Build a Transistor-Powered Electronic Flash

POPULAR
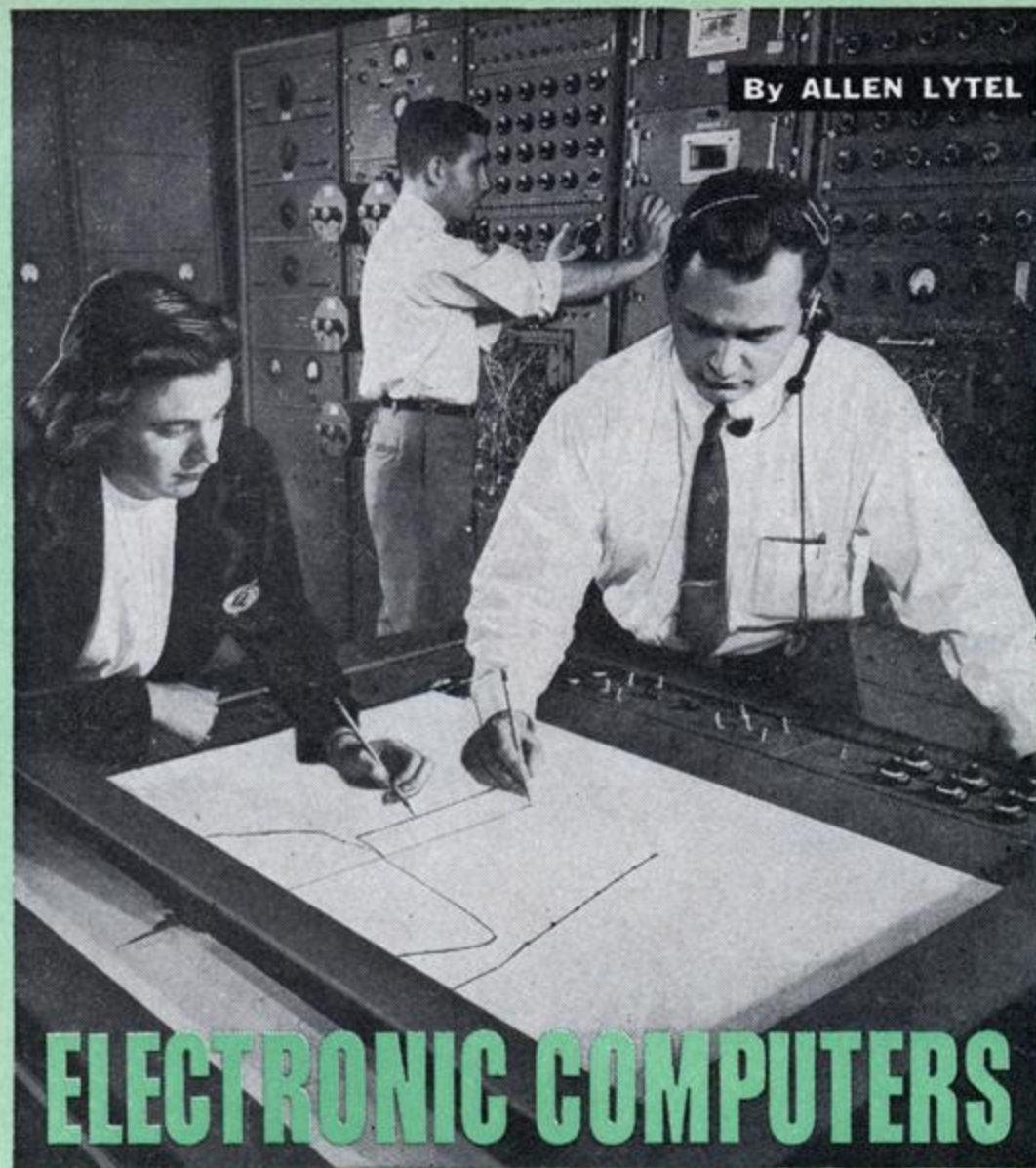# ELECTRONICS

JUNE 1958

35 CENTS

INSTALLING TRANSISTOR RADIO IN A CAR

Space TV—A Russian Proposal

What Computers Are—and Do

Telephone Secretary

Simple Hi-Fi Tuner

By ALLEN LYTEL

Analog computer-plotting board by Reeves as used at Bendix Aviation.

