

SWITCHING PLAN AND CONTROL PRINCIPLES
DESCRIPTION OF SYSTEM OPERATION
NO. 101 ELECTRONIC SWITCHING SYSTEM

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1. GENERAL

1.01 This section is reissued to include the 2A and 3A switch units. Because this reissue covers a general revision, arrows ordinarily used to indicate changes have been omitted.

1.02 The No. 101 electronic switching system (ESS) is for business customers requiring PBX or centrex service. This system has three different types of switch units which are located on customer premises, and a fourth type is planned for the near future. Table A shows the line and trunk capabilities for each type of switch unit.

TABLE A
SWITCH UNIT CAPACITIES

SWITCH UNIT	MAX. LINES	TRUNKS
1A	200	40*
2A	340	80
3A	820	112*

*Added trunks may be obtained by reducing line capacity.

Switching control is centralized, which makes possible a total system capacity of 3200 lines divided among as many as 32 customer switch units.

1.03 This system makes available a number of advanced service features on an economical and flexible basis, while retaining operational compatibility with existing type central office and station equipment.

1.04 These features are made possible by the application of several new system concepts and the exploitation of a number of solid state electronic devices and circuit principles.

1.05 This section describes the organization of the system and its basic operating features. Other related sections describe the operation of the various parts and subsystems in more detail.

2. SYSTEM CONCEPTS AND TECHNOLOGY

A. Electronic Device Speeds

2.01 The most significant aspect of the electronic devices employed in the system is not merely that they are fast acting and therefore offer certain direct improvements in call-handling efficiency, but rather that they make possible entirely new operating and control principles which otherwise could not be realized in practice. Thus, the high speed characteristics of electronic devices are fundamental to the system design.

B. Time Division Switching

2.02 The No. 101 ESS exploits the principle of speech sampling and of time-sharing a common transmission path simultaneously by many talking connections to minimize the amount of equipment needed in the local switching network. This principle has been used previously in frequency-multiplex transmission systems over relatively long distance, wide-band channels and in time-multiplex short-haul carriers for short distances. The No. 101 ESS uses this principle for local switching functions of the sort conventionally performed by relays or similar space division apparatus. The new technique is known as time division switching.

C. Common Control via Data Links

2.03 Coded messages transmitted over high speed, 2-way data links are used in controlling, from a central location, the establishment of talking connections at distant switch units. This constitutes an important extension of the common control principle.

D. Scanning Input Signals

2.04 Periodic sampling is employed in the form of scanning as a means of gathering input information for the system. At the switch unit, a common scanner circuit repetitively tests each line and trunk to determine its off-hook or on-hook state. At the control unit, each incoming data trunk as well as each digit receiver is continually scanned for the arrival of new message bits or dialed digit pulses. Besides economy in equipment, the effect of high speed scanning is

to permit all sources of input signals to have virtually simultaneous access to the circuits designed to receive and store them.

E. Large Scale Magnetic Memories

2.05 Large scale, high speed memories capable of storing many thousands of bits of information at a small cost per bit are used in the No. 101 ESS. These bulk memories or stores are of two types, temporary and semipermanent. A temporary store made of ferrite sheets or ferrite cores permits data to be quickly inserted or removed and stored as long as required. Stores of this type are used for the various transient recording functions required in establishing and maintaining many simultaneous talking connections. A semipermanent store of the permanent magnet twistor type is used for infrequently changed information such as call processing instructions, translations, and assorted reference data. Information in this type store is recorded as magnetized spots on a series of cards which are inserted in a twistor memory module. The information can be quickly read out without destruction. Changing the information on a card, when required, is done externally to the store.

2.06 The implementation of the stored program concept of call processing is mainly dependent on the availability of storage facilities having the foregoing capabilities.

F. Stored Program Control

2.07 The call processor function of interpreting input information, deciding on actions needed, issuing orders, and updating call records is under the direction of a set of instructions, appropriate to each stage of a call, which is stored in a semipermanent memory called the program store (PS). The process, accordingly, is known as stored program control. The outstanding advantage of this method of control is the flexibility it permits. Variations in service features and operational requirements between customers or whole installations, whether at the time of installation or later, can be made by the relatively simple operation of changing the spot magnetization pattern on certain cards of the twistor store. In general, no changes in a switch unit located on the customer premises are required to add or change service feature options. Wiring options during manufacture are also minimized by this design.

2.08 Closely related to the PS is the line information store (LIS), also of the twistor type, which contains class of service and similar information pertaining to particular lines.

2.09 Temporary records of calls being served by the call processor are kept in a ferrite sheet type memory known as the call store (CS).

3. BASIC SYSTEM PLAN

3.01 The organization of the major parts of the system and the trunking plan are shown in Fig. 1.

3.02 Each customer switch unit (maximum 32) has a 2-way data link consisting of two cable pairs for transmitting supervisory and control messages. A 3A switch unit will have one 2-way data link when it has 120 or less working time slots and will have two 2-way data links when it has more than 120 time slots. Also, closely related to the data links, are the digit trunk pairs for transmitting dial tone to the switch unit and for transmitting TOUCH-TONE (T-T) digit or dial signals to the control unit. The number of digit trunks provided depends on customer traffic requirements.

3.03 For calls outside the switch unit, trunk pairs to the central office are required. Owing to the control and signaling functions involved, each central office trunk connects to the central office by way of a trunk circuit which is, effectively, a part of the No. 101 ESS control unit. The number of central office trunks in each switch unit varies, as shown in Table A.

3.04 The maximum extension line capacity varies, depending upon the type of switch unit that is used (Table A). From an operational standpoint, any line may have a conventional dial-type telephone set, a T-T set, or a mixture of the two types.

3.05 The system provides for the use of tie, foreign exchange (FX), and miscellaneous trunks.

3.06 Although only one attendant console is indicated in Fig. 1, if required there may be as many as two for 1A switch units, three for 2A switch units, and up to twelve for 3A switch units.

