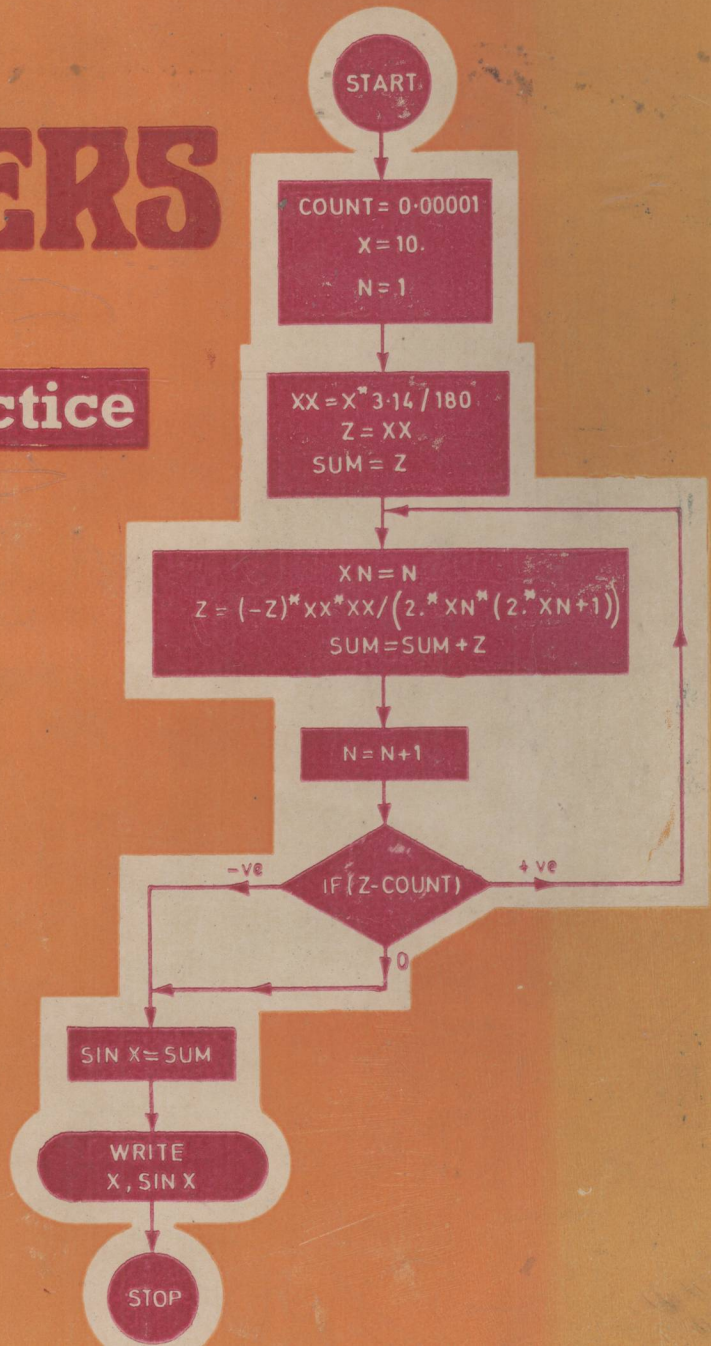
COMPUTER PROGRAMMING FOR ENGINEERS

Theory and Practice

M. M. HASAN



DHANPAT RAI & SONS

COMPUTER PROGRAMMING
FOR
ENGINEERS

(THEORY & PRACTICE)
Digital and Analogue Computation

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(SECOND REVISED & ENLARGED EDITION)

DHANPAT RAI & SONS
1682, NAI SARAK, DELHI-110006
(PHONE : 265367)

First Edition : *1978*

Second Edition : *1980*

Reprint : *1982*

Price : Rs. 35.00

Published by J.C. Kapur, B.A., for Dhanpat Rai & Sons, Delhi-Jullundur, Composed by Rahul Composing Agency, Shahdara, Delhi and Printed at D R. Printing Service, Shahdara, Delhi.

PREFACE TO THE SECOND EDITION

It is a matter of satisfaction that the book has been found to be useful and a second edition has been necessitated within a comparatively short period of two years only.

