No. 101 ESS 4A Switch Unit

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A combination of space division and time division networks makes possible an 800 to 4000 line switch unit private branch exchange for the No. 101 electronic switching system.

I. INTRODUCTION

The No. 101 electronic switching system (ESS) has brought new conveniences and services to private branch exchange and Centrex customers with the 200-line 1A, 364-line 2A, 820-line 3A switch units.[1–4] To extend the No. 101 ESS features to still larger customers, the 4A 4000 line switch unit was designed.

The No. 101 ESS 1A, 2A, and 3A switch units utilize time division for the switching networks. In the 1A switch unit, 240 lines and 40 trunks have access to two buses through a total of 50 time slots. With a partially duplicated bus system in the 2A switch unit 364 lines and 56 trunks are accessed by 60 time slots. The 3A switch unit accommodates 820 lines and 112 trunks with either 120, 180, and 240 time slots and a bus system similar to the 2A.

In general, the traffic capacity of a time division network depends upon the number of time slots; the line capacity depends upon the number of line circuits. As the number of lines increases, the traffic also increases; thus large line capacities require more time slots. The maximum number of time slots per talking bus is determined by the sampling rate and pulse width. The sampling rate is set by the transmission requirements; the pulse width is largely determined by active component performance and stray capacitance.[4] Substantially larger time division switching networks require considerable advancement in components and fabrication techniques.

II. LARGE PBX

2.1 *Multistage Network*

In present switching systems large line capacities with relatively small networks have been obtained with multistage networks. Most of these systems have used space division networks; with the advent of No. 101 ESS, practical time division networks are also available. These two types of networks can be combined in various ways to obtain a large system; the characteristics of the individual networks make some arrangements preferable over others.

2.2 *Characteristics of Relay Space Division Networks*

The classical switching system has used metallic contact space division networks. These relay crosspoints have excellent transmission characteristics with a frequency range that permits simple dc supervision. Low price is an additional advantage. However, large physical size and slow operating speeds are disadvantageous.

2.3 *Characteristics of Time Division Networks*

Small physical size of relatively large capacity networks, high speed operation, and plug-in solid state circuit packs are some of the outstanding features of the time division network. On the undesirable side is the relatively large amount of per line equipment, such as the low pass filters and line transformers. The cost of the line packages in a time division switch unit is approximately half of the total switching unit cost. The transformer, needed for protection against longitudinal voltages in the time division network, blocks the transmission of dc supervisory signal and present solid state electronic devices do not permit an economical time division network that will transmit ringing voltage. Also without gain a transmission loss of approximately 2.0 dB is encountered.

2.4 *Space Division Input Network and Time Divison Output Network*

A 240 time slot 3A switch unit has a traffic capacity of 6,130 ccs* which is adequate for 2,000 lines with average traffic of 3.07 ccs per line. The 4A switch unit uses a two-stage switching network with a space division stage for line inputs and a time division junctor network as shown in Fig. 1. With a 4-to-1 line concentration ratio in the input network and a 3A time division switch with 512 lines inputs, a 2,048 line terminal switch unit is obtained. Minimum per line equipment is required and line concentration increases the traffic on the links with the resulting increase in efficiency of these circuits.

An increase in both lines and traffic, is obtained by using two 3A switching units and twice the number of line concentrators, as

* One hundred call seconds.

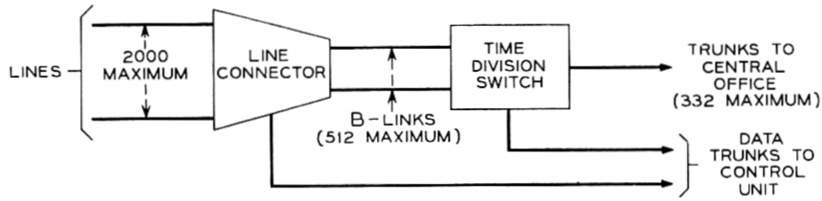

Fig. 1 — No. 101 ESS 2,000 line 4A switch unit.

shown in Fig. 2. With a 4:1 line concentration ratio the combination has 4,000 line inputs, providing a capacity for 3,200 lines with an average of 3.84 ccs per line, or 4,000 lines with 3.07 ccs per line. In the following discussion a single 3A time division switch and line concentrators will be called the 4A-1 switch unit and the two time division switch-line concentrators combination of Fig. 2 will be called the 4A-2 switch unit.

2.5 *Line Concentrator*

The No. 1 ESS 2-to-1 line concentration ratio space-division ferreed-line concentrator[5] was selected for use in the first stage network of the 4A No. 101 ESS switch units. A tip-ring connection pattern of the 32 lines to 16 B-links 2-to-1 ratio concentrator is shown in Fig. 3. To achieve a 4:1 line concentration, the outputs of two concentrators are multipled. With this network, the Private Branch Exchange (PBX) service features must be considered as well as the per line traffic capacity. For example, the six-party conference feature requires that six lines on a single concentrator must be able to get to six B-links that

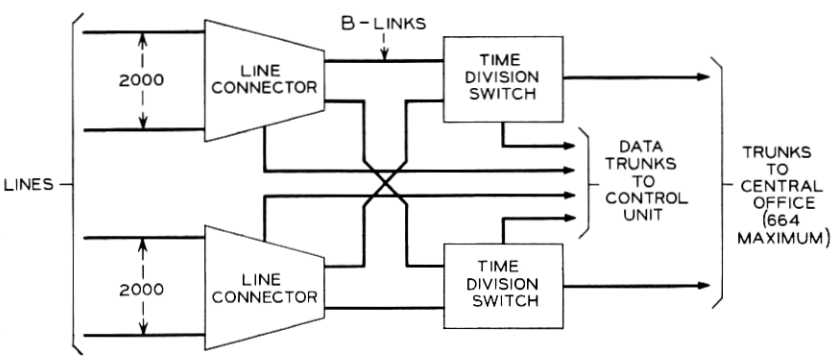

Fig. 2 — No. 101 ESS 4,000 line 4A switch unit.

