COMPUTER SYSTEMS ARCHITECTURE

Instructor

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ABOUT THE UNIT

- **Textbook**

  None

- **Teaching Method**

  2 hours of formal lectures

- **Assessment**

Project	40%
Final Exam	60%

UNIT OBJECTIVES

- **After the end of this unit you will:**
  - be able to comfortably deal with the computer terminology,
  - have an overview of the computer systems components,
  - have a basic understanding of computer architecture,
  - have a good understanding of computer number representation and conversion,
  - have a basic understanding of digital circuits

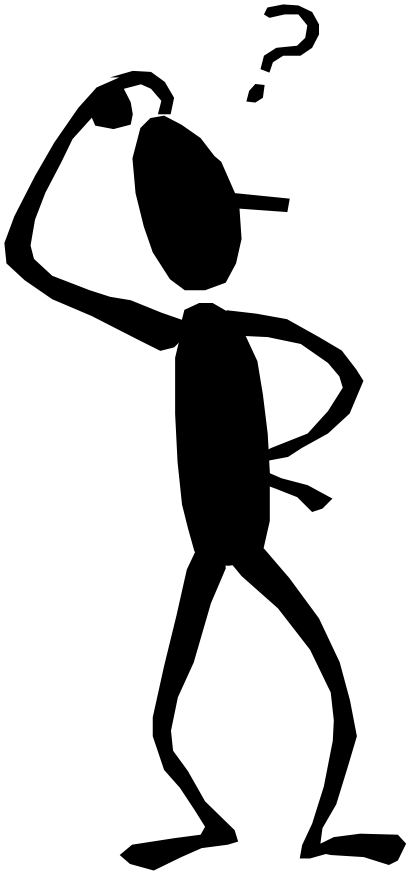
week 0001
Introduction to CSA

CCS1310

Computer Systems Architecture

LECTURE 0001

- What are the benefits of computers?
- What is computer architecture?
- What is a computer?
- How does a computer differ from other tools?
- What can a computer do?
- What can a computer not do?
- How are computers classified?
- How were computers developed?



COMPUTER USERS

- **Main Categories**
  - **Basic users**
    - Perform various tasks using commercial (proprietary or open access) software
    - Largest group
  - **Computer programmers**
    - Develop new programs, simple or complex
  - **Computer technicians and service people**
    - Repair, upgrade
    - Know inner workings of computers and electronics
  - **Computer engineers**
    - Design and build computer components
    - Extensive knowledge of electronics, digital logic, semiconductor physics

COMPUTER SYSTEM'S OPERATIONS
– Why is it important to understand them?

- **Benefits for computer users:**
  - Be aware of capabilities, strengths, limitations of a computer
  - Better understanding of the commands used
  - Be informed about computer equipment and application programs
  - Effectively understand the operating system and use it efficiently
- **Benefits for computer architects:**
  - Programmer: write better programs
  - System Analyst: gain a better understanding of technical specifications of a computer system and the ability to analyze the best way to provide appropriate facilities to meet users needs
  - System Administrator or Manager: gain the ability to maximize efficiency of the systems by optimizing the performance

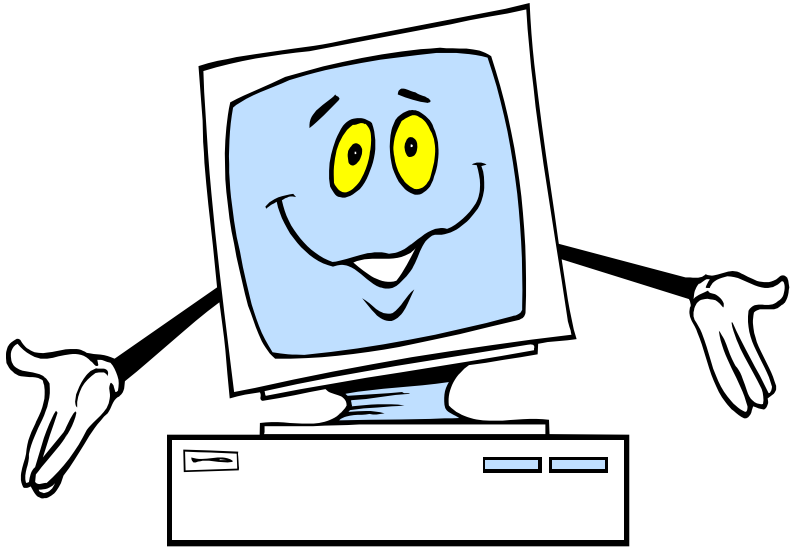
COMPUTER ARCHITECTURE

- What is the difference between computer architecture and hardware?
  - **Hardware** is the actual physical components of the computer
  - **Architecture** is the design of the layout, and connectivity of these hardware components

WHAT IS A COMPUTER?

- An electronic device that performs the tasks:
  - Accept **input**
  - **Process** input according to a set of instructions
  - **Store** the instructions and results of processing
  - **Output** information

But is it **intelligent**?
Does it **provide solutions**?



THE LIMITATION OF COMPUTERS

KEY CONCEPT
Computers only **follow** instructions provided by **people**. Computers cannot **solve problems** by themselves.

To **solve a problem**, one must first

(i) understand the problem

(ii) model the problem

(iii) develop an idea for solving the problem

Computers cannot do these things for us, but they can **help us** develop ideas and understanding faster

THE POWER OF COMPUTERS

- **So, what is the power of computers?**
  - A computer allows one person to **utilize the expertise** of another person
  - Computers work much **faster** than people
  - Computers are (usually) **more reliable** than people when it comes to performing repetitive or tedious tasks

Can a computer …

Cure cancer?

Save the whales?

Eliminate starvation?

Prevent crime?

Why not?

