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System 75:

Physical Architecture and Design

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This paper discusses the physical architecture, the rationale for design choices, and the physical design of the System 75 office communication system. The design features a single equipment cabinet housing up to 720 ports, a display-enhanced attendant console, and a modular-jack-based station-administration facility. The architecture minimizes the small system cost while providing modular building blocks for feature additions and growth. Customer participation in maintenance and administration is encouraged by attention to human factors in design and labeling details.

I. OVERVIEW OF PHYSICAL ARCHITECTURE

The main goals of the physical architecture of the System 75 office communication system are to maximize the amount of service that can be provided by a single-cabinet system, to provide a modular, cost-effective design over a broad range of sizes and needs, and to provide an aesthetically pleasing functional design that will enhance customer participation in system maintenance and administration.

A single cabinet (Fig. 1) houses all equipment needed to support up to 720 ports with any mix of station types or trunks. The common

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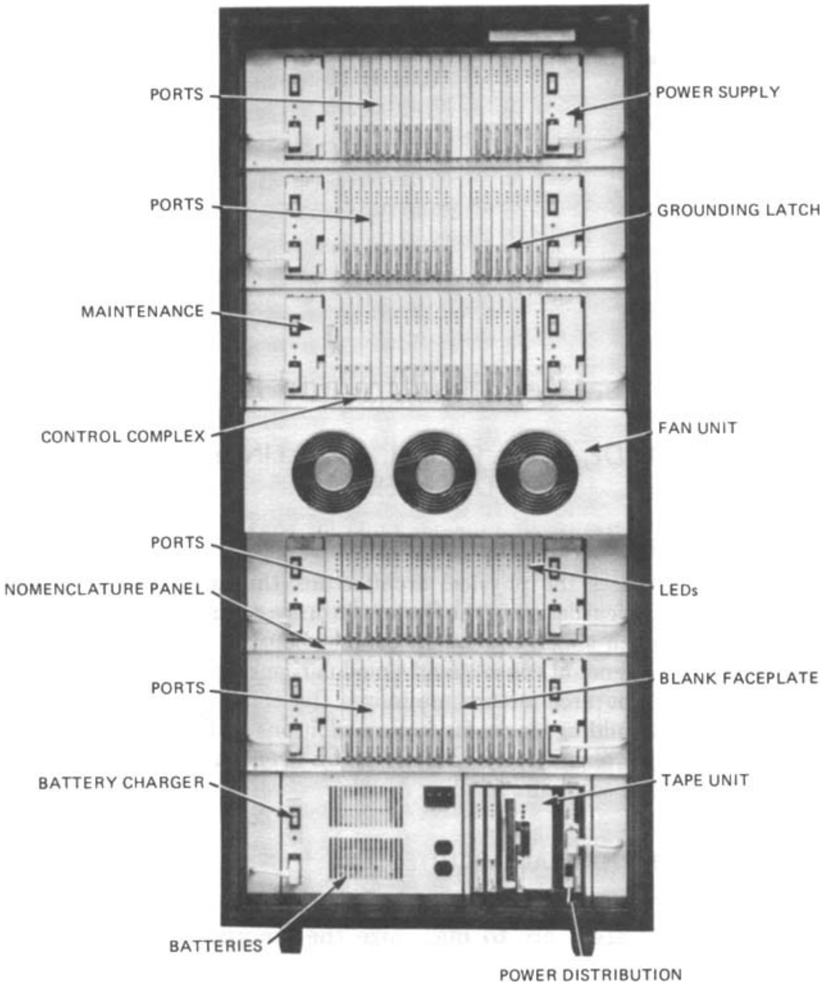


Fig. 1—Equipment cabinet.

equipment complement including the control complex (processor, memory, tape interface, and maintenance circuit packs), fan unit, tape unit, battery charger, and other power-distribution equipment occupies only a small fraction of the cabinet; this leaves ample room for the addition of port carriers, power units, and port circuits.

A new modular-jack-based station-administration facility (Fig. 2) and a new attendant console (Fig. 3) enhance system flexibility and complement the powerful software-based administration and maintenance features.[1,2]

II. CABINET-LEVEL DESIGN

A key trade-off in PBX design is balancing the amount of common

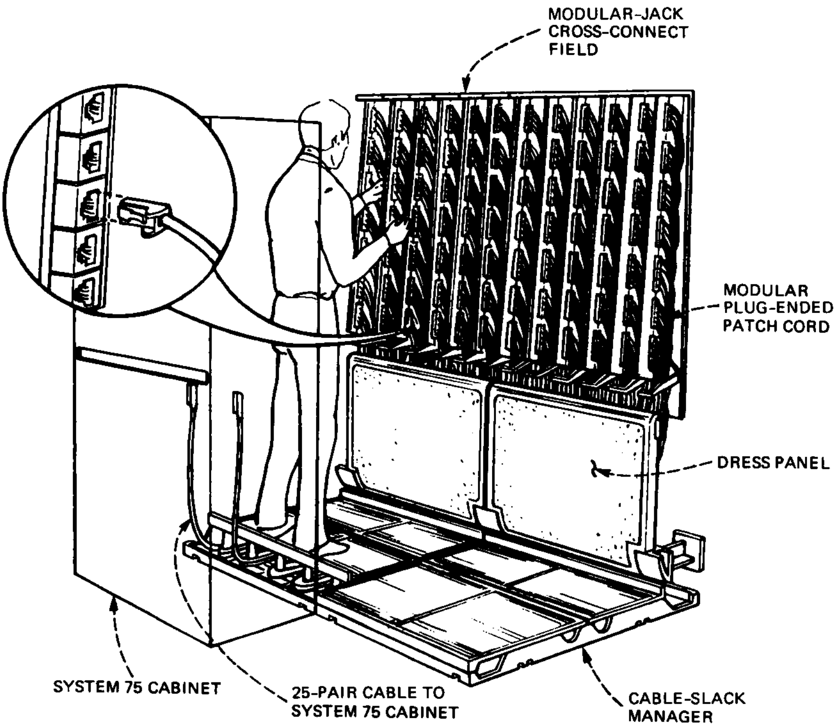
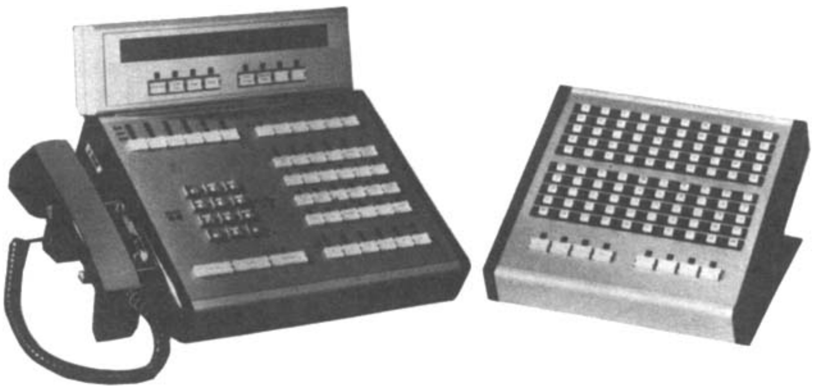