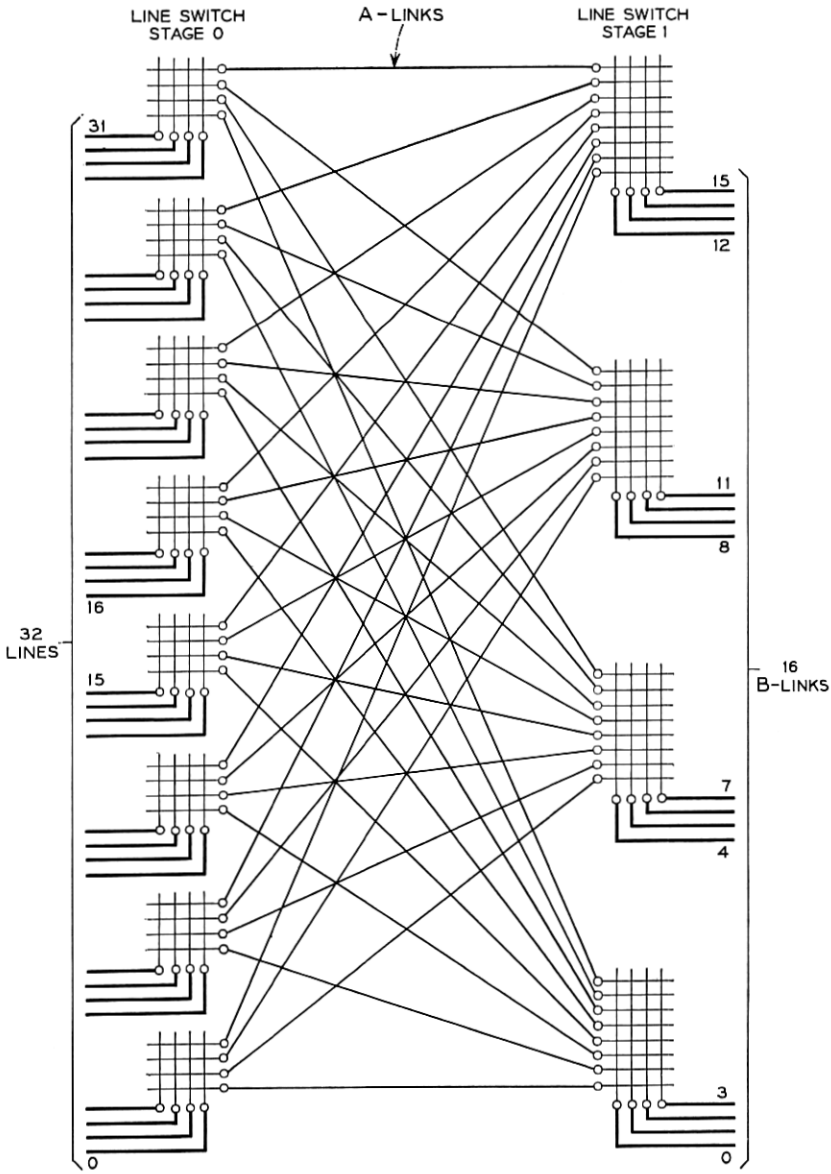

Fig. 3 — Connection pattern of 32:16 concentrator.

connect to one time division switch. Other features involve similar situations but with fewer transmission paths. Thus, the maximum division of links is two, and the interconnection of networks cannot be carried further without the loss of some features. With the 4A-2 switch unit, B-links are grouped with the odd numbered links connected to one time division switch and the even links connected to the other time division switch.

2.6 *Concentrator Traffic Capacity*

The load-service curve for the 2-to-1 ratio line concentrator is shown in Fig. 4. At a probability of 0.004 that a call cannot get an A-B link combination, the usage per line is 8.82 ccs. In the 4A-1 switch unit the 16 B-links of a concentrator terminate on one time division switch. With the 4A-2 switch unit, however, eight B-links from a concentrator terminate on one time division switch and the other eight terminate on the second 3A time division switch. Either arrangement of the 4A switch units may be operated with a 2:1 or a 4:1 line concentration ratio. The concentrator traffic capability per 16 B-links, is 260 ccs for the 4A-1 switch unit and 230 ccs for the 4A-2 switch unit.

These figures indicate the maximum ccs per group of 16 B-links; the per line traffic is obtained by dividing the concentrator maximum traffic figure by the number of equipped lines per concentrator. To

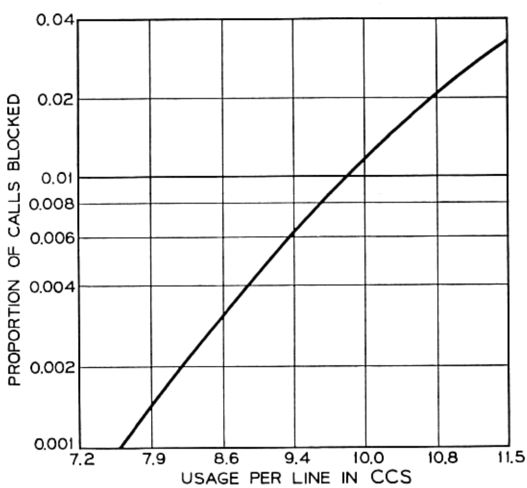

Fig. 4 — Traffic capacity of 32:16 line concentrator.

provide adequate service to a group of high traffic lines a concentrator must be operated with fewer working lines. Since intratraffic requires two links through the network, the percent of intratraffic must also be considered.

