Some of the busiest and most versatile switching machines in the Bell System are PBX's. The 756A, newest of the dial PBX's developed at Bell Laboratories, uses modern crossbar circuitry as a basis for its small size, simple operation and diverse communication services.

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CROSSBAR CIRCUITRY FOR A SMALL PBX

A private branch exchange (PBX), often called simply "a switchboard," functions essentially as a small central office. But because of its location — the customer's premises — the PBX presents a unique challenge in design. The development engineer must make the utility of a central office compatible with the appearance, ease of operation, and small size characteristic of the customer's other office equipment.

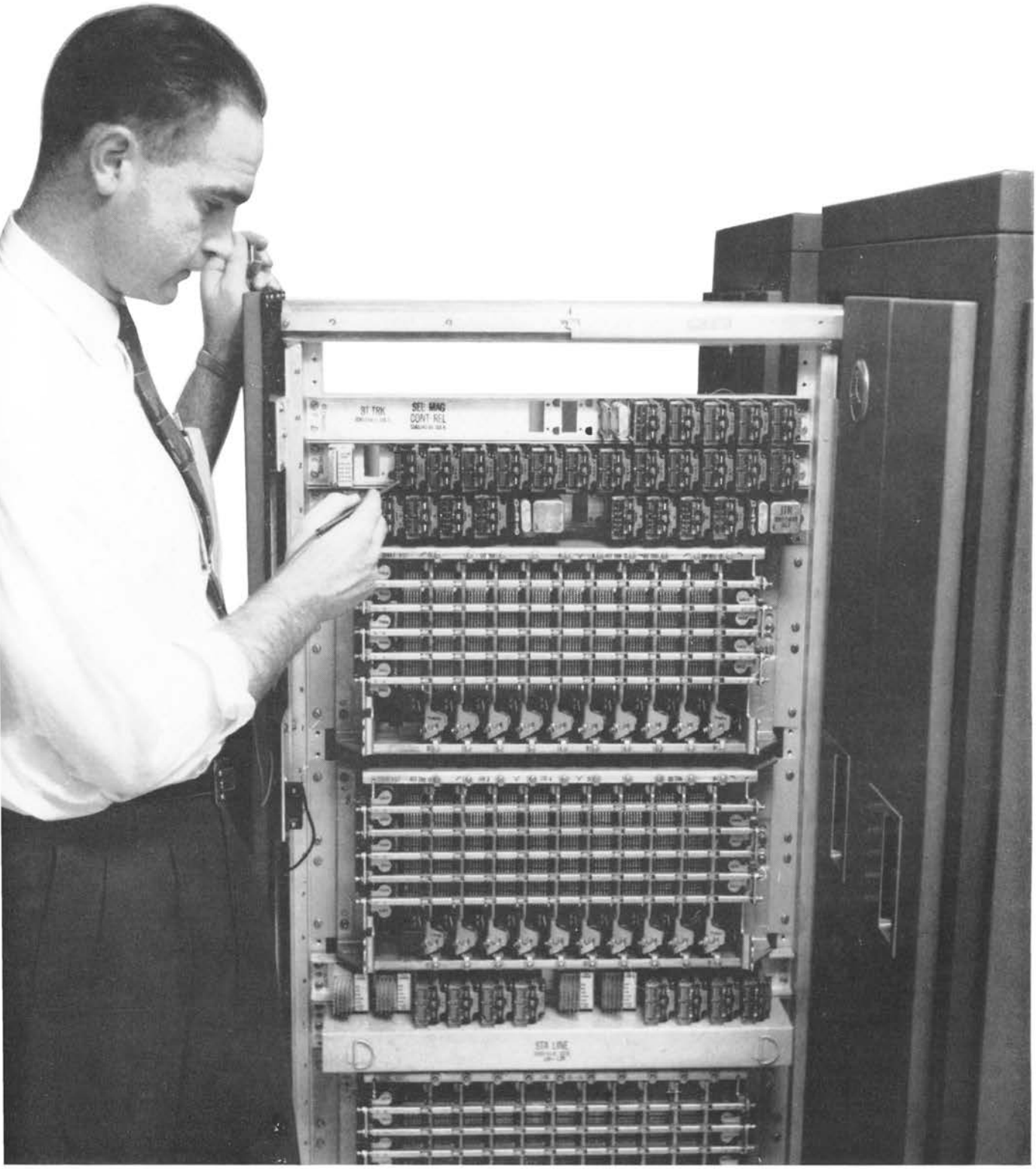
Because it is designed to occupy standard office space, the size and appearance aspects of PBX design assumed more than usual importance in the development of the 756A PBX (RECORD, *December*, 1957). This new dial PBX was designed to serve customers requiring between twenty and sixty extensions and up to ten central-office trunks. It is the smallest "packaged" dial PBX offered to Bell System customers having more than twenty lines. Bracketing the 756A in size are the smaller 755A PBX (RECORD, *June*, 1933) and the next-larger 740E PBX (RECORD, *October*, 1951). Along with the need for compactness and appearance, the system plans called for two other important requisites in the final design of the 756A: (1) reduced operating effort on the part of the attendant, and (2) more versatile communication services.

