

Computer Architectures

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Main Objectives

- Understand how data is represented and processed
 - **Represent data** with 0s and 1s (numbers, text, images and sound)
 - Process 0s and 1s using Boolean Algebra
- Understand the HARDWARE
 - What are computers made of ? (**Digital Systems**)
 - What is “computer architecture”?
 - What is a microprocessor ? (μ p)
- Understand different types SOFTWARE
 - **Machine Language**
 - High level languages
 - Operating systems and “device drivers”

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Syllabus (overview)

- 1. Introduction to *computing machines*
- 2. Data representation
- 3. Boolean Algebra
- 4. Digital Systems
- 5. Memory systems
- 6. Computer Architecture
- 7. Microprocessors
- 8. Peripherals
- 9. Operating Systems, programming languages, and performance evaluation

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Why is it important ?

- Because **we want to understand** the world around us!
- Because only by understanding how computing machines work can we understand:
 - Their **limitations**
 - Their **capabilities**
 - **How to choose** them, to buy them, and to use them properly
- Because it is part of the STI *curriculum* ...
 - You need to know this to get your degree...

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Tough issues (or not...)

- **All information can be described in 0s and 1s**
 - The complete works of William Shakespeare; Michelangelo's Sistine Chapel; Handel's Messiah; your mother's face and voice...
- There is a **mathematical formulation** specifically for working with 0 and 1 (Boolean Algebra)
- You can build a **physical device** that can perform the *AND*, *OR*, and *NOT* logical operations
- **All information processing** can be made using **combinations of AND, OR, and NOT**

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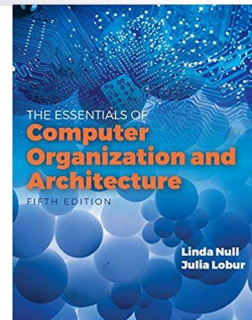
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Bibliography

■ Text book

- **Computer Organization and Architecture**, Linda Null & Julia Lobur, Jones and Bartlett, 5th Edition, 2018



□ Other books

- Introduction to Computer Science
 - An Invitation to Computer Science, 6th Ed, G.Michael Schneider, Judith Gersting, 2012
- Brief introduction with (more or less) recent hardware
 - **Tecnologias de Informação**, Sérgio Sousa, FCA, 2009.
- General introduction to Information Systems
 - **Introduction to Information Systems**, Rainer, Turban *et al.*, John Wiley & Sons, 2011



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Bibliography (more detailed)

■ Digital Systems and Microprocessors

- Digital Fundamentals (10th Ed), Floyd, Prentice-Hall, 2010
- Sistemas Digitais, Padilha, McGraw-Hill

■ Operating Systems

- Modern Operating Systems (Global Ed), Tannenbaum, Prentice-Hall, 2015
- Sistemas Operativos, Alves Marques *et al.*, FCA, 2009.

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Assessment

- Final written exam
 - After the classes end (50 % of the grade) (up to 70%)
- Evaluation during the semester
 - Mini-tests (10+10%)(optional, mainly for feed-back)
 - Dates: 27th October, 15th December
 - If you fail in the mini-tests, the final exam will count more.
 - Assembly language program (20%)
 - Due date: 12th January.
 - Literature review and presentation (10%)
 - List of possible themes (suggestions are welcome)
 - **10 minute** presentation, and **2 page** report
 - **Minimum grade in any item: 9/20**

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Objectives of the presentation

- **Search** for relevant information on Information Technologies
 - Learn about scientific on-line repositories
 - Get to know the most relevant publications
- Learn how to **assimilate** the relevant information
- Learn how to **present** it orally, using visual aids
- Learn how **write** a short technical report

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Rules of thumb for presentations

- Big letters, little text (only key ideas)
- Choose colours carefully (good contrast)
- Do **NOT** read !
- Use figures/schemas/tables when possible
- Rehearse your presentations, and keep the **TIME-LIMITS**

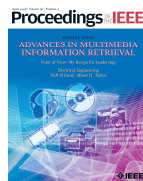
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Themes for the presentations

- Choose a paper from an ACM or IEEE scientific journal
 - Go to the ACM and IEEE websites, and explore ! (using the B-ON access to full papers)
- Examples of “general purpose” journals:



Communications of the ACM



Proceedings of the IEEE



IEEE Spectrum

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How to choose the theme

- Send an email to the teacher:
 - Use your novaims email
 - Start the SUBJECT with **HSTI**
 - Start the email with your NAME and STUDENT NUMBER
 - State the name of the paper/article, the complete reference of the Journal where you found it
 - The PDF of the paper in attachment
 - Send this information 1 WEEK before your presentation
 - You shall receive an email **accepting** your choice **or** suggesting you **choose another** theme

 - Paper/articles from other technical magazines/journals can be accepted if truly interesting
 - The exam will have questions regarding the presentations

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Examples of themes for the presentation

Processadores MIPS

Interfaces homem/máquina 3D

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Dates for the presentation of your Literature review (dates were randomly selected)

Date	Number	Name	Date	Number	Name
26/set	2016656	Salvador Maria Silveira Paio P	15/nov	2016644	Sara Moiteiro Campos
26/set	2015542	Ana Teresa de Jesus	14/nov	2016643	Miguel Farias Agostinho
26/set	2016665	Ricardo J			ia Silvestre
27/set	2013478	Nuno			
27/set	2015402				
3/out	2012				iros Carmona
3/out	201				o
3/out					
10/out					
10/out					
10/out					
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25					
25/out					
31/out					
31/out					
31/out	20				
7/nov	2016				
7/nov	2015579	B			
7/nov	2016653	Maria			
14/nov	2013524	João Carlos			
14/nov	2016647	Pedro Nuno Angelo m			omer Taylan
14/nov	2016640	Rita Nunes Pombo Marcelino			atarina Sofia Boto das Neves
			18/dez	2014517	Ricardo Nuno Pascoal dos Santos

We will wait 1 week so that we have the complete list of enrolled students

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Office hours and contacts

■ Email: vlobo@novaims.unl.pt

□ Office hours

- Tuesday 18:30-19:30 (or whenever agreed)
- By mail, anytime ! (always put COMPARC in the subject)
- Whenever I am free at NovalIMS (!)

□ Supporting materials

- www.novaims.unl.pt/docentes/vlobo, and Moodle platform

□ Changes in the class schedule

- It may be necessary to change classes, and I shall warn on Moodle
- Next Thursday I have a Thesis Discussion just before class...I might be late.

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General background of students

- What optional areas did you study in high school ?
- Do you know the Binary numbering system ?
- Do you know Boolean Algebra ?
- Did you pass in Computation I and II ?

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General overview of computing machinery

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Consider this advertisement:

FOR SALE: COMPUTER – CHEAP! CHEAP! CHEAP!

• Pentium 4 2.0 GHz
• 400MHz 256MB DDR SDRAM
• 2GB L1 cache, 256KB L2 cache, 160GB ATA hard drive, 1 serial port, 1 parallel port, 24mm AG, 1280 x 1024 active matrix TFT LCD, Express video card, Fax/modem, 10/100 Ethernet

GET INCREDIBLE DEALS ON THE HOTTEST TECH TOOLS

Gateway - One 20" All-in-One Computer ... **SAVE \$110**
\$389.99
AFTER SAVINGS

Lenovo - 23" Touch-Screen All-in-One Computer ... **SAVE \$200**
\$599.99
AFTER SAVINGS

BEST BUY EXCLUSIVE

HP - Desktop - 6GB Memory - 1TB Hard Drive **SAVE \$100**
\$349.99
AFTER SAVINGS

BEST BUY EXCLUSIVE

SAVE \$100
\$429.98
AFTER SAVINGS

What does it all mean??

L1 Cache??

GHZ??

MB??

USB??

