The No. 101 ESS, through the use of a family of switch units, can now provide electronic switching features for individual PBX and Centrex customers needing up to 3000 lines. This is a major advance over the previous 200-line capability.

Expanding the No. 101 ESS

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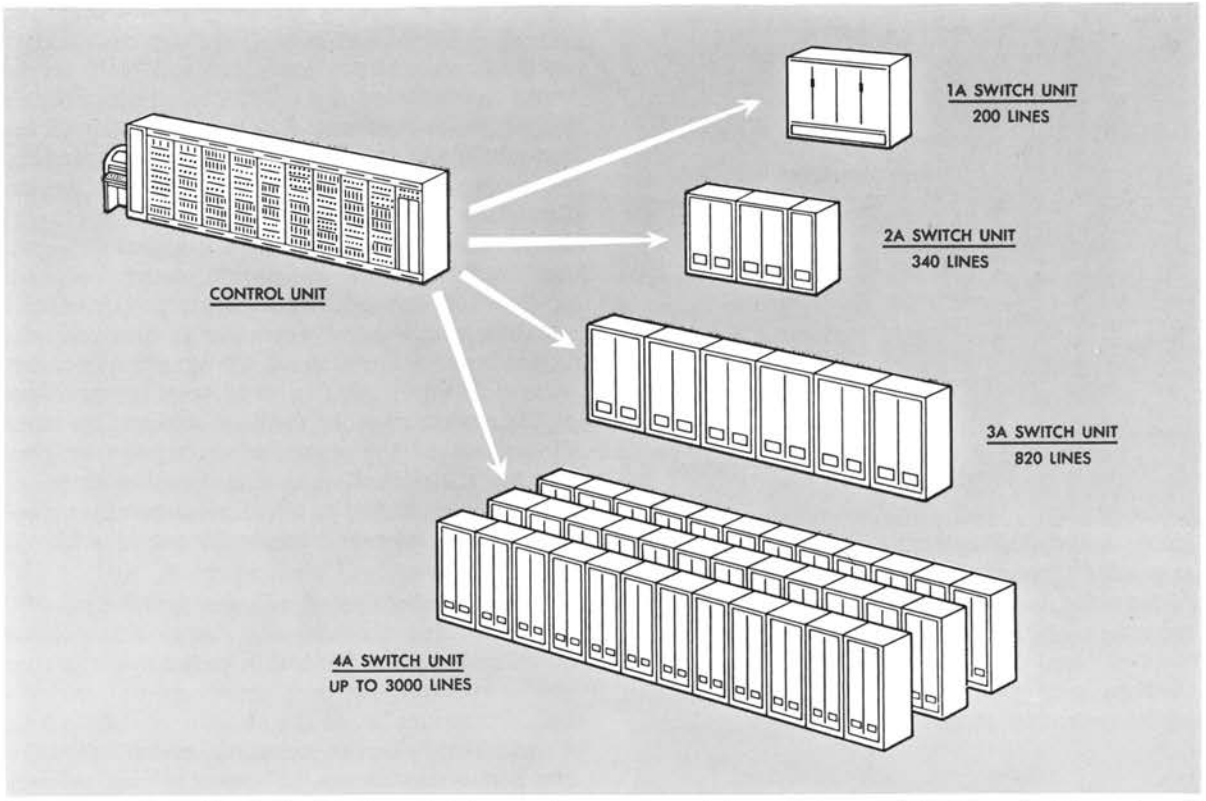
BELL LABORATORIES has been concerned for many years with developing customer switching systems such as those that now furnish Private Branch Exchange (PBX) and Centrex service to businesses and other organizations. These systems have evolved from the early manual PBXs to systems, such as the No. 101 ESS, that use the newest advances in electronic technology and provide the very latest in service features.

Throughout this evolution, Bell Laboratories has been guided by certain rigorous principles: customer switching systems must be readily engineered and installed; they must be highly reliable and maintainable; they must be easily operated by the customer's station users and his PBX attendants; they must offer various combinations of familiar and new service features, packaged according to the latest marketing techniques; and they must be flexible enough to be easily and quickly changed to meet a customer's changing service needs as his business changes.

