

IBM



electronics

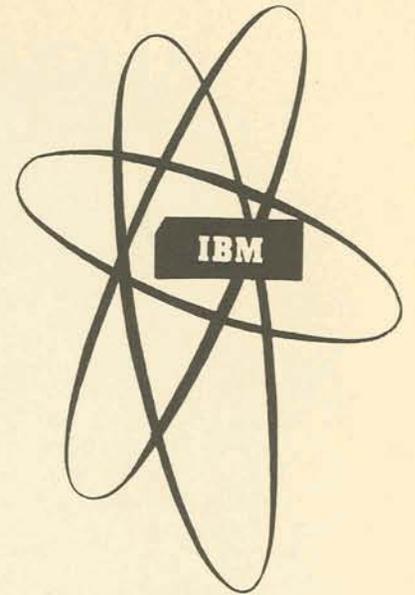
electrons at work

electrons at work

IBM's pioneering research and development in the application of the science of electronics to computing machines has made it possible to produce machines which are hundreds of times faster than calculators based on mechanical principles. Just as these electronic calculators have evolved from knowledge gained in the production of basic IBM Accounting Machines, so has the knowledge gained in the production of electronic calculators made possible the development of better, faster Accounting Machines for commercial and scientific use.

IBM electronic computing facilities now are being used widely, in business offices as well as scientific laboratories, in IBM Service Bureaus as well as in the Technical Computing Bureau at IBM's World Headquarters. For the very largest problems, the Selective Sequence Electronic Calculator is available at IBM's World Headquarters.

To facilitate an understanding of how these electronic calculators are able to perform these computations so rapidly, the following pages describe very briefly the operation of the electronic tube and its application to electronic calculators and business machines.



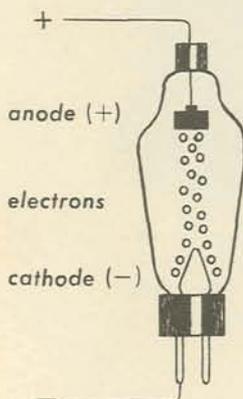
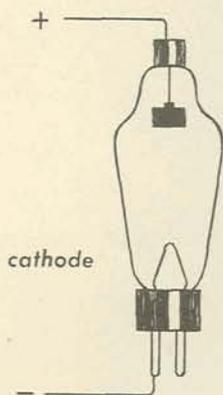
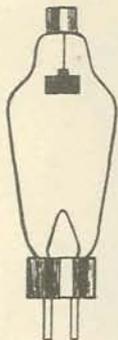
IBM SELECTIVE SEQUENCE
ELECTRONIC CALCULATOR



This machine will assist the scientist in institutions of learning, in government, and in industry to explore the consequences of man's thought to the outermost reaches of time, space, and physical conditions.

J. Watson

electrons at work



As a basic part of the structure of the atom, an electron is the most elementary charge of negative electricity. Electrons are emitted by matter that has been heated, and electronics may be defined as the science concerned with the emission, behavior, and effect of electrons, especially in vacuum or gas-filled tubes.

Electronics is of vital importance to the design of high-speed calculators and business machines. By substituting electronic tubes for moving parts, it is possible to eliminate the mechanical limitations of these parts and perform the required operations at electronic speed.

Electronic tubes do not generate electricity. They control its flow accurately and instantaneously.

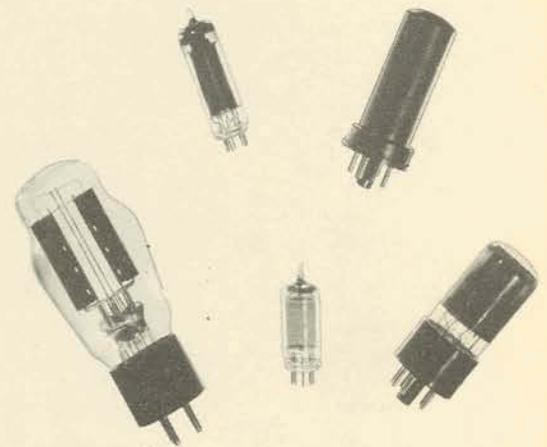
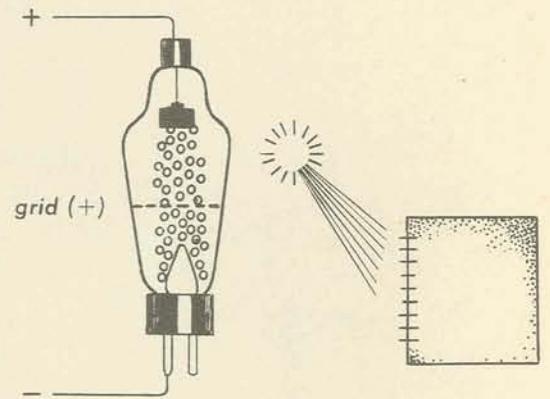
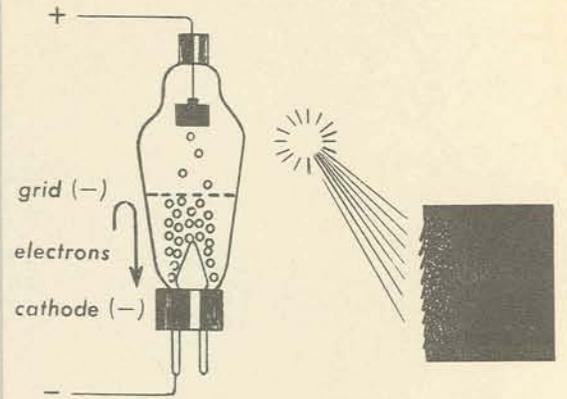
One element of the several which may be found in an electronic tube is made the source of emission of electrons. This is called the cathode.