ELECTRONIC COMPUTERS

what they are and what they do

AUTOMATION has given new importance to electronic computers. From automatic factories to magazine subscriptions, they are becoming a part of our daily life. More applications are constantly being found for computers large and small.

There are two different types of computers: the *digital*, which uses numbers or digits, and the *analog*, which uses a measure, such as voltage, current, or angle of rotation.

While large-scale digital computers have captured the headlines, both types are important. Many more analog than digital computers are now in use although both analog and digital techniques are used in some computers. There are, however, striking differences between the two types. Each has applications where it is best suited; each has good features as well as disadvantages.

A comparison between them involves a measure of the exactness of computed results in terms of accuracy and precision. The *accuracy* is the measure of correctness or validity. *Precision* is something else again. If, for example, you say *pi* is almost 3.15 and I say *pi* is between

3.1 and 3.2, both are accurate if *you* measure to hundredths and *I* measure to tenths. But 3.15 is more precise because it is a measure of greater refinement. If you say *pi* is 3.14159, this is even more precise than 3.15. Thus both accuracy (correctness) and precision (refinement) are important. Digital computers tend to be more precise but both types are accurate within their own limitations.

ANALOG COMPUTERS

There are many forms of analog computers. A bathroom scale is one. When you step on it, the pointer moves across the dial. If your weight increases, the pointer moves farther; if you lose weight, it doesn't move as far. The amount of rotation (angle) depends upon your weight or there is an analogy between the two.

In an analog system, quantities are measured (not counted) and fed as inputs to the computer. The computer acts on the inputs in such a way as to perform a number of mathematical operations or to solve an equation. Results are usually plotted on a graph as output data.

If you want to multiply two numbers using logarithms, you add the log of the first number to the log of the second, and their sum is the log of the result. On a slide
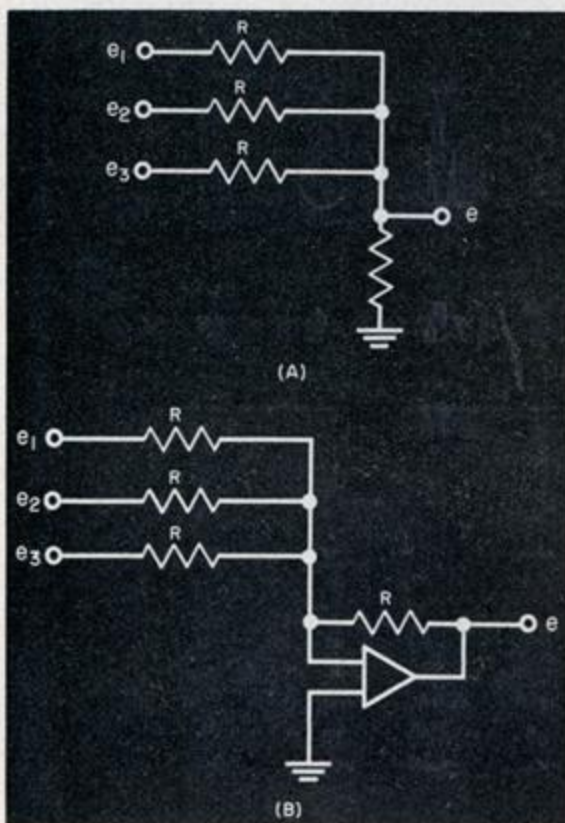
Fig. 1. Analog computer feeds value measurements into input (A), where e is analog of sum of voltages e_1, e_2, e_3. In (B), amplifier is shown in circuit.

rule, you do the same thing mechanically, for a slide rule is only a table of logarithms. The slide rule, then, is an analog computer.

Simpler and More Direct. Analog computers are, in a fundamental sense, more direct and simple than digital computers. An analog computer is not, ordinarily, a high-precision device. As an example, a circuit such as that in Fig. 1(A) will illustrate a simple operation.

The sum of the voltage drops in a series circuit is equal to the source voltage for a resistive circuit. Each input voltage is in series with the output.

With three input voltages (e_1, e_2, e_3) the output (e) will be the analog of the sum of the inputs.* This is an analog adder, and you can modify this circuit so that it will subtract by changing the polarity of any input voltage.

