COMPUTERS

By C. G. NEWSON

INTRODUCTION AND SHORT HISTORY OF COMPUTERS

The development during the 1939-1945 war of basic assemblies of electrical and radio devices to provide circuits for simulating elementary logical operations of the types " and " or " not," and the subsequent organisation of large groups of such basic elements to provide the means of controlled pulse manipulation, mads possible machines such as ENIAC. These machines were capable of performing complex tasks of logical and mathematical analysis and synthesis accurately at very high speeds, being originally designed for scientific computations.

Much of the work of developing these computers was originally carried out at Universities and similar institutions of learning over a period of five years following declassification of information on ENIAC in 1946. In the opening years of the present decade many prototypes were developed chiefly in this country and the United States. It was quickly realised that here were the beginnings of something of major importance not only to scientific compution, but also to commercial and industrial data processing.

It may be asked why did this brain child of scientists find acceptance as an instrument for processing of commercial and industrial data ? It is suggested that one reason was the ever-increasing volume and complexity of such data was tending to become, too much for most conventional means of data processing, therefore, the times and circumstances were ripe for something new.

What is a Computer ?

A computer is a machine which may be actuated by instructions presented to it in the form of numbers to carry out upon information presented to it in numerical form, a sequence, not necessarily predetermined, of operations of a specific limited number of kinds with extreme rapidity and accuracy. This definition reduces the computer from a creature of science fiction to a practical working tool of great potentiality. Each different computer performs various operations with different speed factors.

Numbers—always numbers. What the significance of these numbers may be to the user is quite immaterial to the computer. They may represent items of a pay-roll, of a programme breakdown, of a load schedule or a stock record.

If the fact that a computer works by numbers and only by numbers, and makes use of two kinds of numbers representing respectively what to do and information upon which to do it, can be appreciated, then much of the aura of mystery with which the computer tends to be surrounded will be dissipated-

Furthermore, the reason for the mass preparatory work attendant upon the majority of computer applications will become clear. This initial work is directed towards translating the original data into a language which the computer can understand, that of numbers. The various procedures for getting information into a language which the computer understands are somewhat long and laborious, since these stages may on the average take several months to work out. They may, however, be likened to the setting up of a complex machine tool, a task which can also involve lengthy periods. Once the final programme is finished the computer operates far more speedily and accurately upon information fed to it than any other system, manual or machine.

Finally, a computer is a machine competent to perform certain specific functional operations —to read, to store, to calculate, to choose and to write. Whatever be the subject matter of the material numerically expressed, upon which it is asked to exercise its functions, it does exactly what it is told to do in the order in which it is told to do it.

What meaning those who use the machine choose to place upon the numerical data they feed into the machine, or upon the numerical data they derive from it in printed or punch card form, is their business and not that of the automatom they employ.

Computers in Practice.

Take one specific use of a computer with the Western Region of British Railways, where the pay slips of 11,000 weekly paid staff are all computed in less than two days, and following just one pay slip from the very beginning when the employee clocks "On" and "Off," right up to the point where all calculations have been made and the pay bills despatched to the various pay points where the employee is paid.

The hours of the driver are recorded every day with the extras noted for night duty, expenses and Sunday work. Now that the basic entries have been made, manual data processing can begin. This has to be done first by the time-keeper and usually only includes totalling, checking and adjusting the hours worked. This is soon finished and the pay slip is on its way to the District Pay Bill Office of the Regional Accountant's Department at Paddington Station. Every Monday morning the pay slips arrive—less than two days later everything is computed and information of the amount of pay to be given to the employee is passed back in the form of pay bills. In that short time every pay slip for 11,000 people has been transmuted into hours worked for net wages.

As described earlier, transmutation and the preparation for transmutation is in most cases a lengthy business as compared with ti e computer's speed and accuracy. The preparatory work for the computer's first step is to select from a file a card with details of last week's pay. This card is then punched with all relevant details of this week's pay, no calculating is done, only the punching of information for the computer. This information 's now checked, as it must be very accurate, as the computer cannot judge right from wrong. From another file is taken a card with deductions punched upon it; as they usually stay constant, the same card can be used week after week. The final stage of preparatory work is to arrange all the cards, deduction card and pay card (in that order), each pair being arranged in sequence with others depending on how the computer has been set to accept it.

