Computer Organization and Architecture (Introduction)

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Course Details

- **Core course**
- 4 credits
- Monday and Saturday

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Focus of the Course

- **Study of computer hardware**
  - Architecture and organization view
- **Study of computer system**

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Hand Held Devices and Applications

Slide and Image Inspiration: NPTEL course on Advanced Computer Architecture

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Smart Farming

Slide and Image Inspiration: NPTEL course on Advanced Computer Architecture

Smart Health Care

Slide and Image Inspiration: NPTEL course on Advanced Computer Architecture

Smart Homes

Slide and Image Inspiration: NPTEL course on Advanced Computer Architecture

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Intelligent Transportation Systems

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High Precision Security Devices

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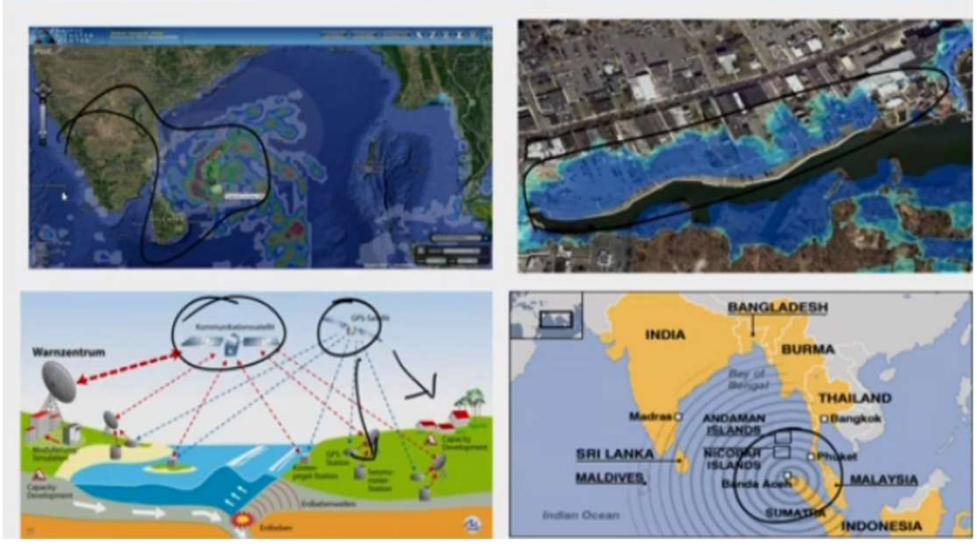
Weather Forecasting



Slide and Image Inspiration: NPTEL course on Advanced Computer Architecture

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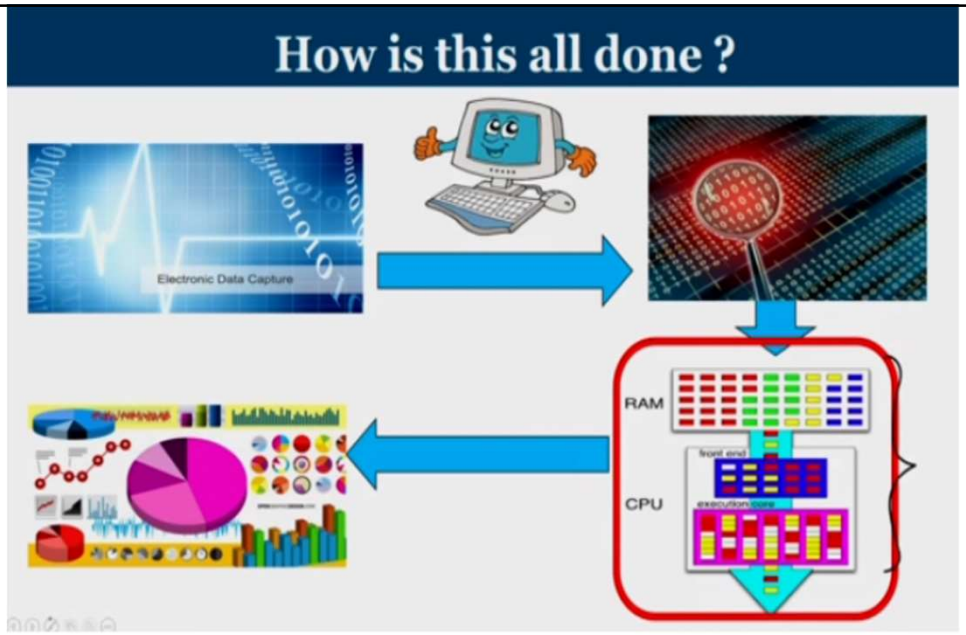