Engineers at Bell Laboratories studied several different switching arrangements to find a system that would satisfy the size and service requirements of the equipment, and yet be economical. Step-by-step and electronic switching schemes were surveyed, as were several types of crossbar switching. The electronic arrangements that were studied were eliminated for the present because many of the required components would not be available in time for reasonably early production.

The plan that evolved from these studies, and the one that is used in the new PBX, is a crossbar switching arrangement with sixteen links that have full, direct access to all lines, trunks and tie trunks. The 756A uses crossbar switches to form connecting paths through the system, and uses common-control circuits to process the dialed information and to operate the switches that establish the talking path.

The most important of these common-control circuits is the "marker." Like its namesake in the No. 1 and No. 5 crossbar systems, the marker locates the lines of calling stations, tests lines to see if they are "idle" or "busy," locates available links, junctors and trunks, and controls the interconnecting of these elements with the lines. Another important circuit in the common-control group is the "dial-pulse register." Registers are used to count and store dial pulses and to supply dial tone to lines requesting service.

The arrangement of the control and trunk circuits and the crossbar switches is shown in the diagram on page 25, along with the marker



The author checks a control-circuit relay at top of "slide," which contains four crossbar switches. Slides were designed to simplify local maintenance.

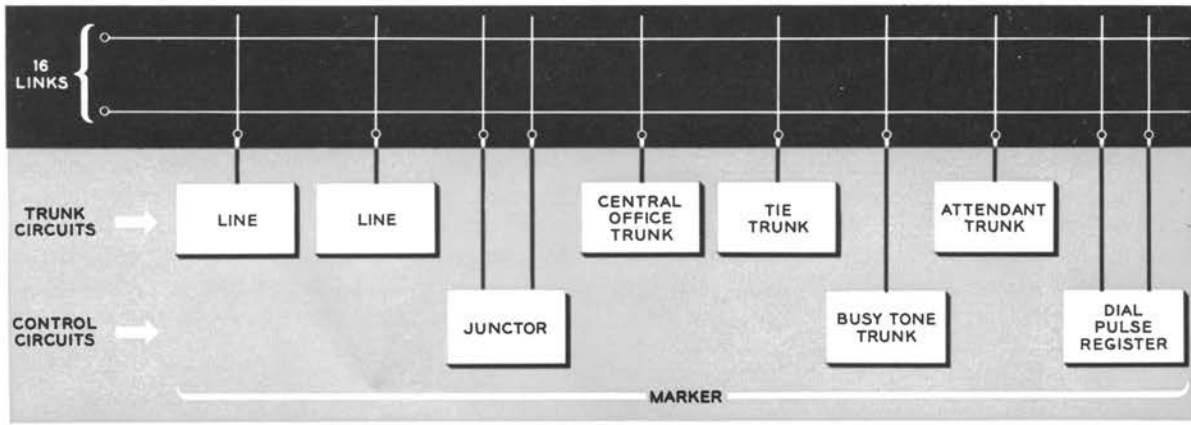


Diagram of linked crossbar switches showing approximate relationship of connecting and control circuits. As diagram shows, all common-control circuits are under the control of one marker.

circuit. Included among the connecting elements are "junctors" which supply ringing and talking power to the connected lines; central-office trunks which connect extension lines or the tie trunks of the PBX to the central office; and attendant trunks that connect tie trunks or extensions to the attendant's console.