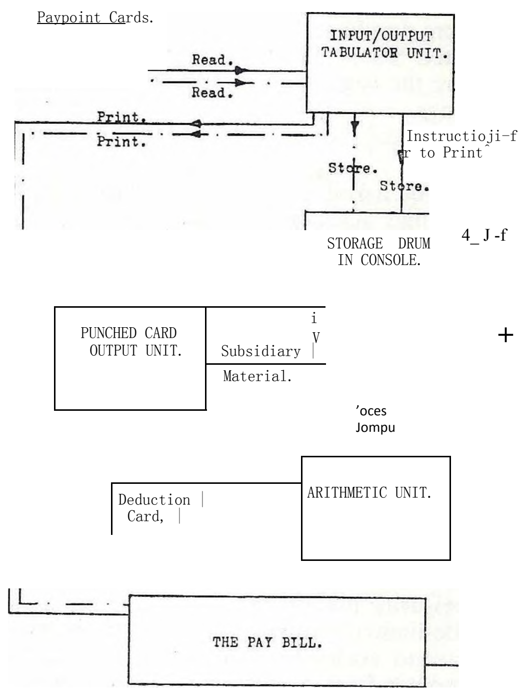
The 11,000 pay bills have now all been prepared for the computer, but it must be realised that in this case no two may be alike, especially in any concern where there are a profusion of different grades with different deductions and bonuses inside each grade. Here is where the computer takes over, in this case the British Tabulating Machine Company's Hollerith Electronic Computer; the processing of the pay slip to follow.

We know that a computer can carry out five simple operations—it can read, store, calculate, choose and write. Here is where the Paddington Office takes the advantages offered. The computer can transmute time into money, and determine on the basis of hours worked how much money should go into each pay packet.

Looking at the five simple processes we might assume that there is really nothing of note, but there must be some advantages of this computer work—and there is. The answer being simply put in three words is "speed and accuracy." The accuracy of a computer cannot really be questioned, but speed of calculation varies with milli-seconds, the usual time factor, five hundred times faster than any conventional calculating machine.

The information fed into the feed mechanism storage device housed in the console unit, it being drawn from the store by registers housed in the electronic unit. Here is where the addition, subtraction, multiplication and division is completed.

A Block Diagram of the Computer used by the "Western Region".



Information from Deduction Card.
Information from Pay Card.
Printing computed information.
Computing information stored from both cards.

The electronic unit can also select one or two courses open to it according to predetermined or arising conditions. Finally, the information is delivered in two forms, one as a printed record with carbon copy from the tabulator unit, and the other in punch card form, part of which, as explained earlier, is kept for next week's input into the computer with a new pay card.

We have explained earlier that manual data processing was necessary, well, manual data processing crops up again in the form of a

programme sheet." In this case, for the 11,000 employees there are 14 programme sheets; for every man there are 502 machine programme steps to cope with all conditions, a further 74 steps when changing grade of pay, and yet another 33 at the end of each pay bill section—609 programme steps in all.

609 programme steps - remember each one takes so short a time that each individual's calculation takes approximately five seconds. Something like 750 pay slips per hour. Something less than 15 hours machine time to prepare pay bills for 11,000 people.

Finishing on a thoughtful note, the deduction card must preceed the pay card as stated earlier. With the very first pair entering the computer checks to see that they are in order, if not it sounds an alarm and refuses to proceed. All during the computing various calculations are checked by the computer time and time again, and if there is any discrepancy the machine sounds the alarm and stops. It makes you think, doesn't it ?

Computers Technically.

On the technical side of computing the fundamental operations performed by digital computers are the arithmetical ones of addition, subtraction, multiplication and division, multiplication and division being carried out in various ways on different machines. Some computers use addition and subtraction with right and left shifting, to give multiples and divisions, this being explained later.

Most digital computors use numbers in the binary notation form, and in order to understand the operations that take place in the machine it is necessary to know something about Binary arithmetic. In binary notation any number is represented by using only the numbers 1 and 0. Zero is represented by 0, one by 1, two by 10 three by 11 and so on.

