With solid-state circuitry, time-division switching, and stored-program control, the DIMENSION* PBX furnishes a host of innovative features. The new Maintenance and Administration Panel adds flexibility in choice of services and helps locate troubles.

The DIMENSION* PBX: A New All-Electronic Customer Switching System

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FIRST CUT INTO COMMERCIAL SERVICE in Minneapolis in late January of this year, the Dimension PBX (Private Branch Exchange) has been very favorably received by its initial customers. The new system offers a number of advantages.

For business customers, many new and useful features are included, such as call waiting with distinctive tones and outgoing trunk queuing (for automatically placing a call via the next free outgoing trunk). In addition, customers have almost unlimited flexibility in choosing their dialing plans and class of service assignments (see table, page 318).

The new system is small, attractively styled, and color-matched to varying office decors. It is compactly housed in one or two cabinets for serving up to about 400 lines.

In addition, trouble-free installation and reliable service are ensured by two series of tests performed during manufacture of the

*Trademark of AT&T Co.

new PBX: exhaustive computer-controlled tests of the hardware, and final tests of the complete system including the attendant console and the program that implements the customer's chosen features.

Finally, but certainly not the least important advantage of the Dimension PBX is its low cost. In spite of its feature capability and operational flexibility, the Dimension PBX competes very favorably in total installed price.

These advantages result from putting various advanced technologies together in the right combination and applying them to the design of a small PBX system. For example, the Dimension PBX has a time-division switching network using new custom integrated circuits. The resulting switch is low in cost, small in size, and high in performance. It has a capacity of about 1700 CCS (hundred call-seconds per hour), sufficient for systems of about 400 lines. System functions are controlled by stored programs executed by a special-pur-

At the console. Judy Paulson, receptionist for Twin City Bottle Company in Minneapolis, talks to a caller using the Dimension PBX.

pose minicomputer optimized for telephone call processing. This common control handles well over 2000 calls per hour under typical business conditions, a capacity that is more than adequate for systems up to about 400 lines. Standard trunk circuits link the PBX to the Bell System network, but a variety of other circuits are available for connection of inter-location tie trunks, WATS (Wide Area Telephone Service) lines, and foreign exchange lines to distant exchanges.

To make this new design a reality, a major tri-company effort went into the planning, design, and manufacture of the Dimension

PBX. Work on formulating design objectives under the guidance of Bell Labs systems engineers at Holmdel, New Jersey began with market studies by AT&T Marketing and with Operating Company workshops conducted by AT&T Engineering. Western Electric and Bell Labs engineers worked side by side to scrutinize the manufacturing aspects of preliminary design, and Operating Company representatives contributed feedback from both employees and customers. Cooperation was also necessary in working out the manufacturing tests required for successful production. This close working relationship among Bell

SELECTED OPTIONAL FEATURES OF THE DIMENSION PBX *

Feature Package 1 (Basic Business Features)

Alphanumeric Display for Attendant Position	Provides a visual display on an attendant's console of four symbols used to identify the calling number, etc.
Call Forwarding	Automatically routes to a designated extension either all calls or all calls directed to an extension that is busy or doesn't answer
Call Hold	Allows use of a code to hold an ongoing call in order to return to a call or to originate another call or feature
Call Pickup	Allows use of a code to answer calls to other extensions within a preset pickup group
Call Waiting	Automatically holds calls to a busy extension; the called party is signaled that a call is waiting
Night Station Service— Full Service	Allows attendant-seeking calls to be reassigned to selected lines and the assignment to remain in effect night-to-night until changed
Outgoing Trunk Queuing	Provides automatic queuing of calls when all trunks are busy and automatic ringback when a trunk is available
Three-Way Conference Transfer	Allows an extension user to dial in a third party while the second party is held; the user can also hang up or drop the third party from the call
Trunk Group Warning Indicators	Provides a visual indication on the attendant console when only a preset number of trunks remain unused in a trunk group

Additional Features in Feature Package 2 (Centrex and Deluxe Business Features)