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Basic components of a computer

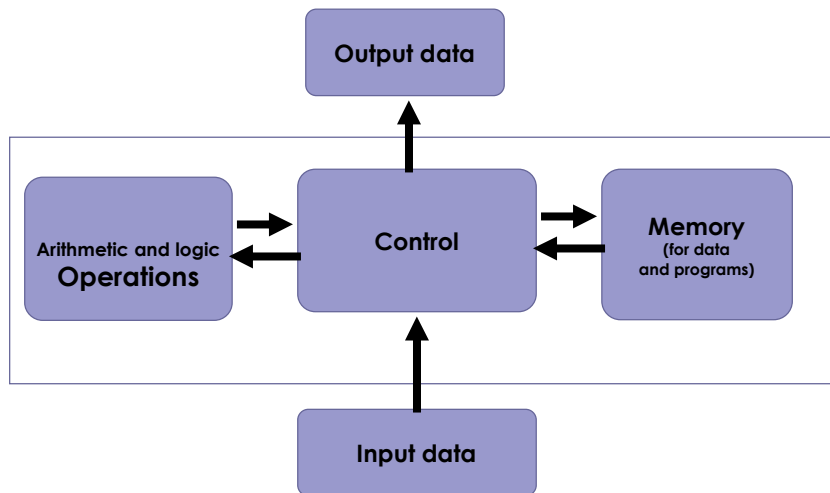
- **Processor** Unit
 - Process data, make computations
- **Memory** Unit
 - Store data, store instructions
- **Input/Output (I/O)** Units
 - Communicate with the outside world

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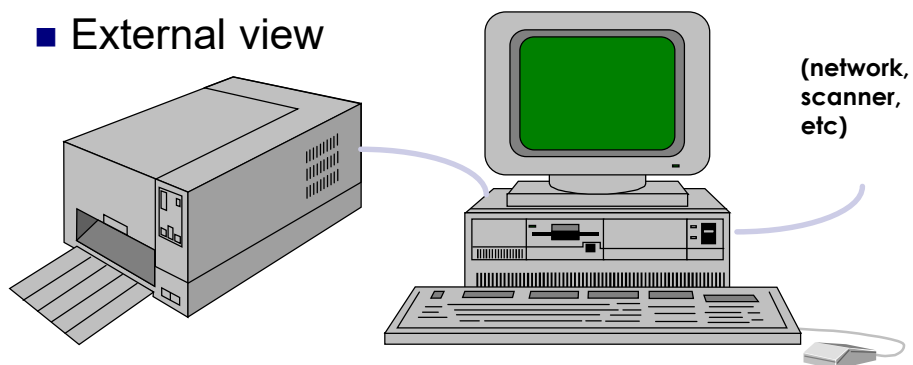
■ Von Neumann Architecture



