THE BELL SYSTEM TECHNICAL JOURNAL
Vol. 61, No. 4, April 1982
Printed in U.S.A.

No. 10A Remote Switching System:

Physical Design

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(Manuscript received June 9, 1980)

I. INTRODUCTION

The physical design objectives of No. 10A Remote Switching System (RSS) were to package the system into as compact a design as possible to allow for easy adaptation to both CDO and pair gain applications, to maintain an economic advantage over other alternatives, and to provide ESS service requirements. The interconnection technology was chosen to permit a 1024-line system to be contained in a single frame and to maximize the use of least-expensive interconnection techniques. Circuit partitioning and frame engineering rules were devised to minimize equipment growth, which minimizes installation cost, and to maximize plug-in apparatus growth, which keeps more costly circuit equipage at a minimum. The single (−48 volt) power requirement and low-current drain [less than the step-by-step (SXS) equivalent] allowed minimum and often reuseable battery plant requirements. The small system size resulted in reuse of existing buildings or use of a small portable modular building. The circuit partitioning and system design was implemented to ensure ESS central office service objectives. Because of the short time between manufacture and service, burn-in of electronic circuitry was instituted to minimize the impact of infant mortality on early service. Low cost was also carried into the sparing philosophy by using predicated performance data in conjunction with accepted centralized spare stocking strategies to identify a minimum spare stock which achieved required service objectives. Each aspect of the No. 10A RSS physical design taken together provides a low-cost, small-size, highly reliable electronic switch which will further extend the market coverage of electronic switching systems.

II. INTERCONNECTION TECHNOLOGY SELECTION

Two system requirements, low cost, and small size, were the driving consideration for selecting an interconnection technology. Low cost was important to maintain an economical advantage of RSS over the alternate choices. In the application of No. 10A RSS to CDOs the alternate economic choice is to maintain the existing electromechanical switching system. For pair-gain applications, the alternative is to provide cable pairs for outside plant growth. Small size was important to simplify the application of electronics to the outside plant. So, in choosing a packaging technology, size and cost were of paramount importance.

A review of the interconnection choices shows four possible levels of interconnection. The first level is within components. This, in general, provides the most dense and least-expensive method and so was chosen to be used as much as possible. The second level of interconnection is the large film circuit or the printed wiring board (PWB) which is connectorized to be pluggable for maintenance reasons. This is the second least-expensive interconnection technique providing the proper technology is selected. The third level is automatic machine wiring between connectors. Since this interconnection technique requires the use of connectors, its cost is greater than level one or two costs, and its use should be minimized. The fourth level is that of inter- and intra-frame cabling. Both are the most expensive technique for interconnection and were used as little as possible in the RSS design.

2.1 First level: components

The first level of interconnection consists mostly of integrated circuits, resistors, capacitors, and transformers. Since IC interconnection is by far the least expensive, its use was to be maximized. IGFET technology was utilized wherever possible because of its high density packaging characteristics. The nature of the circuit design is to use many discrete components other than IC. Therefore, finding the room to mount the components is a much more difficult problem than interconnecting them. To help alleviate this constraint, high-density components are required. Therefore, extensive use of R-DIPs was made which provided, at the same cost, a three-to-ten-times increase in packaging density. Also, a new family of transformers was developed using the ferrite core technology which offered a four-times increase in component density (see Fig. 1). Two custom integrated circuits (ICs) (the Battery Feed IC, and the Control Logic IC1) were developed to significantly reduce the interconnection cost of the line circuit. They, as well as the discrete version of these circuits, are shown in Fig. 2. Thus, to make maximum use of the first level of interconnection, the

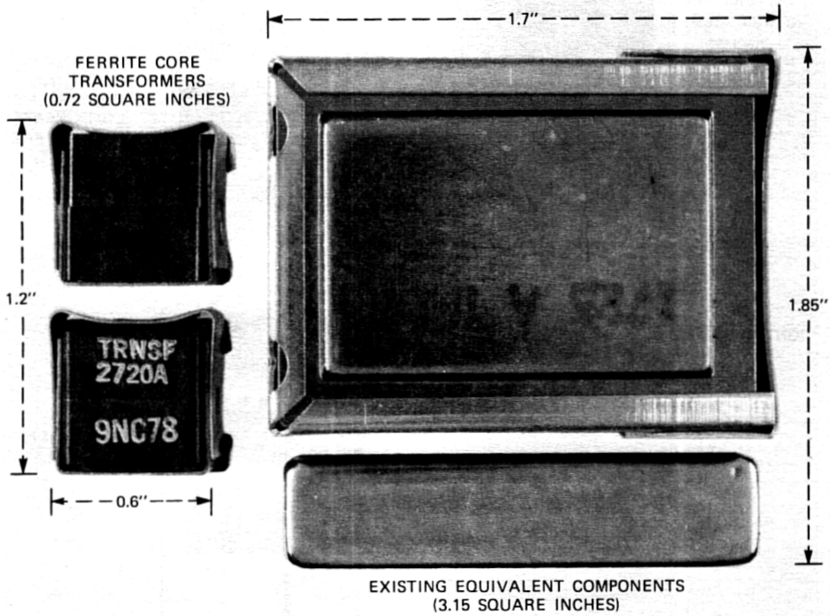


Fig. 1—Space savings of ferrite core transformers.

highest level of integration among ICs, as well as the smallest size among discrete components, was selected.

2.2 Second level: printed wiring boards

The second level of packaging required the interconnection of many discrete components, as well as ICs available in the DIP form. Therefore, PWBs, as opposed to a hybrid technology of film on ceramics, were selected as the second-level technology. An examination of the various complexities of interconnection versus cost for PWB technology is shown in Fig. 3. The interconnection complexity required for No. 10A RSS ranged from *F* through *G*, which is a relatively flat part of the curve giving increased interconnection complexity for little cost increase. Board size was reviewed to determine what effect it would have on cost of second-level interconnection. It has an almost linear relationship between size and cost so that size could be selected more on third- and fourth-level interconnection consideration than on second-level interconnection cost.

2.3 Third level: circuit pack connection system / unit wiring and backplanes

Third- and fourth-level interconnections are determined by the partitioning of circuits onto PWB which implies something about the

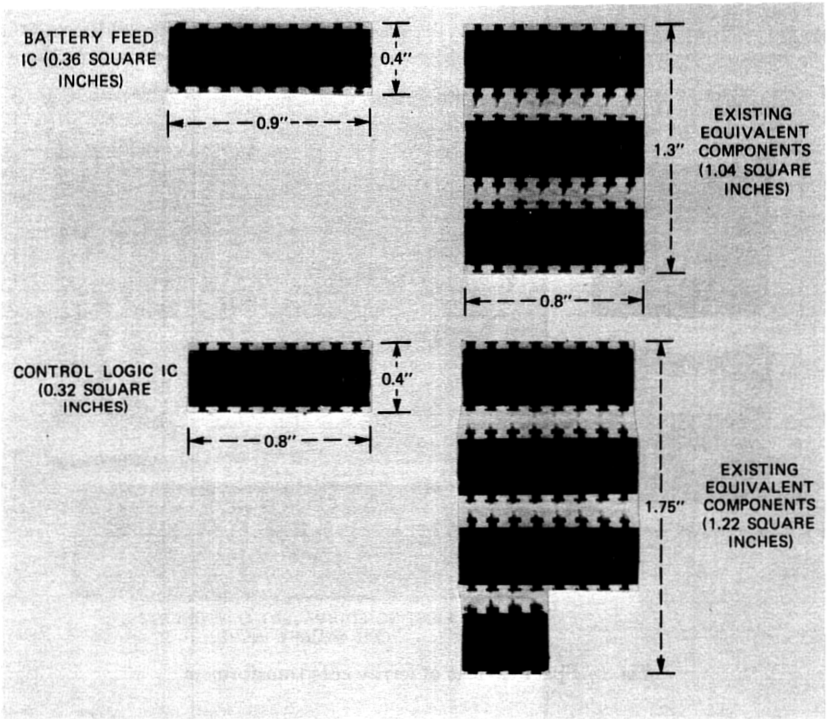


Fig. 2—Space savings of battery feed and control logic ICs.

size of the PWB and the placement of the circuit packs within the framework. The larger the PWB, the more interconnection is done at the less-expensive second level. Also the larger the PWB, the more circuitry can be placed within the physical constraint of an automatic wiring unit (20 by 39 in.). Increasing the circuitry within these automatic wiring constraints results in more interconnection being done by the less costly third level and less interconnection by the most costly fourth-level cabling interconnection. This is most dramatically shown in Fig. 4, which shows a comparison of a 1760-line RSS system partitioned onto 4- by 7-in. circuit packs for the entire system with one line circuit per circuit pack and an 8- by 13-in. circuit pack with 8-line circuits per circuit pack. Notice the significant difference in size, cost, and number of codes and packs which the two partitionings offer. The RSS utilized the 8- by 13-in. circuit packs with 8-line circuits per circuit pack. Any larger size partitioning did not offer much of a decrease in size or cost and was, therefore, not selected.

A circuit pack connector system was developed to meet the following requirements. The majority of the circuit packs (70 percent) required pin-out densities of less than 80 pins per circuit pack, while the

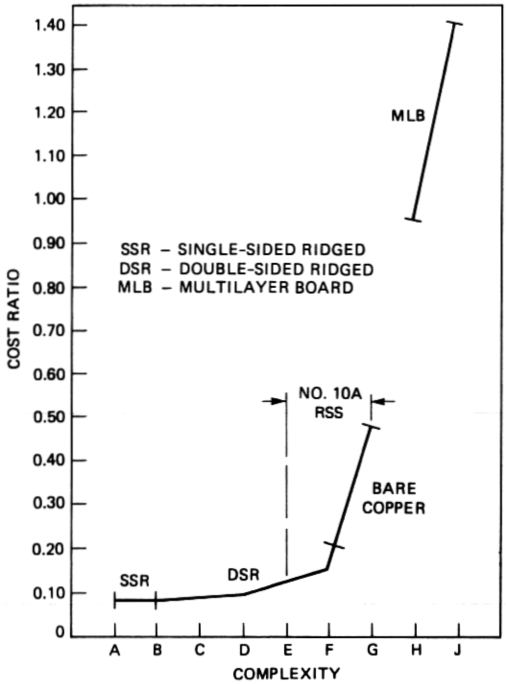
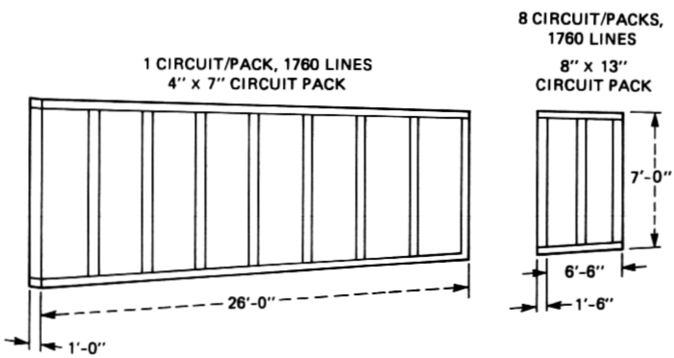


Fig. 3—Printed wiring board technology.



	RATIO 8 CIRCUITS / 1 CIRCUIT
CODES	0.4
PACKS	0.2
VOLUME	0.4
LINE-UP	0.25
COST	0.6
FLOOR SPACE	0.3

Fig. 4—Remote Switching System partitioning (one circuit per pack versus eight circuits per pack designs).

remaining 30 percent required pin-out densities of between 81 and 160. Thus, the connector family would have to have a low-cost member which would provide the low-density interconnection, but with a compatible member which would provide the higher density where required. To keep the third- and fourth-level interconnection cost minimized, the connector family had to be compatible with automatic wiring, PWB interconnection in the backplane, and direct connectorization to the wire wrap pins for cabling. A three-sequence connect was required to allow circuit packs to be plugged into operating frames without disrupting service. The required sequence upon circuit-pack insertion is ground, power, and signal. To meet the above requirements, new members of the 1A technology family of connectors were developed, and a ground first applique contact was developed. The connectors are shown in Fig. 5. The redesign was necessary to provide extension of the power and ground pins to ensure the proper power sequence required. The ground first contact is shown in Fig. 6. It is a solder-plated bifurcated contact which appliques to the connectors. A solder pad is designed onto the circuit pack as part of the usual artwork. The combination of the two provide a moderate resistance (less than 10 ohms) ground contact which mates with the circuit pack

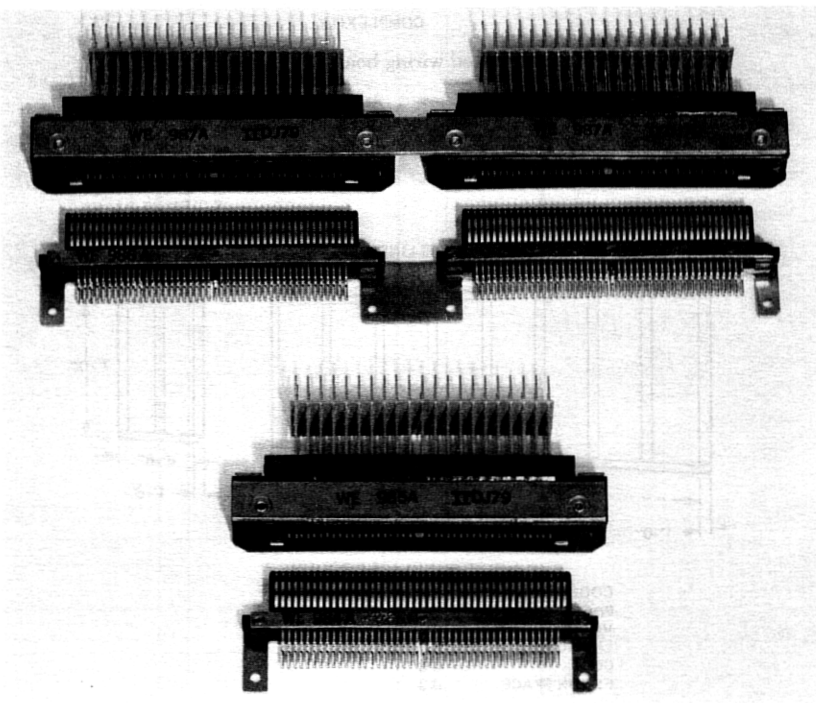


Fig. 5—Remote Switching System circuit pack connectors.