Slide inspiration and Image Source: NPTEL course on Advanced Computer Architecture

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Recap

- **Various applications**
- **Electronic capture of data**
- **The data is processed**
  - **Programs**
    - **Instructions**
    - **Memory**
- **Processor need to fetch the instructions and execute them**

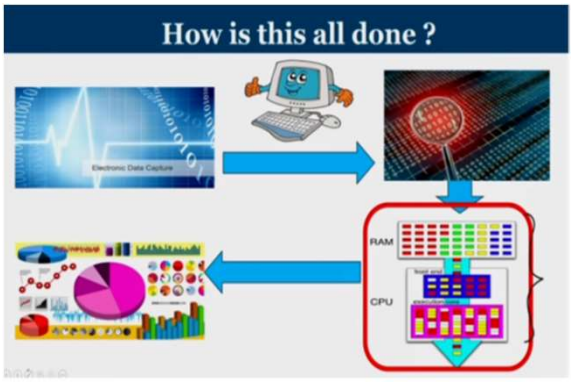

Image Source: NPTEL course on Advanced Computer Architecture

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Digital Computer

- Computer is a fast electronic computing/calculating machine that
  - Accepts digitized input information
  - Processes it according to a list of internally stored instructions
  - Produces the resulting output information
- Internal storage is called computer memory
- List of instructions is called a computer program
- Many types of computers exists that differ widely in size, cost, computational power and purpose of use

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Digital Computer

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Computer : A Complex System

- Contemporary computers contain **millions of elementary electronic components**
- Recognize the **hierarchical nature** of complex system—**computer**
  - **Set of interrelated subsystems**
    - Each subsystem may in turn be hierarchical
  - Designer may focus on a **particular level** of the hierarchy
- At each level designer is concerned with:
  - **Structure**
    - The way in which the components are interrelated
  - **Function**
    - The operation of each individual component as part of the structure

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Four Basic Functions of a Computer

- **Data processing**
  - Variety of data
  - Wide range of processing requirements
  - **A few fundamental methods/types of data processing**
- **Data storage**
  - Store the data
    - **Short-term during processing**
    - **Long-term for later processing**
- **Data movement**
  - Devices that serve as either sources or destination of data
  - **Input-output (I/O) process---peripherals**
  - Data moved over longer distances/remote devices---**Data communication process**
- **Control**
  - Controls the resources, performance of the functional parts

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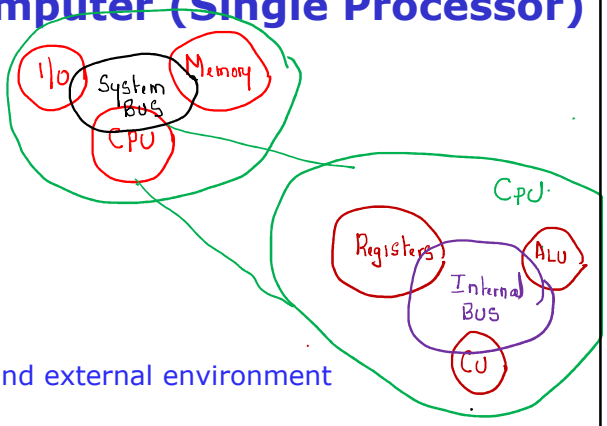
Structure of a Traditional Computer (Single Processor)