Binary notation is very useful for computers because it is often more convenient to use computer devices in such a way that they only have to adopt one of two stables states, rather than one of many stable states. One example of this is the thermonic valve, here it is either conducting or not conducting, to take values in between would involve cost and waste. Of course, the most common input or output system is the punched card or punched paper tape, both of which are inherently two state devices where their information is carried by the absence or presence of a hope. Such two state devices can be made to present either a 1 or a 0. We will quickly finalise binary notation in respect of addition, subtraction, multiplication and division.

In decimal numbers the value of the digit depends on the position of the decimal point. If the number is moved one place to the right, is is then divided by ten, and if moved one place to the left, it is multiplied by ten. In binary numbers the value of a digit also depends on its position in the number, and a binary point is used to separate whole numbers from fractions.

But here each digit position represents a power of two instead of a power of ten. If a binary number is moved one place to the right it is divided by two, and if it moved one place to the left it is multiplied by two.

Now that the binary notation has been discussed, a careful look at medium sized digital computers as a whole from input to output will follow.

Input data, in punch card form, moves past two reading stations. Each station has individual brushes, either 64 or 80, depending on the type of card being read. As each card passes the brushes they sense the presence of, and assign values to, any holes punched in the 64 or 80 column cards. Either station can read the data to be processed. Two stations are useful as they can compare a card with the one following and operate from there. But in the usual case the first station tells the second ahead of time what to read and where to read it. The sensing stations are not limited in number, Powers-Samus computers using three, and with some firms using the photo electric action.

The sensing is now converted into electrical pulses which are sent away to be stored, details will follow later. But just a few words on one of the most important actions which takes place in an electronic digital computer—that of switching. This being done by gate, bi-stable, and buffer inverter units.

In most computers at least two types of gates are used, they are called "and" and "or." These names coming from the similarity between the operations performed by these "gates." The electrical pulses travelling from one part of the computer to another will meet several gates, some will be closed, others open, depending upon certain conditions of operation.

An " and" gate will be open and produce a pulse on its output terminal only when pulses occur on all of its input terminals. An "or" gate will open and produce a pulse on its output terminal when a pulse occurs on any of its input terminals.

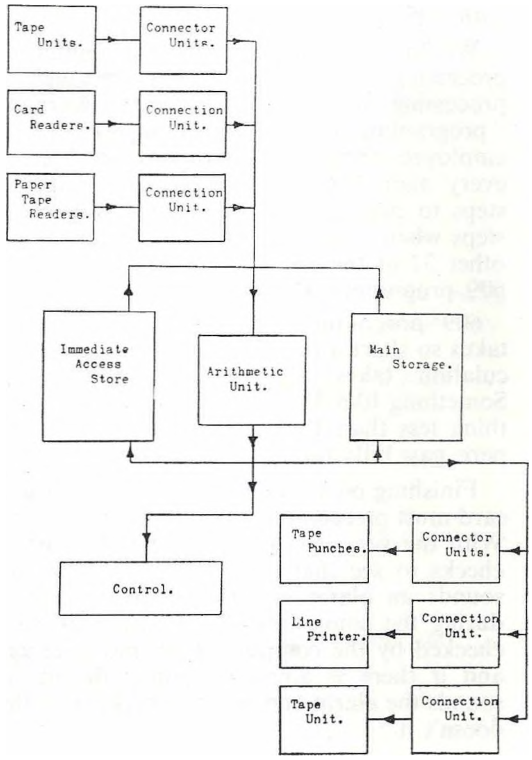
The bi-stable unit is a flip-flop and is always in one of two stable conditions, these conditions are referred to as "set" or "unset"; or, by convention 1 or 0. When either side of a bi-stable unit is set it stays set until the other side is triggered by a pulse, whereupon it changes to the unset state- As well as the ability to represent 1 and 0, it is useful for its characteristics of causing a one digit period delay between pulses on the input and output terminals.

The buffer-inverter has one input and two output terminals. The two outputs may be called normal and inverted. Given a pulse representing a 1 on the input terminal produces a 1 on the normal output terminal, and a 0 on th inverted output terminal, if the pulse on the input terminal represents a 0 then the opposite applies.

Having just covered most inter-connection units, we will catch up where we left off with the electric pulses, which are a direct equivalent to the binary code, being fed away to the computer itself, the real heart of the whole system.