3.07 If a No. 101 ESS customer wants a service providing for identification of the particular extension involved in making a toll call,

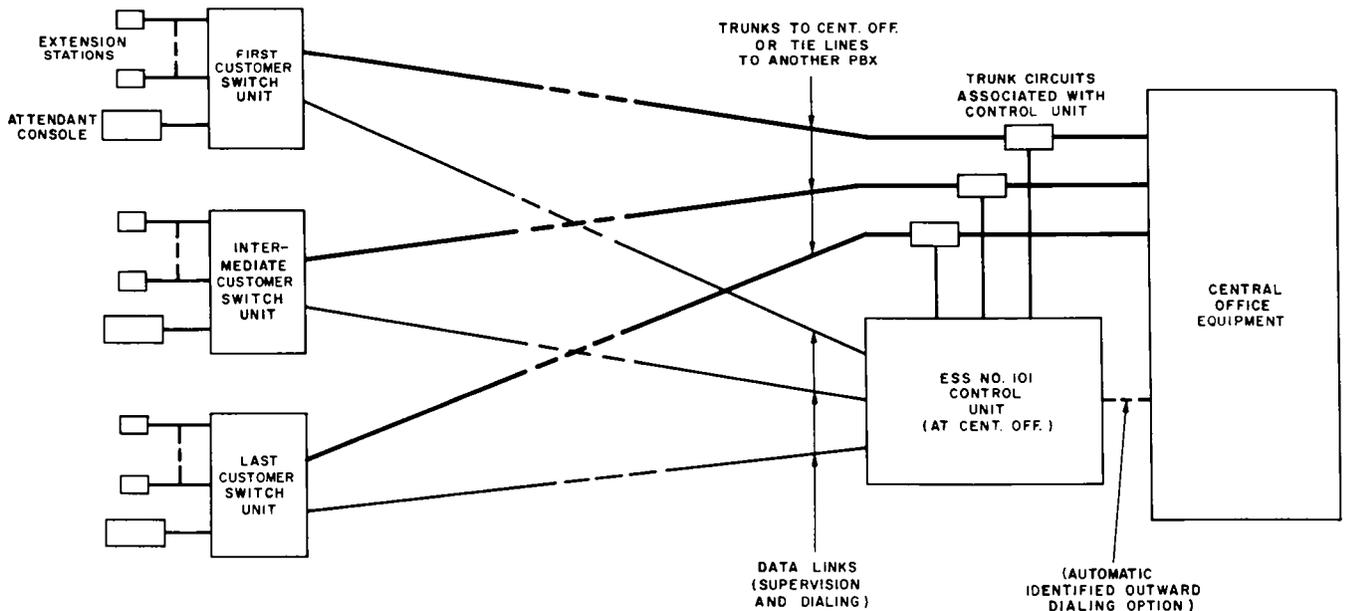


Fig. 1 — Basic System Plan of Electronic Switching System No. 101

the following conditions are necessary: the central office must be provided with automatic message accounting (AMA) or automatic number identification (ANI) equipment; leads must be connected directly between the No. 101 ESS control unit and the central office AMA or ANI equipment; and the appropriate plug-in circuit packs must be installed in the control unit.

4. TIME DIVISION TRANSMISSION AND SWITCHING PRINCIPLES

4.01 Since time division switching is a key feature of No. 101 ESS, an understanding of its principles is essential to an appreciation of system design (see Fig. 2). Developments in transmission theory have shown that periodic short samples of a speech signal are sufficient to define the signal completely, provided these samples are taken frequently enough. Furthermore, many such samples, each from a different signal, may be transmitted over a common path without interfering with one another, provided they are taken sequentially and each confined to its own subdivision or time slot within the sampling period.

4.02 While elementary sampling is adequate for transmitting the frequency and relative amplitude characteristics of speech, a large loss in volume results, if unaided. In a system primarily intended for multiplex transmission, this is compensated for by the use of amplifiers in the transmission channel. In the No. 101 ESS, however, where the emphasis is on taking advantage of the switching possibilities of this principle, losses are kept adequately small through the use of resonant transfer.

4.03 A single transmission channel illustrating this method is shown in Fig. 2. If switches A and B are closed simultaneously, any voltage on low-pass filter capacitor C_A is transferred by way of the common bus to capacitor C_B . Using the constants of the two capacitors and the inductors between them, it is possible to give the bus path a low-loss resonant characteristic so that essentially all of the voltage, initially on C_A , will be on C_B after a time interval equal to half the natural period of the resonant circuit. If the two sampling switches are opened at this point, the transfer of energy is accomplished almost without

loss. In the 1A switch unit each data switch store circuit has 25 words of memory for talking time slots which are read sequentially and repetitively at a 12.5 kc rate. In the 2A switch unit each data switch store circuit has 30 words of memory allocated for talking time slots which are read sequentially and repetitively at a 11.7 kc rate. The 3A switch unit has 60 words of memory allocated for talking time slots. To the user, each time division transmission path appears to be continuous due to the smoothing action of the filters forming a part of each line circuit.

4.04 Fig. 3 illustrates the foregoing description as applied to two separate, but effectively simultaneous, conversation channels over a common bus. In 2A and 3A switch units the common bus involves group and intergroup buses which are connected by time division switches when required by the conversation channel. Fig. 4 indicates the principal types of circuits associated with a common bus. Also shown is the bus clamp circuit used for removing, during the guard interval, any residual charges that may have been left on the bus from the preceding transmission interval. This action gives protection against crosstalk between transmission channels in adjacent time slots.

4.05 The bilateral sampling switches actually used are PNP diodes in the 1A switch unit and are transistors in the other switch units. Their conduction intervals are controlled by a local memory and a system of translators in the network control circuit of the switch unit.

5. MAJOR ELEMENTS OF THE SWITCH UNIT

5.01 Fig. 5 illustrates the broad principles of system operation in terms of its major circuit elements; the basic parts of a switch unit are shown at the left. A scanner circuit interrogates each line and trunk circuit, normally, about 50 times per second for the 1A switch unit and about 10 times per second for the 2A and 3A switch units. When an off-hook condition is detected by the scanner, a 14-bit data message (12-bit for 1A switch unit) is sent to the control unit conveying this information together with the line number.