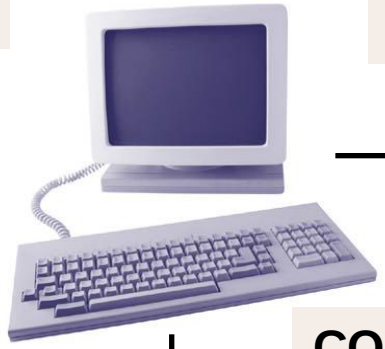
CANs AND CANNOTs

- A computer cannot cure cancer, but it can be used to analyze the behavior of cancer and its reactions to various therapies
- A computer cannot save the whales, but it can be used to track migration patterns, which will help us understand why they are endangered
- A computer cannot eliminate crime, but it can be used to detect crime and recognize social and economic patterns that lead to high crime rates, and thus predict crime occurrences

GENERAL MODULES

DATA
Facts and observations. It is processed by the computer system to provide information. It can take many different forms.

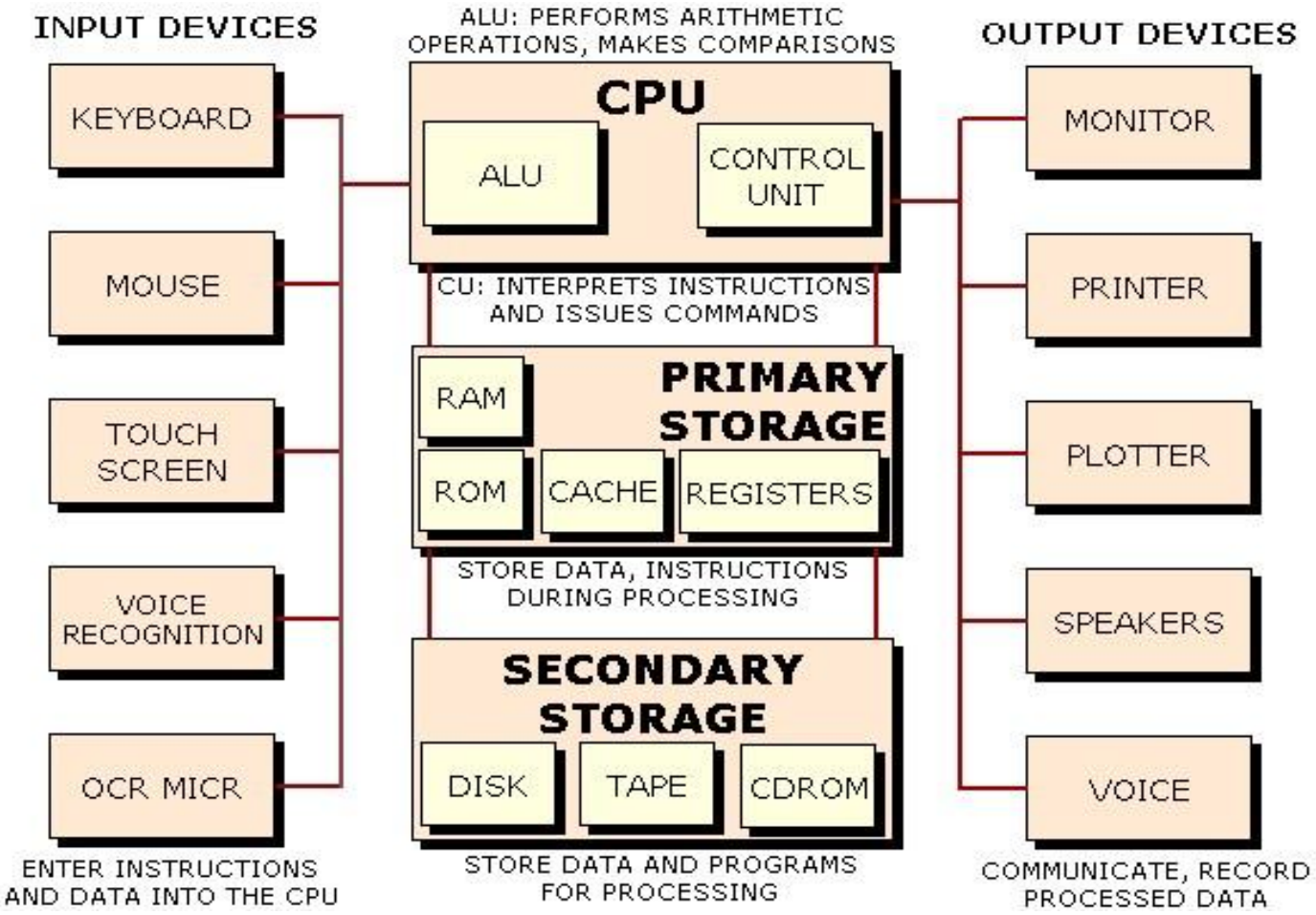
HARDWARE
The most visible part of a computer. It provides the physical mechanisms to input, process, and output data.



SOFTWARE
Programs that tell the computer what to do. Two major categories: system software and application software.

COMMUNICATIONS
Modern information systems depend on the ability of data sharing locally or remotely. Both hardware and software are required to achieve this goal.

BASIC HARDWARE COMPONENTS



TRENDS IN COMPUTER HARDWARE

COMPONENT	TREND	MEASURE
CPU	Increase in speed	MIPS*
MAIN MEMORY	Increase in size	Gigabytes
SECONDARY STORAGE	Increase in data transfer rate Increase in size	Megabytes/sec Gigabytes
INPUT DEVICES	Become more natural to use	Ease of use
OUTPUT DEVICES	Multimedia	Quality of output

