Milestones in Computer Architecture

Raul Queiroz Feitosa

Objective

"In this section we give a brief sketch of some of the key historical developments in order to get a better understanding of how we got where we are."

A. Tanenbaum

Outline

- Computer Generations
- Zeroth Generation: Mechanical Devices
- First Generation: Vacuum Tubes
- Second Generation: Transistor
- Third Generation: Integrated Circuits
- The VLSI Era
- The ULSI Era

Computer Generations

Tanenbaum			Stallings		
generation	**dates**	**technology**	**generation**	**dates**	**technology**
0	1642-1945	mechanical			
1	1945-1955	vacuum tubes	1	1946-1957	vacuum tubes
2	1955-1965	transistor	2	1958-1964	transistor
3	1965-1980	IC	3	1965-1971	SSI &MSI
			4	1972-1977	LSI
4	1980-?	VLSI	5	1978-1991	VLSI
5		invisible computers	6	1991-…	ULSI

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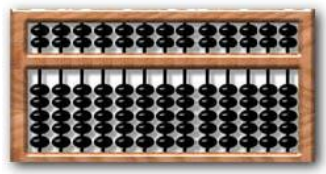
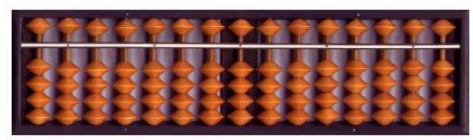
- The ULSI Era

Abacus (≈ 300 B.C.)



Chinese suanpan

Roman Abacus



Japanese soroban

http://www.youtube.com/watch?v=CvsnftXXKdw

John Napier (1550-1617)

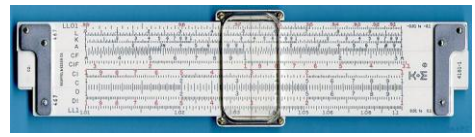
- **Discovered the logarithm (1617).**
- **Introduced the**

Napier's Bones .

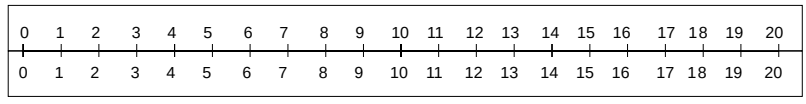
John Napier

which brought about the *slider rule.*

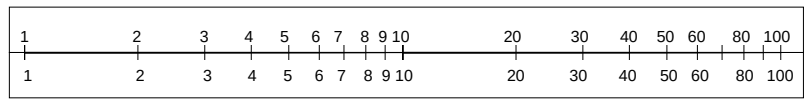
The Slider Rule



- **Linear**



- **Logarithmic (log of product=sum of logs)**



Pascaline

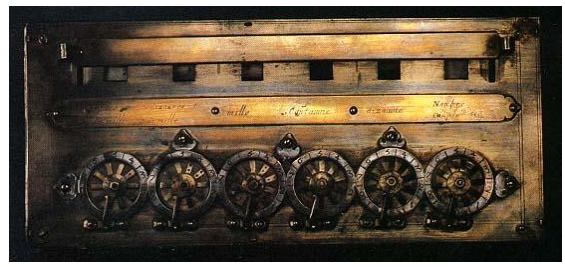
Blaise **Pascal**

(1623-1662)

- French mathematician, physicist, inventor, writer and Catholic philosopher
- wrote a treatise on the subject of projective geometry at the age of 16.
- at age 19 built the *Pascaline* to help his father who was a tax collector.
- At age 31, after a mystical experience, became a philosopher.

Pascaline

- A gear-driven adder, like “modern” odometers.
- Sold just 50, due to its high cost and low accuracy.



Stepped Reckoner

- German mathematician and philosopher.
- Developed the infinitesimal calculus independently on Isaac Newton.
- Developed the binary number system.
- Invented the *stepped reckoner* (1694).

Gottfried Wilhelm **Leibniz**

(1646-1716)

Stepped Reckoner

- All four arithmetic operations.

(replica in the Deutsches Museum)

Jacquard's Loom

Joseph-Marie **Jacquard**
(1752-1834)

- A master weaver of Lyon.
- In 1801 presented his invention in an industrial exhibition in Paris.
- Loom operators smashed the looms and once himself.
- The loom was declared public property in 1806, and Jacquard was rewarded with a pension and a royalty on each machine.
- In 1812 there was more than 11,000 of his loom in operation.

