Chapter 1

Introduction

The word "computer" comes from the word "compute", which means, "to calculate". Hence, people usually consider a computer to be a calculating device that can perform arithmetic operations at high speed.

In fact, the original objective for inventing a computer was to create a fast calculating machine. However, more than 80% of work done by computers today is of non-mathematical or non-numerical nature. Hence, to define a computer merely as a calculating device is to ignore over 80% of its functions.

More accurately, we can define a computer as a device that operates upon data. Data can be anything like bio-data of applicants when computer is used for short listing candidates for recruiting; marks obtained by students in various subjects when used for preparing results; details (name, age, sex, etc.) of passengers when used for making airline or railway reservations; or number of different parameters when used for solving scientific research problems, etc.

Hence, data comes in various shapes and sizes depending upon the type of computer application. A computer ca store, process, and retrieve data as and when desired. The fact that computers process data is so fundamental th many people have started calling it a *data processor*.

The name data processor is more inclusive because modern computers not only compute in the usual sense b also perform other functions with data that flows to and from them. For example, data processors may gather da from various incoming sources, merge (process of mixing or putting together) them all, sort (process of arrangi in some sequence – ascending or descending) them in the desired order, and finally print them in desired form Notice that none of these operations involves arithmetic computations in the usual sense but a computer is most suitable device for performing them.

The activity of processing data using a computer is called *data processing*. Data processing consists of three activities: capturing input data, manipulating the data, and managing output results.. As used in data proces

information is data arranged in an order and form that is useful to people receiving it. Hence, *data* is raw material used as input to data processing and *information* is processed data obtained as output of data processing.

CHARACTERISTICS OF COMPUTERS

Increasing popularity of computers has proved that it is a very powerful and useful tool. The power and usefulness of this popular tool are mainly due to its following characteristics:

1. **Automatic.** An automatic machine works by itself without human intervention. Computers are automatic machines because once started on a job, they carry out the job (normally without any human assistance) until it is finished. However, computers being machines cannot start themselves and cannot go out and find their own problems and solutions. We need to instruct a computer using coded instructions that specify exactly how it will do a particular job. Some of the other characteristics of computers (such as speed and accuracy) are because they are automatic and work on a problem without any human intervention.

2. **Speed.** A computer is a very fast device. It can perform in a few seconds, the amount of work that a human being can do in an entire year – if he/she worked day and night and did nothing else. In other words, a computer can do in a few minutes what would take a man his entire lifetime.

   While talking about the speed of a computer we do not talk in terms of seconds or even milliseconds (10^{-3}) but in terms of microseconds (10^{-6}), nanoseconds (10^{-9}), and even picoseconds (10^{-12}). A powerful computer is capable of performing several billion (10^{9}) simple arithmetic operations per second.

3. **Accuracy.** In addition to being very fast, computers are very accurate. Accuracy of a computer is consistently high and the degree of its accuracy depends upon its design. A computer performs every calculation with the same accuracy.

   However, errors can occur in a computer. These errors are mainly due to human rather than technological weaknesses. For example, errors may occur due to imprecise thinking by a programmer (a person who writes instructions for a computer to solve a particular problem) or incorrect input data. We often refer to computer errors caused due to incorrect input data or unreliable programs as *garbage-in-garbage-out* (*GIGO*).

4. **Diligence.** Unlike human beings, a computer is free from monotony, tiredness, and lack of concentration. It can continuously work for hours without creating any error and without grumbling. Hence, computers score over human beings in doing routine type of jobs that require great accuracy. If ten million calculations have to be performed, a computer will perform the last one with exactly the same accuracy and speed as the first one.

5. **Versatility.** Versatility is one of the most wonderful things about a computer. One moment it is preparing results of an examination, next moment it is busy preparing electricity bills, and in between, it may be helping an office secretary to trace an important letter in seconds. All that is required to change its talent is to slip in a new program (a sequence of instructions for the computer) into it. In brief, a computer is capable of performing almost any task, if the task can be reduced to a finite series of logical steps.

6. **Power of Remembering.** As a human being acquires new knowledge, his/her brain subconsciously selects what it feels to be important and worth retaining in memory. The brain relegates unimportant details to back of mind or just forgets them. This is not the case with computers. A computer can store and recall any amount of information because of its secondary storage (a type of detachable memory) capability. It can retain a piece of information as long as a user desires and the user can recall the

information whenever required. Even after several years, a user can recall exactly the same information that he/she had stored in the computer several years ago. A computer forgets or looses certain information only when a user asks it to do so. Hence, it is entirely up to the user to make a computer retain or forget some information.