Amplifiers are used in many electronic analog computers, as shown in (B) of Fig. 1. Here the output voltage is the actual sum of the input voltages. These are high-gain stages suitable for many operations.

An example of a commercial amplifier is shown in Fig. 2. By the use of simple networks, a single stage (actually two tubes) can perform operations such as addition. Subtraction (negative addition), multipli-

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* An interesting Ohm's law problem; actually, if all the resistors are equal, then: $4e = e_1 + e_2 + e_3$.
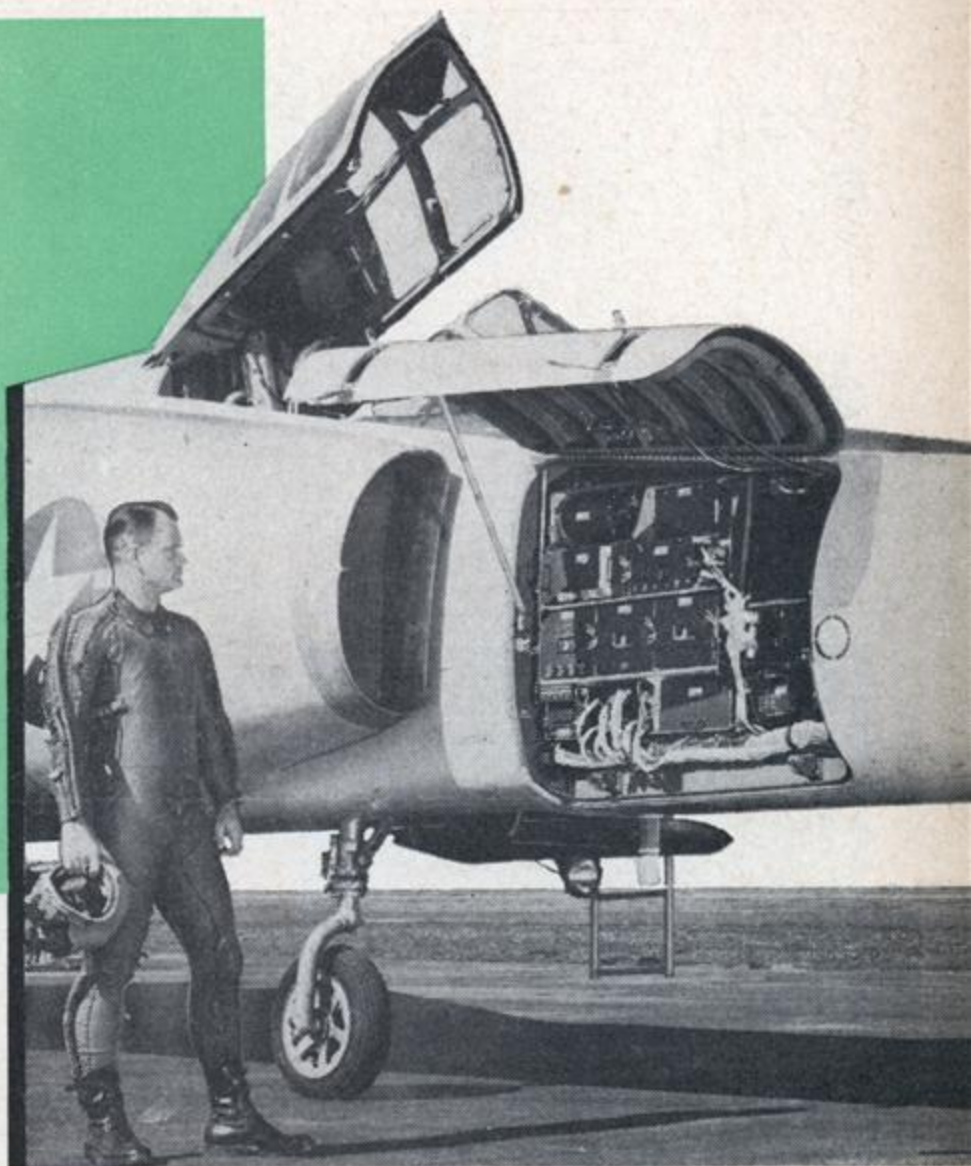
Digital computers tend to be large, but some have been put in small packages, as in this Hughes Aircraft model in the fighter plane above. At left, above, two forms of basic computers are shown being examined; the abacus is actually a digital computer, while the slide rule is an analog computer.