On the basis of suggestions and comments received from different sources, the text has been considerably enlarged to incorporate many of the various advanced facilities available on nowadays Computers. A separate chapter has been included on concept of programming by segments (FUNCTIONS and SUBROUTINES). Facilities like Assigned GO TO, Implied DO type Input/Output statements have also been included in the revised text.

Notable inclusion, however, in this edition is a number of additional Computer Oriented Numerical techniques with sufficient illustrative worked examples. (Chapter 5—Part II). The chapter has been thoroughly rewritten and considerably enlarged.

Five useful additional Appendices like Hints on Efficient Programming; Varying FORTRAN Dialets; Computer arithmetic (Binary Coding) etc. have also been added in this revised text. This would increase its utility as a standard reference book on the subject.

I am extremely grateful to all of them who very kindly offered their comments and suggestions; too numerous to acknowledge them all individually.

I would feel obliged to receive further suggestions for improvement, as well as, for rectification of errors which might have crept in the book for various reasons.

I earnestly hope that the second edition will definitely prove to be more useful and receive greater response than the first.

M. M. HASAN

PREFAE TO THE FIRST EDITION

The book is intended as an introduction to computer programming on both digital as well as analogue computers and covers undergraduate and post-graduate studies of the various Indian Universities in the different branches of Engineering. The book may as well be found useful for students preparing for degrees in Industrial Management, Business Management, etc.

One of the main contributions of modern age is computer. The use of computers is growing fast in India. India is itself manufacturing a few types of computers

Almost all Engineering Colleges in India impart training to students of both U.G. and P.G. classes in this facility of modern age. The absence of a suitable book on the subject to deal with the subject in a simple language with sufficient worked examples of actual programming for the benefit of an average reader, not exposed to a computer before, has been keenly felt. This book takes care of special requirements of an average reader with emphasis on facilities available with India-made computers.

The various principles and methods have been profusely illustrated by means of solved worked examples and their 'Flow-charts'. I have tried to present the subject-matter in as simple and lucid manner as possible and well within the comprehensions of students of all categories. Naturally, in preparation of the text, a number of previous books have been consulted. I am thankful to all those authors, too numerous to acknowledge them individually.

I also wish to acknowledge my grateful indebtedness to Sri J. Chandra, Reader in the Faculty of Engg., University of Jodhpur, in preparation of the book. The book could not have been completed, but for the active help of my distinguished colleague, Sri N.A. Ansari who has corrected the manuscript at places. I would also like to express my gratitude to my brother Dr. M. A. Hasan (Saudi Arabia) whose encouragement was available all the time. Sri S.N. Chaitanya, and Sri V. K. Yadava of Structural Engg. Deptt. and Prof. Agarwal of Electrical Engg. Deptt. Jodhpur University also deserve my thanks for their help and encouragement.

The author would also like to express his deep affectionate appreciation to his wife, Prof. Razia Hasan of the Deptt. of Zoology, Mahila college, Bhagalpur, for her many valuable suggestions during the preparation of the book. Sri O. P. Kapur from M/s Dhanpat Rai & Sons (Publishers) deserves special mention for his valuable suggestions from time to time which went in long way in improving the manuscript to the present level.

Finally, I express my respectful thanks to Prof. S. C. Goyal, Vice-chancellor, University of Jodhpur, for his kind encouragement.

A large number of errors might have crept in the book due to various reasons. I would be very much thankful if they are pointed out to me. Suggestions for improvement will also be very thankfully received.

Monghyr
26th Jan., 1978

M. M. HASAN

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1

Advent of Computer Era

1·1. Introduction. The introduction of computer as human aid has created much controversy. The usefulness or otherwise and its effect have been bitterly debated. More realistically, many people think that computers are going to take away their jobs. However, most of the adverse comments against computers and their use are fundamentally due to lack of proper understanding about the part computer can and do play in their everyday life. In short period, after their advent, computers have proved immensely useful a tool for the well-being of human society and it can now be said with certainty that use of computer is a must for modernising our scientific study programme. It is in no way preventing importance of individuals over the machine. It is still true that machines are not important but the man behind the machine is the sole master.

