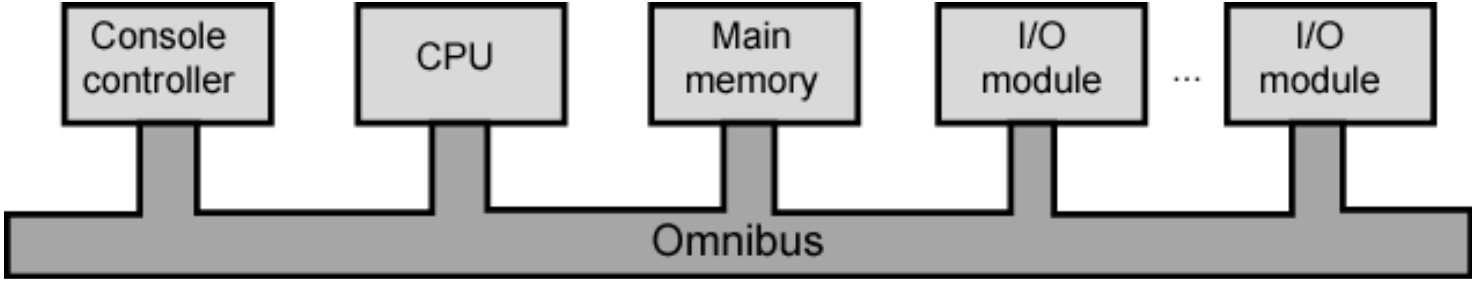
IBM 360 series

Characteristic	Model 30	Model 40	Model 50	Model 65	Model 75
Maximum memory size (bytes)	64K	256K	256K	512K	512K
Data rate from memory (Mbytes/sec)	0.5	0.8	2.0	8.0	16.0
Processor cycle time μs)	1.0	0.625	0.5	0.25	0.2
Relative speed	1	3.5	10	21	50
Maximum number of data channels	3	3	4	6	6
Maximum data rate on one channel (Kbytes/s)	250	400	800	1250	1250

DEC PDP-8

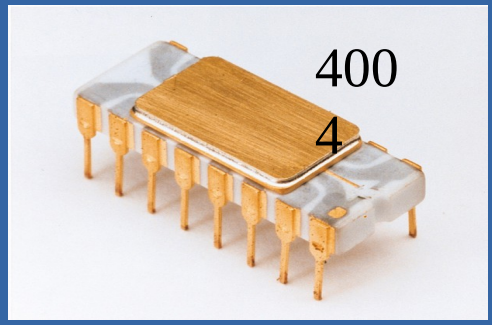
- 1964
- First minicomputer (after miniskirt!)
- Did not need air conditioned room
- Small enough to sit on a lab bench
  - $16,000
  - $100k+ for IBM 360
- Embedded applications & OEM
- BUS STRUCTURE