2.7 *Data Channels to Control Unit*

The No. 101 ESS is a common control system where a control unit in a central office does the call processing for switching networks (switch units) located on subscriber premises.[6] Coordination of activities between switch units and the control unit is maintained via data links between the control unit and each of the associated switch units. Original design of the No. 101 ESS was for a large number of small switch units operating from one control unit; data processing was designed so that a switch unit would use one data link. With the larger switch units more per-switch unit-data capacity was required; this is provided by using multiple data channels. The four bus 3A uses two data links; the 4A-1 switch unit uses three, while the 4A-2 switch unit has six data link circuits.

III. LINE CONNECTOR

3.1 *Block Diagram*

The line connector, shown in Fig. 5, connects station lines to the B-links which are the inputs to the time division switch. Additional required functions are the scanning of lines to detect service requests (off-hooks) and data transmitting and receiving capability.

The line concentrator scans all idle lines; when a new off-hook condition is encountered, scanning is stopped and a data message is sent to the control unit giving the equipment number of the line requesting service. Call processing at the control unit, finding an idle path, sends a connect order to the line concentrator. The line is then connected through to a B-link where it appears as an off-hook request to a 3A time division switch, and its line connector scan point removed transferring supervision control to the time division switch. On a disconnect, the message to the line concentrator removes the line's connection to the B-link and restores the line's scan point.

Line connector circuits have been physically divided into three groups: line switching circuits, line switch controller, and data converter. A line switching frame contains the per line equipment and network for 256 lines. Up to four line switching frames are accessed by a controller frame. A data converter will operate two line switch controllers. The data converter receives serial data from the control

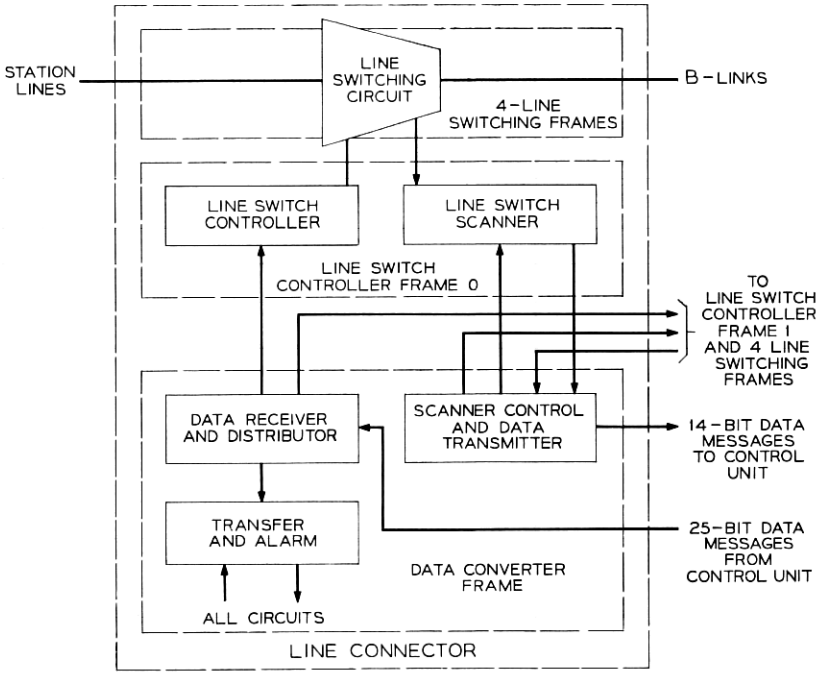

Fig. 5 — Line connector block diagram.

unit and supplies parallel outputs to the controller; in return, parallel information from the controllers is transmitted serially back to the control unit via the data converter.

Most of the circuits use diode transistor logic and follow the design pattern of the No. 1 ESS circuit packs.[7]

3.2 *Line Switching Frame*

The major function of the line switching circuit is the interconnection of lines and links. A line switching frame consists of eight 32-to-16 ratio line concentrators which accommodate a maximum of 256 line terminals and can be connected to provide either a 2:1 or 4:1 line concentration ratio. A block diagram of the circuits within a frame is shown in Fig. 6, and Fig. 7 is a sketch of the seven-foot frame. Besides the eight concentrators in a frame, there is a type 1B ferrod per line, a 48 wire-spring relay translator, and 128 cut-through relays.

Operation of ferreed crosspoint switches in the line concentrators is accomplished by applying a high-current pulse to a selected path