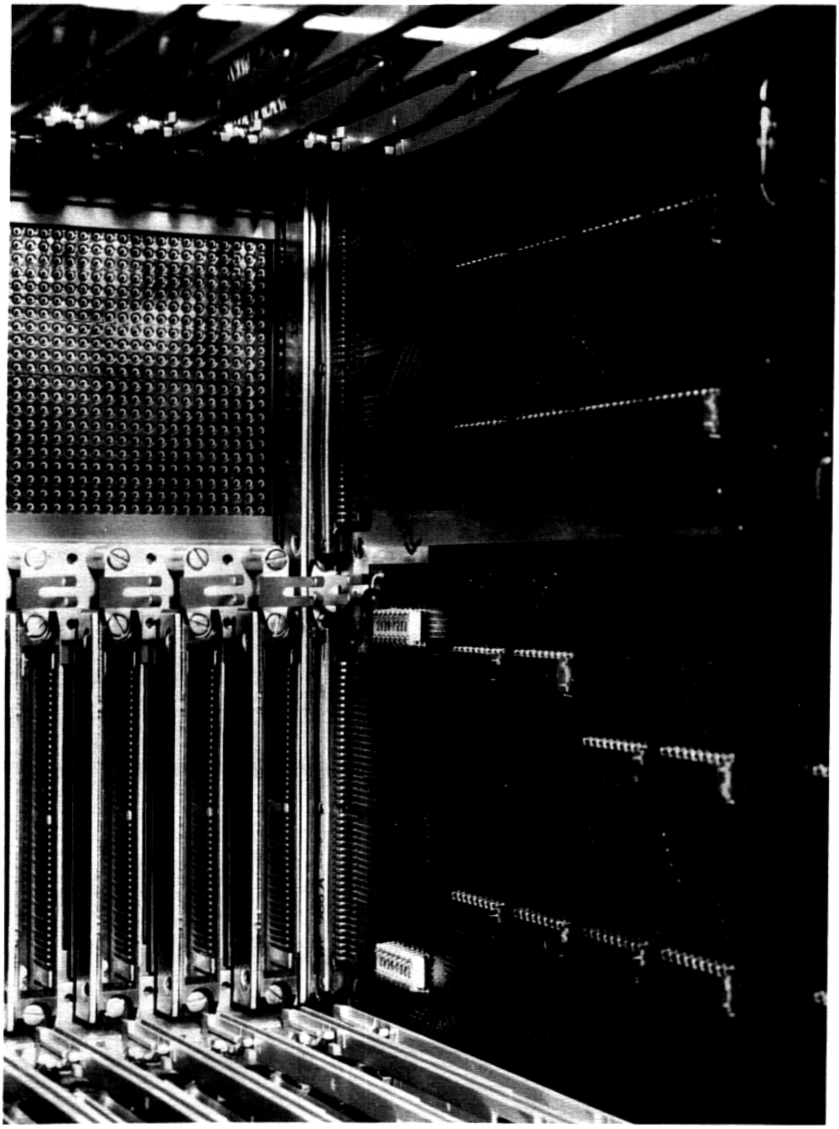


Fig. 6—Ground-first contact.

before the 980-type power contacts mate and, thus, provide the third and initial contact sequence.

The backplane interconnection is realized by a combination of printed wiring, automatic wiring, and connectorized cabling. All power and ground interconnections within a unit are realized by a double-sided PWB with solid segments of power and ground paths on both sides (see Fig. 7). This interconnection technique is much less expensive than the alternative hand termination of large-size power wires multiplying to each connector.

2.4 Fourth level: cabling

Connectorized cables were used because they allowed easy growth

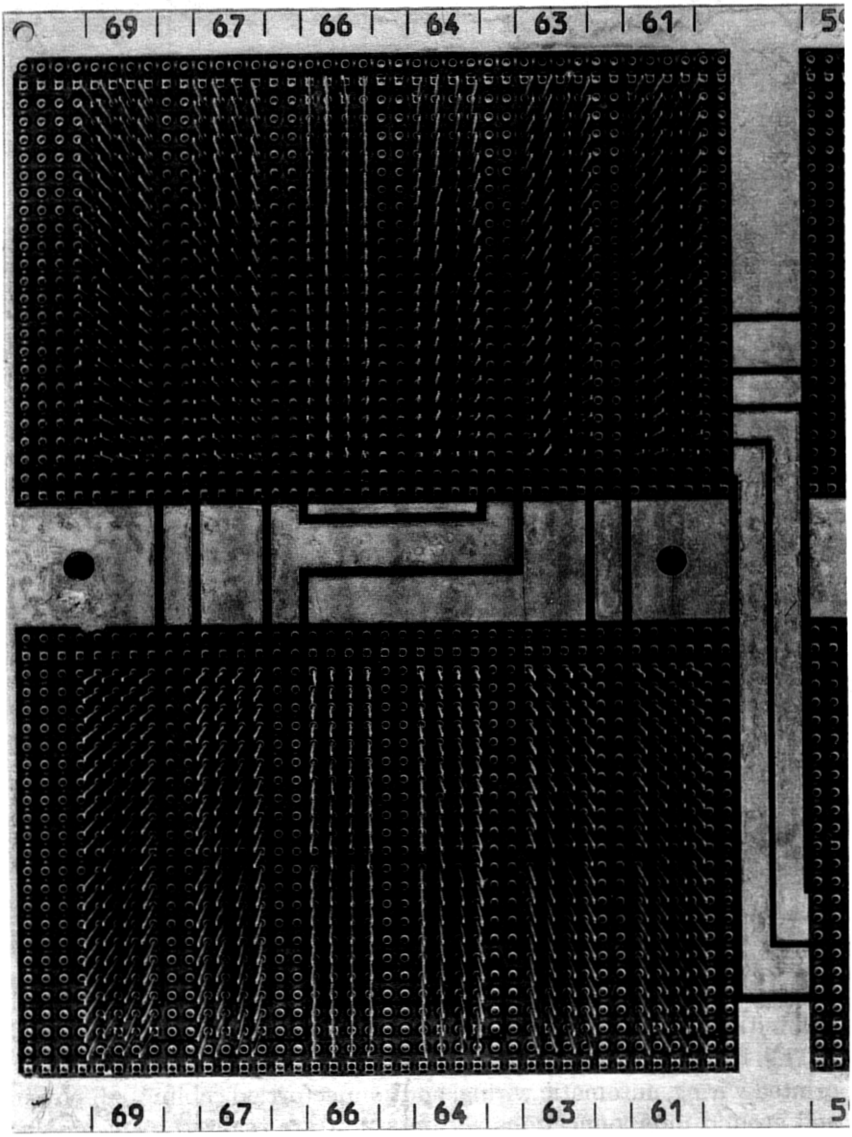


Fig. 7—Backplane printed wire power/ground segmentation.

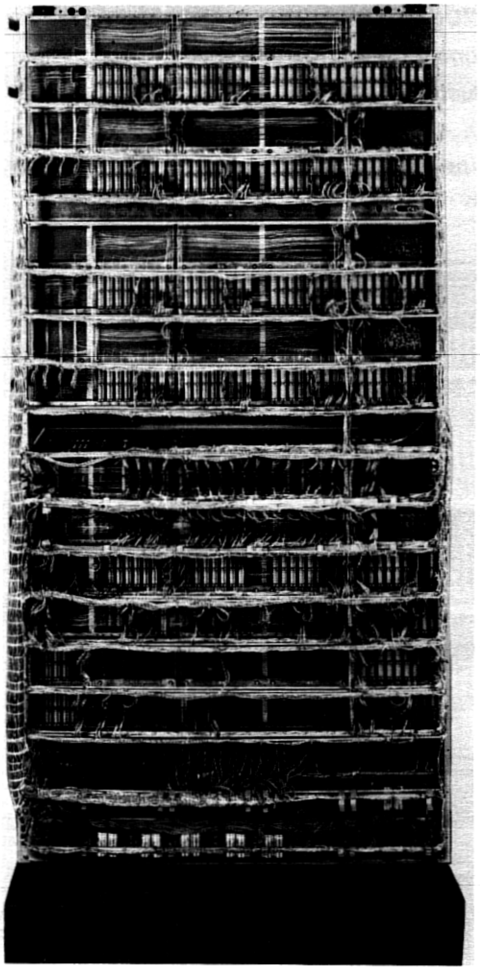


Fig. 8—Connectorized cabling.

of units in the field and a less-expensive alternative to manual termination which exhibits a resulting increase wire verification cost (see Fig. 8). All units were designed to be front removable to allow easy installation of growth units in the field and to allow easy replacement of units for maintenance reasons if the need arises.

In summary, the interconnection technology selected used high-density ICs, small-size discrete components, 8- by 13-in. PWB, the contact sequenced connectors, a ground first applique, PWB intraunit power distribution, connectorized intra- and interframe cabling, automatic wiring, and front removable units.

III. FRAME LAYOUT PARTITIONING AND GROWTH

3.1 Network topology versus frame layout

3.1.1 Introduction

The No. 10A RSS remote terminal frame (Fig. 9) utilizes a standard single-bay framework, 7 ft high by 3 ft 3 in. wide by 18 in. deep, to provide all the necessary hardware to serve up to 1024 lines. This

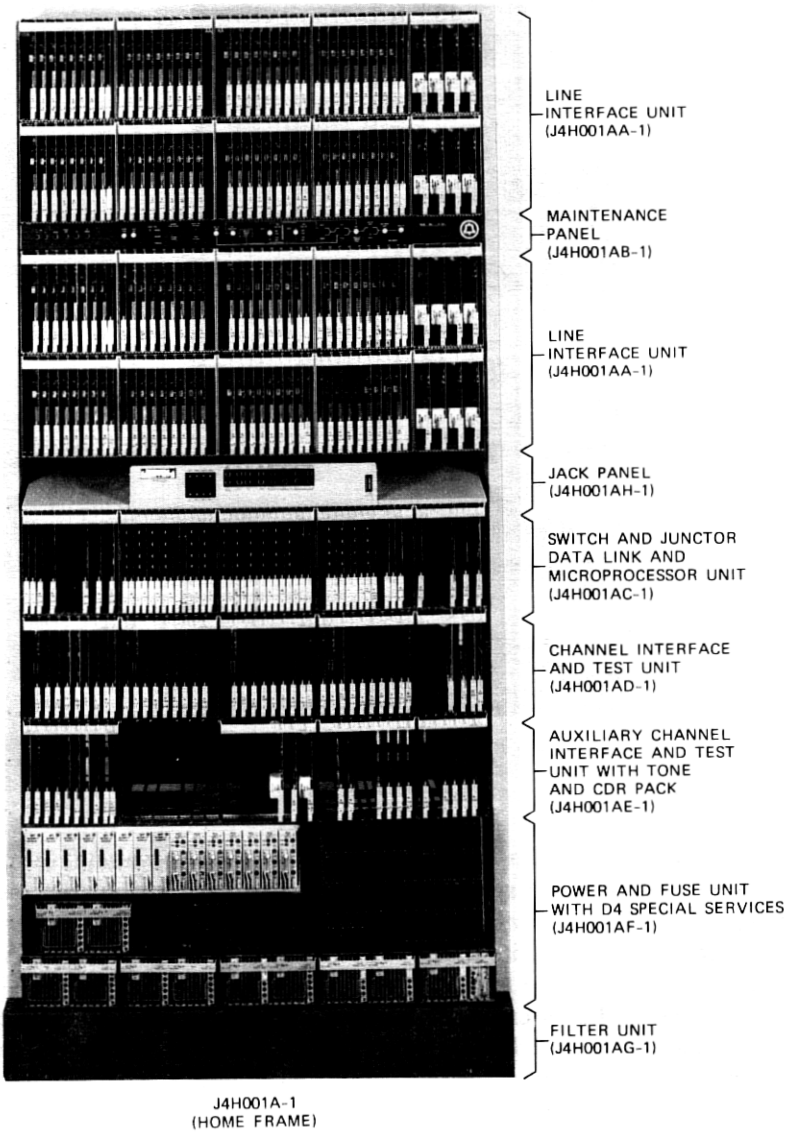


Fig. 9—No. 10A Remote Switching System (1024 lines/120 channels).

hardware includes the line interface, PNPN switching network, processor and memory, data links, transmission facility channels, and power supplies (Fig. 10). Each remote terminal can provide up to 120 channels of which two are used as dedicated channels for the data links (home frame only). For T carrier applications, these channels are provided by an integrated D bank within the RSS. When N carrier is used, N carrier channel banks and data link modems must be provided. A second RSS remote terminal frame (mate) can be added to the initial frame (home) to provide an additional 1024 lines and 120 channels. Except for certain processor, control, and test functions, the basic units are identical in the two frames.