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System components

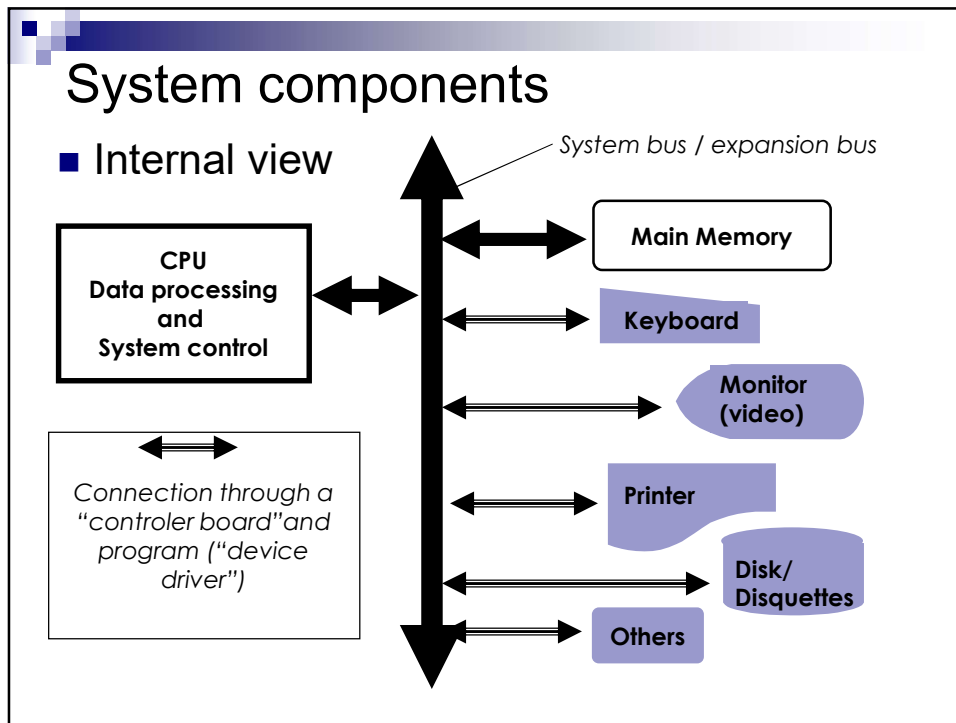
■ External view



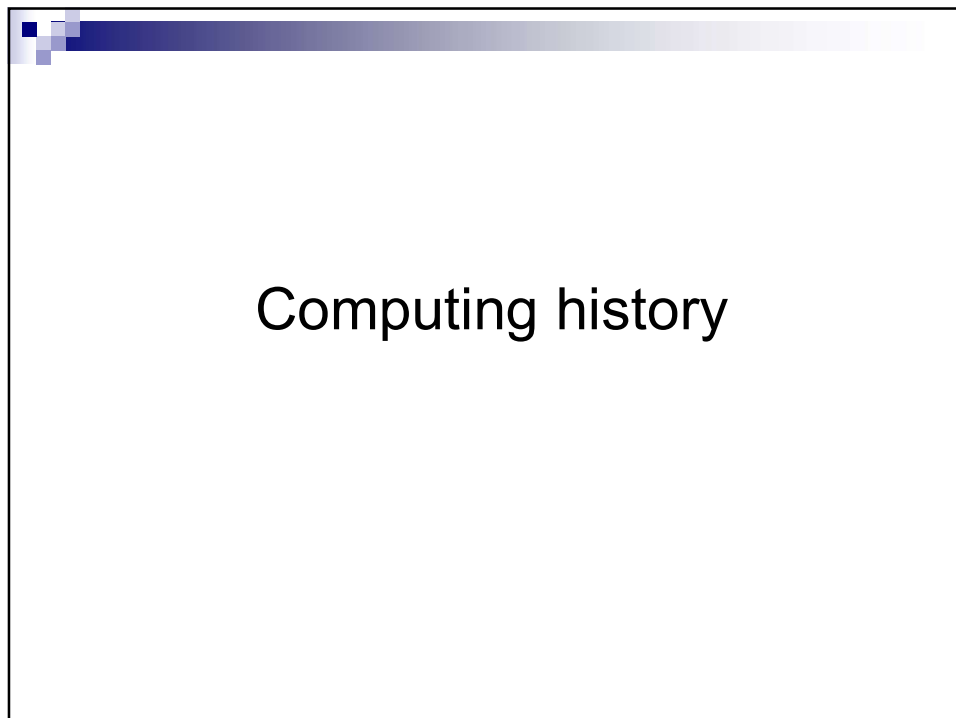
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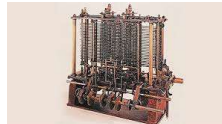
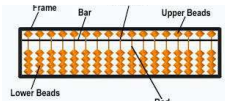
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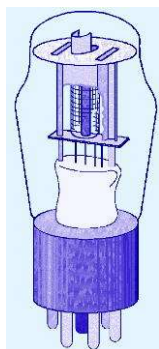
History of *computing machines*

- Machines that process information
 - Make computations, store data, automate processes
- Before computers
 - Abacus
 - Pascal Machines and Leibniz Machines
 - Sums and subtractions with gear wheels
 - Artillery computers
 - Babbage Machines
 - Logarithm tables for navigation and “modern mechanical computer”
 - Hollerith Machines
 - Card readers and rudimentary information processing
 - Dedicated analog machines



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First Generation computers: Vacuum Tube Computers (1945 - 1953)



- Pre-war pioneers
 - Theoretical work
 - “On computable numbers” by Alan Turing
 - Theory for “Switching circuits”
 - Atanasoff-Berry Computer (1937 - 1938) solved systems of linear equations.

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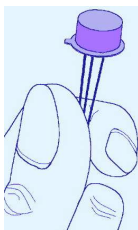
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First Generation computers: Vacuum Tube Computers (1945 - 1953)

- 2nd World War efforts
 - Electronic Numerical Integrator and Computer (ENIAC)
 - John Mauchly and J. Presper Eckert
 - University of Pennsylvania, 1946
 - The ENIAC was the first *general-purpose* computer
 - Colossus
 - Bletchley Park, UK
- Post war efforts
 - First commercial applications by UNIVAC and IBM

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Second Generation: Transistorized Computers (1954 - 1965)



- IBM 7094 (scientific) and 1401 (business)
- Digital Equipment Corporation (DEC) PDP-1
- Univac 1100
- Control Data Corporation 1604.
- . . . and many others.

