
SP-1
ELECTRONIC
SWITCHING SYSTEM

NORTHERN ELECTRIC COMPANY LIMITED
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SP-1 ELECTRONIC SWITCHING SYSTEM

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TABLE OF CONTENTS

SECTION	Page	SECTION	Page
1 INTRODUCTION	2	Marker	13
2 FEATURES AND SERVICES	2	Network Control Circuit	15
Service Features	3	Junctors	15
Types of Lines	3	Bus System and Interface	16
Types of Service	3	Signal Distributor	16
Types of Ringing	3	Scanner	17
Types of Subscriber Dialling	3	Miscellaneous Trunk and Service	
Message Accounting	3	Circuit Frame	19
Connecting Switchboards	3	Trunk Circuits	19
Connecting Desks	3	Service Circuits	19
Connecting Sets	3	Central Control	20
Connecting Announcement Systems	3	Program Store	21
Switching Points and Routing	3	Call Store	21
Dialling Plan	3	Central Processing Unit	23
Outpulsing – Multifrequency	3	Maintenance Centre	24
Outpulsing – Dial Pulse	3	Distribution Frames	24
Impulsing – Multifrequency	3	4 THE SOFTWARE SYSTEM	31
Impulsing – Dial Pulse	3	General Software Structure	31
Coin Features	4	Call Processing	31
Intercepting Calls	4	Maintenance	31
Reverting Calls	4	Administration	31
Partial Dial and Permanent Signal		Organization of the Control	
(PD and PS)	4	of the Software System	31
Incoming Trunks	4	Base Level Executive	31
Outgoing Trunks	4	E-Level Executive	32
Outgoing Trunks to Switchboard or		Maintenance Interrupt Control	32
Desk	4	5 TELEPHONE CALL PROCESSING	32
Automatic Overload Control Features	4	Dial Tone Connection	32
Maintenance	4	Dialling Connection	32
Miscellaneous Features and Circuits	4	Intraoffice Call	33
Automatic Intercepting	5	Establishing The Talking Connection	34
Calling Line Identification	5	Interoffice Call – (Originating – Outgoing)	34
Capacity	5	Interoffice Call – (Incoming – Terminating)	34
Operating Limits	6	Tandem	36
3 EQUIPMENT ELEMENTS	7	Revertive Call	36
Switching Networks	7	6 POWER	37
MINIBAR* Switch	9	NE-111A Power Plant	37
Line Network	10	PH-1 Power Plant	37
Route Network	10	PB-6 Ringing and Tone Plant	38
Route Junctors	10		
Service Network	10		

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

FIGURE		Page
1	SP-1 ESS Block Diagram	8
2	MINIBAR Switch	9
3	Basic Line Link Frame	11
4	Originating Route Link Frame	12
5	Terminating Route Link Frame	12
6	Basic Service Link Frame	13
7	Marker Frame	14
8	Originating Junctor Frame	15
9	Signal Distributor	17
10	Scanner Frame	18
11	Miscellaneous Trunk and Service Circuit Frame	19
12	A Central Control and its Relationship to Peripheral Equipment	20
13	Basic Program Store	22
14	Piggyback Twistor Module	23
15	Basic Call Store	24
16	Call Store Memory Module	25
17	Central Processor Frame	26
18	Printed Circuit Board (Typical of the type used in the SP-1 ESS)	27
19	Central Processing Unit Block Diagram	28
19A	CPU Instruction Formats	29
20	Field Trial Maintenance Centre	30
21	Dial Tone Connection	33
22	Intraoffice Call – Ringing and Talking Connection	33
23	Interoffice Call – Outgoing	35
24	Interoffice Call – Incoming	35
25	Tandem Call	36
26	PH-1 Power Plant	38
27	PB-6 Ringing and Tone Plant	39

SP-1 ELECTRONIC SWITCHING SYSTEM

SECTION 1 – INTRODUCTION

The SP-1 Electronic Switching System is a common control system which relies on a stored program control to give it the flexibility required to meet current telephone requirements and to readily adapt to the sophisticated services of the future. The common control utilizes the high speed of electronic devices to perform the basic switching functions of logic, memory, and input-output control. Control is accomplished by sub-dividing the work required to process a call into small segments, and then time sharing the segments of several calls. High operating speeds enable a very small number of control circuits to service a very large number of lines and trunks.

The SP-1 ESS satisfies the requirements for a system to economically meet the rapidly expanding needs of business subscribers for new features and services. It also allows operating telephone companies to offer custom calling services to residence and small business subscribers. The SP-1 ESS opens the way to automatic transfer of incoming calls to another number (Call Forwarding), and the use of abbreviated dialling for frequently called numbers (Speed Calling). In addition, it will be possible, while speaking on the telephone, to receive an indication that another call is waiting (Call Waiting), and to transfer to this call and back again as often as desired merely by operating the switchhook. Also, this system permits a third party to be dialled and added to the conversation (Three-Way Calling). The flexibility of stored program control permits these and many other services to be provided at considerably less expense and effort than in electromechanical or wired-logic offices.

Perhaps the most advanced design feature to be introduced into the SP-1 ESS is the use of integrated circuits. Components, occupying an area slightly larger than a pin head, are encapsulated in metal units. Aside from the obvious advantage of minimal space requirements, integrated circuits are favoured in cost comparisons and reliability tests over discrete electronic components. Solid-state components are used wherever speed, reliability and size are important factors. They are incorporated in most control circuits and functional elements associated with the setting-up and supervision of calls. Set-up times for establishing network talking paths are in the order of a few hundred milliseconds.

Northern Electric's SP-1 ESS stored program switching system utilizes a unique combination of electronic and electromechanical techniques to achieve the greatest

possible economy, not only in the equipment itself, but also in the associated stored program. This has been realized through three major design approaches. Firstly, the hardware was designed to give the program planners a maximum of flexibility in the choice of order structures. Next, the overall program was analyzed to isolate recurring sequences of instructions which in earlier systems had been spelled out in full whenever and wherever they occurred. Once identified, these sequences need only be included once in the program to be called up as required. This approach alone resulted in a substantial reduction in the size and complexity of the total program, and in the memory units required to store it. Lastly, some of the "intelligence" usually included in the central processing unit was allocated to the peripheral equipment. For example, the use of a crossbar switching network utilizing MINIBAR switches enables normal 'sleeve lead' techniques to be used for indicating busy paths, rather than a 'network map' involving added complexity in both hardware and software.

The main advantage of a stored program electronic switching system lies in increased flexibility and ease of maintenance. Most changes, from the movement of a subscriber from one location to another, to the introduction of a sophisticated new feature, can be carried out by changes to the program rather than by alterations to the wiring or the installation of complex new equipment. Program changes may be fed into the system from a teletypewriter, magnetic or punched paper tape.

SECTION 2 – FEATURES AND SERVICES

The SP-1 ESS is intended for use as a local 2-wire switching unit (class 5 end office) of the common control type, with local tandem switching, and custom calling services available as optional additions to the system. ANI is an inherent capability. The system is suitable for the establishment of a new central office and is compatible with existing step-by-step and NE-5 Crossbar Offices, station apparatus, switchboards and desks, as well as local and toll switching systems. Where a demand for special services develops or can be anticipated, the SP-1 ESS can readily be used to replace the existing electromechanical switching system. All foreseeable numbering plans, including intercontinental toll dialling, can be programmed into the system. International voice band and facsimile transmission, and many types of special calls, can be accommodated by adding program options with the addition of little, if any, central office equipment.

SERVICE FEATURES

Types of Lines

- Individual – message and flat rate
- Two-party – flat rate
- Multiparty – 10-party flat rate (5-code divided ringing)
- Coin – prepay
- Coin – dial tone first
- Coin – semi-postpay
- PBX
- Manual Originating
- Ground Start
- Denied – originating and/or terminating
- Free Line
- Data Line (Hot Line)

Types of Service

- Toll Denied
- Toll Diversion (PBX)
- Bill to another number in the same SP-1 ESS Office
- Q-Z Billing (Special billing code)
- Hotel-Motel Message Register Charging
- TWX
- WATS
- INWATS
- PBX Hunting
- Stop Hunt
- No Hunt
- Overflow Register (for PBX Trunks)
- Random Make Busy
- Make Busy for PBX Trunk
- Series Completion
- Multiline Hunt

Types of Ringing

- AC-DC (immediate ring)
- Emergency Ringback
- Reverting – 2-party
- Continuous (105 volts)
- Multiparty – 5 code

Types of Subscriber Dialling

- DIGITONE*
- Dial Pulse (10 pps)

Message Accounting

- ANI to CAMA for station dialling (one- and two-party)
- MF to CAMA with ANI
- MF to CAMA with ONI
- ONI to CAMA (multiparty)
- Local Message Rate (untimed)
- CAMA Make-Busy Feature
- Q-Z Billing with regular CAMA Position
- Remote Message Register for Hotel-Motel PBX

Connecting Switchboards

- NE-3C, NE-3CL Type in the same or distant building.
- NE-1, NE-3, NE-13 and NE-15 Type when trunk circuits incoming to these switchboards are modified to be electrically equivalent to an NE-3C Type Switchboard.

Connecting Desks

- Information – NE-1, NE-3, NE-7 Type – local and remote – when electrically equivalent to an NE-23A Type Desk.
- Operating – NE-23A Type (information and intercept)
- Repair Service – NE-2 Type
- Service Observing – NE-12 Type
- Local Test – NE-14 Type

Connecting Sets

- Service Observing – NE-6 (portable) Type
- Test Cabinet – NE-3 Type

Connecting Announcement Systems

- NE-6A – Intercepting, Mass Announcement, Permanent Signal, Vacant Code, Partial Dial (Bilingual Optional)
- Code-a-phone®
- NE-7A
- NE-1 ESS

Switching Points and Routing

- Local End Office – Class 5
- Alternate Routing – 6 routes or more
- Local Tandem Features – 2W
- Foreign Area Translation (for routing and charging)

Dialling Plan

- Access Codes – 0+ and 1+
- Operator – 0
- Service Codes – XII
- 7-digit Directory Numbering
- Up to 15-digit toll dialling, including prefixes
- Interchangeable Area and Office Codes
- Emergency Operator Code 911

Outpulsing – Multifrequency

- 14 digits maximum, plus 3 prefix, plus 8 ANI
- Delete up to 15 digits
- Prefix up to 3 digits
- Loop
- E & M
- Wink Start
- Delay Dial – Method A
- Idle Circuit Termination
- Outpulse to CAMA

Outpulsing – Dial Pulse

- 10 digits maximum, plus 3 prefix
- Delete up to 15 digits
- Prefix up to 3 digits
- Loop
- E & M
- Wink Start

Inpulsing – Multifrequency

- 10 digits maximum
- Loop
- E & M
- Wink Start
- Delay Dial – Method A

Inpulsing – Dial Pulse

- 7 digits maximum
- Loop
- E & M
- Immediate Dial (by-link)
- Delay Dial – Method A

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Coin Features

- Prepay Operation
- Return or Retain Coin on Dial "0" and "XII" calls
- Collect and Return Signals using:
 - Inband Signalling
 - Third Wire Control
 - Tip and Ring Control
- Dial Tone First

Intercepting Calls

- Routed to:
 - Regular Intercept Operator
 - Trouble Intercept Operator
 - Regular Operator
 - Announcement System
 - Tone

Reverting Calls

- Two-party flat rate lines
- Ten-party - semi-selective ringing

Partial Dial and Permanent Signal (PD and PS)

- PD: 15-30 second timeout - normal
- 7.5-15 second timeout - overload
- PS: 15-30 second timeout - normal
- 7.5-15 second timeout - overload
- 6-12 second timeout - incoming MF Trunks
- Routing to Announcement, R.O.H. Tone, Operator, High and Wet State as required by Telephone Company.
- TTY output (interval to be defined)

Incoming Trunks

- Local or Tandem, (depending on digits received):
 - Reverse Battery, Idle Circuit Termination, Wink Signal, Delay Dialling
- Toll Switch, Reverse Battery:
 - Inband or 3rd Wire Coin Control, Regular or No-Test, Automatic or Controlled Ring to NE-3C Type Switchboard in the same building or remotely located.
- Local or Tandem (depending on digits received):
 - E & M Lead Supervision, MF Pulsing, Idle Circuit Termination
- Toll Switch, E & M Lead Supervision:
 - Automatic Ring Regular or No-test from NE-3C Type Switchboard

Outgoing Trunks

- TSP at Crossbar Tandem or TSPS No. 1, Loop and E & M Coin and Non-coin, Inband Coin, and Rering control.
- Local or Tandem, Reverse Battery, Idle Circuit Termination
- Local or Tandem, E & M Lead Supervision, MF Pulsing

Outgoing Trunks to Switchboard or Desk

- NE-3C Type Switchboard
 - Reverse Battery, T & R Coin Control, Ringback with or without Class of Service Tone
- Verification Request
 - Reverse Battery, Hi-Lo Supervision
- Intercept
 - Reverse Battery, Hi-Lo Supervision (combined trunk group for regular, trouble and machine intercept)
- Information
 - Reverse Battery Supervision

Traffic Service Position

- Reverse Battery or E & M, Inband for Coin Control and Rering Signals.
- Permanent Signal to NE-3C Type Switchboard
- Repair Service - Hi-Lo Supervision

Automatic Overload Control Features

- Reduce time-out periods for Permanent Signal and Partial Dial
- Temporary reduction of Line and Trunk Scanning
- Eliminate False Cross and Ground Tests

Maintenance

- Plant Measurements - data obtainable from Maintenance TTY
- Station Ringer and DIGITONE test
- Permanent Signal Clearing
- Incoming Trunk Test Lines
- Continuity, Loop Around, Open Circuit, Short Circuit and Balance Tests
- Automatic Line Insulation Testing (ALIT)
 - Maintenance Centre
 - System Status Display
 - Controlled from Local Test Desk
 - Local Maintenance Centre
- Diagnostic Programs
 - Automatic fault recognition and trouble diagnosis of all major system components
- Duplication of major system components and automatic switching to replace faulty duplicated equipment.
- Routine testing of system components regularly scheduled, also on manual request.
 - TTY - Maintenance, Local
 - Maintenance, Remote
 - Service Order, Local (also receive only local TTY at MDF)
 - Service Order Remote
 - ALIT - Remote
- Manual Line and Trunk Testing Arrangements
- Printout of Permanent Signals on Maintenance Centre TTY at intervals
- Office alarm for Permanent Signal Level specified by Telephone Company
- TTY printout of Maintenance Busy Trunks
- Regular Office Alarms extended to remote maintenance TTY
- Provisions for Regularly Auditing State of Memory and Associated Lines and Trunks
- Automatic Progression Trunk Testing (operational, not transmission) including Service Circuit

Miscellaneous Features and Circuits

- False Cross and Ground Tests, Power Cross Test, Network Continuity Tests
- C.O. Communicating System - NE-1A2 KTS with Call Director
- Dial Tone Speed Measurement
- USOC Codes, or derivatives (e.g. line class codes) are used on SP-1 ESS Service Orders
- PBX Toll Diversion and Toll Denial
- Line Load Control (effected from local or remote location)
- Toll Network Protection (effected from local or remote location)
- Calling Line Identification
- Free Number Calls

Miscellaneous Features and Circuits cont'd.

Denied Service – originating, terminating or both
Scanner Applique Circuit – for Miscellaneous Alarm
Circuits

Service Analysis

Emergency Manual Service Lines

Automatic Operational Measurements (traffic and
plant) Output on TTY

Intersender Timing (6 seconds)

Custom Calling Services –

Call Waiting, Three-Way Calling, Call Forwarding,
Speed Calling – List of 8 or 30 numbers with
customer repertoire.

Automatic Intercepting

Intercepting facilities are provided for vacant codes,
vacant or blank numbers, and partial-dial conditions.
Calls to numbers that are permanently or temporarily
disconnected, as well as calls to unassigned numbers,
may be routed to tone trunks, recorded announcement
trunks, or to an operator.

Calling Line Identification

Calling Line Identification routines on calls terminating
within an SP-1 ESS office may be automatically
activated to identify the called numbers and calling
numbers or incoming trunk.

Capacity

As the equipment in the SP-1 ESS may, at various
times, be either traffic dependent, line dependent,
real-time dependent, or feature dependent, the capacity
of the system is not uniquely specified by the
number of installed lines. Modular construction enables
the SP-1 ESS to cater to different offices with different
peculiar characteristics, with a minimum of engineering
and installation effort. With traffic in the order of 3
ccs. (.084 Erlangs) per line, the switching network
could be built out to 35,000 lines. Under average
traffic conditions up to 4 ccs. (0.11 Erlangs) per line,
the capacity of the central control system with a call
capacity of 36,000 busy hour calls would be obtained
at a network fill of approximately 25,000 lines.

Although the SP-1 ESS is designed to accommodate
offices ranging between 2,000 and 20,000 lines both
larger and smaller offices are feasible.

OPERATING LIMITS

Subscriber Loop Resistance (includes subscriber apparatus at 200 ohms equipped with 1000-ohm ringers)

Message Rate or Flat Rate

Loop Start	1780 ohms (2100 ohms with ring trip with ring cycle only)
Coin, Box, Ground Start	1500 ohms
Loop Leakage	30,000 ohms between conductors or between each conductor and earth.
Earth Potential for Coin and 2-party lines	± 10 volts

Pulsing Characteristics

Incoming from Subscriber

Rotary Dial

Speed Range	7.5 to 12.5 pulses per second
Per Cent Break	58% to 70%
Minimum Interdigital Interval	100 ms

DIGITONE Dial

Low Tone	697-, 770-, 852-, 941-Hz; ± 1.5%
High Tone	1209-, 1336-, 1477-, 1633-Hz; ± 1.5%
Minimum Interdigital Interval	40 ms
Minimum Pulse Duration	40 ms
Maximum Speed	10 digits per second

Ambient Service Conditions

Temperature Range	40° to 100°F (5° to 37.8°C)
Relative Humidity	20% to 55%
Normal Voltage Range	-48V: 42.75 to 52.5V + 24V: 20.75 to 26.25V

SECTION 3 – EQUIPMENT ELEMENTS

The SP-1 ESS equipment arrangements are designed to mount on 7-foot (2.1 m) high framework of welded steel construction. Single bay framework 28 inches (711.20 mm) wide, or double bay framework 56 inches wide (1422.40 mm) wide, having 12.5 inch (317.5 mm) deep bases are provided. The frames are self-supporting and require no overhead supports. Interframe cabling between frames in the same lineup is supported by cable racks that are located directly over, and are supported by the top member of each frame. Cross-aisle cable racks are placed at right angles at intermediate points as required. This arrangement rigidly interconnects frames and lineups, providing increased stability. Recommended aisle spacing in an SP-1 ESS office is 31 inches (787.4 mm) for equipment aisles and 23 inches (584.2 mm) for wiring aisles. The recommended clear height below obstructions such as beams, ventilation ducts and pipes is 11-feet (3.35 m) compared to 13'-6" (4.1 m) height in conventional electromechanical switching systems. The versatility of the framework permits the installation of an SP-1 ESS into commercial buildings as well as existing switchrooms. Floor loads are standard 150 pounds (68 kg) per square foot: 100 pounds (45.4 kg) for equipment and 50 pounds (22.6 kg) for cable rack, interframe cable, and maintenance personnel.