The No. 101 ESS, one of the most recently developed customer switching systems (RECORD *November 1963)*, meets these objectives. Its usefulness and versatility forecast many years of effective service to Bell System customers. Accordingly, Bell Laboratories has recently enlarged the original system, enabling it to serve a much wider range of customers by means of a family of switch units. The system can now serve a customer having more than ten times the number of extension stations possible with the original system.

The original version of the No. 101 ESS consisted of a control unit, located in a central office, and switch units, located on the premises of up to 32 customers. The control unit, containing the stored program equipment, receives information initiated either by the customer stations or the central office, and controls the operation of the switch units. The switch units connect customers' telephone stations together, to the central office for access to and from the exchange and toll network, and to lines to and from the customer's other PBX locations. The system renders a variety of services, including many highly useful ones that up to now are more or less unique to electronic systems. These services are applied as the customer wants them by making changes in the stored program.

More than 90 per cent of PBX customers have less than 200 lines. Accordingly, the first switch unit of the family was designed for a maximum of 200 station lines. The new, enlarged system has been arranged so the same control unit can control these switch units as well as new ones with a much greater station capacity. It now



New arrangements of electronic switching equipment have permitted expanding the No. 101 ESS for up to three thousand station lines. A family of switch unit types, 1A through 4A, makes it possible to supply any customer a switch unit that will be the right size for his needs.

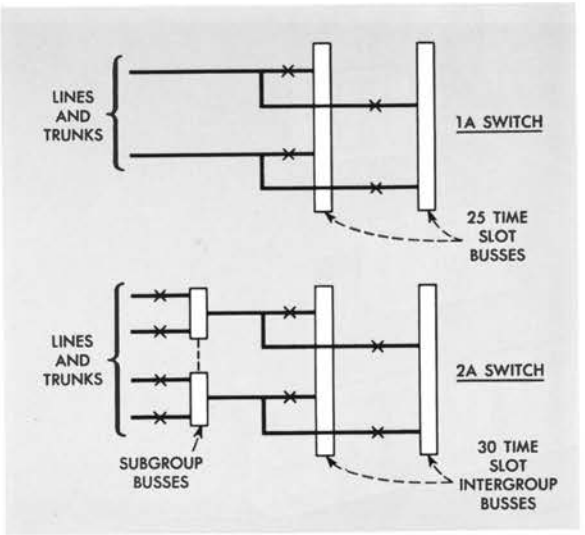
provides all its service features and advantages to customers who need up to 3000 stations.

To provide switch units in economical sizes, three new ones have been developed. One serves up to 340 stations, another serves up to 820 stations, and the third, designed for enlargement by adding modules, serves up to 3000 stations. The switch units are all interchangeable, thus easily accommodating any growth in the customer's business.

A No. 101 ESS complex can be composed of various combinations of switch units. Each combination depends on the traffic characteristics of the various customers and the total sum of their lines. At average traffic rates the expanded system can serve, for example, sixteen 200-line customers, or four 800-line customers, or a combination such as a 2000-line customer, a customer requiring 800 lines and one requiring 200 lines. Where the traffic rates are greater or less than average, the general effect is to decrease or increase the total number of lines that can be served.

The system plan of the No. 101 ESS is particularly suitable for furnishing Centrex service to customers at some distance from the central office, because switching is done on the customer's premises. This reduces the amount of outside plant cable. This type of service, known as "Centrex-CU," has until now been furnished by electromechanical switching equipment — mainly the 701 step-by-step system. "Centrex-CO" service, with all switching done at the central office, is usually furnished by No. 5 Crossbar equipment and requires a separate pair of wires from the central office to each extension on the customer's premises.

For Centrex-CU service, the smaller size of the No. 101 ESS switch units is particularly attractive compared to the large 701 PBX equipment. Also, information essential to the centrex function, such as inward-dialed station numbers and automatic station identity on outward calls to the exchange network, can be rapidly and efficiently transferred between the central office and the No. 101 ESS control unit. Furthermore, the system's traffic can be accurately measured and the system accurately engineered. The system can also be precisely monitored for reliable performance.