- **Central processing unit (CPU)**
  - Controls the operation of the computer
  - Performs the data processing function
  - Simply refereed as **processor**
- **Main memory**
  - Store the data
- **I/O**
  - Move the data between the computer and external environment
- **System interconnection**
  - Mechanism to provide the communication between the functional units
  - **System bus**
- One or more above mentioned components
- **Traditionally a single processor**

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Hierarchical Structure

- **Computer consists of interrelated subsystem**
- **Each subsystem may in turn be hierarchical**
- **Central processing unit (CPU)**
- **Major structural components of a CPU**
  - **Control unit**
  - **Arithmetic and logic unit**
  - **Registers**
  - **CPU interconnection**

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Digital Computer

- **Printed circuit board (PCB)**
  - A rigid, flat board that holds and interconnects electronic components
  - Electronic components are interconnected via copper pathways
- **Motherboard**
  - **Main PCB in a computer**
- **Expansion boards**
  - PCBs that plug into motherboard

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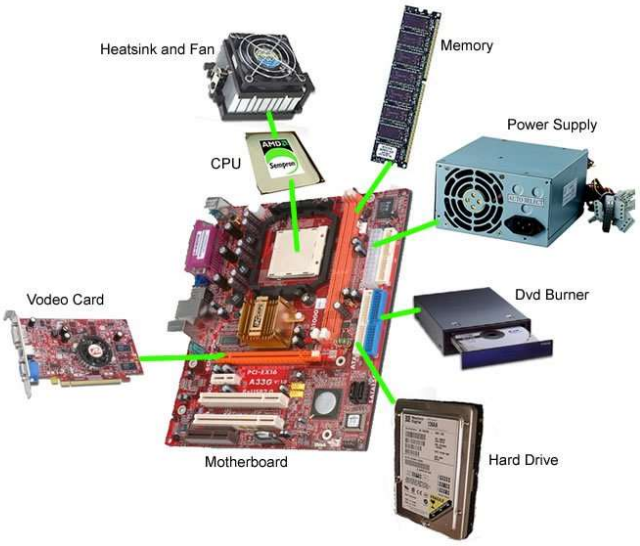

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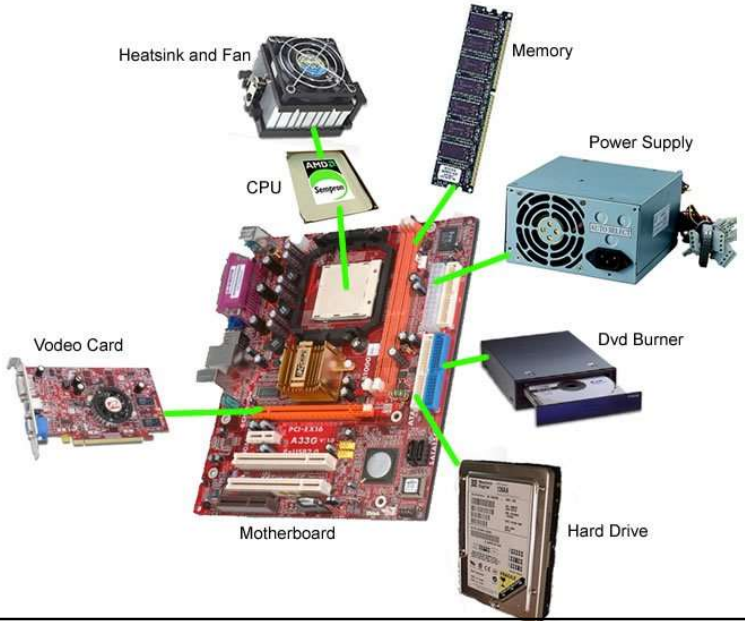
Digital Computer



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Digital Computer-Single Processor