The main equipment units of the SP-1 Electronic Switching System and their relationship are illustrated in Fig. 1, Page 8. Subscriber lines, trunks and various service circuits such as receivers and tone sources, are interconnected through the switching networks. The path required for any connection between two network terminations is determined by central control in conjunction with the marker which receives instructions from central control to operate the appropriate network relays. Scanners and signal distributors are provided as an interface between the high-speed central control and the

relays in the switching networks, the trunks, and the service circuits. The signal distributor operates or releases designated relays defined by instructions from central control.

Switching Networks

The switching network interconnects the lines and trunks served by the telephone office. The basic switching element in the network is the MINIBAR switch, a 200-point 6-wire unit (10 x 20 array) normally used in groups of 5 or 10 switches. The switches are arranged into basic building blocks, or frames, from which all network configurations can be obtained.

There are three basic functional blocks in the system – the Line, Route and Service Networks:

- a) The Line Network connects customer lines and PBX trunks to originating and terminating junctors via 3-wire metallic paths. The line link network has two switching stages, those of line switches and of junctor switches. (Junctors are the links between network blocks. They may or may not have special duties assigned to them.)
- b) The Route Network connects originating junctors and incoming trunks to terminating junctors and outgoing trunks via 3-wire metallic paths. The route network has two mirror image sections; the originating route link network and the terminating route link network. There are four switching stages, two in each section.
- c) The Service Network connects originating junctors and incoming trunks to service circuits via 6-wire metallic paths. This network has three switching stages, those of the originating service switches, the service link switches, and the terminating service switches.

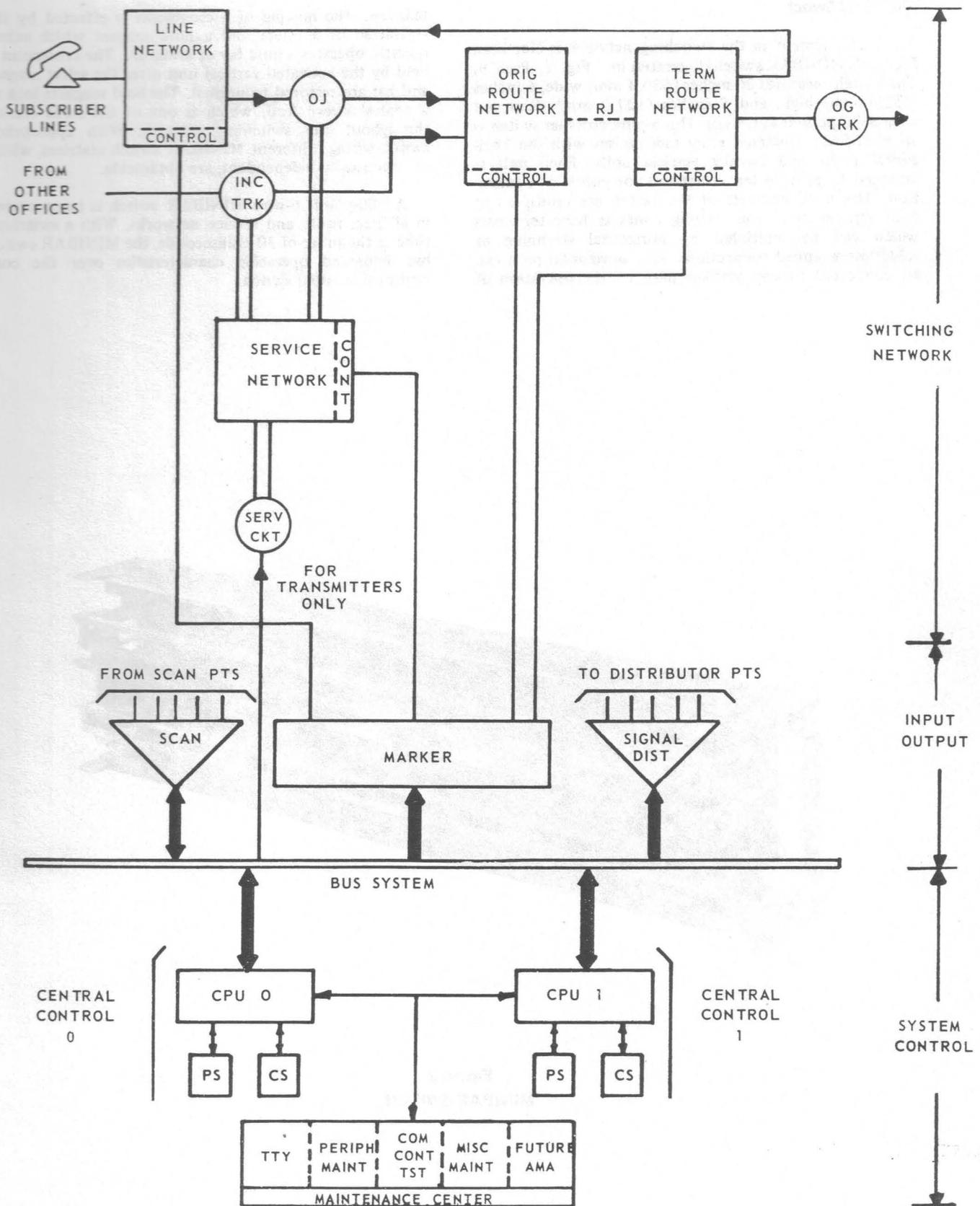


Figure 1
 SP-1 ELECTRONIC SWITCHING SYSTEM
 BLOCK DIAGRAM

MINIBAR Switch

The basic element in the switching network is Northern Electric's MINIBAR switch illustrated in Fig. 2, Page 9. The switch measures 26 inches (660.4 mm) wide, 6 inches (152.4 mm) high, and 5 inches (127.0 mm) deep and weighs 26 pounds (11.8 kg). This 6-wire crossbar switch is an electrically operated relay mechanism with ten horizontal levels and twenty vertical units. Each unit is arranged to provide ten crosspoints or points of connection. The fixed contacts of the switch are multiplied in each vertical unit. The moving contacts have terminals which can be multiplied by horizontal strapping or solderless wrapped connections. Any horizontal path can be connected to any vertical path by the operation of

magnets. The making of a crosspoint is effected by the activation of a select and a hold magnet which subsequently operates a hold bar or armature. The crosspoint is held by the activated vertical unit after the select magnet and bar are restored to normal. The hold magnets lock to a central sleeve lead, which is one of the leads carried throughout the switching network. With appropriate switch wiring, different MINIBAR switch matrices, which are electrically independent, are obtainable.

A 200-point, 6-wire MINIBAR switch is incorporated in all line, route and service networks. With a switching time in the order of 30 milliseconds, the MINIBAR switch has improved operating characteristics over the conventional crossbar switch.

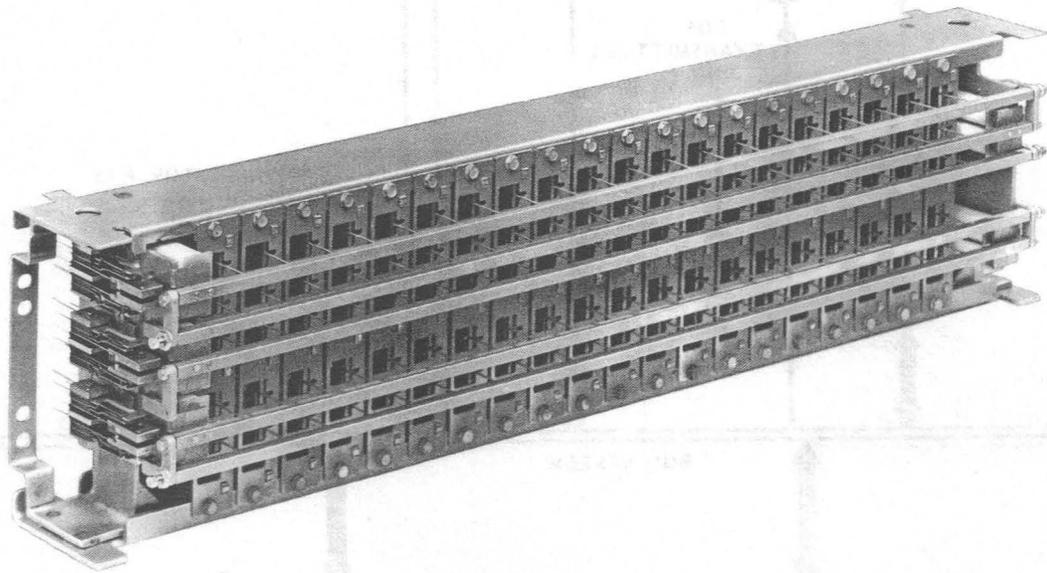


Figure 2
MINIBAR SWITCH

Line Network

The Line Network is located on Line Link Frames (LLF's) Fig. 3, Page 11. Each frame accommodates one basic line network and the control circuit. The switches on a line link frame are divided functionally to provide two switching stages: the line switch stage, and the line junctor switch stage.

The basic line link frame is a 2-bay framework that provides mounting facilities for fifteen 200-point, 6-wire MINIBAR switches. Ten of the switches are assigned to the line switch stage and the remaining five to the line junctor switch stage. Each line switch is physically one-half of a 20-vertical MINIBAR switch; hence, one MINIBAR switch performs as two line switches. Also, since only 3-wire circuits are required, the 10 six-wire horizontal levels of each MINIBAR switch provide appearances for 20 line circuits. Operation of a crosspoint in the line switch connects six horizontal wires (2 lines) to six vertical wires (1 link).

Since the line switches and links are 6-wire, each crosspoint accommodates the connection of two lines to one link. A means for distinguishing which three of the six wires of a link are to be used on a particular connection is provided in the line junctor switching stage. Levels 9 and 8 perform the steering function for the line switch, and determine which of the two incoming 3-wire circuits are to be carried further down the vertical. Levels 7 and 6 steer the 3-wire path to either the left or right side of that same vertical. Levels 0 to 5 simply connect 6-wire horizontals to 6-wire verticals, thus providing two 3-wire outputs each. The outputs are called the even and odd appearances. The combined result is a line junctor switch which, through three crosspoints, can connect any one of 10 inputs on the vertical to any one of 12 outputs on the horizontal.

The basic line link network accommodates 20 line switches and 10 line junctor switches. The line switches are grouped in pairs by interconnecting switch verticals of the same number. With the indicated wiring pattern, this permits access by each of the 400 line inputs to each of the 120 outputs. The capacity of the line link network can be increased to 600 lines by adding a supplementary line switch to each pair of line switches. Since the SP-1 ESS can accommodate up to 63 line link frames, its physical line capacity is as high as 37,800 lines.

The 120 outputs of an LLF connect up to six originating junctor groups on the even appearances and six terminating groups on the odd appearances. A junctor group consists of ten junctor groups each, one junctor per each of the 10 line junctor switches. A set of originating junctors from each line link frame interconnects that frame with 2 to 6 originating route link frames, as well as with 2 to 6 service link frames, depending on the number of junctors per LLF. The terminating junctors associated with each LLF interconnect that frame with 2 to 6 terminating route link frames. The number of junctors and the interconnection pattern depends on both the office size and the office traffic characteristics.

Route Network

The Route Network is built up from route link frames,

which are further distinguished between Originating Route Link Frame (ORLF), Fig. 4, Page 12, and Terminating Route Link Frame (TRLF), Fig. 5, Page 12. Each frame is a 2-bay framework that houses a link network, the originating frame housing the Originating Route Link Network (ORLN), and the terminating frame housing the Terminating Route Link Network (TRLN). Each frame has two stages of switching or a total of four for the complete network, and up to 24 pairs of frames may be used.

The function of the route network is to interconnect originating junctors and incoming trunks with terminating junctors, outgoing trunks and tone-type trunks. It consists of up to 24 paired route link networks. The first of the pair is a 2-stage, 3-wire ORLN, while the mate is a 2-stage, 3-wire TRLN. The TRLN is the mirror image of the ORLN. Complete access is provided between the originating and terminating route link networks through route junctors, which are provided in groups of tens or twenties depending on the distribution patterns. Each pair of route link networks has 200 inputs, 200 outputs, and accommodates 240 route junctors for interconnections.

The route network is unidirectional with all connections arising from requests at the originating side of the network.

Route Junctors

Route Junctors are simply wire junctors with no supervisory function. The route junctors from an ORLN are arranged into 12 route junctor groups, each of which is made up of 2 subgroups of 10 three-wire route junctors. Therefore, every ORLN has 240 route junctors to connect to all TRLN's. This makes the number of junctors between any particular ORLN and TRLN dependent on the number of route link networks with which the office is equipped. When an office is equipped to its maximum of 24 ORLN's and 24 TRLN's, for example, only 10 route junctors exist between any originating and any terminating link network.

Service Network

The Service Link Frame (SLF), Fig. 6, Page 13, is a 2-bay framework that houses a Service Link Network (SLN), which makes up the Service Network. Its function is to interconnect incoming trunks and originating junctors to the service circuits such as digit receivers or ringing controls. There are three stages of switching in the service network: the Originating Service Switches (OSS), the Service Link Switches (SLS) and the Terminating Service Switches (TSS). The OSS and SLS are connected via originating service links, and the SLS and TSS via terminating service links. Each of the three stages is comprised of 10 switches with full access and equal distribution between stages. An OSS is one whole MINIBAR switch. Since 6-wire paths are required through the service network, each switch can interconnect 20 originating junctors and/or incoming trunks on the input verticals with 10 originating service links on the output horizontals. The SLS is one-half of a MINIBAR switch, and can thus interconnect 10 originating service links on the input verticals to 10 terminating service links on the output horizontals. Each TSS physically is also one-half of a MINIBAR switch, and can thus interconnect 10 terminating service links on the input horizontals to 10 service circuits on the output verticals.