These systems had few architectural similarities.

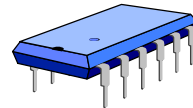
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Third Generation: Integrated Circuit Computers (1965-1980)

- Widespread industrial use
 - IBM 360
 - DEC PDP-8 and PDP-11
 - Cray-1 supercomputer
 - . . . and many others.
- By this time, IBM had gained overwhelming dominance in the industry.
 - Computer manufacturers of this era were characterized as IBM and the BUNCH (Burroughs, Unisys, NCR, Control Data, and Honeywell).



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- The Fourth Generation: VLSI Computers (1980 - ????)
 - Very large scale integrated circuits (VLSI) have more than 10,000 components per chip.
 - Enabled the creation of microprocessors.
 - The first was the 4-bit Intel 4004.
 - Later versions, such as the 8080, 8086, and 8088 spawned the idea of “personal computing.”
- Next ?
 - Massively parallel computers, Quantum computing ?

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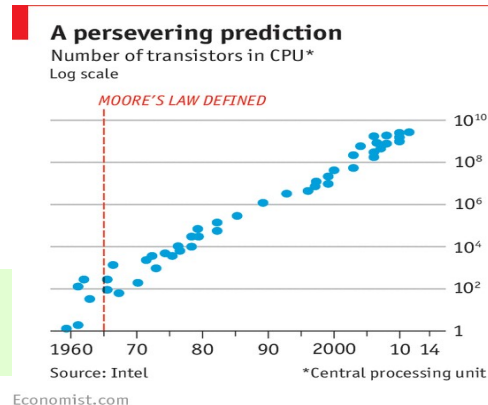
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- Moore's Law (1965)
 - Gordon Moore, Intel founder
 - "The density of transistors in an integrated circuit will double every year."

- Contemporary version:
"The density of silicon chips doubles every 18 months."

But this "law" cannot hold forever ...



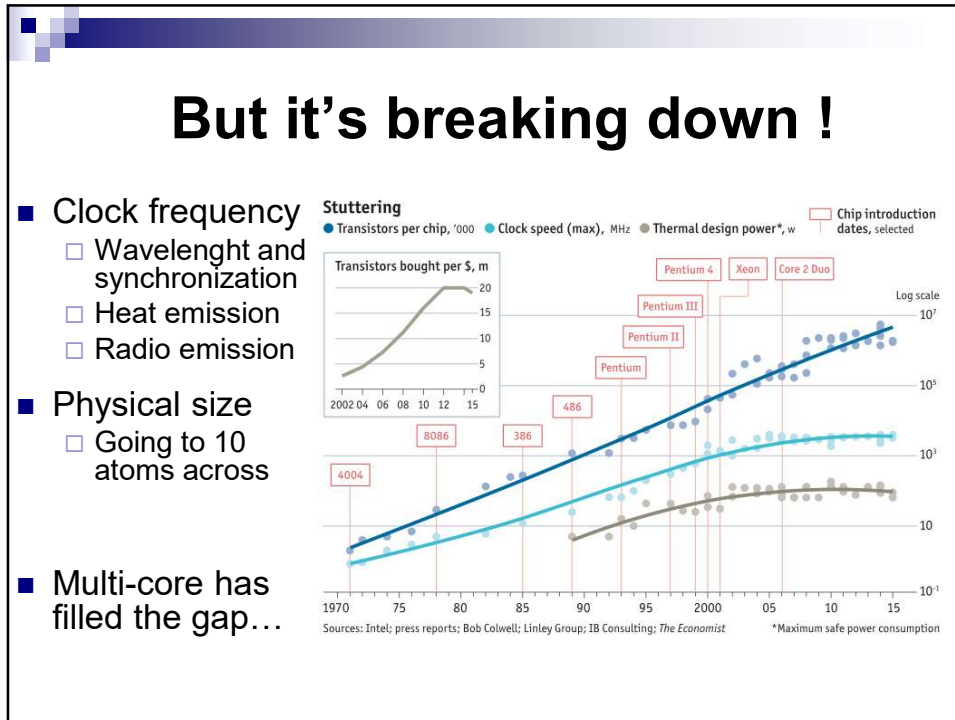
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- Rock's Law
 - Arthur Rock, Intel financier
 - "The cost of capital equipment to build semiconductors will double every four years."
 - In 1968, a new chip plant cost about \$12,000.
 - In 2005, a chip plant under construction cost over \$2.5 billion.
 - For Moore's Law to hold, Rock's Law must fall, or vice versa. But no one can say which will give out first.

