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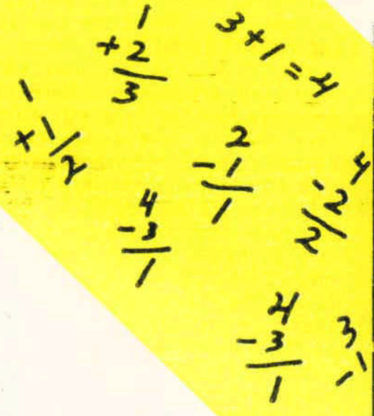
WORLD'S SMALLEST ELECTRIC BRAIN — SEE ELECTRONICS SECTION

World's Smallest Electric Brain



By EDMUND C. BERKELEY* and ROBERT A. JENSEN

E. C. Berkeley explains how Simon gets instructions from a piece of punched tape.

Part I of a series of articles outlining principles and describing construction of electric and electronic computing devices

ON THE COVER of this issue of RADIO-ELECTRONICS is a picture of the smallest existing, complete electric brain. This midget electric brain is named Simon, in honor of Simple Simon of Mother Goose fame. He can be called electric or mechanical for he uses relays; but not electronic, for he does not use a single electron tube. Nevertheless he illustrates in solid hardware the principles of all the giant artificial brains, electronic, electric, or mechanical. He is perhaps the only electric brain small enough to be understood completely by one man.

Simon is about 24 inches long, 15 inches wide, and 6 inches high. He weighs (not counting his power supply) about 39 pounds. He runs on 24 volts d.c., drawing at most about 5 amperes. And in number mentality, Simon at present compares with a child of two years, for he knows only four numbers, 0, 1, 2, and 3.

Simon is slow. He performs each operation in about ⅔ second—unlike the electronic brain finished in 1949 called Binac, which adds at the rate of 3,500 additions per second. And yet Simon is a true mechanical brain, for he has the two essential properties that define a mechanical brain: he can transfer information automatically from any one of his 16 registers to any other, and he can perform endlessly long sequences of reasoning operations.

What is the purpose of this little idiot of an electric brain—or should he be looked on rather as a baby, with capacity to grow? Why was it worth while to build him?

The purpose of Simon

An editorial entitled "Simple Simon" in the *Wall Street Journal* for May 22, 1950, expressed in part the purpose of Simon: it said, "The world may admire a genius but it loves a moron." The same may perhaps be true of the crew of men who want to know how electric brains work, what they are all about, and how to construct them. It may be rather easier to understand the working of a little moron of an electric brain, that a student can easily feel superior to, than it is to understand the working of a giant electric brain, that a student can easily feel inferior to.

Simon was designed and built to exhibit in simple understandable form the essential principles of any artificial brain. He will be useful in lecturing, educating, training, and entertaining—just as a spinning toy gyroscope is both entertaining and instructive. For it is certainly true that the demand for computer-trained electronics engineers, operators, maintenance men, mathematicians, etc., is steadily growing in the new field of automatic computing machinery.

There are now more than a dozen kinds or species of these giant artificial brains. Most are represented by just one example, such as the rather old—but still spry—Harvard IBM automatic sequence-controlled calculator, finished in 1944. This machine handles numbers of 23 decimal digits and can remember 72 of them at one time. There are now in use more than 20 machines of the type known as the International Business Machines card-programmed calculator, and more than 80 of the type known as the Reeves electronic analogue computer.

Digital and analogue computers

These artificial brains are of two main types: *digital* and *analogue*. A digital machine expresses information by the positioning of devices in any one of a small number of exact positions. For example, a human hand with fingers up or down may express 0, 1, 2, 3, 4, 5; or a counter wheel can stop at any one of the spots 0 to 9; or a light can be on or off, 2 positions; or a relay may be energized or not energized; or an electron tube may be conducting or not. All these devices are *digital*.

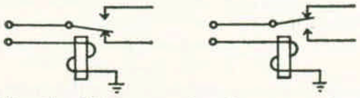


Fig. 1—Diagram showing a register of Simon expressing the information "1,0".

An analogue machine, on the other hand, expresses information as the measurement of a physical quantity, such as distance moved, or amount of rotation, or electric potential, etc. The

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measurement is *analogous* to a number in the computation.

But there is no easy way for an analogue machine: (1) to manipulate alphabetic information given in letters; (2) to express random numbers; (3) to express any numbers with an accuracy of more than 5 or 6 decimal digits; (4) to handle problems where the solution requires different decisions and subroutines, depending on what happens in the course of the problem. All these things a digital machine can do easily. Thus a digital machine can do rather more than an analogue machine. In fact it begins to look as if the digital machine of the future has within itself an unlimited capacity to think. This series of articles will deal mainly with digital electric brains.

How an electric brain works

How does an electric brain work? A good mental picture of the working of an electric brain is an isolated telegraph system, with a number of communicating central stations and a traffic control. The messages that this telegraph system handles are usually pieces of information of standard length, with a standard number of digits.