ANALOG	DIGITAL
Continuous quantity representation or measured values	Discrete quantity representation or counted values
Precise to 1 part in 10^3	Precise to one part in 10^{12} or better
Values may be in multi-dimensions	Values are ordered set of digits
Storage is localized, non-uniform, used *either* for data or instructions	Storage is centralized, uniform (in character), used for *both* data and instructions
Basic operations are usually sophisticated	Basic operations are quite simple
Limited and simple switching	Varied and complex switching
Programing tends to be fixed	Programing is quite flexible
System is (usually) simple, reliable, and expensive	System is (usually) complex, fallible, and expensive
For a given problem (usually) faster*	For a given problem (usually) slower*
Best suited to physical systems	Best suited for statistical (numerical) data

A complete problem, as in equation-solving, not an operation alone.
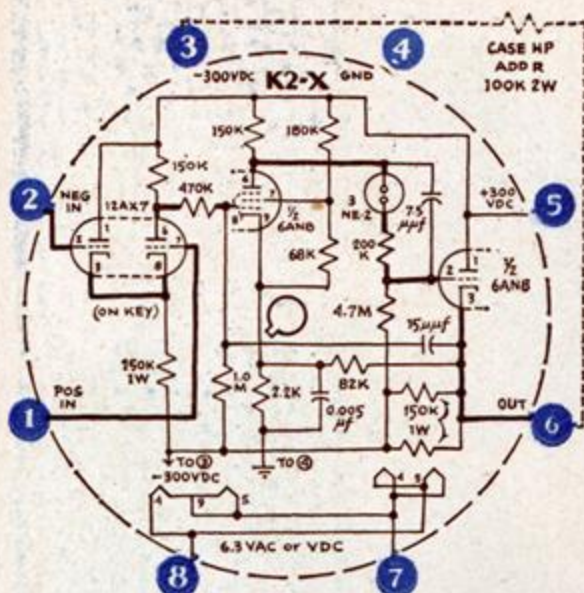
Fig. 2. Philbrick Research analog amplifier.

$$e = \frac{1}{T}\int_0^t e_i\,dt$$

$(T = RC)$

(A)

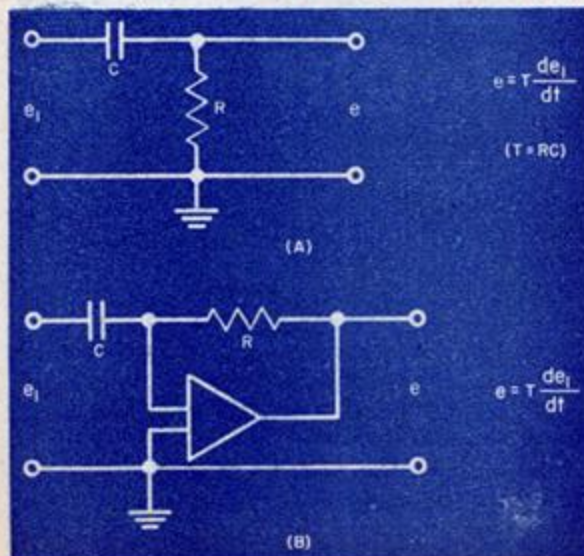$$e = \frac{1}{T}\int_0^t e_i\,dt$$

(B)
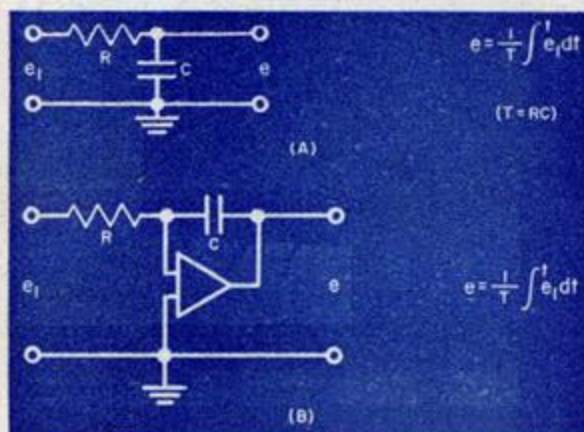
Fig. 3. In circuit (A), a capacitor stores the charge, and voltage across C is integral of charging rate. In (B), amplifier is added, to prevent removal of charge during integration.