The RSS frame hardware is physically partitioned into eight separate units (Fig. 11) based on functional grouping. The line interface unit (J4H001AA-1) provides the first-stage PNPN network, hardware interface between subscriber loop and PNPN network, fanout control, and service circuits for up to 512 lines. This unit measures 16 in. high by 36.25 in. wide and is used twice on a single frame.

The maintenance panel (J4H001AB-1) provides the craft person with several man/machine interface functions in a simple flowchart fashion. It allows the user to perform diagnostics, switch power, remove or restore service, and transfer control. It is 2 in. high by 36.25 in. wide and is only used in the home frame.

The switch and junctor, data link, and microprocessor unit (J4H001AC-1) provide the duplicated microprocessor controllers with associated memory, data link interfaces, and second-stage PNPN network. It is 8 in. high by 36.25 in. wide and provides the microprocessor and data link complex in the home frame only.

The channel interface and test unit (J4H001AD-1) provides 4 digroups with 24 channels, each for a total of 96 channels. For T carrier, each digroup includes most of the functions normally performed in the D banks to convert 24 channels to one T1 line. A power alarm monitor, receiver off-hook circuit, automatic line insulation tester, and miniresponder for transmission testing are also provided in this 8-in.-high by 36.25-in.-wide unit.

The auxiliary channel interface and test unit with tone and customer digit reception backup (J4H001AE-1) provides an additional digroup with 24 channels, remote line testing functions, ground start appliques for signaling lines, such as coin and PBX trunks, *TOUCH-TONE** service receivers for stand-alone service, and scan and distribute points. This 8-in.-high by 36.25-in.-wide unit can be ordered with an[illegible]mbination of these functions.

The power and fuse unit with D4 special services (J4H[illegible]AF-1)

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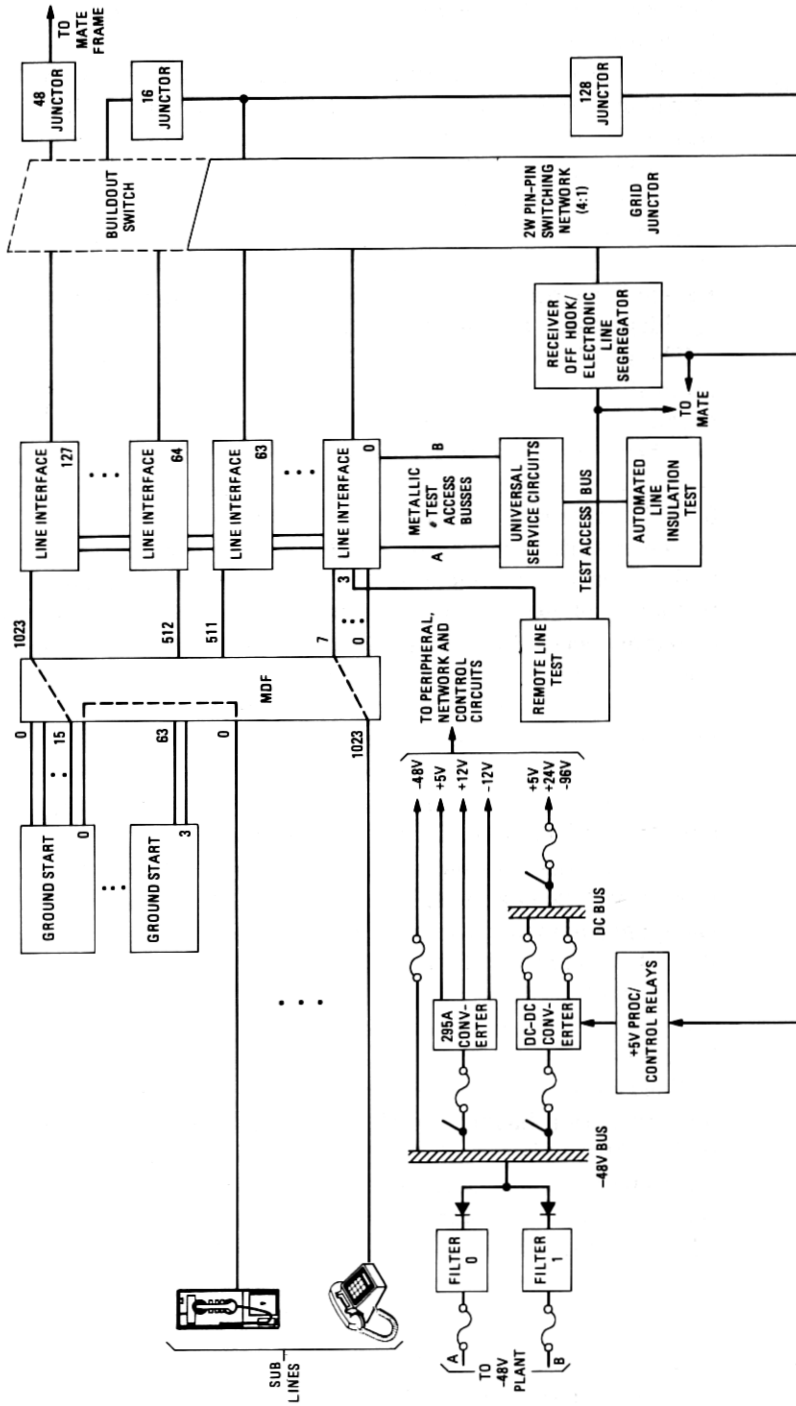

TO MATE FRAME
48 JUNCTOR
16 JUNCTOR
128 JUNCTOR
BUILDOUT SWITCH
2W PIN-PIN SWITCHING NETWORK (4:1)
GRID JUNCTOR
RECEIVER OFF HOOK/ ELECTRONIC LINE SEGREGATOR
TO MATE
LINE INTERFACE 127
LINE INTERFACE 64
LINE INTERFACE 63
LINE INTERFACE 0
METALLIC TEST ACCESS BUSSES
A
B
UNIVERSAL SERVICE CIRCUITS
TEST ACCESS BUS
AUTOMATED LINE INSULATION TEST
REMOTE LINE TEST
1023
512
511
7
3
0
MDF
TO PERIPHERAL, NETWORK AND CONTROL CIRCUITS
0
15
63
0
1023
GROUND START 0
GROUND START 3
-48V
+5V
+12V
-12V
+5V
+24V
-96V
DC BUS
295A CONV-ERTER
DC-DC CONV-ERTER
+5V PROC/ CONTROL RELAYS
-48V BUS
FILTER 0
FILTER 1
A
B
TO -48V PLANT
SUB LINES

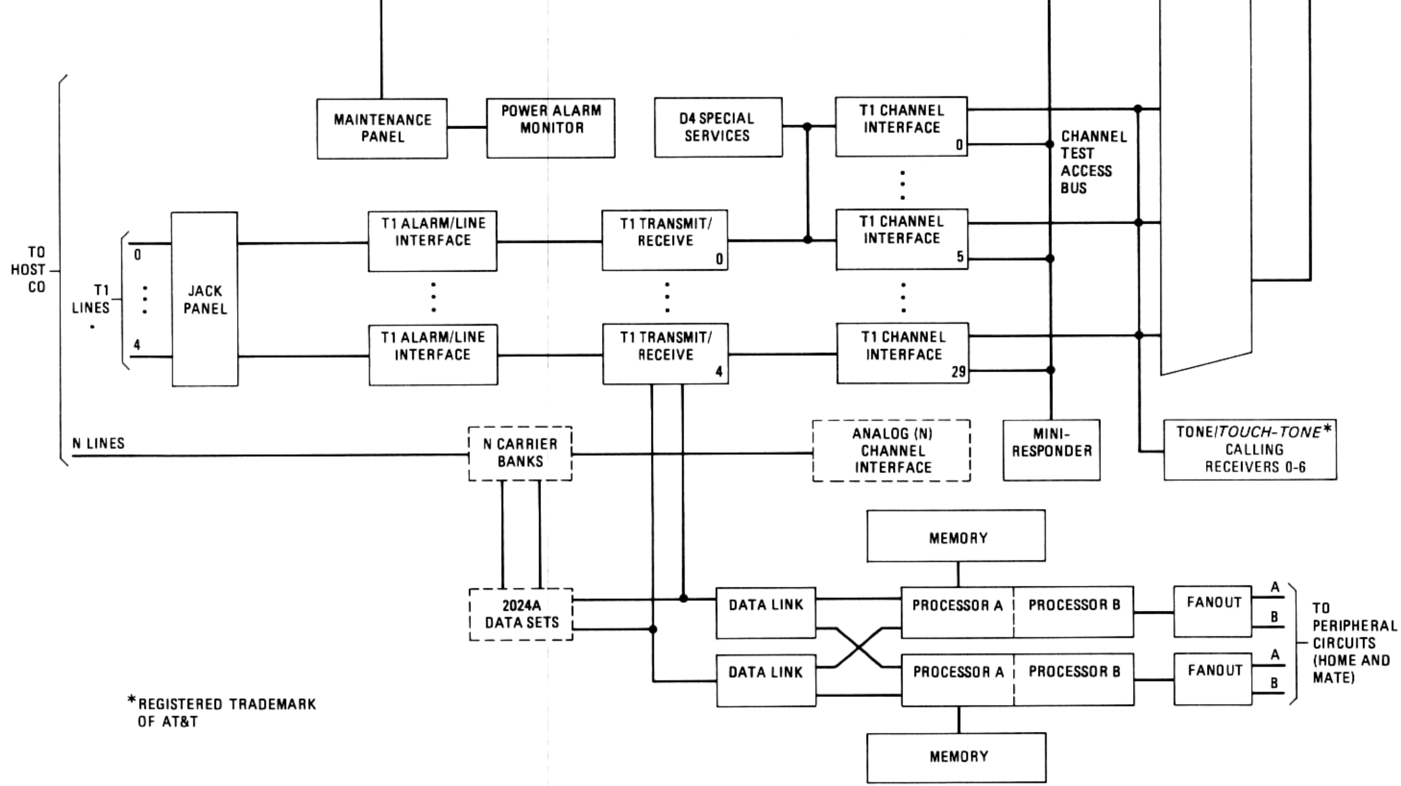
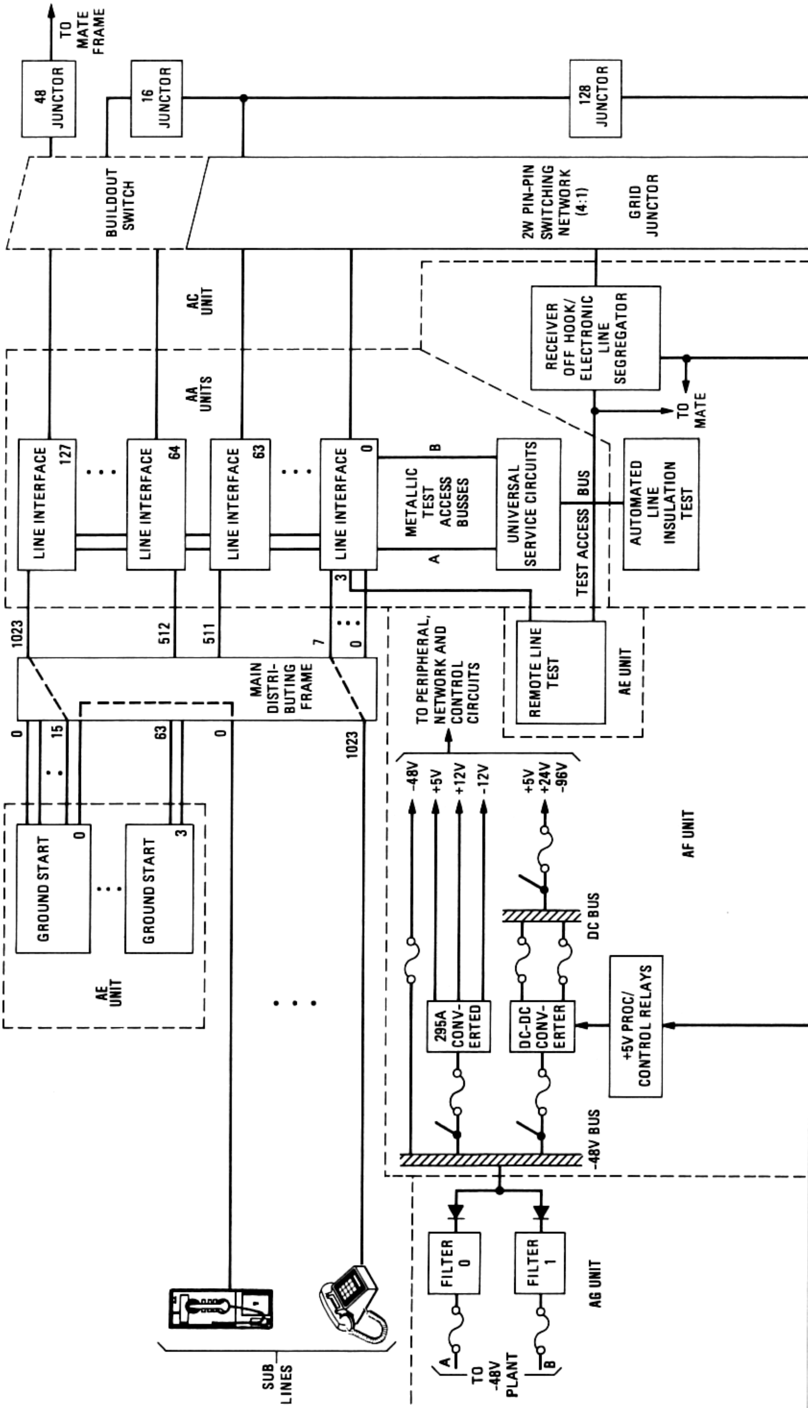


Fig. 10—No. 10A Remote Switching System block diagram.