Fig. 2—Station administration facility.

equipment needed to get started (intercept cost) with the amount of modular equipment required to meet a particular set of customer needs (slope). In addition, the designer must carefully balance the costs of ordering, stocking, maintaining, and administering the system with the cost of the hardware elements themselves. Since the System 75 market spans a large range of sizes and features, minimizing the impact of this trade-off was a major challenge at each step in the design process.

To minimize ordering complexity, simplify installation, and maximize production volume, all common equipment was designed to function over the full range of system configurations. To this end, all wiring required to support the full complement of port carriers is provided in a connectorized manner in all cabinets. The cooling fans are designed to accommodate the maximum equipment load under worst-case conditions. The automatic monitoring and maintenance elements likewise are sized to accommodate any mix of equipment, while detailed configurations are specified in the translation software. Power cabling and battery capacity are similarly designed for worst-case maximum load. With this strategy, the special engineering of



(a) (b)

Fig. 3—(a) Basic service attendant position console. (b) Direct extension selection console.

power and cooling normally associated with a PBX of System 75's complexity is virtually eliminated. Cost of the hardware elements is also minimized by eliminating factory handling of multiple design options and special orders.

2.1 Cabinet

A new welded steel cabinet that uses side panels as structural members was developed. This monolithic design eliminated nearly 32 feet of EMI gasketing as well as the expense of handling removable side panels. A new structural foam door assembly complements the new cabinet. Both cabinet and door have a tough, durable, textured finish, which masks surface imperfections and scratches. A simple pin hinge mechanism with a detent permits the door to stay in an open position for ease of maintenance and allows multiple cabinet lineups where the system is installed together with other product family members. EMI integrity is provided by a gasket contacting conductive paint on the cabinet body. The rear is EMI-sealed by inexpensive metal plates screwed directly to the cabinet frame.

The full-size System 75 cabinet is 32 inches wide, 24 inches deep, and 70 inches high. Fully equipped it weighs approximately 800 pounds. To accommodate smaller customer needs, a 42-inch-high cabinet was designed for up to 240 ports (Fig. 4).

2.2 Equipment cooling

Customer premises systems encounter a wide variety of operating environments. In addition, the configuration flexibility of System 75

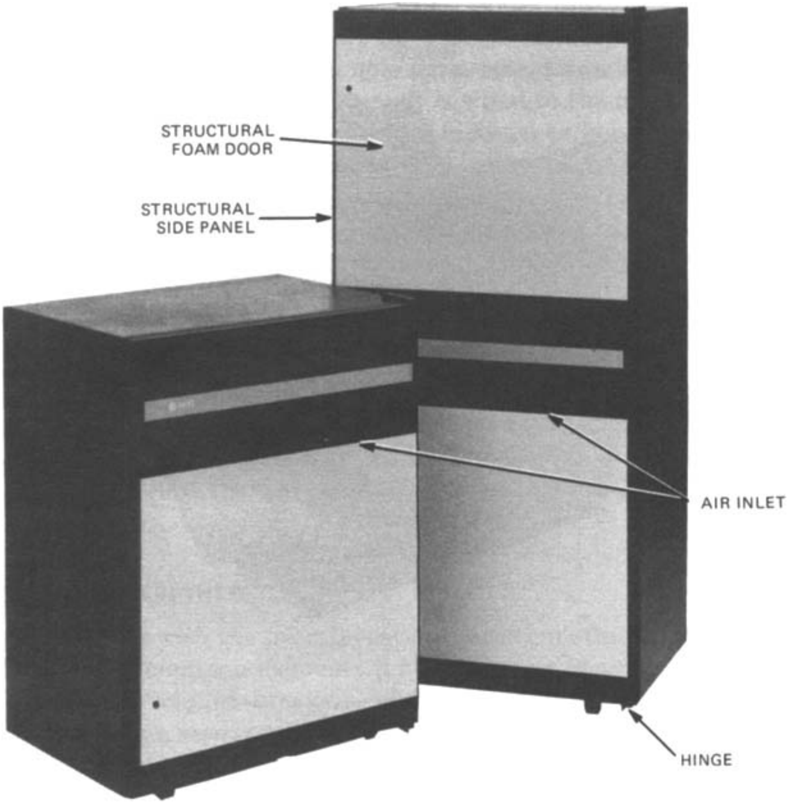
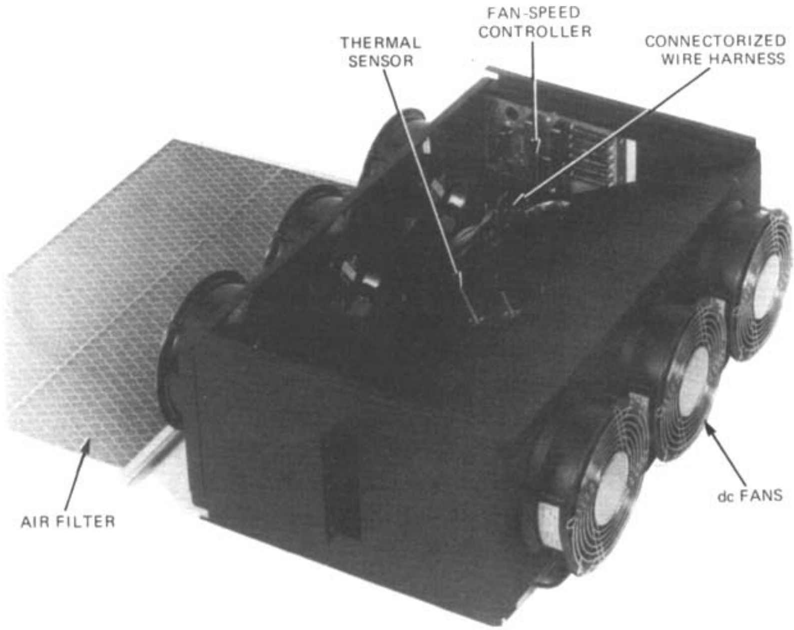