7. **No I. Q.** A computer is not a magical device. It possesses no intelligence of its own. Its I. Q. is zero, at least until today. It has to be told what to do and in what sequence. Hence, only a user determines what tasks a computer will perform. A computer cannot take its own decision in this regard.

8. **No Feelings.** Computers are devoid of emotions. They have no feelings and no instincts because they are machines. Although men have succeeded in building a memory for computer, but no computer possesses the equivalent of a human heart and soul. Based on our feelings, taste, knowledge, and experience we often make certain judgements in our day-to-day life whereas, computers cannot make such judgements on their own. They make judgements based on the instructions given to them in the form of programs that are written by us (human beings).

EVOLUTION OF COMPUTERS

Necessity is the mother of invention. The saying holds true for computers too. Computers were invented because of man's search for fast and accurate calculating devices.

Blaise Pascal invented the first mechanical adding machine in 1642. Later, in the year 1671, Baron Gottfried Wilhelm von Leibniz of Germany invented the first calculator for multiplication. Keyboard machines originated in the United States around 1880 and we use them even today. Around the same period, Herman Hollerith came up with the concept of punched cards that were extensively used as input medium in computers even in late 1970s. Business machines and calculators made their appearance in Europe and America towards the end of the nineteenth century.

Charles Babbage, a nineteenth century Professor at Cambridge University, is considered the father of modern digital computers. He had employed a group of clerks for preparing mathematical and statistical tables. Babbage had to spend several hours checking these tables because even utmost care and precautions could not eliminate human errors. Soon he became dissatisfied and exasperated with this type of monotonous job. As a result, he started thinking about building a machine that could compute tables guaranteed to be error-free. In this process, Babbage designed a "Difference Engine" in the year 1822 that could produce reliable tables. In 1842, Babbage came out with his new idea of a completely automatic Analytical Engine for performing basic arithmetic functions for any mathematical problem at an average speed of 60 additions per minute. Unfortunately, he was unable to produce a working model of this machine because the precision engineering required to manufacture the machine was not available during that period. However, his efforts established a number of principles that are fundamental to the design of any digital computer. In order to have a better idea of the evolution of computers it is worthwhile to discuss some of the well-known early computers. These are as follows:

1. **The Mark I Computer (1937-44).** Also known as Automatic Sequence Controlled calculator, this was the first fully automatic calculating machine designed by Howard A. Aiken of Harvard University in collaboration with IBM (International Business Machines) Corporation. It was an electro-mechanical device (used both electronic and mechanical components) based on the techniques already developed for punched card machines.

   Although this machine proved to be extremely reliable, it was very complex in design and huge in size. It used over 3000 electrically actuated switches to control its operations and was approximately 50 feet long and 8 feet high. It was capable of performing five basic arithmetic operations: addition,

subtraction, multiplication, division, and table reference on numbers as big as 23 decimal digits. It took approximately 0.3 second to add two numbers and 4.5 seconds for multiplication of two numbers. Obviously, the machine was very slow as compared to today's computers.

2. **The Atanasoff-Berry Computer (1939-42).** Dr. John Atanasoff developed an electronic machine to solve certain mathematical equations. The machine was called the Atanasoff-Berry Computer, or ABC, after its inventor's name and his assistant, Clifford Berry. It used 45 vacuum tubes for internal logic and capacitors for storage.

3. **The ENIAC (1943-46).** The Electronic Numerical Integrator And Calculator (ENIAC) was the first all electronic computer. It was constructed at the Moore School of Engineering of the University of Pennsylvania, U.S.A. by a design team led by Professors J. Presper Eckert and John Mauchly.

   The team developed ENIAC because of military needs. It was used for many years to solve ballistic related problems. It took up wall space in a 20 x 40 square feet room and used 18,000 vacuum tubes. It could add two numbers in 200 microseconds and multiply them in 2000 microseconds.

4. **The EDVAC (1946-52).** A major drawback of ENIAC was that its programs were wired on boards that made it difficult to change the programs. Dr. John Von Neumann later introduced the "stored program" concept that helped in overcoming this problem. The basic idea behind this concept is that a sequence of instructions and data can be stored in the memory of a computer for automatically directing the flow of operations. This feature considerably influenced the development of modern digital computers because of the ease with which different programs can be loaded and executed on the same computer. Due to this feature, we often refer to modern digital computers as stored program digital computers. The Electronic Discrete Variable Automatic Computer (EDVAC) used the stored program concept in its design. Von Neumann also has a share of the credit for introducing the idea of storing both instructions and data in binary form (a system that uses only two digits – 0 and 1 to represent all characters), instead of decimal numbers or human readable words.