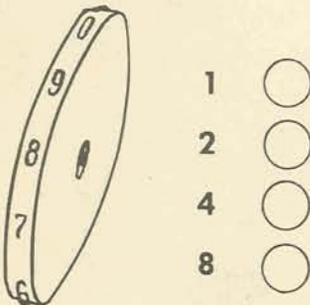
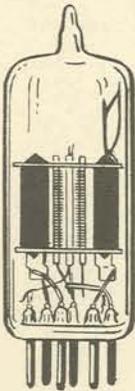
Another tube element, known as the anode, is made positive. When the cathode is heated by an electric current it emits electrons which, being negative, flow to the positive anode.

By introducing a third element, known as the grid, it is possible to control the flow of electrons from the cathode to the anode. This grid acts somewhat like a venetian blind in a window. When a very small electric current makes the grid sufficiently negative, it repels the electrons, much as a closed venetian blind repels the light.

As the grid is made more positive, more and more electrons are permitted to flow through, and the action is similar to the opening of a venetian blind. The grid thus determines precisely the flow of current through the tube.

Electronic tubes have been designed to perform many special functions. Operating at high speed, they have proved particularly valuable in calculators where it is necessary to perform many arithmetical operations for each answer. The fact that electronic tubes react instantaneously to a very small electric current makes them ideal for many other functions where speed and accuracy are important. The following pages describe these specialized functions very briefly.





electronics and calculating

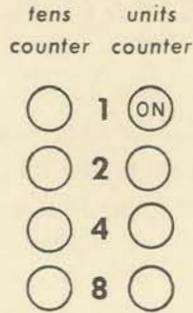
Today's high-speed electronic calculating machines, such as the IBM Electronic Calculating Punch and the IBM Card-programmed Electronic Calculator, are accelerating the progress of science and industry. Capable of operating at many thousand calculating pulses a second, these electronic calculators are able to perform complex arithmetical computations at tremendous speed.

These machines enable scientists and engineers to perform, in a short space of time, calculations that previously would have required months or even years. Just as mechanical devices freed men's hands for more productive labors, these electronic calculators are freeing men's minds from the drudgery of routine computations.

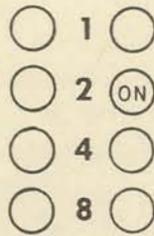
Most electronic counters have as their basic element a double vacuum tube in which both halves are interconnected to form a circuit known as a trigger. The trigger tube always is in one of two stable states. One state may be called *on* and the other *off*. As the tube receives pulses, it changes from one state to the other alternately. The tube will remain in one state or the other until another pulse is received. A trigger tube can be arranged to deliver one output pulse each time it goes off. In this way, two input pulses produce one output pulse.

An elementary electronic counter is composed of four of these trigger tubes with the values 1, 2, 4, 8 assigned to them. Each digit is represented by a different combination of these tubes in an on or off condition. As shown on the opposite page, each pulse applied to the trigger tubes changes the combination to that representing the next higher digit. Such electronic counters easily can accept and count 50,000 pulses in one second.

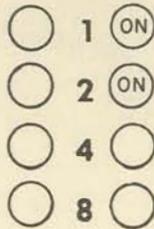
As the **first** pulse, representing a value of 1 is received, the tube representing 1 is turned on.



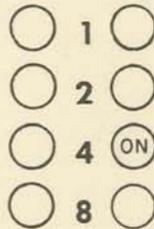
As the **second** pulse is received, the 1 tube turns off, turning the 2 tube on.



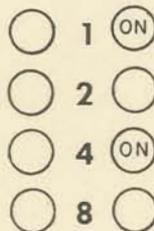
As the **third** pulse is received, the 1 tube turns on, the 2 tube remains on, and the sum of the "on" tubes is 3.



The **fourth** pulse turns off the 1 tube, turning off the 2 tube, and turning on the 4 tube.