In the original 200-line 1A switch each line was connected through a time division switch to two 25-time-slot busses. In the 340-line 2A switch, subgroups of 32 lines are connected through time division switches to subgroup busses, which in turn are connected through time division switches to two 30-time-slot inter-group busses.

Advantages of expanding the system result from the fact that the service capabilities and their administrative features will be made available over practically the entire range of customer sizes. This has at least three important effects. First, customers with the communications potential for growing beyond the initial 200-line limit can now be served by the No. 101 ESS with assurance that they can continue with the same modern system as they grow. Second, the number of lines served by any given control-unit installation will usually be substantially larger during the early period of use. This is expected because, even though most customers are small ones, the effect of extending the system to include large customers is to almost double the number of candidate lines. Thus the economy of the system will be greatly enhanced during its early use since the cost of the control unit will be shared by more lines. Third, more effective engineering, installation, and maintenance methods will evolve as a result of the greater familiarity gained from more widespread use.

The basic system plan of the No. 101 ESS anticipated expansion of the family of switch units to serve larger customers. The physical separation of the switch units from the control unit, with the supervisory and control information being interchanged serially via data links, is one of the keys to the basic plan facilitating the system's expansion.

The important problems that had to be solved were encountered in (1) designing suitable switch units that would be economical over the contemplated switching range, (2) expanding, where necessary, the supervisory and control information interchanged between the larger switch units and the control units, and (3) making such changes in programming as were needed for the additional control information and to accommodate the greater number of digits in the numbering plan of the larger customers. It was highly desirable to solve these problems so the system could be modified without too much disruption in the manufacture of the original system and, equally important, so systems already delivered to the telephone companies could be modified later to operate in accord with the expanded plan.

The expanded system adheres to the time-division switching technique in the switch units as much as possible. With this technique, one time slot is required for each simultaneous conversation. Consequently, as the number of station lines a switch unit serves increases, more simultaneous conversations can be expected and so more time slots are required. Two 25-time-slot busses were used in the original 200-line switch units for a total of 50 slots. In the 340-line switch unit two busses furnish 60 time slots. However, the time slots on each bus are separate in real time in contrast to the original switch whose time slots on each bus were coincident. A schematic diagram of the 50- and 60-time-slot switches is shown on this page.

The increase in time-slots was obtained by substituting transistor switches for the previously used PNPN switches and by increasing the speed of the memory and logic. This permitted the more precise timing required by the larger number of slots. Thus when the decision was made to continue expanding the system, the technique for the 60-time-slot bus was at hand.

The design of a switch unit with greater traffic capacity for fairly large customers involved the problem of increasing the number of time slots still more; it was solved by giving the lines access to more than one 60-time-slot bus. Access to no more than four busses (a maximum of 240 time slots) seemed a reasonable upper limit for this technology. This and the use of higher-speed translation and logic functions made it possible to develop a switch unit that could serve as many as 820 lines. Where low traffic volumes are expected, the lines can be served by two 60-

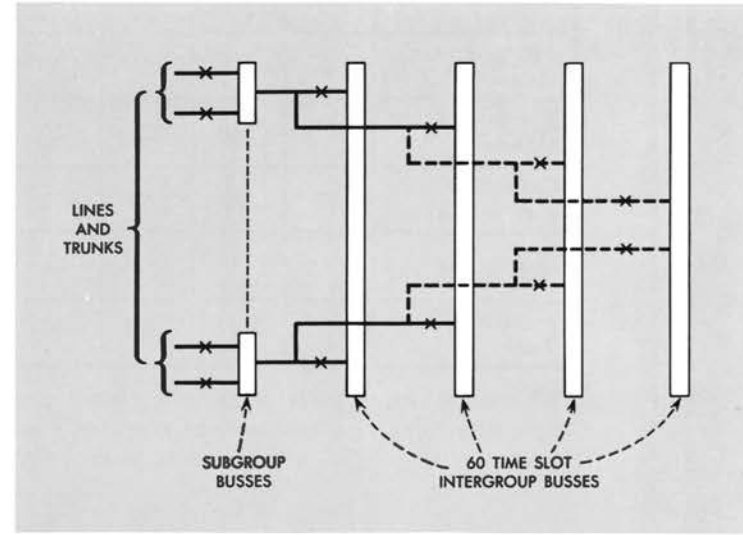
slot busses; for heavy traffic, three or four busses are used. In general, three busses, giving a total of 180 time slots, are enough for heavy traffic users.