5.02 Such an off-hook signal represents a call origination or an incoming trunk call. In this case, the control unit responds with a data

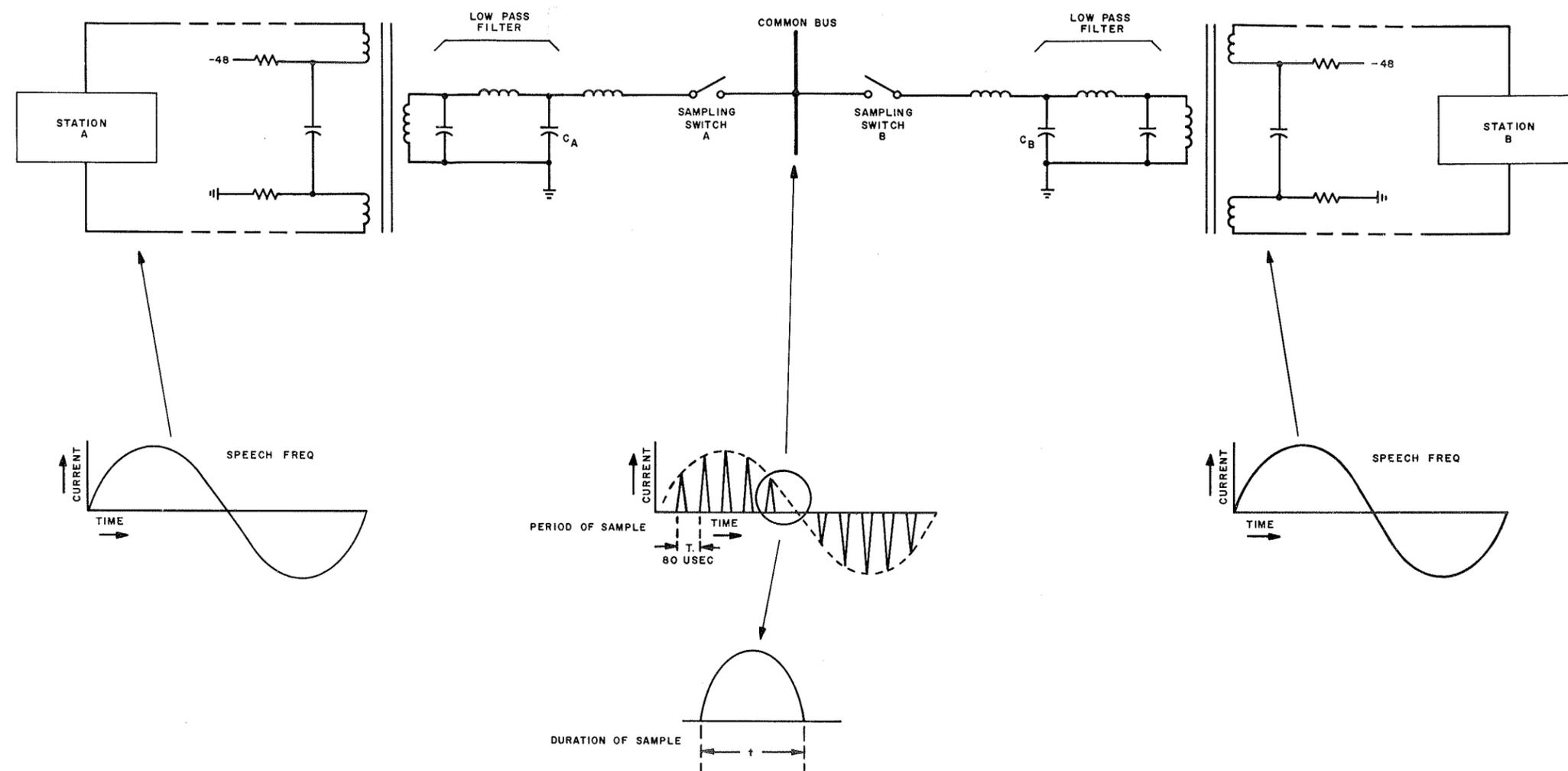


Fig. 2 — Fundamental Time Division Transmission Circuit

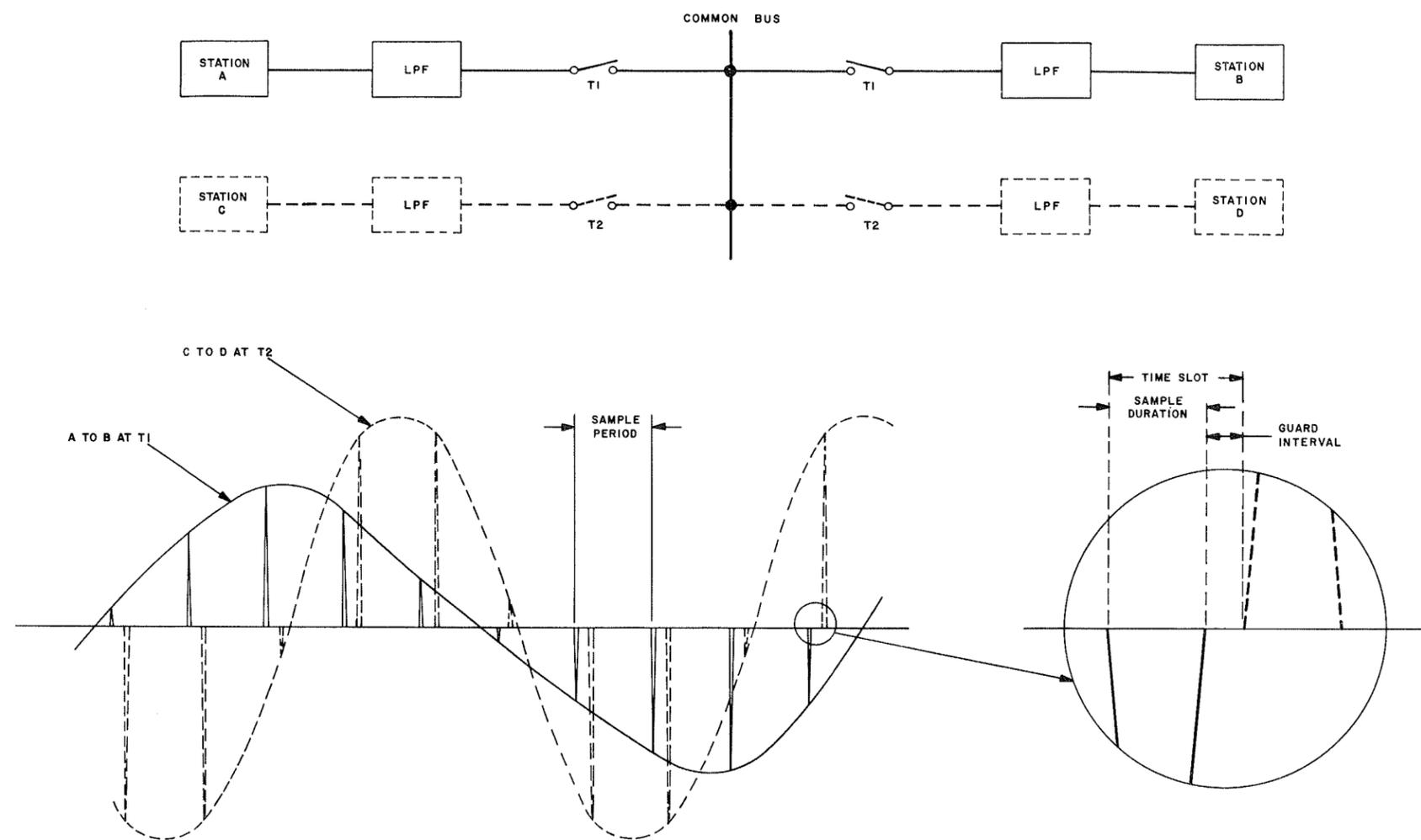


Fig. 3 — Simultaneous Conversation Channels Over a Common Transmission Bus

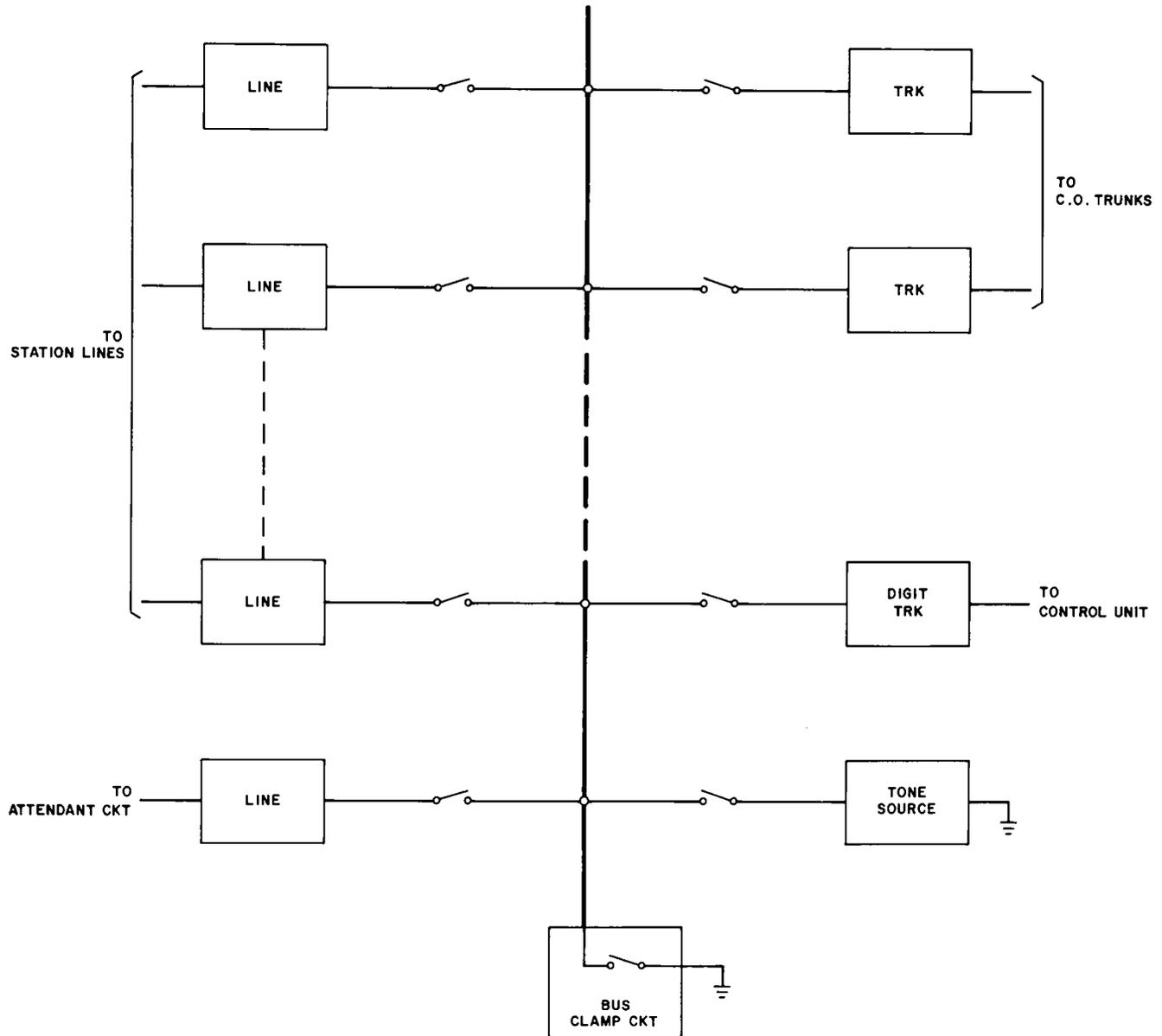


Fig. 4 — Types of Circuits Served by One Time Division Bus

message to the memory and control part of the switch unit which causes time division gates to start operating in the time slot directed by the control unit. For the dial tone part of a line, attendant, or incoming DID call, one gate is associated with the calling line or trunk, the other with the digit trunk. For 2A and 3A switch units additional intergroup switches are involved. Simultaneously, at the control unit, another time division path is set up (through controls not shown) between the digit trunk and one of the control unit digit receivers. The receiver supplies dial tone and the calling line is then free to dial.