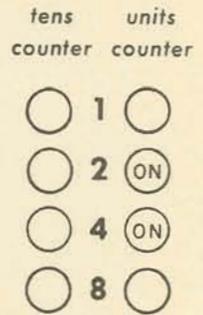


The **fifth** pulse turns on the 1 tube, the 2 tube remains off, and 4 tube remains on.

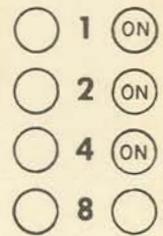


assigned value

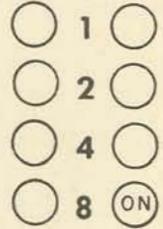
The **sixth** pulse turns off the 1 tube, turning on the 2 tube. The 4 tube remains on.



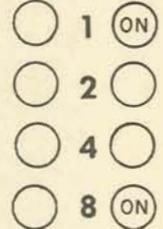
The **seventh** pulse turns on the 1 tube. The 2 and 4 tubes remain on.



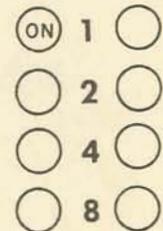
The **eighth** pulse turns off the 1 tube, turning off the 2 tube which turns off the 4 tube which turns on the 8 tube.



The **ninth** pulse turns on the 1 tube, the 2 and 4 tubes remain off and the 8 tube remains on.

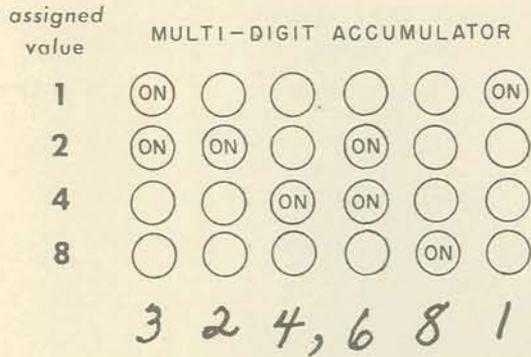


The **tenth** pulse turns off the 1 tube. A locking tube circuit prevents the 2 tube from going on and, at the same time, permits the 8 tube to go off, thus restoring all triggers of the Units Counter to the off position. As the 8 tube goes off, it emits a carry pulse to the 1 tube of the next higher counter (Tens Counter).



assigned value

electrons at work



$$\begin{array}{r}
 6 \\
 6 \\
 5 \times 6 = 6 \\
 6 \\
 \hline
 30
 \end{array}$$

$$\begin{array}{cccc}
 + & - & \times & \div \\
 < & > & = &
 \end{array}$$

These electronic counters, each consisting basically of four trigger tubes, can be combined as a group to form a multi-digit accumulator capable of counting large numbers.

Similarly, groups of trigger tubes are used to store numerical information, by counting pulses received concurrently in each position of a multi-digit storage unit. As required, these numbers are read out of the storage units as a series of pulses which are transmitted to another electronic unit at electronic speed.

Multiplication is repeated addition. This operation is performed electronically by storing the multiplicand in a multi-digit storage unit and then adding this number into an accumulating counter as many times as called for by the multiplier. In an analogous manner, division is performed by repeated subtraction of the divisor from the dividend.

Calculating consists of some combination of addition (+), subtraction (-), multiplication (x), and division (÷). Certain calculating operations also require the recognition of relative values of numbers such as less than (<), greater than (>), and equal to (=). Electronic counters permit the performance of any of those operations as required and are powerful tools for calculating.

other electronic applications

Electronic Amplifiers

The extreme sensitivity of a vacuum tube is used to detect and amplify the small amount of electric current flowing through a conductive mark recorded on an IBM card. Similarly, electronic tubes are used at many points in an electronic machine to amplify a signal and assure positive operation of other electronic units, which must be operated from small signals.