The development of a time-division switch unit able to serve 820 lines with as many as 240 time slots represented a substantial advance, particularly since it was achieved within the framework of overall system compatibility. Bell Laboratories engineers were not content to stop here, however, and ways were sought to carry the expansion still further so the service features of the system could be made available to the very large customers. At this point it seemed desirable to depart somewhat from the time-division switch concept.

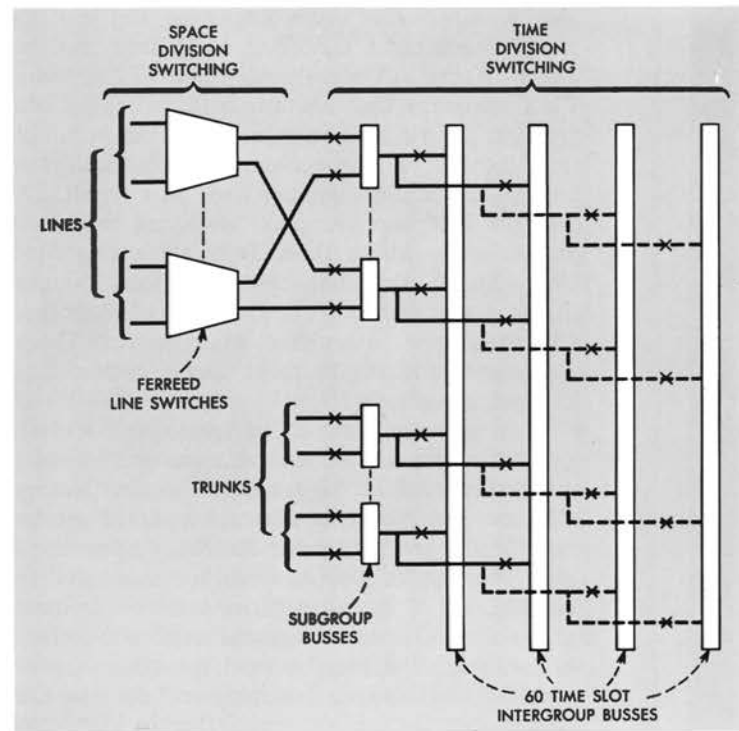
Adequately serving customers having in the order of 3000 station lines by means of a time-division switch requires about 480 time slots. While this could be done by further refining the time-division art, a more readily achievable switching network was decided upon that would give the desired grade of service at an economical level. The network uses multistage switching. The first two stages consist of a ferreed "line switch" network similar to one described in the No. 1 ESS (RECORD, *June 1965*). The control unit sends switching information to these stages over a separate data link. Station lines connected to the input of this network are switched over links to a stage of time-division switching. Access to trunks is through the time-division switch or, if termination to another station is required, back through the line switch.

Using this basic switching plan, a number of networks can be constructed in which the line switches can be arranged for various degrees of concentration. They can be connected to one or two time-division switches, which in turn are equipped for varying numbers of time slots. By this means the networks can be sized to handle efficiently the traffic requirements of customers ranging from 820 lines (the maximum for the time-division switch shown in schematic diagram at right above) up to about 3000 lines. Typical capabilities of this coordinated array of switch units are shown in the table on page 154.

In addition to the larger switch units, a more efficient interface between No. 5 Crossbar central offices and the control unit was designed for transferring direct inward dialed (DID) station line numbers from the central office to the control unit. This new interface is not directly related to increasing the switching capability of the system, but it does make the system more economical for Centrex-CU service throughout the



In the 820-line 3A switch, subgroups of 32 lines are connected through time division switches to subgroup busses, which in turn are connected through time division switches to two, three or four 60-time-slot inter-group busses, depending on the traffic.