1·2. Modern Use of Computers : Data Processing or Information Machines. The list of various fields where computers are used nowadays is so vast that it is rather impossible to mention all of them. To cite an example, let us take the case of preparation of pay bill for the employees of a big firm by a computer. It involves so many jobs to be performed. The pay admissible to different persons may be different. Also, rate of income tax admissible and so their actual deductions like provident fund, recovery of advances, fines and similar numerous operations may be different for different persons.

Apart from working out of the net payable all those entries have to be made in general and personal ledger of the employee. The time required for performing all those tedious tasks must be enormous and chances of errors are also large. All that work can be done much more faster and with better accuracy by the use of a computer.

In scientific and engineering field, many designs which required guessed solution till now due to very time-consuming repetitive complex computations are now being solved through computer without any delay and with better accuracy. Take the example of computer being used for keeping track of numerous aeroplanes flying in a vast area. In case of any trouble while flying, the computers on the ground are able to work out the very time-consuming computations regarding speed, the trajectory of movement and other details for any correction required.

Hence computer is in use in almost every field of modern society. But still it is basically used in the field of 'Engineering'. Some of the uses in this field are :

Analysis, design and estimation of building projects, air tram analysis, design of bridges, dams, weirs, barrages, backwater profile, reinforced and pre-stressed designs, motor generator and transformer designs, design of ships, aeroplanes, traffic control engineering design, circuit analysis, missile design, rocket trajectories, etc., etc.

Besides engineering use, it is used in numerous other fields such as :

(*i*) *Biology.* Livestock breeding control, optimisation of livestock feed mixes, analysis of characteristics of different species, clinical research, etc , etc.

(*ii*) *Statistics.* Mean, median, mode, correlation, regression analysis, frequency, probability determination, etc.

(*iii*) *Business.* Pay roll, billing, mailing, management strategy analysis, stock, inventory, etc.

(*iv*) *Mathematics.* Almost all conceivable calculations are performed by computers.

(*v*) *Industry.* Pay roll, design of component management, analysis of test results, keeping records, data processing, etc.

From all those descriptions one may be able to approach some general principles that exist common to all those listed. Each application can, naturally, be divided into three parts or phases :

(*i*) The gathering of information or data.

(*ii*) The combining, comparing and calculating with these data, in various ways.

(*iii*) The presentation of result along with other data, if required.

Hence, we can locate the common base, *i.e.*, the general function of computers is to transform certain information, or data, into other information derived from it. That is why the computers are more commonly called 'DATA-PROCESSING' or 'INFORMATION' machines.

1·3. Evolution of Computers. Human mind is inquisitive from the very beginning. Necessity for computing must have been felt by the oldest human being also. In the beginning, man's first computing machine may have been his fingers.

Having found that fingers are not able to cope with increased requirements of computation with evolution of civilization, other means like scratches on stones, trees, knots or ropes may have been tried. The process required further perfection and a sort of adding machine called 'ABACUS' was invented even before birth of Christ.

In 1642, the famous French scientist Pascal developed the first type of adding machine or desk calculator. It performed two functions namely addition and subtraction only. In the latter half of 17th century, Baron von Leibnitz constructed a machine called 'Stepped Reckoner' improving Pascal's machine.

In 1822, an English mathematician, Charles Babage invented 'Difference Engine' which was capable of performing simple mathematical calculations at a comparatively very fast speed.

First practical key driven adding machine was patented by Dorn E. Felt in 1887. Its patented name was 'CROMPTOMETER'. In 1889, he added a printing device and called it 'CROMPTOGRAPH'. This was the first to simultaneously compute and print. By 1920, many versions of such calculators were fitted with electrical motors.

In 1937, Howard H. Aishea (America) patented 'Automatic Sequence Controlled Calculator' which was a mechanical device utilizing moving parts. It was capable of multiplying 23 digits in 6 seconds.

The first automatic computer (mark I) was made in 1943 by International Business Machine Corporation (IBM) to the specification of H. H. Aiken.

The first electronic computer (without use of any moving part) was patented by IBM with the help of two engineers. Its name was ENIAC (Electronic Numerical Integrator and Calculator).

Since then sustained researches were made for increasing speed of computation and providing more memory locations. These efforts have resulted in varieties of modern computers capable of more advanced uses. In India, E.C.I.L. (Electronic Corporation of India Ltd.), Hyderabad, are manufacturing following varieties of computers.