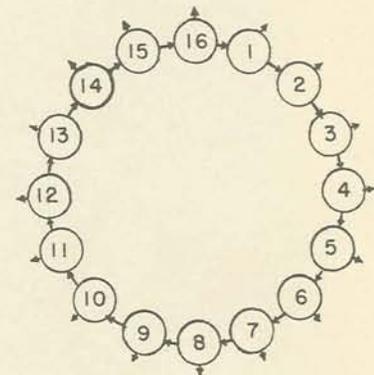
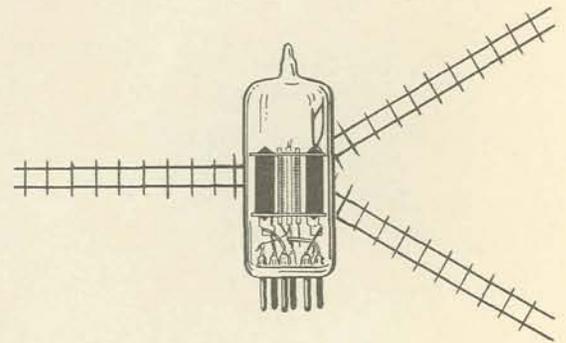
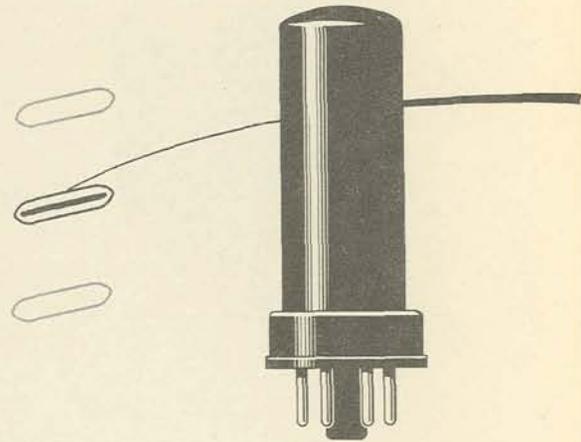
In the high-speed reading of IBM cards, electronic tubes are invaluable because they react instantaneously and positively to the impulses received and control the functions of the machine by amplifying the electrical pulses to the degree necessary.

Electronic Switches

Electronic tubes, with two grids controlling the current to a single anode, act as selectors or switchmen. These tubes only will pass an impulse received on one grid if the other grid is conditioned properly. Groups of such switch tubes are used for such purposes as editing in the Electronic Statistical Machine or column shifting in electronic calculators.

Electronic Timing Control

Groups of electronic tubes, arranged in timing rings, control the sequence of pulses and operations in electronic machines. Actuated by an oscillator or other source of pulses, each tube in the ring turns on successively. As the pulse travels around this electronic ring, it is available for the controlling of machine functions such as addition, subtraction, elimination, and transferring.



The machines shown on the following pages have resulted from an interchange of ideas which is a basic principle of IBM research. In each machine, the principles of electronics have been applied to those functions which could benefit by their application.



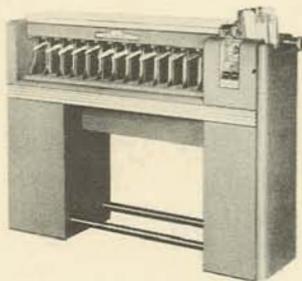
Test Scoring Machine

One of the first business machines to employ electronics, the IBM Test Scoring Machine grades examinations by measuring the flow of electric current through conductive marks on the answer sheets. Electronic tubes amplify the small amount of current which flows through the marks, to actuate a counting device.



Electric Document-Originating Machine

A new advance in creating accounting records was made possible by the application of the electronic mark sensing principle to IBM Accounting. Original facts are recorded on IBM cards. Electronic tubes, in the Electric Document-Originating Machine, amplify the small amount of electrical current passed through these marks to actuate punch magnets. In this way, facts recorded by office or field personnel are translated into punched card records at the rate of 100 cards per minute.



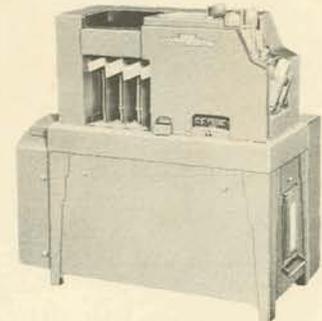
Punched Card Sorter

The application of electronics to the IBM Punched Card Sorter has made it possible to increase the speed of sorting each column to 650 cards per minute. As the IBM cards pass through the machine, a brush senses the holes and completes an electrical circuit with electronic tubes. By the use of these electronic tubes, positive electrical impulses are available instantaneously to control the functions of the machine.

electronic research

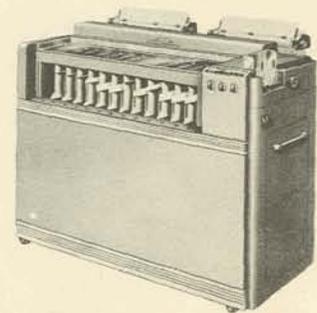
Alphabetical Collator

The Alphabetical Collator employs electronic tubes for the high-speed, accurate reading of alphabetical and numerical information. Operating at a speed of 240 cards a minute, the machine interfiles, compares, selects, and verifies the sequence of IBM cards punched with alphabetical, numerical, or special character designations.