5. **The EDSAC (1947-49).** Almost simultaneously with EDVAC of U.S.A., the Britishers developed the Electronic Delay Storage Automatic Calculator (EDSAC). The machine executed its first program in May 1949. In this machine, addition operations took 1500 microseconds and multiplication operations took 4000 microseconds. A group of scientists headed by Professor Maurice Wilkes at the Cambridge University Mathematical Laboratory developed this machine.

6. **The UNIVAC I (1951).** The Universal Automatic Computer (UNIVAC) was the first digital computer that was not "one of a kind". Many UNIVAC machines were produced, the first of which was installed in the Census Bureau in 1951 and was used continuously for 10 years. The first business use of a computer, a UNIVAC I, was by General Electric Corporation in 1954.

   In 1952, the International Business Machines (IBM) Corporation introduced the IBM-701 commercial computer. In rapid succession, improved models of the UNIVAC I and other 700-series machines were introduced. In 1953, IBM produced the IBM-650, and sold over 1000 of these computers.

   UNIVAC marked the arrival of commercially available digital computers for business and scientific applications.

COMPUTER GENERATIONS

"Generation" in computer talk is a step in technology. It provides a framework for the growth of computer industry. Originally, the term "generation" was used to distinguish between varying hardware technologies but it has now been extended to include both hardware and software that together make up a computer system.

The custom of referring to computer era in terms of generations came into wide use only after 1964. There are totally five computer generations known till today. Below we describe each generation along with its identifying characteristics. Although there is a certain amount of overlap between different generations, the approximate period shown against each are normally accepted.

During description of various computer generations, you will come across several new terminologies and computer jargons that you may not be able to understand properly. However, the idea here is to provide you an overview of the major developments and technologies during the five generations of computers. Subsequent chapters will cover these developments and technologies in detail. The objective of this section is mainly to provide an overview of what all you are going to learn in this entire book.

First Generation (1942-1955)

We have already discussed about some of the early computers – ENIAC, EDVAC, EDSAC, UNIVAC I, and IBM 701. These machines and others of their time used thousands of vacuum tubes. A vacuum tube [see Figure 1.1(a)] was a fragile glass device, which used filaments as a source of electronics and could control and amplify electronic signals. It was the only high-speed electronic switching device available in those days. These vacuum tube computers could perform computations in milliseconds and were referred to as first-generation computers.

The memory of these computers used electromagnetic relays, and all data and instructions were fed into the system from punched cards. The instructions were written in machine and assembly languages because high-level programming languages were introduced much later (computer languages are covered in Chapter 12). Since machine and assembly languages are very difficult to work with, only a few specialists understood how to program these early computers.

Characteristic features of first-generation computers are as follows:

1. They were the fastest calculating devices of their time.
2. They were too bulky in size, requiring large rooms for installation.
3. They used thousands of vacuum tubes that emitted large amount of heat and burnt out frequently. Hence, the rooms/areas in which these computers were located had to be properly air-conditioned.
4. Each vacuum tube consumed about half a watt of power. Since a computer typically used more than ten thousand vacuum tubes, power consumption of these computers was very high.
5. As vacuum tubes used filaments, they had a limited life. Because a computer used thousands of vacuum tubes, these computers were prone to frequent hardware failures.
6. Due to low mean time between failures, these computers required constant maintenance.
7. In these computers, thousands of individual components were assembled manually by hand into electronic circuits. Hence, commercial production of these computers was difficult and costly.
8. Since these computers were difficult to program and use, they had limited commercial use.

Second Generation (1955-1964)

John Bardeen, Willian Shockley, and Walter Brattain invented a new electronic switching device called transistor [see Figure 1.1(b)] at Bell Laboratories in 1947. Transistors soon proved to be a better electronic switching device than vacuum tubes due to their following properties:

1. They were more rugged and easier to handle than tubes since they were made of germanium semiconductor material rather than glass.
2. They were highly reliable as compared to tubes since they had no parts like a filament that could burn out.
3. They could switch much faster (almost ten times faster) than tubes. Hence, switching circuits made of transistors could operate much faster than their counterparts made of tubes.
4. They consumed almost one-tenth the power consumed by a tube.
5. They were much smaller than a tube.
6. They were less expensive to produce.
7. They dissipated much less heat as compared to vacuum tubes.