TO MATE FRAME
48 JUNCTOR
16 JUNCTOR
128 JUNCTOR
BUILDOUT SWITCH
2W PIN-PIN SWITCHING NETWORK (4:1)
GRID JUNCTOR
AC UNIT
AA UNITS
RECEIVER OFF HOOK/ ELECTRONIC LINE SEGREGATOR
TO MATE
LINE INTERFACE 127
LINE INTERFACE 64
LINE INTERFACE 63
LINE INTERFACE 0
METALLIC TEST ACCESS BUSSES
UNIVERSAL SERVICE CIRCUITS
TEST ACCESS BUS
AUTOMATED LINE INSULATION TEST
1023
512
511
7
0
3
REMOTE LINE TEST
AE UNIT
MAIN DISTRI- BUTING FRAME
TO PERIPHERAL, NETWORK AND CONTROL CIRCUITS
-48V
+5V
+12V
-12V
+5V
+24V
-96V
GROUND START 0
GROUND START 3
AE UNIT
15
63
AF UNIT
DC BUS
295A CONV- ERTED
DC-DC CONV- ERTER
+5V PROC/ CONTROL RELAYS
-48V BUS
FILTER 0
FILTER 1
AG UNIT
A
B
TO -48V PLANT
SUB LINES

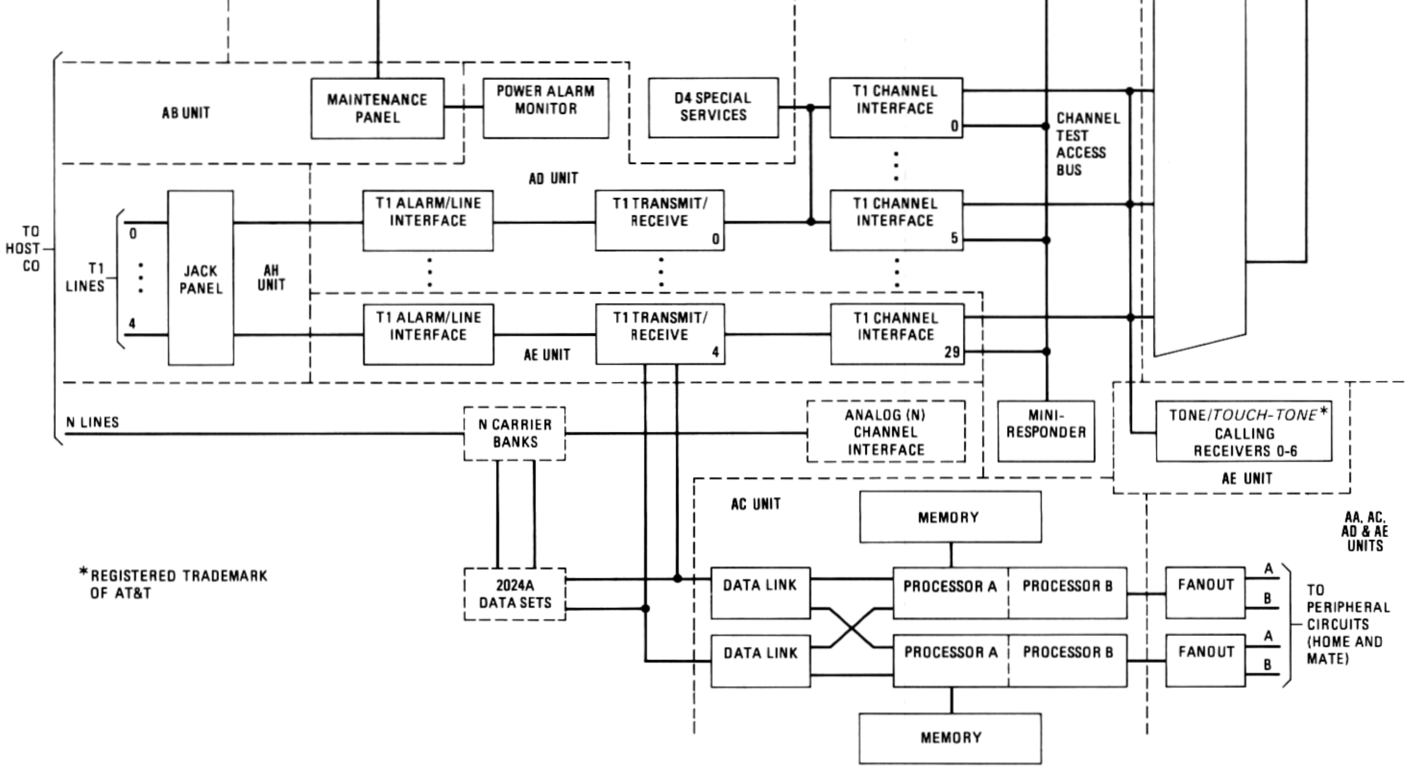


Fig. 11—No. 10A Remote Switching System block diagram (frame partitioning).

provides the power conversion and fuse indication for the entire frame. The unit is designed so that power conversion equipment can grow in relation to the number of required circuits. Provision for up to eight D4-type special services are also included in this 14-in.-high by 38.25-in.-wide unit. A 6-in.-high by 38.25-in.-wide filter unit (J4H001AG-1) is provided in the base of the frame.

The jack panel unit (J4H001AH-1) provides a means of access to the digital T1 lines for testing and monitoring purposes. This unit is 4 in. high by 36.25 in. wide and is mounted on the heat baffle in the center of the frame.

3.1.2 Line interface

The RSS line interface function is provided by the line interface circuit pack (Fig. 12) which acts as the interface between the first stage of the electronic switching network and eight customer lines. These circuit packs are located in the line interface units (J4H001AA-1) with up to 64 packs provided in each of the two units for a total of 1024 lines per frame. Each line interface pack contains eight-line circuits which provide network protection, line supervision, subscriber battery feed, and a cable anticorrosion feature.

3.1.3 The PNPN switching network

The RSS contains an analog, space division, two-wire, two-stage, folded network (Fig. 13). The network fabric is constructed using PNPN semiconductor devices. This miniaturized solid-state crosspoint re-

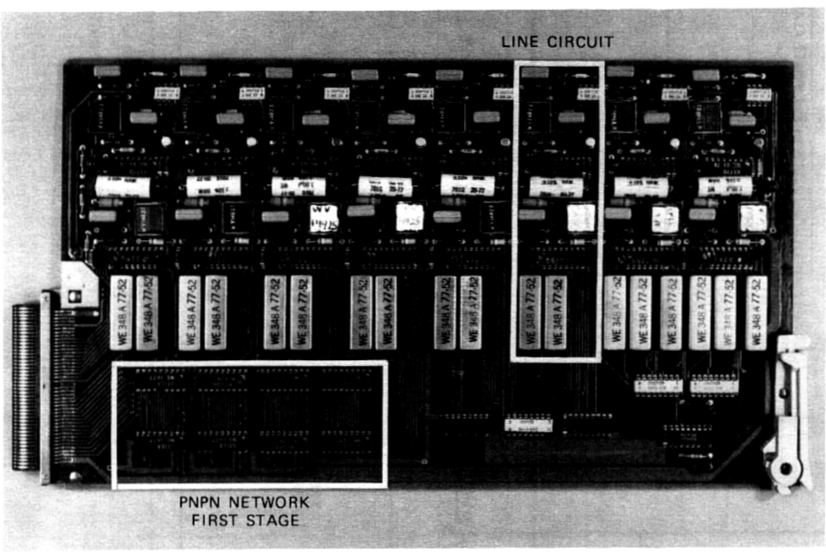


Fig. 12—Line interface circuit pack.

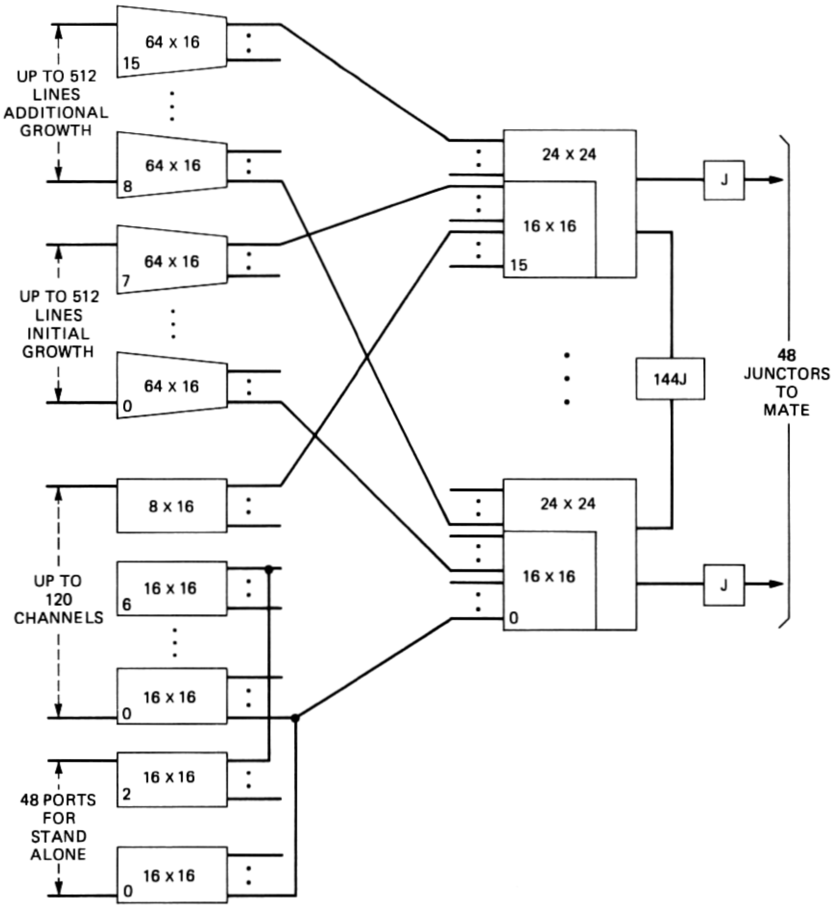


Fig. 13—Remote Switching System network.

quires very low-level signaling to activate a change in its open or closed state and results in a low-cost, compact design because of its small size.

The first stage of switching is contained on the line interface circuit pack (Fig. 12). Each pack contains an 8 by 16 matrix which allows expansion of the first-stage network as the number of lines grows, thereby reducing cost. Eight line interface packs are then combined in a single apparatus housing to form a 64- by 16-in. front-end concentrator. The line-interface pack also contains the access relays required to connect the subscriber tip and ring to the time-shared metallic network buses used for high-level signaling, such as ringing and coin control. The universal service circuits (USCs), also located in the line interface unit, provide the voltages required for this high-level signaling.

The second stage of switching is provided by the grid junctor and build-out switch circuit packs (Fig. 14). Each grid junctor pack contains a 16 by 16 PNPN switching matrix and eight junctor circuits which provide the PNPN path-holding current sources, gain necessary to offset the PNPN device loss, and check circuitry. The build-out switch contains the 8 by 16 and 8 by 24 matrices that increase the size of the grid junctor to a 24 by 24 switch. This second-stage switch expansion occurs above a line size of 512, thereby reducing low line size network cost. Four additional junctor circuits are also added by the build-out switch providing a total of 12 junctors per second-stage switch. Of these four additional junctors, three are reserved for growth to the mate frame. The entire expanded second-stage switch, consisting of 16 grid junctor and 16 build-out switch circuit packs, is contained in less than two-thirds apparatus housings in the center of the switch and junctor, data link, and microprocessor unit (J4H001AC-1).

