

# THE ARCHITECTURE OF COMPUTER HARDWARE AND SYSTEMS SOFTWARE

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## A computer-based information system elements

- *Data*: fundamental representation of facts and observations
  - processed by a computer system to provide the information
- *Hardware*
  - processes the data by executing instructions, storing data, and moving data and information between the various input and output devices
- *Software*
  - system and application programs software
  - determines the work to be performed and controls operation of the system
- *communication*
  - ability to share processing operations and data among different computers and users, locally and remotely
- *Architecture* = hardware, software, communication, and data
- Architecture of computer systems remarkably similar whether the system is a personal computer or mainframe

## INTRODUCTION

- Users do not have to know What do the insides of a computer “look like”. We can:
  - run standard software packages without understanding exactly how they work
  - program a computer in a high-level language without understanding how the machine executes the individual instructions
  - create Web pages without understanding how the Web browser gets its pages from a Web server or how the Web server creates those pages;
  - purchase a computer system without understanding the specifications
- BUT we might:
  - write programs to be faster and more efficient
  - create Web pages that load faster and work better
  - Choose the optimum system
  - Understand the jargon: “XGA TFT display” or “512K level 2 cache” or “56K V.90 modem”, 2.7 gigahertz (GHz) Pentium 4 CPU, 1 GB of RAM memory, 120 GB hard drive, DVD-RAM, “multitasking”, “PCI bus”

**\$995**

**PENTIUM 400 MHz - PCI**

- ◊ Intel 400-MHz Pentium Celeron CPU
- ◊ Motherboard w/ 4 PCI, 4 ISA Slots
- ◊ 512K level 2 cache
- ◊ 32MB RAM up to 256 MB
- ◊ 1.44MB Floppy Drive
- ◊ 64-bit AGP Video Accelerator
- ◊ 6.4GB IDE Hard Drive
- ◊ 24x CD-ROM w/ Sound Card
- ◊ 15" Non-Interlaced Full Flat Screen Monitor .28dp

Englander: The Architecture of Computer  
Hardware and Systems Software, 2nd edition  
Chapter 1, Figure 01-01

**Figure 1.1** A typical computer ad

**FIGURE 1.1**

A Typical Computer Ad

**FASTCAT™ Desktop**  
Top Performance, Great Value!

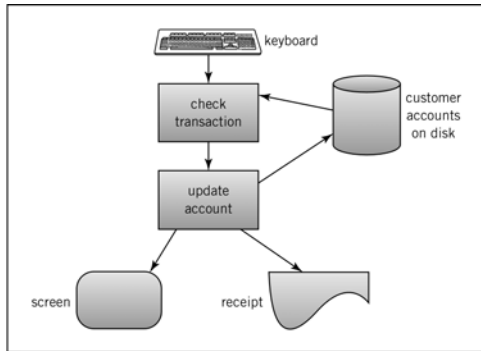
- ◆ Intel® 2.7 GHz Pentium® 4 Processor
- ◆ 1 GB up to 2 GB DDRAM
- ◆ 120 GB Ultra ATA 7200 RPM HD 16 MB cache
- ◆ 10/100 PCI Ethernet card
- ◆ 64 MB GeForce 4x AGP Video
- ◆ DVD-ROM/RAM + CD-R/RW
- ◆ 2 USB-2, 1IEEE-1394 Firewire®
- ◆ 17" Non-Interlaced Full Flat Screen Monitor  
.26dp (1024 x 768) Add \$300 for  
17" TFT LCD (1280 x 1024)

## 1.1 THE USER'S POINT OF VIEW

- A simple online credit card purchasing system

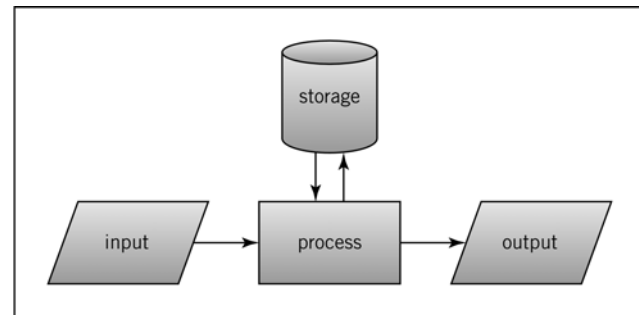
⇒

- **The Input-Process-Output Model**



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Chapter 1, Figure 01-02

**Figure 1.2** A simplified credit card transaction



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Chapter 1, Figure 01-03

**Figure 1.3** A computer process

## Basic Data Processing Operations

- Input/output
- Basic arithmetic and logical calculations
- Data transformation or translation (e.g., program compilation, foreign language translation, file updating)
- Data sorting
- Searching for data matches
- Data storage and retrieval
- Data movement (e.g., movement of text or file data to make room for insertion of additional data)

