A PROPOSAL FOR TRAINING YOUNGSTERS IN DIGITAL COMPUTING TECHNIQUES*

by Rollin P. Mayer**

The proposal outlined here is based on three premises: (1) That the digital computing field needs, and will continue to need, not only more people who are capable of designing and programming digital computers, but more people who understand the basic limitations and potential uses of digital computers; (2) that the computer industry should take an active interest in providing a basic computer training to the largest number of people, in addition to more extensive training to those who show an interest in designing and programming computers; and (3) that the typical 12-year-old youngster has the interest, skill and basic knowledge necessary to build and understand simple working models of practically anything.

Consider a typical 12-year old: You would not be surprised to learn that he's been flying gliders for years, has probably built at least one rubber-powered stick model airplane, and is wondering whether he should spend his allowance on a more fancy model. At this age, he can take his bike apart and put it together again, diagnose and often correct a short circuit on his friend's electric train, build a bridge with his Erector set, and can develop and print pictures taken with his own box camera. He knows the difference between a rocket and a jet, alternating current and direct current, telescopes and microscopes, and between a gasoline engine and a diesel. For a small sum of money - often less than $20 - he can buy himself a working model of any of these things, plus a subscription to a magazine which will keep him informed of progress in the real devices, in the models, and in ways of using and improving the models. It is not surprising to find such youngsters entering the aeronautics, automotive, and electronics industries.

But when it comes to digital computers, our youngster is rather out of luck. He can buy a 4-digit decimal adder for a dollar; but this is hardly inspiring. The cheapest drum storage he could get costs more than his father's automobile.

It becomes apparent that our youngster needs a well-rounded computer package consisting of three parts: (1) a full line of cheap, standardized, general-purpose, digital computers in plan, kit, and assembled forms; (2) a full line of simple instruction manuals; and (3) one or more magazines, sponsored by the computer industry and designed especially for youngsters, covering coded programs for new and interesting problems, discussion of ways of making improvements and modifications to the models, etc.

Given the models and manuals, as described below, the magazine should be clearly written and profusely illustrated. It should stimulate continuing interest in computers by informing the youngsters about new full-scale computers and new problems being handled by them, and by providing a way for the youngster to exchange ideas on logical changes in the models and their in-out devices; on uses of the model around the house, in schoolwork, and for games; and on programming and mathematical tricks.

Each kit or model would include a complete instruction manual especially designed for that kit. General instruction manuals on construction, logic, coding, mathematics, and applications should also be made available. It is proposed that these manuals should be not only very easy for youngsters to understand, but should be exciting, too, even for those who dislike arithmetic and mathematics, and that they should represent the computer as a powerful tool which can be used in many fields, rather than as an end in itself.

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The manuals will be easy to understand if care has been taken to explain the simple relationships between basic elements which the youngster is sure to know. Youngsters are normally not taught calculus until after they understand arithmetic and algebra. But with a calculator at their fingertips, capable of doing the arithmetic automatically, such a sequence of training may not be necessary. For example, it should be easy for them to understand a well-designed description of basic relationships which will train them how to use their computer to solve problems normally handled only by advanced calculus. Remember, we teach six-year-olds how to use numbers without teaching them advanced number theory.

The magazines and manuals discussed above are based on the availability of cheap, interesting computer models. These should be made in standardized sections which can be bought separately and pieced together to form an increasingly useful computing system. Each section should cost no more than $5 with several basic demonstration sections at $1 each or less. Typical sections might include: (1) A 32-register, 8-bit, 4-instruction, display-screen-output basic computer; (2) a 1,024-register, 8-bit storage; (3) a 32-instruction control; (4) an 8-bit multiply-divide arithmetic element; (5) analog and digital inputs; (6) analog and digital outputs. Two storage and arithmetic sections would be required to provide a full 16-bit machine. Thus, a typical full-scale model with eight sections would cost about the same as a bicycle. The speed of such a machine might easily be faster than ten instructions per second.