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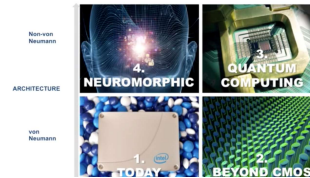
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What is being done

- IEEE International Conference on **Rebooting Computing**, San Diego, 2016
- Technologies “in the aisle”
 - Quantum Computing
 - Neural Computing
 - Neural Hardware, Deep learning, Spiking Networks
 - Approximate Stochastic Computing
 - Bayesian neural computing
 - Analog, dedicated hardware and asynchronous computing
 - Superconducting Computers
 - Advances in massively parallel computing
 - Advances in software engineering with alternate architectures



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Layered structure of organization in computers

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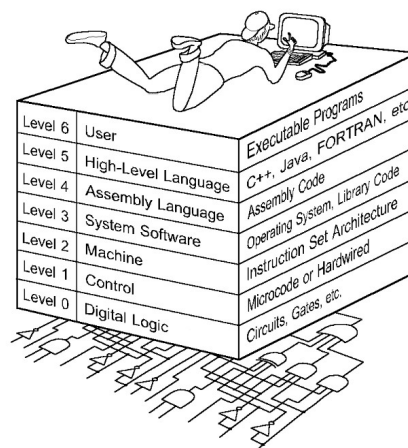
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- Computers consist of many things **besides chips**.
- Before a computer can do anything worthwhile, it must also use **software**.
- Writing complex programs requires a “**divide and conquer**” approach, where each program module solves a smaller problem.
- Complex computer systems employ a similar technique through a series of **virtual machine layers**.

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- Each virtual machine layer is an **abstraction** of the level below it.
- The machines at each level execute their own particular instructions, **calling upon machines at lower levels** to perform tasks as required.
- Computer circuits ultimately carry out the work.



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- Level 6: The User Level
 - Program execution and user interface level.
 - The level with which **we are most familiar**.
- Level 5: High-Level Language Level
 - The level with which we interact when we write programs in languages such as **C, Pascal, Lisp, and Java**.


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- Level 4: Assembly Language Level
 - Acts upon **assembly** language produced from Level 5, as well as instructions programmed directly at this level.
- Level 3: System Software Level
 - Controls executing **processes on the system**.
 - Protects system resources.
 - Assembly language instructions often pass through Level 3 without modification.

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- Level 2: Machine Level
 - Also known as the Instruction Set Architecture (ISA) Level.
 - Consists of instructions that are **particular to the architecture** of the machine.
 - Programs written in machine language need no compilers, interpreters, or assemblers.

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- Level 1: Control Level
 - A *control unit* decodes and executes instructions and moves data through the system.
 - Control units can be **microprogrammed or hardwired**.
 - A microprogram is a program written in a low-level language that is implemented by the hardware.
 - Hardwired control units consist of hardware that directly executes machine instructions.

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- Level 0: Digital Logic Level
 - This level is where we find **digital circuits** (the chips).
 - Digital circuits consist of gates and wires.
 - These components implement the mathematical logic of all other levels.

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- On the ENIAC, all programming was done at the digital logic level.
- Programming the computer involved moving plugs and wires.
- A different hardware configuration was needed to solve every unique problem type.

Configuring the ENIAC to solve a “simple” problem required many days labor by skilled technicians.

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- Inventors of the ENIAC, John Mauchley and J. Presper Eckert, conceived of a computer that could **store instructions in memory**.
- The invention of this idea has since been ascribed to a mathematician, John von Neumann, who was a contemporary of Mauchley and Eckert.
- Stored-program computers have become known as **von Neumann Architecture systems**.