Jacquard's Loom

- Invented (1801) punched wooden card loom.
- Wooden cards were held together by rope.
- Presence/absence of hole allows/stops a thread.

Analytical Machine

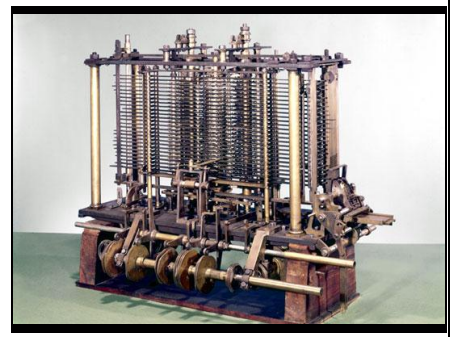
Charles **Babbage**

(1791-1871)

- In 1822 proposed a steam driven **Difference Engine** to compute tables for ocean navigation.
- The project became the most expensive project funded up to then by the British government.
- After 10 years the funding dried up.
- Only in 1991, the engine was built according to Babbage's original plans

Analytical Machine

- In 1837 he proposed the first general purpose **Analytic Engine**
- Programmable due to the punched card technology.
- First noticed that the punched paper could be used as a storage mechanism.
- Created the conditional statement.
- Only built in 1910 (British Museum)



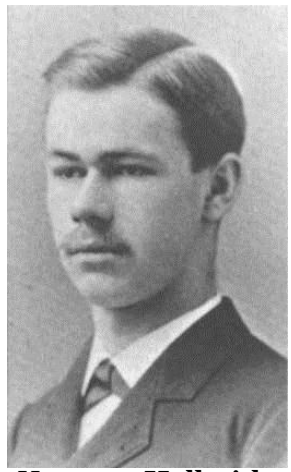
http://www.youtube.com/watch?v=aCsBDNf9Mig&feature=player_detailpage

Analytical Machine

Ada Byron
(1815-1852)

- Babbage's friend.
- The first (Babbage) computer programmer .
- Invented the "subroutine" and the "loops".
- Her notes with sequences of instructions for the never built Analytical Engine, gave her a place in the history as the first computer programmer.

Hollerith Desk



Hermann **Hollerith**
(1860-1929)

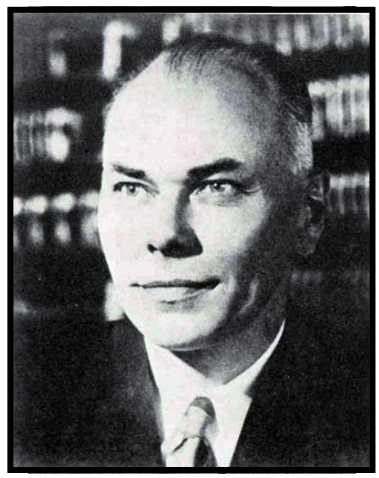
- Got a grant from U.S. census Bureau.
- With his Hollerith desk, from 9 months (1790) and 7.5 years (1880) to 3 years (1890).
- Founder of the **Tabulating Machine Company** (1890) which changed its name to **International Business Machines** Corporation in 1924.

Hollerith Desk

- Converted punched card into *read/write* technology inspired by train conductors.
- Punched cards became ubiquitous.
- Hollerith and his company became an empire.

http://www.youtube.com/watch?v=9HXjLW7v-II

Mark I



Howard **Aiken**
(1900-1973)

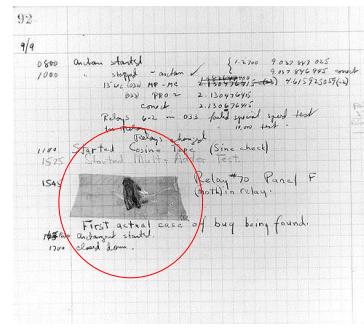
- During his Ph.D. in Harvard, he conceived a mechanical device to solve differential equations numerically.
- Funded by IBM he built in 1944 the *Automatic Sequence Controlled Calculator* (ASCC), later known as Harvard Mark I

Mark I

- **1st programmable computer in US (1944)**
- The machine was designed to produce ballistic "firing tables" replacing the "computer ladies".
- Characteristics:
  - 5 tons,
  - 800 Km of wire,
  - 2.5 m tall and 15 m long,
  - 5 hp electric motor.