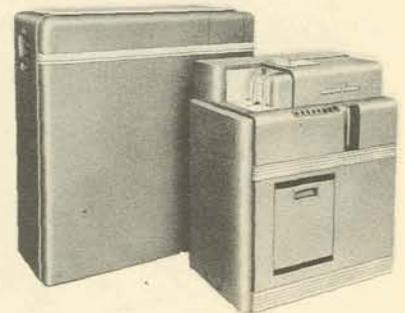
Electronic Statistical Machine

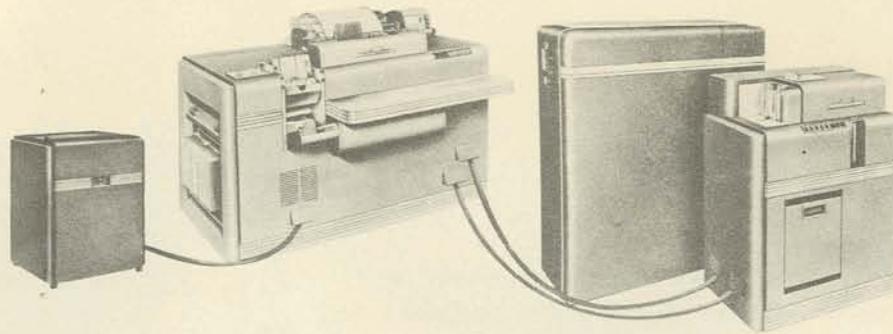
The Electronic Statistical Machine makes use of a special type of electronic tube. This tube has two grids, and both grids must be energized before current can flow through the tube. These tubes act as selectors, or electronic switchmen, and control the flow of number traffic to counters. This is the basis of the machine's editing feature, which automatically rejects and isolates data stating improbable situations.



Electronic Calculating Punch

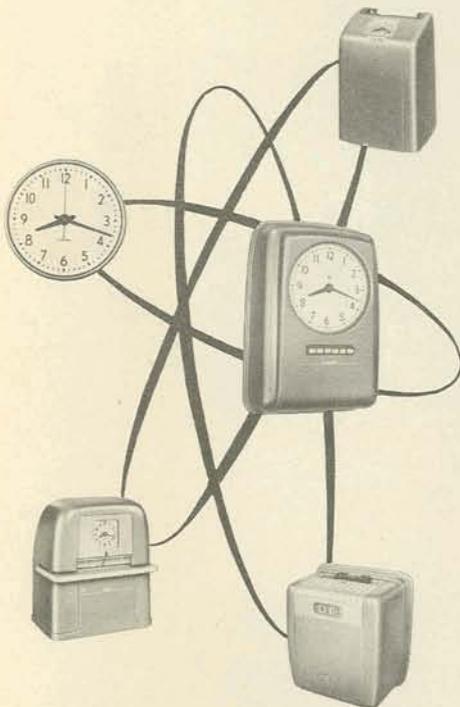
Particularly adapted to parallel type calculations, the all-electronic calculating unit of the IBM Electronic Calculating Punch makes use of many electronic developments. Various types of electronic tubes act as selectors, counters, convertors, and programming and control units. Utilization of these versatile electronic tubes makes it possible for the Electronic Calculating Punch to calculate at 50,000 pulses per second, punch the results in IBM cards at the rate of 100 per minute, and perform up to 60 computing steps for each card.





Card-programmed Electronic Calculator

Through its capacity to remember information stored in its storage unit, the IBM Card-programmed Electronic Calculator permits continuous operation on problems of a sequential or repetitive nature occurring in industrial and scientific computing. The machine consists of an accounting machine, a storage unit, a punching unit, and an electronic calculating unit which, utilizing five digit numbers, computes at a rate of 2,174 additions or subtractions, 79 multiplications, or 65 divisions—in one second.



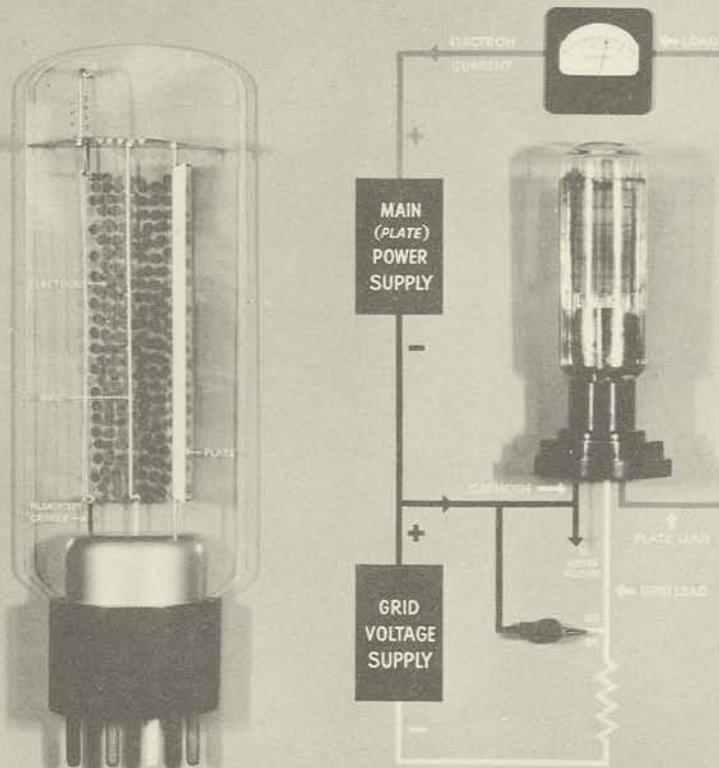
IBM Electric Time System with electronic self-regulation