Automatic Callback	Automatically connects an extension to a formerly busy called number when the line becomes idle
AIOD	Automatically identifies extensions on outgoing calls—which permits direct billing to extensions for toll calls
Code Restriction	Limits the office and area codes that can be dialed from certain extensions
DID	Allows direct dialing to extensions from the DDD network without attendant assistance
Loudspeaker Paging— Deluxe	Provides access for attendants and extension users to voice paging equipment
Remote Access to PBX Services	Allows a user calling from outside the PBX to access the PBX services via an exchange network connection
Tandem Tie Trunks	Permits a caller at a distant PBX to direct-dial tie trunk calls through the switching system
Trunk-to-Trunk Connections	Allows an incoming or outgoing trunk call to be extended via the attendant to another outgoing trunk

Additional Features in Feature Package 3 (Hotel / Motel Features)

Calling Number Display to Station	Allows the number of a calling extension to be displayed at a called extension in the same PBX
Controlled Station-to-Station Restriction	Allows an attendant to prevent certain extensions from receiving calls from other extensions
Hot-Line Service	Allows callers from predesignated extensions to place calls automatically without dialing; these calls can be directed to extensions or trunks
Station Message Register Service (Electronic Display)	Automatically records message unit information for local calls made from each extension

*In addition to the standard features available to all customers.

Behind the scenes. To place a station-to-station test call, *Mike Shackle (above) of Northwestern Bell's Plant department follows the procedures specified on a flipchart of the Maintenance and Administration Panel (MAAP), the Dimension PBX's new tool for diagnosing troubles and entering information into memory. Behind the MAAP is the PBX cabinet containing (from the top) line, trunk, and processor "carriers." To the right of the line carrier is the Alarm Panel, with alarm and fault indicators and associated controls. At right, Tom Cannon of the CSS (Customer Switching System) Field Support department at Bell Labs' Denver laboratory uses the Software Trouble Locating Set to verify proper operation of a Dimension PBX program.*

System companies made it possible to ship the first system within 18 months of the start of the design program.

Switching and Control

A time-division switching network allows many conversations to be switched simultaneously onto a common switching bus. In the pulse-amplitude modulation switching network of the Dimension PBX, portions of each analog speech signal are sampled at regular intervals and switched onto a common bus conductor in allocated time slots. Portions of speech signals from other lines occupy the intervening time slots. Thus, a common bus

with a capability of about 400 lines is time-shared among various conversations in progress. Operating by means of an integrated circuit custom-designed for switching the analog signals onto the electronic bus, this system results in an economical, easy to engineer, and physically compact switching network.

The design also permits a number of additional advantages. For example, it eliminates the need for the call transfer circuits usually required for three-party connections, and because of the nature of the electronic bus furnishes a high-performance four-wire switching interface for tie trunk connections. In addition, since many of the signaling character-

*Strict environmental testing—
essential in developing
a sturdy, reliable PBX...*
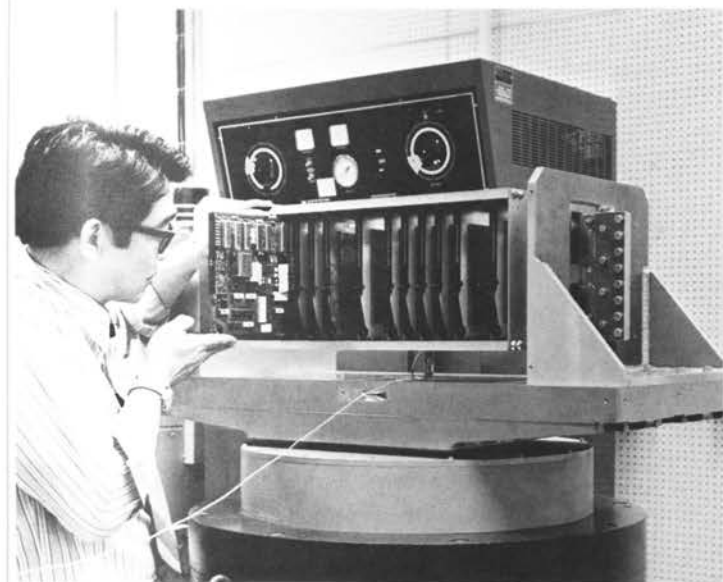
Rough treatment. *At Bell Labs' Denver location, members of the Customer Switching Physical Design department perform environmental tests on components and subassemblies being developed for the Dimension* PBX. *At upper left, Mas Yoshida sets up a test to simulate the vibration occurring during truck or rail transportation, and above, he controls a test setup simulating the shock that might occur during handling. Dan Arvizu, left, operates a* PBX *thermal simulator.*

istics required for the various kinds of trunk circuits are contained in software, only four types of hardware trunk circuits are required.