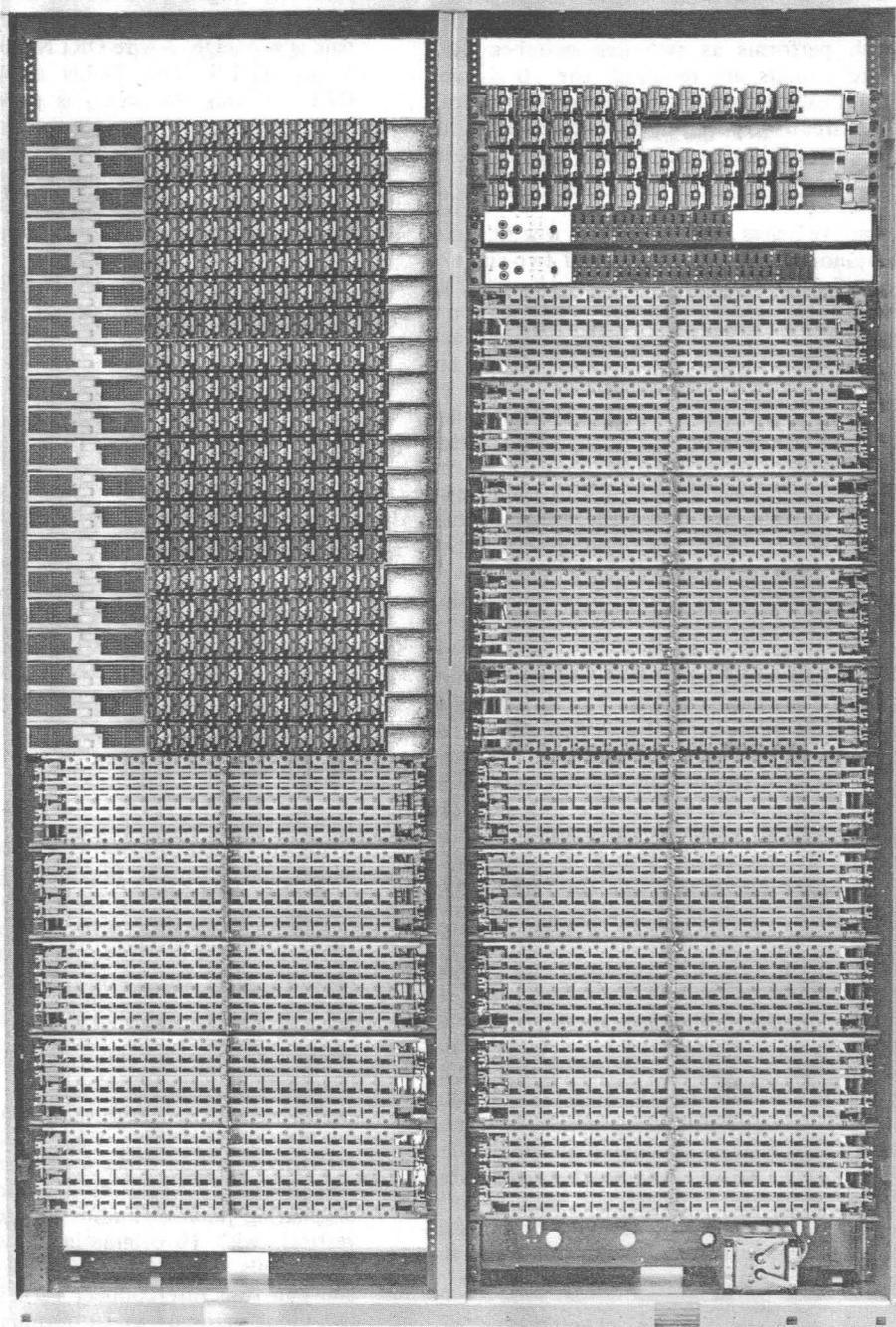


Figure 3
BASIC LINE LINK FRAME

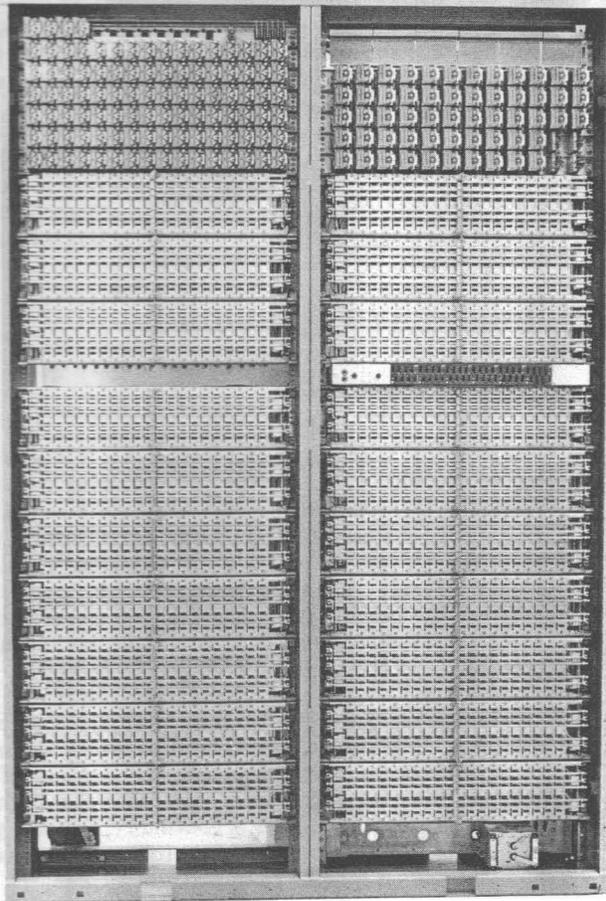


Figure 4
ORIGINATING ROUTE LINK FRAME

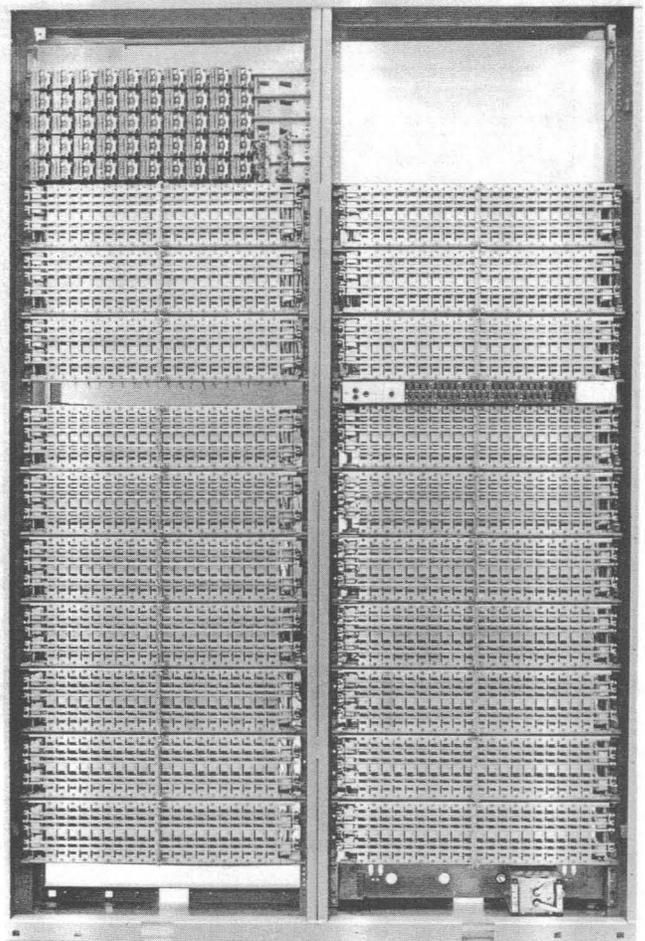


Figure 5
TERMINATING ROUTE LINK FRAME

A basic service link network contains 10 of each of the three different switches and can therefore connect each of 200 inputs to each of 100 outputs. Extension of the basic service link network is achieved in a similar manner to the extension of a basic line link network. Up to two supplementary switches can be multiplied with the basic originating service switches by interconnecting the horizontals of related switches. Nominal service link network capacities can thus be 200, 400, or 600 inputs, competing for 100 service circuits on the outputs. Since the service network can accommodate up to 8 service link networks, it could allow up to 4800 originating junctors and/or incoming trunks to reach up to 800 service circuits.

Six-wire paths permit simultaneous access to both the originating and terminating side of the telephone connection in the incoming trunk or originating junctor from the service circuit.

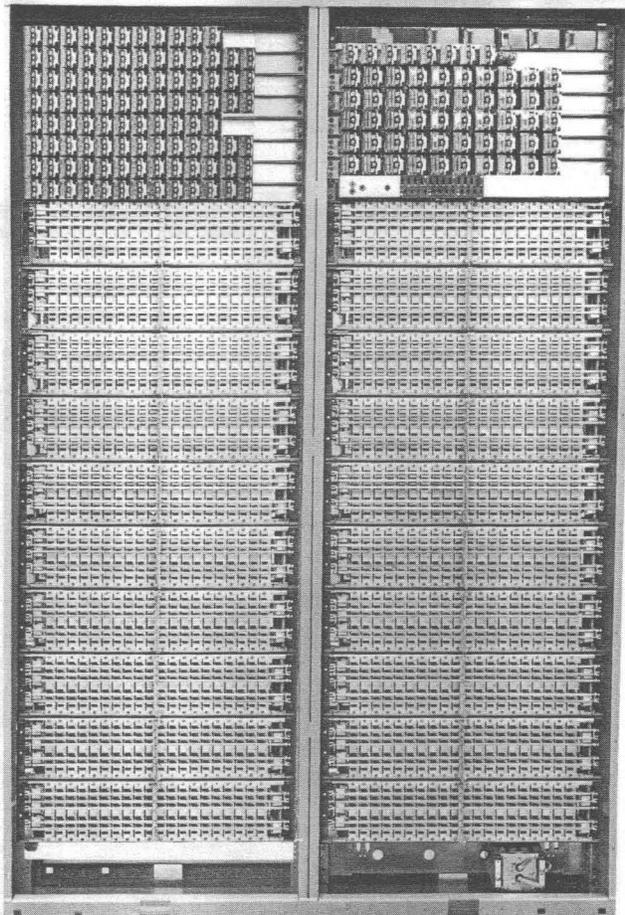


Figure 6
BASIC SERVICE LINK FRAME

Marker

The principal function of the marker, Fig. 7, Page 14, is to set up metallic paths through the switching network by operating the appropriate select and hold magnets in the MINIBAR switches. These paths form either talking channels between subscribers or signalling paths from service circuits to subscribers. Marker operation is initiated and directed by instructions from central control whenever a connection has to be established through the network.

The marker starts its function after it has received a complete order from central control which defines the end points to be interconnected, and a group of paths between the two end points. The order also defines all tests to be performed, such as continuity, battery, ground and double connection test. The four types of connections the marker is required to perform include:

- a) Connections through the service network when an incoming trunk or originating junctor is to be connected to a service circuit;
- b) Connections through the line network and service network when a calling line is to be connected to a digit receiver;
- c) Connections through the route network when an incoming trunk or originating junctor is to be connected to an outgoing trunk appearance;
- d) Connections through the route network and line network when a called subscriber is to be connected to an originating junctor or incoming trunk.

To establish any one of these connections, a five-word order from central control is placed on the peripheral bus. The order includes link network numbers which identify the connectors, switch numbers, switch levels, a group of junctors, plus additional information to set up each particular connection. Each 16-bit word contains an odd parity bit for checking purposes.

A marker has associated with it an interface containing 80 Silicon Controlled Rectifiers (SCR's) divided into 5 groups of 16, for receiving marker orders. Each word of the order is accompanied by an enable pulse sent on a separate lead to direct that word to the proper group of 16 SCR's. The triggered SCR's operate associated groups of relays whose contacts, in turn, are used to operate relays in the contact trees. Via paths in the relay contact trees, the marker operates relay connectors to access the specified network frames. With connections to the frames established, relay contact trees provide paths to operate relays in the network control circuits to access the MINIBAR switch.

Since all sequences followed by the marker are specified by the order, the marker only has to decide which path to choose among all the possible given paths. If, for example, we take the type of connections through the line network and service network when a calling line is to be connected to a digit receiver, the two end points are given, which define the line switch and the terminating service switch. Mercury relays sense the line links associated with the specified line switch and originating junctors in the specified junctor group for busy/idle status by looking at the electrical condition of leads. A link is busy when the sleeve lead is grounded; a junctor is busy when the so-called "C" lead is grounded or has no potential on it.

Matching circuitry pairs, idle links, and idle OJ's with each other form idle paths from the calling line to the input of the service network. One of these idle paths is selected on a preference basis, which then defines an originating service switch. Originating and terminating service links between the two end points on the service network are now sensed for busy/idle. The matching circuitry pairs idle links to select paths through the service network. Again, on a preference basis, one path is chosen. A complete path, called a channel, from the calling line to the digit receiver is now available, and the marker operates the select and hold magnets in the MINIBAR switches required to form that path.

During and after selection and connection, the specified tests are performed. If no abnormal situation is found, the marker releases the network frames and returns to an idle state. If an abnormal situation is encountered during the processing of an order, the marker stops its sequence. The condition is detected by central control via the scanner, and the marker is normally released by a central control order consisting of one 16-bit word. If the marker cannot be released as above, it is force-released via the signal distributor. Central control then reissues the order to another idle marker. Less than 250 milliseconds elapse from the time central control places an order on the peripheral bus until the marker returns to its idle state after performing the order.

The condition of each marker is reported to central control via 32 scan points. The status of operations, the selected path, the busy/idle condition, and the trouble and traffic block conditions are reported on these scan points. If required, a print-out of the status of these scan points, as well as the marker order, can be obtained from central control.

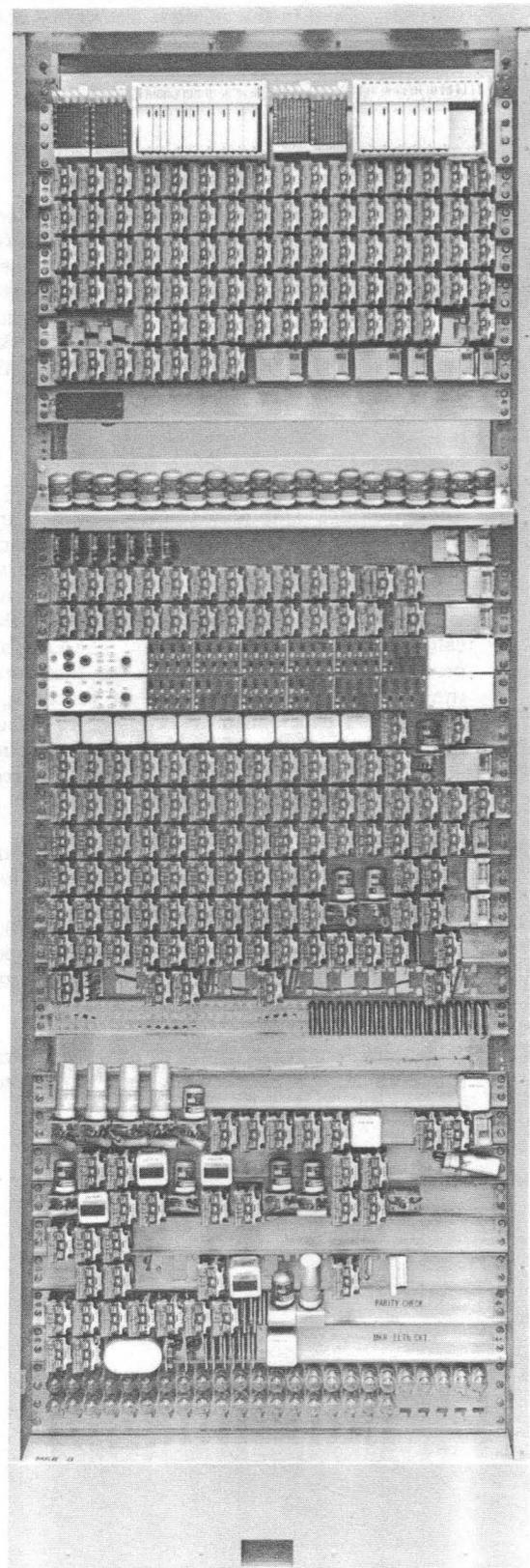


Figure 7
MARKER FRAME

Marker cont'd.

For reliability purposes, a minimum of two markers are necessary, even in the smallest size office in the SP-1 ESS range. A 20,000 line office, with average traffic conditions, will probably require 8 markers to satisfactorily establish all connections required.

Network Control Circuit

A control circuit is associated with each network frame. It assists the marker in locating an idle path from within a group of specified paths in the associated network. After locating an idle path, the marker via the network control circuit, establishes a connection by operating the necessary select and hold magnets of the network's MINIBAR switches. In this respect the network control function is an integral part of the marker function.

Junctors

The Originating Junctor (OJ), Fig. 8, Page 15, serves as the talking bridge and main control point for supervisory signals on intraoffice and most of the outgoing calls. They perform the functions of both intraoffice and outgoing trunks. The OJ connects to the line and route networks via 3-wire connections and supervises both the calling and called parties in this connection. The OJ via 6-wire links provides service network access, so that services such as the provision for dial tone, digit receiving, digit transmitting and ringing can be extended to either the calling or called side of the OJ, and this, either during the setting up of a call or on flashing recall by either party during a talking connection.

The OJ also performs the function of an interoffice trunk when reverse battery supervision and loop signalling are required. In this case the outgoing trunk circuit exists only as a pair of leads on the route network. Additional functions provided by the OJ include impedance compensation, dc isolation and lightning surge current limiting.

Terminating Junctors (TJ's) provide 3-wire paths from the terminating route network back to the line network to carry terminating traffic.

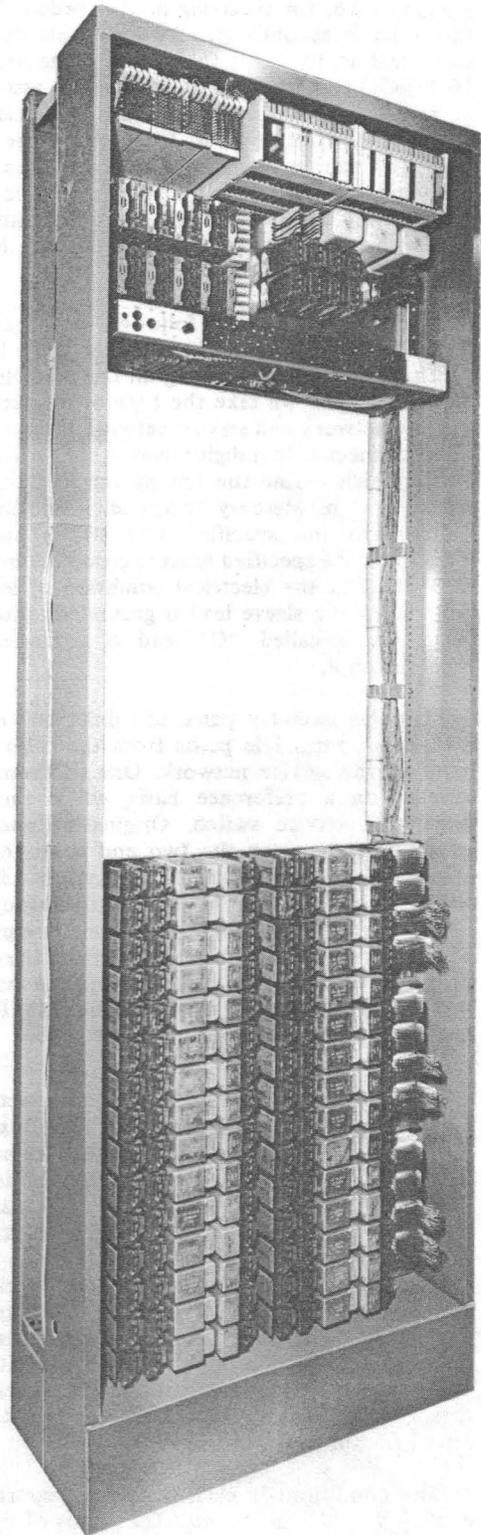


Figure 8
ORIGINATING JUNCTOR FRAME

Bus System and Interface

Balanced ac bus systems, duplicated to ensure overall reliability and driven by the input-output control of the central processor, provide the means of communication to and from various types of peripheral units, e.g., markers, scanners, signal distributors and transmitters. The complete bus system is made up of the following:

- a) The 16-lead Peripheral Bus, which runs from central control to markers, scanners, signal distributors and transmitters. A lead here is defined as a twisted pair of wires.
- b) The Enable Bus, or rather Enable Lead, which provides individual leads from central control to each peripheral unit to allow the selecting or enabling of the unit that is to respond to information transmitted over the bus system. The correct enable lead is selected by means of an enable matrix located in the CPU.
- c) The 16-lead Scan Return Bus, which runs from the scanners to central control. It allows the results of interrogating a scanner section of 16 ferrods to be sent to both central controls.
- d) The 8-lead "All-Seems-Well" (ASW) Bus, which also runs from the scanners to central control. It allows central control to be told whether or not the scanner section just addressed is working correctly.
- e) The Maintenance Bus, which provides the control leads and input-output leads from the maintenance centre to central control.

Each lead consists of a twisted pair of 26-gauge wire having one twist about every 2-1/2 inches (63.5 mm) to give a transmission impedance of 100 ohms. The overall length of each of the 2 legs of the peripheral bus system is limited to approximately 500 feet (152.5 m) imposed by the dc resistance of the wires, the delay of pulses, and the deterioration in pulse shapes.

The use of twisted pairs rather than coaxial cable reduces the cost and physical size of the bus. Running the buses in a metallic cable rack facilitates an orderly arrangement as well as providing electric shielding. The buses run from the CPU to a shield compartment and then over the rows of frames and back to a termination unit located on the common control test centre.

The bus interface units contain the receiving circuitry for the peripheral units. Where the unit, such as the scanner, can operate at electronic speeds, orders from central control are fed from the peripheral bus to the units via bus receivers and pulse stretchers. Where the peripheral units, such as the marker, signal distributor and transmitter, operate at relay speeds, orders are fed from the bus via bus receivers to silicon controlled rectifiers. The rectifiers provide the means for storing the high-speed orders and the necessary amplification to operate associated relays. Enable receivers, fed from enable leads, are included in the interface to allow selection of the peripheral unit that is to respond to the sent order.

Signal Distributor

The purpose of the Signal Distributor, Fig. 9, Page 17, is to operate electrically latching relays located in trunk circuits, service circuits, markers and originating junctors as designated by the central control. It is composed mainly of a controller, a relay contact tree and bus interface circuits. The unit occupies 6-1/2 two-inch (50.8 mm) mounting plate spaces at the top of the Scanner, Signal Distributor, and Originating Junctor Frame. The signal distributor simply operates or releases a specified relay, one at a time, while acting as a buffer between the high-speed central control and the low-speed relay.

Orders to the signal distributor are sent out from central control in coded binary form on one of the two 16-lead peripheral buses. Each order uses 12 bits for signal distributor point selection, and the remaining 4 bits for functional instructions to tell the signal distributor whether to operate or release the selected end point, whether to go into a testing mode or whether to reset itself to an idle state.