The application of electronics to the control of IBM Electric Time Systems has made it possible to eliminate the need for special clock wiring and obtain the additional advantages of flexibility. An electronic transmitter, supervised by a master time control, transmits electronic pulses over the regular 60-cycle power supply line to clocks and signals. Each clock and signal has an electronic tube which receives the electronic pulses emitted by the transmitter. These pulses are used to check the clocks' uniformity with system time and correct them, if necessary, and to sound time signals.

On the following pages are shown several display panels developed by IBM engineers to present the story of electronics as used in calculating and accounting machines.

They are displayed at IBM business shows in various cities, in conjunction with demonstrations of electronic and electric accounting machines. A series of switches permits the visitor to observe by actual operation. Through this medium IBM is acquainting thousands of businessmen, scientists, and engineers with the tremendous speed now possible in calculating and accounting operations.

HOW AN ELECTRONIC TUBE WORKS



An electronic tube does not generate current but regulates its flow by means of the grid, which acts as a valve, controlling the flow of electrons as illustrated above.

The cathode when energized emits electrons. These electrons, being negative, flow to the plate which is positive. This flow of electrons is regulated by the grid. When the grid is sufficiently negative, all electrons are repelled. As the grid is made more positive, more electrons are per-

mitted to reach the plate. The grid thus precisely controls the amount of current flowing through the tube. In this demonstration the grid is either completely positive or negative, resulting in an on or off flow of the electric current.

The electronic tube, in contrast to the relay, has no moving parts and operates almost at the speed of light. A very small amount of energy from the grid supply can control a large amount of current flowing through the tube.

VACUUM TUBES USED AS TRIGGERS

A calculator must have a means for remembering or storing numbers. The basic element of memory or storage in the IBM Electronic Calculator is created by interconnecting both halves of a double vacuum tube to form a circuit known as a trigger. One half of the trigger tube (but never both) is always in a conductive state. The trigger will remain in a given state indefinitely until "triggered" to the opposite state.



Above is a trigger tube. Its two stable states are shown by the indicator lamps. Pushing down on the mechanical trigger shown below will change this trigger tube to the opposite state.

A trigger may be so designed that each time a pulse of voltage is applied it will change to the opposite stable state. Normally only one indicator lamp is used since, by being on or off, it indicates both trigger conditions. Therefore, the trigger is said to be on or off in accordance with the indicator lamp. The trigger below is arranged to deliver one output pulse each time it goes off. Thus for every two input pulses one output pulse is produced.

MANUAL AUTOMATIC

TO OPERATE: SWITCH TO "MANUAL" POSITION AND PRESS BUTTON

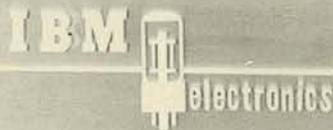


This is a simple mechanical analogy of a trigger. It likewise has two stable states and will remain in either one until forced into the opposite state.

PULSE SOURCE

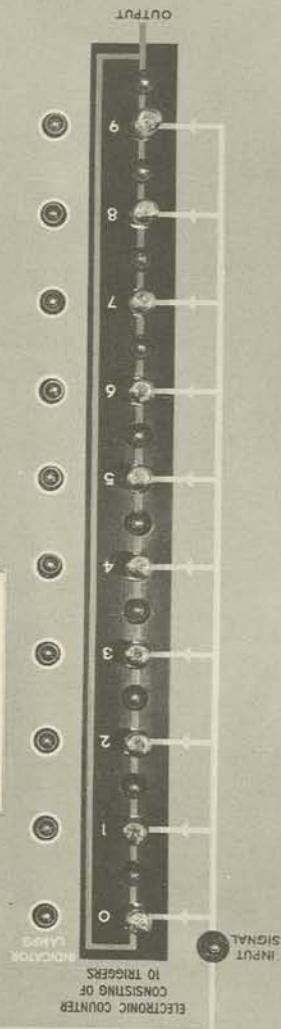
INDICATOR LAMP

OUTPUT

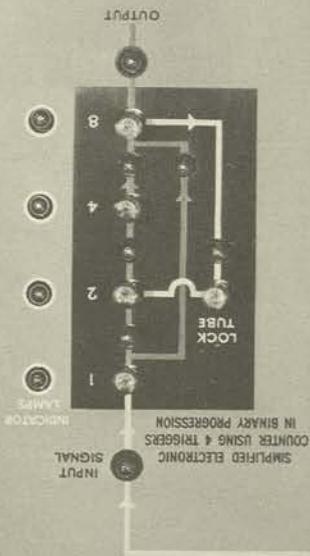




TRIGGERS COMBINED FOR COUNTING



At the left are ten triggers combined for counting and arranged so that only one trigger is on at a time. Each input pulse affects only the trigger which is on, and in turning that trigger off the next trigger is automatically turned on, thereby counting or adding 1. The tenth pulse not only turns the 9th trigger off and the "0" trigger on, but also emits an output pulse which serves for carry-over to the next counter position.