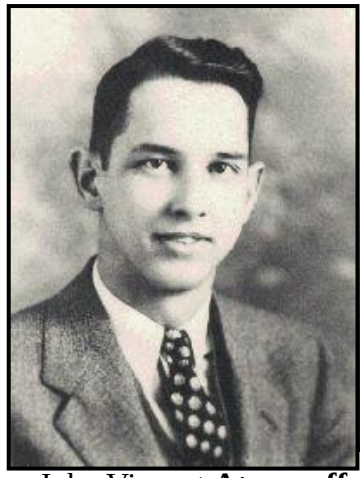
Mark I

Grace Hopper, a Mark I&II programmer, invented the *first* high-level language "flowmatic" → COBOL and the compiler concept.



She found the first computer "bug".

ABC Computer

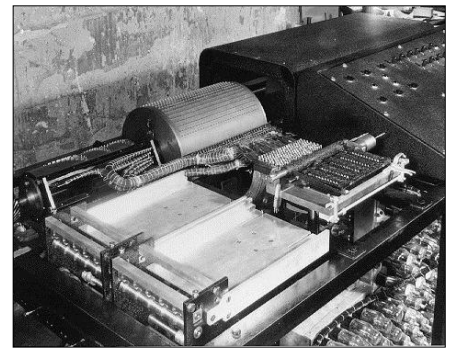


John Vincent **Atanasoff**
(1903-1995)

- Electrical Engineer, professor at Iowa State University
- Conceived the ABC "*in a flash of insight during the winter of 1937–1938*".
- Prototype by the end of 1939 with the help of
  - Clifford Berry (1918-1963), and
  - a U$ 8,500.00 (2010) grant.

ABC Computer

- **First fully electronic computer**
- Conceived (1939) and tested (1942)
- Innovations:
  - Store data as charge in a capacitor
  - Use of binary arithmetic
- But
  - Not programmable,
  - No conditional branch,
  - single problem device (equation system),
  - No offspring.

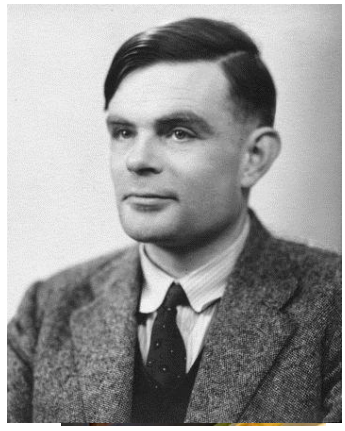


Enigma

Arthur **Scherbius**
(1878-1929)

- Enigma refers to a family of electro mechanical machines used for the encryption and decryption of secret messages.
- First built by Arthur Scherbius in 1918, and widely used by the Nazi Germany during WWII.
- Cracking Enigma code was a major endeavor during the war.

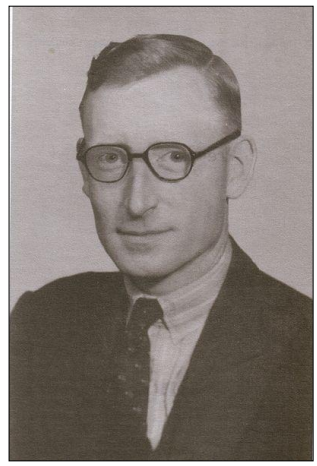
The Bombe Machine



Alan **Turing**
(1912-1954)

- A group of mathematicians working at Bletchley Park (GB) was dedicated to crack the Enigma.
- Few weeks after having joined the group, Alan Turing managed to crack the code.
- He designed an electro-mechanical device, called, Bombe Machine to search all possibilities.
- Theme of a number of movies.