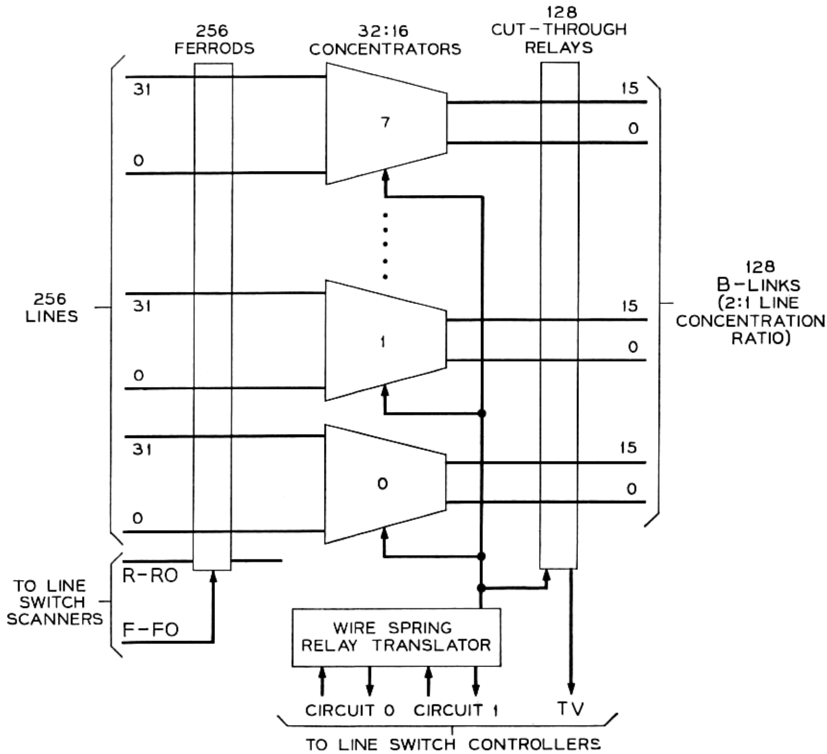

Fig. 6 — Block diagram of line switching circuits.

in the switching network. Three relays, one in each group of 16 of the 48 relay translator, select the path to be pulsed.

The ferrod sensors enable a line scanner to determine the line status since an idle line will normally have its ferrod connected to tip and ring. When service is given to a line, its connection to its ferrod is removed by action of a bipolar ferreed whose winding is in the pulsing path.

When the relay translator is operated to select a pulse-current path, it also operates a cut-through relay associated with the switching network link output. The cut-through relays have a combined function: first, to open the B-link before ferreed crosspoints are operated; second, to discharge the line; third, to connect the balanced pair from the concentrator output switch to a test circuit after the crosspoints are operated; and fourth, to cut-through the connection.

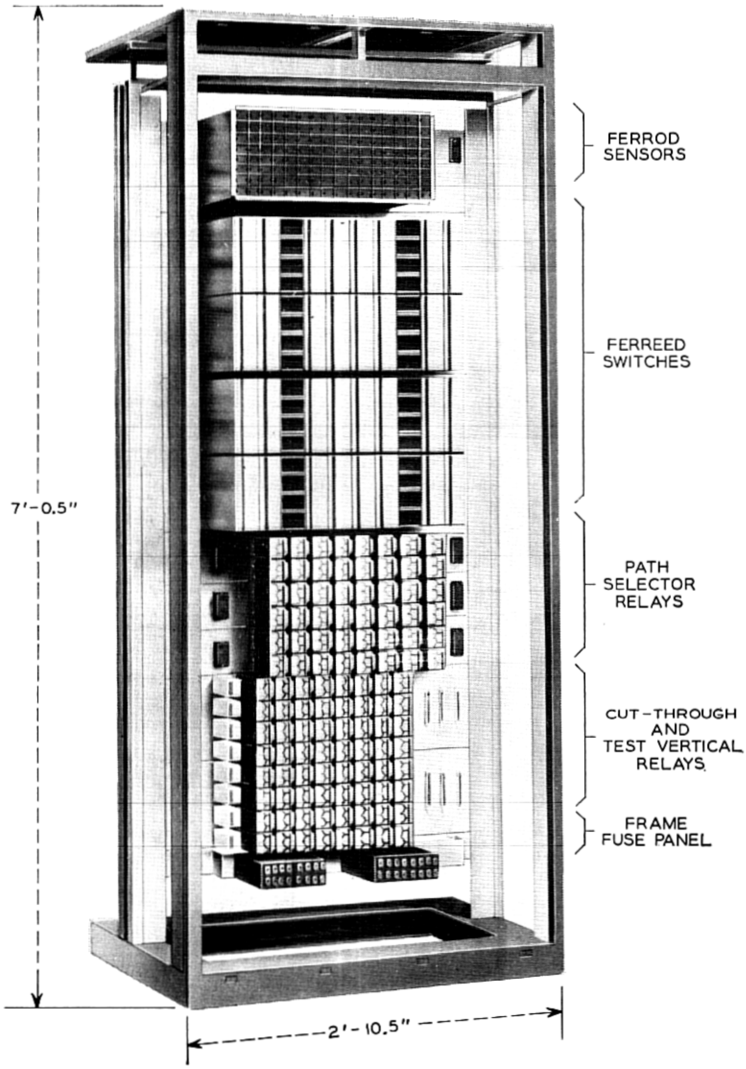

Fig. 7 — Line switching frame.

3.3 *Line Switch Controller Frame*

The line switch controller frame contains two basic circuit groups: line ferrod access circuits (line switch scanner) and line link access circuits (line switch controller). Each circuit is duplicated with one on-line and the other in standby status. Fig. 8 is a block diagram