TDC 12 TDC 312 TDC 316 TDC 3600 TDC 6000	T.D.C. stands for Trombay Digital Computer.

They are Digital computers.

Up to present age, the computers are primarily dependent upon human operator. The set of instructions which tell the machine to perform a given job is called the programme for that job. The task of preparing this set of instructions is therefore called 'programming'. Till now all programming is done through written language. The researchers are trying to manufacture a computer which can understand instructions in spoken language.

1·4. Types of Computers. Computers evolved so far are of the following three types :

(*i*) Analog computers
(*ii*) Digital computers
(*iii*) Hybrid computers

(*i*) *Analog Computers.* This word 'analog' derives its origin from Greek word 'analogy, which means similarity of two quantities.

The slide-rule invented by Gunter in 1720 on the concept of logarithm put forward by Napier in 1717 may be called the primitive type of 'Analog Computers'.

This type of computer functions by establishing similarity between an easily measurable phenomenon with another phenomenon not so measurable.

Many advanced versions have since been added to this type utilising the technique of converting variables in voltages and displaying the same on screen.

It is used for different purposes including computation of flood frequency, forecasting of discharge, etc.

(*ii*) *Digital Computers.* These deal with discreet characters like digits. Nowadays digital computers have an edge over analog type. Problems like preparation of bills, ledgers, solution of simultaneous equations, etc., are solved more easily by digital computers. It has got better speed, less error, more precision against analog computers. Most important point in its favour is that it does not require a physical conception of the problem.

(*iii*) *Hybrid Computers.* It is combination of both and hence can be used with more advantage.

2

Basic Computer Organisation

2·1. Introduction. In this chapter, we shall examine the overall organisation of a computer unit. Then only we shah be able to understand the methodology how one must proceed with the preparation of problem for its solution by the machine.

2·2. Required Functions for a Model Computer. Let us make out the list of required functions a computer should be able to perform for the benefit of an average user.

1. Since this is to be an information-processing machine, it should have ability to perform basic computations on that information. So it must include basic arithmetic operators which we are able to understand, *i.e.*, addition, subtraction, multiplication, division, rounding, taking square roots, etc.

Let this requirement be called 'Processing Ability'.

2. Out of the informations processed a computer should also be able to bring new information to the processing unit when needed. Let this ability be called 'Input Ability'.

3. It may further be required from a computer that it should be able to furnish results in the manner required by the user.

4. Let this requirement be called 'Output Ability'. There must be ability available to a computer to coordinate between the three functions specified above so that the programme is executed in an orderly manner, *i.e.*, in the proper sequence.

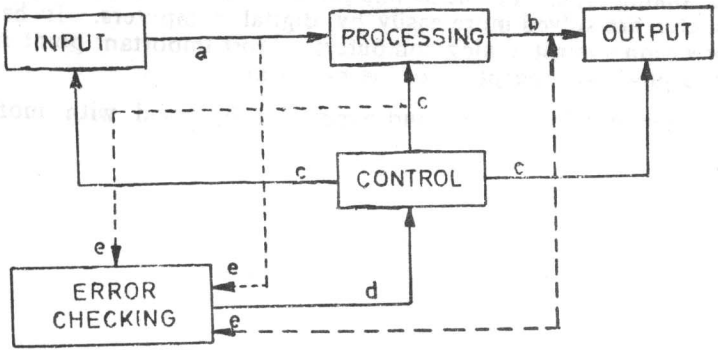


Fig. 1. Initial arrangement of a computer organisation.

Let this ability be denoted as 'Control Ability'

5. There should be another required function to point out the errors in the programme whenever it occurs. Since, there cannot be complete elimination of errors in a programme, this facility would be of great advantage to a programmer.

Let us call this desirable function as 'Error Checking' ability of the computer. For each required ability of function, a suitable device has to be provided.

Schematically, all the five desirable arrangements and their interrelations can be shown as above in Fig. 1.

The lines represent the following :

a—Flow of information in the processing unit.

b—Flow of information out of the processing unit.

c—Flow of information to the various units controlling the operation.

d—Influence of the error detection on the control. (For example, this feature could cause the machine to stop, signal the operator or carry out some special function whenever error was detected.)

e—Communication of checking information to the error detection mechanism.