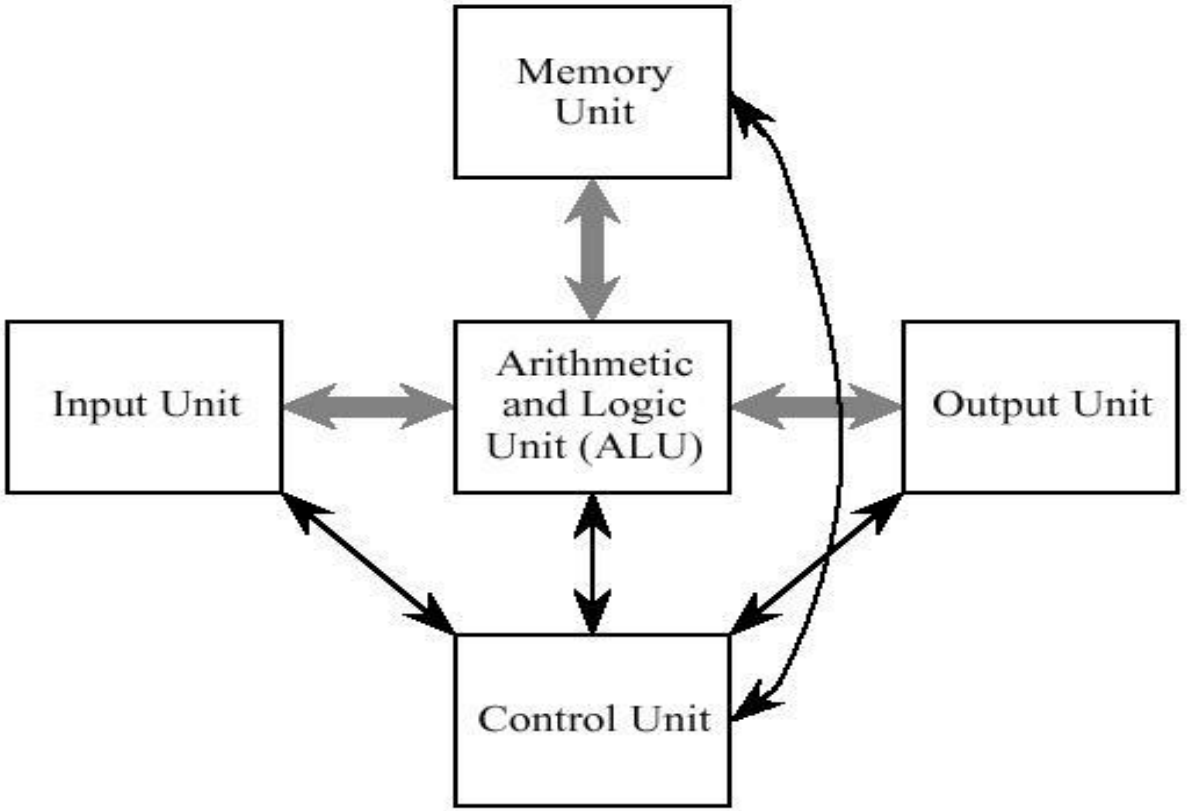
*MIPS: Millions of Instructions Per Second

BASIC COMPUTER SCIENCE CONCEPT - Stored Program Architecture

- **John Von Neumann** Model (1945)
- Five major components:
  1. **Input Unit**: provides instructions and data
  2. **Memory Unit**: where instructions and data are stored
  3. **Arithmetic Logic Unit:** processes instructions and data
  4. **Control Unit:** supervises and directs the operations
  5. **Output unit:** where the results are sent

- **Stored Program Architecture**: **a program is stored in computer's memory (in binary form) along with the data to be processed**
- Key concept: Instructions are sequentially executed

Von Neumann Model

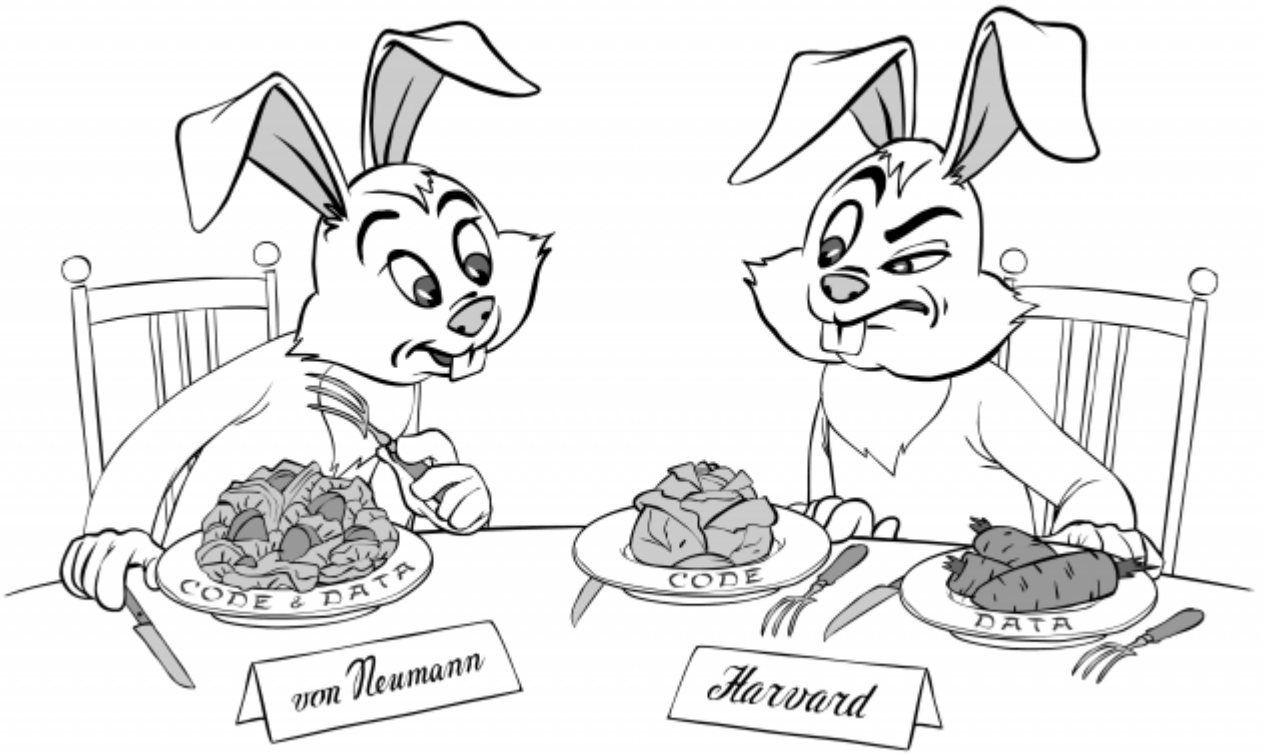


Von Neumann Model bottleneck

- Susceptible to bottlenecks → system performance is affected

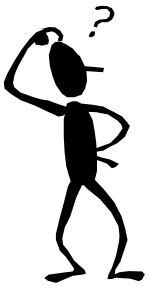
- **Harvard Architecture**
  - Stores machine instructions and data in separate memory units
- **Modified Harvard Architecture**
  - **No physical separation** between the memory spaces for data and instructions,
  - **Technically** described as Von Neumann
  - Two separate *pathways* for data and code