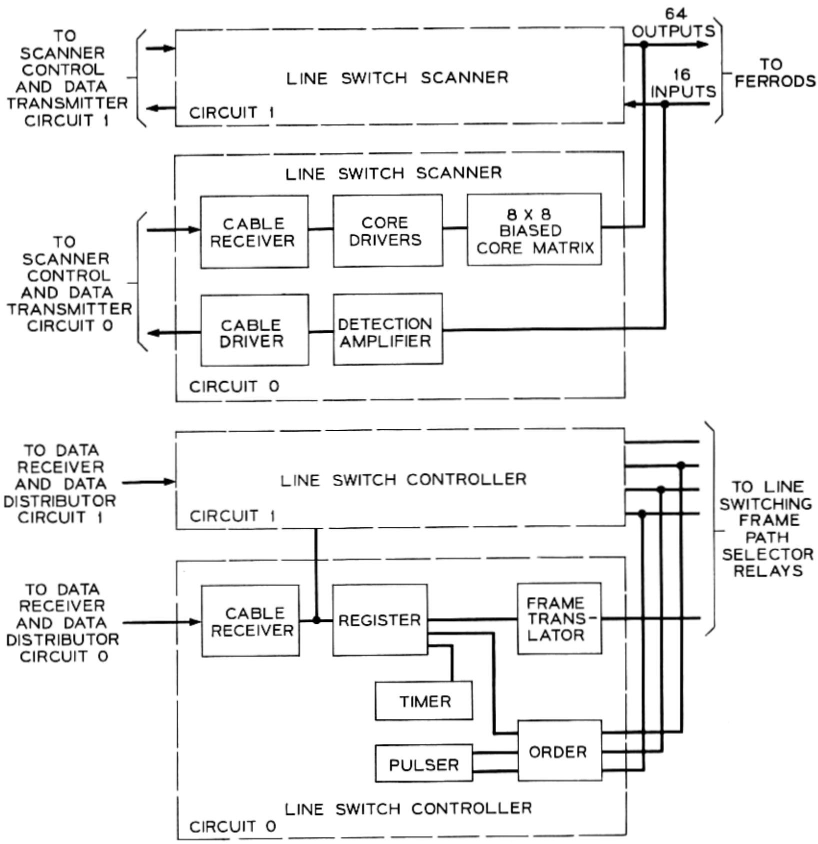

Fig. 8 — Block diagram of line switch controller.

and Fig. 9 shows the frame. A controller frame has the capacity to access four line switching frames, a total of 1024 line terminals.

3.3.1 *Line Switch Scanner*

The line switch scanner receives address pulses from a scanner control.[8] These pulses are applied to a biased core switch to give a 1-out-of-64 translation. Sixteen of these outputs interrogate a 256-ferrod matrix in a line switching frame. One switch output interrogates 16 ferrods simultaneously. These outputs are strobed, amplified, and passed on to the scanner control in the data converter frame.

3.3.2 *Line Switch Controller*

Address and order information to the line switch controller is in three groups: 26 bits of line-link data, order group of 6 bits, and an enable bit. The line-link information specifies where in the network fabric (station line and B-link) an operation should be performed, and the order group data specifies what should be performed.

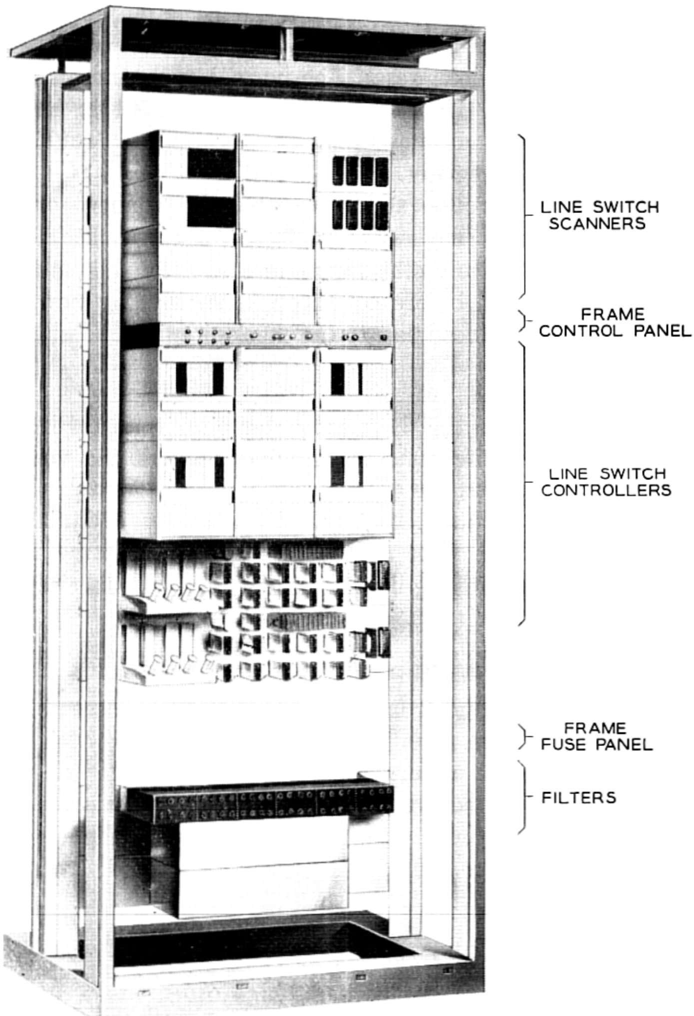

Fig. 9 — Line switch controller frame.

The line switch controller message is placed in a register and translated by a reed relay translator which operates three path selector relays in a line switching frame.

Regardless of the order being carried out, the normal timing sequence is the same. First, the path-select relays operate, selecting, in addition to the pulse path, a cut-through relay. The operation of a cut-through relay operates the high current pulser provided a pulse path exists, and ten milliseconds later the output of the test vertical circuit is strobed. Following the test vertical strobe, the relays are released and the register reset. The normal cycle time is approximately 40 milliseconds. Had the normal cycle failed to be carried out within 45 milliseconds an automatic reset circuit would release the relays and reset the register.

Following each controller action (except the connect order) on any network path in a line switching frame, a cross check is made via the test vertical. Since the test is performed after the high-current pulser has operated and before cut-through occurs, any normal condition will present a balanced pair to the check circuits.

3.4 *Data Converter*

The main function of the data converter circuits is to enable the control unit to access the remote switching network via voice band data links. Three circuits, the data receiver and distributor, the scanner control and data transmitter, and the transfer and alarms are shown in Fig. 10. These make up the data converter frame shown in Fig. 11. All circuits are duplicated except the output circuitry of the transfer and alarms circuit.

