Computer Architecture

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Introduction

- In the past 65 years, there has been rapid advancement in computer technology, this is in terms of better performance and memory.
- What has contributed to better performance is architectural innovations and integrated circuits.
- Emergence of ***RISC*** (Reduced Instruction Set Computer) architecture simplified instruction execution by using techniques like instruction-level parallelism (ILP) and caching that improved overall computer performance.
- Adoption of RISC principles by Intel made them be a tall figure in the microprocessors manufacturing industry.
- In the 1980s and 2000s, there emerged other classes of computers eg pcs, tablets, smartphones due to “super-processors” as compared to the previous decades. ARM architecture became adopted in mobile phones

Introduction (cont...)

- Software evolved from assembly languages to low-level languages(C, C++) to higher programming languages (Java, C#) and scripting languages (JavaScript)
- Saas replaced traditionally locally installed applications
- There emerged new parallelism models : Data-Level Parallelism, Thread Level Parallelism & Request-Level Parallelism hence reliance shifted from ILP
- Performance improvements made a shift from single-core to multi-core processors which is the future

Classes of Computers

- The evolvement of computer technology has led to emergence to distinct computer markets each with different characteristics, requirements and technologies.They include :

  Personal Mobile Devices
  Desktop Computing
  Servers
  Cluster/ Warehouse-Scale Computers
  Embedded Computers

Personal Mobile Devices(PMD)

- Its performance needs are optimised to cater for web and multimedia applications.
- They key factors in these computers are energy efficiency(long battery life), real-time processing and are costly.
- It relies on flash memory for storage instead of hard drives.
- Examples : Smartphones, wearables and tablets

Desktop Computing

- Laptops now dominate the computer technology because of their portability and performance.
- New higher-performance microprocessors are introduced her before expanding to market
- Examples : Laptops, desktops and workstations

Servers

- Are designed for minimal downtime, to minimize revenue loss if system fails
- Its key factors are always available(24/7 up and running), scalable and high throughput when communicating with client side.
- Examples: Enterprise servers, cloud backend & web hosting

Cluster/Warehouse-scale Computers

- Focuses more on scalability than computation speed and uses redundant low-cost hardware with software-based fault handling.
- Its key factors are scalability, fault tolerance and cost-efficient operations.
- Examples : Google, Amazon & facebook/Meta data centers

Embedded Computers

- Embedded computers are found in everyday appliances and industrial systems such as microwaves, networking switches, printers etc
- Its key factors are low cost, efficiency and application-specific functionality
- Unlike PMDs, they can’t run third party apps designed for specific tasks

Classes of Parallelism and Parallel architecture

Types of Parallelism

1. **Data-Level Parallelism (DLP)** – Operates on multiple data items simultaneously.
2. **Task-Level Parallelism (TLP)** – Involves multiple independent tasks executing in parallel.

Ways Hardware Exploits Parallelism:

1. **Instruction-Level Parallelism (ILP)** – Uses techniques like pipelining and speculative execution for modest levels of DLP.
2. **Vector Architectures & GPUs** – Apply a single instruction to multiple data elements simultaneously (high DLP).
3. **Thread-Level Parallelism (TLP)** – Uses multiple threads that interact closely to exploit DLP or TLP.
4. **Request-Level Parallelism (RLP)** – Handles independent tasks with minimal interaction

Defining Computer Architecture

The key components of computer design are Instruction Set Architecture(ISA), Microarchitecture and hardware implementation.
They key aspects to Instruction Set Architecture include :

1. Class of ISA
2. Memory Addressing
3. Addressing mode
4. Operand Types & sizes
5. Operations
6. Control Flow
7. Instruction Encoding

Trends in Technology

Several key hardware technologies are evolving hence shaping the modern computing designs.They include :

1. Integrated Circuit Logic Technology
2. DRAM technology
3. Flash Memory
4. Magnetic Disks
5. Networking Technology

Performance Trends include :

1. Bandwidth throughput has improved
2. Microprocessors and networks have significant gain with bandwidth over latency
3. Memory and disk storage prioritize but still have bandwidth advances

Trends in Power and Energy in Integrated Circuits

Power and Energy Considerations :

1. Ensuring power supply systems can handle peak power demands
2. Sustained Power Consumption
3. Energy efficiency. Energy per task is more reliable than power consumption

Techniques for Power efficiency

1. Clock gating
2. Overclocking
3. Dynamic Voltage-Frequency scaling
4. Designing for Typical Cases

Trends in cost

Factors influencing cost:

1. Time, Volume and Commoditization
- Cost decreases every time due to learning curve, we've seen the decrease in prices of computer technology gadgets prices from the 1980s to now the 2020s
- Higher production volume lowers cost by improving efficiency
- Commoditization(Flash Memory, CPUs) increase competition hence no monopoly and reduces costs

2. Cost of integrated Circuits
- Manufacturing process impacts cost through wafer price, yield, and defects per unit area.
- Die size affects cost significantly: larger dies reduce the number of usable chips per wafer, increasing cost per chip.

$$\text{Cost per die} = \text{Cost of wafer} \; / \; (\text{Dies per wafer} \times \text{Die yield})$$

Trending cost (cont..)

3. Key areas for Designers

- **Die area** is the primary factor under a designer's control that influences cost.
- Larger dies increase cost exponentially due to defect probability and lower yield.
- Additional steps like **testing, packaging, and final validation** further contribute to costs.