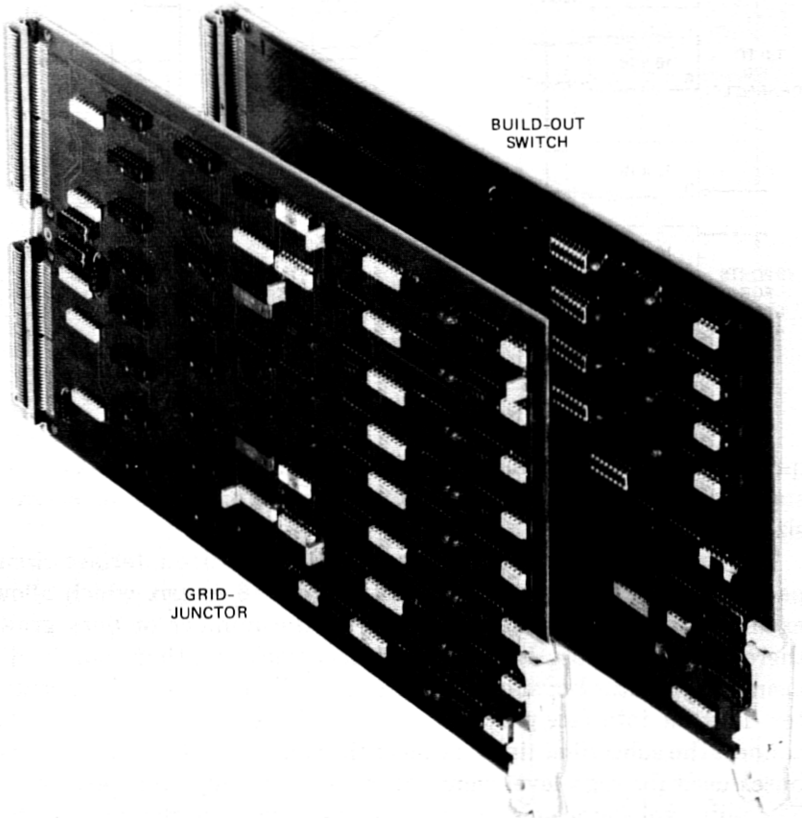


Fig. 14—PNPN network center-stage circuit packs.

The first stage of transmission switching is contained on the channel interface circuit packs (Fig. 15). Each pack provides the circuitry necessary to interface four audio channels between the remote terminal and its host ESS and provides a 4 by 16 matrix. This again minimizes cost by allowing the expansion of switching for transmission as the need for facility channels grows. A group of four-channel interface packs are combined to form a 16 by 16 switch. Each of the five-frame digroups contains one-and-a-half 16 by 16 switches on six channel interface packs for a total of 24 channels per digroup and 120 channels per frame. These channel interface packs are housed in the channel interface (J4H001AD-1) and auxiliary channel interface (J4H001AE-1) units.

3.1.4 Carrier / D4 Special Services

The RSS remote terminal provides the ability to interface with several types of facility groups. Transmission of voice circuits and data link messages to the host RSS can be routed over either T carrier or N (N2, N3, or N4) carrier at distances from 75 to 175 miles, depending on the type of carrier involved. Radio facilities are also technically feasible. These facilities may be mixed within a single RSS frame on a per-digroup basis.

Digital T carrier is intended as the primary mode of transmission for RSS, and an integrated D bank will be provided within the RSS for T carrier applications. This T carrier hardware is provided by the alarm interface, transmit/receive, and T1 channel interface circuit

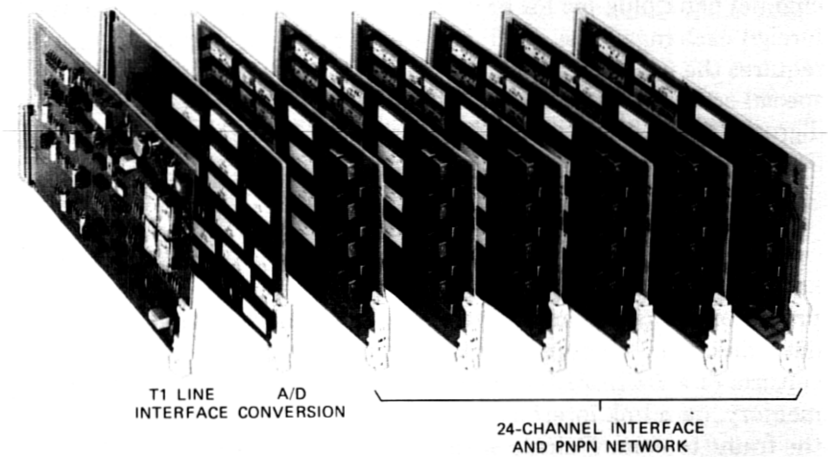


Fig. 15—Transmission and switching interface circuit packs.

packs (Fig. 15). The channel interface pack, in addition to providing the previously described first-stage network switch, acts as the interface between the electronic network and the T1 digital carrier. It provides the transmission path conditioning and the conversion from voice frequency to multiplexed pulse amplitude modulated transmission for four audio channels. When six of these packs are combined with the transmit/receive and alarm interface packs, a full T1 group of 24 channels is formed. The transmit/receive pack performs the analog-to-digital and digital-to-analog conversion functions, while the alarm interface pack acts as the direct interface between the RSS frame and the 1.544-MHz T1 line. It incorporates the required bipolar receiver, transmitter, alarm circuitry, and maintenance features to facilitate fault location.

The N carrier option is indicated by the dashed boxes in the RSS block diagram (Fig. 10). An analog channel interface circuit pack is used in place of its digital counterpart and plugs into the same frame positions. It also provides four channels per pack and performs many of the same functions as its digital equivalent. However, alarm interface and transmit/receive packs are not used. Instead, the output of the channels is cabled directly off the back of the RSS frame to the N-carrier banks. For each data link on N carrier, an external data set is required at each end of the facility link. This data set is cabled directly between the RSS frame and the N-carrier banks. The appropriate RSS frame local cable is then unplugged to remove the data link from interfacing with the T1 facility.

Provision is also made within the RSS frame in the power and fuse unit (J4H001AF-1) for up to eight built-in standard D4 special-service channel bank plug-ins for such applications as off-premise extensions, foreign-exchange lines, and private lines. Each special-service line requires the use of a channel on the carrier system. However, if the D4 special-service option is used, the last four channels of the first two digroups are reserved solely for D4 special-service use by the installation of two frame cables that tie it into the carrier system.

3.1.5 Processor/memory

The RSS frame contains duplicated microprocessor complexes which act as the controlling entity for the entire remote terminal. These processor complexes are located on each end of the switch and junctor, data link, and microprocessor unit (J4H001AC-1). Each controller consists of a *BELLMAC**-8 microprocessor with associated circuitry, memory, data link interface, and fanout interfaces located throughout the frame to communicate with peripheral systems.

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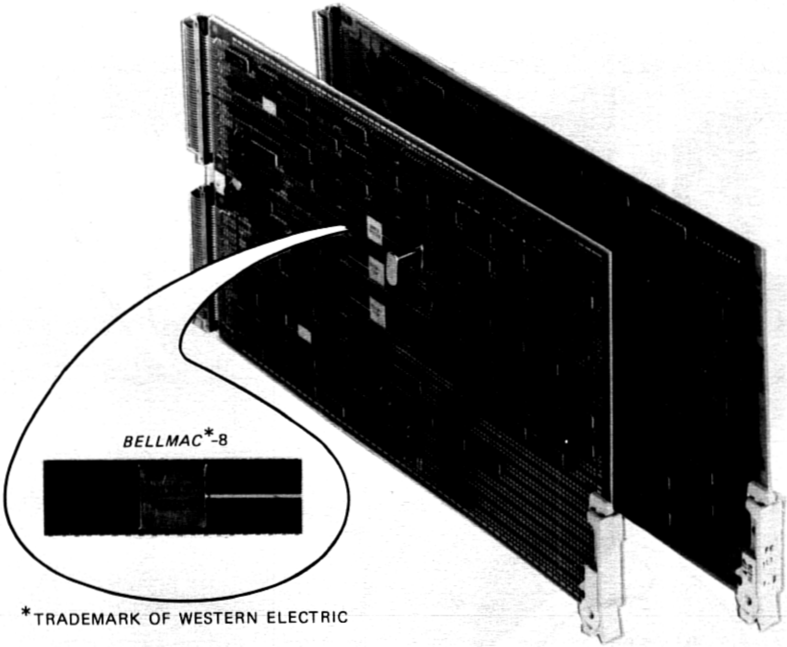

Fig. 16—Microprocessor circuit packs.

The No. 10A RSS *BELLMAC*-8 based microprocessor and associated circuitry is contained on two circuit packs (Fig. 16). This controller provides features such as extended addressing range, multiple vector interrupts, error checks, access to external circuitry, and communication with its duplicated mate. The processors are physically interconnected using tape cabling to reduce noise and communicate both through I/O ports and by a bus coupling arrangement.

The RSS memory complex contains both Random Access Memory (RAM) and Erasable Programmed Read Only Memory (EPROM) (Fig. 17). The RAM board contains 24,576 bytes of data with parity (24K by 9-bit) and is used twice in each processor complex for a total of 48K of RAM. The RAM memory utilizes a 4K by 1-bit static memory device. The EPROM board contains 63,488 bytes of data with parity (62K by 9) and is used three times in each processor complex for a total of 192K of EPROM. The EPROM board utilizes a 2K by 8-bit memory device which may be erased by exposing the board to ultraviolet (UV) light, and then programmed by applying signals to the board's edge connector. A portable apparatus called *PROMUS** reprogrammer (Fig. 18)

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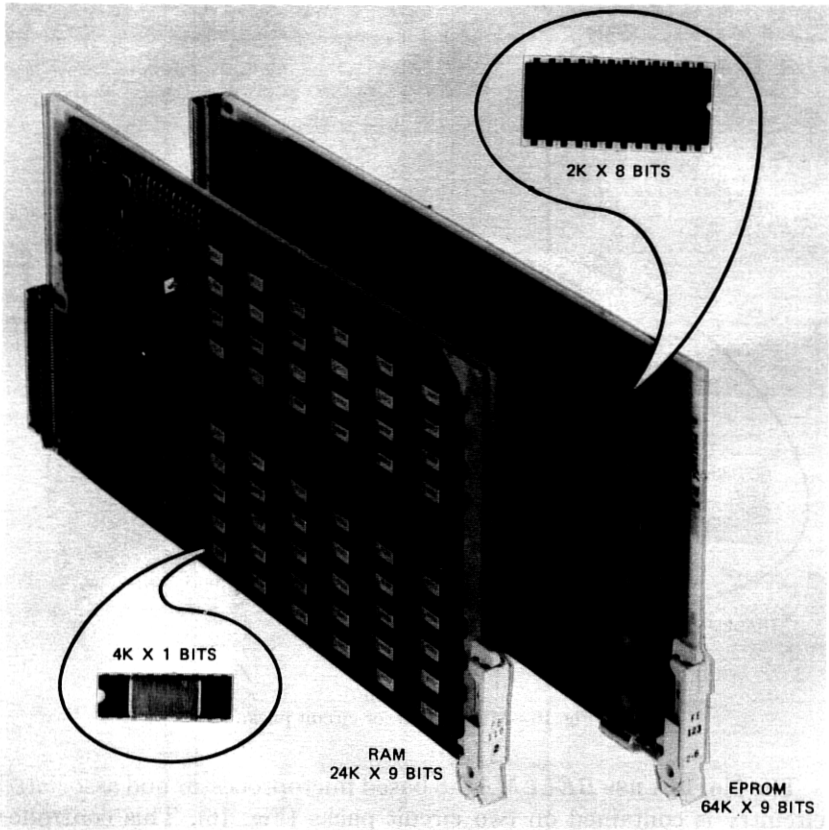

Fig. 17—Memory circuit packs.

is used to erase old data by UV light (approximately 30 minutes) and to both program and verify the new data (approximately 70 minutes), which are obtained via a dial-up link to the host computer.

The data link interface circuit pack provides the interface between the microprocessor controllers and the two voice channels assigned to perform the data link operation. The data link interface performs the implementation of signal protocol, transmission error detection, appropriate message formatting, and also allows either processor to access either data link.

The fanout circuit pack provides the interface between the duplicated processor complexes and the peripheral systems. These packs are distributed throughout the frame in close proximity to the peripheral circuits to which they interface. While a fanout pack has access to only a single processor, any peripheral circuit pack may be accessed by two fanout boards—one from each processor. This minimizes the

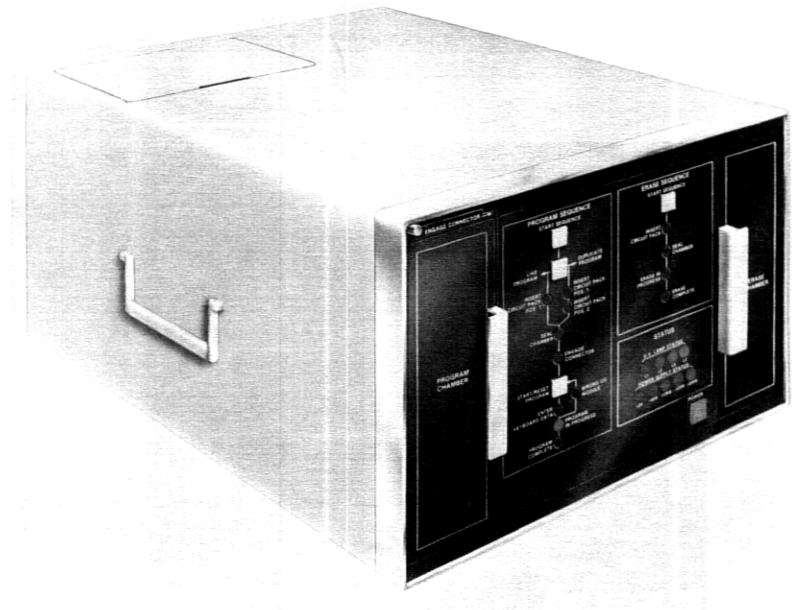

Fig. 18—*PROMUS* reprogrammer.

impact of the removal or the failure of a fanout pack. Fanout circuit packs are added as required and as the number of peripheral circuit packs increases. This reduces the cost of control for small-sized systems.

