An electronic switching system that operates in microseconds, provides new kinds of telephone service, and is compatible with existing electromechanical systems has been developed at Bell Laboratories.

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The No. 101 Electronic Switching System

THE BELL SYSTEM telephone switching network is a flexible and versatile system. Using electromechanical switching techniques, it is responsive to the communications needs of Bell System customers and can be adapted, in most cases, to new services as the need arises. It is characteristic of telephone communications engineering, however, to continually seek more flexible methods that may lead to further extension of telephone services. Over the years, intensive studies made at Bell Laboratories have shown that electronic switching systems are quite feasible and that electronic techniques are readily adaptable to a wide range of new services. Electronic systems also have many other advantages for the customer and the telephone engineer.

A large number of Bell System customers are businesses served by private branch exchanges (PBXs). In many instances, these exchanges have been virtually tailored to the communications needs of the customer and they must be rearranged physically if these needs change. Electronic switching techniques make it possible to easily change services and accommodate new requirements stemming from a customer's growth. Many modern businesses are so complex and change and grow so rapidly that they have created a need that can be filled most effectively by an electronic switching system. The No. 101 Electronic Switching System (ESS), recently developed at Bell Laboratories, fills this need for PBX and Centrex customers.

From the point of view of service to the customer, the No. 101 ESS offers an array of new features in addition to all the traditional ones. Among the important new services are Centrex features (RECORD, *October* 1962), TOUCH-TONE Calling, abbreviated dialing, add-on conference, dial transfer, automatic reroute, and universal attendant consoles (RECORD, *June* 1963), in place of switchboard positions. A compact switch unit which occupies only about one-tenth the floor space of the older PBXs is all that is required on the customer's premises to effect these services.

To provide these services with economy and efficiency, the system embodies a number of new switching techniques. Among the most characteristic are:

Shared Centralized Control. The switching equipment and the control equipment are separated. The control unit, located in a telephone company office, controls simultaneously a number of customer switch units.

Stored Program Control. Highly versatile control of switching and service features is attained by stored program techniques. Switching instruc-

tions are stored in plug-in electronic memories and these are consulted and acted upon as dictated by the service demands and the internal system logic. This technique allows features to be changed or added easily at the control unit. It does not require any action at the customers offices.

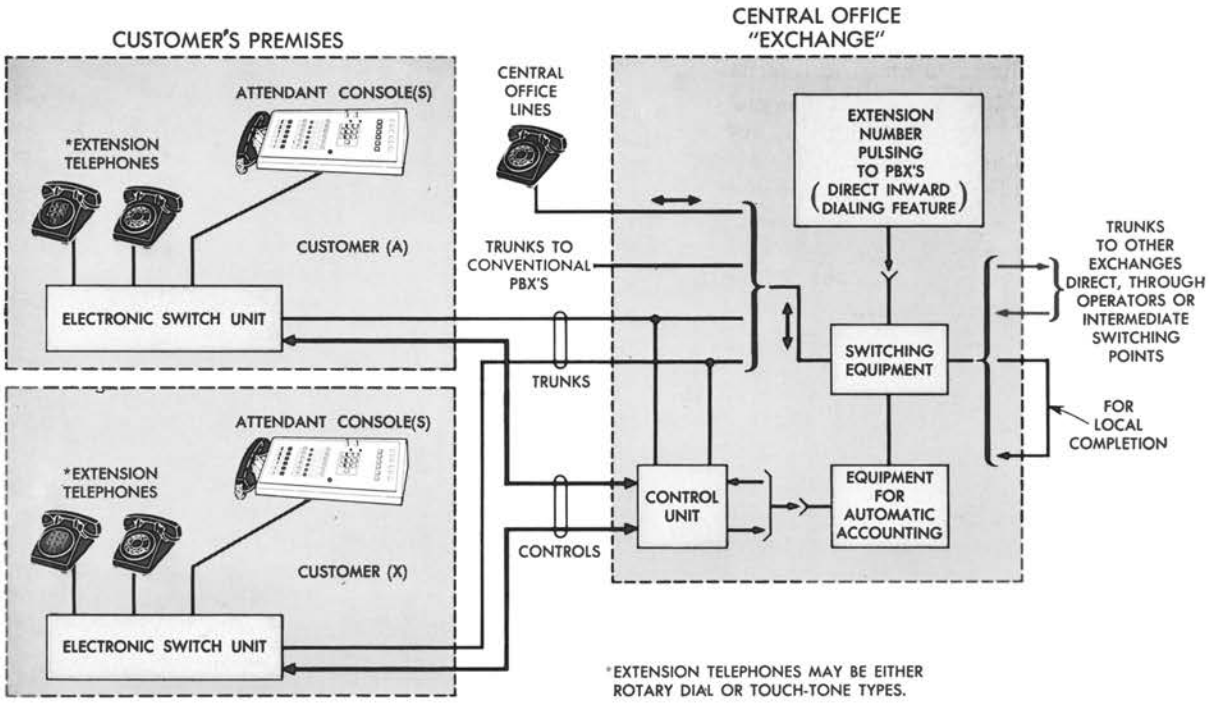
Time Division Switching. The time division networks in the switch units keep to a minimum the space requirements on the customer's premises and enable simple and flexible growth capabilities within the limits of the system.