Fig. 4. Circuit (A) will differentiate, but an amplifier is often used, as in circuit (B).

$$e = T\frac{de_i}{dt}$$

$(T = RC)$

(A)

$$e = T\frac{de_i}{dt}$$

(B)

cation (the input multiplied by the gain of the amplifier), and division (multiplication with less than unity gain) can all be accomplished quite directly.

Other mathematical operations also can be done in a single stage, and this is the inherent value to the analog approach. Among the basic analog operations are integration and differentiation. Integral calculus deals, among other things, with the determination of a variable quantity when the law of its change is known.

Integration, as shown in Fig. 3(A), uses a capacitor C to store the charge received. The voltage across C is, at any instant, the integral of the charging rate. This circuit computes the time integral of the input. An amplifier is added, as in Fig. 3(B), to prevent the removal of the charge on C.

The inverse of integration is, of course, differentiation, or the determination of the rate of change of a quantity with respect to another quantity, usually time. A simple circuit, Fig. 4, will act to differentiate, but again an amplifier is often used. This amplifier has resistive feedback.

Parts of Analog Computer. A block diagram of an analog computer is shown in Fig. 5. A series of amplifiers and passive elements, such as resistors, inductors or capacitors, form an electrical system which represents (is an analog of) the problem to be solved. The computer has *control* (central signal component) for determining the operation and for introducing the input data, a *power supply,* a *display* or output (central response component and scope) which presents the final data, and the *operation* unit (component computing assemblage), the part which does the actual computing. Memory is distributed throughout the system.

An analog computer is at its best when a precision of three or four digits is sufficient, no program branches are required, and when there is one independent variable. Data which is available in analog form, such as varying voltage, can be directly fed to an analog computer.

The disadvantages of an analog computer are its lack of precision and its limited flexibility. Usually the computer has to be reconnected, by means of patch-cords, to run a different problem.

DIGITAL COMPUTERS

A digital computer *counts* rather than measures. Most large computers are digital in nature; they are versatile and, in structure, the electronic type has many small building blocks.

A cash register is a digital computer and so is an abacus. Because numbers are used, any required degree of precision may be ob-

SWEEP

Fig. 5. Major units (right) of an analog computer.

Fig. 6. Block diagram (below) of a digital computer.

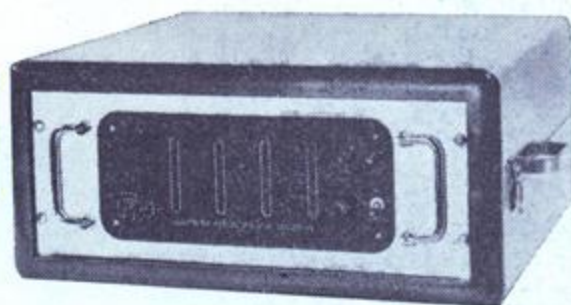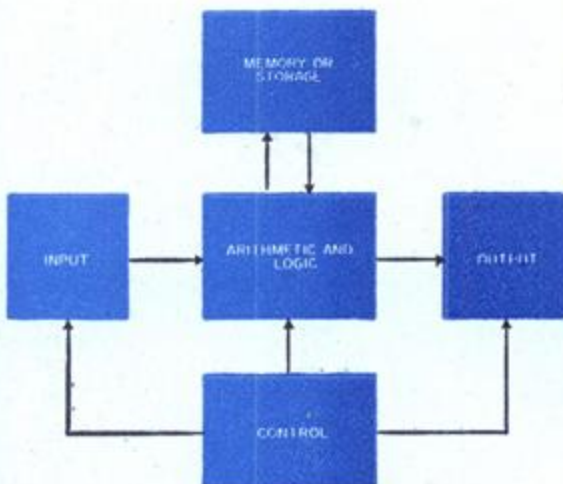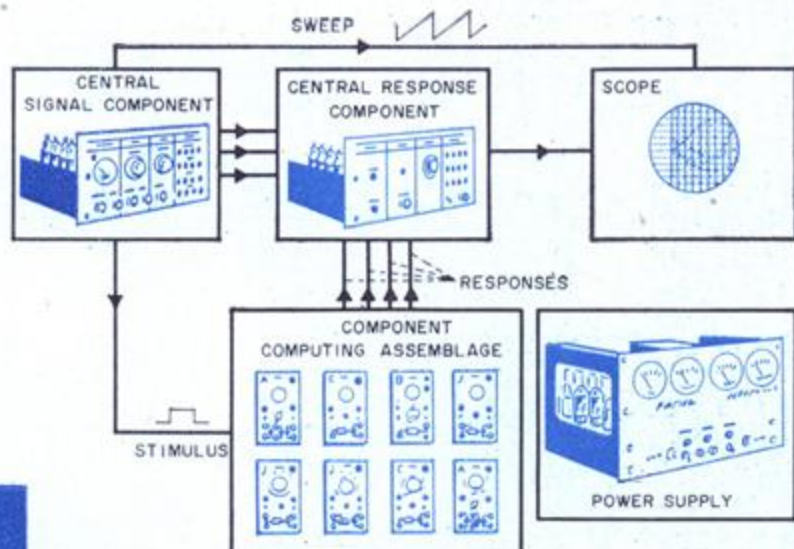**Fig. 7.** Diagram of a binary counter as used in a digital computer (bottom, right). See text on page 111.