Von Neumann vs Harvard

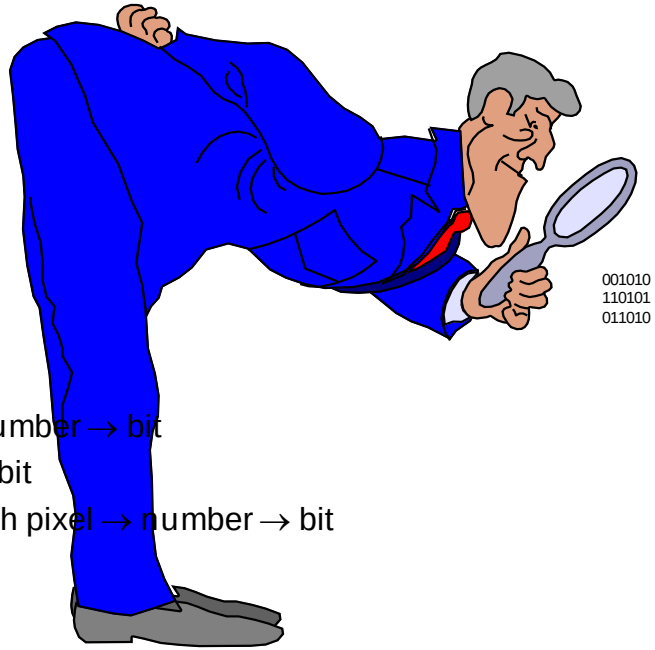


BASIC COMPUTER SCIENCE CONCEPT

Data Formats



- Numeric
- Alphanumeric
- Graphic (bmp, jpeg)
- Audio (wav, mp3, mid)
- Video (avi, mpeg)



Sound → pitch → number → bit

Letter → number → bit

Image → color at each pixel → number → bit

HOW DOES THE COMPUTER UNDERSTAND INPUT?

- Two distinct electrical states (OFF, ON or 0, 1)
- Binary System: uses only 0's and 1's

DATA REPRESENTATION

- **Bit**
  - A bit (binary digit) is the **smallest unit of data** all electronic computers use
  - A bit has a single binary value, either 0 or 1
- **Byte**
  - A unit of data that is **eight binary digits** (bits) long
  - A byte is the unit most computers use to represent a character such as a letter, number, or symbol
- 1 Byte = 8 bits
- 1 Kilobyte (Kb) = 2^{10} bytes = 1,024 bytes
- 1 Megabyte (MB) = 2^{20} bytes = 1,048,576 bytes
- 1 Gigabyte (GB) = 2^{30} bytes = 1,073,741,824 bytes
- 1 Terabyte (TB) = 2^{40} bytes = 1,099,511,627,776 bytes

PERFORMANCE MEASURES

MIPS (Million of (basic) Instructions Per Second)
The number of MIPS is a general measure of computing performance and, by implication, the amount of work a computer can do.

MFLOPS (FLOating Point Operations)
The number of instructions that involve floating point numbers.

Gigahertz (GHz)
A billion cycles of electromagnetic currency alternation per second and is used as a unit of measure for the “clock speed” of processor.

COMPUTER CLASSIFICATION
- with respect to processing power

SUPERCOMPUTERS

FLOPS

- Have the most processing power of computers generally available (very expensive)
- 10 times faster than mainframes
- To increase speed even further, companies link individual processors
- Primarily used for scientific and military work, but recently also for business
- Especially valuable for large simulation models that require complex mathematical calculations

SUPERCOMPUTER

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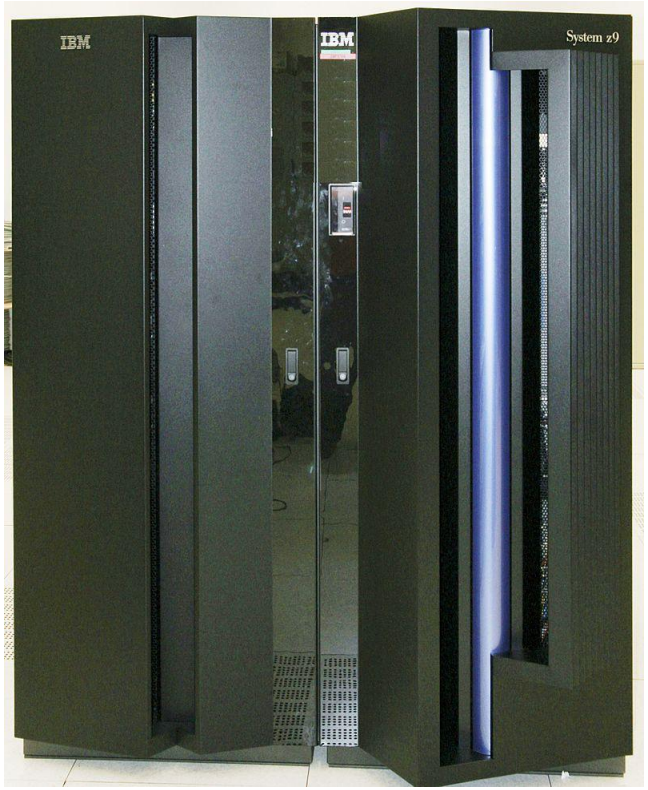
MAINFRAMES