2·3. The Arrangement of the Different Components of a Computer. Needless to say that this type of arrangement is quite limited in its scope for processing informations. It will be capable of reading single piece of information from the input, will process it and write it on the output before the processing unit is available for more work. Up to the previous arrangement, it had no unit to compare one item with another or to use data in any different order than that in which it was introduced. It cannot store or temporarily keep data with it until the data is no longer required. So one extra device has to be provided for this. Let it be called as 'Memory Unit'.

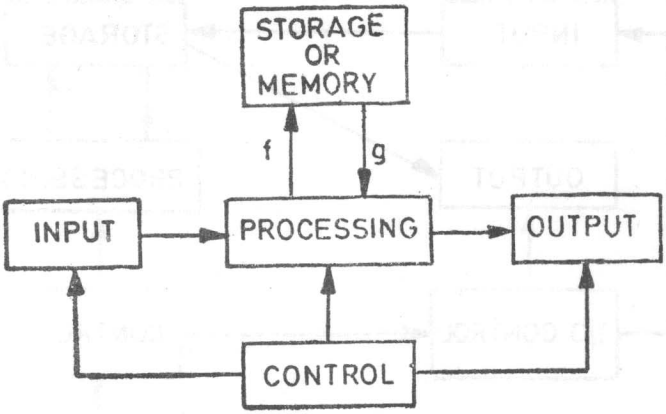


Fig. 2. Improved computer organisation (addition of memory).

Since error checking is required for all different units of a computer, it may not now be represented in further schematic diagram, but shall be assumed to be present for any function. So the improved schematic diagram of computer arrangement is shown in Fig. 2.

In the improved arrangement, storage or memory unit has been added along with two lines of communication. It shows that the processing unit can store information in the memory (f) and take back information from the memory (g). In the arrangement control has not been shown to communicate directly with storage, but causes the processing unit to make such communication. Also it is to be noted that data enter storage from the input through the processing unit and become output data by passing through the same unit.

This arrangement now provides the facility of keeping the data temporarily in memory location for any subsequent rearrangement or comparison with other data.

2·4. Improvement on the Basic Organisation. To obtain a more balanced computer organisation it is desirable to connect input and output units directly to memory location. This will free the processing unit from the necessity of waiting while input or output data move through them. However control is not free as yet as it will control the flow of data from input or output units. At the time, when control is busy with data flow supervision the processing unit will sit idle as it requires direction of control at every step. So the above suggested arrangement requires further modification as the processing unit is also not free to process further programme due to engagement of control in previous programme. So, the situation is improved by providing more control units working under the direction of main control. The arrangement is shown in Fig. 3.

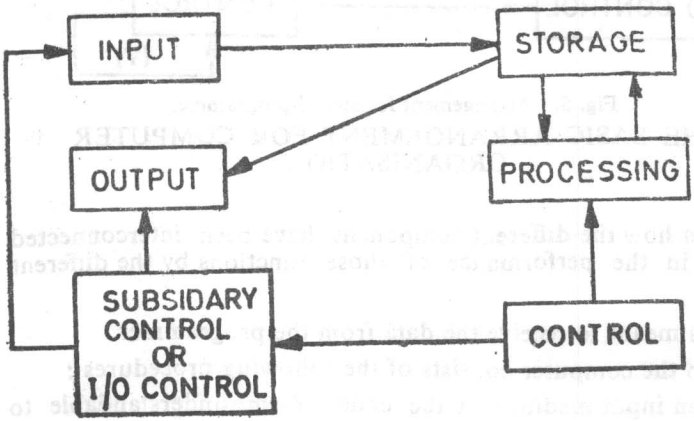
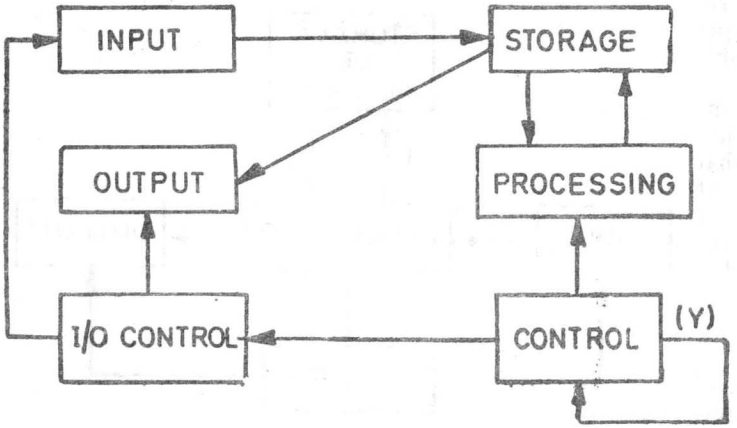