5.03 The dc dial pulses are converted in the switch unit to tone spurts for transmission to the control unit digit receiver; T-T signals are transmitted over this channel without modification.

5.04 Through other data messages, the control unit changes the information in the switch unit memory so that the first time division connection is released and others are set up as required by the progress of the call. These include connections that transmit a ringing control signal to the line circuit of party B while transmitting

audible ring tone to party A. When party B responds to the ring, a new off-hook message goes to the control unit resulting in yet another message to the switch unit memory, this time causing a time division path to be established between parties A and B for talking purposes. Similarly, connections are established between an extension and a central office trunk or between a trunk and an attendant, etc.

6. MAJOR ELEMENTS OF THE CONTROL UNIT

A. Data and Digit Store

6.01 The large volume of work done by the call processor (CS, PS, and program control areas) restricts the time devoted to receiving new input information, or to issuing orders, to only a few microseconds in each case. This, together with the random nature and relatively slow speed with which information is received at the control unit, necessitates the use of a data and digit store for temporary storage of such information pending its transfer on a parallel or all-at-once basis to the call processor at a time convenient to the latter. Similarly, the data and digit store is necessary as a place where outgoing data messages are quickly deposited by the call processor prior to their re-transmission to switch units on a bit-by-bit basis.

6.02 The data and digit store is under the immediate control of the data control circuit. This, together with the digit and sender control circuits, forms a closely knit group of circuits that perform a variety of functions relative to handling input and output data and digit information. The symbol for the store, shown in the lower middle part of Fig. 5, helps visualize the fact that the data, digit, and sender control circuits have access to any word in the store required for inserting or removing bits of information.

B. Data Trunk and Digit Receiver Scanning

6.03 A primary function of data control is simultaneously scanning the data trunks and addressing sections, or words, of the data and digit store corresponding to these trunks. The purpose of this dual operation is to put incoming data bits, as they arrive, into their allotted places in the store and, conversely, to read out

previously inserted outgoing data, one bit per scan (1.36 msec) to the outgoing data trunks.

6.04 A given scan, in addition to covering all data trunks (one set for each switch unit), also covers 3 of the possible 42 digit receivers whose outputs correspond to any dial pulses or T-T digits that may have been received. Such digital signals are also written into the section of the data and digit store allotted to the receiver in question.

C. Call Store

6.05 Call processing requires that a record be immediately available of the status of each call being handled in each switch unit of the system. The records must be continually updated to keep abreast of all subscriber and call processing actions. The CS is a temporary, ferrite sheet memory and is used for this function. This store also records other temporary information such as the availability of trunks, digit receivers, and other common equipment.

D. Program Store

6.06 As indicated previously, the PS is the main handbook or reference table for the system. It contains the instructions or sequences of logical operations required at each step of call processing. It is of the semipermanent, twistor type.

E. Line Information Store

6.07 The LIS is also of the semipermanent type. It contains per-line information about class of service, hunting sequences, abbreviated dialing lists, and other translation information.

F. Program Control

6.08 The program control (PC) circuit interconnects the three stores of the call processing section with each other and with the data, digit, and sender control areas. It consists of a large body of logic and a number of registers. Processing involves examining new information from the switch units (obtained by way of the data and digit store), inspection of existing call records, and with the aid of instructions from the PS, determining what new orders should be issued to advance the progress of the call.

