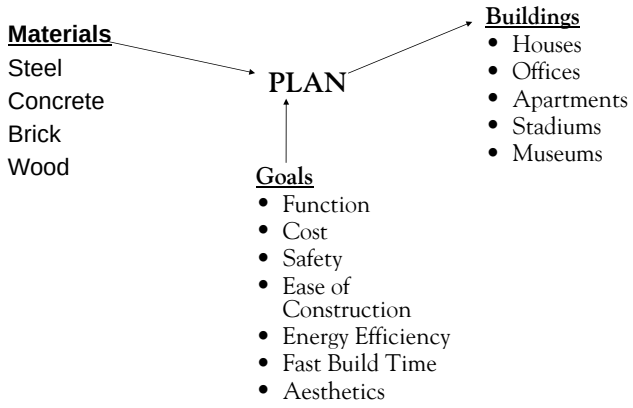
Microprocessor Design & Organisation HCA2102

Introduction

The role of a building designer or architect:



The role of a computer designer or architect:

Design Goals

Functional
- Needs to be correct
- What functions should it support

Reliable
- Does it continue to perform correctly?
- Hard fault vs. transient fault
- Google story - memory errors and sun spots
- Space probe vs. PC reliability

High performance
- "Fast" is only meaningful in the context of a set of important tasks
- Not just "Gigahertz"
- Impossible goal: fastest possible design for all programs

Design Goals

Low cost
- Per unit manufacturing cost (wafer cost)
- Cost of making first chip after design (mask cost)
- Design cost (huge design teams…)

Low power
- Energy in (battery life, cost of electricity)
- Energy out (cooling and related costs)
- Static vs. dynamic power, sleep modes, peak vs. average
- Cyclic problem, very much a problem today

Challenge: balancing the relative importance of these goals
- And the balance is constantly changing

Rapid Change

	1971-1980	1981-1990	1991-2000	2004	2010
Transistors (M)	0.01-0.1	0.1-1	1-100	250	1000?
Clock (MHz)	0.2-2	2-20	20-1000	3500	10000?
MIPS	<0.2	0.2-20	20-2000	7000	100000?

- Exciting: perhaps the fastest moving field… ever
  - Processors vs. cars
    - 1985: processors = 1 MIPS, cars = 60 MPH
    - 2000: processors = 500 MIPS, cars = 30,000 MPH?

First Microprocessor

- Intel 4004
  - •1971 (first microprocessor)
  - • 4-bit data
  - • 2300 transistors
  - • 10 µm PMOS
  - • 108 KHz
  - • 12 V
  - • 13 mm2

Recent Microprocessor

- Intel Pentium 4 + HT
  - •2003
  - • 32/64-bit data
  - • 55M transistors
  - • 0.9 µm CMOS
  - • 3.4 GHz
  - • 1.2 V
  - • 101 mm2

Technology Trends

- •Processor (SRAM)
  - • Density: ~30%, Speed: ~20%
- • Memory (DRAM)
  - • Density: ~60%, Speed: ~4%
- • Disk
  - • Density: ~60%, Speed: ~10%
- • **Changing quickly and with respect to each other!!**
  - • Fundamentally changes design
  - • Different tradeoffs
- • Exciting: constant re-evaluation and re-design

Applications/Domains

Another shaping force: **applications**

- • Applications and application domains have different requirements
  - • Domain: group with similar character
- • Lead to different designs
- • **Scientific**: weather prediction, genome sequencing
  - • First computing application domain: naval ballistics firing tables
  - • Need: large memory, heavy-duty floating point
  - • Examples: CRAY T3E, IBM BlueGene
- • **Commercial**: database/web serving, e-commerce
  - • Need: data movement, high memory + I/O bandwidth
  - • Examples: Sun Enterprise Server, AMD Opteron, Intel Xeon/Itanium

More Recent Applications/Domains

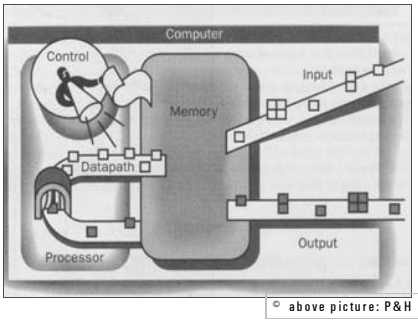
Desktop: home office, multimedia, games

- • Need: integer, memory bandwidth, integrated graphics/network?
- • Examples: Intel Pentium4, AMD Athlon, IBM Power5 (G5)
- • **Mobile**: laptops
  - • Need: **low power**, integer performance, integrated wireless?
  - • Examples: Intel PentiumM, AMD Turion, Transmeta Efficeon
- • **Embedded**: PDAs, cell phones, automobiles, door knobs
  - • Need: low power, **low cost**, integrated DSP?
  - • Examples: Intel, StrongARM, X-Scale, Transmeta TM3200
- • **Sensors**: disposable “smart dust”
  - • Need: extremely low power, extremely low cost

Organisation & Function

- Organisation is the way in which components relate to each other
- Function is the operation of individual components as part of the structure

Components of a computer: Assembly Line

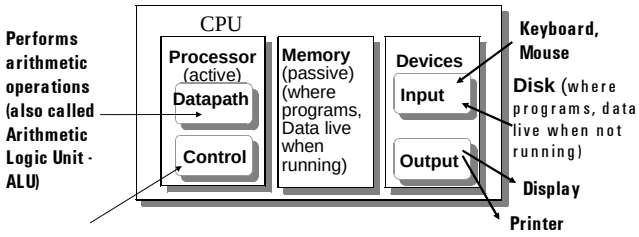


The processor gets instruction and data from the memory. Input writes data to the memory and output reads data from the memory.