Fig. 3. Separate input-output control.

In an arrangement as above, all the units would be able to operate simultaneously except when they need simultaneous access to memory unit.



Now, to achieve further improvement, there should be further ability within the computer, such that control unit should have power to change the sequence of instruction it gives to different units of the computer organisation. We can illustrate this feature by line diagram shown in Fig. 4.

This facility has been shown by adding a further line of communication (Y) in the diagram in Fig. 4.

Fig. 4. Computer organisation with self-control arrangement.

A more desirable computer-organisation would be if control is also provided direct access with storage. The control will have added ability for 'READ' and 'REMEMBER' information it is processing. When there is facility of read and remember that information which ist i going to programme, such arrangement may be called 'stored-programme arrangement'. This facility can be provided by connecting storage with control by another line of communication (Z) shown in the schematic diagram in Fig. 5.

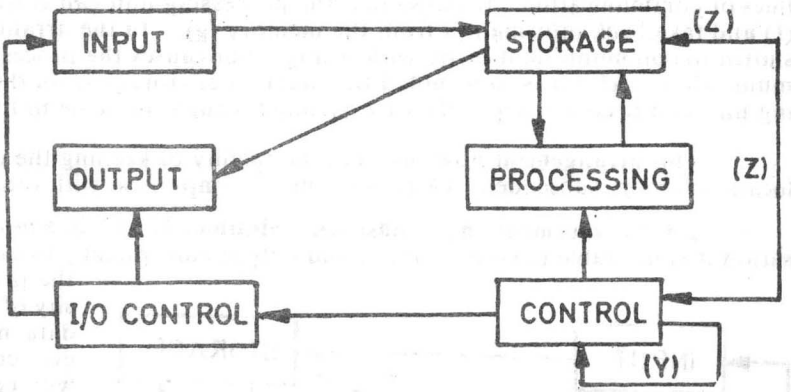


Fig. 5. Arrangement for stored-programme.

The basic organisation of computer-components has been explained above However, all computers may not have been organised as such. However, present-day computers are mostly arranged in the fashion as explained above differing only in details.

THE BASIC ARRANGEMENT FOR COMPUTER ORGANISATION

Much difference does not lie in how the different components have been interconnected together, but actual difference lies in the performance of those functions by the different devices.

2·5. Input Unit. This unit is meant to receive the data from the programmer.

The communication of data to the computer consists of the following procedures :

(1) The data is prepared, on an input medium. in the coded form understandable to the computer.

(2) The coded data is fed to an input device and is translated by it automatically into a form which is recognised by the machine.

The input unit may consist of one or several such input devices. Some of many different kinds of input media and devices generally employed in nowadays digital computers are :

(1) Punch card,
(2) Punch paper tape,
(3) Magnetic tape,
(4) Magnetic ink character reader,
(5) Optical character reader,
(6) Console typewriter, and
(7) Cathode ray tube.

2·5·1. Punch Card. The punch card is the most useful and commonly employed media for communicating with the computer. The standard punch card has 80 columns, each consisting of 12 punching positions. Data is recorded on it by punching rectangular holes in the columns usually done by using a keypunch which is exactly similar to a typewriter This is done by pressing of the suitable key of the typewriter which punches the corresponding holes into the similar column of the card. Some are represented by a single punch, and some by two or more punches in a given column. The characters so represented are usually printed at the top of the card in their respective columns.

Punch cards are read with the help of a card reader, an input device, which has a reading speed of 300–1600 cards per minute.

