

# An Introduction to the Bell System's First Electronic Switching Office

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A FULLY electronic telephone central office is being developed for experimental Bell System service. Both the electronic devices themselves and their system organization represent major changes in the art of telephone switching. The electronic switching system consists of electronic voice frequency switches controlled by electronic memory and logic. However, the system is not designed on the basis of direct substitution of electronic circuits for corresponding relay circuits of an existing switching system. Rather, the electronic circuits are organized in ways that exploit the advantages of the electronic technology.<sup>1</sup>

One of the obvious differences between the electronic and the electromechanical switching technologies is simply speed of operation. The electromechanical devices such as relays operate in times measured in milliseconds, often many milliseconds. The operate times of electronic devices such as transistors are measured in microseconds, often small fractions of a microsecond. Thus, the relative speeds differ by a ratio of well over 1000. This dramatic difference in speed permits a given amount of electronic equipment to handle much more telephone traffic than a corresponding amount of relay equipment. The high-speed operation also permits the system designer to organize the electronic system quite differently and often much more efficiently.

Comparison of existing types of electromechanical systems with the electronic system now under development shows that in the electronic system the various equipment units are much more specialized. This functional concentration or specialization of function is well illustrated by the case of memory. In relay systems the memory function is widely dispersed throughout the system. For example, in a modern relay switching system, memory functions are performed in all of the various kinds of circuits. In the electronic system much of the memory function is concentrated in two memories, one temporary and one permanent, which perform most of the memory functions for the system.

In a similar manner most of the logical operations of the electronic system are performed in a single functional unit. Again this contrasts sharply with electromechanical systems whose relay contacts are used for logical operations in all parts of the system.

Functional concentration permits the electronic system to be organized into a group of major components, each of which performs some single major system function. These equipment units can thus be designed to perform their function very efficiently and, because of the high speeds, perform it for the entire system. A further result is the simplification of the interconnections between the various equipment units. The number of wires connecting these units together is measured in tens rather than the hundreds or even thousands of wires often used in relay systems. The electronic system has a further advantage of understandability by virtue of the simplified relationships among the functional units.

Most of the signals that flow between units can be described as a combination of an action and an address. The address gives the location at which the action is to be performed. For example, the temporary memory might receive an order to write or read at a particular memory site. Alternatively, the switching network might receive a set of signals representing the action of "connect a voice path" and the addresses or identities of the terminals to be joined.

## SYSTEM OPERATION

A block diagram of this electronic switching system is shown in Fig. 1. The memory and logic units are separated from the voice switches and gain access to lines and trunks only through the scanner and selector. The scanner and selector are multiposition diode switches which may be directed to particular terminals for collecting or transmitting information. The function of the scanner and selector is to permit the fast control circuits to be time shared among the telephone customers. Information gathered by the scanner is processed by the controls and results in orders to the switching networks or to trunks via the selector. At any instant the system is usually engaged in processing only a part of a single call. Simultaneous actions involving more than a single call rarely occur.

In order to meet the real-time demands of the telephone customers, some system actions are given higher priorities than others. For example, it is more important to count a dial pulse than to detect a call origination because of the transient nature of the dial pulse. Thus, in each 5-msec interval, the system goes through its more urgent tasks first and then, if it has time, completes its less pressing commitments. The cycle time for any single logic memory, or scanner function is 2.5  $\mu$ sec. While this provides 2000 operations in each 5-msec interval, many of the tasks take

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<sup>1</sup> A. E. Joel, "Electronics in telephone switching systems," *Bell Sys. Tech. J.*, vol. 35, pp. 991-1018; September, 1956.

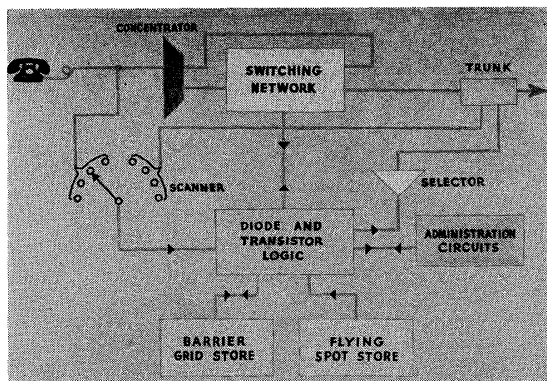


Fig. 1—Electronic switching system block diagram.