Colossus

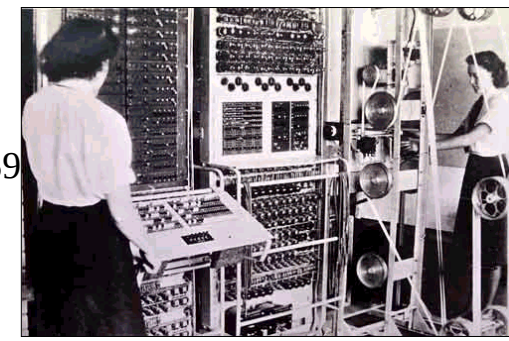


Thomas Herald **Flowers**
(1905-1998)

- Involved in a project to break the *Enigma* codes during WWII.
- Confident on valves due to his experience at the General Post Office.
- Built Colossus in 11 months (January 1944).
- Acknowledged only in the 70's, since the project was kept classified even after the war.

Colossus

- **First (?) programmable electronic computer**
- two or more tried multiple possibilities simultaneously → parallel processing.
- decommissioned in 1959 and 1960 .
- Not general purpose.



The Z Family

Konrad **Zuse**

(1910-1995)

- German civil engineer.
- Being too "lazy" to do the calculations at Henschel, he designed a machine to do it.
- "reinvented" programming and "reintroduced" the binary representation.
- Created the *Plankalkül*, the actual first high-level programming language (1948).
- His contribution was acknowledged much later.

The Z Family

Z1

- It was a mechanical, binary and electrically driven programmable computer.
- First freely programmable with instructions from a punched tape.
- It used Boolean logic and binary floating point numbers.
- Destroyed in the bombardment of Berlin in December 1943.
- "Rebuilt" in 1989.

http://www.youtube.com/watch?v=XlCOigL8vWg

The Z Family

Z3

- First fully **operational** programmable computer (1941)
- The Nazi Government considered it "strategically unimportant".

http://www.youtube.com/watch?v=289TNbmdaiA&feature=related

- Electro-mechanical (relays).
- Boolean logic and binary floating point numbers.
- A *von Neumann* architecture before *von-Neumann*.

Outline

- Computer Generations
- Zeroth Generation: Mechanical Devices
- **First Generation: Vacuum Tubes**
- Second Generation: Transistor
- Third Generation: Integrated Circuits
- The VLSI Era
- The ULSI Era

ENIAC

Electronic Numerical Integrator and Calculator

- Eckert and Mauchley (Pennsylvania University) got a grant to develop a computer for military purposes.

John William **Mauchly**

(1907 – 1980)

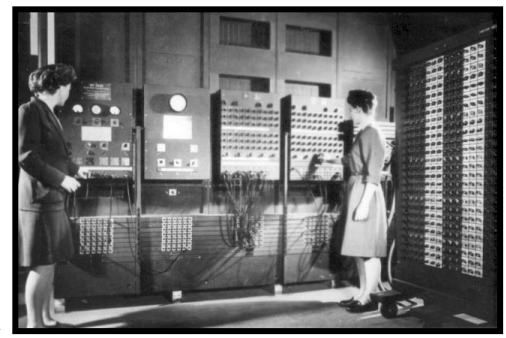
John Adam Presper **Eckert** Jr.

(1919 – 1995)

ENIAC

Characteristics:

- Decimal (not binary)
- 20 accumulators of 10 digits
- Programmed manually by switches
- 18,000 vacuum tubes
- 30 tons
- 1350 square meter
- 140 kW power consumption
- 5,000 additions per second



(U.S. Army photo from the archives of the ARL Technical Library)

ENIAC

- When finished after the war (1946), Eckert and Mauchley promoted a summer school for their scientific colleagues.
- This launched a bunch of new projects (EDSAC, JOHNIAC, ILLIAC, MANIAC, WIZAC.)
- Eckert and Mauchley began the EDVAC project.
- They left Pennsylvania University to found the **Eckert-Mauchley Computer Corporation** → **Unisys**.

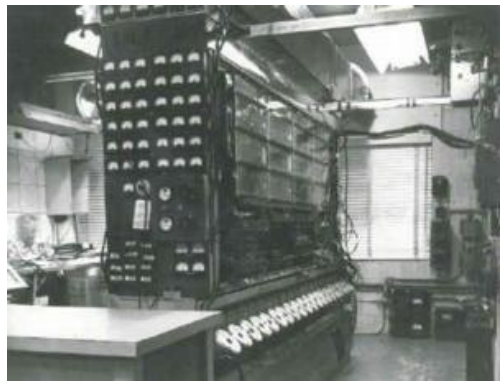
EDVAC

Janos **von Neumann**

(1903-1957)

- A Hungarian Jew regarded as one of the greatest mathematicians in modern history.
- Ph.D. at the age of 22.
- 10/36 major papers by age 25/30.
- In 1930 emigrated from Germany to US
- Worked at Princeton University till his death.
- Was the most notable ENIAC consultant.