Fig. 4—Small and medium cabinet configurations.

presents a wide range of thermal loads. In keeping with the common equipment philosophy, the fan unit was designed to cover the maximum anticipated load of 2500 watts under the worst-case design criteria of 120°F at 10,000-foot elevation. Early analysis confirmed by laboratory measurements indicated that a three-fan unit using available dc fans operating at 48V would fit within the height of a carrier module and could effectively cool up to three fully loaded carriers. By placing two such units (six fans) in a central location, one directed upward and the other downward, a full cabinet could be cooled.

Additionally, the thermal design combined alarms for high-temperature fan failure, clogged filters, and other maintenance needs together with a fan-speed controller to adjust fan speeds automatically to compensate for varying thermal loads and operating environments. The resultant design (Fig. 5) is a 9-inch-high integrated module housing all six fans; removable, washable air filters; fan-speed con-



troller; and connectorized wiring to mate with power and alarm leads in the cabinet wiring harness.

Secondary design benefits include cleaner inlet air than is available at the base of the cabinet, low acoustic fan noise when full fan power is not required, and a separately testable unit that can be quickly replaced in the field.

The small cabinet uses the same design with three fewer fans at reduced cost.

2.3 Cabinet wiring

The system architecture includes a Time Division Multiplexed (TDM)* bus and distributed power, which allows simple internal cabinet wiring. The TDM bus is terminated at each end by a paddle-board-mounted bus terminator and is interconnected from carrier to carrier using inexpensive flat cables terminated on paddle boards that plug directly onto the backplane pins.

Field installation of additional carriers is accomplished through the addition of a flat cable and reuse of the bus terminator. The remaining

* Acronyms and abbreviations used in the text are defined at the back of the *Journal.*

intercarrier wiring consists of leads for power unit status and carrier identification. These terminate on a single connector at each carrier position, again allowing for simple replacement or additions in factory or field. The power unit ac/dc input is wired to the front of each unit to permit addition or replacement of modular power supplies without removal of back panels or carriers. All cabinet wiring, independent of size or configuration, is contained in a single connectorized cable harness designed to simplify factory assembly.

2.4 Power distribution and tape unit

System 75 is equipped with a high-capacity tape recorder to back up the volatile memory. This unit, along with the standard system battery plant and all required power distribution, filtering, and power factor correction hardware, is housed in a modular unit at the bottom of each cabinet. This unit occupies the vertical space of a single circuit pack carrier (9 inches high) and supports the entire range of system configurations.

III. POWER ARCHITECTURE

In keeping with the overall cost optimization strategy, the power is divided into common elements (battery, power factor inductors, EMI filters, main circuit breakers, etc.) and modular, carrier mounted, switching type rectifiers.

The modular rectifiers use a five-pin connector designed to accept either commercial quality 110 Vac or 144 Vdc from the battery backup unit as inputs. Regulated outputs of −48, −5 and +5V are provided directly to power buses on the carrier backplanes. Additional voltages or regulation are supplied on the circuit packs, thus creating a standard circuit pack to backplane power interface. In addition, the attendant console and the cooling fans are powered from a modular rectifier. As a result, the entire system requires only one standard 110V, 50A outlet for installation and a single, self-contained battery plant for backup.

This modular architecture readily accommodates international applications since pin-compatible rectifiers that accept different input voltages and frequencies can readily be designed. Similarly, any backup system providing 110 Vac or 144 Vdc can be accommodated.

3.1 Maintenance and recovery

The use of individual power supplies to power each carrier ensures that the failure group associated with any given supply is minimized. In addition, the power units contain software-resettable circuit breakers. This combination, when coupled with software-driven maintenance, virtually eliminates the need for craft or customer intervention to replace fuses or reset circuit breakers tripped by an accidental overload or transient conditions. Fusing is used only to meet Underwriters Laboratories requirements and to protect against fire or personnel safety in the event of a catastrophic failure such as damage to the insulation on the power cord.

Since the individual rectifiers are only three inches wide and nine inches high and weigh roughly nine pounds, additions or replacements are easily accommodated.

3.2 Battery holdover

For protection against transient power outages such as those frequently encountered during lightning storms, System 75 uses a 144 Vdc, 2.5 ampere-hour battery plant. This dc power together with the ac line power is distributed by five conductor cables to all switching power supplies within the cabinet.

As described by Lu et al.,[2] holdover strategy is under system software control to ensure optimal use of the available battery power.