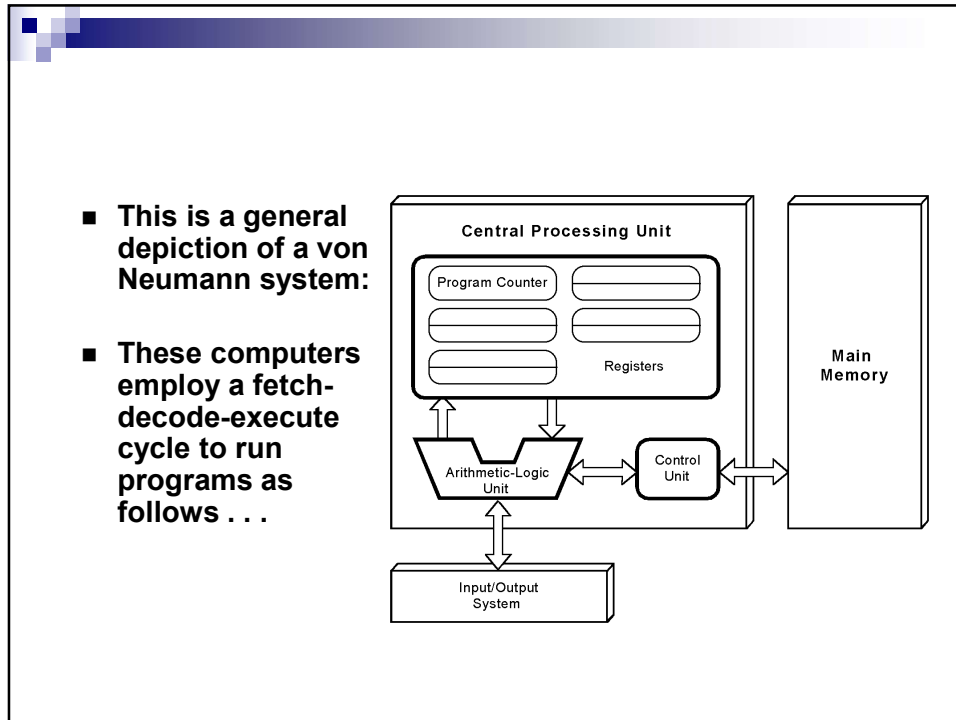
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- Today's stored-program computers have the following characteristics:
 - **Three hardware systems:**
 - A central processing unit (CPU)
 - A main memory system
 - An I/O system
 - The capacity to carry out sequential instruction processing.
 - A single data path between the CPU and main memory.
 - This single path is known as the *von Neumann bottleneck*.

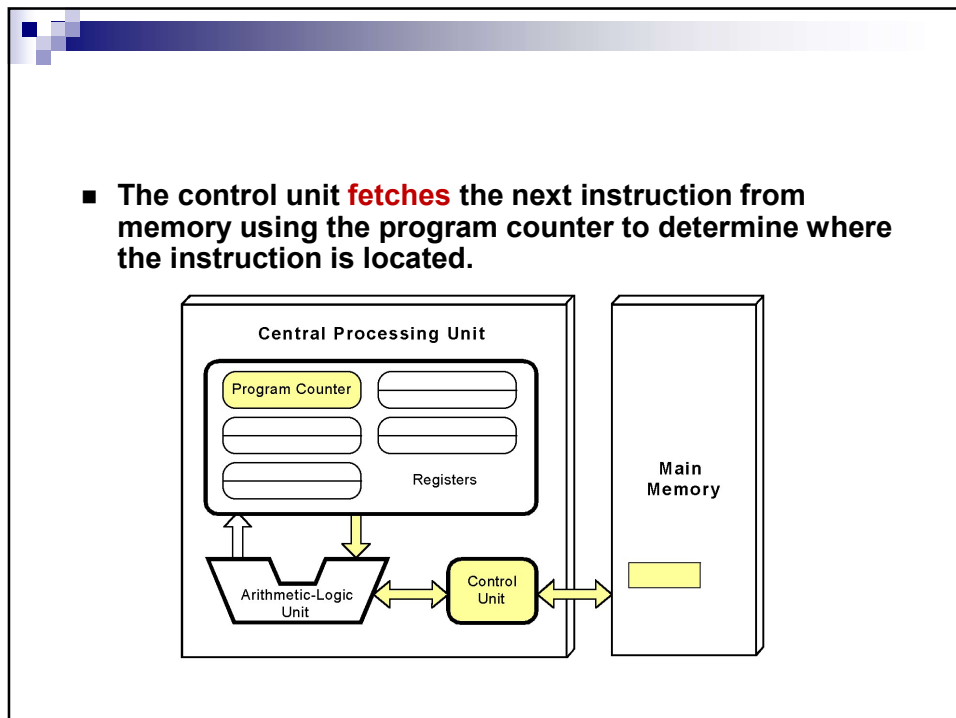
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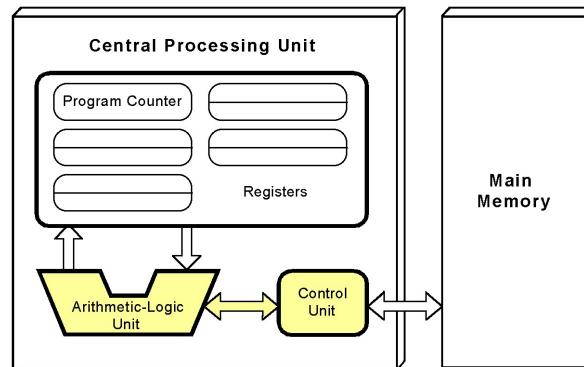