3.1.6 Power

The RSS frame provides all the power conversion and fusing for the entire system. The power complex (J4H001AF-1 and J4H001AG-1 units) is a multivoltage, multiconverter, multifuse system. It consists of 19 converters supplying 6 voltages and 180 fuses when fully equipped. It receives its input from the −48 volt office plant. Current drain for a fully equipped single frame during busy hour traffic is approximately 15 amperes.

The RSS power complex uses various types of power converters (Figs. 10 and 19). Some of these converter codes have a single output voltage (+5V:131L1A, +24V:131N1A, or −96:130L), while others are of the multivoltage type (+5V, +12V, and −12V:295A). Also, some of the converters are dedicated to certain circuit packs, while others power a common bus which is used throughout the frame. In either case, the number of converters can grow as the number of circuit packs increases, thereby reducing power equipment costs for small systems.

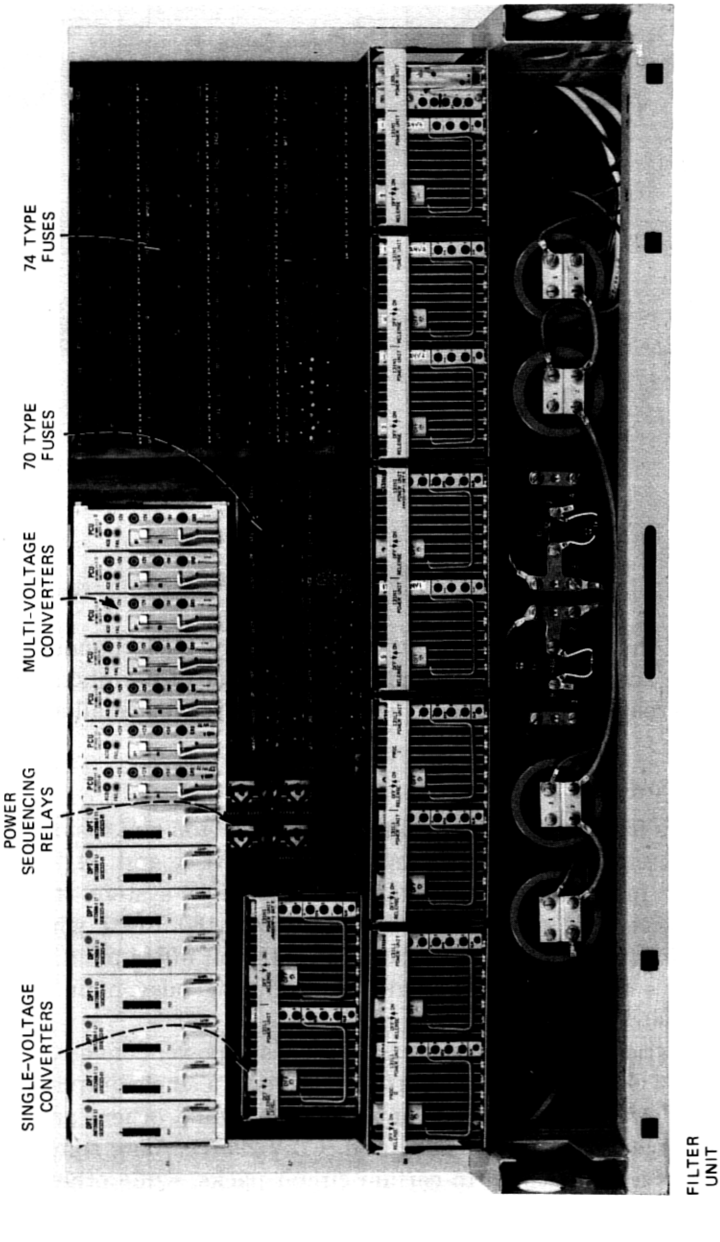

Fig. 19—Remote Switching System power complex.

Power distribution is accomplished from the converters using frame local cabling and backplane printed wiring to the required circuit packs. Circuit-pack removal from the frame is done under power with the exception of the processor complexes and their associated fanouts. These packs cannot be removed or inserted without first removing power by means of the maintenance panel. Correct power sequencing to the processor complexes is accomplished via the control relays in the power unit.

The power complex utilizes two different families of fuses. Of the 180 fuses in the frame, 64 are the 70 type, with pop-out alarm indicator, and 116 are of the 74 type, featuring fast blow time and low voltage drop to maximize protection of electronic circuitry and components. When a 70-type fuse blows, the fuse body expands lengthwise by spring action to provide visual indication and makes an electrical contact to provide an electrical indication of the alarm. The 74-type fuse does not contain an integral fuse alarm assembly, but instead uses an external Light Emitting Diode LED mounted beneath each fuse block. An alarm condition exists when a fuse's corresponding LED is illuminated.

The power alarm monitor circuit pack is the interface between the RSS processor and the frame power complex. It serves as the monitoring and controlling vehicle (via 55 scan points and 15 distribute points) by monitoring all fuses and converter output voltages, enabling the maintenance panel so that power can be removed from the processor complexes, testing fuse alarm scan points, and performing converter performance tests.

3.1.7 Miscellaneous

The RSS frame provides various specialized features which are located in the auxiliary channel interface unit (J4H001AE-1). The remote line testing feature is contained on three circuit packs and provides a modified end arrangement of the existing Western Electric remote testing system. These packs contain a *BELLMAC*-8 microprocessor to control the test circuits which provide a telemetry interface to receive host instructions, dc line test voltages, tip and ring access via the metallic access bus to the line under test, line measurements, and return of the detected results to the host.

The ground start applique circuit provides an interface between the line interface circuit packs and those loops requiring ground start supervision such as coin first, coin telephone, and PBX trunks. Each ground start circuit pack contains 16 identical circuits which can interface a like number of line interface circuits. Each frame contains provision for up to four ground start circuit packs for a maximum of 64 ground start lines per 1024-line frame.

The *TOUCH-TONE* service receiver circuit pack contains the receivers, tone circuits, and network ports via an 8- by 16-bit first-stage switch (Fig. 13) necessary for stand-alone operation. Provision for up to six receiver circuit packs exists in each frame with equipage based on the number of equipped lines.

The miscellaneous scan and distribute circuit pack provides 24 scan points and 32 distribute points required by the system for scanning and distributing capability, such as testing functions and office alarms. With provision for up to four scan and distribute boards per frame, a single frame can be equipped with 128 distribute points and 96 scan points.

3.2 Frame growth/options

The RSS frame contains 19 separate lists required for system growth and optional features. These lists are designed to provide an easy means to engineer the RSS frame equipage and can be divided into three basic categories: basic frame equipment and optional units (lists 1 to 4), apparatus required for system growth (lists 5 to 10, 13 to 16), and apparatus required for optional features (lists 17 to 21).

IV. BUILDINGS AND ENCLOSURES

4.1 Floor plans

A fully equipped RSS frame (1024 lines) weighs approximately 1100 lb, which includes 100 lb for interframe cabling and overhead cable racks. The resulting floor loading is 90.25 lb/ft^2, figured using a 2-ft operating aisle space and a 2-foot 6-inch maintenance aisle space. A second frame can be added to provide growth to 2048 subscriber lines and 240 channels. When two frames are used, the two frames must be adjacent because of lead length restrictions on common circuitry.

The compact size of the 10A RSS remote terminal frame permits a number of different enclosure options, such as the reuse of an existing building, construction of a new modular building, or an electronic hut for pair-gain applications. In many CDO applications, it will be possible to reuse the existing building, power plant, and main distributing frame, in which case floor space need only be provided for the RSS frames and a bay or two of miscellaneous equipment. Figure 20 shows a typical CDO replacement floor plan after the SXS equipment is removed.

The RSS frame has been designed to meet all central office environmental operating requirements as outlined in the New Equipment Building Systems (NEBS) building specifications. The RSS equipment design objectives require a normal operating ambient temperature of 40 to 100°F with short-term limits of 35 to 120°F for up to 72 hours.

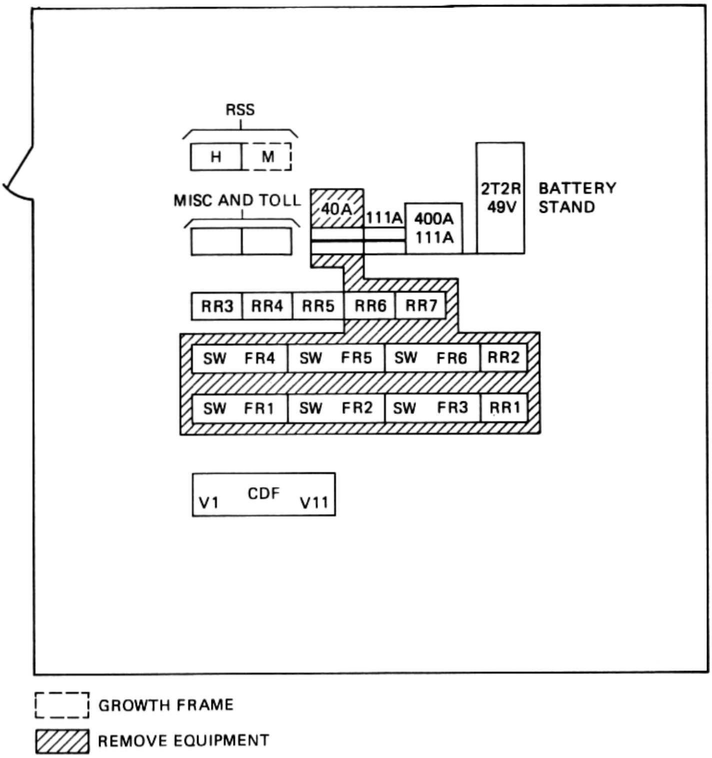

Fig. 20—Typical RSS floor plan as a CDO replacement (800 lines step-by-step office).

Relative humidity can vary from 20 percent to 55 percent, with short-term limits of 20 percent to 80 percent.

For pair-gain applications, a new enclosure called an electronic equipment enclosure will be available. This enclosure contains sufficient space for two RSS frames, two miscellaneous equipment bays, a −48 volt power plant, a main distributing frame, and a cable entrance facility. Preinstallation of equipment at a service center prior to shipment may be provided which should offer a shorter, more uniform installation with reduced shipping costs. Fig. 21 shows the floor plan for the electronic enclosure.

4.2 *Electronic equipment enclosure*

The electronic equipment enclosure is a building-like enclosure which can be used for both large pair-gain applications and new wire centers where no existing structure will generally be available. This shelter has floor dimensions of approximately 10 by 20 ft and can be erected with various optional architectural facade treatments, which

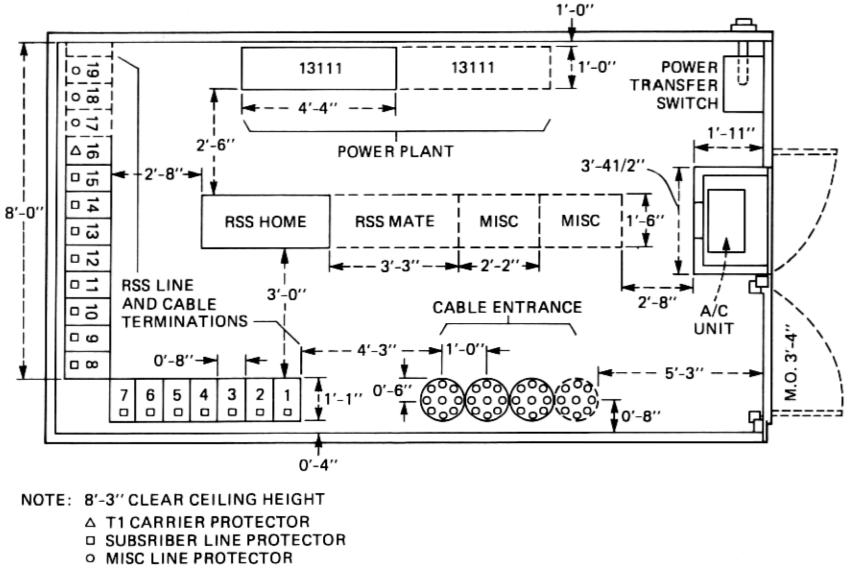

Fig. 21—Remote Switching System floor plan (electronic equipment enclosure).

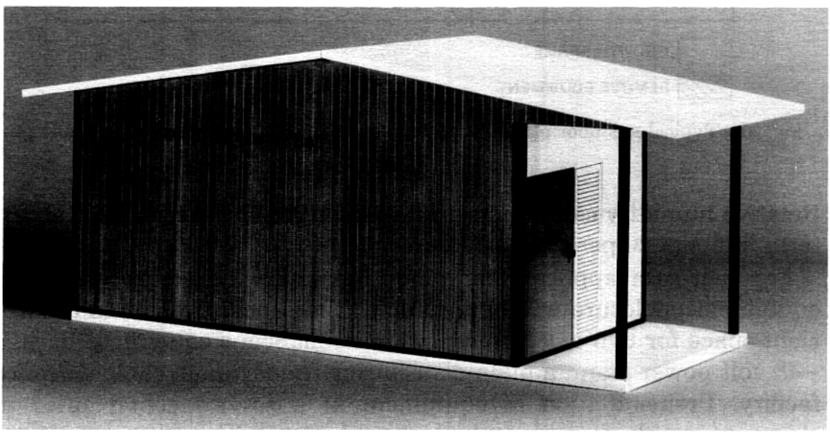

Fig. 22—Typical electronic equipment enclosure.

are expected to satisfy the aesthetic needs of most applications (Figs. 22 and 23).