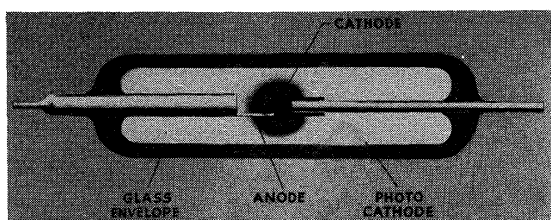


Fig. 2—Gas diode electronic crosspoint.

a number of operations to complete. Further, the number of tasks varies sharply with the telephone traffic. In a typical interval the system would first scan about half of the lines which are dialing in order to gather and record any new dial pulses. Next would come selector actions involving, perhaps, pulses being sent out on trunks to other offices. Then, any traffic awaiting network action might be completed. If this exhausts the interval because, for example, a large number of dial pulses occurred, then the system immediately goes back and repeats these high priority tasks in the next interval. This defers the lower priority tasks, but not for long since the probability that two successive intervals will both be overloaded is low. In the second interval the other dialing lines are scanned, and so forth. Then, lower priority tasks such as regeneration of the barrier grid stores, scanning of all lines for call origination, etc., are completed.

These actions result in all lines being scanned ten times a second for call origination. If a line is found which is drawing current but which the memory reports was idle on the last look, the controls recognize a service request and record the situation in the memory. The presence of this line number in the memory results in the line being scanned 100 times a second during dialing. The higher scan rate is required to insure detection of all dial pulses.

#### SWITCHING NETWORK

The switching network and the associated concentrator network provide the voice frequency paths for interconnecting telephone lines with each other and with trunks and various signals (ringing, dial tone, etc.). The switching element is a cold-cathode gas tube as shown in Fig. 2.

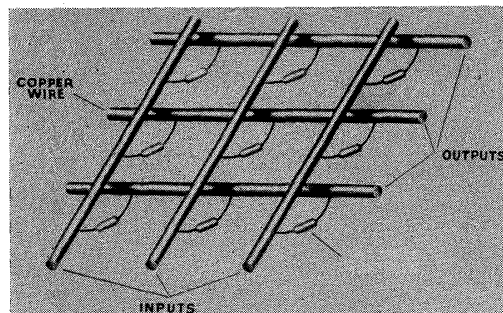


Fig. 3—Gas diode switch.

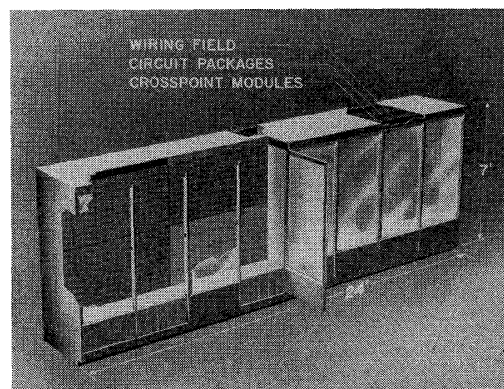


Fig. 4—Cabinet arrangement for the switching network.

It is a neon-filled diode utilizing a hollow cathode to obtain negative resistance in the conducting condition.<sup>2</sup> This tends to compensate for transmission losses of transformers and other elements in the talking path. These gas tubes are arranged into switches of the type shown on Fig. 3. Application of one half of the breakdown voltage on an input and an output wire causes the gas tube joining these wires to fire and connects the wires for speech transmission. Only one side of the transmission circuit is switched, the other side being grounded. Large numbers of these switches are connected together to form the complete network. A typical connection would be through one tube in a concentrator switch, then through six tubes in the switching network, and finally through one tube in a concentrator switch to the other telephone. Fig. 4 shows the physical form of the switching network. The gas tube crosspoints and the control circuits are assembled in plug-in packages which are then inserted in the cabinet. This permits easy maintenance and growth.

#### LOGIC

In general, the circuitry used for the processing of control information in the electronic switching system can be characterized as asynchronous and dc coupled, using germanium-alloy junction transistors as the active elements.

<sup>2</sup> W. A. Depp and M. A. Townsend, "Cold cathode tubes for audio frequency signaling," *Bell Sys. Tech. J.*, vol. 32, pp. 1371-1391; November, 1953.

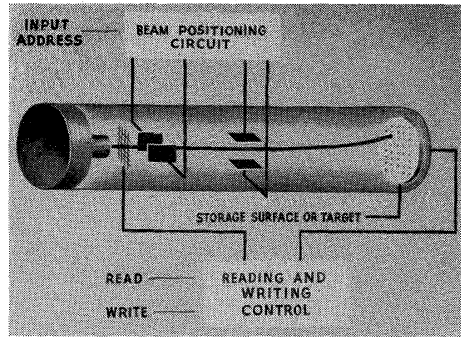


Fig. 5—Barrier grid store block diagram.