3.3 UL and CSA qualification

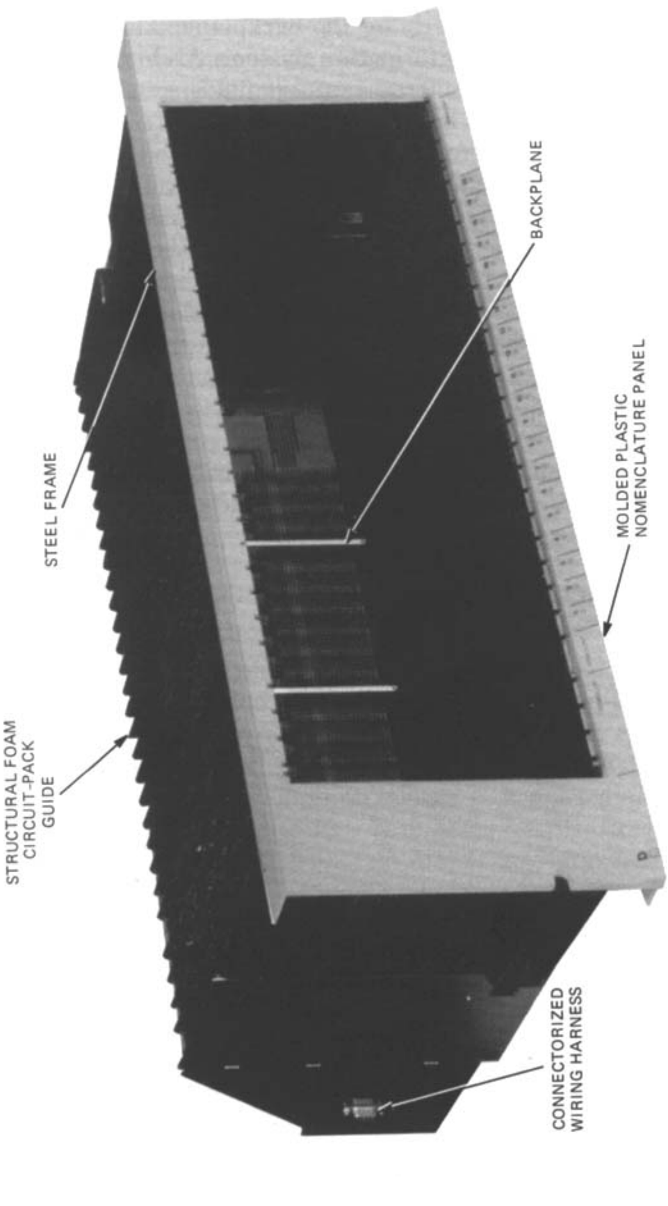
As System 75 will be competing for sales in many new markets, all elements of the system were listed with both Underwriters Laboratories (USA) and the Canadian Standards Association (Canada).

IV. CARRIER DESIGN

A basic building block for System 75 is the newly designed circuit pack carrier shown in Fig. 6. A single structural foam plastic molded part forms the carrier guides and backplane support. The draft angle of the guides, used to allow proper removal of the part from the mold, is also used to introduce a slight bow to the guides when the foam part is attached to the backplane. This inward bow gives just enough pressure to the circuit pack to provide comfortable tactile feedback as the circuit pack is inserted into the carrier.

A formed steel frame is used to provide the structural integrity needed to support a combined circuit pack load of up to 60 pounds. The frame also provides the alignment of the circuit pack in the lower rail of the slot as well as the rigid surface required to accommodate the forces generated by the latch as the circuit pack connector engages and disengages the backplane pins.

A molded plastic part is placed over the steel frame when the carrier is installed in the equipment cabinet to facilitate the alignment of the circuit pack in the upper rail of the slot, to provide a slanted surface for labeling of the carrier, and most importantly, to give a clean, aesthetically pleasing visual surface to the assembled unit.


STEEL FRAME
BACKPLANE
MOLDED PLASTIC NOMENCLATURE PANEL
STRUCTURAL FOAM CIRCUIT-PACK GUIDE
CONNECTORIZED WIRING HARNESS

Unique carrier codes are created by associating different backplanes with the generic building blocks described above.

A single connector brings the carrier identification and alarm leads from the wiring harness to the carrier.

Each port slot is connected to the building wiring by a 25-pair connector terminated directly on the backplane. Through the implementation of the AT&T Information Systems Architecture (ISA), pin assignments for terminals, cross-connect fields, system cables, backplanes, and circuit packs have been coordinated to ensure compatibility with all present and future AT&T Information Systems products. This standard interface allows any of the many unique codes of port circuit to be installed in any port slot. This universal port-slot concept is of considerable value in both the factory and the field.

For System 75, two codes of backplane are required: one providing the dedicated slots for the common equipment along with 10 port slots and a second code housing 20 port slots. Up to four of these port carriers plus one common equipment carrier may be installed in a full cabinet. Field or factory installation simply requires mounting the carrier (four screws), connecting the already provided wiring harness connector, and snapping the molded frame in place. A molded blank is provided where carriers are not required to contain cooling air and to enhance the appearance.

V. CIRCUIT PACKS

5.1 Common design parameters

All circuit packs use the 8-inch by 13-inch *Fastech*™ board outline and the 200-pin *Fastech* connector. Faceplates are sized to fill the width of the slot (typically 3/4 inch) and present a standard pattern of three Light-Emitting Diodes (LEDs) (red, green, and yellow) for uniform maintenance. A special grounding latch protects the circuits from electrostatic discharge during installation.

Manufacturing considerations—such as orienting components for machine insertability, providing lands for automatic testing, and complying with the requirements associated with aqueous cleaning of water soluble flux—also apply to all designs.

5.2 Control circuit design

Control circuit packs include processor, memory, network control, tape control, protocol interfaces, and maintenance. These circuits are unique functional entities occupying dedicated slots in the control carrier and, thus, do not conform to the universal slot concept. High functional density and critical design parameters dictate the use of multilayer board technology. Since each circuit type represents a unique design, details will not be presented.

5.3 Service and port circuit design

Service circuits (pooled modems, tone generator, and tone detector), as well as port circuits (lines and trunks), are designed to meet the universal slot interface criteria. This criteria ensures that unique customer configurations can easily be accommodated, but imposes constraints on the circuit pack designer since signal, power, and ground leads must be uniform over a wide variety of functional designs.

Circuit density is another important parameter on System 75 high-volume line and trunk circuits. Achieving this density required extensive use of surface mounted VLSI, interconnection of components on Hybrid Integrated Circuits (HICs) used both in Dual In-line Package (DIP) and Single In-line Package (SIP) configurations, and the use of multilayer board blanks.

The final design consideration for all port and service circuits is to take advantage of the basic hardware architecture. To this end, all port circuits contain three sections: a system bus interface section that ties the circuit to the time division system bus, a port control processor (angel) section that interfaces this port to the main processor complex, and a functional section that provides the unique interface required for that particular circuit pack's function. Some broad design considerations for each of these sections is given below. A typical 8-port circuit pack is shown in Fig. 7.