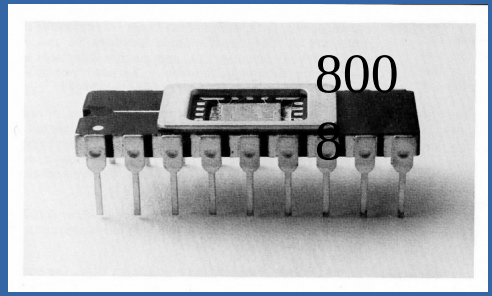
DEC - PDP- 8 Bus Structure

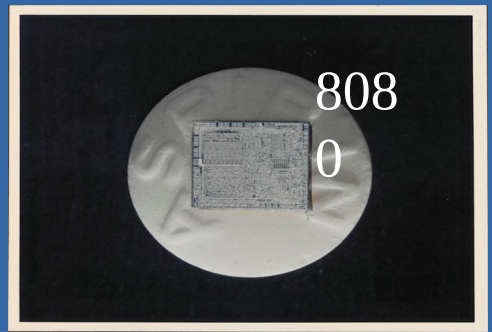


Intel Processors

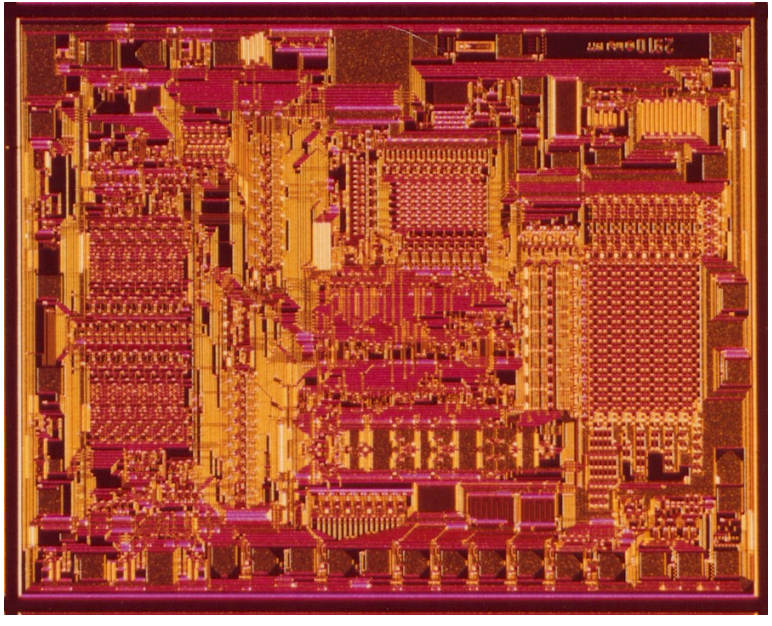
- 1971 – Intel 4004: First commercial microprocessor, 4-bit, 2,300 transistors.
- 1974 – Intel 8080: Popular 8-bit processor, used in early personal computers, general purpose microcomputer.
- 1978 – Intel 8086: Introduced the x86 architecture, 16-bits, foundation for future architectures.
- 1982 – 80286: 16-bit processor, introduced protected mode for multitasking.







Intel Processors



x86 Processor

Almost 40 years after its introduction in 1978, the x86 architecture continues to dominate the processor market outside of embedded systems.

Intel Processors

- 1985 – 80386: 32-bit processing, virtual memory, multitasking support.
- 1989 – 80486: Integrated pipelining, powerful cache technology, improved performance.
- 1993 – Pentium: Superscalar architecture, faster floating-point operations.
- 1995 – Pentium Pro: Advanced for servers/workstations, introduced out-of-order execution.
- 1999 – Pentium III: SSE instructions for digital signal processing, multimedia & gaming.

Intel Processors

	Pentium III	Pentium 4	Core 2 Duo	Core 2 Quad
Introduced	1999	2000	2006	2008
Clock speeds	450–660 MHz	1.3–1.8 GHz	1.06–1.2 GHz	3 GHz
Bus sidth	64 bits	64 bits	64 bits	64 bits
Number of transistors	9.5 million	42 million	167 million	820 million
Feature size (nm)	250	180	65	45
Addressable memory	64 GB	64 GB	64 GB	64 GB
Virtual memory	64 TB	64 TB	64 TB	64 TB
Cache	512 kB L2	256 kB L2	2 MB L2	6 MB L2

Intel Processors

2000 – Pentium 4: High clock speeds, NetBurst architecture.

2006 – Intel Core (Duo, i3/i5/i7/i9): Multi-core revolution, energy efficiency.





Intel Processors

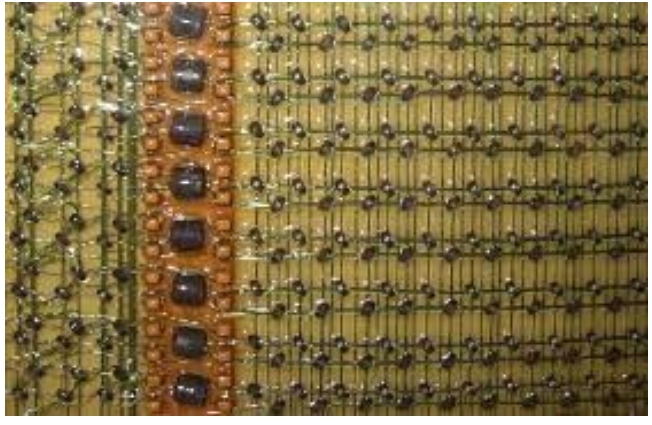
What about Today?