Every signal distributor can receive its order from either one of two peripheral buses. The selected signal distributor's receiving circuitry is enabled to receive the sent order. The point selection bits trigger the appropriate silicon controlled rectifiers (out of the group of 12), which provide a means for storing this portion of the order and the necessary current to operate the required relays in the relay contact tree. Another 3 silicon controlled rectifiers are used to provide buffering and amplification for 3 of the 4 functional bits mentioned above.

The contact tree consists of 10 multicontact relays and 6 wire-spring relays, which translate the code from the silicon controlled rectifiers to select a path from the apex of the contact tree to the specified signal distributor point. The relays are wired such that a distinction can be made between 255 points.

The validity of the received code is verified by code checking circuitry in the signal distributor controller, and if satisfactory, the operate or release pulse, as stipulated on one of the four functional leads, is cut through the contact tree. The latching relay, after changing states, offers a potential in agreement with the new state to indicate execution. The difference in potential is sensed by the detector, and the controller cuts off the current through the contact tree and releases all relays, thus returning the signal distributor to an idle state. All events, from the time an order is issued until the return to the idle state, take less than 25 milliseconds.

If the change in potential is not sensed by the detector within a certain period of time, the controller maintains the signal distributor in its busy state. The state in which the signal distributor operates is reported to central control through 4 scan points in the controller. The information made available through these points includes busy/idle status, validity of the received code, test mode operation, and the condition as described above where execution has not been confirmed.

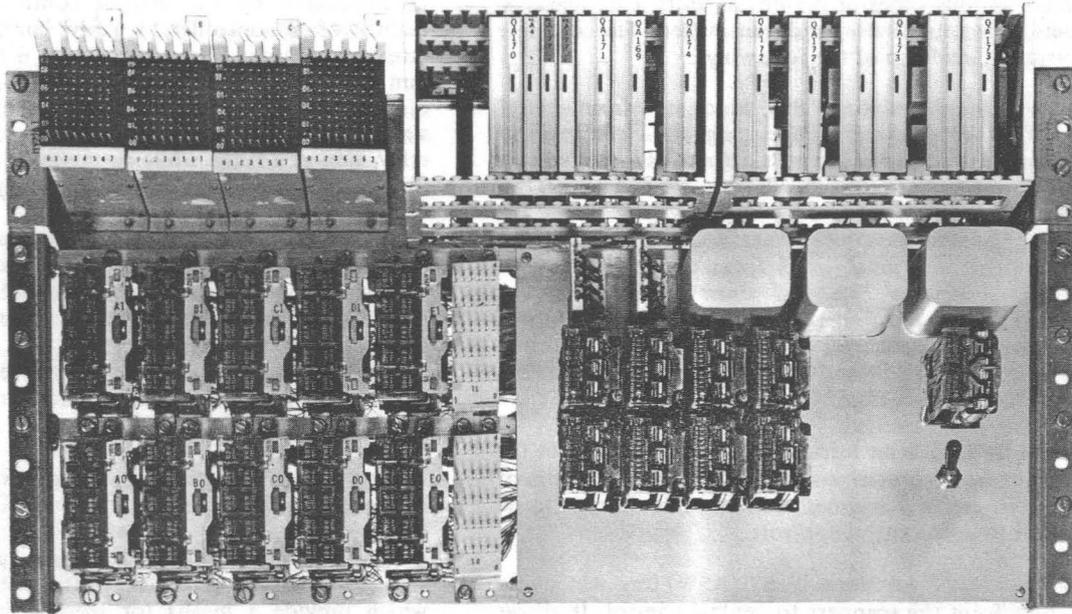


Figure 9
SIGNAL DISTRIBUTOR

For maintenance and failure detection, a simple maintenance circuit including a typical signal distributor point is provided on all signal distributors. A signal distributor, while in 'test mode', can be analyzed through this maintenance circuit, and via the 4 scan points its condition can be reported back to central control.

Each signal distributor can normally serve up to 255 signal distributor points. To find the number of signal distributors in an office, a count is made of the number of distributor points in originating junctors, trunk circuits, service circuits, markers and scanners, plus miscellaneous equipment where latching relays are located. A 10,000 line SP-1 ESS Office has about 3700 distributor points requiring a minimum of 15 signal distributors. Normally one or two additional signal distributors will be required, since limitations imposed by packaging and other factors do not allow full utilization of all 255 points in every signal distributor.

Scanner

Scanners are under direct control of the program-controlled central control via a high speed communication bus system. They are used by central control to gather information regarding the state of lines, junctors, trunks, service circuits, markers, signal distributors and miscellaneous diagnostic scan points. This information is gathered at definite time intervals, as specified by the program in central control. Each circuit to be sampled by the scanner is connected to one or more sensing elements (scan points). On instruction from central control, information

about the state of the scan points is collected and sent by the scanner to central control. Each scanner has the capability of reading 16 individual scan points at one time. The operate time of the scanner is at electronic speeds.

All circuits checked by scanners are wired to one or more current sensing elements called ferrod sensors. The current sensing element consists of a saturable ferrite rod with an interrogate winding, a readout and two control windings. The operation of the ferrod is as follows:

- a) A pulse is sent through the interrogate winding.
- b) If the control windings, which are connected in series with the circuit to be sensed, carry little or no current, the interrogate pulse will be coupled through to the readout winding, resulting in an output pulse.
- c) If the control windings, due to the state of the circuit, carry sufficient current to saturate the ferrite rod, the interrogate pulse will be blocked, and no output pulse will occur on the readout winding.

A typical scanner illustrated in Fig. 10, Page 18, consists of an unduplicated ferrod matrix and an associated duplicated controller containing the access and readout circuitry, plus certain checking circuitry. The matrix of 1024 ferrod sensors is arranged in 64 rows of 16 sensors each. Only one row of sensors can be interrogated at a

time. A group of 16 ferrod sensors in each array is reserved for scanner maintenance. The effective size of a scanner, therefore, is 1008 scan points. Every scanner contains, in general, three ferrod sensor types to be capable of monitoring any type of circuit or diagnostic point. The sensitivity and the scanning rate required for the scan point depends on the type of information required for call processing.

When the central processing unit wishes to examine the state of certain circuits, it sends out an order on one of the two peripheral buses; the program in central control determines which bus to choose. Each order consists of two address pulses in 1-out-of-8 codes. At the same time, an enable pulse is sent out to a particular scanner over the appropriate enable lead. This scanner then is the only peripheral unit that responds to the order. The order identifies one of the 8 rows and one of the 8 columns in the core matrix, thus selecting one of 64 biased ferrite cores. The two coincident pulses switch the core to produce an output pulse.

In the ferrod matrix there are 64 interrogate loops, each loop corresponding to one ferrite core. A loop is formed by connecting in series the interrogate windings of 16 ferrod sensors in a row. To prevent unnecessary duplication, the readout windings of the 64 sensors in a column are connected in series to form a readout loop. Thus the output pulse from the ferrite core simultaneously interrogates 16 ferrods, one in each readout loop. The response of the selected row of ferrods is fed into detector amplifiers in the readout circuitry of both controllers. Each controller sends a 16-bit binary pattern on its scan return bus, each bit corresponding to one of the 16 ferrods interrogated. Interpretation is left to central control. Since the reply from any particular scanner appears on both scan return buses, it allows a check in central control by matching the information on the two buses.

To ensure dependable operation, a certain amount of checking circuitry is provided. During a normal scanning cycle, three checks are performed within the scanner:

- 1) Access Check – that the particular scanner has been accessed by an enable pulse coincident with at least one address pulse.
- 2) Core Selection Check – that no more than one core has been selected.
- 3) Interrogate Check – that at least one core has switched.

Successful completion of these checks is indicated to central control by the All-Seems-Well (ASW) output, sent simultaneously with the pulses from the ferrod matrix. To retain the identity of the particular scanner replying on the scan return bus, a unique 3-out-of-8 ASW code is used for every scanner. The absence of any of the ASW bits at the time of scan return indicates a trouble condition. In such a case, central control enters a scanner maintenance program to determine and locate the fault.

Each scanner can serve up to 1024 scan points. Since the maintenance ferrods, of which there are 16 per scanner, are not available for general scanning purposes, the effective scanner size is reduced to 1008 scan points.

The number of scanners is thus defined by the total number of scan points in the office located in lines, originating junctors, trunk circuits, service circuits and miscellaneous diagnostic points. A 10,000 line office with approximately 14,000 scan points, accounted for mainly by the 10,000 required to scan lines, could be served by 14 scanners.

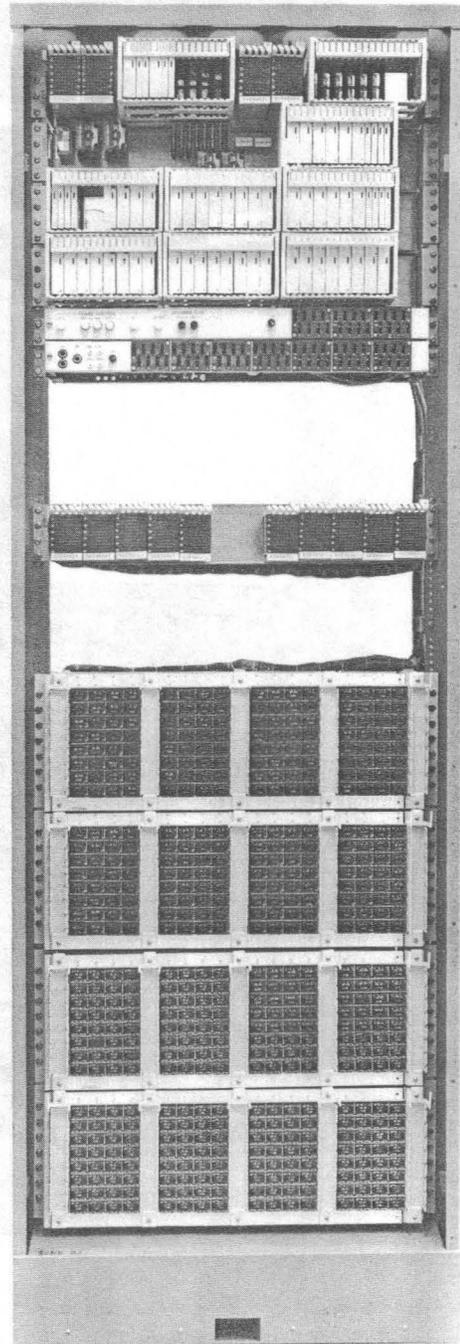


Figure 10
SCANNER FRAME

Miscellaneous Trunk and Service Circuit Frame

The Miscellaneous Trunk and Service Circuit Frame (MTS), Fig. 11, Page 19, is a single-bay frame arranged for mounting SP-1 ESS trunk, service, and service test circuits requiring either or both signal distributor or scanner points.

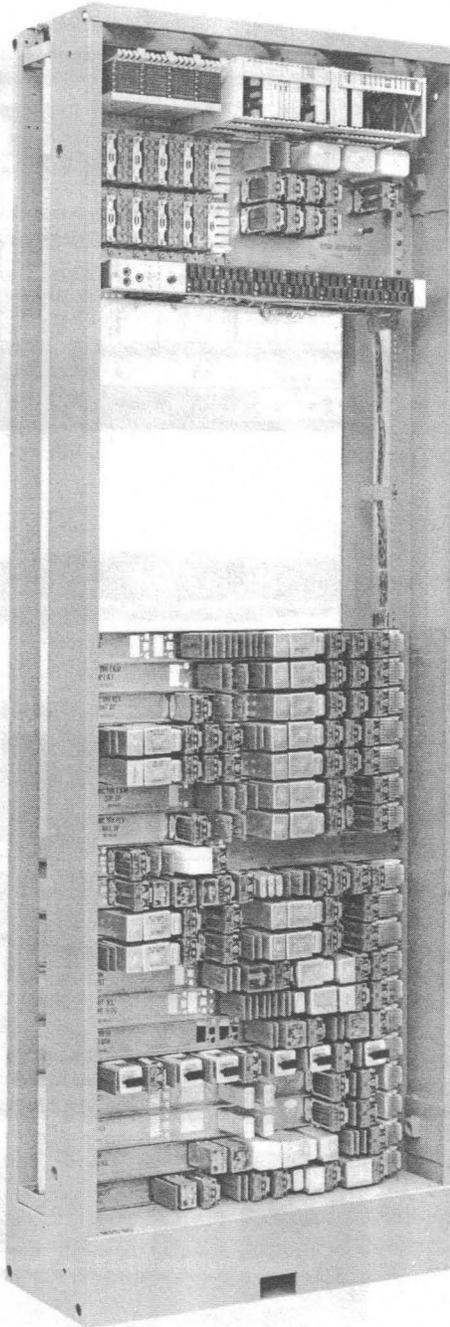


Figure 11
MISCELLANEOUS TRUNK
AND SERVICE CIRCUIT FRAME

Trunk Circuits

The trunk circuits in the SP-1 ESS have been simplified in comparison with conventional trunk circuits in the sense that they provide only transmission paths, and in certain cases, supervision, dc isolation, and impedance compensation. Other functions associated with conventional trunk circuits are performed by the central control and the service circuits in the system.

There are three basic classes of trunk circuits in the SP-1 ESS:—

- a) Outgoing trunks, which are used on calls to distant offices;
- b) Incoming trunks, which are used on calls from distant offices. These calls may terminate in this office, or be switched through it to another office.
- c) Two-way (bothway) trunks, which may be used in place of both incoming and outgoing trunks.

Various types of the three basic classes of trunk circuits are available to permit the SP-1 ESS to work with other switching systems, covering both manually operated switching and automatic switching centres.

Service Circuits

The service circuits perform functions which can be handled more economically by a few special circuits than by providing additional equipment in every trunk circuit and originating junctor. The circuits include transmitters and receivers for handling the signalling information needed to set up a call, ringing circuits for alerting called subscribers, coin control circuits for collecting or refunding coins, plus some special circuits. New features can be readily added without the need for extensive office changes. The SP-1 ESS is thus compatible with a large variety of other equipment with which it will have to communicate as a switching system.

To cater to both standard rotary dial and DIGITONE subsets, the Originating Digit Receiver (ODR) is provided in two versions. In the first version, a dial pulse receiver is used to receive the rotary dial pulses. In the second version, the same dial pulse receiver is used in conjunction with DIGITONE detection circuitry to receive dialling information from both DIGITONE and rotary dial telephone sets. The receiver sends dial tone to the calling subscriber and then accepts the digital information, making it available to central control via the scanner.

The Incoming Digit Receiver (IDR) provides the means for detecting signalling information on incoming calls. This information is arranged in a suitable form and made available to central control via the scanner. An IDR is used only in cases of multifrequency (MF) pulsing. In the case of DP pulsing, normally associated with step-by-step offices, the digits are transmitted without prior notification. This means that insufficient time is available to connect an IDR, and thus to ensure reception of all transmitted digits, scanning is done at the incoming trunk.

Transmitters are used for sending digital information to distant offices. A DP transmitter is used when the distant office is a step-by-step type. In order to signal to another

Service Circuits cont'd.

SP-1 ESS Office or an NE-5 Crossbar Office, an MF transmitter is normally used. A combined MF DIGITONE transmitter is available for DIGITONE outpulsing. This feature could be used for DIGITONE pulsing on foreign exchange lines or direct-in-dialling to a PBX equipped to receive DIGITONE over its trunks. Transmitters are controlled by central control via the bus system.

Ringling signals to the called line and audible ringback to the calling line are applied by the common ringing circuit. The classes of lines covered include individual, two-party, coin and PBX. Special ringing circuits are used to provide multiparty ringing, revertive ringing, call forwarding ringing, and operator class-of-service tone.

Central Control

The Central Control is a binary digital machine consisting of a processor and a memory. The memory stores the programs which are used to control the processor. These programs consist of appropriate combinations of precisely defined instructions. The instructions are interpreted and executed by the processor to control the actions of all other units in the system. The central control relationship to peripheral equipment is shown in Fig. 12, Page 20, and Fig. 1, Page 8. In the SP-1 ESS the processor is called the Central Processing Unit (CPU). The instructions, though of many different types, are executed only one at a time. Hence, by performing logic operations, the central control

causes connections to be established in the network, control trunks, markers, junctors and service circuits via signal distributors. Also, by using maintenance and diagnostic programs it analyzes troubles, and causes the results of tests to be printed out. It thus performs the basic job of call processing and in addition performs certain administrative tasks. A few of the CPU actions which do not require stored program control are performed under hardware control by "wired logic."

The memory portion of central control is divided between semi-permanent and temporary memory, in the Program Store (PS) and Call Store (CS) respectively. The stored information in both memories is word organized, which means that a single address presented to the memory will result in an entire word being read or written.

The central control, because of its importance to the system, is completely duplicated. During normal operation, both central controls are in the working state, with one being in the active and the other in the standby mode. Each central control has access to the bus system; however, only the active one of the two is permitted to output onto the bus. Match circuitry is employed to check that information handled by the two processors is identical. In case of mismatch, the central control at fault is temporarily removed from service while the other central control continues to perform all required operations without loss of calls in progress. Fault detection and diagnostic programs are run automatically.