5.3.1 System bus interface section

The system bus interface section of each pack, located adjacent to the backplane connector, consists of five custom-designed bus buffers

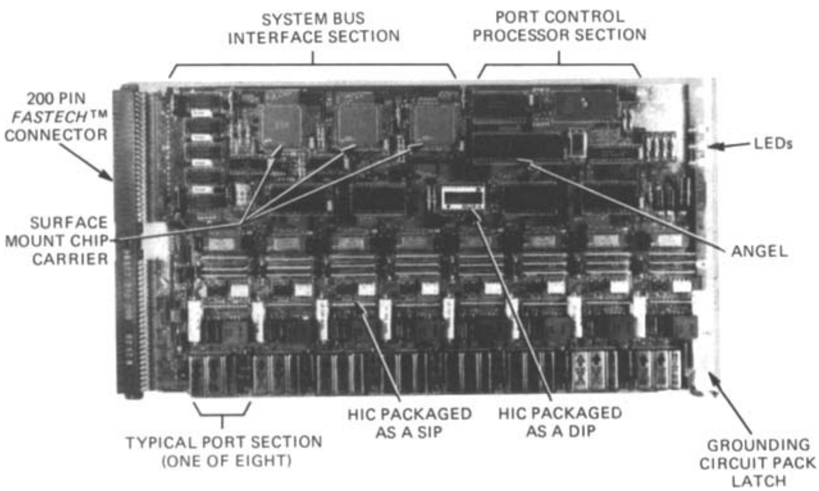


Fig. 7—Central office trunk circuit pack.

that interface the circuit pack to the switch. These buffers are then coupled to custom VLSI devices designed to interface the bus. The devices are located in the same position on each circuit pack to eliminate noise coupling with sensitive analog voice-path circuitry on adjacent circuit packs and to ensure consistent performance.

5.3.2 Port control processor section

Each port circuit pack contains a port control processor (angel) complex, which adapts the system bus interface section to the station interface section. This section, based on the 8051–8052 microprocessor family, performs all required functions to service both the system bus and the station interface, as well as perform automatic maintenance functions.

5.3.3 Functional interface section

Each pack also contains a station, or trunk, or service interface section that provides the interface to an individual type of terminal, trunk, or service. These functional interface configurations are replicated on a port by port basis on each pack to ensure consistent, quiet performance. Designing in this manner allows increased efficiency in noise-reduction efforts, since analysis done on a single port can then be applied to all others. To further reduce audible noise—especially in view of the fact that all circuit packs interfacing analog facilities are designed using double-sided circuit boards—all critical circuit paths on the packs are surrounded by substantial amounts of printed grounding for noise suppression.

VI. ATTENDANT CONSOLE

The attendant console is the most visible and most active station of a PBX. Its design must combine human factors, rugged functional design, and asthetics with efficient, cost-effective manufacture and ease of maintenance.

The functions and operations of the System 75 attendant console are similar to the highly successful *Dimension*® PBX and *Dimension* System 85 consoles to preserve product family architecture and minimize attendant training. Other features such as providing both tactile and audible feedback on button pushes, right- or left-handed handset/headset mounting, and individual tone controls have also been provided in the new design.

Important new functionality includes the use of the standard ISA four-pair wiring plan and Digital Communications Protocol (DCP) to interface the console to the system. This feature allows the attendant console to plug into any modular jack since the console interface to the switch is identical to any other digital station.

An additional new feature is the incorporation of a 40-character alphanumeric display, which, when coupled to the software-based functionality, both facilitates and enhances message retrieval, calling/called party identification, and other critical attendant functions.

6.1 Console physical design

An exploded view of the attendant console (Fig. 8) shows the details

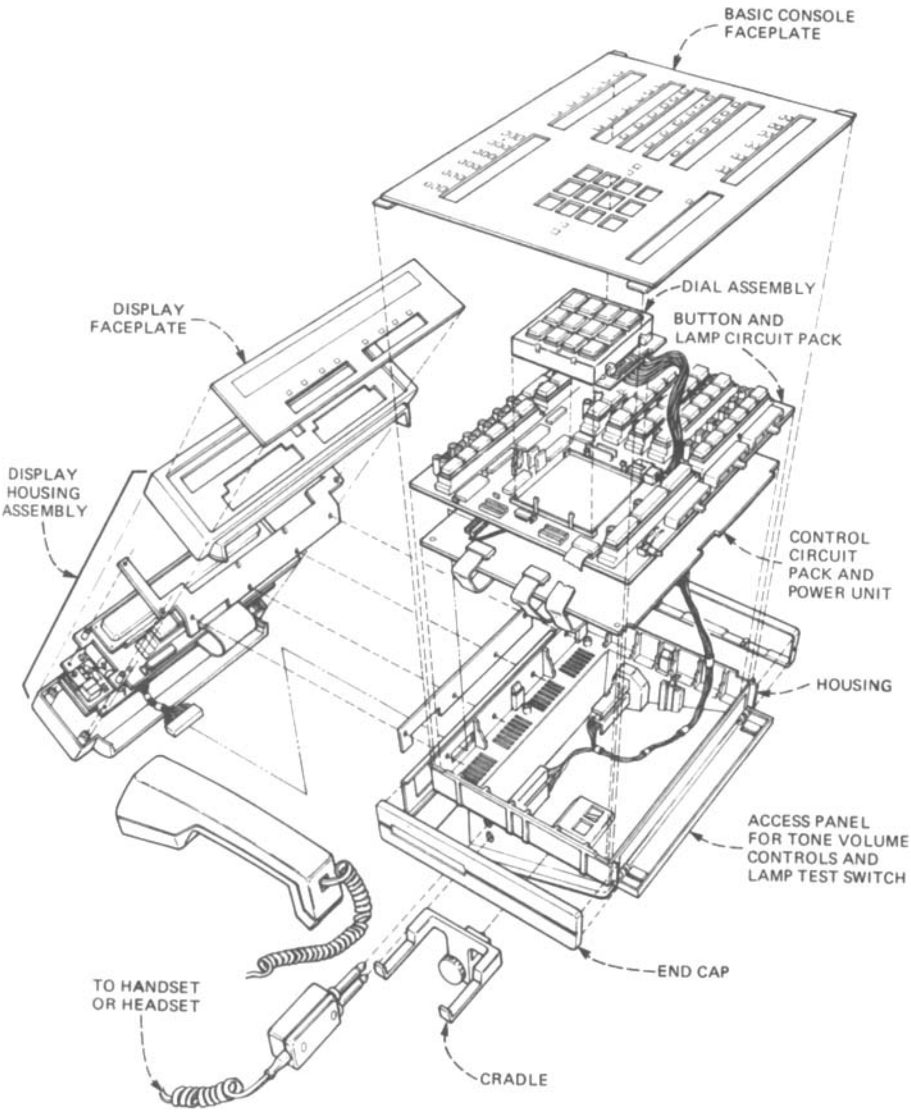


Fig. 8—Attendant console, exploded view.

of the console physical architecture. All components, keys, and LEDs are mounted on independently testable and replaceable units for ease of assembly and repair. The entire unit snaps together for easy assembly. Product family identity with other System 75 terminals is preserved. All interconnection cables are keyed to prevent inadvertent damage. A heavy rubber-footed steel base keeps the console in place as keys are jabbed by the user.