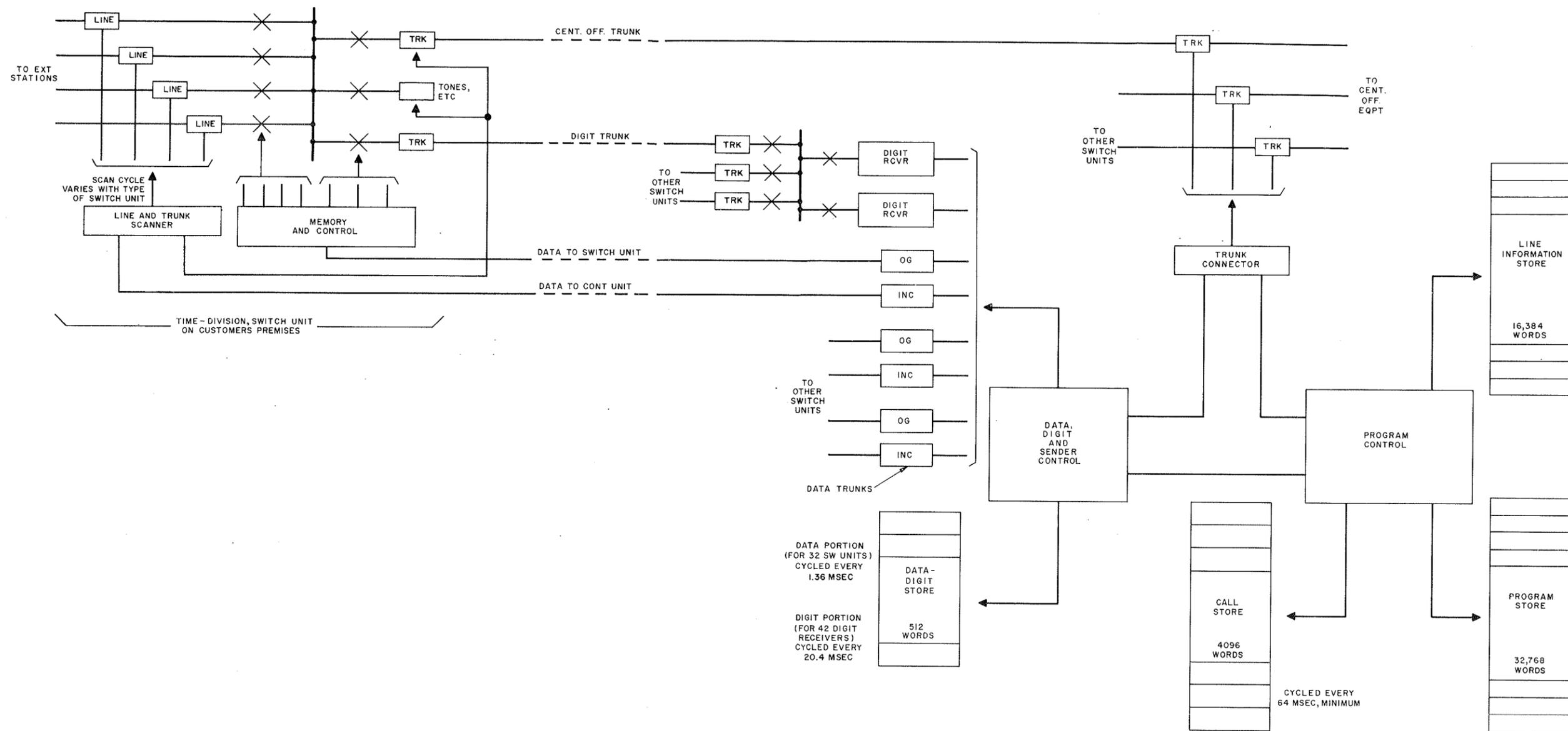


Fig. 5 — Major Switching and Control Elements

G. Trunk Connector

6.09 The trunk connector circuit is used on central office or tie trunk calls for originating outgoing calls, answering incoming calls, disconnecting, and outward dial pulsing, when required. Through addresses presented to it, the trunk connector is directed to establish a seizure or released condition on any trunk of any switch unit. These directions and addresses are presented by PC when a seizure or disconnect function is required or, repetitively, by sender control when outgoing dial pulses are to be created.

7. SYSTEM BLOCK DIAGRAM

7.01 Fig. 6 is a block diagram of the system with most of the supporting circuits shown by name as well as the major circuits.

7.02 There are two or more time division bus systems at the switch unit, each associated with separate data switch store circuits. There is also a transfer and alarms circuit which exercises local control of the redundant features of the switch unit and determines which scanning and data transmitting circuit is used. If there is evidence of trouble, the transfer and alarms circuit takes out of service one of the time division buses. The transfer and alarms circuit receives orders by messages from the control unit.

7.03 With all buses in service a maximum total of 50 time slots for the 1A switch unit, 60 time slots for the 2A, and 120, 180, or 240 time slots for the 3A are available for simultaneous calls. In case trouble develops in a bus or data switch store circuit, the traffic capacity is reduced by the number of time slots in the defective circuit for the period of the difficulty.

8. DUPLICATION OF CONTROL UNIT EQUIPMENT

8.01 Fig. 7 shows that the control unit, rather than being duplicated as a unit, has been sectionalized so that a number of different working modes can be established. This plan enhances the overall reliability of the system.

8.02 The administration of the redundant features of the system is under control of the maintenance center.

9. DESCRIPTION OF LOGIC CIRCUITS USED IN NO. 101 ESS

9.01 In order to read and understand electronic logic circuits for the No. 101 ESS, it is necessary to understand how the basic logic elements (gates, flip-flops, binary counter cells) function in this system. This summary of the operation of logic elements is inserted here to assist in the understanding of the simplified logic circuits shown in this and other BSPs on the system.

9.02 The No. 101 ESS uses negative logic in most of its transistor-resistor logic (TRL). Low level logic (LLL) uses positive logic. Negative logic means that the lower, or less positive, potential of a 2-state (binary) signal is defined as a 1 (one). This is different from what is stated in Lesson 9 of the Electronic Switching Prerequisites — Plant Training Course No. 42, published by the American Telephone and Telegraph Company. The operation of three basic logic elements is described as follows.

TRL GATES

9.03 A TRL gate, as shown in Fig. 8, performs OR logic on positive inputs and AND logic on ground inputs. It also performs logical negation, i.e., a positive input produces a ground output. The latter function is often referred to as an inverter.

9.04 The TRL gates function so that whenever any input resistor is driven with approximately +5 volts, the gate output is near ground, and whenever *all* of the input resistors are held at ground the output of the gate is at approximately +5 volts.

TRL FLIP-FLOPS

9.05 A TRL flip-flop is shown in Fig. 9. It consists of two TRL gates interconnected so that the output of each is connected to the input of the other.

9.06 The TRL flip-flops function so that whenever a positive potential is placed on the SET (S) lead the A lead goes to a negative potential and the B lead goes to a positive potential. Also, whenever a positive potential is placed on

the RESET (R) lead, the A lead goes to a positive potential and the B lead goes to a negative potential. The A and B leads will always be in the opposite state from each other.

TRL BINARY COUNTER STATE

9.07 A TRL binary counter stage is shown in Fig. 10. It consists of two TRL gates interconnected similarly to a flip-flop, with the addition

of a third type of input, a pulse steering network. The SET and RESET leads are similar to a flip-flop, i.e., a positive input on the SET lead makes the A lead negative and the B lead positive and a positive input on the RESET lead gives the reverse outputs. In addition, each time the I input lead goes from off ground to ground, the potential of both output leads A and B are reversed.