MIPS

- Not as powerful, large and expensive as supercomputers.
- Used by large corporations where data processing is centralized and large databases are maintained (banks and financial institutions)
- Applications can be large and complex allowing for data and information to be shared throughout the organization
- High primary storage and high capacity secondary storage (GB-TB)
- Hundreds or thousands of terminals can be linked

MAINFRAME



https://youtu.be/UJfnQt-YSIM

COMPUTER CLASSIFICATION
- with respect to processing power

MINICOMPUTERS

- Also called midrange computers
- Relatively small, cheap, and compact
- Perform the same functions with mainframes but to a limited extent
- They are now somewhat obsolete; considered to have been replaced by servers

SERVER

COMPUTER CLASSIFICATION
- with respect to processing power

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MICROCOMPUTERS

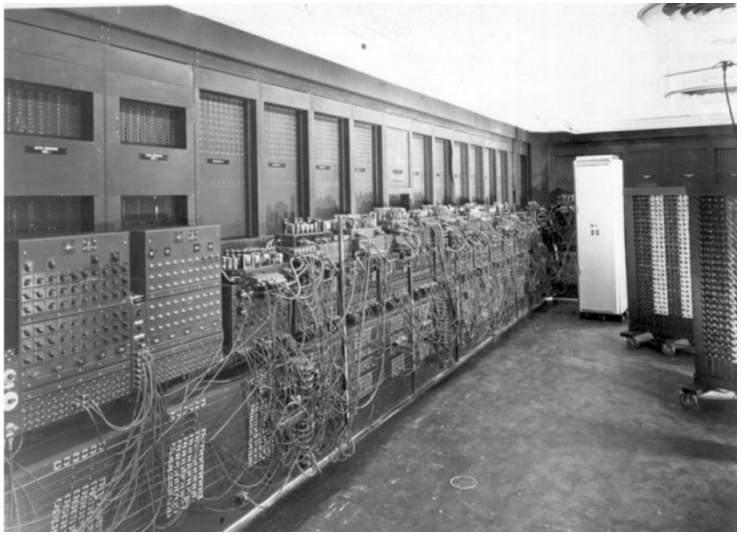
- Built around a single chip processor
- Relatively small in size
- Designed to be used by a single individual
- The least expensive computers
- Also called Personal Computers or PC's
- Categorized into desktop and portable

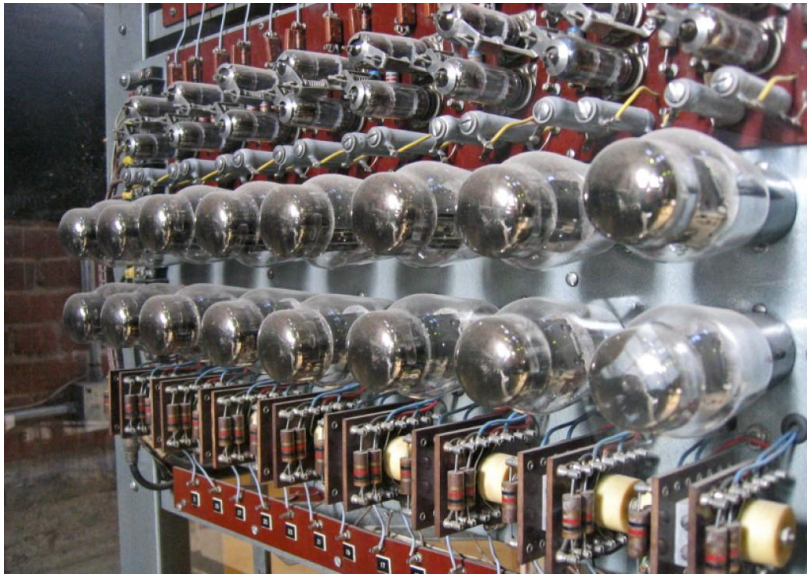
COMPUTER GENERATIONS

- FIVE generations
  - Based on evolution of chip technology
  - Characterized by the electric current flowing through various processing mechanisms

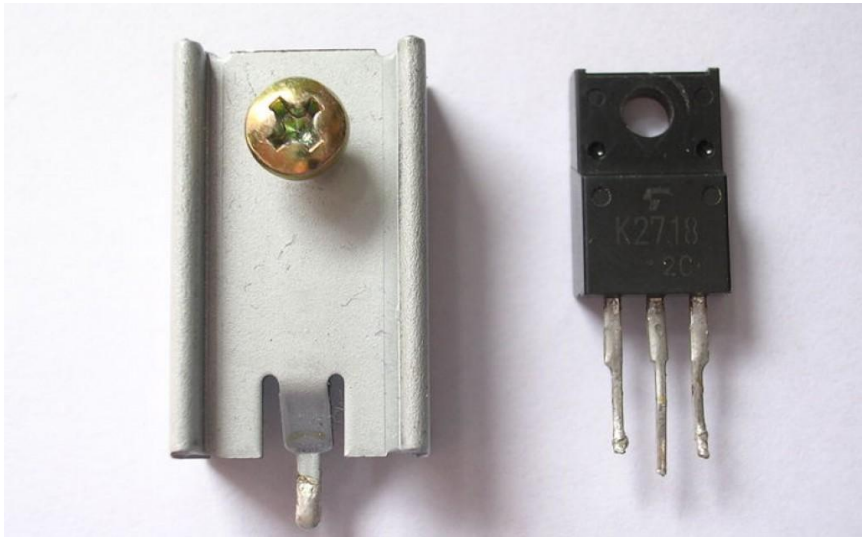
FIRST GENERATION (1940s – 1950s)

- Vacuum tubes
- Magnetic tapes for external storage
- Punched cards for input
- Punched cards and paper for output
- Generated too much heat (malfunctions)
- Could solve one problem at a time
- **Human operators to set switches**
- **Machine language**
- ENICAC & UNIVAC I typical examples