As a heart has three valves which it can draw upon, so the computer has three stores for information, whether it be relevant to the immediate problem or one to come. The user of a computer wishes to have speed of operation and large storage capacity at the lowest cost. Fast stores are costly (in relation to their storage capacity) and consequently the large capacity can only remain available economically by using a second, slower store and sometimes even three. As the actual arithmetic unit and store capacities are so important, different equipments will be compared-

A Block Diavrin of a Typical Computer.



The Ferranti Pegasus has a high speed computing store, where all arithmetical operations are carried out combined with a lower larger main store, a magnetic drum. The computing store is made up of single word registers made of nickel delay lines to any of which there is immediate access.

The E.M.I's Emidec has three stores comprising a magnetic core matrix for immediate access, four or more magnetic drums, for information of a very much wider type, and magnetic tape for main backing-up storage. Magnetic tape is sometimes referred to as input/output equipment. Emidec can use up to 16 magnetic tape units, each lending themselves to the category of a storage device. Emidec's arithmetic unit also has a store referred to as an accumulator, but this unit in Emidec is not a genuine store.

English Electric's Deuce, on the other hand, uses an acoustic mercury delay line for quick access storage. The backing store is again a magnetic recording on a drum. Magnetic tape or storage is again handy as a final and complete backing store up to four units may be used.

Standard Telephones and Cables, Ltd., Stantic Zebra differs from the other three in having only one large store, a magnetic drum. Having mentioned the drum many times, I think a little information concerning one specific type would be appropriate. The Stantic Zebra drum is of a conventional type, although more detailed in its function than most. The drum is 6" in diameter, it is hollow aluminium coated with a thin layer of nickel, revolving at 6,000 r.p.m., information being recorded on the surface of the drum by means of read/write heads. In writing an A/C is passed through the head, and this causes a pattern of magnetisation to be formed on the drum surface as it passes beneath the head. The phase of the writing current wave form is made to represent binary digits, which are reproduced by the magnetic pattern. In reading, the pattern of magnetisation is converted into a voltage wave form which is then amplified and decoded to produce the binary digits it represents. The surface round the circumference of the drum which passes beneath a head is called a track. By spacing heads along the length of the dram a large number of tracks are formed. The number of tracks on machines differ, but a usual number is around 270, of these tracks 95 per cent will form the main store.

In the example above, 256 out of 273 tracks are for main storage. 12 are used as special purpose, one word capacity, stores. Two more are used by the arithmetic unit for holding partial results of calculations, of the remaining three tracks, one controls the timing wave frequency which is 128 Kc/s, with the other two controlling everything in the computer, these being the control registers.

The main store offers facilities for storage of 8,192 words each of 33 binary digits. Each different machine, of course, as its own word length, in the case of our example, it is 33 numbers.

The figures above differ from machine to machine as can be appreciated, but at the end of the text follows a very comprehensive table of values for different computers.

Having covered the magnetic drum in respect of one machine, it is time now to generalise again on digital computers as a whole.

The read/write heads are clustered in groups usually each covering a set of tracks. Each position on the dram is given a code and depending where the information required is on the drum, then any one of the groups is activated, selecting in turn the track, then at the precise instant the head passes over a point on the drum the information required is selected.

To perform the necessary arithmetic, the "read/write" heads withdraw the respective digits from the fast stores passing them through the computer proper, the arithmetic unit, and again being put back into the appropriate fast store and, if desired, back to the slower permanent store of the magnetic drum. This happens many thousand of times before the completion of one calculation.

Whenever a transfer between the computing and main stores takes place, the new word is written where the old one was, thereby obliterating the old one, this permits great economy of storage space. The same storage locations being used over and over again, especially when the process is repetitive. But, the transfer does not spoil the word in the storage location from which the reading has taken place. The same applies for the transfers within the main computer and store.

The arithmetic unit being the real heart of the equipment needs some mention here. Some machines use the decimal system, others use a modified decimal and binary system, but the usual system is the one already fully covered, that of binary notation.