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Digital Computer

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Contemporary Computers

- **Multiple processors**
- **Terms**
  - CPU: Portion of the computer that fetches and executes instructions
    - ALU
    - Control unit
    - Registers
    - On a single processing unit- processor
  - Core: An individual processing unit on a processor chip
    - A processing unit consisting of a control unit, ALU, registers and perhaps cache
    - Equivalent in functionality to a CPU on a single-processor system
    - Sophisticated processing units– specialised for vector and matrix operations are also referred as cores
  - Processor: Physical piece of silicon containing one or more cores
    - Multicore processor

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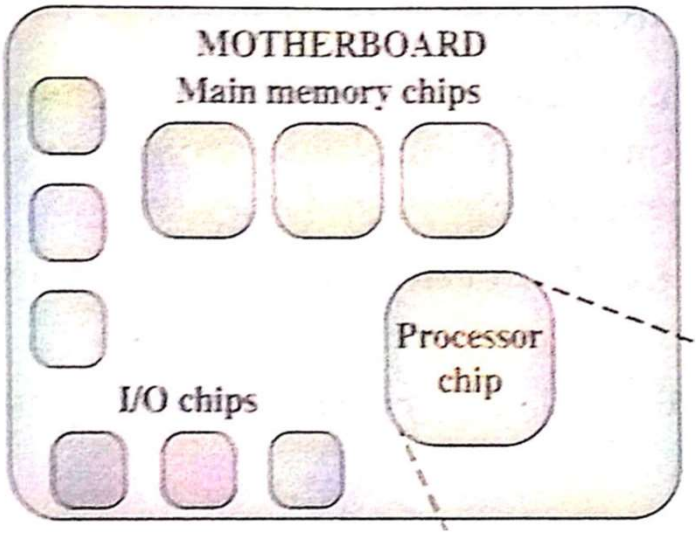
Simplified View of a Multicore Computer



- Motherboard comprises of chips
- Chip is a single piece of silicon on which electronic circuits and logic gates are fabricated

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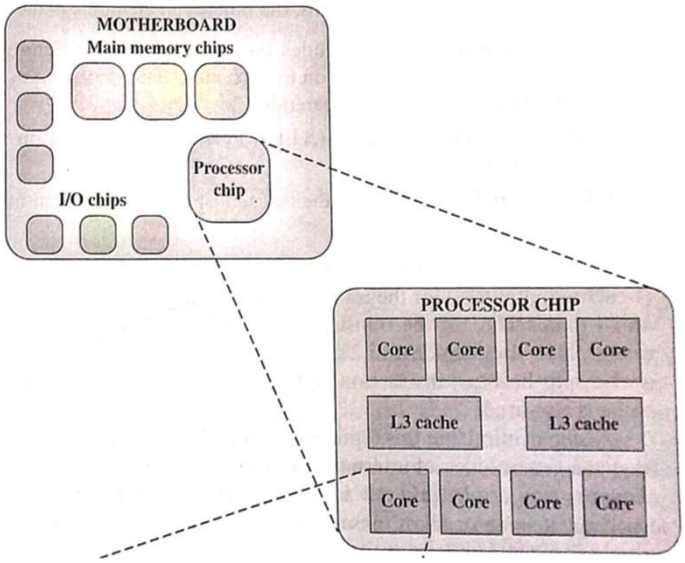
Image Source: Computer Architecture and Organization, William Stallings, Pearson

