information from the input station, but also knowledge of the designated registers. So at each cycle we must also give the machine the signals that call for the designated two registers at each cycle. Computer register No. 3 is omitted from this diagram because we do not need it for this problem, but we shall have occasion to use it later for other problems.

So, for our particular series of commands, we shall suppose that the codes of the registers are 000 to 111 as shown right above them in Fig. 1, and that these codes are also given to the machine, cycle by cycle. The machine is constructed to know that the first code refers to the sending register, and that the second code designates the receiving register.

What information then will be on the tape, cycle by cycle? The tape will contain the following information:

Cycle	*Information*
1	24-000-100
2	13-000-101
3	PLUS-000-110
4	—-111-001
5	45-000-100
6	31-000-101
7	MINUS-000-110
8	—-111-010
9	—-001-100
10	—-010-101
11	COMPARE-000-110
12	—-111-011

Of course, just as the registers are represented by codes such as 000 or 100, so the numbers like 24 and 13 and the operations PLUS, MINUS, COMPARE will be represented by codes. Certainly, the machine will not be required to translate a collection of alphabetical letters into an operation indication. Probably, all of these numbers and operations will be translated into sets of 1's and 0's corresponding to equipment that has two different stable conditions.

Circuits

Fig. 1 is a schematic diagram of the flow of a problem through an electric brain. But what is the diagram of the actual circuits?

In Fig. 2 is shown the main transfer circuit for the electric brain of Fig. 1. By looking at Fig. 2, we can see most, though not all, of the essential electrical network for making the events of Fig. 1 happen.

Down the center is a four-line bus; this is sufficient for transferring one decimal digit coded into binary notation. The second decimal digit could be provided for by another four lines of bus, but these have been omitted for the sake of simplicity.

On the right side of Fig. 2 are the eight sets of relays which correspond to the eight registers of Fig. 1. We note that we cannot read in from the bus to either the INPUT REGISTER or the COMPUTER 5 REGISTER. This is as it should be, because COMPUTER 5 REGISTER is filled from the information in COMPUTER REGISTERS 1, 2, and 4 and the INPUT REGISTER is filled from the tape.

The sets of terminals marked T1's, T2's, and T3's are energized at an earlier time. Their hold contacts hold a pattern of information in the relay registers. There are, however, exceptions: for example, provision must be made for resetting any register before information is read into it. But as usual, we will not consider complications until a later stage.

On the left side of Fig. 2, we see mainly the "read-out" contacts of the relay registers on the right side of Fig. 2. Since any one of the eight registers can be read out of, all eight of the registers are represented.

The very first transfer is of the decimal digit 4 (in binary, 0100) of the first number, 24. Before this transfer begins, we see the binary number 0100 stored and held in the INPUT REGISTER RELAYS, recorded there in red 0100, the 0's saying that relays 8, 2, 1 are not energized and the 1 saying that relay 4 is energized. Consequently, on the left side we see the number also stored in the INPUT REGISTER CONTACTS.

Now, we want to transfer out of the INPUT REGISTER, code 000, into COMPUTER REGISTER NO. 1, code 100. Accordingly, information in the tape energizes the SELECT-RECEIVING-REGISTER RELAYS in the pattern 100, and the SELECT-SENDING-REGISTER RELAYS in the pattern 000 (using the terminals T4's and T6's, respectively), and affecting the positions of their contacts.

We now pulse terminal T5. This picks up only the ENTRANCE RELAY for COMPUTER REGISTER NO. 1, and connects only the pickup coils of COMPUTER REGISTER NO. 1 to the bus.

We are now ready to pulse terminal T7 and read through the whole circuit, the main transfer circuit. This we do. As soon as we do it we transfer the pattern 0100 into COMPUTER REGISTER NO. 1. All the circuits that carry current during this process are shown in red. This same general process repeats once each cycle, and again and again, carries out the automatic operation of the electric brain according to the instructions on the tape.

How many tapes?

One of the questions considered in designing an electric brain is whether it should have one tape, several tapes, or no tapes.

For a small machine such as Simon there is an advantage in having one tape, because one tape-reading mechanism is cheapest. In each cycle of such a machine, there can be three times: at two of the times, the machine reads from the tape the codes of the receiving register and the sending register, and at a third time the machine reads from the tape the number or operation information.

It is often more efficient to have two tapes. Usually they will consist of a *problem tape*, containing the numbers belonging to a particular problem, and a *program tape*, containing the transfer commands, operations, and constants (the numbers that do not change from problem to problem).

It is still more efficient to put almost all of the program into the storage or *memory* of the computer. This often becomes possible when we go to electronic computers with 1,000 or more registers in the *rapid memory*, where the rapid memory is the part of the storage registers of the machine and any specified piece of information can be gotten at very quickly. This is in contrast to the *slow memory*, where many seconds or some minutes may be needed to get at a specified. piece of information. For example, we can store dozens of useful common routines, such as a procedure for getting square root, in the rapid memory of the machine, and then tell the machine to pick up any one of them and use that procedure when a given indication in the problem occurs. This has been done with the Model 6 relay computer in Bell Telephone Laboratories in Murray Hill, N. J., which is a particularly well-educated electric brain; it has routines and subroutines which are numbered in the hundreds; they belong to half a dozen levels of "intelligence," and can call for each other.