"I think there is a world market for about five computers."

Thomas J.Watson (1945)

## Computer Abstractions and Technology

### Introduction

- Performance from a historical perspective – during our lifetime
- The oft quoted comparison with transport industry
- Computer as an intellectual tool, a consumer item, and an appliance
- Speed vs performance
  - Add memory; new model being hierarchical memory
  - Increase clock speed; new model being add [specialized] processors; parallel processing
- Why study computer architecture?

### Classical Hardware

- Communication with a computer
  - *Hitchhikers' Guide to the Galaxy*
  - The ultimate answer: **42**.
  - The question: *What do you get when you multiply nine by 6?*
  - Do you see a problem here?
- Binary arithmetic
  - Based on binary numbers, implemented by a simple switch with two states: *off* (or 0) and *on* (or 1)
  - ***B**inary dig**it*** or *bit*
  - *Instructions* are simply numbers the computer *understands* to perform a job
    - I could tell you that when I say 0, the class is dismissed :-)
  - Binary numbers are used for both instructions and data
- Assembler
  - The primitive way to communicate with the computers in a human-like language
  - Instead of issuing a command like

    ```
    3E  01  02
    ```

    to add two numbers (01 and 02 are locations where these numbers are kept), a programmer could say something like

    ```
    ADD A, B
    ```
  - Is it improvement? A simple program (assembler) will create the binary equivalent from the human-like language
- Next step in the evolution ladder – *compiler*

  - Translate a more English-like (or mathematical notation) language to binary
  - Allows for increase in productivity of a programmer
  - Resulted in languages like COBOL that were truly verbose
  - A C statement such as

    ```
    c = a + b;
    ```

    would be written in COBOL as

    ```
    ADD A TO B GIVING C.
    ```
  - High-level languages made the programs somewhat machine independent
- *Subroutine libraries*
  - Collection of functions to perform tasks needed by many programs
  - Used for math functions, such as square root and trigonometry
  - Also used for I/O
- *Operating system*
  - Ultimate control program to control system resources
    * System software
    * Application software

**Organization of a simple computer**

- CPU, memory, storage devices, I/O devices, peripheral devices
- Mouse
  - A basic pointing device
  - Can be used to determine the position in two dimensions
  - Optical vs mechanical mice
- Monitor
  - Raster cathode ray tube (CRT), achieved through an electron gun
  - Refresh rate of between 30 to 90 Hz
  - Image composed of pixels (picture elements)
  - Display matrix or bitmap
  - Simplest display – 1 bit per pixel (BPP)
  - Gray scale display – 256 gray scale values per pixel, or 8 BPP
  - Color display – 8 BPP for each of the three primary colors (red, green, blue), giving 24 BPP per pixel
    * A total of $2^{24}$ colors, or 16 million different colors
  - Liquid crystal display (LCD)
    * Thin, low power display
    * Rod shaped molecules in a liquid that bend the light entering the display, possibly from behind the display
  - Bit map stored in a *frame buffer* or *raster refresh buffer*
- Motherboard

- A plastic board containing packages of chips, including processors, cache, memory, and connectors for I/O devices such as networks and disks
- Processor or *Central Processing Unit* (CPU) is the guy who does all the work; this is the *brain*
- Memory keeps all program code and data while the program undergoes execution
  * *Read-only memory* (ROM)
  * *Random Access Memory* (RAM)
- Hierarchical memories
  * DRAM – Dynamic random access memory
  * Cache – Small fast memory to act as a buffer for DRAM
- Abstraction
  * Hiding lower level details in abstract concepts
  * Sending output to print device
- Instruction set architecture (ISA)
  * Abstraction of hardware
  * Interface between hardware and low-level software
  * Consider the relationship between machine code and assembly language, and go one step down
  * Abstraction allows for multiple *implementations* implementations of the same ISA
- Backward compatibility of new ISA
  * Macintosh changed from 68000-based machines to PowerPC
  * Intel tried to keep the basic ISA in successive generations of the 80x86 family, starting from original 8086 to latest Pentium Pro
- Magnetic disks, or secondary memory
  * DRAM is volatile
  * Magnetic hard disk retains the information when power is turned off
  * Organized as a collection of platters, rotating on a spindle at constant speed
    · The disks on my Sun Blade 100 rotate at 7200 RPM
  * Movable arm with read/write head
  * About 5-10 ms for data access compared to 5-20 ns for DRAM
- Communications
  * Information exchange between computers at high speed
  * Sharing of resources such as disks and I/O devices
  * Accessing machines remotely
  * *Ethernet* or LAN
    · High speed network, typically 1 MB per sec
    · Limited to one mile
  * WAN
    · Backbone of the internet
    · Based on optical fibers
    · May not be as fast as Ethernet

**Integrated Circuits**

- Transistor – a simple on/off switch
- An IC combines zillions of transistors on a single chip

- VLSI – Very Large Scale IC, with gazillions of transistors on a single chip
- Silicon
  - Basic building block of ICs
  - Known as *semiconductor* because it does not conduct electricity very well
- Chip building requires adding materials to silicon so that it can
  - conduct electricity very well
  - insulate electricity very well
  - conduct or insulate like a switch
- VLSI manufacturing
  - Start with an ingot of silicon crystal, 6-12" in diameter and 12-24" long
  - Create wafers no more than 0.1" thick
  - Process by creating patterns of chemicals to create conductor, insulator, and switch regions
  - Process may result into imperfections, and so, a number of *dies* are created on each wafer
  - Imperfect dies are discarded, with good dies *bonded* to wires or I/O pins in a *package*, called chip