CENTRAL SIGNAL COMPONENT

CENTRAL RESPONSE COMPONENT

SCOPE

RESPONSES

STIMULUS

COMPONENT COMPUTING ASSEMBLAGE

POWER SUPPLY

MEMORY OR STORAGE

INPUT

ARITHMETIC AND LOGIC

OUTPUT

CONTROL

Photo at right (above) is of a Fischer & Porter analog-to-digital converter. It converts output of analog computer into data which is used by digital machine.

INPUT → A → B → C → D → E

	A	B	C	D	E
DECIMAL	1	2	4	8	16
20	0	0	1	0	1
10	0	1	0	1	0
5	1	0	1	0	0
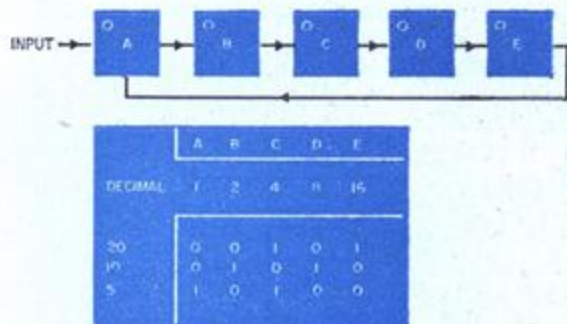
tained by carrying more digits. Since digits are used, the computer components (transistors, vacuum tubes) respond to *on* and *off* states like a switch which is either open or closed.

In many respects a digital computer is a kind of automatic calculating device which follows directions. Many digital computers can be represented by the block diagram in Fig. 6, and there are variations of this fundamental computer.

The basic units are: the *arithmetic and logic* section, which performs the actual arithmetic operations; the *memory* or storage which retains the program, the problem, and the results; the *control* unit which directs the computer operation; the *input* device for translating all input information to a form usable by the computer; and the *output* device which translates the computer output into a form which is most usable.

Operational Details. The *arithmetic* unit is an accumulator which can store information and, under proper control, act on this stored data which the accumulator obtains from the memory. A number from the memory can be placed in the accumulator. Upon receipt of an order such as "and," a number will be added to the number already present in the accumulator, which then contains the sum. This can be transferred to the memory or it can be retained by the accumulator for further operations.

For a "subtract" operation, the accumulator finds the difference and attaches the proper sign. To "multiply," a series of additions is made in the accumulator. To "divide," a series of subtractions is made.

The *memory* has a large number of locations or addresses, all of which can store information and retain it until needed.

ger; therefore the idea of the passenger has been abandoned.

In lieu thereof, the radio transmitter has been suggested as a passenger. It will certainly provide intelligent means for obtaining important facts about the vast spaces existing throughout the universe.

When the world of science knows for a certainty that the radio waves can carry through interstellar space, the time when further and more ambitious attempts to communicate with our planetary neighbors will be hastened.