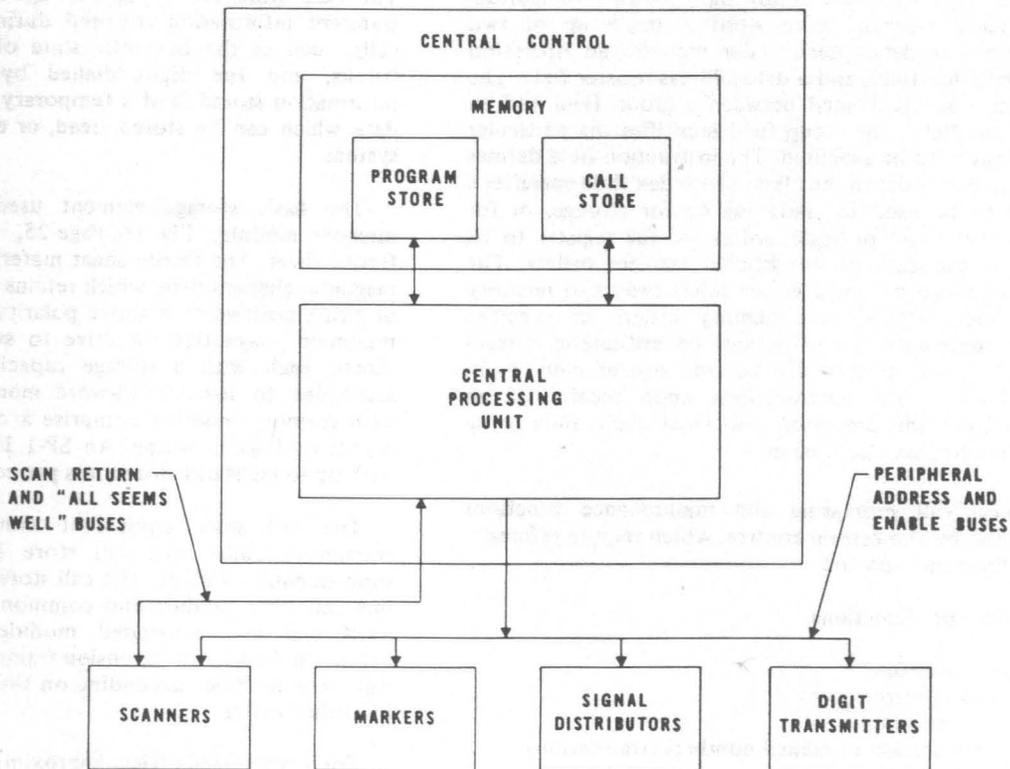


Figure 12
A CENTRAL CONTROL AND ITS RELATIONSHIP TO PERIPHERAL EQUIPMENT

Program Store

The Program Store (PS), Fig. 13, Page 22, contains the program and translation information that the central processor used to direct the operation of the SP-1 ESS. It acts like an instruction manual listing the plan of action which guides the system, step-by-step, in the performance of the system operation. All operating programs, and certain data translation information on lines and trunks, are stored in the semi-permanent memory of the Program Store. The memory device used is the Piggyback Twistor (PBT) Fig. 14, Page 23, an electrically alterable, non-destructive readout device. The advantage of the PBT over the permanent magnet twistor lies in the ease and the much shorter time required to alter the stored data. The bit element of the PBT consists of two dissimilar magnetic tapes spirally wrapped onto a copper wire. The tapes perform the storage and sense functions. Information is written into a bit by setting the outside tape to either positive or negative saturation.

A memory module, the basic building block of the Program Store, is formed by stacking 64 planes of 64 words each to give a total of 4096 words. Each plane consists of 54 pairs of twistor wire placed beside each other, and enclosed by 64 one-turn copper solenoids wrapped around the twistor wires at equal intervals. The net result is a 64 word plane having 54 bits per word. Four memory modules are combined to form a PS unit of 16,384 randomly accessible 54-bit words. The number of units making up the PS in a particular office varies with office size and features required.

To perform a required function in central control, a program is executed by following a number of instructions. Each program store word is made up of two instructions (orders). Each order includes an operation code, an index field, and a data-address-register field. The operation code is divided between a group field and an instruction field. The group field identifies the particular class-of-order to be executed. The instruction field defines the particular order in the class. The index field specifies a register to be used for indexing or for storage, or for certain arithmetic or logic orders, or the register to be tested in the case of conditional transfer orders. The data-address-register field either refers orders to memory or provides data for non-memory orders, or specifies register combinations and options on arithmetic instructions. Any stored word can be read out of memory in approximately 3.5 microseconds upon receipt of an address from the processor, the total cycle time being approximately six microseconds.

Typical call processing and maintenance functions performed by the central control, which require reference to the Program Store are:

Call Processing Functions

- a) scan control
- b) trunk control
- c) digit counting
- d) interpretation of dialled numbers (translation)
- e) equipment selection
- f) marker orders
- g) ringing and outpulsing control
- h) charging decisions
- i) timing

Maintenance Functions

- a) fault recognition and diagnostic
- b) preventive maintenance

Administrative Functions

- a) teletype control
- b) office administration

The program store is divided into two storage areas, protected and unprotected. The protected area is that in which the actual call processing, maintenance programs, and some semi-permanent data are stored. The protection consists of certain "locks" which must be opened before the master program can be altered. This provides a safety feature necessary in order to avoid accidental machine or man-made changes in the master program. The unprotected area of the store is that portion which is constantly being read or occasionally written into during the normal operation of the system.

The total available capacity of the semi-permanent memory is 196,608 words per central control which is divided into 3 blocks of 65,536 words each. They are addressed as Program Store, Data Store 0, and Data Store 1. As the names imply, the Program Store block stores the programs, while the two Data Store blocks store the semi-permanent data required by the office. Data may also be stored in the Program Store block, although programs cannot be stored in Data Store.

Call Store

The Call Store (CS), Fig. 15, Page 24, is used to store transient information required during the processing of calls, such as the busy/idle state of lines, junctors and trunks, and the digits dialled by a subscriber. The information stored is of a temporary nature and contains data which can be stored, read, or erased readily by the system.

The basic storage element used in the call store memory module, Fig. 16, Page 25, is the multi-aperture ferrite sheet. The ferrite sheet material has a square loop magnetic characteristic which retains remanent magnetism of either positive or negative polarity and requires a fixed minimum magnetization drive to switch the core. The sheets, each with a storage capacity of 256 bits, are assembled to form 2048-word memory modules. Four such memory modules comprise a call store unit with a capacity of 8192 words. An SP-1 ESS may be provided with up to eight call store units per central control.

The call store equipment mounts on single bay framework called the call store basic and call store supplementary frames. The call store basic frame contains one call store module and common control facilities for itself and any associated modules mounted on the extension frame. An extension frame can have one or two call store modules depending on the requirements of the individual office.

For a large-sized office, approximately 20,000 installed lines, the word requirement for basic service is 16,000 words, and hence 2 call store units are needed in each central control. Each call store unit provided is self-contained to simplify testing of individual stores during

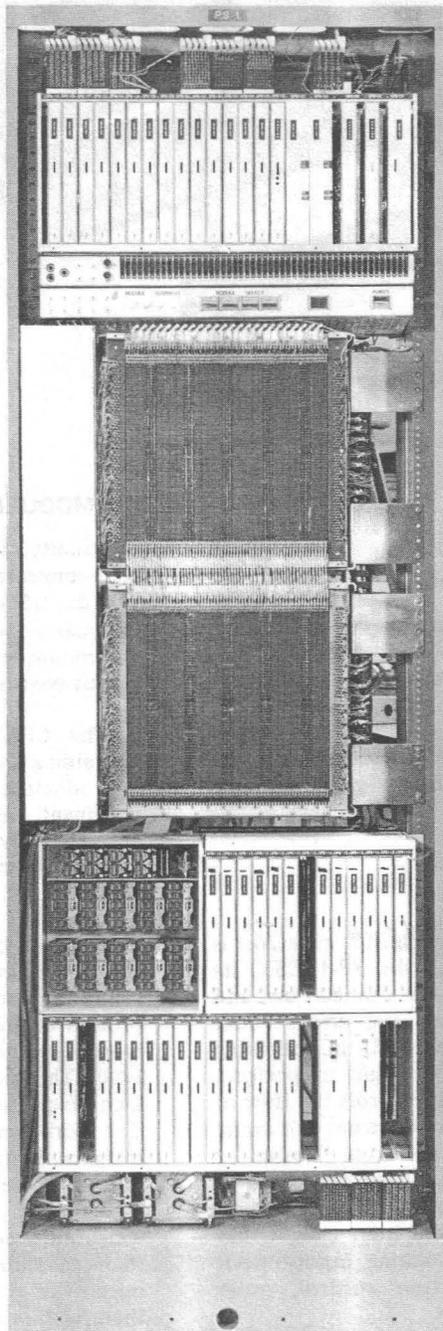


Figure 13
BASIC PROGRAM STORE

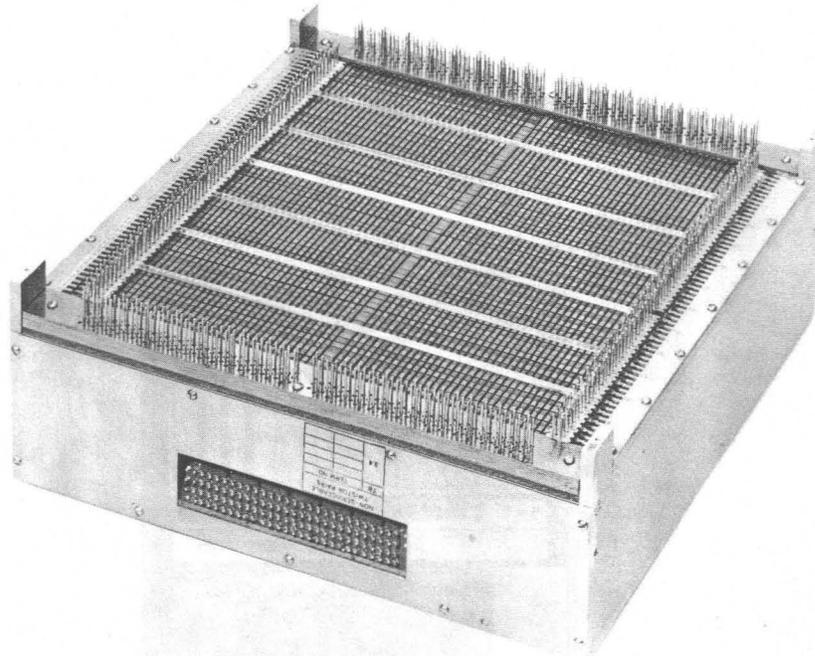


Figure 14
PIGGYBACK TWISTOR MODULE

Call Store cont'd.

production and installation. A common control section governs the selection of the correct store, the starting of the read or write cycle, and the control of maintenance circuits.

Since 16-bit arithmetic was found to be sufficient for the SP-1 ESS, 16 bits, plus a single odd parity bit, are used in the Call Store.

Central Processing Unit

The Central Processing Unit (CPU), Fig. 17, Page 26, is the primary data processing unit of the SP-1 ESS. Its function is to set up customer network connections, and to detect and analyze system faults and errors under direction of a stored program. The CPU in following orders from the program, uses wired logic to perform information processing operations. It controls the flow of input data from the peripheral units, processes this input data and decides what action should be taken. Thus under control of the stored program, it causes basic actions to be carried out in all parts of the system and decisions to be made in the process of completing telephone calls. Other functions required for the CPU are clocking, input-output control, interrupt control, instruction control, order decoding, and sequencing.

Among the advanced design features of the SP-1 ESS are the printed circuit boards Fig. 18, Page 27, which are double clad and utilize plated-through holes for circuit

continuity. The circuit packs plug into 86-pin connectors, interconnected by point-to-point wiring. The circuit boards, 65 of which comprise a CPU frame, are used extensively where speed of operation and reliability are of paramount importance. Twenty-eight distinctive types of circuit boards perform all the CPU functions.

The CPU's are on a 2-bay framework, each bay containing a complete and independent central processing unit identified as CPU-0 and CPU-1. One of the CPU's is dominant, and should it fail the other takes over automatically. The same information is processed in both CPU's, but only the dominant unit controls the office.

The CPU is traffic and line independent insofar as every office contains only one duplicated CPU. However, the upper limit of the office size is limited by the real time behaviour of the CPU, that is, how many calls it can process during the busy hour. The capacity is therefore more directly related to the calling rate than the holding time. The distribution of traffic in terms of outgoing, incoming, and intraoffice calls, also plays a major role. The work time for an outgoing plus an incoming call, for instance, is almost double the work time for an intraoffice call. A higher percentage of intraoffice calls permits a higher main telephone capacity. The different calls are weighted according to their load requirements to bring them to a common denominator in terms of equivalent intraoffice calls. The central control load capacity can then be expressed in those terms; for the fully duplicated central control in the SP-1 ESS, it is 36,000 equivalent intraoffice busy hour calls. For a particular traffic distribution and traffic level, this defines the line capacity, of the office, an average being about 25,000 lines.

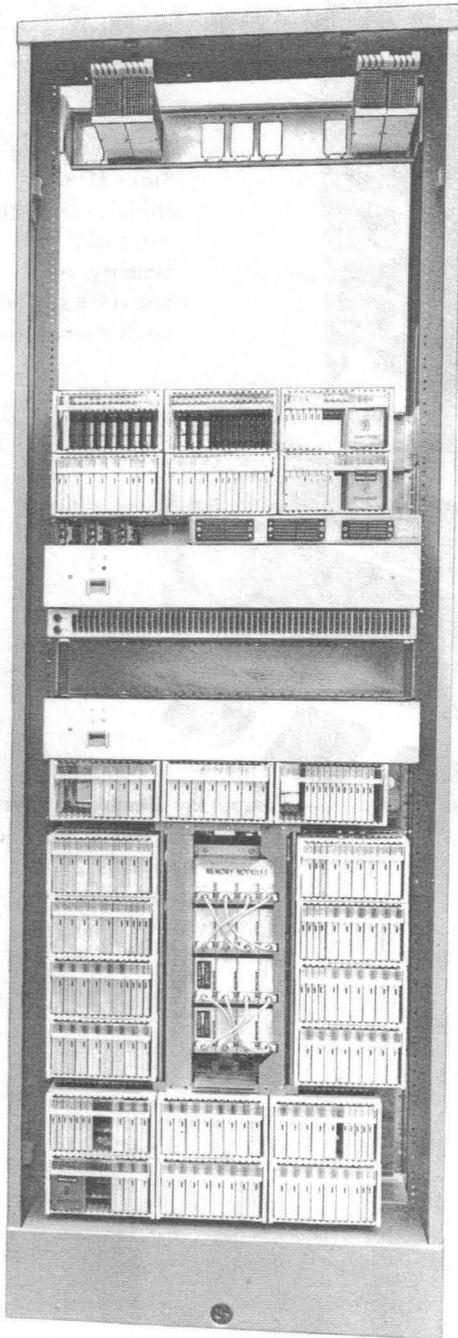


Figure 15
BASIC CALL STORE FRAME

Central processor organization is illustrated in Fig. 19, Page 28. It is essentially a parallel binary (16-bit) machine operating at a basic clock rate of 2 MHz. The two instruction formats used in the CPU are illustrated in Fig. 19A, Page 29.

Maintenance Centre.

The stringent requirements for reliability which have come to be expected of telephone service have resulted in extensive maintenance programs designed to detect and diagnose equipment failures. In the SP-1 ESS, the objective is to have a down time of less than one to 2 hours in 40 years. Its maintenance operations include checks at specific points in normal call processing to determine whether the system has behaved as expected. If failure has occurred, maintenance programs are called in to determine the reason for failure. Also, routine maintenance and administrative functions are fitted in at times which will not interfere with the system's basic task of call processing.

The maintenance centre, Fig. 20, Page 30, is the main interface between the switching system and operating telephone company personnel. It includes facilities for system tests and control, alarm indication and maintenance of lines and trunks. The primary communication facility is provided by the teletypewriter. When a "fault" occurs, its location is determined by the central control and this information is printed out on the teletypewriter. Service personnel can instruct the active central control to perform various functions via the teletypewriter.

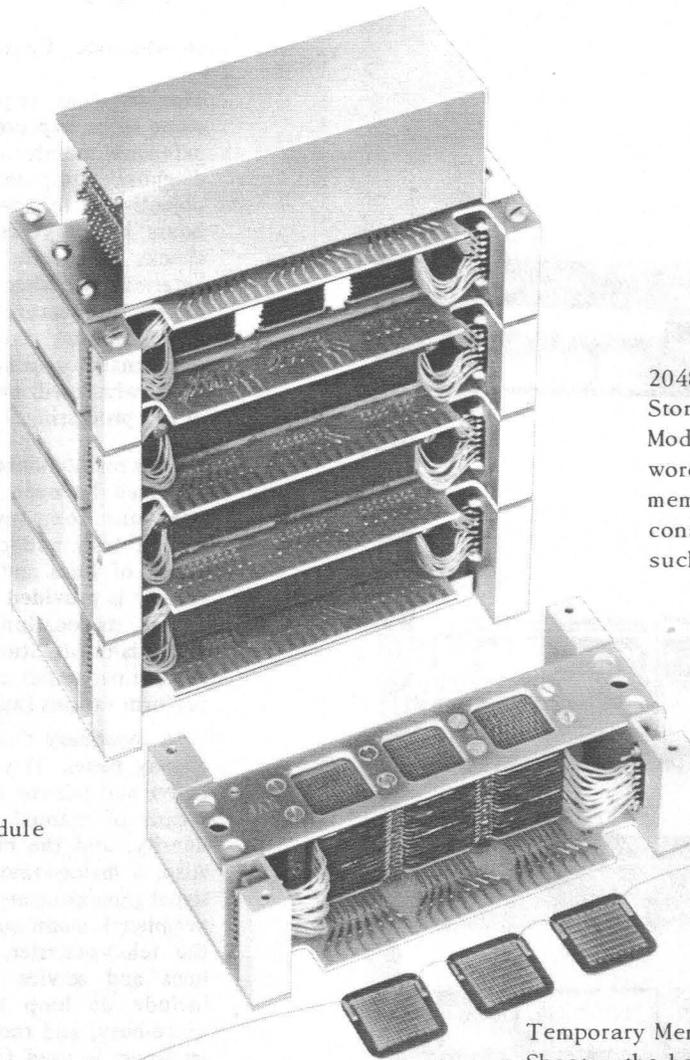
A secondary means of communication is the alarm and display panel. This panel gives a visual indication of the active and passive states of the duplicated equipment, the means of manual control over these states, the traffic density, and the malfunction of any part of the office. Also, a major-minor alarm indicator and some associated signal generators are provided for major-minor alarms. The peripheral maintenance system test panel together with the teletypewriter, provide for maintenance of trunks, lines and service circuits. The operations undertaken include dc loop testing, transmission testing, circuit-make-busy, and the handling of permanent signals. A tape transport is used for initial loading and updating of the memories at office extension times.

Distribution and Grouping Frames

Distribution and grouping frames are used to interconnect two groups of leads in a pattern according to office assignment. The pattern can be rearranged when assignments are changed.

All outside cables terminate at a protector frame to prevent damage to office equipment from lightning surges and power crosses. From the protectors, the customers line cables terminate on the main distributing frame, and the incoming and outgoing trunk circuit cables terminate on the incoming-outgoing trunk distributing frame. Quick-connect terminal blocks allow easy rearrangement of the interconnection pattern.

In the SP-1 ESS, grouping circuits are required between the incoming trunks and the originating route and service appearances, between the outgoing trunks and the terminating route appearances, and between the service circuits and the service link appearances. There are a maximum of 8 grouping frames in an SP-1 ESS Office.



2048 - word Call Store Memory Module-One 8192-word call store memory unit consists of four such modules.

Ferrite Sheet Submodule
16-ferrite sheets
stacked in each of
three rows.

Temporary Memory Ferrite Sheet – the basic storage element contains 256 holes with a storage capacity of one bit per hole.