## Basic High-Level Language Constructs

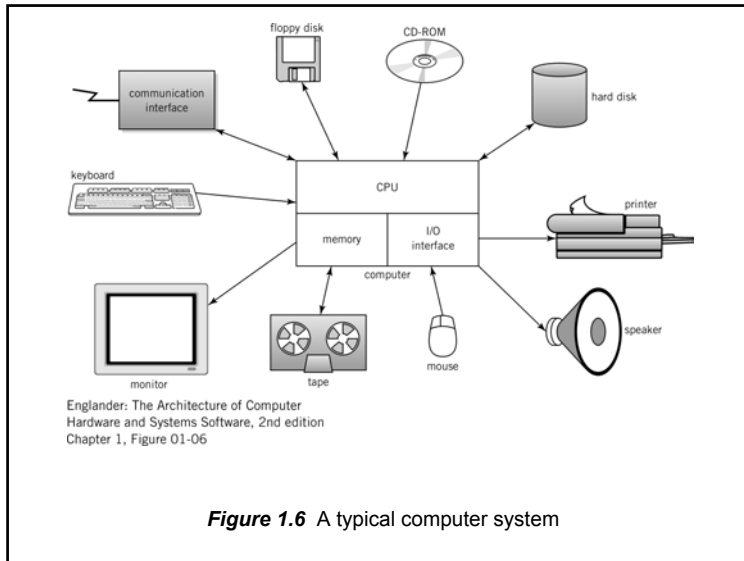
- Input/output (including file storage and retrieval)
- Arithmetic and logical assignment statements
- True/false decision branching (IF-THEN-ELSE or IF-GOTO)
- Loops and/or unconditional branching (WHILE-DO, REPEAT-UNTIL, FOR, GOTO)

## 1.2 COMPONENTS OF THE COMPUTER SYSTEM

- The computer hardware
- The software, provides instructions that tell the hardware
  - exactly what tasks are to be performed
  - in what order
- The data may be
  - numeric, alphanumeric, graphic
  - other forms
  - always representable in a form that the computer can manipulate
- The communication component
  - consists of hardware and software
  - transports programs and data between interconnected computer systems

## The Hardware Component

- Keyboard and mouse provide **input** of program text, data, and commands
- A display screen is commonly used to observe **output**
- Calculations and other operations in a program performed by a **central processing unit (CPU)** inside the computer
- **Memory** is provided to hold your programs and data while processing is taking place
- Other input and output devices, such as disk and tape,
  - used to provide long-term storage of programs and data files.
  - Data and programs transferred between the various input/output devices and memory for the CPU to use
- The CPU, memory, and all the input, output, and storage devices form the **hardware** part of a computer system



## CPU

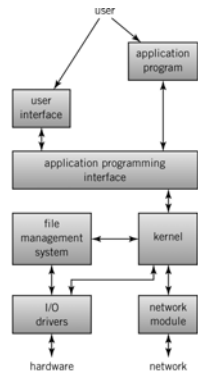
- Conceptually, the CPU is a composition of:
  - The **arithmetic/logic unit**, or **ALU**, where arithmetic and Boolean logical calculations are performed
  - The **control unit**, or **CU**, which controls the processing of instructions and the movement of internal CPU data from one part of the CPU to another
  - The **interface unit**, which moves program instructions and data between the CPU and other hardware components (often a **bus**)

## RAM (random access memory)

- = main memory, primary storage, working storage
- Holds programs and data for access by the CPU
- Made up of a large number of cells. Each cell
  - Numbered and individually addressable
  - Holds a single binary number representing data or an instruction
  - The basic size is 8 bits, known as a **byte** of memory
- 8 bits of memory can only hold 256 different patterns
  - ⇒ neighboring cells always combined to form groupings with a larger number of bits
- In many systems, 4 bytes combine to form a **word**

## The Software Component

- Two major categories of software: system software, application software
- **Operating system** = system software helps
  - manage files, load and execute programs, accept commands from mouse and keyboard
  - examples: Windows and Linux
- Application programs
  - Ex: Microsoft Word, Netscape, user programs
  - normally run to get your work done
- The operating system is made up of many components. Most obvious element is the user interface that
  - allows to execute programs, enter commands, and manipulate files
  - accepts input from a keyboard and a mouse or other pointing device
  - outputs presentation on the display
  - manages windows



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Chapter 1, Figure 01-08

**Figure 1.8** Simplified operating system block diagram

## OS modules

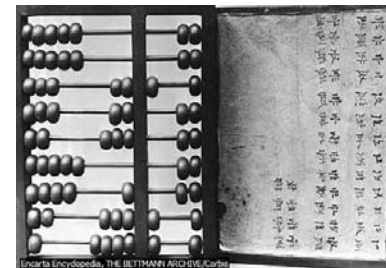
- The **application program interface**, or **API** = an interface for application programs and the internal services provided by the OS.
- The kernel
  - manages memory by locating and allocating space to programs
  - schedules time for each application to execute
  - provides communication between programs that are being executed
  - manages and arranges services and resources that are provided by other modules
  - provides security
- The file management system
  - allocates and manages secondary storage space and translates file requests from their name-based form into specific I/O requests
  - The actual storage and retrieval of the files is performed by the I/O drivers that comprise the I/O component. Each I/O driver controls one or more hardware devices of similar type
- The network module controls interactions between the computer system and the network(s) to which it is attached