In the basic 4A switch, groups of lines up to a total of 2048 are connected to ferreed switching networks which in turn are connected to group and inter-group time division busses similar to the 3A switch. Additional groups of lines can be connected through additional ferreed switches to the time division switch to obtain extra line capacity. An additional time division switch can be connected so as to provide greater call carrying capacity.

	Switch Unit					Typical Network Arrangements					
	1A	2A	3A			4A (1 Time Div. Sw.)			4A (2 Time Div. Sw.)		
Time Slots	50	60	120	180	240	120	180	240	240	360	480
Approx. Traffic Capacity (CCS/L)	6	4	4	6	8	1.6	2.5	3.4	2.1	3.3	4.5
Nominal Number of Lines	200	340	820	820	820	2000	2000	2000	3000	3000	3000
Central Office and Tie Trunks	40	80	112	112	112	332	332	332	664	664	664
Digit Trunks	6	7	12	18	24	12	18	24	24	36	48
Attendant Trunks	3	3	6	9	12	6	9	12	12	12	12

The several switch units in ascending sizes make it possible to serve a customer of practically any number of lines efficiently. Some increase in the number of trunks can, of course, be obtained with any of the switch units by reducing the maximum number of station lines correspondingly.

range of its switching capability by eliminating the need for line-link pulsing from the serving No. 5 Crossbar office, as discussed below.

In Centrex-CU service an additional switching operation takes place at the customer's location after an incoming call is switched through the local central office to a trunk to the centrex. Electromechanical customer switching systems (such as the 701 step-by-step and 757 crossbar PBX systems) that contain both switching controls and switching networks within a single unit located on the customer's premises, must receive the station number over this trunk. The No. 101 ESS was originally designed to be consistent with this method. To provide this function, No. 5 Crossbar central offices examine dialed digits destined for the connected centrex-CU, then select a trunk to the Centrex-CU and retransmit the digits to it using conventional dial-pulse methods.

This arrangement, called Line Link Pulsing (LLP), requires a considerable amount of equipment associated with each trunk to the Centrex-CU, and also requires a complement of senders specifically provided to pulse the station digits over the trunks. The new method developed for the No. 101 ESS, called "Direct Access," eliminates this additional equipment and substitutes a high-speed, relatively low-cost interface.

After receiving an incoming call for the Centrex customer, and upon receiving the digits that identify the called Centrex station, the No. 5 Crossbar system marker connects directly to the No. 101 ESS control unit and immediately transmits the station digits to it over a multiplicity of wires. The control unit returns the line link location of one of the Centrex customer's trunks, whereupon the marker establishes a connection to the trunk. The No. 101 ESS then uses the station digits to connect the required station to the trunk. Thus not only is the LLP equipment eliminated, but the speed of connection is increased too.

The new expanded No. 101 ESS can furnish PBX and Centrex service over a wide range of customer sizes, from the small to the very large. In addition to these basic types of service it can also provide all these customers an extensive array of service features, some of which, such as console operation, camp-on and call transfer, are becoming well known and favorably accepted by customers introduced to them through other systems. Beyond these, the system has many other service features, such as "Speed Calling" by abbreviating the called number, automatically shifting the destination of calls by the called station, and letting the called station select and hold incoming calls without the need of an auxiliary key telephone system. All these services and functions, including TOUCH-TONE® calling, can be furnished relatively simply for each customer without significant equipment changes other than those involved at the telephone set, and a customer's service is readily convertible from one service "package" to another. Centrex-CU operation is made easier and more economical, and customer growth can be easily accommodated with the new interchangeable switch units.

The expanded No. 101 ESS, with its wide range of services and great flexibility, not only meets present service objectives, but is also very much in tune with the progress toward long-range objectives in electronic switching. Experience is indicating that the basic system plan and techniques of the No. 101 ESS are adaptable to meet the ever-increasing needs of telephone engineers and their customers.