Figure 16
CALL STORE MEMORY MODULE

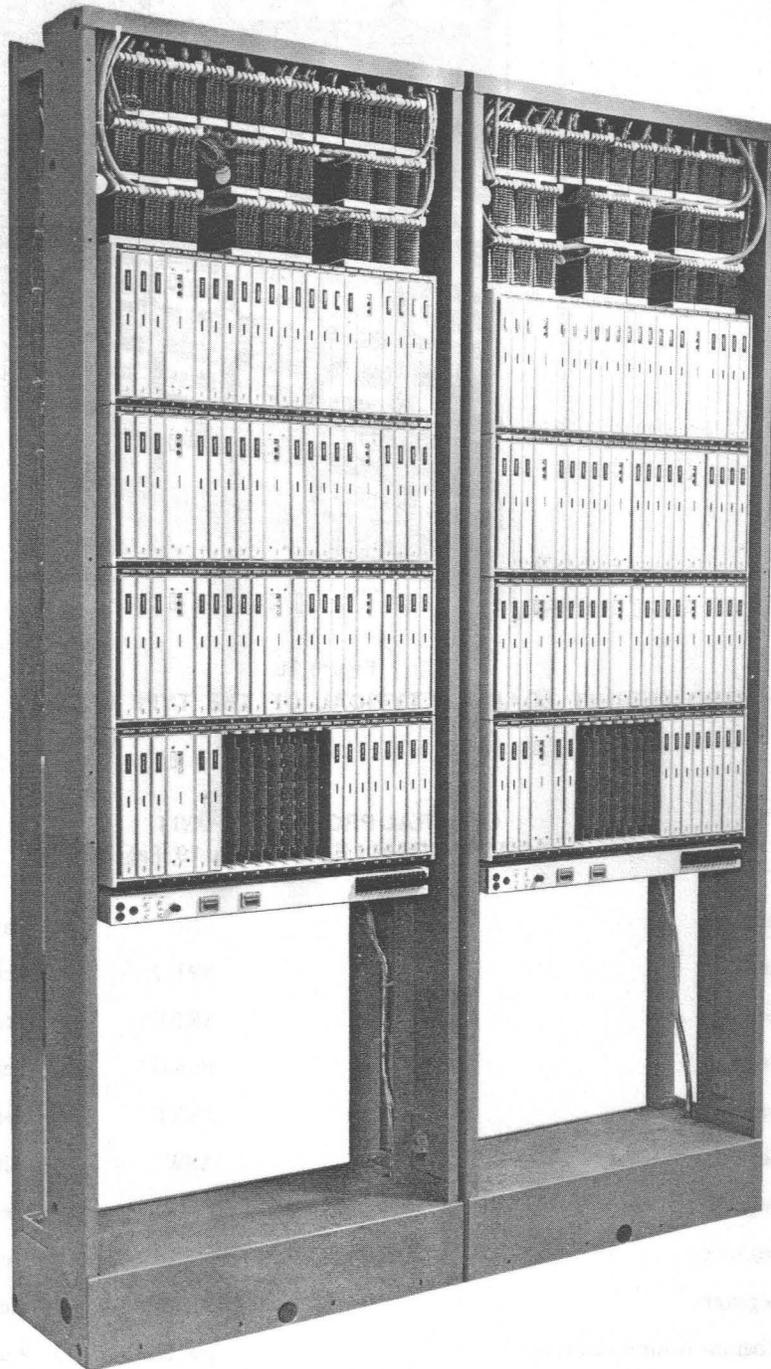


Figure 17
CENTRAL PROCESSOR FRAME

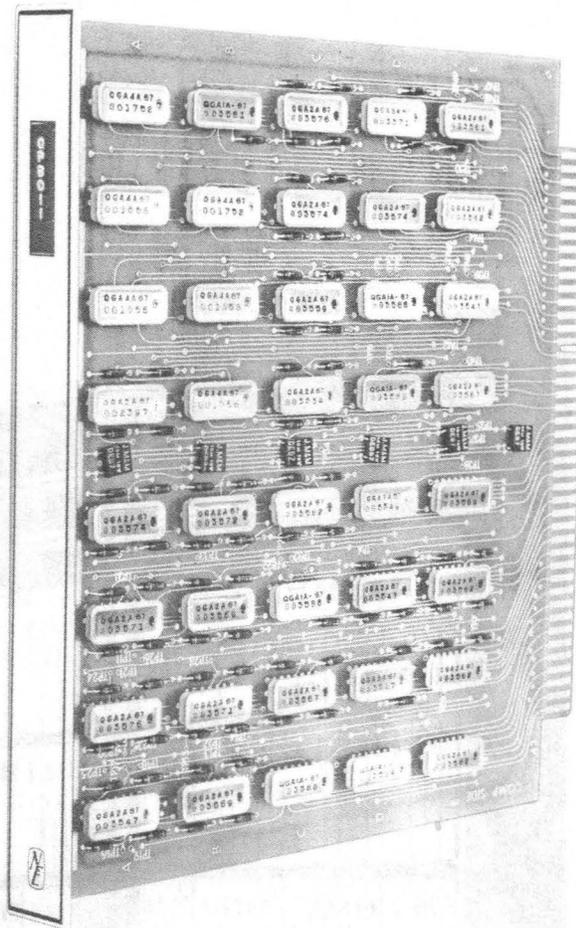


Figure 18
PRINTED CIRCUIT BOARD – TYPICAL OF THE TYPE USED IN THE SP-1 ESS

CENTRAL PROCESSING UNIT
BLOCK DIAGRAM LEGEND (Fig. 19, Page 28)

A	– Register	FIR	– Fault Indication Register
B	– Register	SRBO	– Scan Return Buffer 0
C	– Register	SRB1	– Scan Return Buffer 1
M	– Register	PBRO	– Peripheral Buffer Register 0
S	– Register	PBR1	– Peripheral Buffer Register 1
W	– Register	ASW	– All-Seems-Well
X	– Register	CPU	– Central Processing Unit
Y	– Register	CTR	– Centre
Z	– Register	REG	– Register
PAR	– Program Address Register	FN DECODE	– Function Decode
PSOR	– Program Store Output Register	ALU CONDI- TION	– Arithmetic Logic Unit Condition
POB	– Program Order Buffer	DIAG. GATES	– Diagnostic Gates
ALU	– Arithmetic Logic Unit		

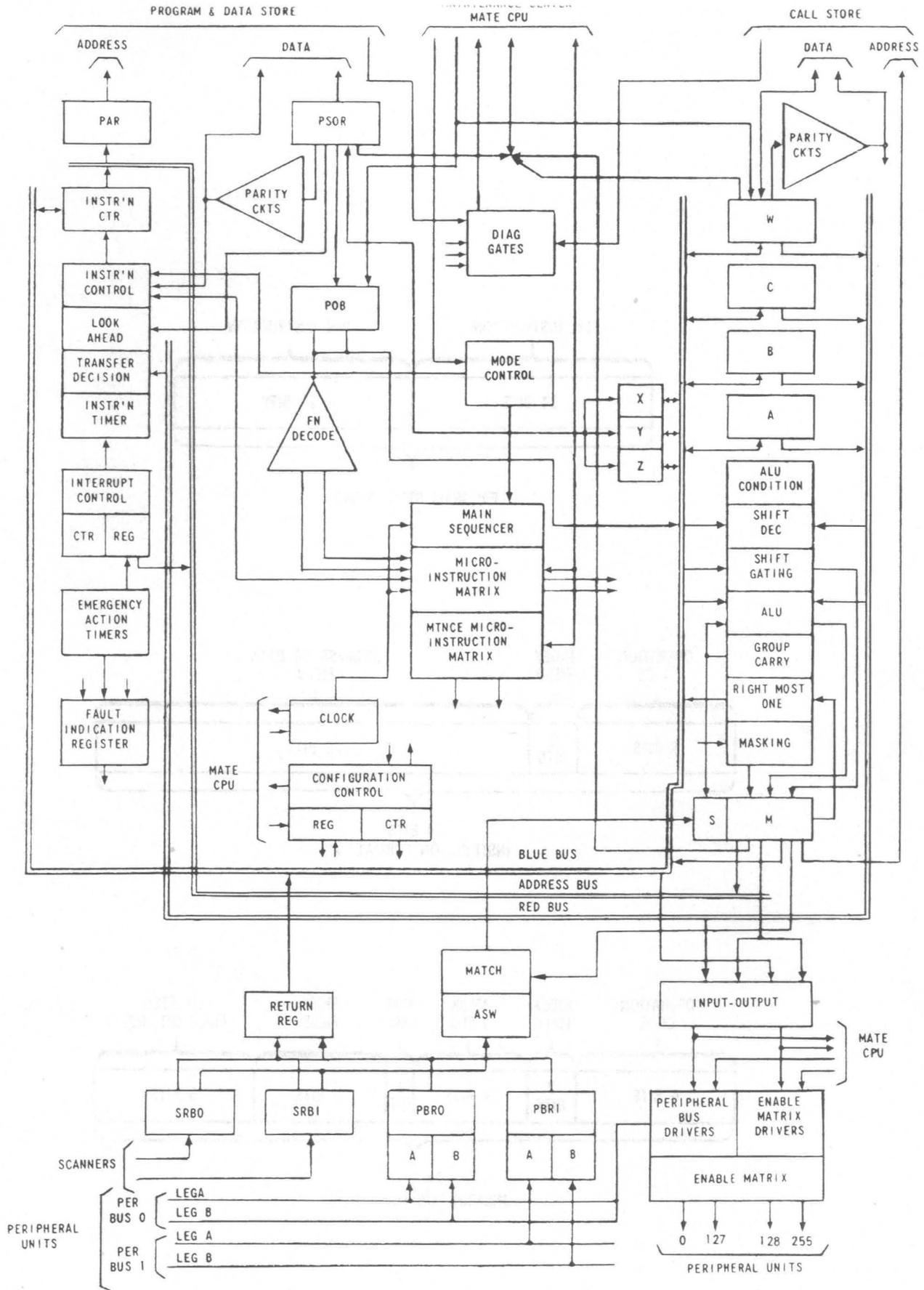


Figure 19
CPU BLOCK DIAGRAM

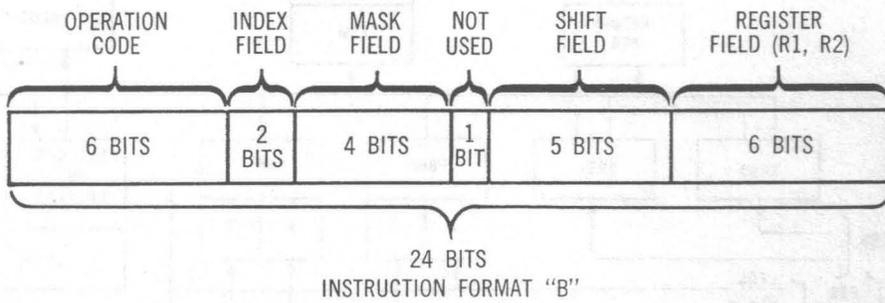
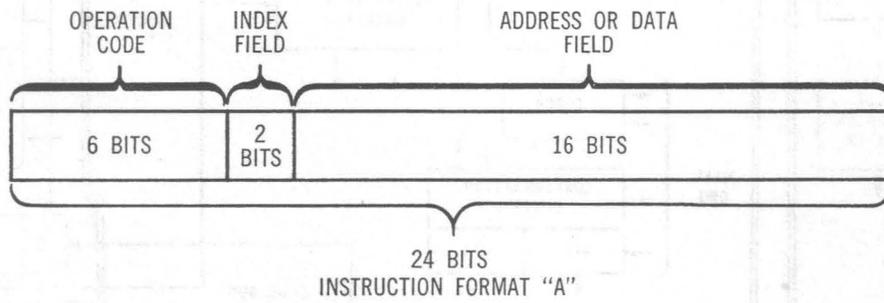
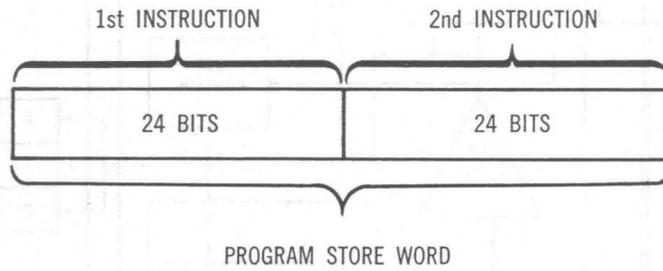


FIGURE 19A
CPU INSTRUCTION FORMATS

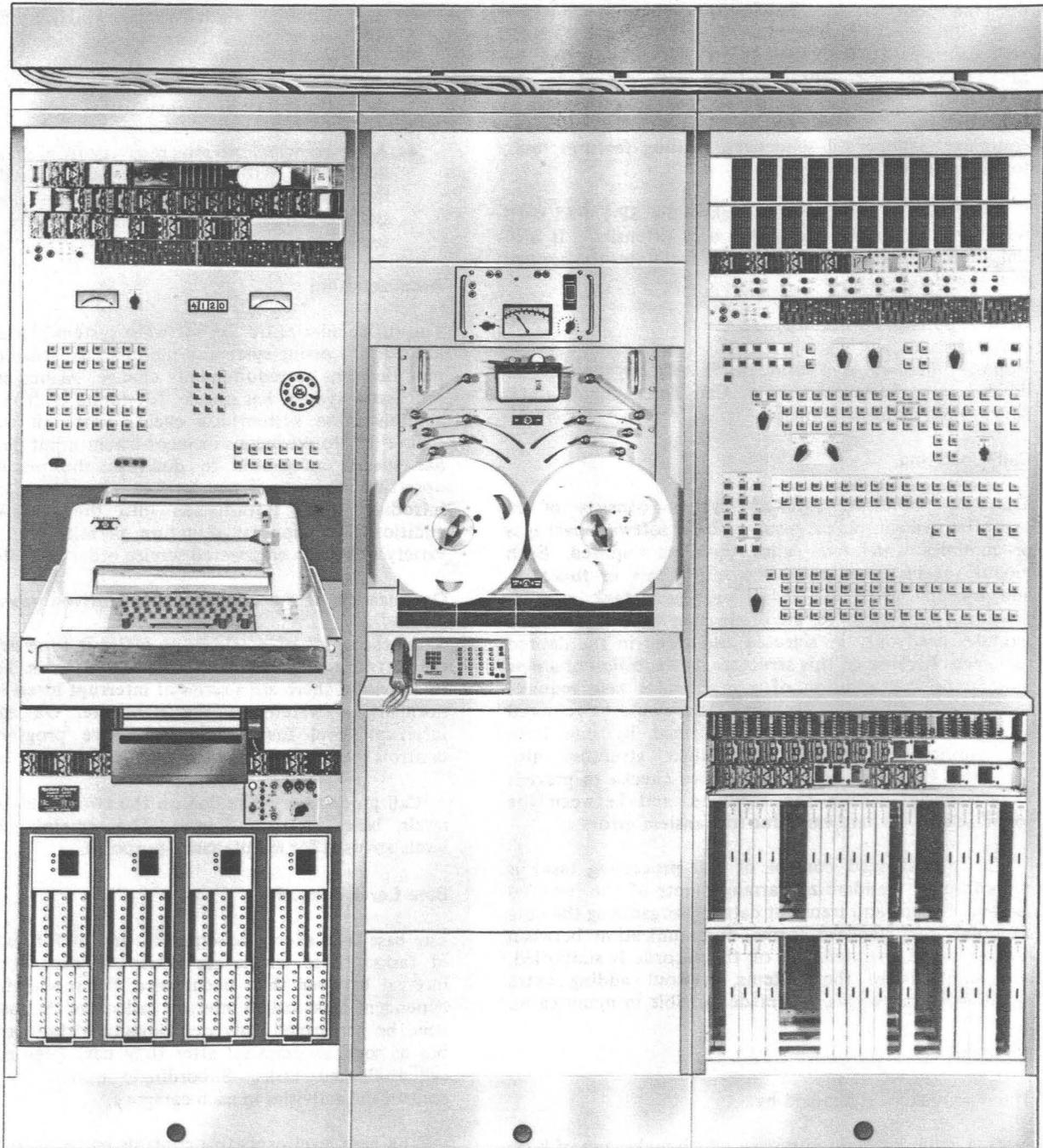


Figure 20
MAINTENANCE CENTRE

SECTION 4 – THE SOFTWARE SYSTEM

Electronic and semi-electronic switching system descriptions tend to emphasize the operational flexibility derived from the use of stored programs. However, a stored program for a telephone office develops into a large logical structure with many interrelated parts. Such a program, like that of a sequential relay or semi-conductor logic circuit, can be so constructed as to be internally flexible or not, depending on the intent of the system designer.

To obtain this flexibility the stored program for the SP-1 ESS is modularly organized with regard to the control of the sequences of required actions, such as establishing connections, and the data which specifies the equipment, numerical sequences, routing features, etc., for any given office.

The modular organization makes the SP-1 ESS software system readily changeable and extensible. It also simplifies the system's structure and facilitates the control over the use of real time.

General Software Structure

From a functional viewpoint, the software system can be divided into three main parts: Call Processing, Maintenance, and Administration.

Call Processing

The call processing software system consists of an executive system, plus a group of basic software packages or modules which are called upon as required. Each module of program performs a minor task or function, and for any given major call processing task, such as providing dial tone to an originating line, the desired modules need only be selected and listed in the desired sequence. Because of this structure, the addition of a new module or the addition of a new major task requires significantly less program change than would be required if the call processing were performed by one large interwoven sequence. This modular structure also facilitates the inclusion of progressive checks to prevent inconsistencies within the software, and between the software and the hardware, due to transient errors.

The modularized control of call processing tasks is supported by standardized arrangements of the required semi-permanent and transient data. By organizing the data structure into standard forms, communication between programs and maintenance of the records is simplified, and additions to the systems, without adding extra maintenance programs, are made possible in many cases.

Maintenance

The maintenance is handled by:

- a) A fault recognition system which makes use of both hardware and software. Each of these implementations are used in the design where they are most effective in producing a reliable and maintainable machine. This system analyzes both the maintenance hardware and what might be called "normal call processing hardware" as to their ability to perform as intended.

- b) A system which finds the faulty hardware module of the machine, removes this module from service, places a good module of the machine in control, and initiates a diagnostic procedure.
- c) A diagnostic system which finds the faulty hardware submodule and reports diagnostic information to the maintenance personnel so that repair time is minimized.
- d) A continuous audit system which monitors the accuracy of the software records in relation to the state of the hardware where applicable, to prevent transient errors from having a cumulative effect on the performance of the machine.
- e) A system which permits recovery from major record destruction without affecting established connections. This system is utilized when the above audit system cannot cope with an unusually complex sequence of errors.