2·5·2. Punch Paper Tape. This is similar to Punch Cards except that it is a continuous strip of paper whereby a character is represented by a combination of circular holes punched across the width of the tape. Its chief advantages is that it provides a compact storage medium and is also priced low. The combination of holes provide the code. The punching is done by teleprinters, laboratory data recorders and business machines.

The input device for reading the punch paper tapes is called Paper Tape Reader, and has a reading speed of 100–1000 characters per second.

2·5·3. Magnetic Tape. The magnetic tapes used in computer are similar to tapes used in audio tape recorders. One polarity is used to represent binary bit '1' and the other binary bit '0'. Each character on it is represented as a column of binary bits, in a code similar to that of paper tape. Each channel can record 800–1600 or more binary bits an inch.

Reels of magnetic tapes are mounted on a device known as magnetic tape drive for reading or writing of the data.

Its chief advantage is that it is erasable and reusable.

2·5·4. Other Devices. Other devices in this category include Magnetic Ink Character Reader, Optical Character Reader, Console Typewriter, Cathode Ray Tube, etc. Magnetic Ink Character Reader is a high-speed input device which can take the data directly from the source document. Optical Character Reader is designed to read numeric and alphanumeric characters from printed documents produced by typewriters, cash registers, line printers, and imprinting machines of various types. Console typewriter is a device mainly used for communication between the computer Operator and the computer. It can be used to enter any instructions into the control unit of the computer. It also provides to print and communicate any information about a programme inside the computer – as for example, error-message.

Cathode ray tube is both an output and input device. Its operation is similar to a television picture tube.

Besides these devices, special purpose data transmission units are also employed in nowadays organisations.

2·6. Memory Unit. It stores, instructions, datas, and intermediate results. When

required, it supplies the stored informations to other units of the computer. The memory unit may have one or more devices of the following two categories.

(1) Internal storage unit, and

(2) Auxiliary storage unit.

(1) **Internal Storage.** It is an essential part of the memory unit. The devices usually employed are : (1) Magnetic core memory ; (2) Thin-film memory ; (3) Plated-wire memory ; and (4) Thin-rod memory.

(2) **Auxiliary Storage.** This arrangement supplements the main storage and can store the millions of characters either sequentially or at random. Data in Auxiliary Storage is not directly processable except when routed through the main storage (or Internal storage) for processing. Commonly employed devices in this category are : (1) Magnetic tape drive ; (2) Magnetic disk drive ; and (3) Magnetic drums. Its main advantage is that millions of datas can be held in comparatively very inexpensive form of storage and hence is almost a must in commercial data-processing programmes.

2·7. Control Unit. This unit is the most essential unit of a computer organisation as it controls all the activities in the computer and directs its step by-step operations. It interprets the instructions of a programme sequentially and directs the appropriate units for their executions and supervises its orderly execution.

2·8. Processing Unit (or Arithmetic Unit). This unit which receives command from the control unit, and datas (informations) from the memory unit, first analyses and rearranges the datas and then carries out the designed arithmetic and logical operations in accordance with the dictates of the instructions.

2·9. Output Unit. This unit which has access from all other units of the computer organisation accomplishes the output of the stored results (from the memory unit) into a form the user instructs which is understandable to him. In essence, it prints or produces the results in the desired format.

The output devices generally employed are :

(1) Line Printer,

(2) Graph Plotter,

(3) Visual Display Unit,

(4) Card Punch or Paper Tape Punch,

(5) Console Typewriter and Teletypewriter,

(6) Magnetic Tape Drive, Magnetic Disc Drive, and Magnetic Drum.

Out of these, a line printer is most widely used output device as it provides a printed copy of the result along with the programme-listing which can be easily used for subsequent references and is also convenient to read and understand. It is as fast as 6000 or more lines per minute wherein each line consists of 96, 120, 132, 144 or 160 character positions. In spite of such high speed, usually off-line printing is done as the speed of printing is not as high as the sp ed of the processing of informations by the computer. For that reason obviously, the one-line printing is costlier as it wastes valuable computer time Therefore output information is often recorded first in auxiliary storage unit by devices like magnetic tape, magnetic disc, or magnetic drum, etc., and is then printed off-line through the printer.

Other devices are also used in special circumstances which depend primarily upon the purpose and the facilities available.