Semiconductor Memory

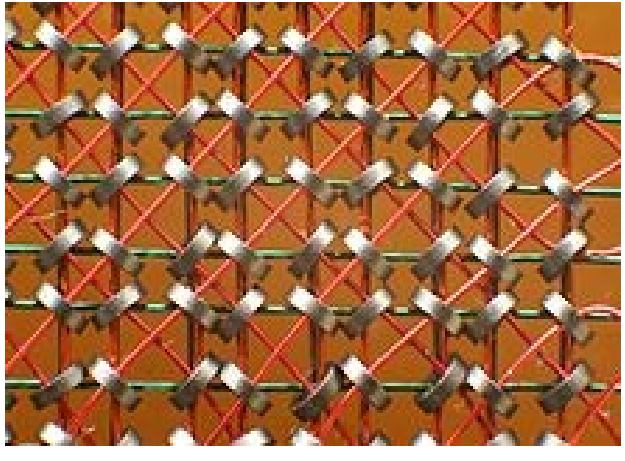
- 1970
- Fairchild
- Size of a single core
- i.e. 1 bit of magnetic core storage
- Holds 256 bits
- Non-destructive read
- Much faster than core
- Capacity approximately doubles each year

Semiconductor Memory





Semiconductor Memory



Magnetic Memory

Computer Performance



- Design for Performance
- Performance Assessment

Design for Performance

- The performance of computers has dramatically increased in the last multiple decades.

- Performance might be seen in terms of *response time* or *throughput.*

→ Response time: the time between the start and completion of a task.

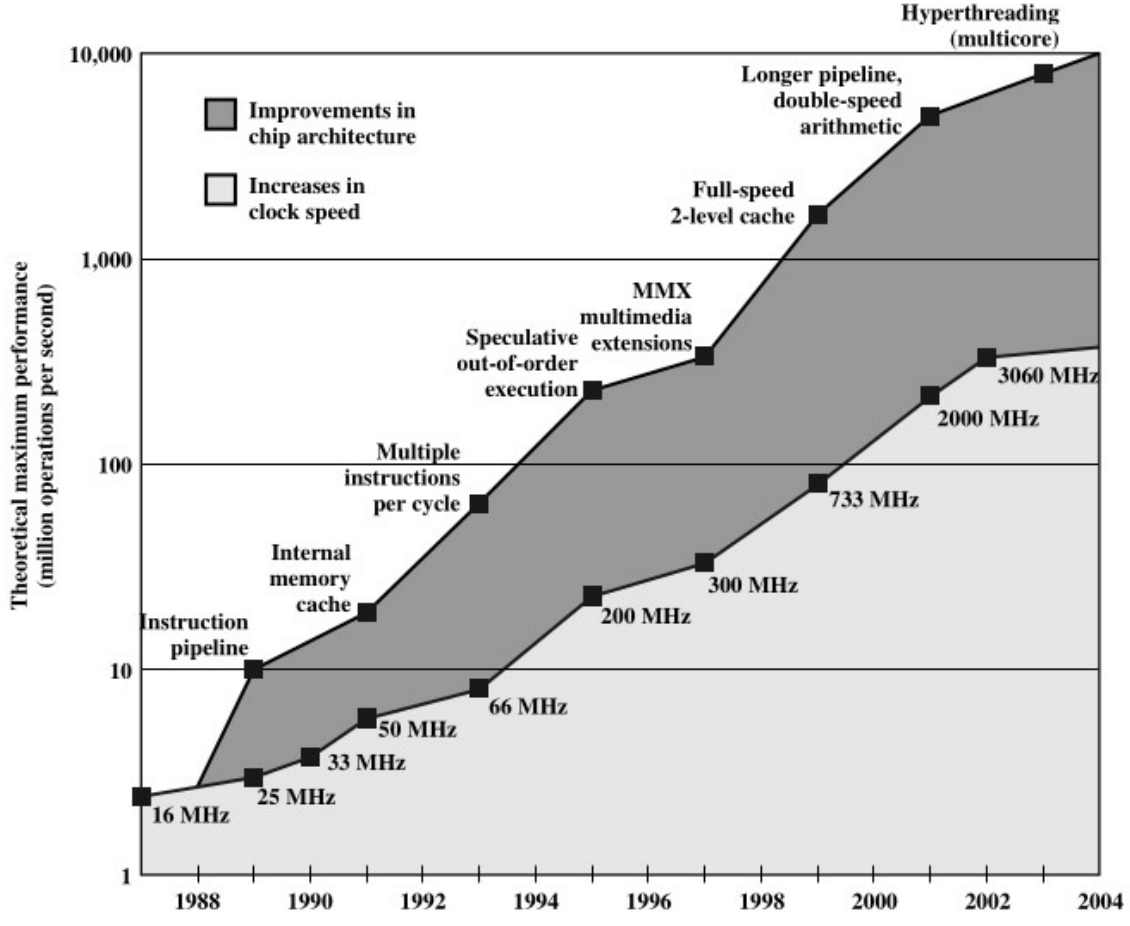
→ Throughput: the total amount of work done in a given time.