Simplified View of a Multicore Computer



- Processor chip contains multiple cores
- 8 cores
- Shared L3 cache

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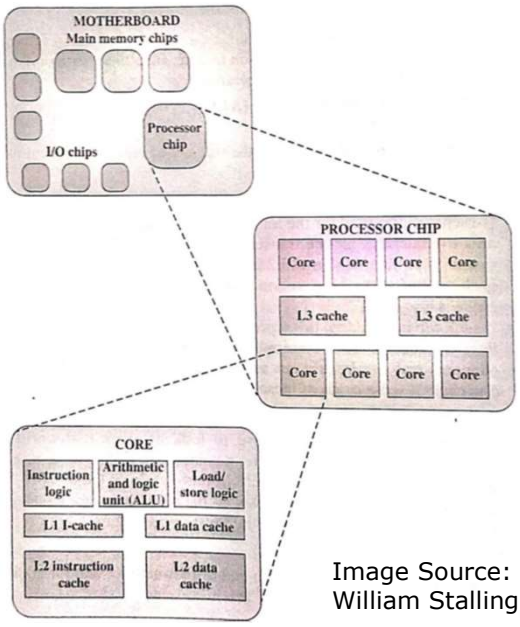
Image Source: Computer Architecture and Organization, William Stallings, Pearson

Simplified View of a Multicore Computer



- Functional elements of a core
  - Instruction logic
    - Fetching and decoding
  - Arithmetic and logic unit
  - Load/store logic
  - L1 cache
    - Instruction and data
  - L2 cache
    - Instruction and data

Image Source: Computer Architecture and Organization, William Stallings, Pearson

History of Computers

- **First generation**
  - Vacuum tubes for digital logic elements and memory
- **Second generation**
  - Transistors replaced vacuum tubes
  - Smaller, cheaper and generates less heat
  - Provision of system software
- **Third generation**
  - Integrated circuits
  - Microelectronics
    - Reduction in the size of digital electronic circuits
    - Small scale integration (SSI): A few gates or memory cells packaged together

Later Generations

- Less general agreement on defining generations of computers
  - There have been a number of generations
- Advancement in hardware technology
  - More than 10000 components per chip
    - Large scale integration (LSI)
    - Very large scale integration (VLSI)
  - Ultra large scale integration: More than one billion components
  - Semiconductor memory—development in memory technology
    - Earlier magnetic memory
  - Microprocessors—density of processor chips increased
    - First microprocessor-Intel 4004– Contain all components of a CPU on a single chip
    - Number of bits that can be handled (4, 8, 16 and so on)

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Later Generations

- **Intel x86 architecture**
  - Complex instruction set computer (CISC)
  - Stands number one in the market share of non-embedded systems
- **ARM architecture**
  - Reduced Instruction set computer (RISC)
  - Embedded systems

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Embedded Systems

- Use of electronics and software within a product
  - As opposed to general-purpose computer such as laptop or desktop computer
- **Millions of computers sold every year**-laptops, personal computers, workstations, servers, mainframes and supercomputers
- **Billions of computer systems that are embedded within larger devices**
  - Cell phones, digital cameras, video cameras, calculators, microwave ovens, home security systems, washing machine ….
- **Internet of things (IoT)**
  - Major drivers in the proliferation of embedded systems

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Computer Organization and Architecture

- **Computer Architecture**
  - Aspects that have direct impact on the logical execution of a program
  - Also called as **Instruction Set Architecture (ISA):** instruction formats, instruction opcodes, registers, memory
    - ADD instruction: A programmer is allowed to use
    - MUL instruction
- **Computer Organization**
  - Operational units and their interconnections to realise the architectural specifications
    - How the ADD operation should be internally realised?
      - Transparent to the programmer
    - Whether MUL instruction will be implemented by a special multiply unit or by repeated use of ADD instruction
      - Decision based on anticipated frequency of use of an instruction, relative speed of the approaches cost and physical size of an a special multiply unit

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Computer Organization and Architecture

- Many computer manufactures provide an architecture that may span many years
  - Many models that may follow the same architecture but different organization
  - Different models have different price and performance characteristics
- Course focus:
  - Organization and Architecture both
- Single processor computer

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Computer Types

- **Personal computer** ---common form of desktop computer
  - Processing and storage units, visual display and audio output units and a keyboard
- **Notebook computers**
  - Portable compact version of the personal computer with all its components packed into a single unit
- **Workstations**
  - High-resolution graphics input/output capability, dimensions of a desktop computers
  - Significantly more computation power than personal computers
- **Enterprise systems-mainframes**
  - For business data processing in medium to large corporations
  - More computation power and storage capacity than workstations can provide