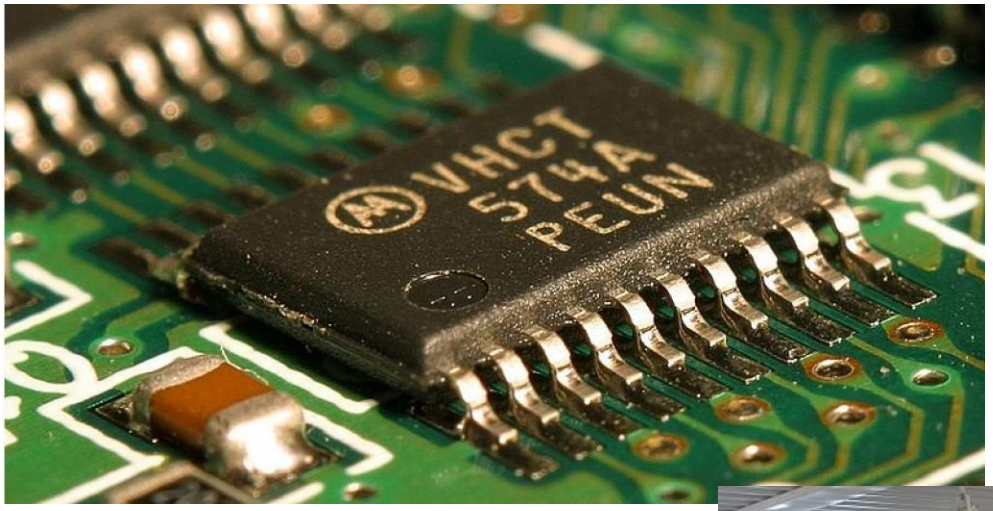


SECOND GENERATION (1950s – 1960s)



Transistors
Magnetic disk introduced for storage
Multiple punched cards fed into a magnetic tape for input
Punched cards and paper for output
Assembly AND High-level languages (FORTRAN, COBOL, BASIC)
OS introduced
Human operator to handle punched cards

THIRD GENERATION (1960s – 1970s)



Integrated circuits
Improved disk storage
Monitors and keyboards for I/O
More high-level languages (PASCAL)
First complete operating system
Minicomputers used commercially
IBM System/360 typical example

FOURTH GENERATION (1970s – today)

Microprocessor
Microcomputer
CPUs
Mouse
GUI
Magnetic disk most common storage
Fourth generation languages emerged

FIFTH GENERATION (present & future)

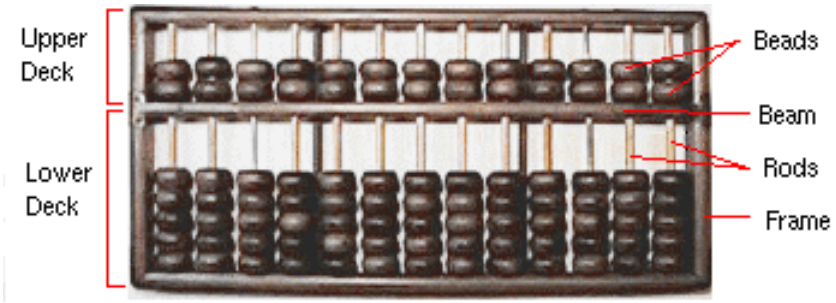
True Artificial Intelligence
Machine Learning
Understand Natural Language
See the world in 3-D

WHO INVENTED THE COMPUTER?

- Questions we can ask:
  - Who invented the computer?
  - Why was the computer invented?
- It is more accurate to say the computer evolved, rather than that it was invented (no one owns a patent for the invention of the computer)
- Many prototypes were invented, each based on earlier work or ideas
- Let's look at the evolution of computers...
- https://youtu.be/VMuQppYtTCo

AT THE BEGINNING

- Ancient times
  - The abacus was invented ~5,000 (!!!) years ago by the Babylonians, later upgraded in Asia



  - The abacus is the original mechanical counting device
  - Possible operations include:
    - addition, subtraction, multiplication, and division
    - even fractions, root square and statistics

CONTINUING ON

- 1600s:
  - In 1621, William Oughtred invented the slide rule
  - In 1642, Blaise Pascal invented the "Pascaline", the first mechanical digital calculator with operations:
    - addition and subtraction
    - multiplication and division (added later)

SIDE NOTE…

- 1800s:
  - Joseph Jacquard (a silk weaver) automated the pattern-weaving process in 1804
  - He encoded patterns on punched cards, which were read by the machine
  - So what?
    - First programmable machine!

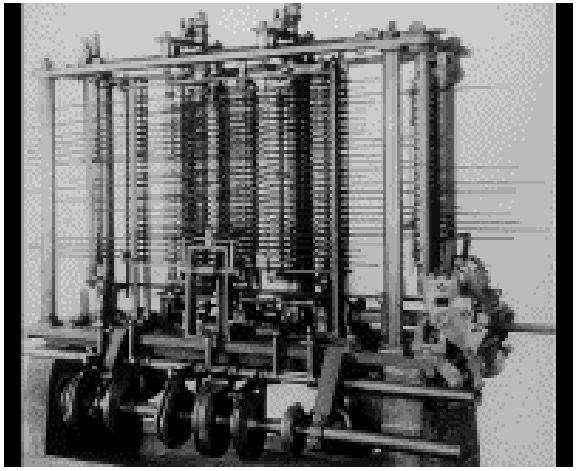
CONTINUING ON

- 1800s, continued...
  - English mathematician Charles Babbage wanted to calculate using steam. Why?
  - human computers make too many mistakes
  - steam was latest, greatest technology
  - steam does physical tasks, why not mental?

- Proposed the difference engine (1822)
  - wheels & shafts calculate using method of difference (easy process to mechanize)
  - printed results
  - never completed

WE ARE GETTING SOMEWHERE...