It is constructed of small general purpose circuit packages which are interconnected in accordance with the system control operations to be performed.

Logical operations are performed by conventional semiconductor diode AND and OR gates. To permit standardization of the design of these gate circuits, transistor gate amplifiers are placed in chains of diode logic to maintain appropriate signal levels. Bit storage associated with the logic circuitry consists of groups of double-ended flip-flops. These transistor flip-flops are coupled to the diode logic circuitry and to external circuitry composed of relays, gas tubes, or magnetic cores through specially designed amplifiers. Other miscellaneous circuit packages include inverters, emitter followers, pulse stretchers, and cable pulsers.

Most of the logic circuit packages are based upon grounded emitter transistor configurations in which the transistors are held out of saturation by self-biasing or diode feedback arrangements. This permits high-speed pulse operation at reasonable gains (0.5- $\mu$ sec rise and fall times with current gains of approximately 15 in the gate amplifier).

The logic circuit packages are physically laid out on printed wire boards with all components crimped around the edge and dip soldered. The circuit boards are all jack mounted in the equipment. Both cards and jacks are coded to prevent improper interchange of packages. A shoe is provided on each card using transistors, the removal of which permits the transistors to be tested without unsoldering their leads.

#### THE TEMPORARY MEMORY

Two general types of memory are provided, temporary memory and permanent memory. The temporary memory is used to record data which must be changed in the course of processing a telephone call. Conversely, the information recorded in the permanent memory is not changed during a call, although numerous references to this permanent information may be required. The distinction between these two forms of memory is therefore based not on reading but rather on their writing characteristics. In the temporary memory, information may be recorded in little over 1  $\mu$ sec whereas several minutes are required to change information stored in the permanent memory.

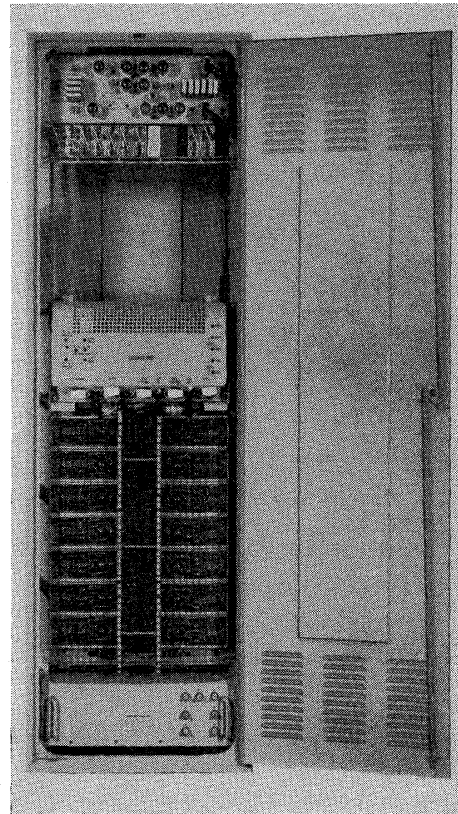


Fig. 6—An early model of the barrier grid store.

The temporary memory device used in the electronic switching system is the barrier grid tube.<sup>3</sup> This is an electrostatic storage tube wherein binary bits of information are recorded as electrostatic charges. An electron beam and electrostatic deflection plates provide access to the individual storage areas on a mica target. Writing is controlled by manipulation of the electric field at the mica surface.

The complete barrier grid store, shown in Fig. 5, consists of the barrier grid tube, deflection circuits to position the electron beam, circuits to turn the electron beam on and off and to pulse the target, an amplifier for the output signal, and control circuits to cause the various operations to occur in the correct sequences and at the right times. The barrier grid stores now operating are capable of storing 16,384 bits in a 128 by 128 array. In addition, the functioning times are quite short: 0.4  $\mu$ sec to deflect the beam; 0.7  $\mu$ sec to erase, of which only 0.3  $\mu$ sec is required to read; and 0.7  $\mu$ sec to write. The typical cycle is to read and then write at a given address, and this requires less than 2  $\mu$ sec. Fig. 6 shows an early model of a store having these characteristics.

#### THE PERMANENT MEMORY

In the electronic switching system there is a need for millions of bits of storage with access for reading in no

<sup>3</sup> M. E. Hines, M. Chroney, and J. A. McCarthy, "Digital memory in the barrier-grid storage tubes," *Bell Sys. Tech. J.*, vol. 34, pp. 1241-1264; November, 1955.