The crossbar switches used in the 756A are the conventional ten-by-ten (ten "horizontals" and ten "verticals") switches used in both the No. 1 and the No. 5 crossbar systems. Physically, the crossbar equipment is arranged on sliding racks as shown in the photograph at the left. Electrically, the crossbar switches are wired together as though the entire group of connecting links were one, long crossbar switch with ten horizontals and numerous verticals.

All of the communication circuits that can be connected through the PBX are wired to the verticals. This arrangement permits any of the lines or circuits appearing on the verticals to be connected to any of the other circuits by any of the horizontals. The ten horizontals are wired in a special way that makes available sixteen links.

This method of wiring the crossbar switches, illustrated in the second of the diagrams with this article, is also used in the No. 1 and No. 5 crossbar systems. As the diagram shows, a pair of horizontal paths are wired on each of eight of the ten horizontals. The two remaining horizontals are used to control which one of the pair of paths is used. This wiring arrangement increases the number of available crosspoints per crossbar switch from 100 (10 x 10) to 160 (16 x 10). These 16 horizontal paths carry all the calls through a 756A PBX.

Despite the compactness of the equipment, all of the circuits for the new PBX were designed to work as simply and independently as possible. At the same time, the circuits provide adequate assurance of reliable operation in spite of such troubles as dirty relay contacts and false connections between adjacent terminals. Maintenance on the customer's premises was the important consideration in stressing simplicity and reliability in the circuit design.

The 756A PBX, like the smaller 755A, has only a single marker to set up all calls. Where so many lines and trunks are controlled by a single circuit, however, safeguards must be provided to insure continuous service. One safety feature in the circuits is the provision of enough access channels to prevent a single trouble from affecting service to more than ten station-lines.

In the marker, the vital portions of the circuit are furnished in duplicate and function in parallel. A failure in any of the vital parts of the marker will cause an alarm, but the duplicate part of the circuit will complete the call. Specifically, if any of several relays important in the operation of the marker fail to operate, another relay will operate to perform that function. Any relay failure will cause an alarm.

A "second trial" feature is also included in the PBX. This means that if the marker finds improper continuity in a connection being set up, the connection is released and another attempt made to establish it by using a different link and a different trunk or junctor. If the call cannot be completed on the second attempt, the marker will connect the calling line or trunk to busy tone.

After the second trial, the marker releases and serves other waiting calls, even if the call cannot be completed to busy tone. Troubles, such as the failure of a marker relay to operate, must occur on two successive uses of the marker before the

trouble alarm is operated. This arrangement prevents momentary troubles from causing unnecessary alarms.

Although it is one of the smallest PBX's, the 756A offers customers all of the usual PBX services. With a dial PBX, customers connected to the system can avail themselves of a number of services by dialing a predetermined one- or two-digit code. These services include station-to-station calls, calls to other PBX's connected by tie trunks, calls to and from the telephone central office, dial conferences, paging, code calling, telephone dictation, recorded announcements and "class-of-service" treatment of the lines.

In addition to these many station features, the 756A PBX is outstanding in its small, modern, easily operated facilities for the attendant. The PBX attendant's principal job is to handle calls incoming from the central office. Each call appears at the attendant's console (*see photograph on opposite page*) as a lamp signal with an auxiliary ringing signal. She answers the call by pressing the "pick-up" button near the lighted lamp.

To complete an incoming call to an extension, the PBX "operator" merely presses the "hold" button, and then dials the two-digit number of the called telephone. She disconnects by pressing the pick-up button of another trunk, or if no call is waiting, she disconnects by pressing the common "release" button. The connection is automatically released when the parties hang up.

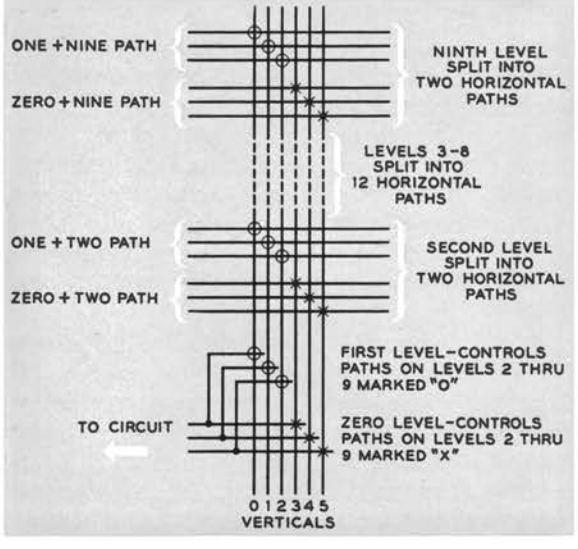


Diagram showing how 10 horizontals are arranged to form (and control) sixteen links. Crosspoints on Level 0 or Level 1, as well as those on Levels 2 through 9, must be energized to complete a connection through the switch.