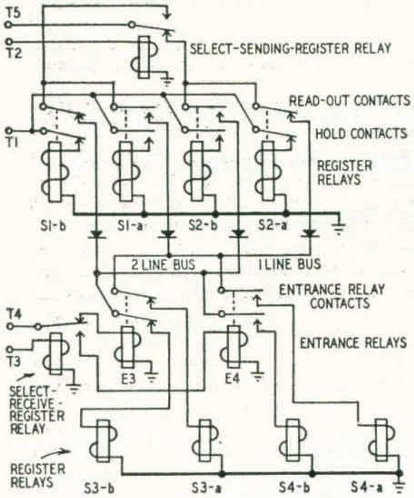

Fig. 2—A simplified schematic showing how Simon transfers information from either of two read-out storage registers to either of two read-in registers.

One of the stations is called INPUT. Here information comes in from the outside world to the telegraph system; it is put into a form ready to be sent somewhere else in the system.

Another of the stations is called OUTPUT. Here information that the telegraph system has produced is given back to the outside world.

There are a whole flock of stations called STORAGE No. 1, STORAGE No. 2, STORAGE No. 3, and so on. Here information may be stored without changing while waiting for some other part of the system to call for the information and do something more with it.

A very important station with room for several incoming pieces of information is the COMPUTER. This station is combined with a factory, a calculating device that can accept several pieces of information and manufacture new information out of them.

For example, the calculating device may have four receiving points or platforms. On two platforms, the computer takes in two numbers such as 140 and 25. On the third platform the computer takes in an order to subtract, multiply, or find which is bigger, etc. On the fourth platform the computer delivers a result (for example, 115), the result of combining 140 and 25 according to the order to subtract.

To calculate with this telegraph system, we must have some way of organizing traffic through it. That is the duty of the central traffic control. The most automatic way for sending information through the system is:

(1). At any one time connect just two telegraph stations, such as "Albany" and "Boston";

(2). Specify the direction of traffic, such as "from Albany to Boston." Then as soon as the proper connections have been completed, send the signal "go," and the information at Albany will be transferred automatically to Boston.

There are two ways to get the central traffic control to function properly. One is to have all the orders ready ahead of time, and tell it to do just as it is told. This is dictatorship. The second way is to have some special wires of the telegraph system run into the central control, and let information from time to time (though not all the time) come from the system into the central control—feedback. The central control then knows what is going on and can direct the following steps. This is democracy. This second technique of course is a honey, even with electric brains, and a good electric brain does compute some—or even most—of its own instructions.

Information

Such then is the mental picture of the working of an electric brain. But just what do we mean by information?

For the purposes of an electric brain, information is simply the arrangement of certain physical equipment. For example, a hand with two fingers up and three down is regularly considered to express the number two. Or suppose we take a pair of relays, a left-hand one and a right-hand one. Either one of these relays may be energized (let us report this condition as 1) or not energized (report this condition as 0). The information therefore that this pair of relays can represent is 00, 01, 10, and 11—four possibilities. (Here 10 is not ten, and 11 is not eleven). Let us number these four possible pieces of information 0, 1, 2, 3. Now we have the exact way a register of Simon expresses numbers (see Fig. 1).

Transfer of information

An electrical brain, like an automatic telegraph system, can transfer information automatically from one register to another. How does this take place?

Suppose we take some registers of Simon (a little simplified) and see how transfer does take place. Let us take two storage registers S1 and S2 (S for storage) from which we may read out information, and two more storage registers S3 and S4, into which we may read information. Each of these registers has two relays to supply the four possible pieces of information. Suppose we desire to transfer information from register S2 into register S3.

Looking at Fig. 2, we see 12 relays, of which eight are the relays for registers S1 to S4. We also see five terminals, T1 to T5, which energize the relays. The terminals are energized, that is, carry current, in the sequence of their numbers.

Let us consider time 1. At this time the circuit running from T1 to ground passes through both the closed HOLD contracts and the coils of (two out of) four relays S1-b, S1-a, S2-b, and S2-a. By a previous operation, the two relays S1-b and S2-a were energized and are now held up by continuous current from terminal T1. We see that information "1,0" is stored in register S1 and that information "0,1" is stored in register S2.

Let us pass to time 2, and look for terminal T2. At time 2 we see that the SELECT-SENDING-REGISTER relay is energized, and consequently register S2 is selected to send out its information.

Now let us pass to time 3, and look for terminal T3. The SELECT-RECEIVING-REGISTER relay, whose pickup coil is connected to T3, is not in this case energized. As a result, register S3 is selected to receive.

Passing to time 4, we look for terminal T4. As current flows along the wire from T4, the entrance relay for register S3 is energized. We have connected the pickup coils of register S3 to the bus, and therefore S3 can receive information from the bus.

We have now completed all the preparations needed to transfer information from register S2 to register S3. We now pass to time 5. Pulsing terminal 5, we see that the pulse of current flows as follows:

(1). through the selection circuit that selects the sending register S2;

(2). through the readout contacts of the sending register S2;

(3). through the rectifiers (which prevent back circuits);

(4). through the bus;

(5). through the contacts of the entrance relay belonging to the receiving register S3;

(6). into the coils of the receiving register S3 (naturally and properly, only the right-hand relay S3-a is energized, however); and

(7). to ground.

This then is an illustration of the principle of transferring information from one register to another. The scheme is entirely general: a pattern of information "written" in one register is "copied" in another.