The general system plan is depicted on page 376. Each switch unit is connected to the control unit by two groups of control conductors. One group, consisting of two pairs of conductors called data links, transmits supervisory information from the switch unit to the control unit and switch control information from the control unit to the switch unit. The second group, called digit trunks, is provided as required by the volume of traffic and transmits called numbers from the PBX extension telephones to the control unit. Talking connections between PBX extension lines are established through the switch unit. Calls to and from the central office use trunks to the switch unit in much the same fashion as they do in electromechanical PBX systems.

A switch unit (see the drawing on page 377) can serve up to 200 extension lines. Each line, trunk, and attendant console is individually terminated in a plug-in terminal circuit in the switch unit. The actual switching stages of any talking connection are established by successive joinings of the terminal circuits in the switch unit. For example, a calling line is first connected to a digit trunk for dial tone and dialing, then it is connected to audible ringing tone, and finally it is connected to the called party or to a central office trunk. Three or four terminal circuits can be joined together for conference calls, or, for example, to bridge an attendant's telephone circuit on a connection between an extension line and a trunk.

Time division switching permits all calls in the switch unit to simultaneously share a common transmission path called a common bus. A cycle of time for the bus is divided into discrete, rapidly recurring time positions called time slots. Each time slot serves as a switched-in link over which a

The switch unit cabinet is designed to blend with the decor of any modern office. Universal console is compact and attractive.



General system plan of the No. 101 ESS. The control unit is located on telephone company owned or leased space. It has a capacity of up to 3200 lines which can be distributed over as many as 32 switch units. Each customer can choose whatever features and services benefit his business.

call connection can be established. Thus, when terminal circuits are to be joined in a talking connection, they are assigned the same time slot. Each switch unit has 50 time slots, so that 50 call connections can exist simultaneously.

Supervisory detecting equipment in the switch unit continuously scans the terminal circuits and informs the control unit as to their supervisory states. If the state of a line does not change between scans, the system does not take any action. If there is a change (i.e., from on-hook to off-hook, or vice versa) the nature of the change and the coded identity of the point at which it occurred is transmitted by the switch unit terminal equipment over the data link to the control unit. In the case of an extension starting a call, the output signal is transmitted to the control unit which then returns information to the switch unit. This last message contains the coded identities of a specific time slot and of the line and digit trunk terminal circuits which are to be connected. The data receiver causes this information to be written into the specific time slot position in a memory unit contained in the switch unit. This changeable memory unit has an information position for each time slot.

The control unit (see the drawing on page 378), which can serve up to 32 switch units, operates much like a data processing system. Its inputs are indications of changes in the supervisory states of terminal circuits and dialed digits from extension telephones. Its outputs consist of switching orders to the switch units and outpulsed digits to the central office or to tie lines. Both input and output information are assembled in a ferrite sheet type of changeable memory element called the digit and data store. Input information is read out sequentially and processed. Output information is transmitted as switching orders to the switch units or out-pulsed through a sender portion of the control unit.

The stored program that tells the control unit how to operate on the inputs in order to determine the proper outputs is incorporated in a semi-permanent magnetic memory device called a "twistor." Program instructions are embodied in magnetized spots on non-magnetic metallic "cards." To change the program, one card can be substituted for another in the twistor, or a card can be withdrawn and its magnetic patterns changed.