VII. FACILITIES INTERFACE

The main function of any PBX is to connect various facilities (lines, trunks, terminals, host computers, etc.) to one another. A secondary need is to connect auxiliary equipment (music sources, Station Message Detail Recording [SMDR] recorders, etc.), the system administration terminal, and remote maintenance centers to the switch. The range of System 75 interconnection is shown in Fig. 9.

To accommodate this wide spectrum of needs System 75 conforms to the AT&T Information Systems architecture and the four-pair uniform station/terminal wiring plan. This conformance ensures that building wiring, terminals, and most adjuncts installed for use with other AT&T Information Systems products can be used or reused directly with System 75.

The facility interface can further be divided into three areas: the interface between the switch cabinet and its adjuncts, the interface between the stations and the switch, and the interface between the external Central Office (CO) facilities and the switch.

7.1 Switch cabinet interface

Figure 10 shows the external interfaces of the System 75 cabinet. As can readily be seen, the universal port concept and the hardware architecture greatly simplify this interface.

7.2 Station interface

The most important customer need in administration is to perform station moves, upgrades, or installation of additional stations. Complementing the software-driven user-friendly administration terminal is a modular-jack-based cross-connect field (Figs. 2 and 11) human-engineered to accommodate the user with minimal training. Key elements include a cable-slack manager to organize the 25-pair port cables, modular molded plastic cross-connect modules, and modular plug-ended patch cords.

7.2.1 Hardware

The basic hardware building block is a two-piece, hinged, molded plastic column housing small circuit modules containing 25-pair cable

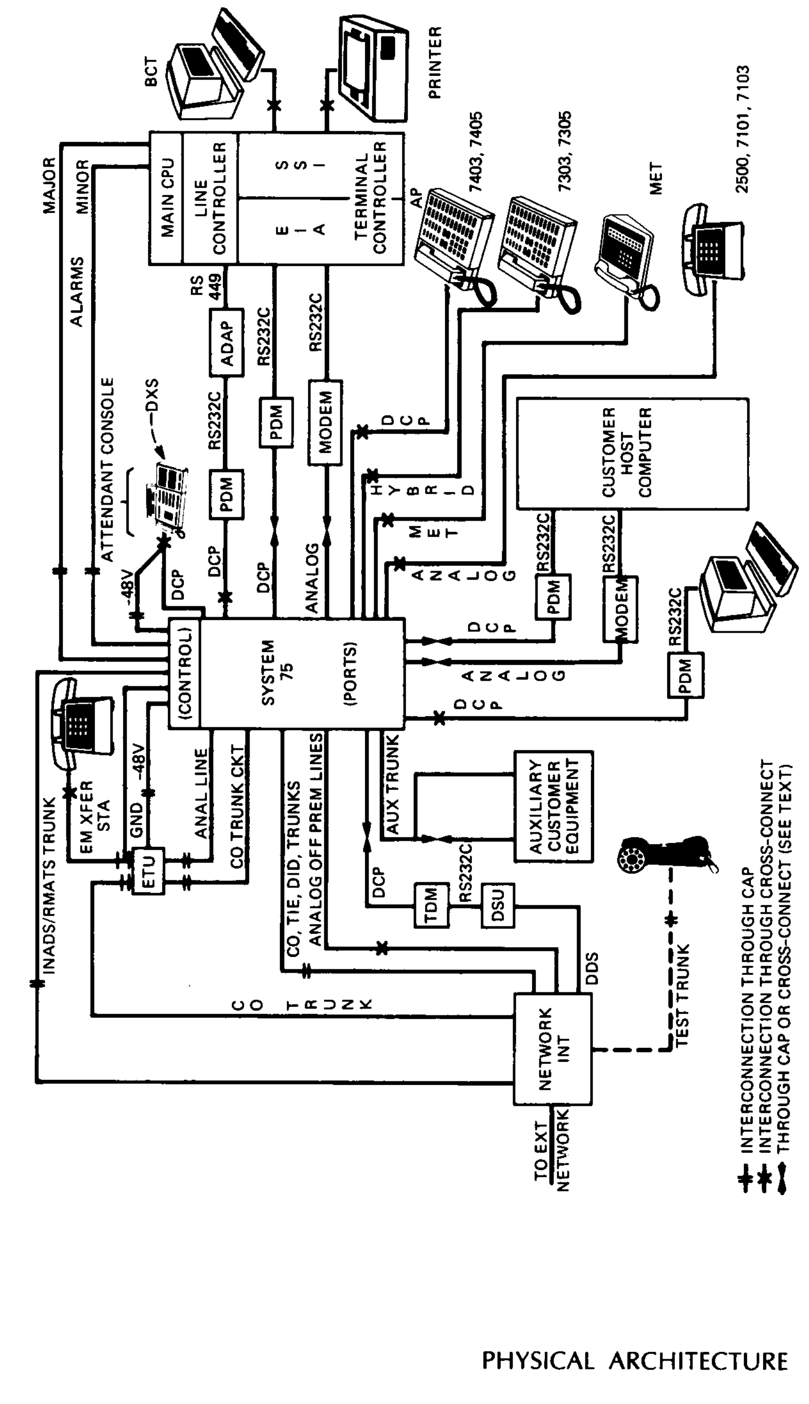


Fig. 9—Facilities interconnection.