The counter shown above is the type of decimal counting device used in the IBM Electronic Calculator. Four and one-half tubes produce the same result as the ten tubes in the electronic counter at the left. From "0" to "9" the operation is simply that of four triggers in cascade or sequence. However, in a normal cascade as the tenth pulse turns the first trigger off, the second trigger would be turned on, leaving a count of $8 + 2 = 10$. To achieve a "0" indication on the tenth pulse an auxiliary circuit causes the output of the first trigger to turn the fourth trigger off. A lock tube controlled by the fourth trigger prevents the second trigger from going on. Every time the fourth trigger goes off, an output pulse is produced, thus giving one output pulse for every ten input pulses.

MANUAL AUTOMATIC

COUNT KEY RESET

TO OPERATE, SWITCH TO "MANUAL" POSITION AND PRESS BUTTONS

AN EXPLANATION OF THE BINARY SYSTEM

When man first learned to count, he began by associating objects with his fingers and toes, and as a result developed a number system based on 10. Actually, a number system can be made using any number as its base. When one counts by dozens and gross, or divides the foot into 12 inches, or the year into 12 months, a system based on 12 is being used. The binary system uses the number 2, and is often favored by engineers because it requires the least possible number of tubes to represent any given value.

The binary numerical system used in electronic counters assigns to successive tubes the values 1, 2, 4, 8, 16, etc., with each tube having a value twice that of the one before it. More than one tube can be on at the same time, and the number in each case is the sum of the values of the tubes which are on. For example, when the first tube (representing 1) and the third tube (representing 4) are on, the number is 1 plus 4 or 5.

The chart below shows the tubes which are on for each number "0" to "9" in the binary system. By using sufficient numbers of tubes, amounts of any size can be represented.

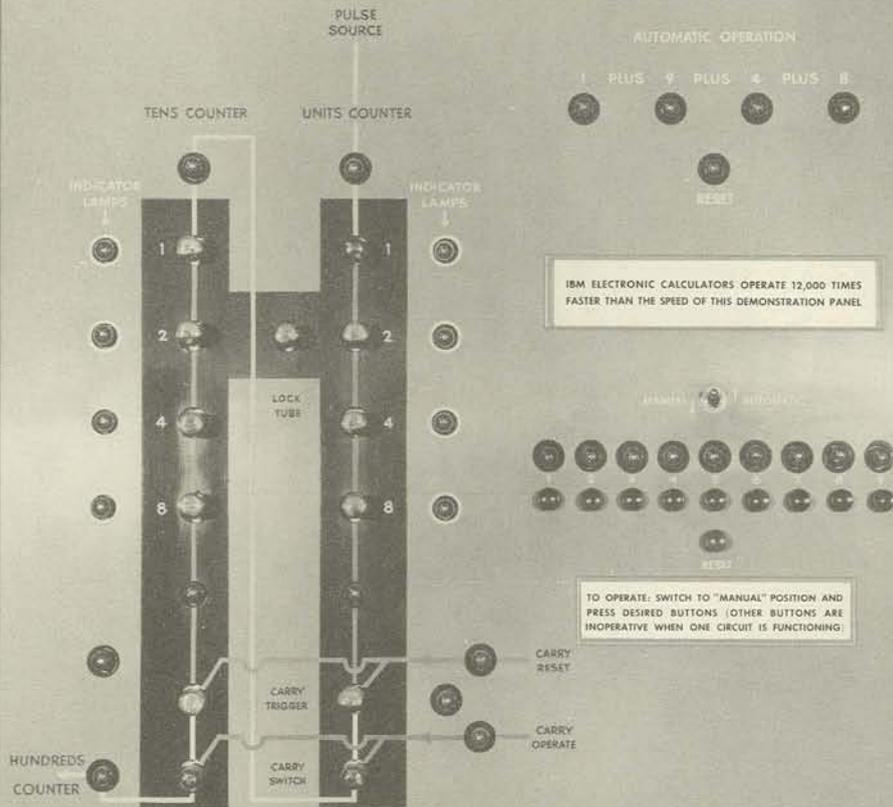
DECIMAL NUMBER	0	1	2	3	4	5	6	7	8	9
FIRST TUBE (VALUE 1)	●	●	●	●	●	●	●	●	●	●
SECOND TUBE (VALUE 2)	●	●	●	●	●	●	●	●	●	●
THIRD TUBE (VALUE 4)	●	●	●	●	●	●	●	●	●	●
FOURTH TUBE (VALUE 8)	●	●	●	●	●	●	●	●	●	●