The second-generation computers were manufactured using transistors instead of vacuum tubes. Due to the properties of transistors listed above, these computers were more powerful, more reliable, less expensive, smaller, and cooler to operate than the first-generation computers. They used magnetic cores for main memory, and magnetic disk and tape as secondary storage media. Punched cards were still popular and widely used for preparing and feeding programs and data to these computers.

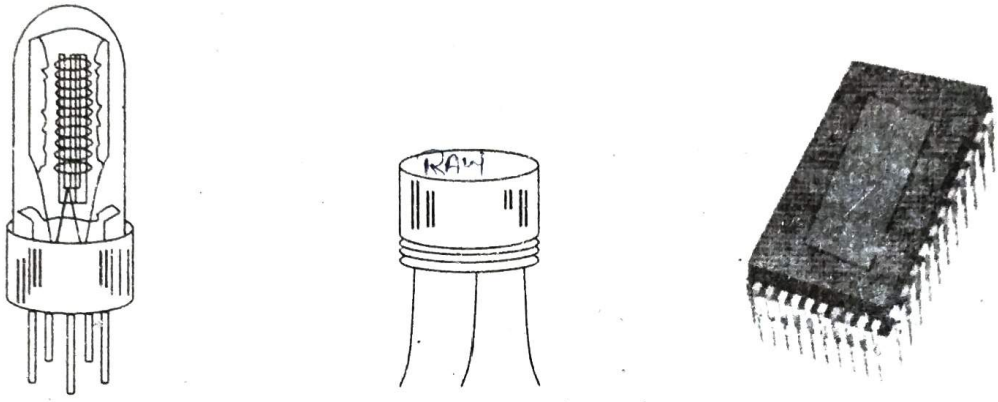
On software front, high-level programming languages (like FORTRAN, COBOL, ALGOL, and SNOBOL) and batch operating system emerged during second generation. High-level programming languages were easier for people to understand and work with than assembly or machine languages making second-generation computers easier to program and use than first-generation computers. Introduction of batch operating system enabled multiple jobs to be batched together and submitted at a time. A batch operating system causes automatic transition from one job to another as soon as the former job completes. This concept helped in reducing human intervention while processing multiple jobs resulting in faster processing, enhanced throughput, and easier operation of second-generation computers.

The first-generation computers were mainly used for scientific computations. However, the second-generation computers were increasingly used in business and industry for commercial data processing applications like payroll, inventory control, marketing, and production planning.

Characteristic features of second-generation computers are as follows:

1. They were more than ten times faster than the first-generation computers.
2. They were smaller than first-generation computers and required smaller space.
3. They consumed less power and dissipated less heat than the first-generation computers. The rooms/areas in which the second-generation computers were located still required to be properly air-conditioned.
4. They were more reliable and less prone to hardware failures than the first-generation computers.

5. They had faster and larger primary and secondary storage as compared to first-generation computers.
6. They were easier to program and use than the first-generation computers. Hence, they had wider commercial use.
7. In these computers, thousands of individual transistors had to be assembled manually by hand into electronic circuits making commercial production of these computers difficult and costly.



(a) A Vacuum Tube (b) A Transistor (c) An IC Chip

Figure 1.1. Electronic devices used for manufacturing computers of different generations.

Third Generation (1964-1975)

In 1958, Jack St. Clair Kilby and Robert Noyce invented the first integrated circuit. *Integrated circuits* (called *ICs*) are circuits consisting of several electronic components like transistors, resistors, and capacitors grown on a single chip of silicon eliminating wired interconnection between components. The IC technology was also known as "microelectronics" technol. gy because it made it possible to integrate larger number of circuit components into very small (less than 5 mm square) surface of silicon, known as "chip" [see Figure 1.1(c)]. Initially the integrated circuits contained only about ten to twenty components. This technology was named *small scale integration* (SSI). Later with the advancement in technology for manufacturing ICs, it became possible to integrate up to about hundred components on a single chip. This technology came to be known as *medium scale integration* (MSI).

Computers built using integrated circuits characterized the third generation. Earlier ones used SSI technology and later ones used MSI technology. ICs were smaller, less expensive to produce, more rugged and reliable, faster in operation, dissipated less heat, and consumed less power than circuits built by wiring electronic components manually. Hence, third-generation computers were more powerful, more reliable, less expensive, smaller, and cooler to operate than second-generation computers.

Parallel advancements in storage technologies allowed construction of larger magnetic core based random access memory as well as larger capacity magnetic disks and tapes. Hence, third-generation computers typically had few megabytes (less than 5 Megabytes) of main memory and magnetic disks capable of storing few tens of megabytes of data per disk drive.