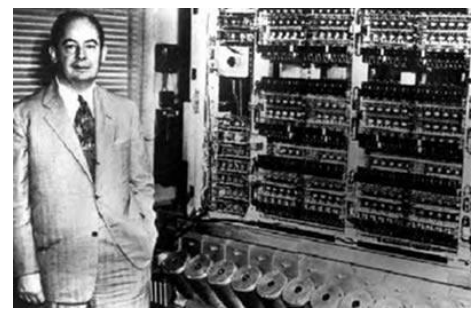
EDVAC



- Eckert and Machley were the main designers,
- Binary (not decimal) arithmetic.
- Sequential memory (mercury delay lines)
- Introduced the Stored Program concept - main memory storing programs and data.
- Precursor of the von Neumann Architecture.

IAS – the von Neumann Machine

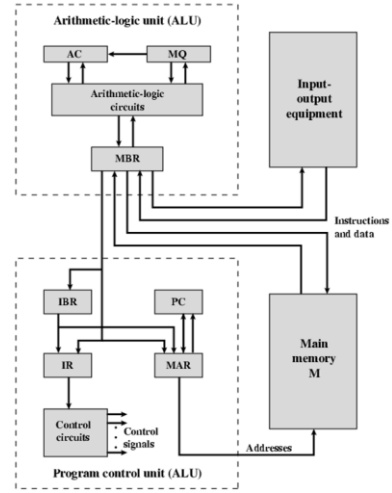
- **Characteristics:**
  - stored program,
  - binary data,
  - parallel memory
  - interpreting instructions from memory,
  - Input and output equipment operated by control unit.



IAS – the von Neumann Machine

Details:

- Memory Buffer Register (MBR)
- Memory Address Register (MAR)
- Instruction Register (IR)
- Instruction Buffer Register (IBR)
- Program Counter (PC)
- Accumulator (AC)
- Multiplier Quotient (MQ)



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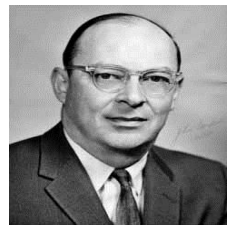
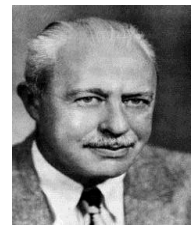
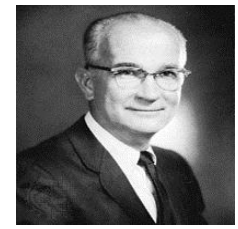
Transistor invented in 1948



John Bardeen
(1908-1991)



Walter Brattain
(1902-1987)



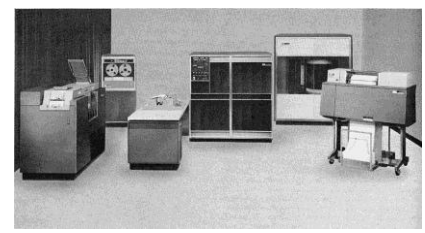
William Shockley
(1910-1989)

High level programming languages
System Software

Second Generation: Transistors

IBM 1401

- Launched by IBM in 1959.
- Little business oriented.
- Decimal computer.
- One of the most successful IBM product (≥ 20,000 units sold up to 1971).



Second Generation: Transistors

IBM 7094

- Launched by IBM in 1962.
- Made IBM the major force in scientific computing.
- Binary computer.
- Double precision floating point.

Second Generation: Transistors

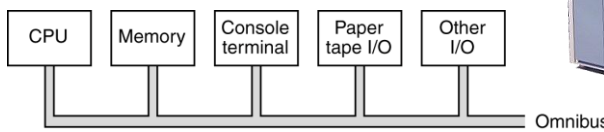
PDP-1

- DEC was founded in 1957
- PDP-1 was launched in 1961
- ½ performance of IBM 7090
- $ 120,000 (PDP-1)
- millions (IBM 7080)
- Introduced the CRT.
- First video game (spacewar) at M.I.T.