- 1800s, continued...
  - Charles Babbage moved on to the analytical engine (1834)
  - general purpose calculating device
  - embodies many modern computing concepts:
    - Memory
    - programmable processor
    - output device
    - user-definable input of programs & data
  - proposed using punched cards
  - never built



  - Lady Ada Lovelace was the first programmer
    - suggested using binary
    - loops

LAZINESS AS A VIRTUE …

- 1930s–40s:
  - Konrad Zuse was lazy: he didn't want to perform calculations by hand, so he invented a computer
  - used electric relays, 2 states (on/off)
  - used binary instead of decimal (easier to represent)
  - War broke out, funding appeared
  - Konrad Zuse's Z3:
  - 1st programmable, general-purpose, electromechanical computer

WARTIME CODEBREAKING

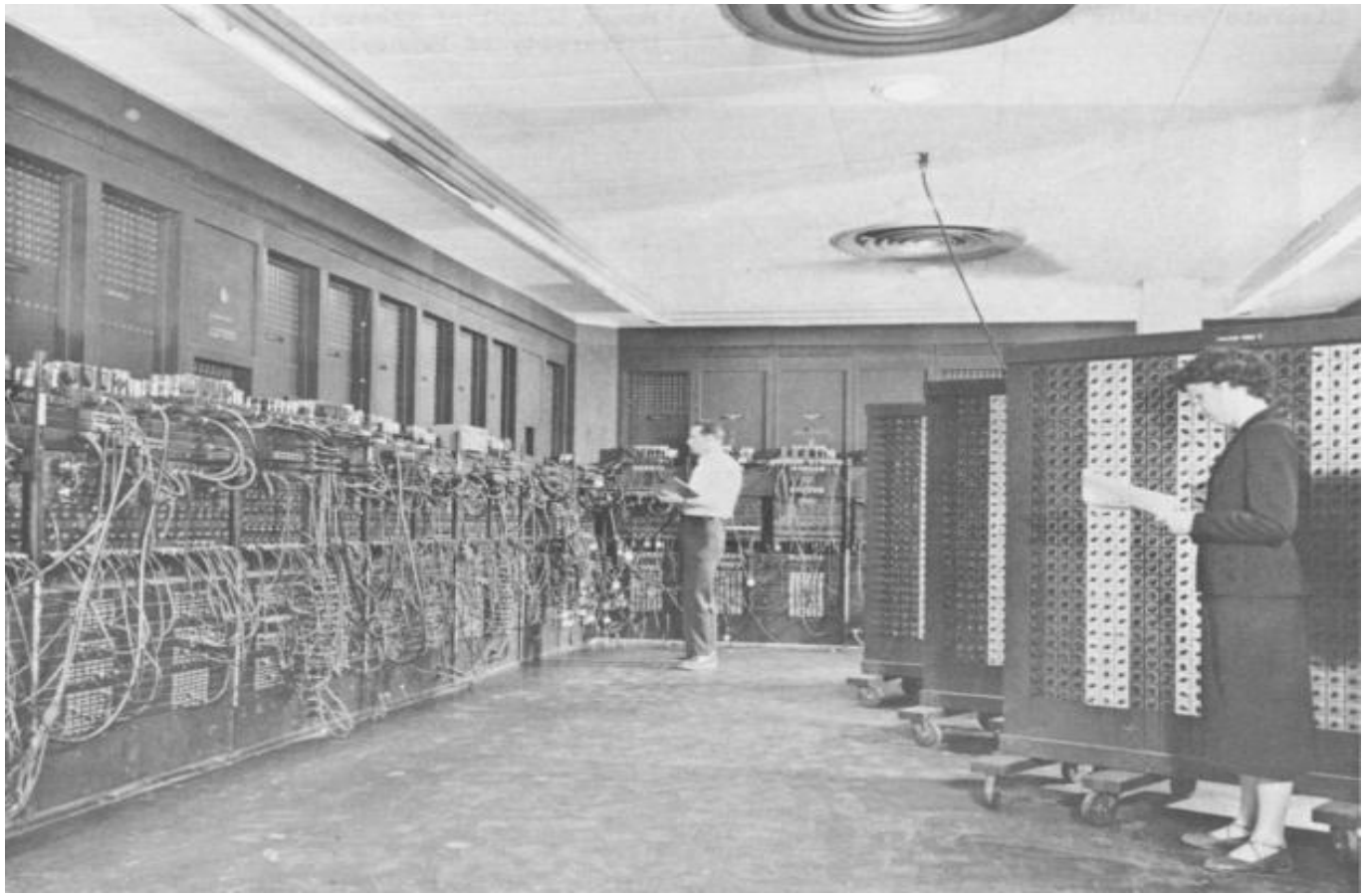
- So far, computers crunch numbers
- British mathematician Alan Turing believed machines could do any theoretical process a human could do
- Letters are just symbols: use machine to break codes
- **COLOSSUS**, a top secret machine to break the ENIGMA's codes
- Turing test:

  Given 5 minutes, a keyboard & a monitor, if we are not more than 70% sure it is a machine, we have to admit it has shown some intelligence

DURING THE WAR

- America Enters the War, needed firing tables calculated
- Howard Aiken, and IBM:
  - **Mark I:** **Electromechanical** digital computer
- Need something faster
- J. Presper Eckert & John Mauchly
  - **ENIAC**: Electronic Numerical Integrator & Computer
  - vacuum tubes (speed increased thousandfold)
  - Patented as 1st **electronic**, general-purpose computer in 1946, patent later voided
  - ready after the war… (oops)
  - limitations:
    - no internal storage
    - rewire plugboards & set switches
    - took days to re-program

ENIAC



POST – WAR

Post-war: 1940s and early 50s

John von Neumann

- memory easier to change than rewiring hardware
- separate hardware & software
- store program & data
- theoretical blueprint for all future computers

Freddy Williams designed the **EDSAC**: the first stored-program computer

Eckert & Mauchly Computer Company 1946

- **UNIVAC**: first **commercial** general-purpose computer, delivered to US Census Bureau by Remington-Rand, 1951

PROBLEMS

Late 1950s, into 1960s

Growing problem: SOFTWARE!