This may answer the cynical queries of skeptics who demand to know what use all this sort of thing is to the world. Every new scientific fact produced supplies further tools with which to better our fast-growing and complicated structure of civilization. Let us hope success crowns the efforts of all men who dare to pioneer the distant fields of our universe. —30—

Electronic Computers

(Continued from page 43)

Each location can be described and located, so that either the information which it contains can be obtained or the location for new storages can be described.

In this type of computer, all of the information needed for a solution to a problem may be stored in the memory, including all of the steps or program required for the solution. Once the proper information is placed in the memory, the computer is independent of all outside devices until a solution is reached. Then the final results are stored until they are needed through the output device.

A magnetic-core memory is an example

Answer to crossword puzzle appearing on page 65.

10^4	10^3	10^2	10^1	10^0
10,000	1000	100	10	1
		3	5	2
	4	1	6	7
5	0	2	1	3

Table 1. Decimal system is based on the number 10. The number 352 is actually 3x100, plus 5x10, plus 2x1. Figure out 4167 and 50,213 for yourself.

of an internal memory system in actual use. This is a large group of tiny ring transformers which are magnetized in one direction (clockwise) or the other (counterclockwise). Other memories include the early use of relays (open and closed for 1 or 0), magnetic drums (circular tracks of magnetic materials with pulses or no pulses for a 1 or a 0), the Williams tube (a cathode-ray tube with dots stored on the face for data), the capacitor store (where the charge on a capacitor changes with the digital data), a transistor or vacuum-tube memory (where the tube or transistor is either on or off for a 1 or a 0), and the delay line (which takes pulses and delays them until they are needed).

In the *control section*, the implementation of the program is directed. The control unit observes the instructions and plans their proper execution by following the principles of operation for a given machine. This selection may translate a multiply order into a series of additions, which it actually is to the computer.

Both the *input* and *output* devices are similar but they perform opposite functions. An input unit reads information from punched cards, magnetic tapes or special keyboards, and codes this data so that the computer can handle and use the information. The opposite function is performed by the output unit, which converts the results of computer operation to usable form such as typed sheets or punched cards for the control of production machines.

Binary Notation. Binary numbers which represent instructions or quantities for computation are usually presented in the binary or two-value system rather than the decimal system.*

Any on-off device can be used with the binary system. Numbers can represent letters and combinations of letters can, of course, make words, and complete sentences can be remembered.

A look at the ordinary decimal notation is helpful. Table 1 shows what everyone

---

* We count by tens because we have ten fingers but a relay switch, tube, or transistor is either *on* or *off*, which is the reason for the binary (two-number) system. See *After Class* in the January 1958 issue for details of binary system.

1,000,000,000 digits. UNIVAC, for example, has a magnetic tape memory for 86,000,000 digits.

THE HUMAN COMPUTER

A *human* is a computer, and our own methods of calculating resemble both digital and analog. When a child counts on his fingers, he is computing with digits. When you lead a target with a shotgun, you are doing an analog computation. If you lay out a problem on paper, you are preparing a program.

The computer operates very quickly—far more quickly than any human operator—but it requires instructions for each step. In a sense, a digital computer may be thought of as a very fast clerk of limited intelligence.

While the differences between the human brain and the electronic computer (size, reliability, input-output, and organization) are important, the similarities are even more striking. All of the following points are indications of these similarities:

Arithmetic—Both can perform the basic operation of addition and by derivation, subtraction (negative addition), multiplication (repeated addition) and division (repeated subtraction).

Program—Both can and do follow a fixed program, for problem solving and computing.

Decisions—Both can make decisions based upon the need for one or another course of action (a digital computer is good at this).

Storage—Both can store information and transfer information both into and out of storage. Note that the computer has a *completely erasable* memory (no human has this). Since the computer memory can be erased, the computer has no prejudice; it will never prejudge a problem. —30—

BINARY NOTATION

Decimal Values	2^5 32	2^4 16	2^3 8	2^2 4	2^1 2	2^0 1
1					0	1
2					1	0
3					1	1
4				1	0	0
5				1	0	1
6				1	1	0
7				1	1	1
8			1	0	0	0
9			1	0	0	1
10			1	0	1	0
15			1	1	1	1
25		1	1	0	0	1
30		1	1	1	1	0
37	1	0	0	1	0	1

Table 2. Binary system is same as decimal system, but it uses powers of 2 rather than 10. See text.