# DESIGNING A LOW COST GENERAL PURPOSE COMPUTER

By

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## I. Logical Design.

Since the late war a number of computer projects have been started. Most of them have stressed the construction of large computing centers, staffed by expert programmers and more or less available to the general public as a technical service. There is another approach to the computation problem. This one is to develop small, relatively low-cost computers which, we hope, can be widely used. The direct advantages to this approach are:

1. Low investment in computer and installation.

2. Low operating expense.

The indirect advantages are:

1. Less pressure to keep the machine running full time in order to amortize a large investment. This means a smaller programming staff, perhaps only one person.

2. A wider dissemination of computer know-how, resulting from more computers being in the field. More problems will be adapted for automatic processing if the computers are available.

The problem is, of course, to actually design and build a machine low in cost, and yet embodying enough elegant features to be useful. Computer Research Corporation believes it has been among the first to attempt this not-so-easy task.

The design of a computer seems to be a matter of constantly arriving at compromises. Three aspects, usually conflicting aspects, must be considered. They are the financial cost of a feature equipmentwise, the cost in engineering effort, and the desirability of a feature from the programmer's standpoint. As it works out, the first two usually throw cold water on the ideas of the third. In order to give instances of some of the problems involved, I shall now describe the CRC 102A, and how its features were determined.

The memory of a computer sets the character of the whole machine. The magnetic-drum type is reliable and is a type with which Computer Research Corporation has had considerable experience. Once the type was selected, the size of the 102A memory was left at 1024 words—the same as the CRC 102 memory. We felt that to enlarge the drum memory, after adding an auxiliary tape memory of 100,000 words, was unnecessary.

The magnetic-tape unit deserves some attention. Almost everyone recognizes the usefulness, perhaps the necessity, of a tape unit for storing tables, often-used programs, and masses of data too large to fit into the drum memory. For the utmost utility, the tape unit should be capable of being edited without going through the computer. In other words, it should be capable of being used as in-out equipment. This last feature does not affect the computer, but does involve a rather large piece of auxiliary equipment. The 102A does not include such a tape-editing unit, although with slight modification another unit being built by us could serve in the 102A system.

The tape unit is capable of independent block-search, when once instructed by the computer. Up to eight tape units can be simultaneously connected to the 102A, and all can block-search at once while the computer is working on something else. To us, this seemed about as flexible a tape system as economic considerations would permit.

The CRC 102A, like the 102, is a serial, fixed-point, binary machine, using a 3-address code. We never seriously considered making it decimal, even though many users are interested only in decimal operation. Other programmers have said that they prefer binary. The simplicity of binary circuits cannot be overlooked, so binary it remained. However, as a convenience to the decimal faction, the machine can receive or print both octal and decimal numbers on its in-out equipment.

The in-out equipment is one of the most costly and important parts of a computer system. There are two means of filling, or emptying, the 102A: from a Flexowriter, either directly or via the paper tape; or from an IBM card-reader and to an IBM card-punch. The first facility is a basic one. The second, because of the considerable amount of computer equipment involved, is optional. It was designed in because so many people want it.

There may be an optimum ratio between arithmetic and in-out circuits in a computer. I would estimate that if one includes the IBM card commands, the ratio is about 1 to 1 in the 102A.

Another very important characteristic in a computer is speed. By electronic standards, the 102A is not fast. It is difficult to get high speed in a drum computer without going to parallel recording of words and special coding. The former multiplies equipment many times, and is not in keeping with equipment economy. However, one cannot sacrifice speed indefinitely for the sake of simplicity. Time costs money in a computer. For example, time wasted in converting number systems in the 102A during in-out operations should not be excessive. A compromise solution to the speed problem was to make the 8-word buffer register, required for the in-out operations, also serve as a small, low access-time storage. Another trick, easily accomplished, is to change the order of word numbers around the drum so that two commands can be carried out per turn. This is possible for add, subtract, and the other simple commands. The maximum rate of which the 102A is capable is eighty 3-address operations per second. A fair average might be sixty. As an example of operating speed, the machine takes about 0.08 seconds per decimal digit to convert decimal numbers. When one considers the whole machine, the needs of computing and of the in-out operations seem to be in fair balance.

The last, but not the least, question to be answered is, What instructions can the computer understand? Aside from some basic ones, there is plenty of room for disagreement. Some people think that programming is simpler with few instructions. We are inclined to the opposite viewpoint. Another significant reason for including a rather comprehensive list of instructions is to save machine time and memory space. This is perhaps more important in a small, slow machine. In all, the 102A has 25 instructions. In the arithmetic group are Add, Subtract, Multiply (Rounded), Multiply (Double Precision), Divide (Rounded) and Divide (With Remainder). In the control group are Extract, Test for Overflow, Compare on Magnitude, Compare Algebraically, Shift Over Entire Word, Shift in Magnitude, Shift to Binary Point. The last was put in specifically for the convenience of those who work with floating-point numbers. The command shifts one number while subtracting from another. In the in-out group are ten instructions: three for the tape, three for IBM cards, two for the Flexowriter, and two for the buffer register. Finally there are Halt and a Special Test command for checking programs.

When a computer is to be sold to organizations without computer experts, it is especially important that it be a reliable machine. Naturally, we have been as conservative in our design as possible. But faults are certain to occur. Most of these should be anticipated by preventive-maintenance routines. The residue will require work by someone who knows the machine.

## II. Physical Design.

The computers built by Computer Research Corporation employ a few standard circuits which are used over and over. From the start, we have made up the logical circuits of flip-flops and diode nets, all d-c coupled. The diodes have been mounted individually in clips for easy removal. The reason for this is not lack of confidence in the diode itself, particularly, but the great advantage it offers in checking out and trouble-shooting the machine. By judiciously removing a few diodes, one can eliminate large sections of the machine as sources of error.

Recently we have started to make the standardized FF's, drivers, etc., as plug-in assemblies. This is advantageous, from the standpoint of both production and maintenance.

The computer proper will be housed in a cabinet 2-1/2 feet by 5 feet by 6-1/2 feet high. The tape unit or units are separate, of course. The third piece of equipment is the operating console, containing a few switches and the Flexowriter.

The memory drum is 12 inches in diameter. The 1024 words are arranged in 16 channels, 64 words per channel. The drum is totally enclosed. All of the arithmetic registers are recorded on the same drum.

The simplicity of this computer and the straight forwardness of its design method greatly facilitate the training of a maintenance engineer. A good electronic engineer without previous computer experience can learn to troubleshoot the 102A in four to six weeks. Because of this fact, and because of the above-mentioned simplicity, no checking circuits have been incorporated in the machine. A few circuits to aid in finding trouble are present. One advantage of a serial machine is that it is pretty obvious when something has gone wrong, although finding out what it is can be difficult.

Designing a computer is like building a chain. There is no use in having great strength in some sections if others are weak. We tried to design a machine with no particular outstanding feature, except its overall utility at a moderate cost.