On software front, standardization of high-level programming languages, timesharing operating systems, unbundling of software from hardware, and creation of an independent software industry happened during third generation. FORTRAN and COBOL were the most popular high-level programming languages in those days. American National Standards Institute (ANSI) standardized them in 1966 and 1968 respectively, and the standardized versions were called ANSI FORTRAN and ANSI COBOL. The idea was that as long as

programmers follows these standards in program writing, a program could be run on any computer with an ANSI FORTRAN or ANSI COBOL compiler (see Chapter 12 for details). Some more high-level programming languages were introduced during the third-generation period. Notable among these were PL/1, PASCAL, and BASIC.

We saw that second-generation computers used batch operating system. In these systems, users had to prepare their data and programs and then submit them to a computer centre for processing. The operator at the computer centre collected these user jobs and fed them to a computer in batches at scheduled intervals. The respective users then collected their job's output from the computer centre. The inevitable delay resulting from this batch processing approach was very frustrating to some users, especially programmers, because often they had to wait for days to locate and correct a few program errors. To rectify this situation, John Kemeny and Thomas Kurtz of Dartmouth College introduced the concept of timesharing operating system. Timesharing operating system enables multiple users to directly access and share computing resources simultaneously in a manner that each user feels that no one else is using the computer. This is accomplished by using a large number of independent, relatively low-speed, on-line terminals connected to the main computer simultaneously. Introduction of timesharing concept helped in drastically improving the productivity of programmers and made on-line systems feasible, resulting in new on-line applications like airline reservation systems, interactive query systems, etc.

Until 1965, computer manufacturers sold their hardware along with all associated software without any separate charges for software. For example, buyers received language translators for all languages supported on a computer they purchased. From user's standpoint, software was free. However, the situation changed in 1969 when IBM and other computer manufacturers began to price their hardware and software products separately. This unbundling of software from hardware gave users an opportunity to invest only in software of their need and value. For example, now buyers could purchase only the language translators they needed and not all language translators supported on the purchased computer. This led to the creation of many new software houses and the beginning of an independent software industry.

Development and introduction of minicomputers also took place during the third-generation period. Computers built until the early 1960s were mainframe systems that only very large companies could afford to purchase and use. Clearly, a need existed for low-cost smaller computers to fill the gaps left by the bigger, faster, and costlier mainframe systems. Several innovators recognized this need and formed new firms in the 1960s to produce smaller computers. Digital Equipment Corporation (DEC) introduced the first commercially available minicomputer, the PDP-8 (Programmed Data Processor), in 1965. It could easily fit in the corner of a room and did not require attention of a full-time computer operator. It used timesharing operating system and a number of users could access it simultaneously from different locations in the same building. Its cost was about one-fourth the cost of a traditional mainframe system making it possible for smaller companies to afford computers. It confirmed the tremendous demand for small computers for business and scientific applications, and by 1971, there were more than 25 computer manufacturers in minicomputer market.

Characteristic features of third-generation computers are as ollows:

1. They were more powerful than second-generation computers. They were capable of performing about 1 million instructions per second.
2. They were smaller than second-generation computers requiring smaller space.
3. They consumed less power and dissipated less heat than second-generation computers. The rooms/areas in which third-generation computers were located still required to be properly air-conditioned.
4. They were more reliable and less prone to hardware failures than second-generation computers requiring lower maintenance cost.

5. They had faster and larger primary and secondary storage as compared to second-generation computers.
6. They were general-purpose machines suitable for both scientific and commercial applications.
7. Their manufacturing did not require manual assembly of individual components into electronic circuits resulting in reduced human labor and cost involved at assembly stage. Hence, commercial production of these systems was easier and cheaper. However, highly sophisticated technology and expensive setup was required for the manufacture of IC chips.
8. Standardization of high-level programming languages allowed programs written for one computer to be easily ported to and executed on another computer.
9. Timesharing operating system allowed interactive usage and simultaneous use of these systems by multiple users.
10. Timesharing operating system helped in drastically improving the productivity of programmers cutting down the time and cost of program development by several fold.
11. Timesharing operating system also made on-line systems feasible resulting in usage of these systems for new on-line applications.
12. Unbundling of software from hardware gave users of these systems an opportunity to invest only in software of their need and value.
13. Minicomputers of third-generation made computers affordable even by smaller companies.

