ECE 251: Computer Architecture

Week 01 Notes - Abstractions & Technology

Prof Rob Marano

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1. Definition of a Computer

- **General Purpose**: A modern computer is defined by its ability to process algorithms across vast magnitudes.
- **The Software/Hardware Interface**: The Instruction Set Architecture (ISA) serves as the boundary between software (instructions) and the physical hardware.
- **The Five Components**:
  1. Input
  2. Output
  3. Memory
  4. Datapath (ALU)
  5. Control Unit
- *Processor (CPU) = Datapath + Control*

2. The Stored Program Concept

- Pioneered by John von Neumann in the mid-1940s.
- Revolutionized computing by storing **both the instructions and the data** in the computer's memory.
- **Key Advantages**:
  - *Programmability*: Easily reprogrammed by loading new instructions (no rewiring).
  - *Flexibility*: A single computer can be used for a wide range of disparate applications.
  - *Instructions as Data*: Programs can be manipulated and modified like any other data (enabling compilers, assemblers, and operating systems).

3. von Neumann vs. Harvard Architectures

Feature	**Von Neumann (Princeton)**	**Harvard**
Memory	Single memory space for instructions & data	Separate memory spaces
Access	Sharing the same memory bus	Simultaneous access capability
Pros	Simpler design, efficient memory use	Faster instruction fetch
Cons	*Von Neumann Bottleneck* (shared bus)	Complex design, physical split
Use Cases	General-purpose PCs, laptops	DSPs, embedded systems

4. Performance of a Computer

- **Execution Time**: The time it takes a computer to complete a single task (primary focus for individual users).
- **Throughput**: Total work done per unit time (primary focus for datacenters).
- **The CPU Performance Equation**:

CPU Execution Time

$$\text{CPU Time} = \frac{\text{Instruction Count} \times \text{CPI}}{\text{Clock Rate}}$$

- **IC (Instruction Count)**: Determined by the program and compiler.
- **CPI (Cycles Per Instruction)**: Determined by the ISA and hardware.
- **Clock Rate**: Determined by hardware technology.

5. The Power Wall & Multicore

- **The Power Wall**: We can no longer increase processor clock speeds endlessly due to thermal dissipation limits.
- $P_{dynamic} \propto \text{Capacitance} \times \text{Voltage}^2 \times \text{Frequency}$
- **The Solution**: Multi-core Processors.
  - Instead of one blistering fast core, deploy multiple slower cores executing in parallel.
  - *Impact*: Programmers must now write parallel code to extract performance (Ahmdal's Law limits sequential scaling).