3.4.1 *Incoming Data Circuits*

The serial data message from the data receiver is assembled in a 25-bit shift register, then gated in parallel to the line switch controllers. Both incoming data circuits are active so that either may supply incoming maintenance messages to the transfer and alarms circuit; only one circuit at a time is permitted to gate to the controllers. The 25-bit data message includes a two-bit start code and an odd parity bit.

3.4.2 *Scanner Control and Data Transmitter*

Line scanning is carried out with the high order bits of a 12-stage binary counter supplying address pulses to the line switch scanner access circuits. The low order four bits of the address counter are

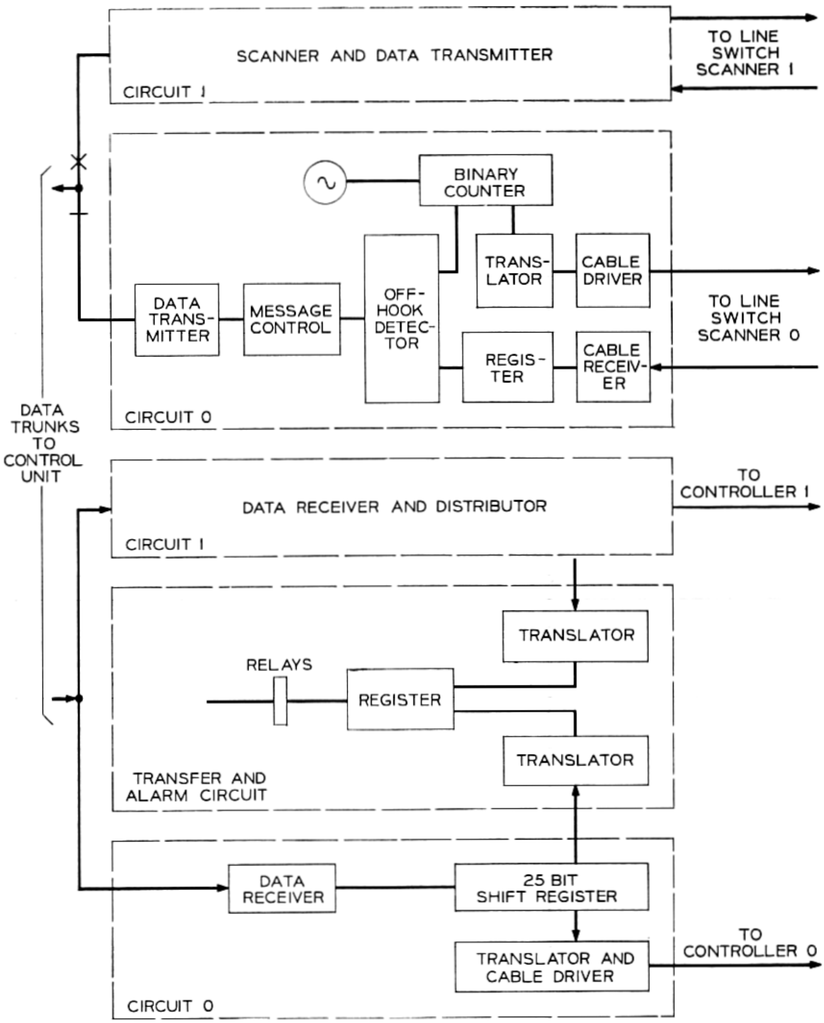

Fig. 10 — Block diagram of data converter.

used to interrogate a 16-bit register that receives line ferrod outputs. When an off-hook is detected, the address counter is stopped and a 14-bit data message is transmitted to the control unit. The data message consists of a one-bit start code, 12-bit equipment number, and an odd parity bit. Scanning resumes when either a scanner go-ahead is received from the control unit or a 0.5-second timer operates.