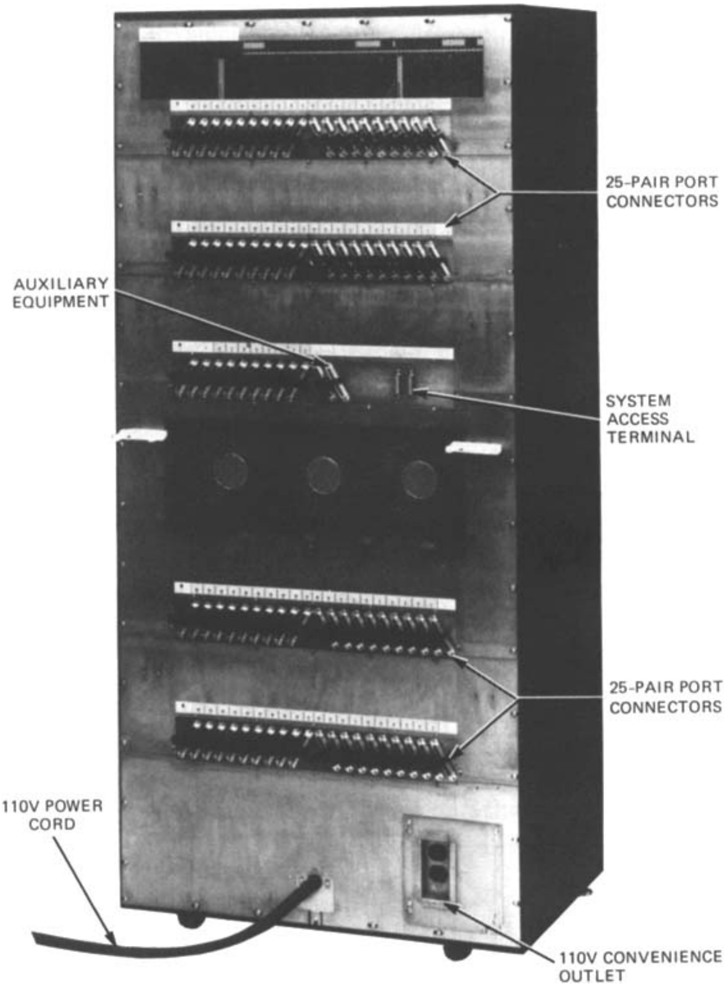


Fig. 10—Equipment cabinet external interfaces.

connectors together with modular jacks. Port circuit modules expand a 25-pair port cable into eight ports consistent with System 75 circuit-pack density, and station modules expand a 25-pair cable into six jacks consistent with the Information Systems Architecture four-pair station wiring plan. Each column accommodates three port-circuit modules and four building-cable modules for a total of 24 stations. Columns attach with interlocking tabs; thus, only the first unit need be accurately installed and leveled. All connecting cables in a column are accessible via a vertically hinged section specially designed to reduce any stresses on the cables induced by opening and closing the unit. The modular patch cords used for the connections are modified by the

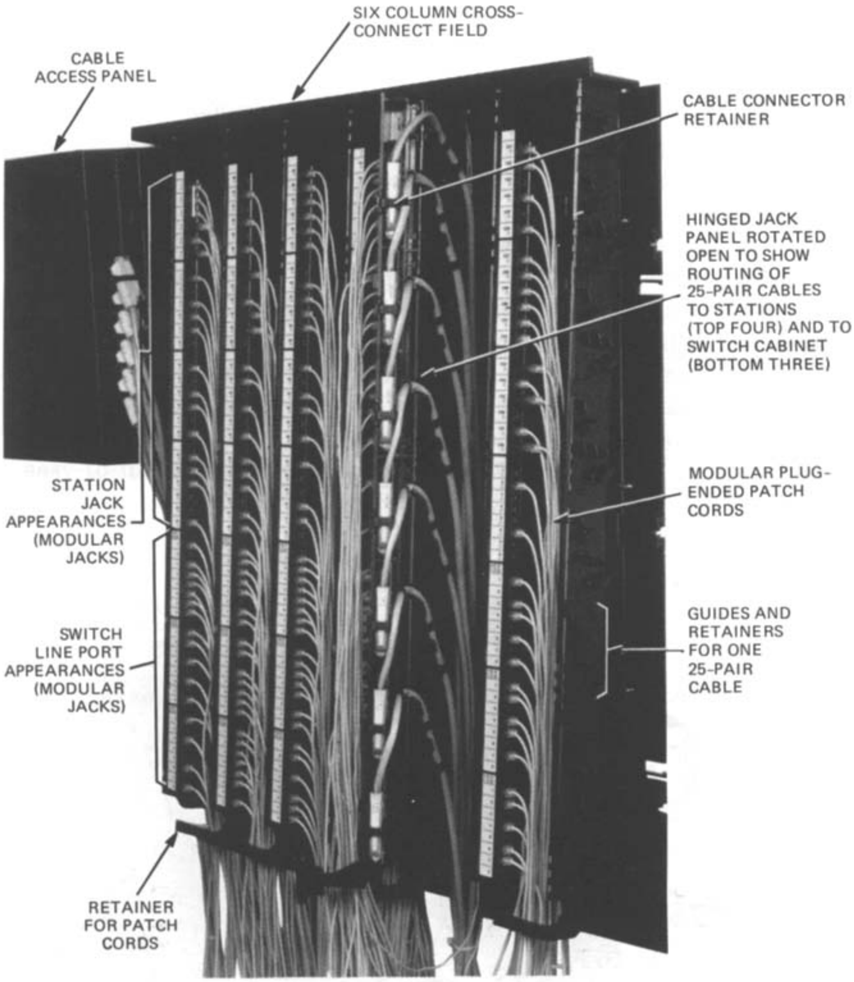


Fig. 11—Modular-jack-based cross-connect field.

addition of triangular wings intended to protect the tab on the modular plug and serve as an anti-snag feature when removing cords.

7.2.2 Labeling

To further facilitate customer participation, a labeling plan employing graphic symbols to represent items such as jacks, carriers, and circuit packs is used. Identical designations (Figs. 12 and 13) appear on the cabinet, carriers, cables, cross-connect, and station wall jacks making rapid station moves or upgrades possible. In addition, the traditional blue and purple PBX colors are used to denote station-side and switch-side connections, respectively.