A control unit contains two twistor memories. One, the program control store, records the basic program. This is designed into the system and it determines the routine the system will follow to effect any service feature or carry out any operation. This store is changed only if the system de-

sign is changed. The second twistor, the line information store, records those factors of call processing related to telephone company administration. It includes information such as the switch units in service, the number of lines in each unit and the number of attendant consoles associated with it, the number and types of trunks, and the particular service features elected by the customer. Finally, another ferrite sheet changeable memory element, the call status store, keeps an up-to-the-minute record of the status of all lines, trunks, and other terminal circuits which are active in the system.

The actual routine of call processing involves all the memory elements in a continuous interplay. The identity of a line, trunk or other source of input signals is referred to the call status store; the resulting status information influences the output information required to advance the call. Output information may be determined directly in the program store, or after consulting the line information store. For instance, when an extension user lifts his receiver to start a call, the number of the extension is referred to the call status store. Because the extension was idle before starting this call, its identity will not be found in the call status store. Under these conditions the program store will furnish information that the extension is starting a call and output information is generated that causes the line to be connected to a digit trunk in order to give the extension user dial tone. The call status store is also searched to determine the busy or idle state of the called line. If a called line is found busy, the line information store is consulted to see if the line is in a hunt group, and to determine what other lines are in the group. The call status store then is searched to see if a connection can be made to an idle line in the group. If no line is idle, output information is sent to generate busy tone.

These principles of operation, which can take full advantage of the microsecond response speed of the system, are the basis of some new switching techniques that, in turn, are the basis of many new services. For example, during a call a customer can get dial tone without disconnecting merely by flashing his switchhook. Then he can dial, and establish connections to other extensions. A number of new features are built on this technique:

Add-on conference. One customer in a talking connection can add one or two more parties in a conference arrangement merely by dialing; he

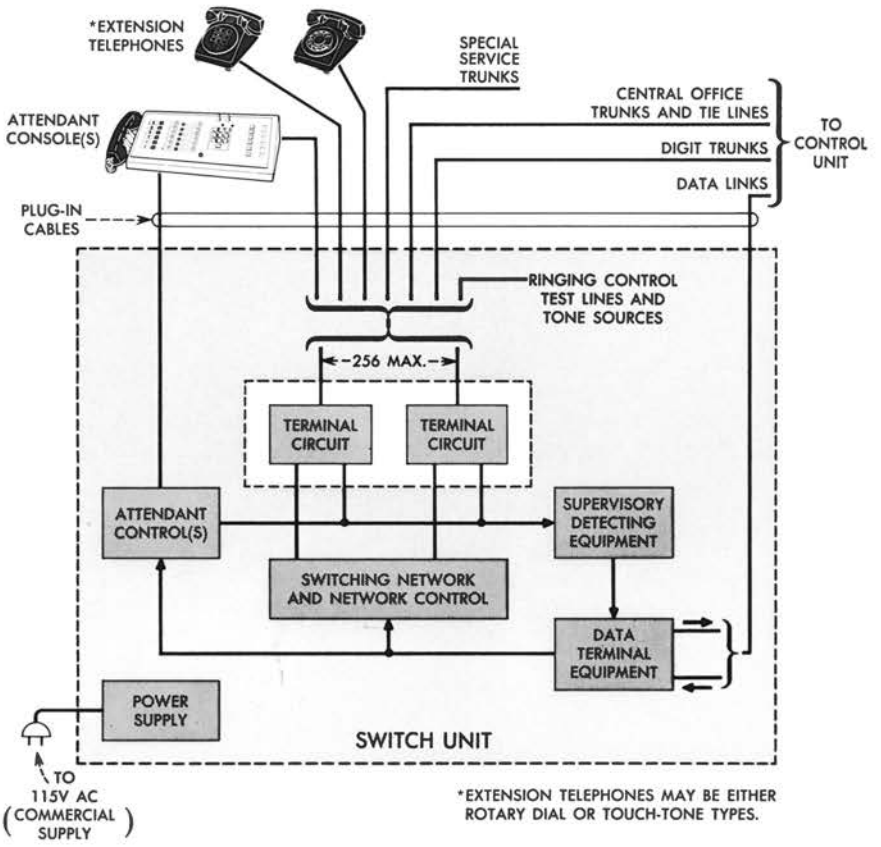
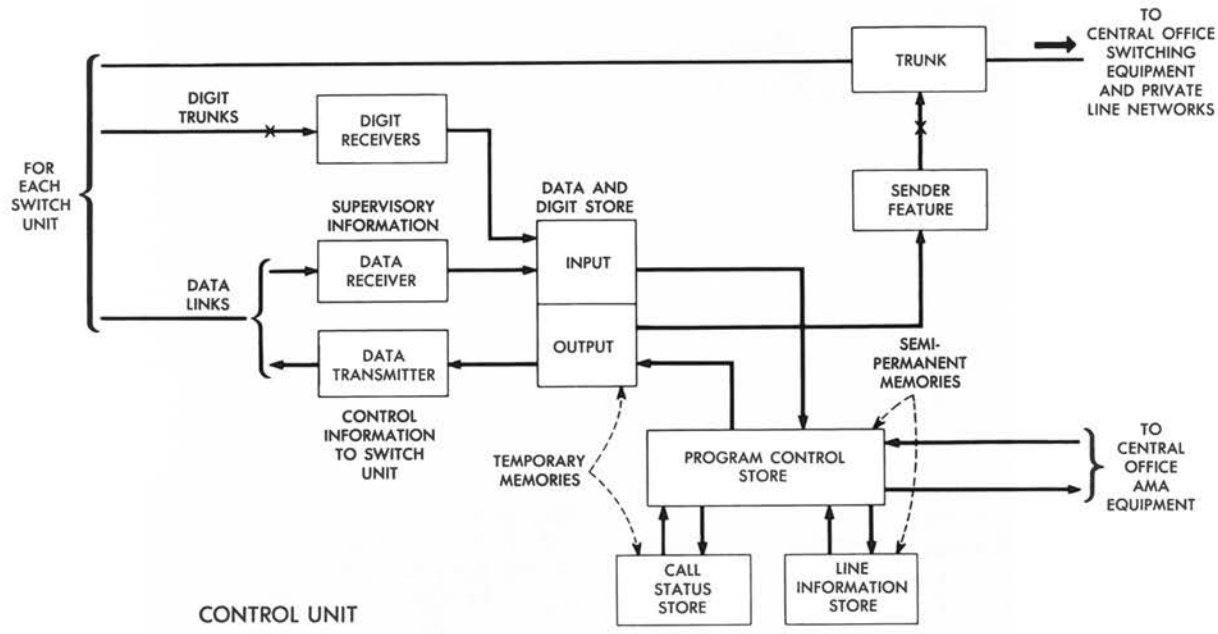