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Computer Types

- **Servers**
  - Sizeable data storage units and are capable of handling large volumes of requests to access the data
  - Education, business …
  - Remote request over Internet
  - Internet servers
- **Supercomputers**
  - For large scale numerical calculations
    - Weather forecasting, aircraft simulation

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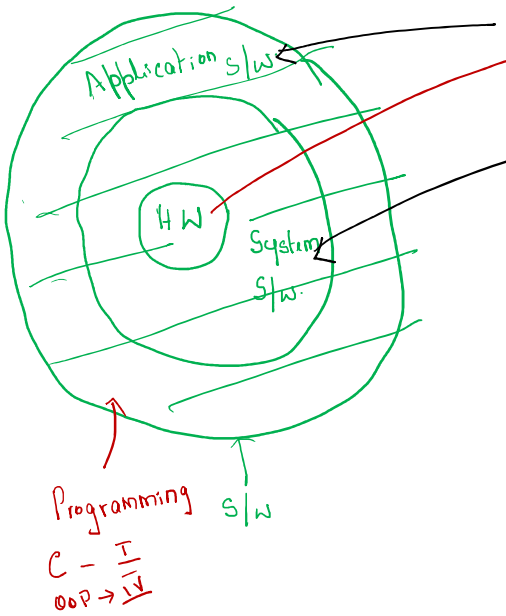
Layered View of a Computer System



COA - III

DSD - IV

System Programming
- OS → V
- Compiler → V
- Assemblers (SP) - IV
- DBMS → V

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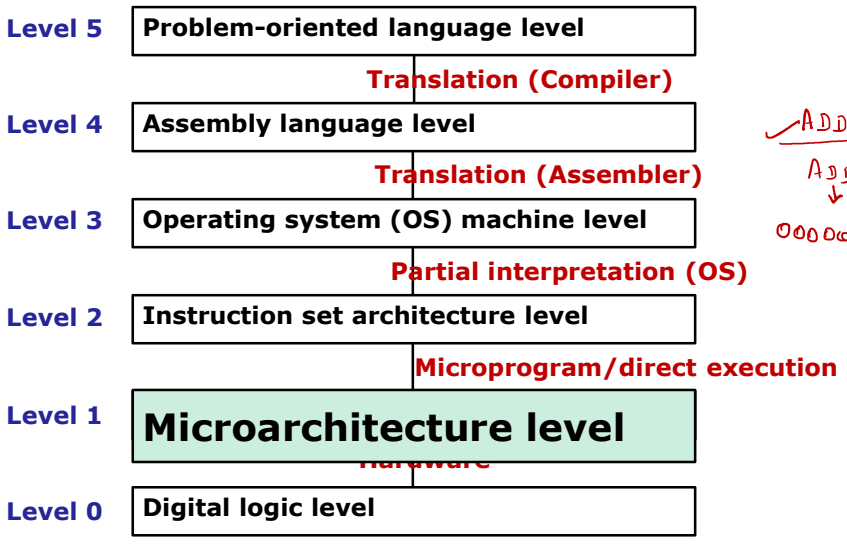
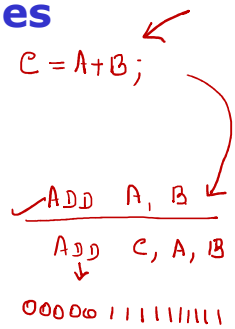
Computer as Multilevel Machines