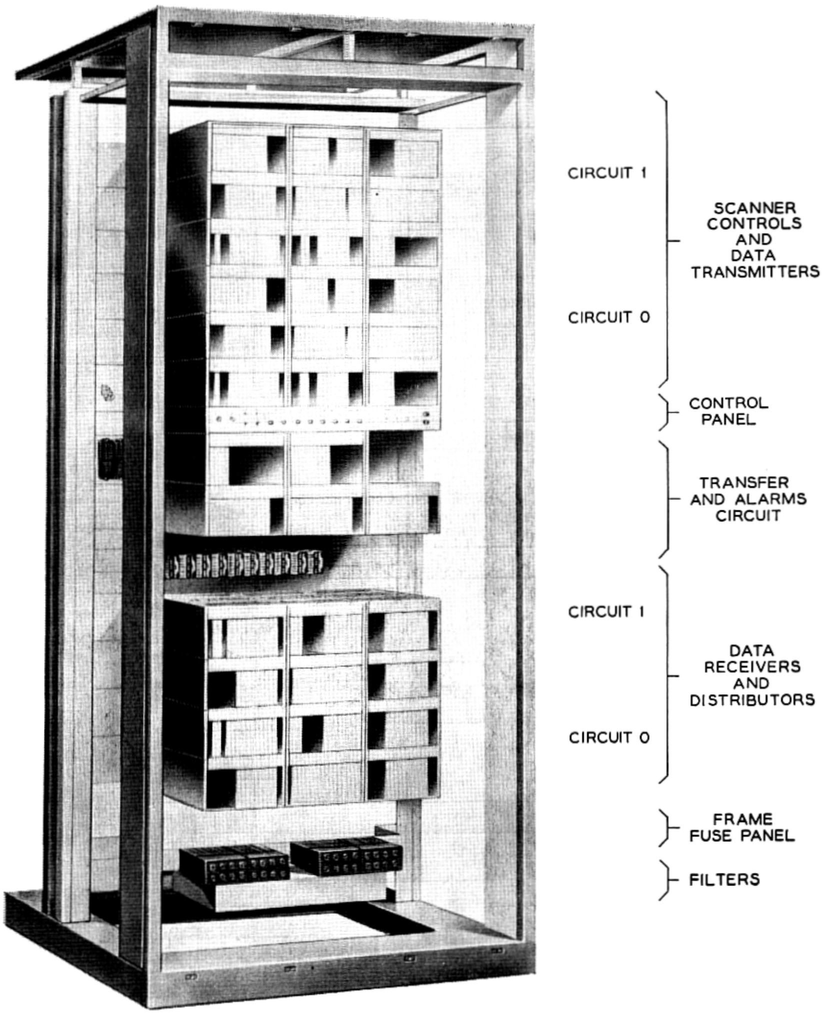

Fig. 11 — Data converter frame.

3.4.3 *Transfer and Alarms Circuits*

The main role of the transfer and alarm circuit is to control the on-line and off-line status of the various duplicated circuits and to inform the control unit, via the on-line scanner control and data transmitter, of the non-normal conditions. A 21-bit maintenance register makes up the maintenance scan points that are scanned in sequence by the on-line scanner following line scanning.

3.5 *Reliability and Maintenance Features*

The electronic circuits of the line connector are duplicated with one circuit on line and the other in standby in order to allow the system to operate in the presence of a failure. However, a finite probability of simultaneous failures in duplicated circuits remains; to decrease this probability, frequent testing is used.

During the normal call processing of setting up and tearing down calls, three conditions can exist that require immediate attention: (*i*) the on-line incoming data circuits receive a message with wrong parity, (*ii*) an enabled line switch controller times out, or (*iii*) a cross in the network of a line switching frame is detected. These three conditions set priority scan points so that the on-line scanner control and data transmitter will immediately send a message to the control unit. Upon receipt of this priority message at the control unit, the last message sent to the line connector will be repeated; if this message results in a failure, a teletypewriter printout results and maintenance programs are called into action, systematically switching gear and retransmitting messages to find a working mode.

IV. 4A SWITCH UNIT OPERATION

4.1 *Organization of the 3A*

Two basic circuit groups make up the 4A switch unit, the line connector and the 3A switch unit. The 3A switch unit is referred to as a 3A time division switch when used as part of the 4A switch unit. To adapt the 3A switch unit as to serve as the second stage network in the 4A switch unit it is only necessary to change trunk and line group assignments. In the 3A, line groups 5 and 6 are reassigned as trunk groups, and groups 8 through 15 are assigned to B-links. The 240 time slot 3A time division switch has the capability for a total of six 6-port conference circuits, 12 attendants, 24 digit trunks, and a maximum of 332 trunk circuits:

Type of Trunk	*Circuits*
CO* only	144
Tie† or CO	144
Tie or special service (FX, WATS, tel. dict, code call)	24
Tie only	20

* Central office.
† Tie trunk.

The 4A-2 switch unit has twice the number of circuits and trunks as the 4A-1 switch unit, however, the number of attendant circuits remains the same for both with a maximum of 12. The 3A time division switch controls all attendant functions directly.

Station lines connect to the line connector; trunks and service circuits terminate on the 3A time division switch.

4.2 *Two-Step Operation*

The basic elements of a 4A switch unit are shown in Fig. 12, duplicate equipment and maintenance circuits are not shown other than the four intergroup buses. Establishing or taking down connections in the 4A-type switch units requires two operations, one in each of the networks. Scanner circuits in each network scan all idle-inputs. As discussed in Section 3 scanner circuits in the line connector interrogate the line ferrods, and when an off-hook is encountered, scanning is stopped and a 14-bit message is sent to the control unit indicating the line connector equipment number that went off-hook. The 14-bit message contains a one-bit start code, an odd parity bit, and a 12-bit equipment number. Call programs at the control unit select a path (A-link and B-link) and a 25-bit message is transmitted to the line connector. Also, the control unit alerts the 3A time division switch portion of the program to expect an off-hook from the B-link just assigned. The 25-bit message contains the order (connect in this case), the equipment number, and B-link involved in the connection. The message also contains a two-bit start code and an odd-parity bit. The message is shifted into the line connector data distributor and gated to the line switch controller.

Once the controller is enabled, all of the various functions are carried out to perform the desired network action. First the path select relays are operated which in turn operate a B-link cut-through relay removing the potential from the ferreed crosspoints that are to be pulsed. The ferreeds are pulsed to connect the line, A-link, and B-link together, also, the cutoff ferreed is operated to disconnect the ferrod from the line. Relays are released and the B-link will now appear off-hook in the 3A time division switch. This off-hook will be handled just as in normal 3A operation. In this instance, the B-link will be connected to a digit trunk so that dialing may occur.