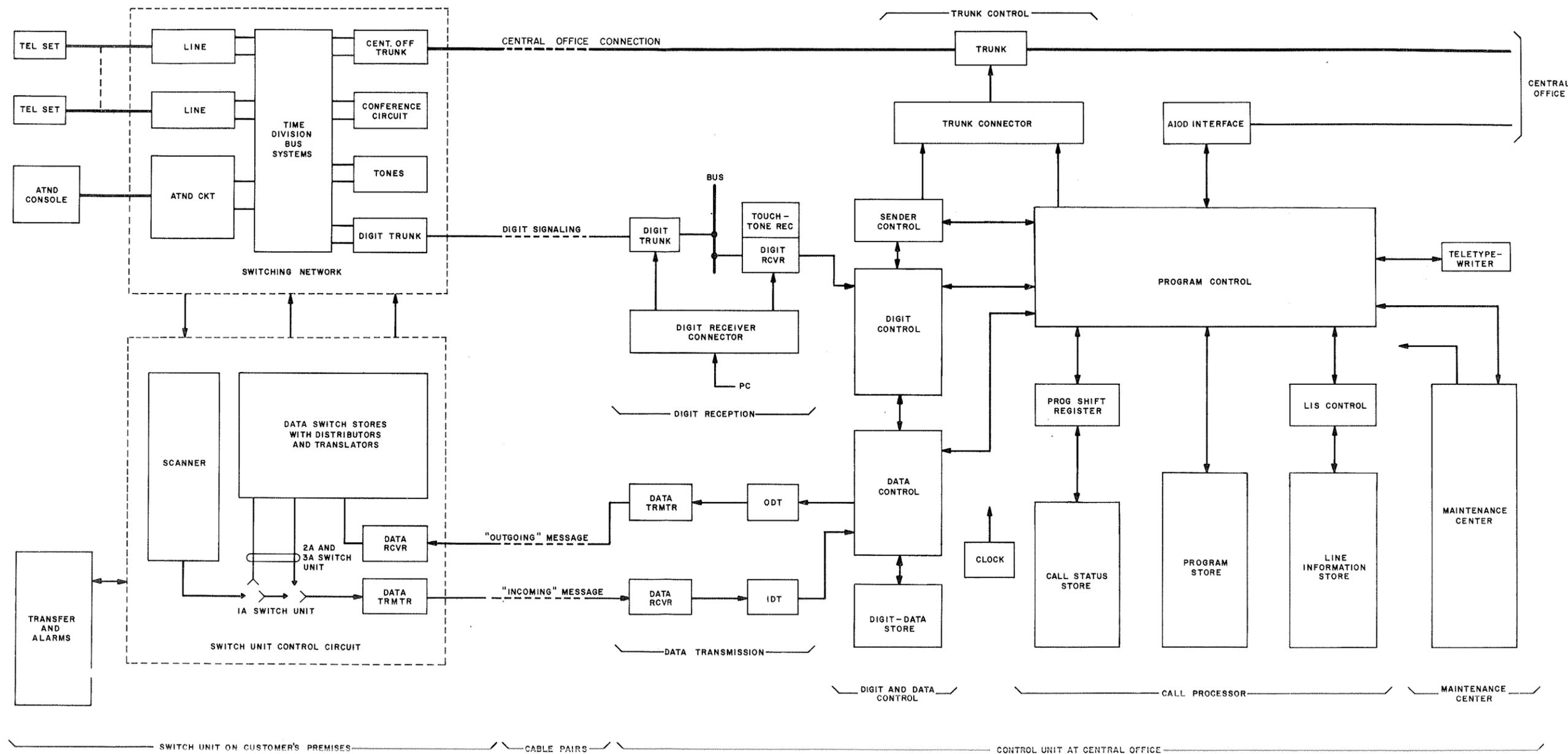


Fig. 6 — Block Diagram of No. 101 Electronic Switching System

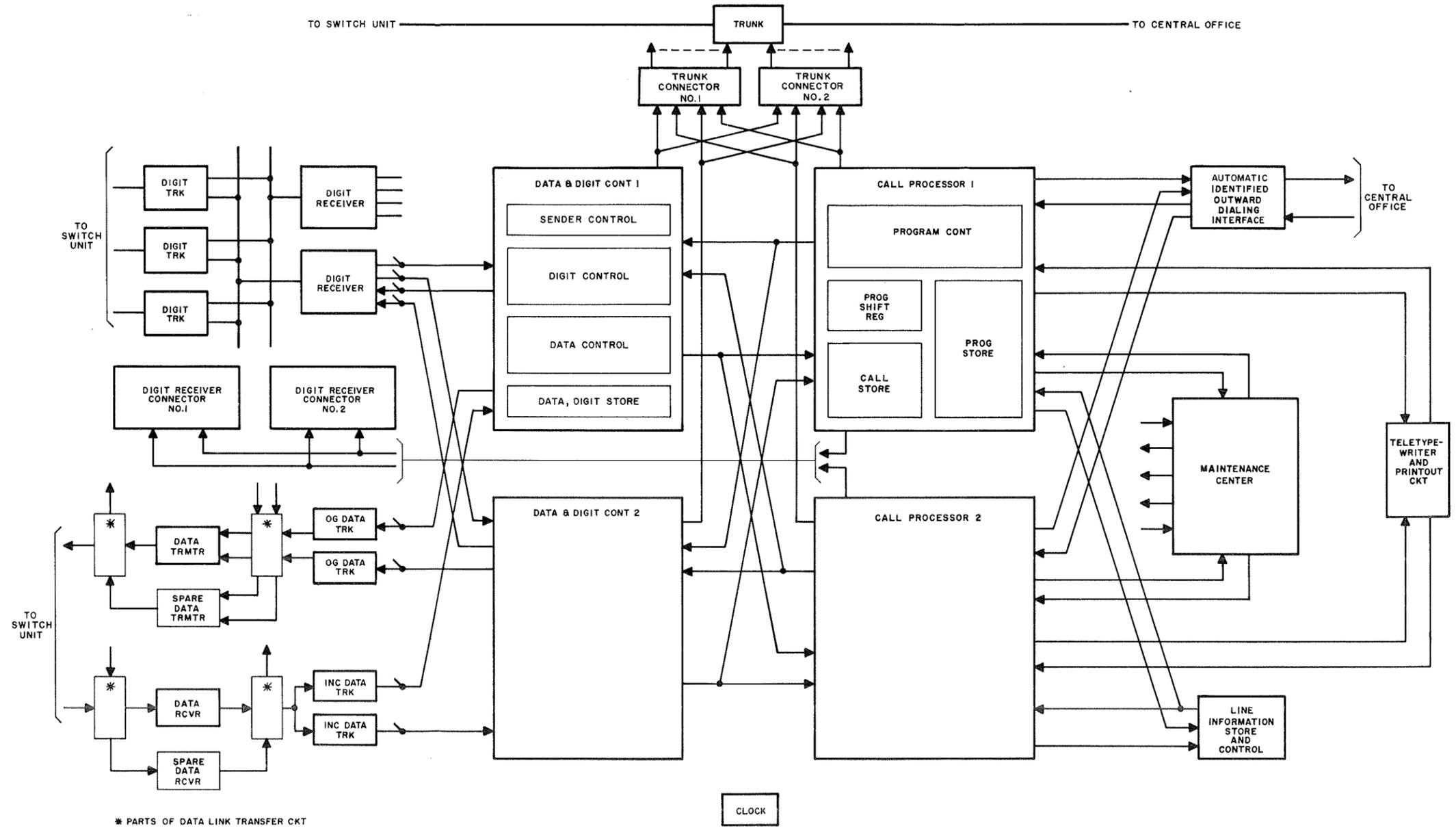


Fig. 7 — Duplication of Control Unit Equipment

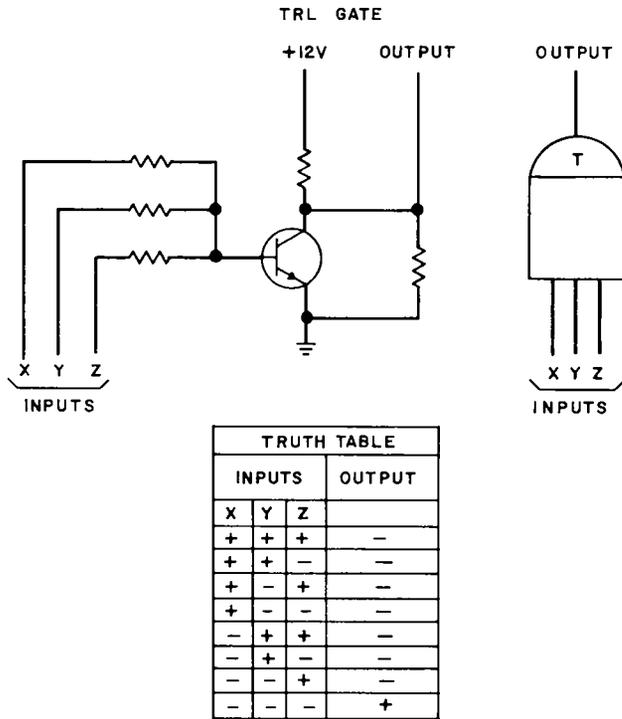
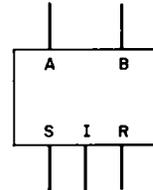
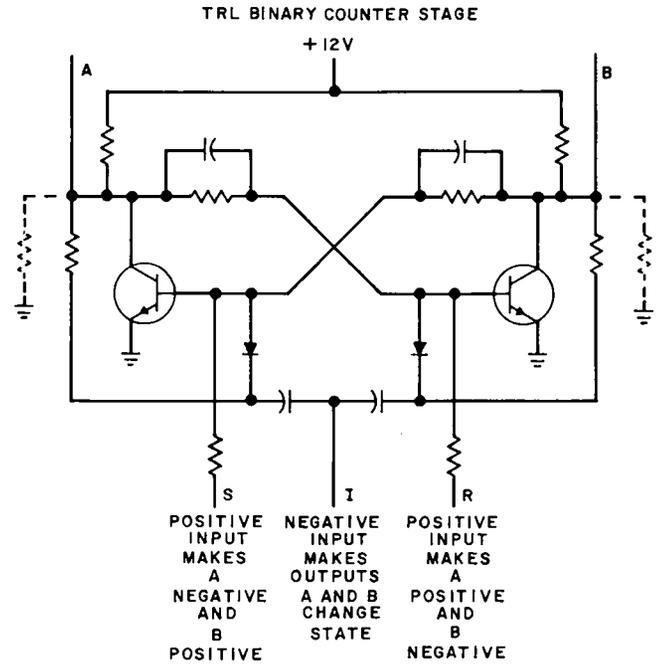
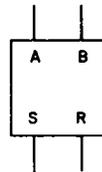