The electronic equipment enclosure is capable of accommodating two RSS frames providing 1536 lines (2048 maximum). To avoid the need for traffic balancing, pair-gain applications are limited to 1536 lines. Standard central office environment (temperature between +40 and 100°F, maximum long-term relative humidity of 55 percent) is maintained over an external ambient of −40 to 120°F by the heating and air conditioning equipment. A modular 131B power plant consisting of three 35A rectifiers, a control unit, and two high-gravity lead-calcium battery strings will provide approximately 14 hours of reserve at 32°F and 8 hours of reserve at −10°F for 2 fully loaded RSS frames.

4.3 External interfaces

Because of the compact nature of the RSS frame, a large number of external interfaces must be made via interframe cabling. All cabling is connectorized at the No. 10A RSS end to simplify field installation, testing, and unit repair by allowing front removable units to be easily replaced. External interfaces to a single RSS frame consist of:

Type	Number of Pairs
Subscriber tip and ring	1024
T carrier (in)	5
T carrier (out)	5
N carrier (in)	240
N carrier (out)	240
Scan points	96
Distribute points	128
Ground start appliques	128
D4 special services	16
Miscellaneous	13

V. RELIABILITY ASPECTS OF NO. 10A RSS

5.1 The RSS outline block diagram

In the RSS outline shown in Fig. 24, the following items are worth noting:

• The RSS is equipped with a duplicated controller group. The

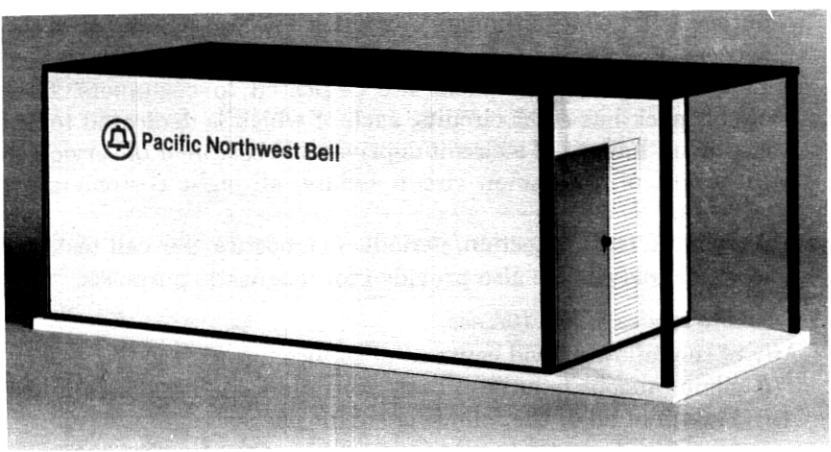

Fig. 23—Typical electronic equipment enclosure.

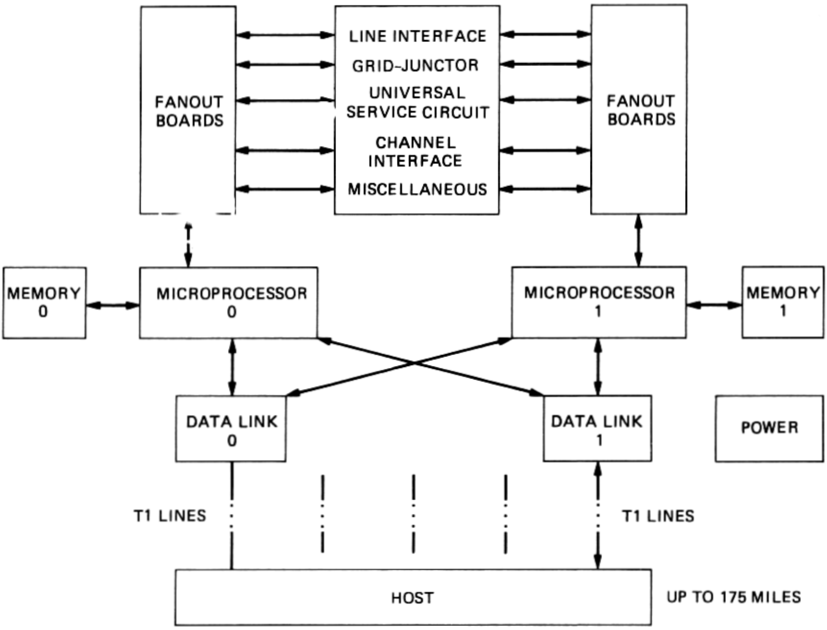

Fig. 24—Remote Switching System block diagram.

controller group consists of memory, microprocessor, and data link circuit packs. Failure of a duplicated group will affect the entire office and total service outage will occur.

- Replicated junctors, universal service circuits, fan-out circuit packs, and voice channels are provided. The failure of some of the replicated units will cause traffic problems, but customer outage will not take place. Should all replicated units fail, an entire office outage will occur, although this has a low probability of occurrence.
- Line interface circuit packs are dedicated to customers. Each circuit pack has eight circuits, each of which is dedicated to one customer. Failure of a circuit deprives one customer of service. In the event of a common circuit failure, all eight customers are affected.
- Automatic fault detection, periodic diagnostics, per-call test, and internal analysis are also provided for diagnostic purposes.

5.2 *Failure modes in No. 10A* RSS

Any of the following will cause total service outage:

(*i*) Simultaneous failures of both controllers and data links (DLIs).

(*ii*) Failure of all of the following circuit packs:

(a) Grid-Junctors (G-JS)

(b) Fan-Outs (FOS)

(c) Universal Service Circuits (USCs)
(d) Line Interfaces (LIs)
(e) Channel Interfaces (CIs).

(*iii*) Failure of the following items related to power:
(a) Both −48 volt office buses
(b) All +24 volt converters
(c) Both of the +5 volt converters dedicated to the microprocessors
(d) Both multivoltage converters dedicated to the DLI, FO, and CI
(e) Both +5 volt peripheral converters.

Partial service outage will occur under the following conditions:

(*i*) Greater than 10 percent service degradation

(a) Failure of two mating fan-out boards will affect 128 lines (eight LIs from each side will be affected).
(b) Failure of two mating fan-out boards will affect 512 lines (four USCs from each side will be affected).
(c) Failure of any two fan-out boards, one from each side (will bring 128 lines down if LI is affected and 512 lines down if USC is affected).

(*ii*) Greater than 1 percent service degradation

A blown fuse will affect 64 lines.

(*iii*) Greater than 0 percent service degradation

A component failure on the LI board may affect service of as many as eight customers.

5.3 Mean repair time

It is difficult to determine the repair time for various types of troubles for an unstaffed office, but, a general formulation can be made based on No. 1 ESS experience. The formulation includes the travel time required to dispatch a craft person and the degree of difficulty encountered in the repair of the trouble. From ESS experience thus far, the average repair time for staffed offices is two hours. For unstaffed offices, the calculations must include a 2-hour travel time for the craft person. Therefore, the mean repair time for No. 10A RSS was assumed to be four hours.

5.4 Failure rates for No. 10A RSS circuit packs

In evaluating the reliability of RSS, it was necessary to obtain failure rates on all components under typical office conditions. These rates were obtained from the Bell Laboratories Reliability Information Note Book, KS specifications for commercial devices, advice from various Bell Laboratories device engineers, and some field data. They did not

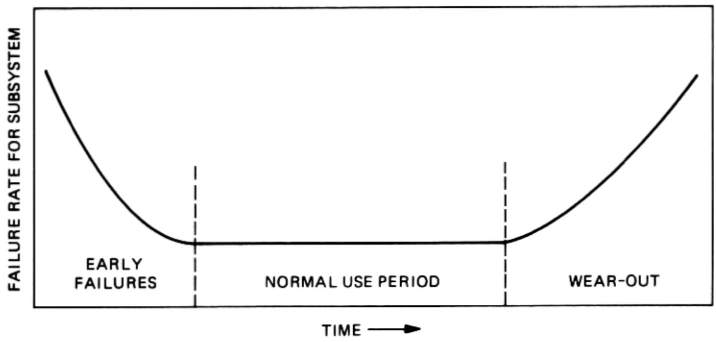

Fig. 25—Bathtub curve.

include software induced outages, errors on the part of craft persons, or unusual environmental conditions such as lightning, earthquake, fire, etc. The study concerned itself only with the electronic functioning of system components.

Mean failure rates are assumed to be constant, although they tend to decrease with an increase in time. For a long-term reliability study, the steady state portion of the bathtub curve is assumed (see Fig. 25). In this case, the components on all of the circuit packs were studied to determine the failure rate for each. The results are shown in Table I. For a 1024-line, fully equipped RSS frame, the data show that

(*i*) approximately half of the total FITS* are attributed to LI packs (FE101), which is directly related to customer line performance (every ten weeks one LI will fail),

(*ii*) about seven percent of the total system FITS come from controller groups, which are duplicated and do not seem to have serious consequences in terms of service loss to customers (they may have an impact on maintenance schedule for Bell Operating Companies),

(*iii*) fan-outs, USCS, and G-J circuit packs constitute one-third of the total system FITS (here again, the consequences are not serious), and that

(*iv*) FITS associated with automatic diagnostic features, fault detection, and internal analysis constitute about 10 percent of the total FITS.

Analyzing FITS from various components on RSS circuit packs (see Table II) shows that

(*i*) most of the failures come from integrated circuits. The controller group (FE107, FE109, FE113, FE123) shows a high usage of ICS,

* FITS = Failures in one billion hours.

Table I—Plug-in failure rates (1,024 lines, 120 channels fully equipped office)

Circuit No.	Circuit Name	No. of Circuits	Percent of System FITS	MTBF* (yrs)
FE101	LI	128	44.6	0.21
FE102	G-J	16	8.5	1.08
FE103	CI	30	5.3	1.73
FE104	FO	32	12.4	0.75
FE105	USC	16	8.7	1.06
FE106	BOS	16	3.7	2.50
FE107	DLI	2	0.4	23.30
FE108	GS	4	2.9	3.20
FE109	PROC I	2	1.6	5.65
FE110	MEM I	4	2.4	3.82
FE111	TR	5	1.0	8.93
FE112	T1-ALI	5	1.0	9.19
FE113	PROC II	2	0.8	11.57
FE114	*TOUCH-TONE* service receiver	6	1.1	8.38
FE115	ROH	1	0.2	42.18
FE116	PAB	1	0.3	34.08
FE118	RLT I	1	0.2	37.55
FE119	RLT II	1	0.2	45.53
FE120	MSD	4	2.4	3.90
FE123	MEM II	4	2.3	4.35
Steady state total FITS = 1,234,563 (MTBF* = 28 days)				

* Mean time between failures.

In terms of customer service effect, the LI boards are of most concern, since they account for about 50 percent of the total system FITS.

Table II—Percent FITS in RSS components

Components	Percent FITS
ICS	43
Capacitors	29
Relays	7
Others*	21

* Transistors, transformers, resistors, diodes, etc.

which account for approximately 90 percent of the total controller FITS,

(*ii*) the second highest number of failures comes from capacitors and in LI boards, tantalum capacitors contribute about 42 percent of total LI FITS, and that

(*iii*) the contribution of all other components, including power converters, to failures (FITS) is small.

5.5 Downtime predictions for No. 10A RSS

To determine downtime for any system, the following parameters must be studied:

Table III—Remote Switching System performance in relation to downtime

Service Outage (Percent)	Objective for Downtime (min/yr)	Expected RSS Downtime (min/yr)
100	3	0.025
$100 > x \geq 10$	10	0.107
$10 > x \geq 1$	21	1.32
$1 > x \geq 0$	53	134*

* (8 customers affected)

Table IV—Line circuit downtime

Line Circuit Spare Description	Downtime* (min/yr)	
	With Spare	Without Spare
One spare for 31 circuits	0.03	1076
One spare for 255 circuits	0.27	1076

* Note: Average repair time = 4 h.

- Failure rates of components
- Repair time for various troubles
- Status of subsystem, i.e., Simplex or Duplex, etc.

These parameters determine the availability or unavailability of the subsystem or system. The method of determining downtime is shown in the Appendix. The results of downtime calculations are shown in Table III. From the results, the following comments are pertinent:

- For the entire system, the standard of no more than three minutes per year downtime is adequately realized. The downtime, because of hardware troubles, is 0.025 minutes per year.
- Partial system downtime can be caused by simultaneous outages of fan-out boards, which is a remote possibility. However, the objectives are met for customer groups greater than ten percent.
- For less than 1 percent of the total customers, the downtime objective is met by having a switchable circuit for every 31 circuits, or 255 circuits. Downtime calculations made suggest that sparing makes downtime almost negligible. (See Table IV.)

5.6 No. 10A RSS burn-in considerations

The interval between RSS ship-date and service is much shorter (four weeks) than that for most electronic switching systems. Also, the No. 10A RSS is unstaffed and may be situated in a hut that, instead of air conditioning, merely has an exhaust fan to circulate the air and bring the ambient temperature close to the outside temperature. Therefore, it is imperative that No. 10A RSS perform near its steady state reliability objective prior to service. This can be accomplished by various burn-in procedures.