When the line goes on-hook the B-link goes on-hook, the 3A time division switch detects the change in scan point condition and sends a 14-bit data message to the control unit. The control unit deter-

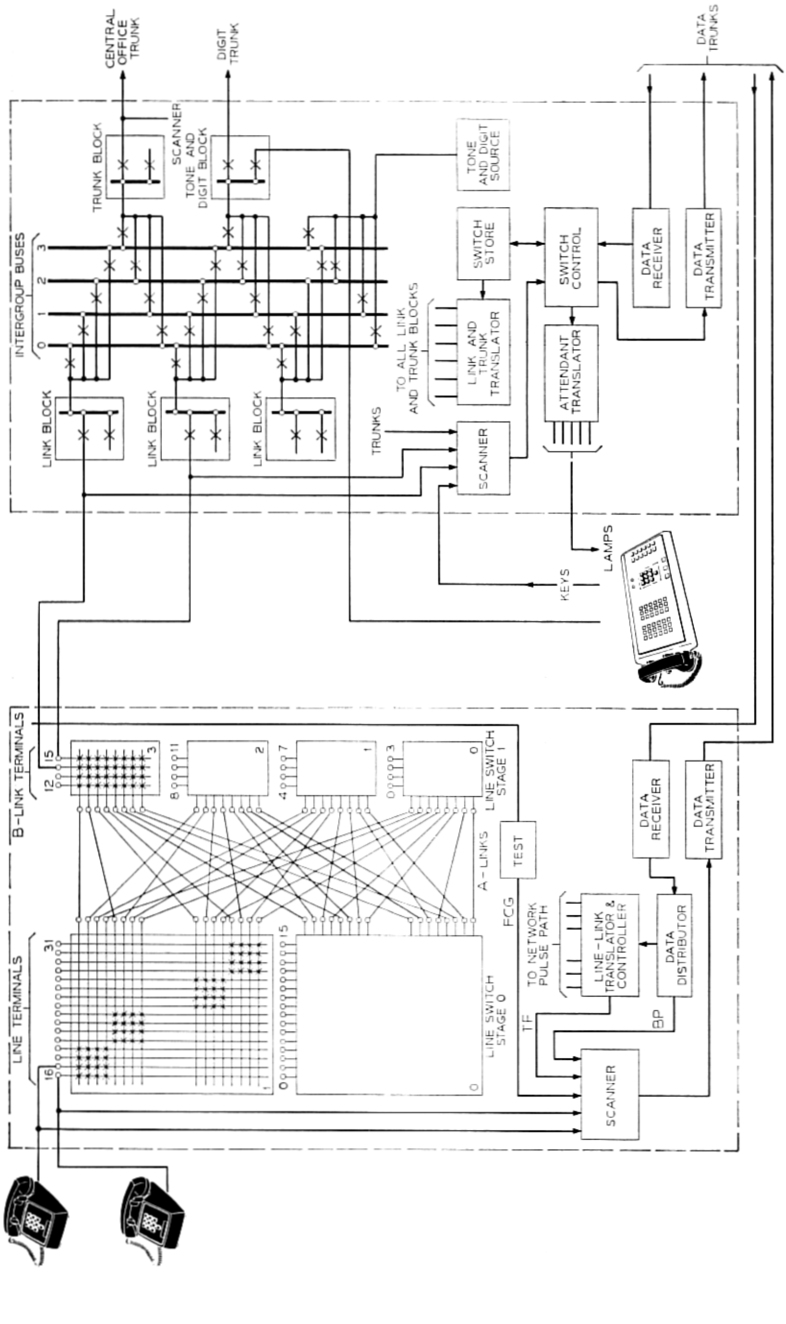

Fig. 12 — Basic elements of a 4A switch unit.

mines from its memory what changes need to be made in the 3A time division switch and in the line connector. A 47-bit message is sent to the 3A time division switch to cause it to disconnect the time division connection, and a 25-bit message is sent to the line connector. The 25-bit message is similar to the connect message, except that the order is now a disconnect which causes the line switch controller to disconnect the line from the A-link and to release the cutoff ferreed, thus restoring the ferrod sensor so that the next off-hook occurrence of the line will be detected. Before the relays are released the network path is tested via the test vertical.

A line-to-trunk call involves the time division connection of the trunk to the intergroup bus in the 3A time division switch, the time division connection of the intergroup bus to a B-link to the line connector, and connection through two ferreed switches in the line connector to the line. Tone, dialing, and ringing connections are set up in a similar manner. A line-to-line call involves two sets of ferreed switches plus the time division connections in the 3A time division switch.

4.3 *Plug-In Units*

Cables between the frames of the line connector are equipped with plug-in connectors except for the power leads. Two cable racks are provided, one at the top and the other at the bottom of the frames. Frames are of one size and fasten together in a line with end panels on the end frames. Individual front and rear panels are the same for all frames. B-link cables connect directly from the line connector frames to the 3A time division switch units and do not connect to the distributing frame.

4.4 *Options and Growth*

All the options are provided by plug-in, that is, a frame has the same wiring regardless of the options selected at the time of installation. In the data converter frame, the data link option of either loaded or nonloaded facilities is obtained by placing the circuit packs involved in the proper position in the mounting tray. If the second controller frame is used, a second set of cable drivers and receivers is installed in the positions provided.

A controller frame is equipped to handle four line switching frames (1024 line terminals); if less than the four frames are provided, the unused outputs are left idle.

A line switching frame has a 2:1 concentration ratio; by paralleling B-links (connecting the outputs of concentrators 0 and 4, 1 and 5, 2 and 6, and 3 and 7) a 4:1 concentration ratio is provided. Two plug-in jumper cables on the frame provide this option.

V. STATUS

The first 4A switch unit was placed in service in February 1967 by Illinois Bell Telephone Company to provide telephone service for more than 1300 telephones at Bell Telephone Laboratories, Indian Hill, Naperville, Illinois. By the end of 1967 a total of six 4A switch units were in operation. The 4A-2 switch unit is scheduled for service in 1969.

VI. SUMMARY

The 4A switch units provide all of the No. 101 ESS service features to large PBX and Centrex customers with requirements for up to 4000 lines. Two stage switching with a combination of space and time division has resulted in an attractively priced system.

VII. ACKNOWLEDGMENTS

The designers of the 4A switch unit have drawn heavily upon the work of others in both the No. 1 ESS and No. 101 ESS. Mr. J. G. Kappel supplied the traffic analysis of the line concentrator.

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