Administration

The office administration software system has, similar to the call processing system, a modular structure to permit modifications as requirements change. Again, as the call processing system has checks for faults built into it, the administration system has checks within it to prevent failure due to erroneous or inconsistent input data. It also has special safeguards to diminish the possibility of upsetting the machine performance with improper introduction of information into the data store. In addition, the modular structure permits the use of a variety of human engineered service order formats.

Organization of the Control of the Software System

Since the work of a telephone office is time dependent, the software control is divided on a time basis. To achieve this division there are a series of interrupt levels which are normally activated by the hardware. On each such interrupt level there is an executive program which controls the sequence of task execution on that level.

Call processing is handled on the two lowest interrupt levels, base level and E-level. The remaining interrupt levels are used for maintenance purposes.

Base Level Executive

The base level executive sequences are the following types of tasks: those which are relatively insensitive to the interval between their occurrence; the moderately time-dependent tasks called interject tasks; and the tasks which need be performed only occasionally without regularity, but as soon as practical after they have been requested, called flagged tasks. Subordinate executive programs control the activities in each category.

The base level executive controls entry to routine task programs for scanning lines for originations, processing dial tone requests, analysis of data from and preparing data for service circuits, establishing stable connections, and processing disconnect requests. It also controls flagged tasks, audits, and maintenance executive functions. These routine tasks are arranged, of course, with regard to frequency of their occurrence and sequence in

which they occur in order to maximize the traffic capacity of the office.

Between each base level task, the base level executive determines if sufficient time has elapsed to require base level executive interject tasks to be done. Such tasks are performed at a nominal 0.1 or 0.2 second interval as appropriate to the task. These tasks, with a moderately controlled repetition interval,

- a) supervise incoming trunks for origination, answer and disconnect;
- b) supervise originating junctors for answer and disconnect;
- c) time for hits, flashes and disconnect;
- d) supervise ringing circuits for call processing and maintenance actions which may occur during the ringing state of a call;
- e) supervise operator trunks, and
- f) time and set the flags for long period repetitive tasks such as traffic recording and partial dial or permanent signal detection and processing.

E-Level Executive

The E-level executive sequences are as follows: tasks which must be performed at closely controlled fixed intervals to interface real time signal; and tasks which should be performed at fixed intervals for optimum usage of real time by the system.

These tasks are arranged to distribute the work load evenly at each interrupt, to limit the maximum time allocated to each interrupt so as to prevent overrun, to control the ratio of time spent by base and E-level programs, and to minimize the variations between initiation of any one program.

The E-level controlled tasks include: digit reception and transmission, by-link trunk scanning, critical timing functions used during base level control sequences, teletypewriter input-output control, signal distributor control, and the marker control functions.

Maintenance Interrupt Control

The high interrupt level maintenance programs are entered upon conditions such as: a mismatch between the CPU's, parity failure, and time out of emergency action timers. Therefore, normal entry into, and basic control of these programs are effected by the fault detecting hardware. However, further control exists to co-ordinate the activity between the programs on each interrupt level and to permit maintenance of the interrupt system itself. There are three normal maintenance interrupt levels. A failure causes the execution, on the middle (C) level of a fault recognition program which is designed to halt the operation of the faulty machine. The top (B) level program assists in maintaining sanity of the system by activating initialization procedures. The lower (D) level program restarts the good machine with minimal disturbance to call processing, initiates requests for diagnosis of the faulty machine, and restores the synchronization of the two machines after faults are cleared.

SECTION 5 – TELEPHONE CALL PROCESSING

The following is a general description of the processing of basic types of calls, indicating how the various units in the SP-1 ESS interact to perform as a switching system.

Dial Tone Connection

When the subscriber lifts the handset to originate a call, Fig. 21, Page 33, current flows through the ferrod sensor associated with the calling line on the line link frame. The scanner, via the scan return bus, passes the state of the sensor on to the central control. On recognition of this request for service, the line scan program marks the calling line busy in call store, obtains the line equipment location from the translation area of data store, and places control of the call under the universal call sequence for dial tone by marking a universal call register area in call store.

Translation areas of data store are again interrogated to find the calling line class-of-service and an originating junctor group serving the line link frame on which the line terminates. An order is sent to the signal distributor to operate an electrically latching relay in the selected receiver, to prepare the receiver to hold the upcoming connection. Then an order is sent to an idle marker with all necessary information to connect the calling line and the digit receiver. The marker selects one idle path among all possible paths within the given junctor group between the calling line and digit receiver and, through network controls, operates the select and hold magnets of the MINIBAR switches required to form a path. To complete its function the marker indicates on scan points the originating junctor it selected, so that this can be retained in call store along with the other status information.

The signal distributor causes the digit receiver to provide dial tone to the calling line to indicate that the subscriber may now dial a desired number. All the events leading up to a dial tone connection normally occur within a fraction of a second. At this point, call control passes from the universal call sequence for dial tone to the digit receiver scan program, which runs under real time interrupt control.

Dialling Connection

The subscriber, after hearing dial tone, dials the called party number. Dialling must start within a specified time after reception of dial tone, or the dial tone connection is dropped and the line is given permanent signal treatment. The time allowed varies between 7.5 to 30 seconds, depending on traffic load conditions as specified by the program. Similarly, a time limit also applies to the period between dialling one digit and the next – the interdigital time. A line exceeding this time period is given partial dial treatment. Dial tone is removed after the first digit is received, by release of the latching relay previously operated to cut through dial tone.

The digit receiver accepts the dialled information and makes it available to central control via the scanner. The digit analysis routines in software decide as early as possible during dialling, the number of digits to be expected. After dialling is complete, a relay in the originating junctor is operated via the signal distributor to provide holding ground for the hold magnets in the line link network. Also, via a signal distributor, the relay

previously operated to prepare the digit receiver, is released. This releases the digit receiver and clears the network connection from the receiver to the originating junctor. A 3-digit translation routine examines the first 3 digits after all expected digits have been received, and determines the type of call.

Intraoffice Call

A calling subscriber, upon receiving dial tone proceeds to dial the number of a subscriber served by the same office Fig. 22, Page 33. Upon recognizing the first digit by means of the digit receiver scan points, the digit receiver scan program system calls for a universal call sequence which will remove dial tone by sending a signal distributor order to release the latching relay in the digit receiver. Meanwhile, as the subscriber dials, the program assembles the digits in call store.

Upon examining the meaningful digits, the universal

call sequence determines that the request for service should be treated as an intraoffice type call. Upon examination of translation data and the called line busy/idle status, the universal call sequence determines the class-of-service. A latching relay is operated in the originating junctor to hold the line connection to the calling subscriber; the latching relay in the digit receiver is released thereby opening the holding path, and the receiver is made idle in call store.

Another universal call sequence selects an idle ringing circuit on the service link frame previously used for the dial tone connection. It also prepares the circuit by operating a signal distributor point in the ringing circuit in order to prepare the holding path for the upcoming connection, as was done for the digit receiver. An order is sent to an idle marker with all necessary information to connect the originating junctor to the ringing circuit. The marker selects one idle path through the service link frame and closes all crosspoints required to form the path. An

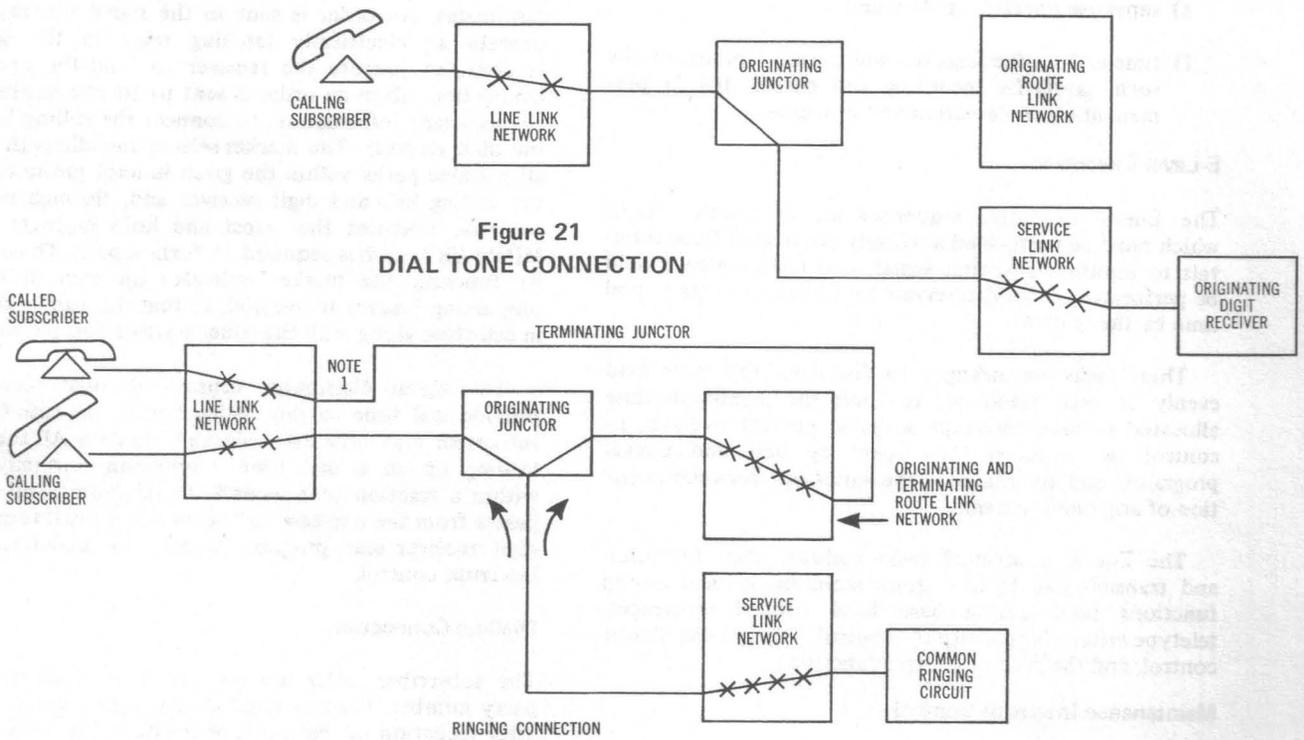


Figure 21
DIAL TONE CONNECTION

NOTE 1 — THE TWO LINES MAY OR MAY NOT BE ON THE SAME LINE LINK NETWORK

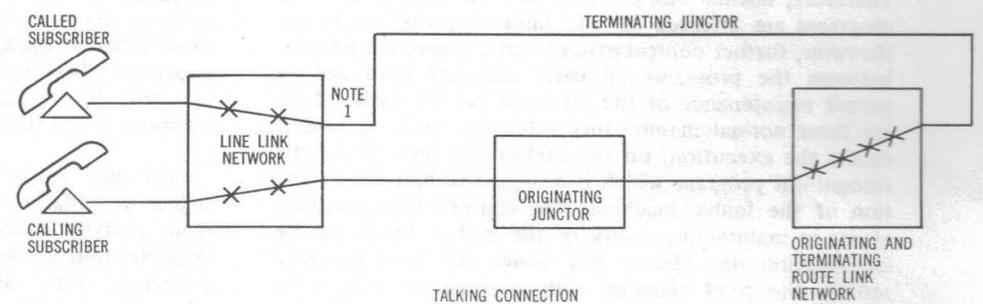


Figure 22
INTRAOFFICE CALL

NOTE 1 — THE TWO LINES MAY OR MAY NOT BE ON THE SAME LINE LINK NETWORK

Intraoffice Call cont'd.

order is sent to another idle marker with all necessary information to connect the originating junctor through the route network and line network to the called line. Once the connection is established, the ringing circuit is activated, via a signal distributor action, to provide ringing to the called line and audible ringback to the calling subscriber.

Establishing the Talking Connection

When the called party answers, a relay in the ringing circuit operates and as a result:

- a) Ringing and audible ringback cease.
- b) The state of the scan points in the ringing circuit changes to inform the ringing circuit scan program that the called party answered.
- c) The splitting relay in the originating junctor is released, thus establishing the talking path through the originating junctor.

The ringing circuit scan program now passes control to a universal call sequence which, again via the action of the signal distributor, releases the relay previously operated in the ringing circuit. This causes removal of the holding path, which releases the ringing circuit and associated crosspoints in the service link frame. After all these complex events, the talking path is established.

Interoffice Call — (Originating — Outgoing)

A calling subscriber dials the number of a subscriber served by a distant office or a distant operator, Fig. 23, Page 35.

Once the dial tone connection is established and the dialling stage complete, central control determines that the request for service should be treated as an outgoing call.

From the translation of the office code, it also obtains the routing information. The program selects an idle transmitter of the correct type on the service link frame used for the dial tone connection. Via the signal distributor, central control operates one of two latching relays in the transmitter, depending on whether loop, E&M, or battery-ground signalling is required. A marker order is assembled by central control and sent to an idle marker to connect the transmitter to the originating junctor through the service link frame. Holding ground for the hold magnets associated with the service network crosspoints is applied through the transmitter.

A second marker order is required for the outgoing portion of the connection. Central control selects an outgoing trunk of the correct type. The trunk circuit defines the TRLF, while the originating junctor defines the ORLF. Central control therefore issues a marker order with this information, plus the associated group or partial group of route junctors. If the marker cannot find an idle path between the originating junctor and the specified trunk, the normal sequence is stopped, and the situation reported to central control via scan points in the marker. The unsuccessful marker is released by means of a marker

order and call processing reverts to a second marker order.

When assembling a new marker order, central control attempts to select another outgoing trunk. If the marker receiving the new marker order is unsuccessful in finding an idle path through the route network, it is also released by a marker order. Central control, via a signal distributor, releases the latching relay in the transmitter which causes release of the service network connection. This in turn releases the splitting relay in the originating junctor. Similar to connecting a busy tone source to the calling line, central control, via the marker, connects an overflow tone source to the line.

In the normal case, where the marker finds one or more idle paths from the originating junctor to the specified trunk, it selects one on a preference basis, and causes closure of the crosspoints required to form that path. Holding ground for the route network connection is provided through the originating junctor. Depending on whether MF or DP pulsing is used between the two offices, central control will guide the transmitter in one of two ways:

- a) If DP, central control waits in the order of 800 milliseconds, and then instructs the transmitter, via the bus system, to send the necessary digits.
- b) If MF, central control, via the bus system, orders the transmitter to send a seizure signal to the distant office. After receiving the start to pulse signal from the distant office, central control, via the bus system, orders the transmitter to send the necessary signalling information.

In either case, central control checks on the progress of digit transmission via the scanner, and controls the interdigital intervals via the bus system. Having sent all the necessary information, central control orders the release of a signal distributor point in the transmitter, which causes release of the service network connection.

Interoffice Call — (Incoming — Terminating)

Central control, through the scanning of incoming trunks, detects the seizure signal from the calling office, Fig. 24, Page 35. After detection of the seizure signal, central control sends an order to an idle marker to connect an incoming digit receiver (not required for calls from step-by-step offices) to the incoming trunk through the service network. Via a signal distributor, central control operates a latching relay in the digit receiver to send the start to pulse signal to the calling office, which is later removed by release of the signal distributor point. The digit receiver accepts the transmitted information and makes it available to central control via the scanner. After reception of all digits, the digit receiver is released by release of a signal distributor point, which also causes release of the service network connection. From the transmitted digits, central control determines that the call is to be completed in this office. With the interoffice call established, an incoming trunk provides the supervision in the terminating office, while an originating junctor provides supervision in the originating office.

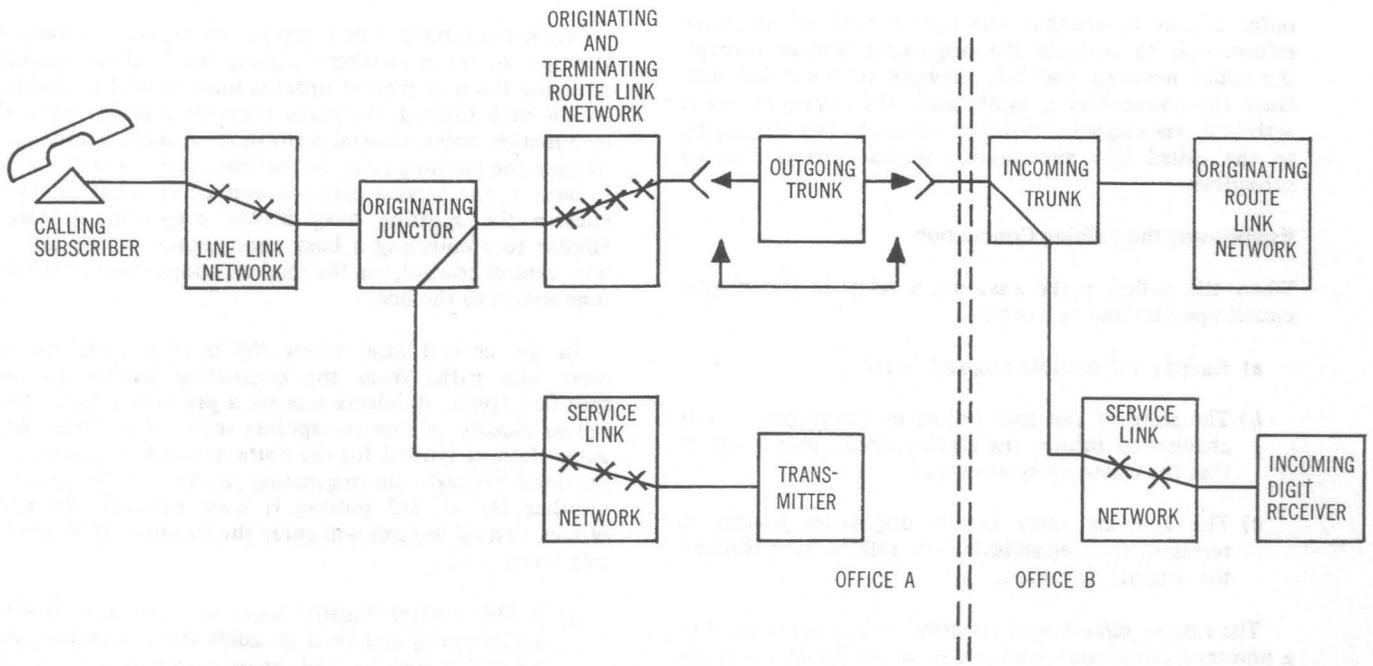


Figure 23
INTEROFFICE CALL - OUTGOING

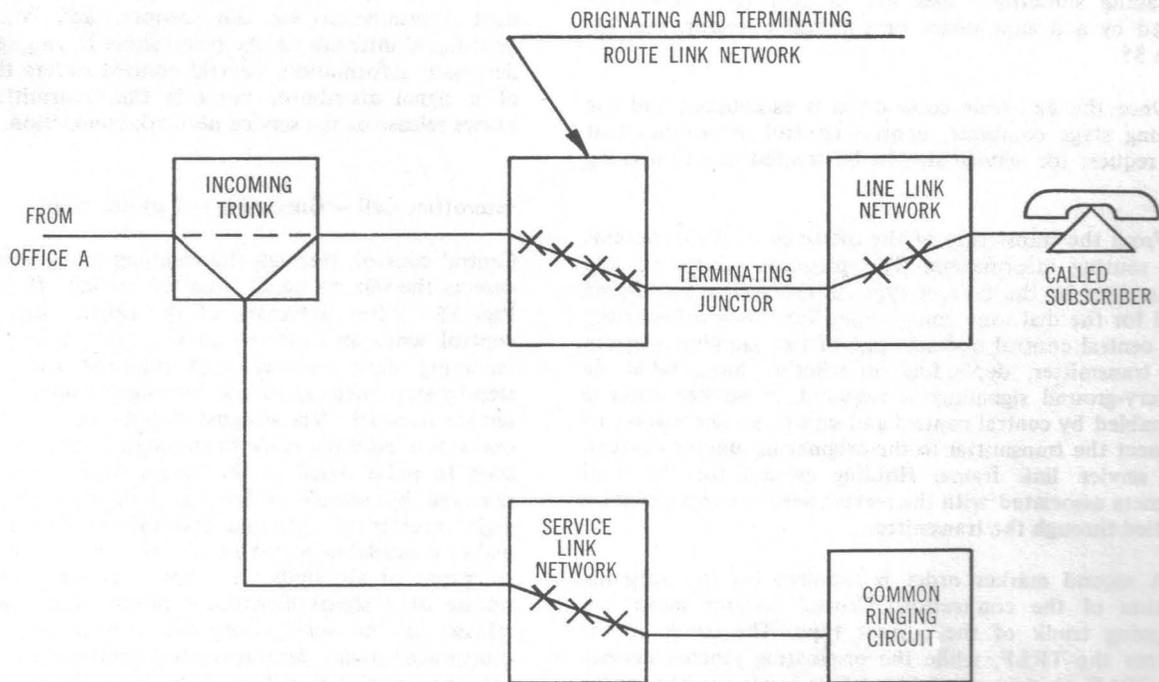


Figure 24
INTEROFFICE CALL - INCOMING

Tandem Call

On a tandem call, Fig. 25, Page 36, the call from a distant office is switched through the SP-1 ESS Office to reach a subscriber in another office. For a tandem call, central control would determine from the transmitted digits that the call is for a distant office. The procedure followed is identical to an outgoing interoffice call, with the special incoming trunk in the tandem office replacing the originating junctor in the originating office.