Design for Performance

Factors Enabling Performance Enhancement

- Clock Speed
- Instruction Parallelism (Pipelining, branch prediction, Data Flow Analysis, Superscalar execution, speculative execution)
- Multicore systems
- Memory Technology and Organization
- I/O throughput
- Graphical Processing Units (GPUs)

Design for Performance



Design for Performance

Why don’t we keep increasing clock rate?

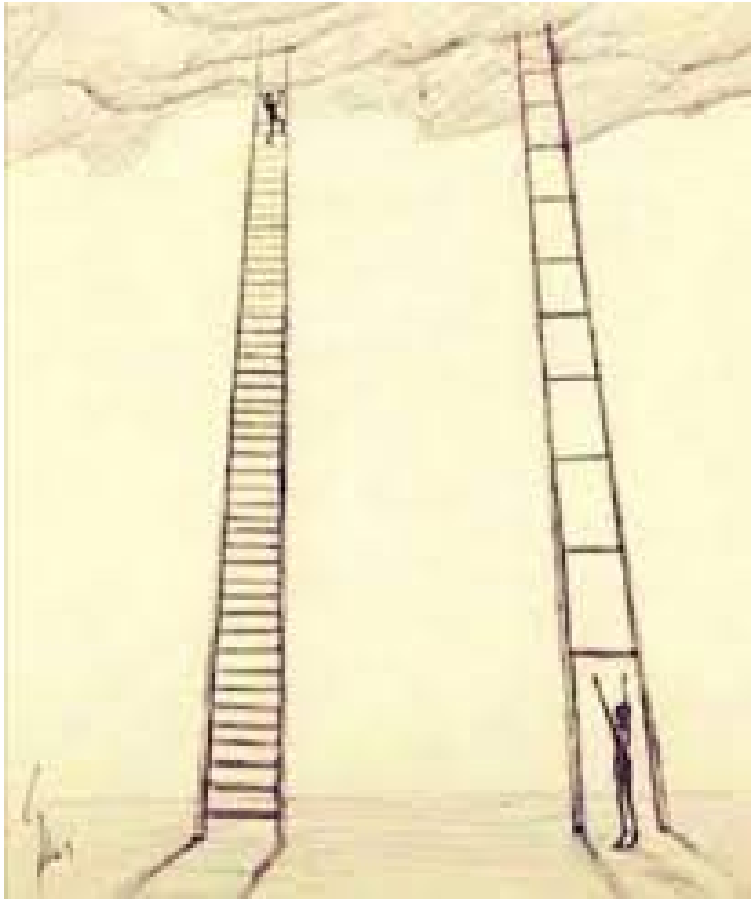
- RC delays
- Power dissipation
- Physical Technological Limits
- Memory Latency

Performance Assessment

- Clock speed: Clock speed can’t be a sole measure of performance.
- Instructions Execution Rate: though it seldom might be used to measure performance, it’s not a valid assessment means.
- Benchmark: SPEC and other benchmark software are normally used as a more valid means of assessment.
- Amdahl’s Law: provides insight about the gain from parallel (multiple) processors.

Summary

Never Underestimate the Importance of Simple Steps!



Thank you,

Questions?