The design goals mentioned above can be met by adhering to several basic principles:

First, the computer should be mechanical. Basic computer techniques can be easily observed on functioning mechanical parts. Parts can be easily and cheaply made by youngsters out of paper, or mass-produced as plastic or metal stampings. For example, $3.40 buys enough pins for 1,024 8-bit registers. Second, the computer should be binary. The ease of making such parts outweighs the necessity for teaching the binary system to the youngster, who will learn it readily enough.

Third, all action should be positive and should not depend on friction, inertia, or springs. This allows the parts to work at any speed - as slowly as you wish for demonstration, and as fast as you wish, limited only by the strength of the materials and of the drive motor. The use of springs tends to increase the forces required to drive the device. The use of positive action allows several steps to be performed on the same input pulse, perhaps allowing a complete single-address instruction to be performed on each input pulse.

Fourth, and finally, the parts should be made as small and light as possible, consistent with strength, manufacturing tolerances, and ease of repair or observation. Lighter parts have less inertia and can be driven faster or with less power.

A number of experimental models of logical circuits built according to these principles will now be discussed.

Figure 1 shows an 8-bit register cut from paper. Each bit operates as a toggle element whose spring is formed by bending the central strip of paper into a Z-shape. This violation of the no-spring principle might be justified if a large memory can be made so simply. The selection of a given register would be done by moving the register to the left. Read-in would be accomplished by moving a digit bus (not shown) upward or downward. Read-out would be accomplished by allowing the tab of each bit to engage a lightweight output bus. Note that read-out would not tend to disturb the setting of the toggle.

Figure 2 shows a more reliable, but more costly, 8-bit register. Each bit is represented by a pivoted arm whose position is locked by tabs on the locking bar. Selection, read-in, and read-out are accomplished simply by moving the register to the right. Both ends of each pivoted arm would then come in contact with two halves of a corresponding digit bus (not shown) so that the arm and the bus would be forced to the same angle: If the locking bar is moved forward with the register then a positive read-out takes place, but if the locking bar is not moved forward, then a positive read-in takes place.

Figure 3 shows three such registers mounted in their frame. This is the state of progress on a demonstration model which will consist of thirty-two 8-bit registers, a selection counter, and a Charactron-style output display made of cardboard and bits of mirror. It will be used to test the speed and reliability of a small system and the feasibility of sectional, expandable construction.

Figure 4 shows one type of AND circuit. The "secondary flip-flop" assumes the position of the "primary flip-flop" only when the circuit is not being operated. While the circuit is being operated, the "primary flip-flop" may be altered as much as desired without affecting the output signals.

Figure 5 shows an adaptation of this basic AND circuit to form a one-stage binary counter. The primary flip-flop is set and cleared by the output pulses, thus causing it to be complemented on each input pulse. The primary flip-flop is locked while the secondary flip-flop is sensing it.

Figure 6 shows a model of this binary counter cut from 3 x 5 card stock, pivoted with common pins, and connected to a drive motor. A cover plate holds the parts together. This model has been run at 40 cycles per second, for over an hour at no load. Only slight wear is evident in the counter itself, operating margins have deteriorated only slightly, and it looks like it might last another hour or more.

These are typical of the inexpensive computer elements which can be used to intrigue and train the 12-year old, who, by the time he graduates from high school will be able to perform many of the tasks for which graduate engineers are now employed.

When you consider the remarkable interest in computers that would be generated by the ready availability of a computer, and of instruction in its use, to any 12-year old, the computer industry should be happy to provide whatever moral, technical, and financial support is necessary to provide the most reliable and workable standardized models, the most eagerly read manuals, and the most interesting magazines.

How long will it be before a teenager appears at the local airport complete with radio-controlled model airplane, acoustical tracker, and computer-controlled stunt patterns?