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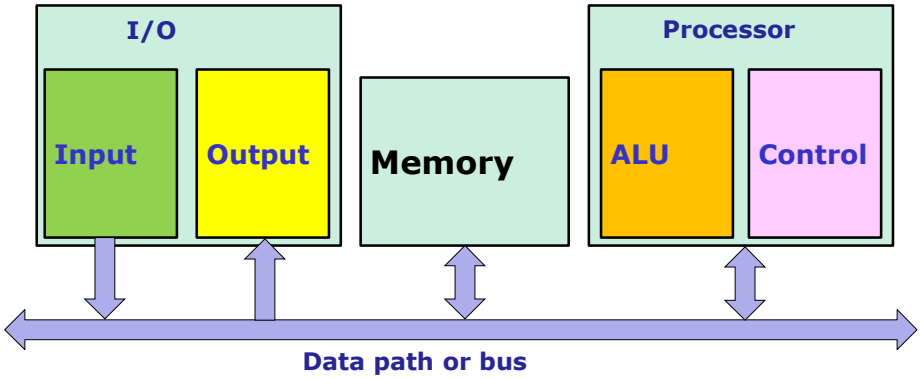
Microarchitecture Level

- **Functional Units**:
  - Input Unit
  - Memory Unit
  - Arithmetic and Logic Unit (ALU)
  - Output Unit
  - Control Unit



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Subject Code CS 202	Computer Organization and Architecture (COA)	Credits: 4 (3-1-0) Total hours:56
Course Objectives	The course explores the hardware aspects of a computer system design.	
Module 1		**8 Hours**
Overview of Computer Architecture & Organization, contrast between computer architecture & organization, logical organization of computers; basic operational concepts, bus structures, performance, processor clock, basic performance equation, clock rate, performance measurement, Von Neumann machine, instruction format, execution cycle; instruction types and addressing modes.		
Module 2		**10 Hours**
Computer Arithmetic: representation of integers and real numbers, fixed point arithmetic, arithmetic and logical unit design, addition and subtraction of signed numbers, design of fast adders, multiplication of positive numbers, signed operand multiplication, fast multiplication, integer division, floating-point numbers and operations.		
Module 3		**8 Hours**
Basic Concepts of Memory System: Semiconductor RAM memories, ROM memories, speed, size, and cost, cache memories mapping functions, replacement algorithms, performance considerations, virtual memories, secondary storage.		
Module 4		**15 Hours**
Control Unit Design: Instruction sequencing, instruction interpretation, control memory, hardwired control, micro programmed control and micro programmed computers. I/O organization, bus control, Serial I/O (study of asynchronous and synchronous modes, USART & VART), parallel data transfer Program controlled: asynchronous, synchronous & interrupt driven modes, DMA mode, interrupt controller and DMA controller.		
Module 5		**15 Hours**
Organization of CPU: Single vs. multiple data path, ISA, control unit, instruction pipelining, trends in computer architecture, CISC, RISC, VLIW, introduction to ILP, pipeline hazards: structural, data and control, reducing the effects of hazards.		

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Reference books	(1) Carl Hamacher, ZvonkoVranesic and SafwatZaky, "Computer organization", 5th Edition, Tata McGraw Hill, 2002. (2) J. P. Hayes, "Computer architecture and organization", 3rd Edition, McGraw Hill, 1998. (3) Patterson and Hennessy, "Computer architecture: A quantitative approach", Morgan Kaufmann, 2000. (4) Hwang and Briggs, "Computer architecture and parallel processing", McGraw Hill, 1985. (5) David A. Patterson& John L. Hennessy, "Computer organization and design", Morgan Kaufmann, 4th edition, 2012.

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References

- **Carl Hamacher, Zvonko Vranesic and Safwat Zaky, "Computer Organization", 5th Edition, Tata McGraw Hill, 2002**
- **William Stallings, "Computer Organization and Architecture: Designing for Performance", 10th Edition, Pearson**

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To Summarize

- Hierarchical nature of a computer
- Structure of a computer
- Function of a computer
- Internal of a single processor system
- Contemporary computers with multiple processors
- History of computers
- Computer organization- computer architecture
- Computer types
- Layered view of a computer system
- Computer as a multilevel machine
- Microarchitecture level
- Course content

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Thank You

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