Programming in machine language:

- 0's & 1's
- hardware specific
- difficult & tedious to write & debug programs!
- everyone has custom software

Not enough programmers!

Software costs 2-4 times the amount of the machine!

Compilers: Fortran & COBOL

REPLACING THE VACUUM TUBE

Late 1950s, into 1960s

Transistors invented in 1956

- 50th the size of vacuum tubes
- no heat
- 100th weight
- less power needed

New problem: wiring the transistors together

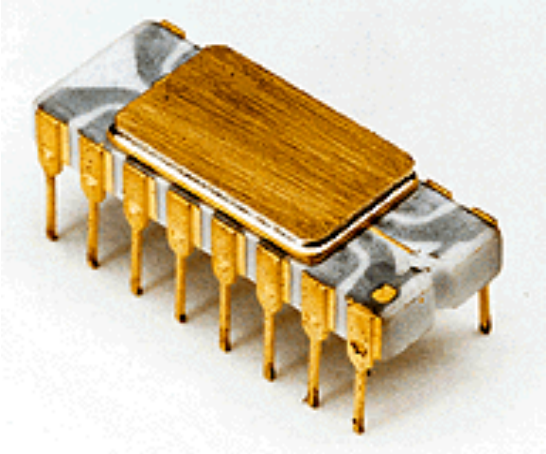
- "tyranny of numbers"
- tangled mess of wires, hard to trace

Solution: integrated circuit

- silicon, altered to create transistors & other components, with layer of metal on top (which is evaporated except for connections)
- wiring now part of manufacturing process

SMALLER THAN EVER

- 1959: first integrated circuit (IC) announced
  - Not used right away: too expensive
  - First IC cost $1000
- 1960s:
  - Drive to put man on the moon
  - Need to fit computer in spaceship
- 1970s and Silicon Valley
  - ICs: smaller, denser, faster, cheaper
- 1971: first “microprocessor”: Intel 4004



ADVANCES IN TECHNOLOGY

1971 – now

- Do some research on your own …

- Speed: doubles every 1-2 years
- Memory: doubles every 3-4 years
- Weight, Size: relatively constant except for notebooks & PDAs

Moore's Law:

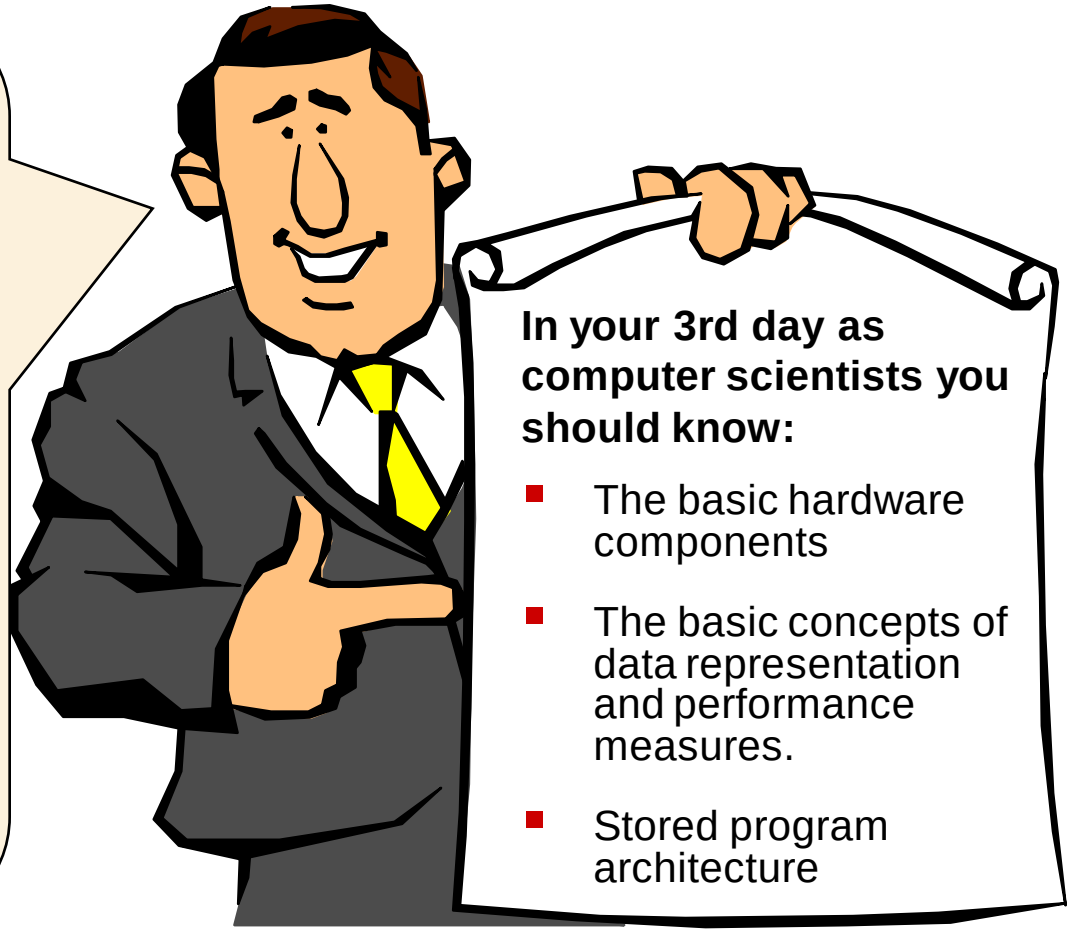
Gordon Moore predicted that the number of transistors per integrated circuit would double every 18 months

SUMMARY

Knowing the architecture of computers is beneficial both to computer users and computer architects.

A computer is comprised of many hardware components but they relatively easy to understand.

Computers can be classified according to many criteria one of which is processing power.



In your 3rd day as computer scientists you should know:

- The basic hardware components
- The basic concepts of data representation and performance measures.
- Stored program architecture