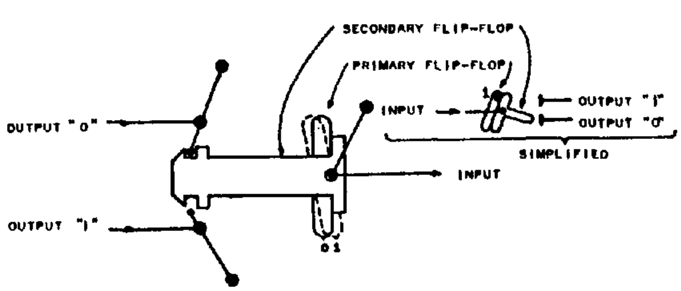

FIG. 4
BASIC "AND" CIRCUIT

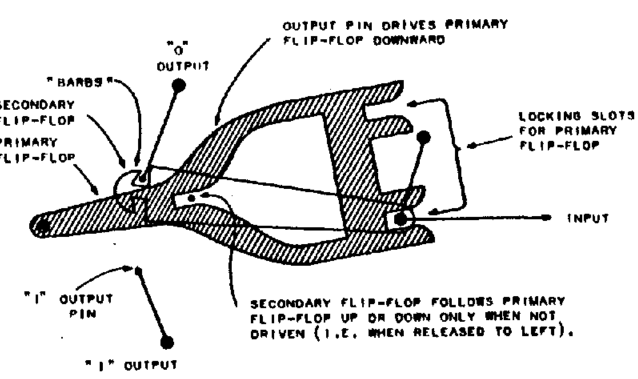

FIG. 5
BINARY COUNTER

1-66192-1

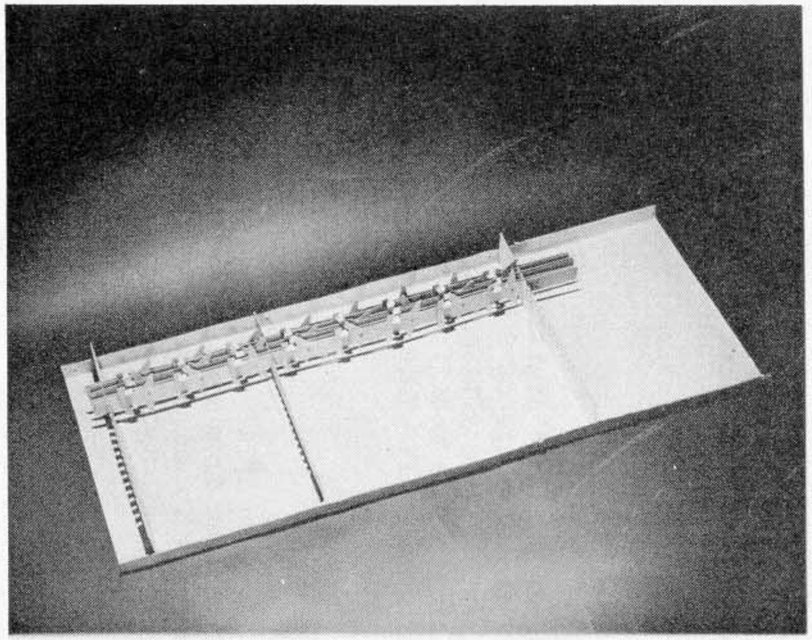