Revertive Call

A revertive call is a call between two subscribers on the same multiparty or two-party line. This type of call progresses to the point where it is known the request for service should be treated as a local call and central control determines that the calling party wishes to talk to someone with the same line appearance.

During the dial tone connection, when determining the class-of-service, central control identified the call as originating from either a multiparty or two-party line. Central control selects and connects a ringing circuit to the originating junctor through the service network in the same manner as for the intraoffice call. Due to special functions being required, a special ringing circuit is selected, rather than a common ringing circuit which is used for other intraoffice calls. No connection through the route network is required. If ringing should be applied to the tip side of the line rather than the ring side, a signal

distributor point is operated in the ringing circuit. Central control orders the operation of a third signal distributor point in the ringing circuit to cut through busy tone to the calling subscriber. The calling subscriber is expected to go on-hook within a time period of about 25 seconds, or the call is not processed. Central control, from scan points in the ringing circuit, recognizes the on-hook condition. A fourth signal distributor point in the ringing circuit is operated to reverse the leads from the ringing circuit, such that the leads carrying the ringing current are connected to the line rather than to the route network side of the originating junctor. A fifth signal distributor point in the ringing circuit is operated to apply coded ringing to the line and cut off the busy tone source.

During the time that coded ringing is sent to the called subscriber on either the tip or ring side, revertive ringing is always sent out on the opposite side. The calling subscriber will hear one or the other ringing signals, depending on which side of the line he is on in relation to the called subscriber. Either party going off-hook will operate the ring-trip relay in the ringing circuit. This causes the talking connection to be established. Since ringing is tripped, the calling subscriber should delay lifting the handset too soon in order not to give the called subscriber the impression that the call has been abandoned. If, of course, the called subscriber does not answer, the calling subscriber will go off-hook to stop the ringing. If neither party goes off-hook within a time-out period of about 3 minutes, all connections are released.

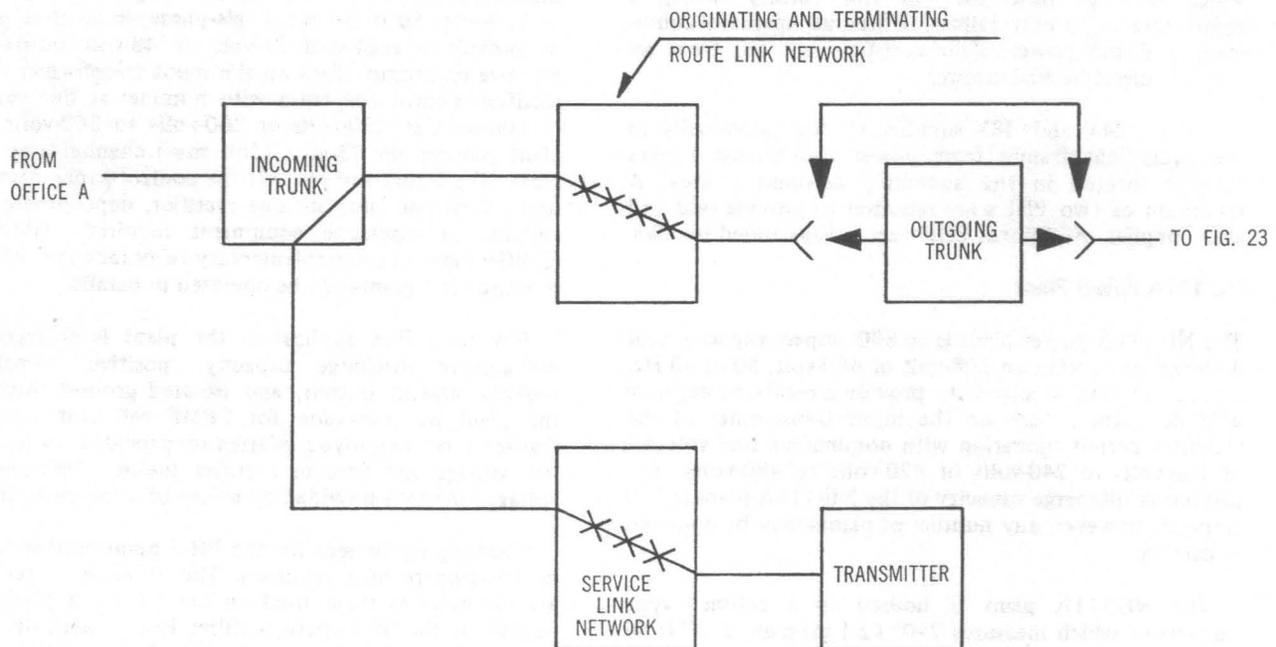


Figure 25
TANDEM CALL

SECTION 6 — POWER

The SP-1 ESS uses conventional DC power plant equipment which provides negative 48-volt supply and positive 24-volt supply. The negative 48-volt supply is used for operation of the peripheral equipment, the program stores, and the maintenance centre. The positive 24-volt supply is used for the central control, memory, peripheral interface, and some peripheral control circuits. Small amounts of positive 24-volt supply is also required in the scanners, signal distributors, and the maintenance centre.

The NE-111A, 800-ampere capacity and the PH-1, 400-ampere capacity power plants are suitable as negative 48-volt supplies, the latter for smaller offices only. The PH-1 power plant is also suitable as a positive 24-volt supply for the system. Both power plants provide battery reserve. A converter plant using NSQ605 type static d-c generators is available for the positive and negative 130-volt supply required for coin control and test trunks.

The normal ac requirements are:

208V or 120V single-phase for rectifiers used on the PH-1 power plant.

208V or 480V three-phase for rectifiers used on the NE-111A power plant.

120V single-phase for appliance outlets, frame lighting and ac operated equipment.

Certain ac operated equipment such as recorded announcement machine, teletypes and data sets require uninterrupted protected 120-volt single-phase ac power. This supply is obtained from a dc-to-ac static inverter which operates from the -48 volt battery during a commercial ac power failure. Other ac operated equipment and the power plant rectifiers are fed from an essential diesel-backed supply.

Fused +24V and -48V supplies are fed individually to the equipment frames from power distribution frames (PDF's) located in the switching equipment area. A minimum of two PDF's are required to provide odd and even supplies. Additional PDF's are always added in pairs.

NE-111A Power Plant

The NE-111A power plant is an 800-ampere capacity unit designed to operate on 208-volt or 480-volt, 50 or 60 Hz, 3-phase nominal ac power to provide a regulated negative 48V dc output. Taps on the input transformer of the rectifiers permit operation with nominal a-c line voltages of 208-volts to 240-volts or 420-volts to 480-volts. The maximum discharge capacity of the NE-111A plant is 800 amperes; however, any number of plants may be operated in parallel.

The NE-111A plant is housed in a cabinet type framework which measures 7'-0" (2.1 m) high, 2'-3" (686 mm) wide and 2'-6" (762 mm) deep. The initial control bay accommodates, in addition to two 100-ampere silicon controlled rectifiers, discharge equipment, and charge and discharge control circuitry. If necessary, the rectifiers in the control bay may be omitted and the space equipped with additional discharge fuse panels. The control bay is equipped with an alarm lamp to indicate any alarm condition within the cabinet.

Cabinet-type supplementary rectifier bays mount one to four 100-ampere rectifiers on a back-to-back basis. With the exception of the voltage sensing leads, the control and alarm leads for these rectifiers are paralleled on terminal strips and one set of leads per supplementary bay is run to the control bay. Rectifier charge leads are paralleled on busbar terminations at the top of the rectifier bay and 4 leads (2 battery and 2 ground) are run to the control bay thus reducing cable congestion. Each supplementary bay is equipped with an alarm lamp to indicate the failure of any rectifier within that bay.

The battery for this plant consists of one or more 24 cell strings floated at 52 volts. CEMF cell switching is not employed.

The 100-ampere SCR rectifiers used with the NE-111A plant automatically regulate the output within $\pm 0.5\%$ with ac voltage variations of $\pm 10\%$ for all outputs from no load to full load. The rectifiers are equipped with a high voltage shutdown feature.

Distribution to the switching equipment is through 600-ampere switch and fuse units to the power distribution frames located in the switching area from which the equipment frames are fed through smaller sized fuses. The plant is also equipped with smaller sized fuse panels to provide distribution to the inverter and converters which are normally located in the power area. The charge and discharge ground bars are insulated from the power plant framework.

PH-1 Power Plant

The PH-1 power plant, Fig. 26, Page 38, is a 400-ampere capacity solid-state unit designed to operate on 208-volt or 120-volt, 50 or 60 Hz, single-phase nominal ac power to provide a regulated 24-volt or 48-volt positive or negative dc output. Taps on the input transformer of the rectifiers permit operation with nominal ac line voltages of 100-volts to 130-volts or 200-volts to 260-volts. The plant mounts on 23-inch (584 mm) channel-type relay racks. The initial bay mounts the control panel, discharge fuse panels and possibly one rectifier, depending on the amount of discharge equipment required. Additional rectifiers mount on supplementary relay rack frames. Two or more PH-1 plants can be operated in parallel.

For SP-1 ESS application the plant is arranged for 400-ampere discharge capacity, positive 24-volt or negative 48-volt output, and isolated ground. Although the plant has provision for CEMF cell switching, this feature is not employed. Alarms are provided for high and low voltage and fuse or rectifier failure. High and low voltage sensing is provided by means of solid state circuits.

Charging equipment for the PH-1 plant consists of 50- or 100-ampere SCR rectifiers. The 100-ampere rectifiers are the same as those used on the NE-111A plant. The output of the 50-ampere rectifier is automatically regulated within $\pm 1\%$ from no load to full load for ac line voltage variations of $\pm 10\%$.

The output ripple does not exceed 0.2%. Ammeters, current limiting, dc filtering, voltage test jacks, and a low-voltage indicator, are provided as standard features on the 50-ampere rectifiers; while voltmeters, forced load share, sequential start and high voltage shutdown are

optional features. For SP-1 ESS application both the 50- and 100-ampere rectifiers are equipped with the high voltage shutdown feature. Up to ten 50-ampere rectifiers or five 100-ampere rectifiers can be operated in parallel to provide for a maximum charging capacity of 500-amperes.

Distribution to power distribution frames is through 400-ampere fuses. The 48-volt plant is equipped with smaller sized fuse panels or circuit breaker panels for other distribution.

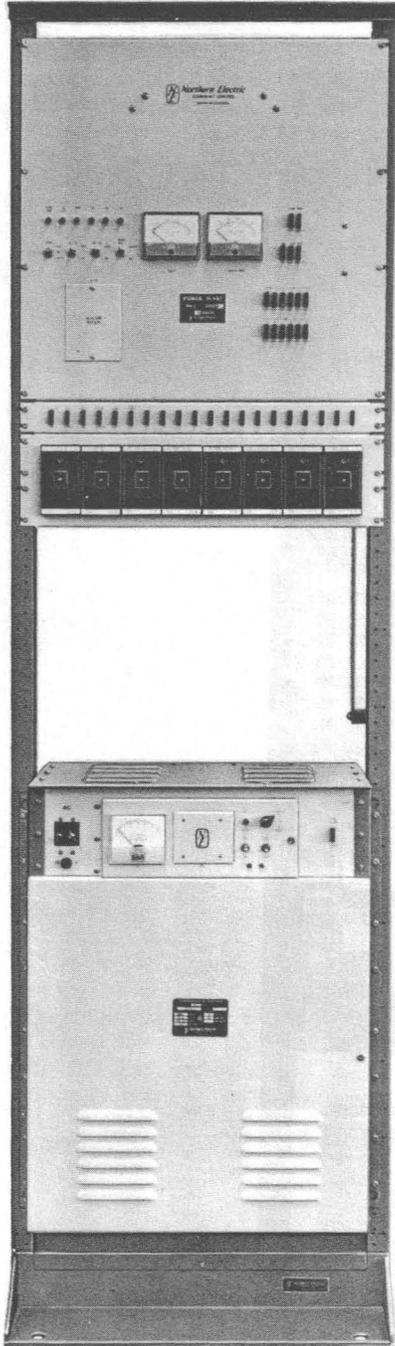


Figure 26
PH-1 POWER PLANT

PB-6 Ringing and Tone Plant

The PB-6 Ringing and Tone Plant, (Fig. 27, Page 39, is designed to provide 20 Hz ringing current and precise tones. Utilizing integrated logic circuits, the PB-6 has a fully solid-state interrupter and typifies the new generation of apparatus required for use with the SP-1 ESS. The plant is operated from the office battery making it independent of the ac supply. One ringing and tone plant is provided per SP-1 ESS Office.

The PB-6 consists of three basic subgroups: an interrupter, tone generator and ringing generator, all of which are mounted on a single-sided frame. Both electrical and acoustical noises have been reduced to a degree where the ringing plant can be mounted adjacent to the switching system, instead of in a separate power room as before, thus reducing shielded cable requirements and decreasing transmission loss and induced noise. The ringing and tone plant will provide the following:

- a) Duplicate solid-state inverters to supply $20 \text{ Hz} \pm 1 \text{ Hz}$ ringing current at nominal voltages of 86- and 105-volts rms.
- b) Duplicate solid-state interrupters providing for CODE 1 GEN. on 3 brushes for single- and 2-party ringing and 5 codes for multiparty ringing. Revertive ring, pick-up, 60 and 120 IPM ground signals, and tone interruptions.
- c) Duplicate precise tone generators providing the necessary tones with frequency stability of ± 0.5 percent and maximum harmonic distortion of one percent.
- d) Transfer circuits, providing for the transfer of duplicated equipment, are automatically or manually controlled.

The interrupter, which provides ringing codes and other required interruptions, employs oscillator-fed logic circuits. These circuits are integrated flip-flops and NAND gates giving high reliability and low power drain.

Four standard frequencies are produced by the tone generator: 350 Hz, 440 Hz, 480 Hz and 620 Hz. Except for the "high tone" and "camp on" which are single tones, all the other tones are combinations of two frequencies.

The ringing generator consists of a dc-to-ac thyristor inverter, using a ferro-resonant transformer and a stable frequency triggering signal generator. Besides providing the source of ringing current for the central office, the ringing generator provides a low voltage supply for the integrated circuits in the various sub-units of the PB-6.

Detectors sense the output of the various units. The detectors provide unit failure signals to the audible and visual alarm circuits and via scan points to the switching system central control.

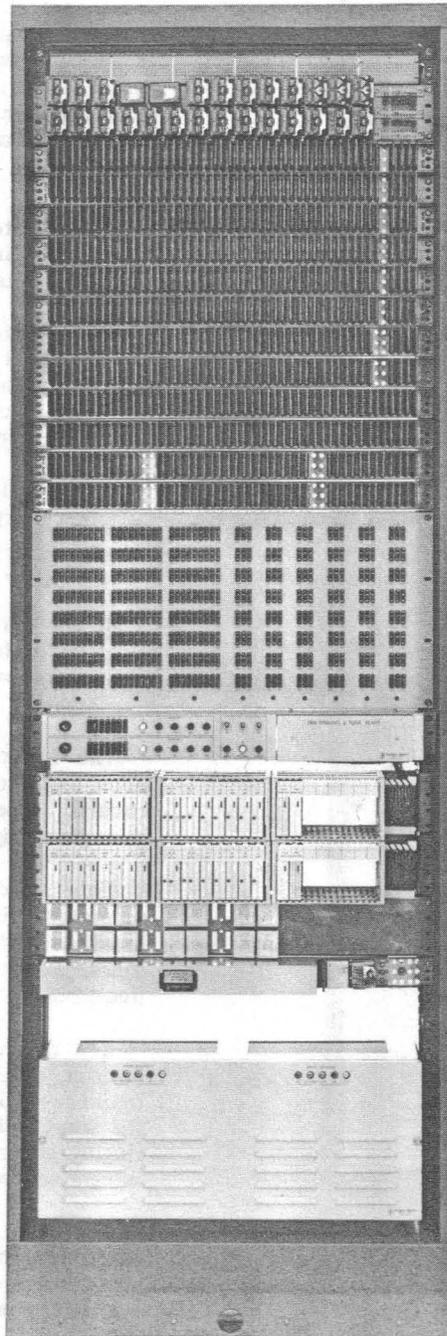


Figure 27
PB-6 RINGING AND TONE PLANT

NOTES

NOTES

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