Fourth Generation (1975-1989)

Average number of electronic components packed on a silicon chip doubled each year after 1965. This progress soon led to the era of *large scale integration* (*LSI*) when it was possible to integrate over 30,000 electronic components on a single chip, followed by *very large scale integration* (*VLSI*) when it was possible to integrate about one million electronic components on a single chip. This progress led to a dramatic development – creation of a microprocessor. A *microprocessor* contains all circuits needed to perform arithmetic logic and control functions, the core activities of all computers, on a single chip. Hence, it became possible to build a complete computer with a microprocessor, a few additional primary storage chips, and other support circuitry. It started a new social revolution – *personal computer* (*PC*) revolution. Overnight computers became incredibly compact. They became inexpensive to make, and suddenly it became possible for anyone to own a computer.

During fourth generation, semiconductor memories replaced magnetic core memories resulting in large random access memories with very fast access time. On the other hand, hard disks became cheaper, smaller, and larger in capacity. In addition to magnetic tapes, floppy disks became very popular as a portable medium for porting programs and data from one computer system to another.

Another significant development during fourth-generation period was spread of high-speed computer networking enabling interconnection of multiple computers to enable them to communicate and share data. Local area networks (LANs) became popular for connecting computers within an organization or within a campus. Similarly, wide area networks (WANs) became popular for connecting computers located at larger distances. This gave rise to network of computers and distributed systems.

On software front, several new developments emerged to match the new technologies of fourth generation. For example, several new operating systems were developed for PCs. Notable among these were MS-DOS, MS-Windows, and Apple's propriety OS. Since PCs were for individuals who were not computer professionals, companies developed graphical user interfaces for making computers more user friendly (easier to use). A

graphical user interface (*GUI*) provides icons (pictures) and menus (list of choices) that users can select with a mouse. This enables new computer users to learn to use a PC quickly. Several new PC-based applications were also developed to make PCs a powerful tool. Notable among these were powerful word processing packages that allowed easy development of documents, spreadsheet package that allowed easy manipulation and analysis of data organized in columns and rows, and graphics packages that allowed easy drawing of pictures and diagrams. Another very useful concept that became popular during fourth-generation period was that of multiple windows on a single terminal screen. This feature allowed users to see the current state of several applications simultaneously in separate windows on same terminal screen. During fourth-generation period, UNIX operating system and C programming language also became very popular.

Characteristic features of fourth-generation computers are as follows:

1. PCs were smaller and cheaper than mainframes or minicomputers of third generation.
2. Although the fourth-generation mainframes required proper air-conditioning of the rooms/areas in which they were located, no air-conditioning was required for PCs.
3. They consumed less power than third-generation computers.
4. They were more reliable and less prone to hardware failures than third-generation computers requiring negligible maintenance cost.
5. They had faster and larger primary and secondary storage as compared to third-generation computers.
6. They were general-purpose machines.
7. Their manufacturing did not require manual assembly of individual components into electronic circuits resulting in reduced human labor and cost involved at assembly stage. Hence, commercial production of these systems was easier and cheaper. However, highly sophisticated technology and expensive setup was required for manufacturing LSI and VLSI chips.
8. Use of standard high-level programming languages allowed programs written for one computer to be easily ported to and executed on another computer.
9. Graphical user interface (GUI) enabled new users to quickly learn how to use computers.
10. PC-based applications made PCs a powerful tool for both office and home usage.
11. Network of computers enabled sharing of resources like disks, printers, etc. among multiple computers and their users. They also enabled several new types of applications involving interaction among computer users at geographically distant locations. *Computer Supported Cooperative Working* (*CSCW*), or *groupware* is one such application in which multiple members working on a single project and located at distant locations cooperate with each other by using a network of computers.
12. In addition to unbundled software, these systems also used add-on hardware feature that allowed users to invest only in the hardware configuration and software of their need and value.
13. PCs of fourth generation made computers affordable even by individuals for their personal use at home.

Fifth Generation (1989-Present)

The trend of further miniaturization of electronic components, dramatic increase in power of microprocessor chips, and increase in capacity of main memory and hard disk continued during fifth generation. VLSI technology became *ULSI* (*Ultra Large Scale Integration*) technology in fifth generation resulting in production of microprocessor chips having ten million electronic components. In fact, the speed of microprocessors and the size

of main memory and hard disk doubled almost every eighteen months. As a result, many features found in the CPUs of large mainframe systems of third- and fourth-generation systems became part of microprocessor architecture in fifth generation. This ultimately resulted in availability of very powerful and compact computers becoming available at cheaper rates and death of traditional large mainframe systems.