The central-office trunks of the 756A are arranged for "delayed-through supervision." This means that on a call which has been completed by the attendant, the PBX customer can recall her to the connection by "flashing" the switchhook. This flashing will not cause a disconnect signal to be transmitted to the central office. A single operation of the switchhook will cause the trunk to flash a lamp at the attendant's position at 120 interruptions per minute, and will also sound an audible "recall" signal at the console.

On toll calls made from a PBX, toll operators sometimes have occasion to "ring back." The 756A is arranged so that a ring back on calls originated without assistance from the attendant will signal the calling station. If the attendant was involved in originating the call, the ring back will call in the attendant. The attendant can then re-supervise the call or write a "ticket" for it.

The attendant's console of the 756A PBX has a minimum of controls. The hold button, operated to call in dial tone to complete a call into the PBX, is also arranged to release the inward connection in case a dialing error was made or a different station is desired by the trunk.

In a sense, this operation is similar to the floor switch that changes the headlights from high to low in an automobile. The first operation connects the attendant inward to the PBX; the next time the button is pressed the inward connection is released; the next operation again connects the attendant inward, and so on. The state of the call (and the button) at any given time is easily determined by the lamp signals and the audible tones at the console.

Another arrangement that simplifies the attendant's console is the automatic establishment of a "split" connection when the attendant connects a trunk to one of the lines of the PBX. With a split connection, she can announce the call to the station without the outside party "listening in." If the attendant does not want a split connection, she momentarily disconnects, and on returning to the call she is bridged on the connection between the trunk and the station. This feature avoids extra control buttons on the console for arranging split or bridged connections.

A new service of particular interest to customers is "camp-on." If the attendant, in extending an incoming call to a PBX line, finds the line busy, the circuits will automatically camp-on the busy line. The held call will then automatically "cut-through" to the busy line as soon as it becomes idle.

Aside from assuring the calling customer a

Mrs. H. Kuhl demonstrates how an attendant releases an incoming call by pressing the "RELEASE" key. Additional six-key modules may be added to this new PBX console unit.

priority on the busy line and reducing his holding time to a minimum, the camp-on feature frees the attendant to handle other calls and automatically does the job of monitoring incoming calls that are held. A lamp flashes once every second to advise the attendant that the call has not yet been completed, and she in turn can make reports to the calling party.

If the attendant finds a line busy, and another call camped-on as well, she receives an indication of this situation by a two-per-second lamp flash. She then informs the customer that someone is already waiting. If the customer so requests, she completes the call to another station or she holds the call with the regular hold button and puts it through later.

The circuits that make possible the camp-on arrangement use three different potentials on the "sleeve" leads of the crossbar links. The link-test connector circuit places —48 volts on the sleeve leads of all links. All idle links have the same potential, —48 volts, on them, but the busy links will have only about —5 volts. When the marker is attempting to establish a camp-on call, it places a direct ground on the sleeve lead of the called line. This ground also appears on the sleeve lead of the connected link.

In this way, the link-test circuit locates the one link which is grounded from among those which have either —5 volts or —48 volts connected to them. The marker then connects the calling trunk to the proper link and establishes a "camp-on" condition in the trunk. A diode sensing-circuit in the trunk monitors the link and completes the camped-on call as soon as the established call is terminated.

The 756A PBX provides three classes of service. These are (1) "restricted," (2) "toll denied" and (3) "toll allowed." Restricted stations are prevented from placing calls to central-office trunks except with the assistance of the attendant. These stations may also be restricted from tie trunks to other PBX's if desired.

A toll-denied station, on the other hand, may dial central-office calls direct by first dialing "9" to get "outside" dial-tone. As the name implies, toll-denied telephones may not dial long-distance calls. This calling privilege is reserved for toll-allowed stations, which have complete freedom to dial all types of calls. Classes of service are easy to install or change, since they appear as simple, bare-wire "straps" on terminal strips.

A prototype model of the 756A PBX has performed very well in a trial installation in Cleveland, Ohio. Production is now well under way, and a number of 756A PBX's are being installed.