## OS location

- Nearly always stored on a hard disk
- The bootstrap or IPL (Initial Program Load) program in the OS is stored within the computer using a **ROM**, or **Read Only Memory**
  - tools to test the system
  - load the remainder of the OS from the disk or network

## 1.5 A BRIEF ARCHITECTURAL HISTORY OF THE COMPUTER

- the abacus, already in use as early as 500 BCE, in common use until the 1500s

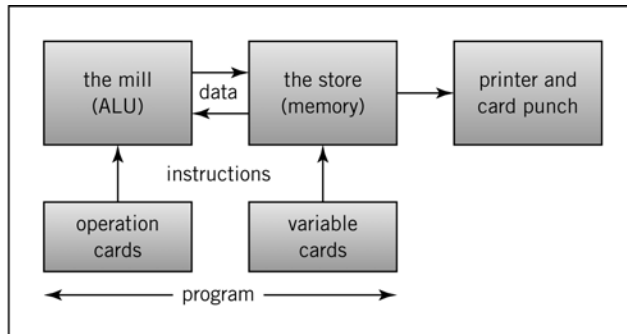


## Early Machines

- Blaise Pascal
  - invented a calculating machine in 1642 at the age of 19
  - was never able to construct the machine
- In 1801, Joseph Marie Jacquard
  - invented a loom that used punched cards to control the patterns woven into cloth
  - program provided by the punched cards controlled rods that raised and lowered different threads in the correct sequence to print a particular pattern
  - First documented application of punched cards to hold a program for the use of a semi-automated, programmable machine.

## Analytical Engine

- Charles Babbage, early 1800s
- spent much of his fortune attempting to build a mechanical calculating machine: “analytical engine”
- the mill capable of
  - selecting one of four arithmetic operations
  - testing the sign of a number with a different program branch specified for each result
  - sequence of operation specified by instructions on the operation cards
  - variable cards, specify particular memory locations for the data involved in the calculations
  - memory of 1000 50-digit decimal numbers
  - Each digit was to be stored using a ten-toothed gear known as a counter wheel



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**Figure 1.12** Block diagram of Babbage's analytical engine Source: From *Computer Architecture and Organization 2e*, J. Hayes, copyright © 1988, by McGraw-Hill Companies, pg. 14 Reprinted by permission.

## Modern electronic computers

- George Boole
  - developed the Boolean logic
  - recognized the relationship between binary arithmetic and Boolean logic
  - ⇒ makes possible the circuitry that implements the modern electronic computer
- The Mark I
  - built in 1937 by Howard H. Aiken and associates at Harvard U. with help and funding from IBM
  - used thousands of relays
    - mechanical binary switches controlled by electrical currents
  - fundamental design was decimal.
- Similar electromechanical computer designed and built by Conrad Zuse in Germany

## ABC: totally electronic digital

- Devised by John V. Atanasoff, a physicist at Iowa State College, in 1937
- Built in 1939 by Atanasoff and Clifford Berry (grad. Student)
- Electronic vacuum tubes as the switching components
- Built to solve physics equations
- ABC was a binary-based machine
  - arithmetic/logic unit with 30 units that could do + and -
  - a rotating drum memory that held 30 binary numbers of 50 digits
  - punched card input. Each punched card held 5 15-digit decimal numbers
  - numbers converted to binary as they entered the machine
- Precursor to ENIAC

## ENIAC

- Electronic Numerical Integrator and Computer
- WWII research :solution to formulas related to ballistic missile trajectories
- designed and built 1943-1946 operated until 1955
- by John W. Mauchly and J. P. Eckert at the U. of Pennsylvania
- Storage: 20 ten-digit decimal number + 100 numbers in ROM
- Calculations performed using decimal arithmetic
- 10 electronic vacuum tube binary switches were used for each digit
- Input and output used punched cards
- The system provides printed output
- Programs not stored internally, hard wired with externally
- Led to UNIVAC I, 1st commercial computer in 1951
- 18000 vacuum tubes
- floor space more than 15000 square feet
- weighed more than 30 tons
- average error-free operating 5.6 hours only

## Vacuum tube



## ENIAC



# von Neumann Architecture

- In 1945, John von Neumann
  - ENIAC consultant
  - proposed a computer with significant improvements
- A memory that would hold both programs and data:
  - stored program concept
  - ⇒ avoid rewiring the control panels for changing programs
- Binary processing of data
  - simplified the design of the computer
  - use of binary memory for both instructions and data
  - recognized the natural relationship between
    - ON/OFF nature of switches and
    - calculation in the binary number system, using Boolean logic