Due to this fast pace of advancement in computer technology, we see more compact and more powerful computers being introduced almost every year at more or less the same price or even cheaper. Notable among these are portable notebook computers that give the power of a PC to their users even while travelling, powerful desktop PCs and workstations, powerful servers, and very powerful supercomputers (see Chapter 20 for a detailed description of these types of computers).

Storage technology also advanced very fast making larger and larger main memory and disk storage available in newly introduced systems. During fifth generation, optical disks also emerged as a popular portable mass storage media such as *CD-ROM* (*Compact Disk - Read Only Memory*).

During fifth generation, there was tremendous outgrowth of computer networks. Communication technologies became faster day-by-day and more and more computers were networked together. This trend resulted in emergence and popularity of the Internet and associated technologies and applications. The Internet made it possible for computer users sitting across the globe to communicate with each other within minutes by use of *electronic mail* (known as *e-mail*) facility. A vast ocean of information became readily available to computer users through the *World Wide Web* (known as *WWW*). Moreover, several new types of exciting applications like electronic commerce, virtual libraries, virtual classrooms, distance education, etc., emerged during the period.

Tremendous processing power and massive storage capacity of fifth-generation computers also made them a very useful and popular tool for a wide range of multimedia applications that deal with information containing text, graphics, animation, audio, and video data. In general, the data size of multimedia information is much larger than textual information because representation of graphics, animation, audio, or video media in digital form requires larger number of bits than that required for representation of textual information.

Characteristic features of fifth-generation computers are as follows:

1. Portable PCs (called notebook computers) are much smaller and handy than PCs of fourth generation allowing users to use computing facility even while travelling.
2. Fifth-generation desktop PCs and workstations are several times more powerful than PCs of fourth generation.
3. Although fifth-generation mainframes require proper air-conditioning of the rooms/areas in which they are located, no air-conditioning is normally required for notebook computers, desktop PCs, and workstations.
4. They consume less power than their predecessors do.
5. They are more reliable and less prone to hardware failures than their predecessors were, requiring negligible maintenance cost.
6. Many of the large-scale fifth-generation systems have hot-plug feature that enables a failed component to be replaced with a new one without the need to shutdown the system. Hence, the uptime of these systems is very high.
7. They have faster and larger primary and secondary storage as compared to their predecessors.
8. They are general-purpose machines.

9. Their manufacturing does not require manual assembly of individual components into electronic circuits resulting in reduced human labor and cost involved at assembly stage. Hence, commercial production of these systems is easier and cheaper. However, highly sophisticated technology and expensive setup (affordable only by a few organizations in the world) is required for manufacturing ULSI chips.
10. Use of standard high-level programming languages allows programs written for one computer to be easily ported to and executed on another computer.
11. More user-friendly interfaces with multimedia features make the systems easier to learn and use by anyone, including children.
12. Newer and more powerful applications, including multimedia applications, make the systems more useful in every occupation.
13. Explosion in the size of the Internet coupled with Internet-based tools and applications have made these systems influence the life of even common people.
14. These systems also use the concept of unbundled software and add-on hardware allowing the users to invest only in the hardware configuration and software of their need and value.
15. With so many types of computers in all price ranges today, we have a computer for almost any type of user whether the user is a child or a world-fame scientist.

Figure 1.2 summarizes the key technologies and features of the various generations of computers discussed above.

We have looked at the history of computing divided into five generations and we have seen how quickly things have changed in the last few decades. Technological progress in this area is continuing at the same rate even now. In fact, the fastest-growth period in the history of computing may be still ahead.

Points to Remember

1. People usually consider a computer to be a calculating device that can perform arithmetic operations at high speed. It is also known as a data processor because it not only computes in the usual sense but also performs other functions with the data.
2. The activity of processing data using a computer is called data processing. Data is raw material used as input to data processing and information is processed data obtained as output of data processing.
3. Computers are characterized by their being automatic, speed, accuracy of computing, diligence, versatility, power of remembering, and lack of intelligence and feelings.
4. Charles Babbage is considered the father of modern digital computers.
5. Some of the well-known early computers are the MARK I (1937-44), the ATANASOFF-BERRY (1939-42), the ENIAC (1943-46), the EDVAC (1946-52), the EDSAC (1947-49) and the UNIVAC I (1951).
6. Dr. John Von Neumann introduced the "stored program" concept that considerably influenced the development of modern digital computers. Due to this feature, we often refer to modern digital computers as stored program digital computers.
7. "Generation" in computer talk is a step in technology. It provides a framework for growth of computer industry. Originally, it was used to distinguish between various hardware technologies but it has now been extended to include both hardware and software.
8. Till date, there are five computer generations namely, first, second, third, fourth, and fifth generation.
9. Key hardware and software technologies and key characteristics of computers of the five different generations are summarized in Figure 1.2.