Second Generation: Transistors

PDP-8

- Launched by DEC in 1965 .
- It started the minicomputer phenomenon.
- Introduced the single bus.



Second Generation: Transistors

CDC 6600

- Introduced by Control Data Corporation (1964).
- One order of magnitude faster than IBM 7094 (or any other existing computer).
- Highly parallel CPU.

Second Generation: Transistors

Seymour Cray

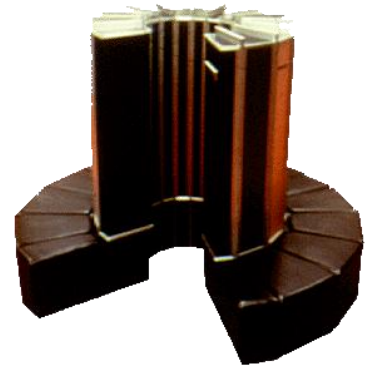
- father of supercomputing
- Former CDC designer.
- Founder of Cray Computer Corporation in 1971.

Seymour Cray (1925-1996)

Second Generation: Transistors

Cray-1

- Introduced in 1976.
- C shape to keep the wire length below 1,2 m.
- Other models in the family followed in the next generations.
- Refrigeration system using Freon.



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Third Generation: Integrated Circuits

Robert Noyce

- invented in 1958 the Silicon Integrated Circuit.
- co-founded
  - Fairchild Semiconductor (1957)
  - Intel (1968).

Robert Noyce (1927-1990)

Third Generation: Integrated Circuits

IBM System/360

- Introduced in 1964
- Innovations:
  - Family concept
  - Emulation
  - Multiprogramming

Third Generation: Integrated Circuits

DEC leads the minicomputer market.

PDP-11

VAX

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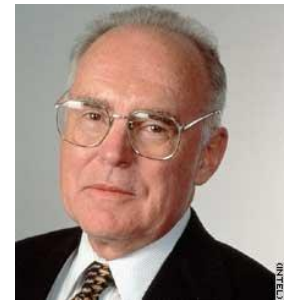
The VLSI Era

Moore's Law

"Number of transistors on a chip will double every year."

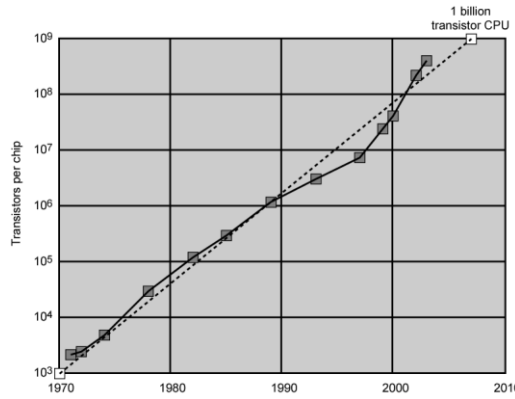
Actually after 1970's number of transistors doubles every 18 months.



Intel's co-founder Gordon Moore

The VLSI Era

Growth in CPU Transistor Count



The VLSI Era

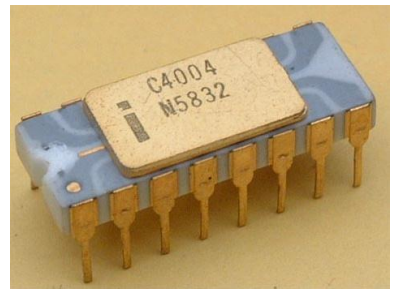
With the increased integration density

- 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.

The VLSI Era

The Personal Computer Age (4th/5th?)

