How an Electronic Brain Works

Part IX—Some electronic circuits for computers and how they are used for adding and subtracting

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IN THE previous article we began the discussion of an electric brain to be built around electronic tubes instead of relays. We discussed the storage information in the form of the state of a flip-flop, or pulses circulating in a delay line, or magnetized spots on a magnetic surface, or charges on the screen of an electrostatic storage tube.

But how do we compute? As soon as we have arranged to read, write, and erase information at electronic speeds, we need to consider how to compute with electronic elements.

For computing purposes, a unit of information is represented as a pulse, either a rise and fall of an otherwise constant voltage, or else a fall followed by a rise. We will call the first kind a positive pulse or a 1, the second kind a negative pulse or a –1, and the absence of a pulse a 0. See Fig. 1.

In a computer, the pulses are usually of a standard duration, and may be for example ⅕ of a microsecond long and spaced ⅘ of a microsecond apart. In this case the pulse repetition rate would be 1 megacycle per second. In some computers, 1 and –1 pulses are both treated as the presence of information, the binary digit 1, the logical truth value 1, or "yes"; while 0 is treated as the absence of information, the binary digit 0, the logical truth value 0, or "no."

Phase inverter

The first computing element we need to consider is a *phase inverter*. In computer work, a phase inverter changes a positive pulse to a negative one, or a negative pulse to a positive one, that is, "inverts" the pulse. See Fig. 2. In this figure, and in Figs. 3 to 8, part *a* is the circuit diagram; *b* is its block diagram representation which we use for convenience; and *c* is a function table that indicates what the circuit does. Any grid-controlled electronic tube can act as a phase inverter.

Logical AND circuit

The next computing element we need to consider is called a "logical AND circuit." This is one of the meanings of the electronic term "gate." See Fig. 3. In this circuit, a pulse appears on the output line if, and only if, two pulses come in simultaneously on two input lines.

A tube with two grids, normally cut off with either one or no pulses, is one of the forms which a logical AND circuit can take. The reason for the word "and" is that we have a pulse on output line C if and only if we have a pulse on input line A *and* on input line B. This (with emphasis on the idea "both") is the regular meaning for "and" in logic. This type of circuit may take many forms with and without electronic tubes.

Logical OR circuit

Another computing element is called a "logical OR circuit", sometimes called "buffer." It allows a pulse on the output line if a pulse comes in on either one or both of the two input lines. See Fig. 4.

A tube with two grids, which is normally conducting, is one of the forms which a logical OR circuit may have, although there are others. The reason for the word "or" is that a pulse is on output line C if a pulse is on input line A or if a pulse is on input line B, *or both*. This nonexclusive meaning of the word "or" is its regular meaning in logic.

Logical EXCEPT circuit

Another computing element is called a "logical EXCEPT circuit," or inhibitory gate. In this a pulse is allowed out on the output line if a pulse comes in on a specified one of the two input lines *except* if a pulse comes in at the same time on the other input line. See Fig. 5.

The circuit shown in Fig. 5 will act as a logical EXCEPT circuit. Its constants are chosen so that when A is not pulsed, whether or not B is pulsed, still there is no output on line C. If A is pulsed and B is pulsed, the two pulses, coinciding in time and of opposite phase eliminate the pulse on line C. If A is pulsed and B is not pulsed, then the pulse goes on through. Other circuits besides that shown in Fig. 5 are of course possible.

Electrical delay lines

The computing section of an electronic computer also uses an electric delay line of very short delay, such as one pulse time, or a few pulse times. A circuit that does this appears in Fig. 6. These are different from the long sonic

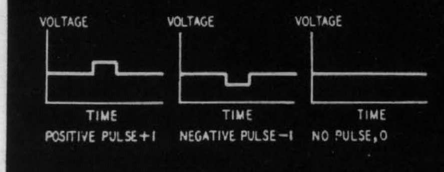

Fig. 1—Pulses are used in electronic computers to represent information. A positive pulse may mean +1, a negative pulse –1, and no pulse 0. Other pulse combinations are sometimes also used.

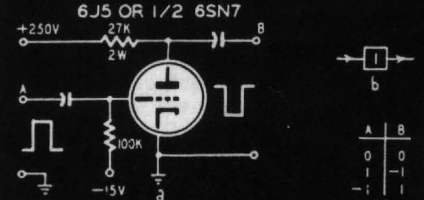

Fig. 2—A phase inverter circuit for computers. Part *a* is the circuit, *b* is its symbol for block diagrams, and *c* is a function table for this circuit.

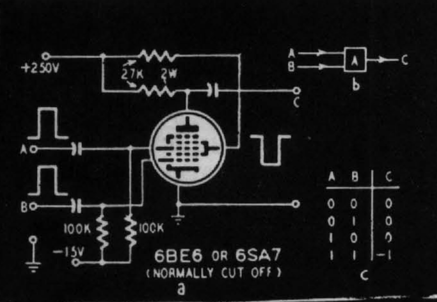

Fig. 3—A logical AND circuit, or gate. Output pulse appears at C only when inputs appear simultaneously at A and B.

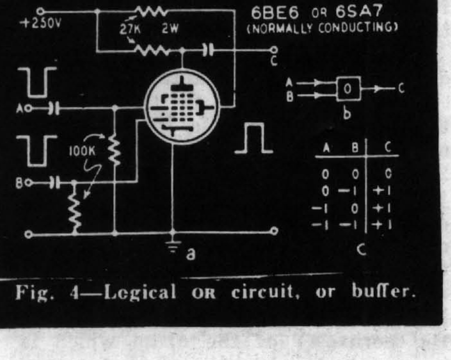

Fig. 4—Logical OR circuit, or buffer.