FIG. 3

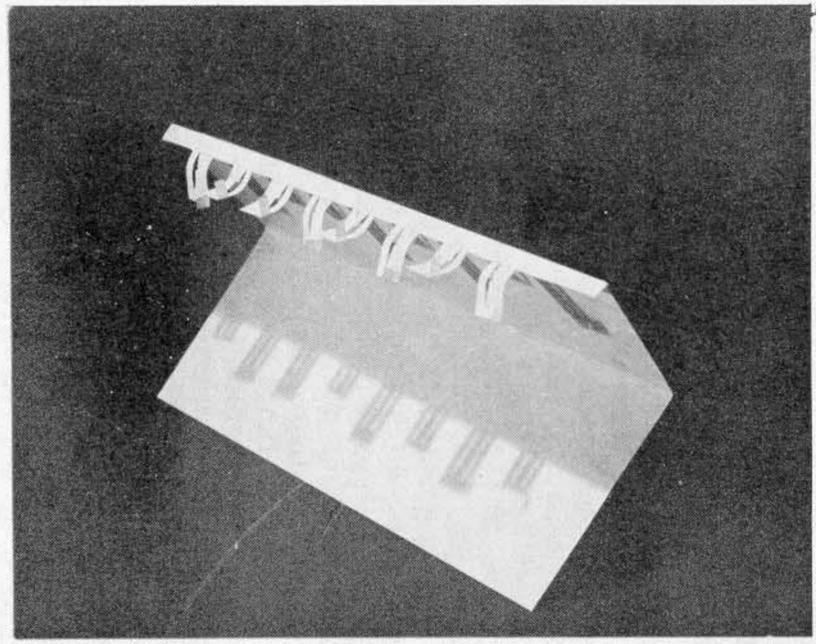

FIG. 1

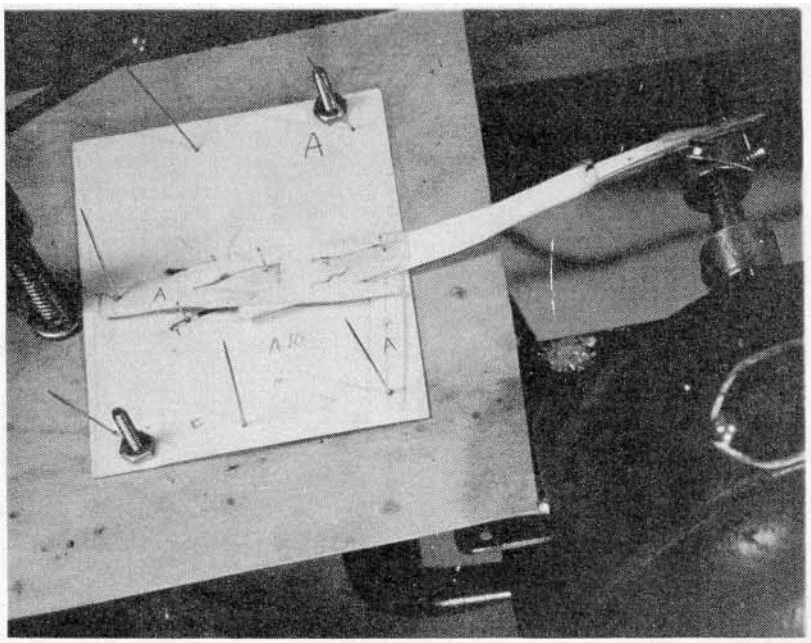

FIG. 6

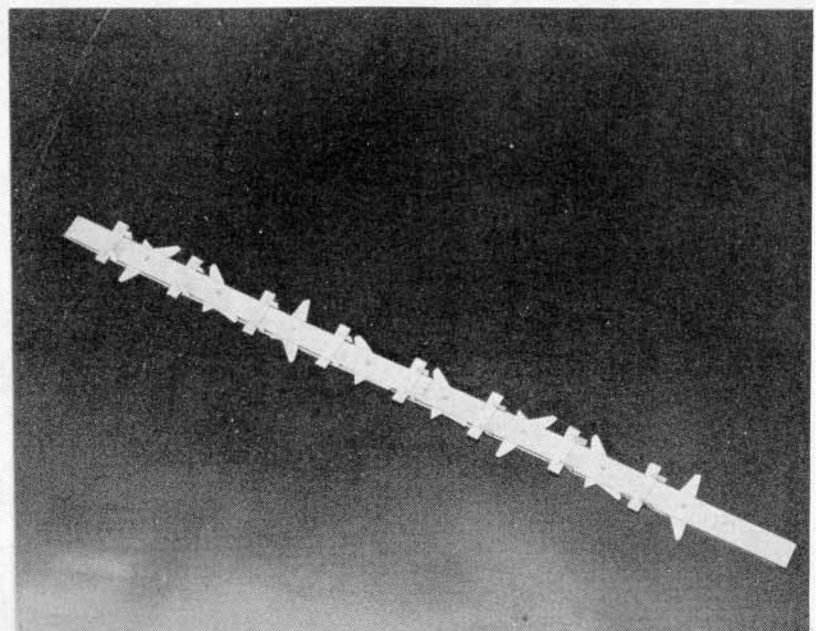

FIG. 2