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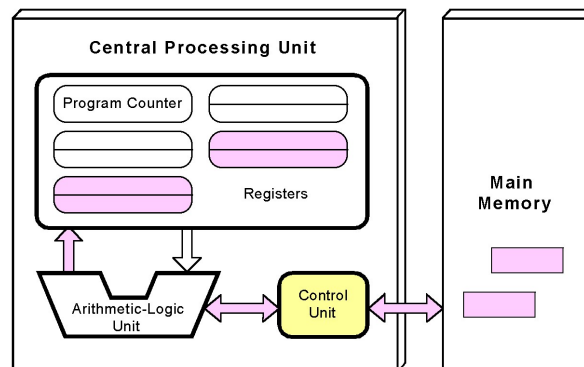
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- The instruction is **decoded** into a language that the ALU can understand.



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- Any **data operands** required to execute the instruction are fetched from memory and placed into registers within the CPU.

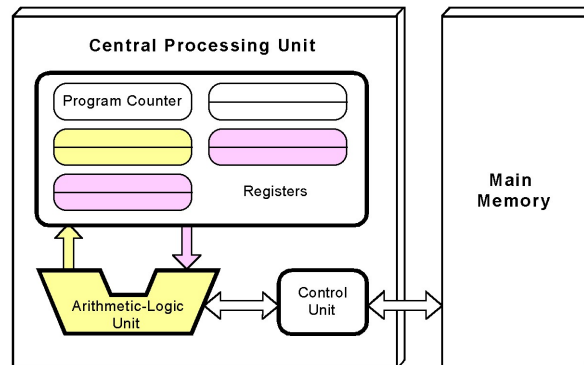


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- The ALU **executes** the instruction and places results in registers or memory.



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- Conventional stored-program computers have undergone many incremental improvements over the years.
- These improvements include adding **specialized buses**, **floating-point units**, and **cache memories**, to name only a few.
- But enormous improvements in computational power require departure from the classic von Neumann architecture.
- Adding processors is one approach.

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- In the late 1960s, high-performance computer systems were equipped with dual processors to increase computational throughput.
- In the 1970s supercomputer systems were introduced with 32 processors.
- Supercomputers with 1,000 processors were built in the 1980s.
- In 1999, IBM announced its Blue Gene system containing over 1 million processors.

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- **Parallel processing** is only one method of providing increased computational power.
- More radical systems have reinvented the fundamental concepts of computation.
 - These advanced systems include **neural hardware computers, genetic computers, quantum computers**, dataflow systems,
 - At this point, it is unclear whether any of these systems will provide the basis for the next generation of computers.

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- This chapter has given you an overview of the subject of computer architecture.
- You should now be sufficiently familiar with general system structure to guide your studies throughout the remainder of this course.
- Subsequent chapters will explore many of these topics in great detail.