Generation (Period)	Key hardware technologies	Key software technologies	Key characteristics	Some representative systems
First (1942-1955)	Vacuum tubes; electromagnetic relay memory; punched cards secondary storage	Machine and assembly languages; stored program concept; mostly scientific applications	Bulky in size; highly unreliable; limited commercial use; commercial production difficult and costly; difficult to use	ENIAC, EDVAC, EDSAC, UNIVAC I, IBM 701
Second (1955-1964)	Transistors; magnetic core memory; magnetic tapes and disks secondary storage	Batch operating system; high-level programming languages; scientific and commercial applications	Faster, smaller, more reliable and easier to program than previous generation systems; commercial production was still difficult and costly	Honeywell 400, IBM 7030, CDC 1604, UNIVAC LARC
Third (1964-1975)	ICs with SSI and MSI technologies; larger magnetic core memory; larger capacity magnetic disks and tapes secondary storage; minicomputers	Timesharing operating system; standardization of high-level programming languages; unbundling of software from hardware	Faster, smaller, more reliable, easier and cheaper to produce commercially, easier to use, and easier to upgrade than previous generation systems; scientific, commercial and interactive on-line applications	IBM 360/370, PDP-8, PDP-11, CDC 6600
Fourth (1975-1989)	ICs with VLSI technology; microprocessors; semiconductor memory; larger capacity hard disks as in-built secondary storage; magnetic tapes and floppy disks as portable storage media; personal computers; spread of high-speed computer networks	Operating systems for PCs; GUI; multiple windows on a single terminal screen; UNIX operating system; C programming language; PC-based applications; network-based applications	Small, affordable, reliable, and easy to use PCs; more powerful and reliable mainframe systems; general purpose machines; easier to produce commercially	IBM PC and its clones, Apple II, TRS-80, VAX 9000, CRAY-1, CRAY-2, CRAY-X/MP
Fifth (1989-Present)	ICs with ULSI technology; larger capacity main memory; larger capacity hard disks; optical disks as portable read-only storage media; notebook computers; powerful desktop PCs and workstations; very powerful mainframes; the Internet	World Wide Web; multimedia applications; Internet-based applications	Portable computers; more powerful, cheaper, reliable, and easier to use desktop machines; very powerful mainframes; very high uptime due to hot-pluggable components; general purpose machines; easier to produce commercially	IBM notebooks, Pentium PCs, SUN Workstations, IBM SP/2, SGI Origin 2000, PARAM 10000

Figure 1.2. Computer generations – A summary.

Questions

1. What is a computer? Why it is also known as a data processor?
2. What is data processing? Differentiate between data and information. Which is more useful to the people and why?
3. List and explain some important characteristics of a computer.
4. What is garbage-in-garbage-out?
5. Who is known as the father of modern digital computers and why?
6. Who invented the concept of stored program? Why is this concept so important?
7. Why are modern digital computers often referred to as stored program digital computers?
8. Which was the first commercially produced computer? When and where was it first installed?
9. Write full form of following abbreviations used in computer terminology: IBM, ENIAC, EDVAC, EDSAC, UNIVAC.
10. What is "generation" in computer terminology? How many computer generations are there till date?
11. List the various computer generations along with the key characteristics of computers of each generation.
12. List key hardware technologies used in building computers of each of the five generations.
13. List key software technologies used in building computers of each of the five generations.
14. What are the advantages of transistors over vacuum tubes?
15. What is an IC? How it helps in reducing the size o computers?
16. List the advantages of IC technology over transisto technology.
17. Write the full form of following abbreviations used in computer terminology: GIGO, IC, SSI, MSI, LSI, VLSI, ULSI.
18. Why were first- and second-generation computers more difficult and costlier to produce commercially tha computers of subsequent generations?
19. Name the technologies used for constructing main memory in first-, second-, third-, and fourth-generation computers.
20. Name the secondary storage media popularly used in first-, second-, third-, fourth-, and firth-generation computers.
21. What is a microprocessor? How it revolutionized the computer industry?
22. Name some applications that emerged due to emergence of computer networks.
23. Name some applications that emerged due to emergence of the Internet.
24. Name some representative computer systems of each o the five computer generations.