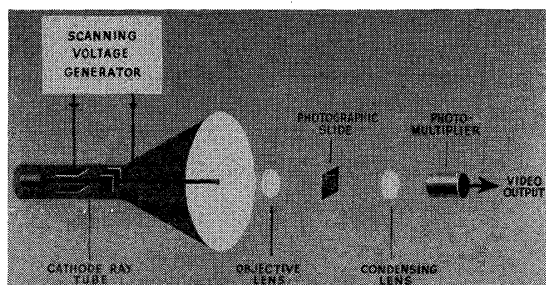


Fig. 7.—Television flying spot scanner.

more than  $2.5 \mu\text{sec}$ . This information is of a semipermanent character and, for reliability, must not be lost by any failure of an electronic element. Storage of a photographic character was developed to meet this need. A group of photographic plates can store vast amounts of information as transparent or opaque spots and, with optical interrogation, an electrical malfunction cannot cause a loss of the stored information. Fig. 7 shows an example of a type of photographic storage, the flying spot scanner used in television. This represents a method for converting the transparency of a selected area on a photographic emulsion into an electrical signal. As shown in Fig. 8, the flying spot store uses similar techniques to read a number of photographic areas simultaneously.

In the photographic memory under development, over forty photographic areas 1.5 inches square are used to hold approximately three million bits of information. Each area is an array, 256 by 256, and individual spots are approximately 0.006 inch in diameter. Each photographic area has associated with it a lens to focus the spot of light from a cathode-ray tube. By use of a multiplicity of lenses in front of the same cathode-ray tube, a number of photographic areas can be interrogated simultaneously. Quick random access to any of the 65,536 words is achieved by electrostatic deflection of the cathode-ray beam.

In order to achieve practical photographic storage it is necessary to find means for positioning the small spot of light on the face of the cathode-ray tube to an accuracy and reproducibility of less than  $1/1000$  of an inch and in times of the order of a millionth of a second. This problem has been solved successfully. The basis of the solution is an optical-electrical feedback system which uses mechanical edges as the references for spot positioning. Fig. 9 is a photograph of an early model of the flying spot store.

#### CONTROL BY A STORED PROGRAM

The use of a stored program in place of wired logic is made possible by high-speed, random access, large capacity, permanent memory. The complexities of a telephone office are such that hundreds of thousands of bits of program are required. The real-time nature of the system requires fast random access, even though the stored information is changed infrequently. This substitution of memory for logic makes the remaining wired logic become a general purpose unit for interpretation and routing of order

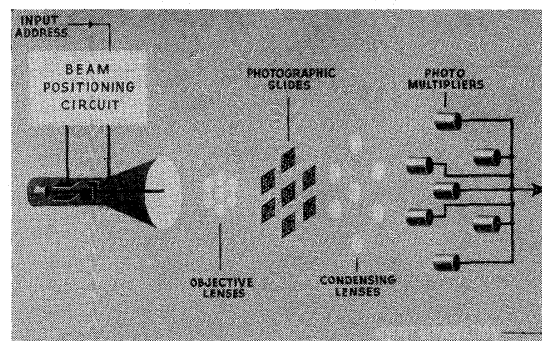


Fig. 8—Flying spot store block diagram.

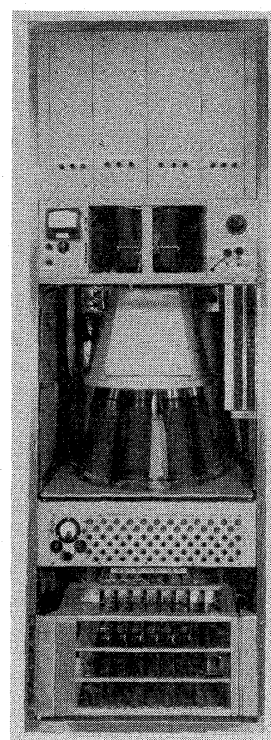


Fig. 9—An early model of the flying spot store.

words. Thus, the machine problems are solved not by "logic" but by looking up the answers in the "back of the book." The stored order words thus control the system sequences and decisions for both telephone calls and internal trouble detection and location. The advantages of the use of a stored program are reduced system complexity, fewer variations in manufactured units, reduction in wired options, simplified engineering of particular installations, and great flexibility. This flexibility permits the addition of new features and changes in control sequences with little or no change in hardware. The electronic switching system can be programmed to perform a wide variety of complex tasks and to render telephone service in a wide variety of ways. Changes in operation or provisions of new services are achieved by modification of stored information rather than by changes in wired connections. This same ease of modification is also useful for changes in line