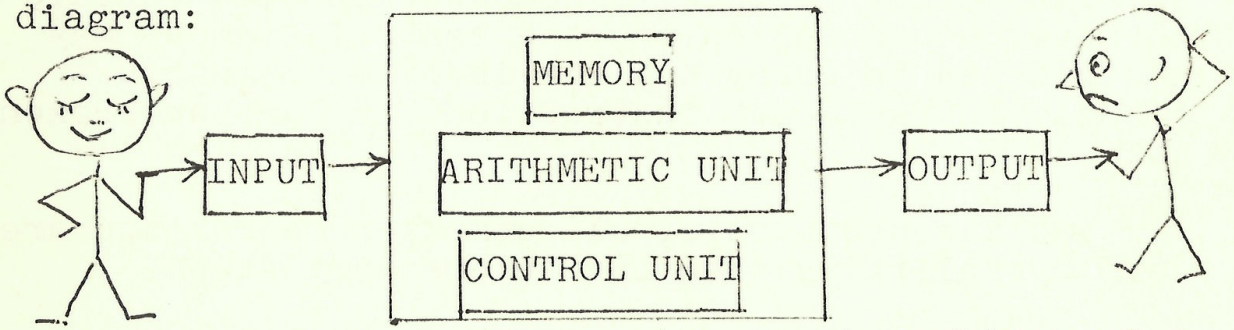
THE SECRET LIFE OF A DIGITAL COMPUTER

It has been said that "behind every great computer there is a great memory". As with most sayings of course, this is not the whole story. The other essential features of a simple digital computer are the so-called

i) "arithmetic element", which does a multitude of operations, some of these quite complicated and not all of them "arithmetic" operations

ii) "the control element" which keeps an eye on the proceedings.

We present our problem to the computer through the INPUT and receive the, hopefully, correct solution through the OUTPUT. Illustratedwith a diagram:



Before looking at the innermost workings of a computer let us consider the most common INPUT devices. These are, in order of speed, punched cards, punched paper tape and magnetic tape, discs and drums. Data stored in these devices must be stored in some form of binary notation, i.e. where each alphabetic or numerical character is represented in code by a binary number. For example the number 8.75 would appear as 1000.11. This form of storage permits easy relocation in the main memory of the computer. However the choice of number system is merely a technical matter, the binary system has the greatest advantages for

simplifying the electronics and the internal logic of a machine.

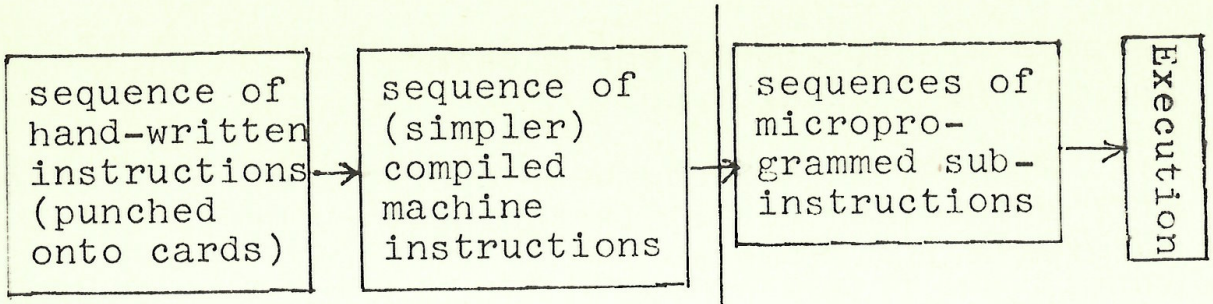
The simplest computer operations are extremely complex. As an example of number processing, suppose the computer is asked to evaluate the quantity z from the expression $z = x + y$, where x and y are stored in the memory. Before the control element makes any attempt to do this, the equation must be translated into four computer instructions as follows:-

i) fetch x from the memory and place it in the arithmetic element;
ii) do the same for y;
iii) perform the addition
iv) place the result in the memory at the location reserved for z.

When all equations have been broken up in a similar manner to this, a computer program is said to have been compiled and the control element may now proceed to carry out the individual instructions. In fact each instructions is further broken up.

As a general rule, all computer operations are done by splitting them into elementary steps.

A computer program, and its data, are stored in the memory, and in the previous example each of the four instructions will be fetched separately from memory. But these instructions will each give rise to from four to eight more elementary instructions and this translation is speeded up, in modern machines, by having it done while the program is running, by what is called the "micro-programming", which is done in high-speed registers. A computer program thus experiences the following metamorphoses:



No execution

During this time the machine reads our instructions, translates them into machine language and stores them in the memory

"Execution time"

During this time the machine interprets the instructions and carries them out

Finally, during execution, each micro-programmed sub-instruction is carried out by the control element which then coordinates the operations of the memory, the arithmetic element, and other related systems.

Broadly speaking the uses of the computer fall into two categories: commercial and scientific. Commercial applications, such as banking, accounting, inventory maintenance, and scheduling are generally typified by large volumes of data on which a small number of operations will be performed requiring great sophistication and efficiency. Scientific applications, such as weather prediction, engineering design, and general research require not so much data storage but rather a greater flexibility of operations usually oriented towards the processing of numbers (as opposed to commercial systems which process names and other messages). It may further be said that scientific calculations are not always numerical operations but sometimes involve so-called "logical operations". A logical operation is a comparison of quantities to see whether they are the same or different or what relations they bear to each other. This dichotomy of process however is only apparent to the pro-

grammer since, within the machine, all operations are of the logical type.

Finally in all computer operations, a knowledge of the internal detail is the best guide to the machine's limitations.

N.V. Williams

THE FOUR 4'S

Here is an old pastime that has fascinated people for nearly a hundred years. It was invented by Richard Proctor in 1881 (do you notice anything unusual about this number?) and since then has appeared in the Mathematical Gazette (1912) and Scientific American (1964).

All you have to do is to write as many whole numbers as you can using precisely four 4's and the standard mathematical symbols. See how far you can get using only brackets, +, −, × and ÷. When you get stuck, you may use the square root sign, the decimal point (including $.\dot{4} = .444\ldots = \frac{4}{9}$) and the factorial sign ($2! = 1\times2$, $3! = 1\times2\times3$ etc.). To get you started, $1 = \frac{44}{44}$, $2 = \frac{4}{4} + \frac{4}{4}$ (better than $4(4-4) + \sqrt{4}$), $3 = \frac{4+4+4}{4}$. The numbers from 4 to 8 are given on page 36.

Let us know how you get on and we will publish the names of those who get the furthest.