Diagram of a customer switch unit for the No. 101 ESS. The unit can be plugged into a 115-volt wall outlet. Its operating power is only about 600 watts, less than that of a home toaster.



The control unit contains in its memory elements a series of stored programs that detail each step needed to set up a call or direct a special service feature. The control unit sends data messages to the switch unit, telling it what actions it must take in completing a call or in taking down connections.

does not need operator assistance.

Dial transfer. A customer can transfer a call to another extension by dialing the new number.

Dial hold. A customer can put one call in a hold position, dial another customer for consultation, then return to his original call.

Either standard rotary dial or TOUCH-TONE dial telephones can be used with the system. The control unit regenerates all digital information before it is transmitted over tie lines or trunks. TOUCH-TONE signals are converted to dial pulses so that TOUCH-TONE equipment is needed only in the No. 101 ESS and not at the serving central offices.

Abbreviated dialing also makes use of this technique. The calling party simply dials a 3-digit code and the system outpluses the 7 or 10-digit number of a previously specified customer. Before the output digits are sent the input digits are referred to the line information store which may have special instructions to interpret them as a signal to outpulse other number or digit combinations.

Special codes also can be used to temporarily modify established programs of call routing and treatment. For example, a customer can dial a code that will cause his incoming calls to be routed to another extension. This feature is called automatic reroute. Restrictions on particular telephones also can be effected for certain codes. For example, calls from the restricted telephones on which the prefix "9" is dialed may all be routed to the attendant. Other lines can be partially restricted—they can be permitted to place central office calls to up to 15 specific office codes, and denied access to all others. In the same way, some lines can be permitted local calls and denied access to toll points. Yet another pattern of restriction can be applied to abbreviated numbers; access to these numbers can be limited to specified extension lines and to the attendant.

The No. 101 ESS can provide Centrex features such as direct inward dialing (DID) and automatically identified outward dialing (AIOD). Incoming calls can thus be routed directly to the extension without going through the attendant. For outgoing calls, central office Automatic Message Accounting (AMA) equipment can be arranged in direct association with the No. 101 ESS control unit. In this case, the number of the calling extension, and not the number of the PBX, will be recorded for billing.