The unit usually has two accumulators, each with a circulation path with adder and subtractor enabling it to perform all the required operations. The accumulators are used for the formation of sum and differences, or partial results, the results being fed to any store that requires it, or may just be circulated in order to be right or left shifted, for multiplication or division, or to have another number added to or subtracted from it. The accumulators are on the surface of the magnetic drum and are fed by three input paths which are an undelayed path, a one digit delayed path, and a two digit delayed path. If when the information was first obtained from the drum, before circulating, it was read just one digit too soon, it can be seen that in the undelayed path the word will be right shifted by one digit, in the second case the word will become normal and in the third case, when the two digit delayed path is employed, the word will be left shifted by one digit.

As has already been stated when a digit is left shifted it is effectively doubled, and if shifted to the right, halved. Thus, this is used in most computers for multiplication and division, the information being circulated many times until the required operation has been completed.

After every calculation has been completed the results are transferred from the drum to the output unit. Most output units will have two sensing stations with the last checking the output of the first.

The type of output differs from machine to machine, the main one being punched cards, but paper tape and teleprinters are also used extensively, with magnetic tape being used for lengthy storage.

Some Facts, Tables and Principal Characteristics

The first table shows Production and Exports Digital Computers and Electronic Calculators in the U.K.

	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
Total	1	0	3	3	8	1	11	17	45	130
Export	0	0	1	0	0	0	5	0	3	30

Above is the proof that the Computer Industry is as yet very young - but it grows rapidly with every year

Manufacturer & Model	**Channels**	**Word storage capacity**		**Operation**	**Speeds (mS).**
	1/P. O/P.	Immediate	access/Main	Sub'Add.	Mult./Div.
British Tabulating Machine Co. Ltd. Hec 1201.	1. 2.	4.	1024.	2.5	5/40
EMI. Electronics Ltd. Emidec 1100.	Up to 16	1024	16384	.125	1.12
English Electric Co. Ltd. Deuce.	2 2	402	8192	.064	2
Ferranti Ltd. Pegasus. 2.	Up to 26	56	7168	.3	2/5.5
I.B.M. United Kingdom Ltd. I.B.M. 650.	Up to :— 6 2	60	2000	0.77	12/16.
Leo Computors Ltd. Leo II.	Up to 4.	2048	65536	.34	.99/3.96
National Cash Begister Co. Ltd. Elliot 405.	2 2	512	16384	0.1	3.3
Power-Samas Accounting Machines Ltd. Pluto.	Up to 26.	56	8192	0.3	2/5.5
Standard Telephones and Cables Ltd. Stantic-Zebra.	2 2	12	8192	0.312	11/35
I.B.M. U.K. Ltd. 805 Ramac.	] 2	–	5000000	–	—

Model	**Prices (£)**	**Machines delivered (correct to Dec. 58.**	
		Business	**Scientific**
Hec 1201.	40,000	31.	—
Emidec 1100.	165,000	–	—
Deuce.	121,500	2.	19.
Pegasus.	150,000	5.	17.
I.B.M. 650.	220,000	6.	1.
Leo II.	170,000	4.	—
National-Elliot 405.	120,000	6.	1.
Pluto.	180,000	—	—
Stantic-Zebra.	34,000	1.	12.
Rainac 305.	70,000	—	—

FINAL CONCLUSIONS

It can be said that this young industry grew from a very small beginning and has adapted itself with extraordinary speed and thoroughness to new skills and new opportunities. The customers too have been quick to grasp when and where they can save time, money and mental drudgery by befriending a robot. Britain has not been so lavish on computers as the United States, but it can safely be said that there are only a few cases when the Americans have left their counterparts in Britain -very far be hind. The British machines' true quality is now being recognised in overseas markets, mainly because of their great value for money.

What will come after the computer? Far sighted men in Universities, Industry and in Government posts have been pooling their ideas and it seems certain that thinking machines are possible and their entrance into the modem scene is chiefly governed by matters of engineering, money and time. Combining the features of both anologue and digital computers then they can unite "intuition" and "experience" to solve problems which logic alone cannot solve.

With every development of automatic machines someone will try to involve Frankenstein legends, but whatever form thinking machines take they will remain locked in their metal cabinets. Like the computer they will come to be regarded as slaves rather than monsters, and if they release human minds for higher purposes we shall be grateful for them-