How an Electronic Brain Works

Part VIII—The flip-flop circuit and other methods used to store information in electronic computers

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IN THE previous articles of this series, we have described a simple example of an electric brain made up of relays.

We have shown that we can have a complete, and rather interesting, miniature electric brain made up essentially of the following: 16 registers, each consisting of two relays, which may store

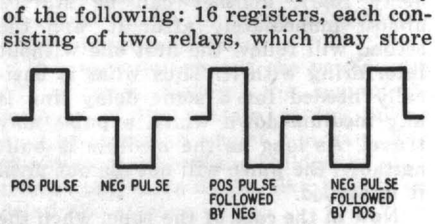

Fig. 1—Pulses like these carry information in electronic computer circuits.

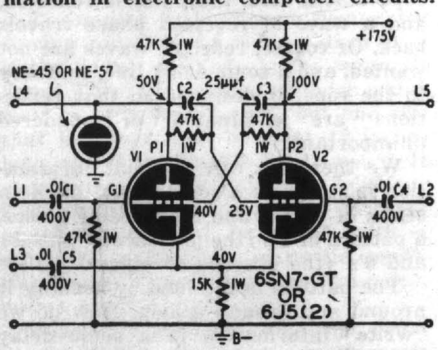

Fig. 2—A flip-flop circuit. V1 is conducting when the voltages are as shown.

numbers 0, 1, 2, 3, (in binary, 00, 01, 10, 11), or operations "addition," "negation," "greater-than," "selection" (codes 00, 01, 10, 11); and 1 register, consisting of 5 relays, which stores instructions (codes 00000, 00001, ... 11111).

There are many problems which require such vast amounts of computation that they have never been attacked by human mathematicians. Relay brains have been able to handle some of these problems. But even a relay brain is too slow for the biggest problems, such as computing the aiming direction of a missile that will intercept another one (like a buzz-bomb) in time to shoot it down. The fastest that an ordinary relay can operate is about 5 or 10 milliseconds. However the fastest that an electronic tube can operate is better than a microsecond.

So, with our background of understanding how a relay automatic computer operates, we can now set out to see how an electronic brain can operate that would compute a thousand times faster than a relay brain. We must translate the ideas we have been dealing with out of the language of relays into the language of electronic tubes.

It must be remembered that no one has yet constructed a complete operating miniature electronic brain. Consequently most of the information here given is derived from work that has been done with the giant electronic automatic computers.

Information

How shall we make electronic equipment express information? In electronic computers, just as in relay computers, the basic piece of information is a binary digit, a yes or a no, a 1 or a 0, a tube conducting or not conducting, the presence or absence of a certain change of voltage, etc. It is much easier and more direct to construct an electronic computer that operates in the pure binary system than it is to construct one that operates in the decimal system.

There are several main systems for representing information. The first system is that 1 is represented by a pulse of voltage (either positive or negative) at a certain time, and 0 is represented by the absence of a pulse at such time. A second system is that 1 is represented by a positive pulse of voltage, and 0 is represented by a negative pulse of voltage. Here, the absence of a pulse at a time when a pulse is expected becomes a useful indication that something has gone wrong. A third system makes use of a pair of pulses: a positive followed by a negative denotes a 1, and a negative followed by a positive denotes a 0. The second and third systems are more reliable, and for that reason are used in some automatic computers; but the first system is simpler and has the advantage that the presence of information is indicated by a pulse that may be either positive or negative. Fig. 1 shows the pulse arrangements. The minimum duration of a pulse depends on the time of operation of electronic tubes, which range in the neighborhood of 1 microsecond to 1/20 of a microsecond in most computer circuits.

Because of the speed of operation of an electron tube, many automatic electronic computers operate serially—that is with a bus consisting of just one line along which all pulses travel. One of those finished recently (the Bureau of Standards Eastern Automatic Com-

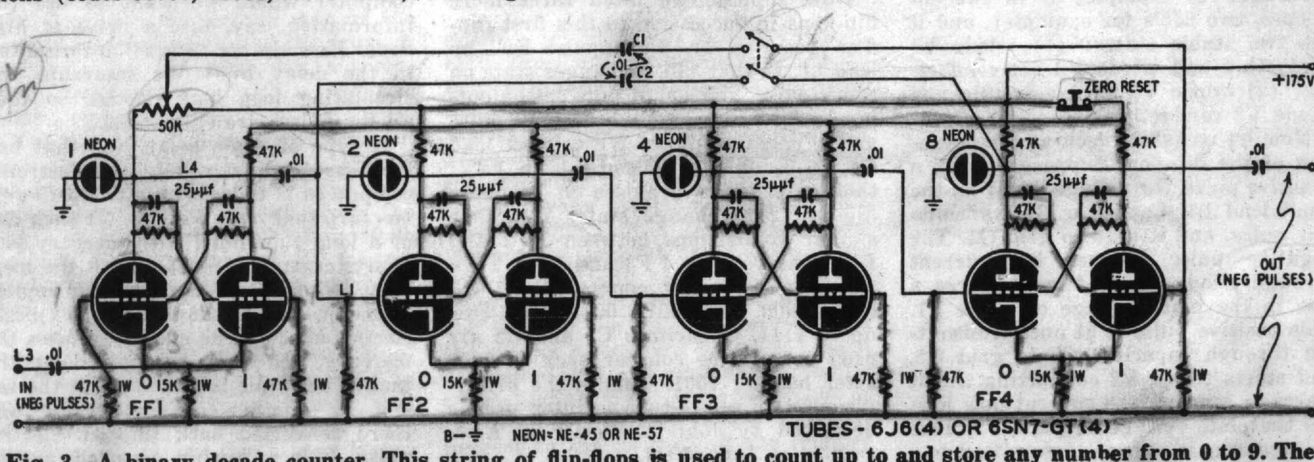

Fig. 3—A binary decade counter. This string of flip-flops is used to count up to and store any number from 0 to 9. Then it resets, passing an impulse to a similar unit, which acts as the "tens" bank, and so to any desired number of decades.