SYMBOL	FUNCTION	DESIGNATION SEQUENCE
	CABINET	1, 2, 3, . . ., n
	CARRIER	A,B,C,D,E
	SLOT	1, 2, 3, . . . , 20
	JACK	1, 2, 3, . . ., 400
	SITE	A, B, C . . .
	FLOOR	
	BUILDING	

Fig. 12—Symbolic nomenclature system.

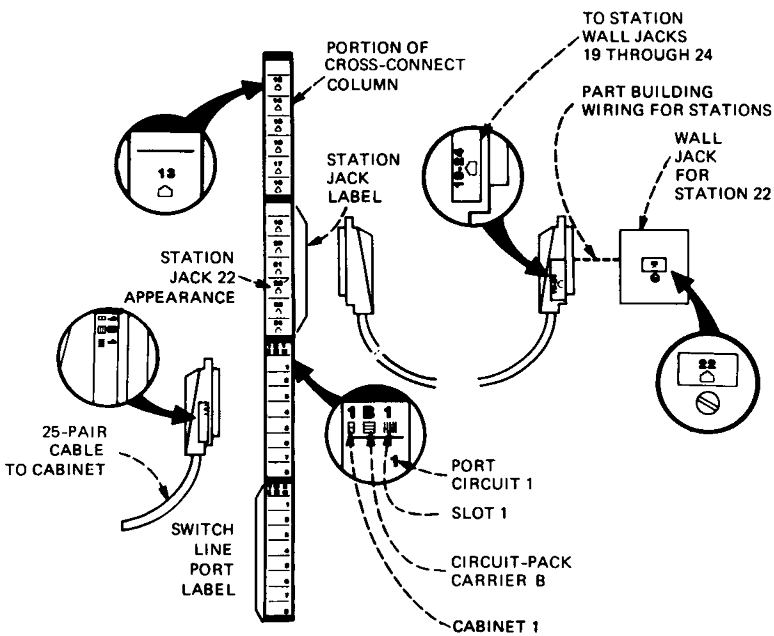


Fig. 13—Equipment labels.

The labeling plan was devised with several human factors considerations in mind. Combinations of letters and numbers are used to identify items since alphanumeric sequences are easier to remember than strings of numbers. Graphic symbols were chosen to represent items to remove all language association and make the labeling plan suitable for international use.

7.3 External facilities

Consistent with FCC regulations and the uniform building wiring plan, all external facilities present 25-pair connectorized appearances. In principle, these could be connected directly to the switch. In practice, it is essential to fan out these interconnections to provide maintenance and test personnel access to the individual pairs. Since this activity is generally performed by a trained technician and since these connections are seldom rearranged once installed, traditional insulation displacement cut-down blocks are used. In System 75, these blocks along with emergency transfer relays are housed in a factory wired module housed in an inexpensive structural foam housing. This easy-to-install cable access panel is shown in Fig. 14. Trunk rearrange-

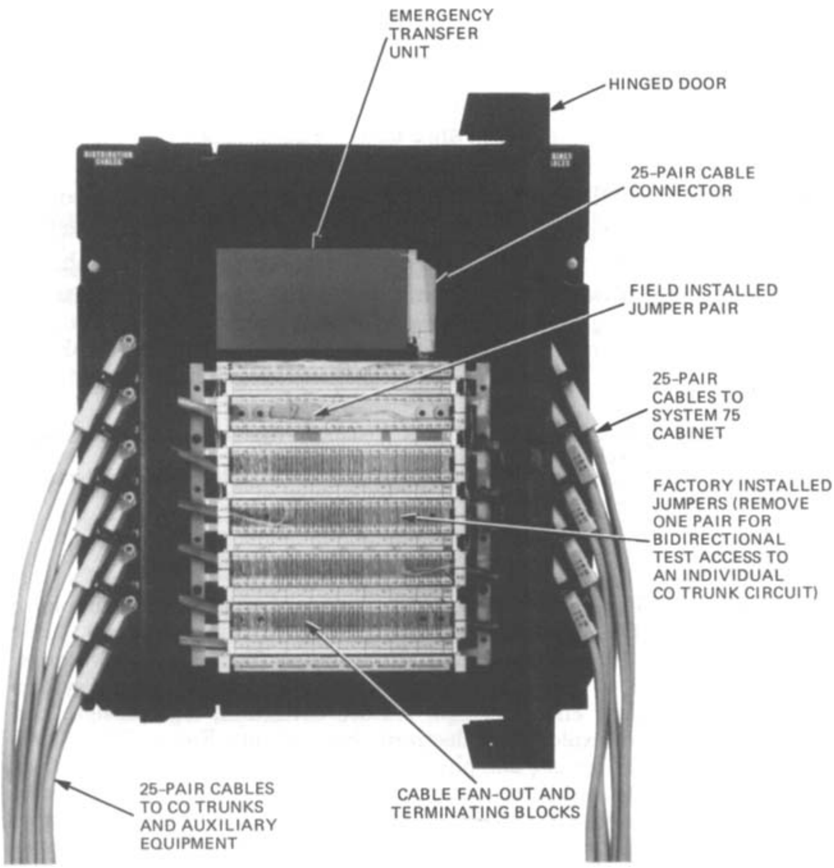


Fig. 14—Cable access panel.

ment and special circuit termination is accomplished by removing straps and wiring directly to the blocks.

Auxiliary customer equipment (music sources for music on hold, paging amplifiers, etc.) is housed in a separate cabinet. Interconnection to System 75 is either by a dedicated cable or by passing through the interconnect hardware.

7.4 Alternate arrangements

While facility-interconnection arrangements have been designed to optimize System 75 installations, the uniform wiring plan assures that System 75 can be connected to existing wiring or to the hardware recommended for larger *Dimension* system 85 installations should such facilities already be in place and/or the customer have such a preference.

VIII. SUMMARY

The goals of maximizing the amount of service housed in a single cabinet while providing a modular physical architecture that can be tailored to the customer's size and feature needs have been met. The software-based administration and maintenance features are effectively complimented by user-friendly hardware ranging from the modular-jack-based station cross-connect field to the simple modular power units. New technology such as surface-mounted VLSI, structural foam carriers, and modular switching regulators is combined with familiar hardware such as modular jacks to provide a user-friendly, cost-effective, manufacturable design.

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AUTHORS

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