The binary system is employed in the IBM Electronic Calculator to reduce from 10 to 4 the number of tubes required to express values from 0 to 9 in each individual counter position. It is not used beyond 9 because of the necessity to print answers in the decimal form. Therefore, we refer to it as a modified binary representation. Similar sets of 4 tubes are used for each counter position. A set of 4 tubes could represent the numbers up to 15 (1 plus 2 plus 4 plus 8 equals 15), but through the use of a fifth "locking" tube, each counter position is arranged so that instead of passing from 9 (1 plus 8) to 10 (2 plus 8), the counter position restores to 0 (all tubes off), and emits a carry impulse to the next higher counter position. In this way, the results printed or punched are in decimal form and are indistinguishable from what would have been obtained if 10 tubes had been used for each counter position.



HOW AN ELECTRONIC COUNTER WORKS

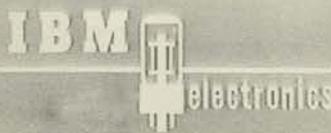
To read the amount in the counters: Add the values shown beside the illuminated indicator lamps



IBM ELECTRONIC CALCULATORS OPERATE 12,000 TIMES FASTER THAN THE SPEED OF THIS DEMONSTRATION PANEL

TO OPERATE: SWITCH TO "MANUAL" POSITION AND PRESS DESIRED BUTTONS (OTHER BUTTONS ARE INOPERATIVE WHEN ONE CIRCUIT IS FUNCTIONING)

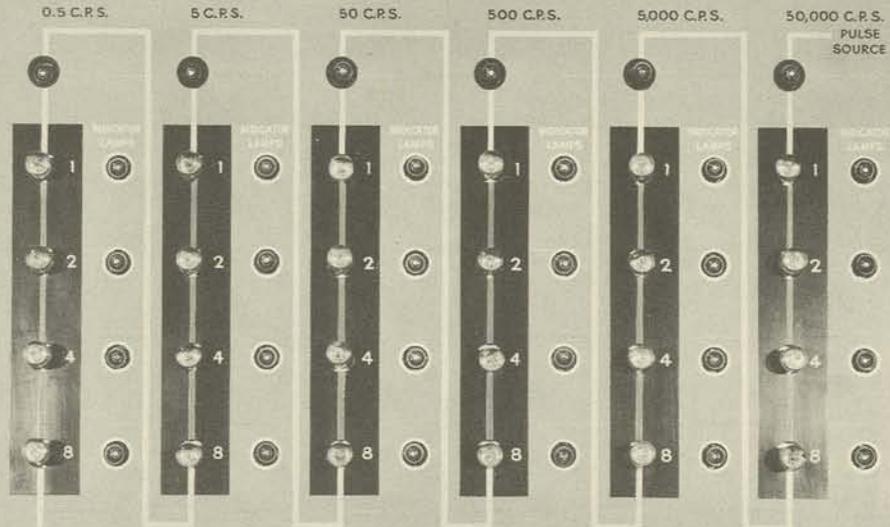
Provision for carry-over makes the four and one-half tube storage device a true counter. Usually the output pulse is stored in a "carry" trigger and, by means of a "switch" tube, is transmitted to the input of the next higher order counter after the adding portion of the cycle.



ELECTRONICS

THE FASTEST CALCULATING MEDIUM KNOWN TO MAN

ONE MILLION PULSES EVERY 20 SECONDS



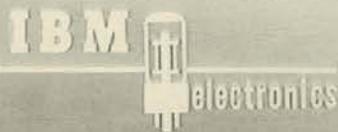
Each electronic counter above operates ten times as fast as the one at its left, portraying the tremendous speed (50,000 cycles per second) of the IBM Electronic Calculator.

To demonstrate the speed at which electronic counters in the IBM Electronic Calculator normally operate, six electronic counters are arranged so that the output of one is used to drive the second, its output in turn to drive the third, and so on. This is the electronic equivalent of the six position mechanical counter at the left. *One million electronic pulses produce one output pulse shown at the left which operates the mechanical counter, advancing it one digit every twenty seconds.*

OUTPUT PULSE

9 9 9 9 7 1 0 0 0 0 0 0

AUTOMATIC OPERATION



electrons at work



IBM
TRADE-MARK [®]

INTERNATIONAL BUSINESS MACHINES CORPORATION
World Headquarters Building • 590 Madison Avenue, New York 22, N. Y.

Form No. 52-8037-0-20M—5/50-P



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