Although the No. 101 ESS is compatible with all electromechanical central office systems, the Centrex features will be operable only where complementary features are activated in the connecting central offices. For example, DID is effective only when the No. 101 ESS operates in conjunc-

tion with No. 5 crossbar, crossbar tandem, and step-by-step systems. AIOD is possible only with No. 5 crossbar, but developments are under way that will make this feature available in other central office systems equipped with AMA or ANI systems.

Up to three Universal consoles can be associated with each switch unit. The number needed depends, of course, on the volume of traffic requiring attendant assistance. A call distribution feature evenly divides the traffic among all consoles associated with a switch unit. The console operates by the "switched loop" method so that it is associated with a call only while the attendants services are needed. When a call is directed to the attendant, the console is "switched in" to the connection through an entry called a "loop." When the calling and called parties begin to converse and the attendant is no longer needed, the console is "switched out" and the loop is free for another call. A console can be equipped with up to six loops which enables it to handle six calls simultaneously.

If a call is placed through the attendant to an extension that is busy, a "Camp-on" feature will allow the calling customer to wait and to be connected automatically when the called customer becomes free. Also, an "Automatic Recall" feature can time the waiting period and recall the attendant if the called customer is still busy when the time is up. The attendant can also use a "Busy Verification" feature to confirm that the line actually is busy, or to override a busy indication in an emergency.

A "Transfer" feature permits the attendant to release a connection on an established call and make a new connection to another extension in the PBX.

M. A. Townsend (standing) and W. F. Means inspect one of the twistor memory stores in an experimental control unit of the No. 101 ESS at Bell Laboratories. Mr. Means holds a program card. H. F. Priebe, in background, checks equipment in the line data frame portion of the unit.

A "Holding" feature permits the attendant to delay the completion of a call while she gets information pertinent to its completion. Also, a "Splitting" feature allows her to separate the calling and called parties so that she may talk to each privately.

The control unit is programmed to continually send test calls—about one a minute—through the system. If a test fails because of a defective unit of equipment, the unit is switched out of service and a duplicate unit is switched in. At the same time, information on what part of the system has failed is printed out on a teletypewriter at the control unit. Thus, the system can continue to service customers while repairs are being made. Control equipment is duplicated. If one program store malfunctions, another can take over immediately. In the switch unit, the common bus is actually not a single element, but two, each with a capacity of 25 calls. If one bus malfunctions, the other will continue to give service at reduced capacity.

A basic tenet in the design of the system was equipment "packaging." In the switch unit, the common switching elements (the switching network and control, the supervisory detecting equipment, and the data terminal equipment) are furnished at maximum capacity. The switch unit requirements for a particular customer are met by plugging in the necessary number and type of terminal circuits and console control equipments. The control unit is similarly packaged. The principal control bays are installed essentially as a package in all cases, with equipment engineered as required to meet the interface and trunk requirements individual to the switch units.

The No. 101 ESS is now being given a field trial in New Brunswick, New Jersey. A control unit in the New Brunswick central office is serving three switch units — two installed in the offices of New Brunswick commercial customers, and one serving a group of Bell Laboratories engineers at the Holmdel Laboratory. The first commercial system, manufactured by the Western Electric Company, is being installed to serve a number of customers at Cape Canaveral. Another will serve the Bell System exhibit at the New York World's Fair in 1964. Meanwhile, Bell Laboratories is continuing with further developments that will make the principles established in the No. 101 ESS more widely applicable to Bell System customers.

Horn Antenna Tops Bell System Fair Exhibit

A horn antenna that will transmit all television programs originating from the New York World's Fair has been placed atop the Bell System's exhibit building on the fair grounds.

The antenna is part of the exhibit and will serve as the principal entry point to the nation's television network when the fair opens next April. Perched atop a 14-story-high microwave tower, it also will handle incoming and outgoing closed circuit TV as well as data transmission. A second antenna atop a building in midtown Manhattan will complete the first relay leg for nationwide broadcasts.

Installation of transmission equipment will start immediately so that circuits will be ready for use well in advance of the fair's opening. Visitors will be able to see transmission and control equipment as well as programs being televised through the glass-enclosed base of the tower.

The microwave tower is a highlight of the exhibit, the heart of which is a 400-foot long floating-wing pavilion 24 feet above the ground. Though supported at four points, the enclosed pavilion appears to be suspended in mid-air.