© above picture: P&H

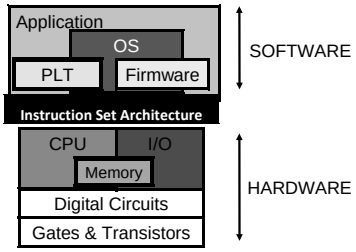
Control sends the signals that determine the operations of the datapath, memory, input and output

Anatomy: Components of any Computer



Tells the datapath, memory and I/O devices what to do according to the wishes of the program

Instruction Set Architecture: A critical Interface



- ISA represents the computer seen from the point of view of the programmer
- It insulates the software from the hardware

Types of Computers

- **Supercomputers**
- **Mainframes**
- **Mini-computers**
- **Workstations**
- **Micro/Personal/Home computers**

Speed
Cost
Complexity

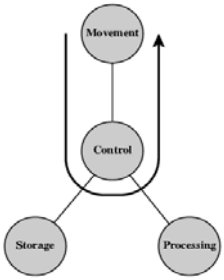
History of Computers

1st Generation Computers (1940s to early 1950s) based on vacuum tubes technology.
1943 – ENIAC: first fully electronic computer, designed by John Mauchly.
1944 – Mark I: Howard Aiken.
1946 – EDVAC: first stored program computer by Von Neumann.
2nd Generation Computers (late 50s to early 60s) based on transistors technology.
more reliable, less expensive, low heat dissipation.
IBM 7000 series, DEC PDP-1.
3rd Generation Computers (late 60s to early 80s) based on Integrated Circuits (IC).
IBM 360 series, DEC PDP-8.
IC – many transistors packed into single container.
low prices, high packing density.
4th Generation Computers (present day) LSI/VLSI/ULSI
small size, low-cost, large memory, ultra-fast PCs to supercomputers.
5th Generation Computers (future)
massively parallel, large knowledge bases, intelligent.
Japan, Europe and US advanced research programs.

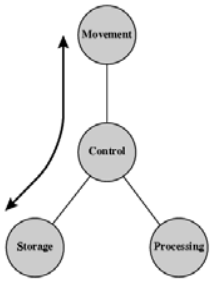
Functions

- All computer functions can be summarised as:
  - Data processing
  - Data storage
  - Data movement
  - Control

Operations: Data movement

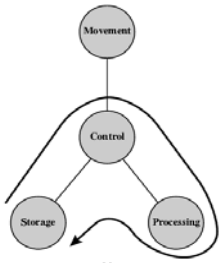


Operations: Storage

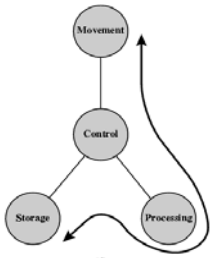


Operations:

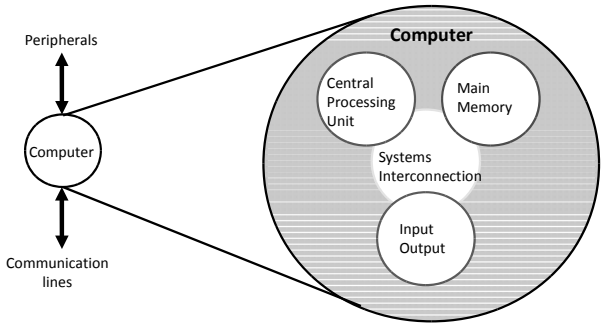
Processing from/to storage



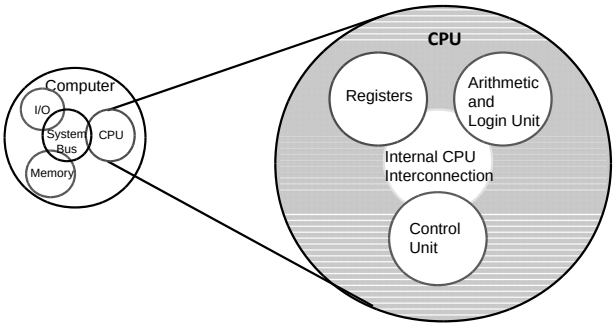
Processing from storage to I/O



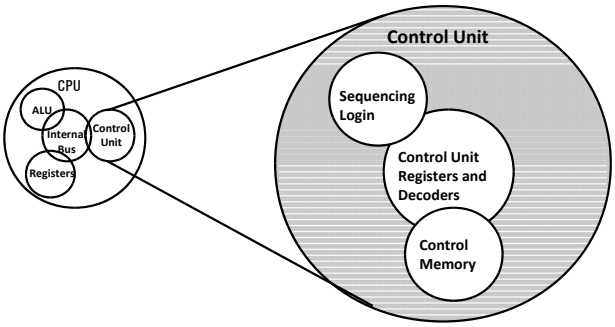
Structure - Top Level



Structure - The CPU



Structure - The Control Unit



Internet Resources- Web sites to look for

- WWW Computer Architecture Home Page
- CPU Info Center
- ACM Special Interest Group on Computer Architecture
- IEEE Technical Committee on Computer Architecture
- Intel Technology Journal
- Manufacturer's sites
  - Intel, AMD, Transmeta (acquired by NovaFora)