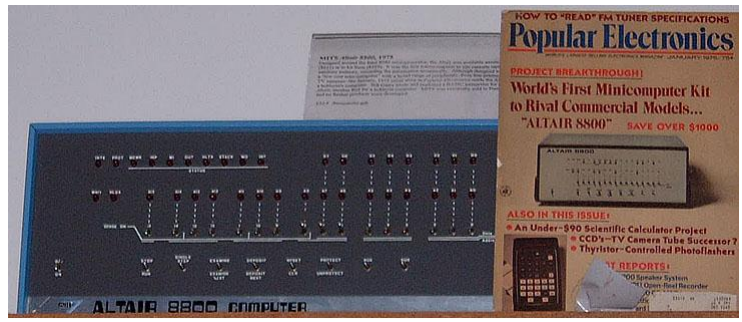
- Intel introduces the first microprocessor 4004 (1971)



The Personal Computer Era

The Personal Computer Age (4th/5th?)

- Altair 8800, the first PC is introduced in 1975



worth watching → http://www.youtube.com/watch?v=Hd_ptbiPoXM

The VLSI Era

The Personal Computer Age (4th/5th?)

- Steve Jobs and Steve Wozniak found the Apple Inc. in 1976

Steve Jobs Steve Wozniak

http://g1.globo.com/tecnologia/noticia/2010/11/primeiro-computador-comercializado-pela-apple-em-1976-vai-leilao.html

The VLSI Era

The Personal Computer Age (4th/5th?)

Apple introduces Apple I (1976) and Apple II (1979)

The VLSI Era

The Personal Computer Age (4th/5th?)

with the Macintosh (1984) the GUI concept

The VLSI Era

The Personal Computer Age (4th/5th?)

The Apple GUI concept in 2010 (iPad)

The VLSI Era

The Personal Computer Age (4th/5th?)

- IBM introduces the IBM-PC (1981)
- Equipped with the MS-DOS Operating System

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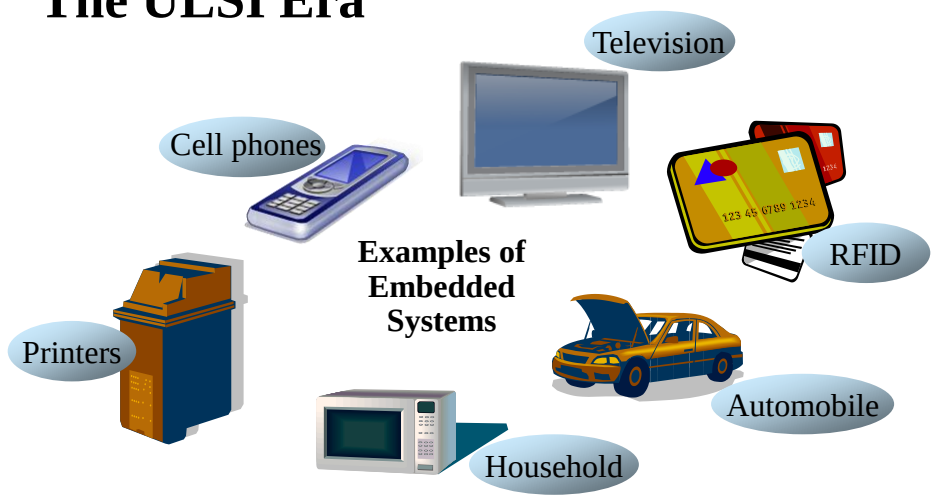
The ULSI Era

Embedded Systems

"A combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a dedicated function.

In many cases, embedded systems are part of a larger system or product, as in the case of antilock braking system in a car".

The ULSI Era



The ULSI Era

Ubcomp (4th/5th?)

- Ubiquitous computing / pervasive computing / intelligent environment / everyware is a trend toward embedding information processing into everyday objects and activities.
- *"…small, inexpensive, robust networked processing devices, distributed at all scales throughout everyday life and generally turned to distinctly common-place ends"* Joyce Shofield

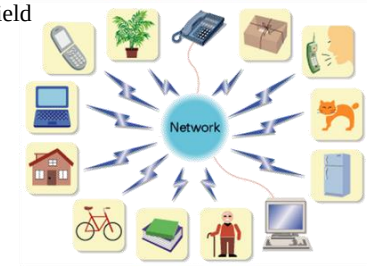


Image from www.ibm.com/developerworks/mydeveloperworks/blogs/ctaurion/entry/internet_das_coisas_e_cloud_computing14?lang=en

Text Book References

These topics are covered in

- Stallings - section 2.1
- Tanenbaum - section 1.2
- Parhami - section 3.3

Milestones in Computer Architecture

END