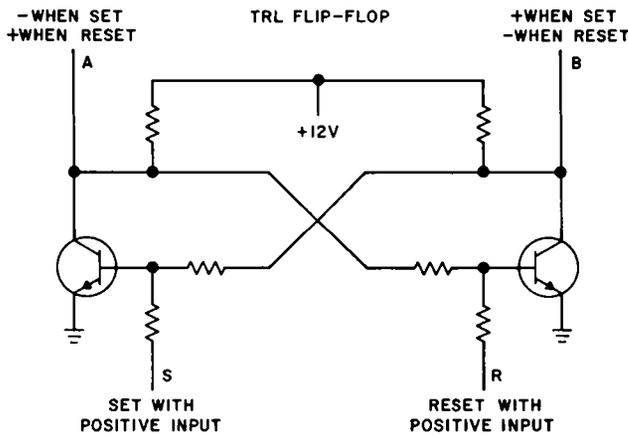


Fig. 8 — TRL Gate



TRUTH TABLE						
PREVIOUS STATE OF					NEXT STATE	
A	B	S	I	R	A	B
+	-	+		-	-	+
-	+			+	+	-
+	-			+	-	+
-	+	+		-	-	+
+	-			-	-	+
-	+			+	+	-
+	-			+	+	-
-	+			+	-	+

Fig. 10 — TRL Binary Counter Stage



TRUTH TABLE			
S	R	A	B
+	-	-	+
-	+	+	-

Fig. 9 — TRL Flip-Flop