To eliminate early failures, burn-in in the factory at the circuit pack level, as well as at the frame level, appears to be the most economical approach, in which case marginal and weak components are weeded out. The following assumptions are made in order to arrive at burn-in procedures:

(*i*) The majority of circuit pack components obey the following relationship:

$$\left|\frac{\lambda}{\lambda_1}\right| = \left|\frac{t}{t_1}\right|^{-m},$$

where

λ = FITS corresponding to time t,

λ_1 = FITS corresponding to time t_1,

m = constant for components, $m = -1.2$, and

λ corresponds to the steady state failure rate, which takes place at $t_1 = 4400$ hours (6 months) of system operation.

(*ii*) Burn-in failures are the result of manufacturing errors and material defects.

To accelerate failures, temperature burn-in, heat test, and power cycling are the burn-in methods used for No. 10A RSS, and are based on other Bell System experience.

Steady-state failure rate data for No. 10A RSS plug-ins show that early failure rates can be estimated using the assumptions just described. Figure 26 shows the relationships among instantaneous failure

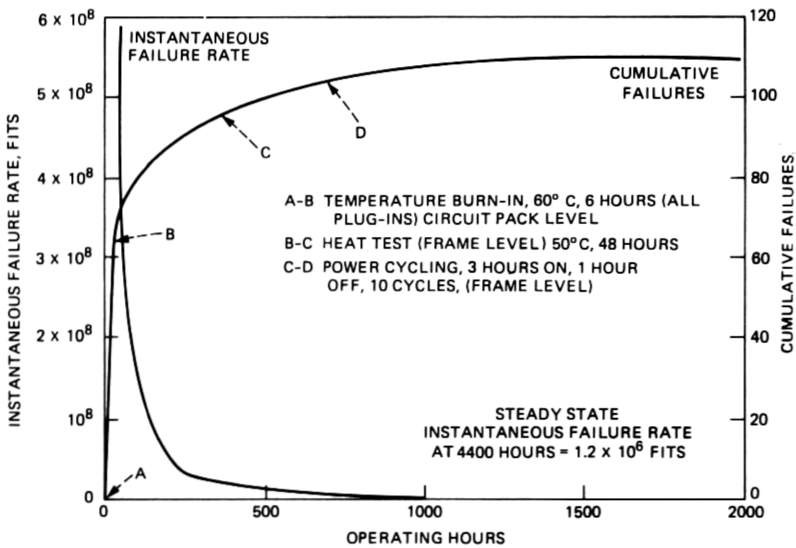

Fig. 26—Relationship between instantaneous failure rate, cumulative failures, and operating time.

rates, cumulative failures, and time of No. 10A RSS plug-ins subjected to operating stresses. The estimated number of failures for a fully equipped, 1024-line RSS frame is 115 within the first six months of operation in the field with no burn-in. Of course, some failures will be eliminated during system test and installation and before cutover. However, such failures are costly and place a burden on system test engineers and installers which, in turn, lengthens the duration of testing and installation. Based on this logic, it is assumed that the strategy of having failures occur during system test and installation for a system with no burn-in is offset by increased system test and installation interval.

The burn-in procedures for No. 10A RSS were intended to eliminate 85 percent of the failures in the factory. Table V and Fig. 26 show the burn-in procedures, acceleration factors, and failures eliminated. The economic analysis shows that a substantial net gain to the Bell System results because of the burn-in procedures.

5.7 Sparing philosophy for No. 10A RSS

As the price of plug-in modules increases with the advent of electronic systems and increased component density on plug-ins, a need for a sparing philosophy based on plug-in reliability appears to be necessary. To determine the spare requirements for RSS plug-ins, the Erlang-C traffic model is used, in which the spare requirements is a function of plug-in failure rate, turnaround time (spare replacement interval), and the service continuity objective (availability of spares when needed).

The main emphasis of the No. 10A RSS sparing philosophy is on quality of service to a customer or a group of customers and on economics. Based on these considerations, the plug-ins were divided into three classes:

Class I. Plug-in modules with frequent occurrences of failure.

Class II. Plug-in modules whose failure can cause partial or total

Table V—Factory burn-in

Burn-in Procedure	Acceleration Factor	Failures Eliminated	(See Fig. 3)
1. Temperature burn-in, all plug-ins 60°C, 6 h	3.4	64	*A* to *B*
2. Heat test RSS frame 50°C, 48 h	6.1	33	*B* to *C*
3. Power-cycling* RSS frame 3 h on, 1 h off, 10 cycles	—	7	*C* to *D*

* An acceleration factor of 8 can be estimated from data set experience at Bell Laboratories. More important, however, is that power cycling eliminates device failures that are caused by a unique mixture of thermal, electrical, and fatigue-type alternating stresses. Temperature burn-in alone may not be able to eliminate all marginal components based upon Arrhenius relationship.

service outage. This, of course, is a serious category in terms of spare requirements.

Class III. All other plug-ins whose failure would affect traffic capacity, quality of service, or system maintenance.

The classification of No. 10A RSS plug-ins, based on these definitions, are listed in Table VI.

In using the Erlang-C model for RSS, the relationship between the service continuity objective or availability and the load offered to inventory (L) is shown in Fig. 27. When the spare quantity required is less than or equal to one spare, two spares are assigned, with the additional spare acting as a "spare for a spare." When two or more spares were required, an additional spare was not provided.

The availability of the spare was taken to be 0.99, which means that once in 100 repairs there is no spare available. The failure rates and mean time between failures (MTBF) for all No. 10A RSS plug-ins, showed this availability level of 99 percent to be more than adequate for system operation. The condition of having no spares for all plug-

Table VI—Spare philosophy classification and spare requirement

Classification	FE Circuit	Circuit Name	Inventory Load*	No. of Spares
I	101	LI	1.44	6
II	104	FO	0.52	4
	107	DL	0.12	2
	108	GS	0.09	2
	109	MPA	0.051	2
	110	MEM I	0.078	2
	111	TR	0.033	2
	112	ALI	0.033	2
	113	MPB	0.027	2
	123	MEM II	0.069	4
III	102	G-J	0.276	3
	103	CI	0.180	2
	105	USC	0.282	3
	106	BOS	0.120	2
	114	TTR	0.036	2
	115	ROH	0.006	2
	116	PAB	0.009	2
	118	RLT I	0.009	2
	119	RLT II	0.006	2
	120	MSD	0.078	2
		Converters		
II		131N1	0.024	2
III		131L1	0.918	2
		J57380-C-1LI	0.036	2
		130L	0.006	2

$$* \text{ Inventory load} = \frac{\text{spare replacement interval}}{\text{mean time between repairs}}$$

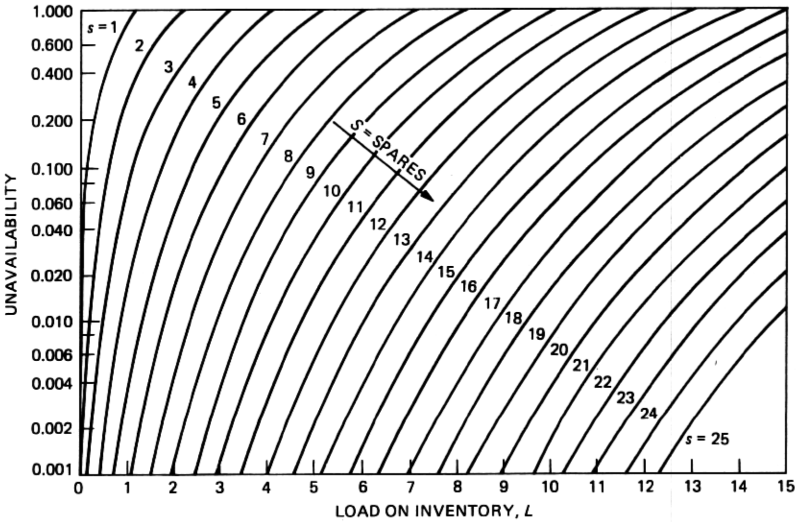

Fig. 27—Relationship between unavailability of spares and load on inventory.

ins, except the line interface (FE101) circuit pack (see Table VI), occurs less often than once every 40 years.

5.8 Sparing strategies: economic consideration

Sparing strategies depend mainly on the geographical location of the RT, on economics, and on service quality objectives. Three strategies are possible for the No. 10A RSS:

(*i*) Spares at both RT (Class I) and at host (Class II and Class III).
(*ii*) Spares at both RT (Class I) and at SCC (Class II and Class III).
(*iii*) Spares at RT (Class I), host (Class II), and at SCC (Class III).

The strategy to be selected is a judgmental matter and is a Bell Operating Company decision that is primarily based on the geographical location of the RT and on economics.

The sparing strategy (*ii*) is economically superior to (*i*) and (*iii*) and it meets the service quality objectives. The normalized price per RT for these strategies is shown in Fig. 28. With the increase in RTs per host and in hosts per SCC, the spare price per RT decreases. However, the price differences between strategies (*ii*) and (*iii*) are insignificant. Strategy (*i*) is uneconomical when there are only a few RTs, but it is an important strategy for situations where the SCC is too far from the host and the host is in the vicinity of all the RTs. Strategy (*ii*) appears to be economical and convenient to manage if the distances between the RTs and the SCC do not require craft persons to travel more than two hours to keep downtime within acceptable limits. Strategy (*iii*) appears to be an acceptable solution if the distances involved between the RT and host are not overly significant and SCC is relatively far away from the RT and host.

5.9 Summary of reliability aspects of No. 10A RSS

(*i*) Service requirements are met in areas where the units are duplicated and replicated.

(*ii*) Burn-in in the factory must be performed to economically eliminate weak components and improve customer service. Steady-state reliability is achieved by cumulative 100-hour burn-in.

(*iii*) Spare requirements can be determined using the Erlang-C traffic model, where reliability information becomes a key parameter. Economical sparing strategy can be formulated by keeping spares at the RT, as well as at the SCC.

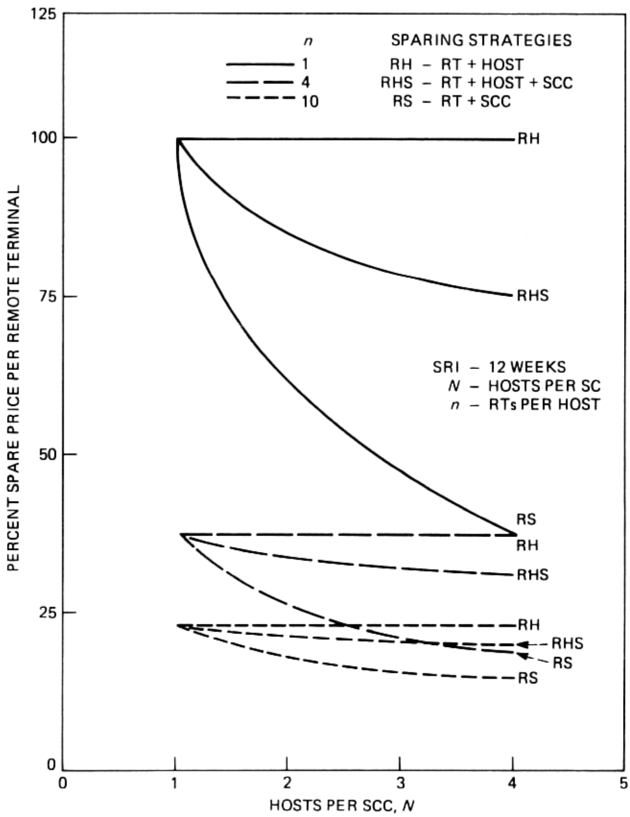

Fig. 28—Relationship between percent spare price per remote terminal and hosts per SCC for sparing strategies (SRI = 12 weeks).

VI. SUMMARY

Each aspect of the No. 10A RSS physical design serves to ultimately provide a low-cost, small-size highly reliable electronic switch. Interconnection technology selections were made to achieve low cost and small size. Frame layout partitioning and growth were devised to reduce equipment growth and to maximize plug-in apparatus, which decreases engineering and start-up cost. The resulting small equipment size maximizes the reuse of existing buildings or allows for the use of a small portable modular building. Circuit partitioning, sparing philosophy, and burn-in procedures ensure ESS central office service objectives, while providing low-cost maintenance.

APPENDIX

Downtime Calculations

A = Availability of a system.
$\bar{A}$ = Unavailability of a system.
$A + \bar{A} = 1.$
$A = \mu/\lambda + \mu.$
$\bar{A} = \lambda/\lambda + \mu.$
λ = Failure rate.
μ = Repair rate.
Expected down time
= $(\bar{A})(8760)(60)$ min/yr Simplex Model.
= $(\bar{A})^2(8760)(60)$ min/yr Duplex Model.
Expected down time in case of N duplicate units
= $(\bar{A})^N(8760)(60)$ min/yr.

Example

Consider a subsystem with 50,000 FITS, repair time = 4 h.
$\lambda = (50{,}000)\ (10^{-9})$ failures./h.
$\mu = 0.25$ repairs/h.
Expected down time
= 105 min/yr (Simplex).
= 0.021 min/yr (Duplex).
= 0.42 by 10^{-7} min/yr (Triplex).