The choice of control circuits is one of the most critical elements in the design of a small, economical PBX. For the Dimension PBX, advances in integrated circuit technology allowed stored-program control to be extended from larger electronic switching systems to small customer-premises switching equipment for the first time.

The minicomputer designed for the system is a small, 16-bit machine tailored to the cost, physical space, and maintenance objectives of the Dimension PBX. It incorporates both Western Electric and commercial integrated circuits. The main memory device is a commercial metal-oxide semiconductor (MOS) device containing 4096 bits of storage. Each circuit pack containing 17 of these devices has a capacity of 4096 16-bit (plus one parity bit) words. The maximum configuration of 16 circuit packs thus allows a maximum memory capacity of about 64,000 words. However, for each installation, the size of the memory (the number of circuit packs used) directly reflects the number of the features ordered.

A high-performance magnetic tape cartridge is used to load the feature programs into the main memory. This secondary or backup memory contains several million bits of storage—sufficient for the main program and a large number of off-line programs used to diagnose troubles and to input or revise information pertaining to a particular installation.

Software

The assembly language used to translate a user's instructions for the processor is based on a language developed previously at Bell Labs for use in small electronic switching offices. A complete software support system was available for this language—including editors, loaders, extensive simulation capabilities, operating system programs, and debugging programs (see right-hand photo, page 319). The language offers a repertory of approximately 150 sixteen-bit instructions tailored to call-processing applications.

Based on this software assembly language, an efficient, high-level programming language, easy to understand and write, was developed. Several new instructions were added to simplify the scanning and maintenance operations required for the Dimension PBX.

The organization of the software programs for use in the PBX makes extensive use of tables to store the state of calls in progress. This orderly method of organizing the call processing programs helps to minimize the interaction of software with peripheral hardware units, such as the memory, network, and console circuits. This structure also leads to convenient control of various tasks, such as line and trunk scanning, and allows the system to modify task priorities under varying traffic conditions.

For the initial installation of the Dimension PBX on a customer's premises, the class-of-service information (the dialing plan, directory number translations, and system features) is generated by Western Electric for the tape cartridge provided with the customer's machine. This information corresponds to the features requested on the original order form by the customer.

Another requirement, however, is for an easy-to-use method of adding or revising customer information on an in-service basis on the customer's premises. The Maintenance and Administration Panel (MAAP) was designed to meet this need (see left-hand photo on page 319). The MAAP unit also furnishes diagnostic information for locating trouble conditions and doing other maintenance tasks.

Console

The console for the Dimension PBX was developed at Bell Labs in Holmdel, New Jersey. It is a new all-electronic design using light-emitting diode (LED) displays (see the illustration on page 317). Electronic design allows the console to be connected by a small cable (12 pairs of wires), which improves appearance and makes installation easy.

A number of new features were developed for the console. For example, the busy or idle condition of the extension numbers is displayed on the DSS (Direct Station Selection) and busy lamp field on the top panel of the console. A set of "group select" keys under the DSS and busy lamp field is used for selecting different hundreds groups for display.

Just above the dial pad is a set of buttons and lamps used for supervising the console's switched loops. The use of five lamps for indicating the state of a call on the switched loop allows flashing indicators to be reserved for alerting attendants and eliminates the need to distinguish between various lamp flashing rates, as is frequently required in many present systems.

Physical Design

To minimize costs and to smooth the transition from development and early production to high volume manufacturing required examination of various facets of design and manufacturing:

• Design documentation practices were reviewed to ensure that both current and new technology could be converted rapidly into manufacturing information.

• The standard and planned photographic, plating, fabricating, soldering, assembling, and testing equipment and processes were reviewed to locate those that would reduce manufacturing intervals and minimize new capital investment.

After evaluating the factors involved, design engineers established equipment features for two important elements of the system, the printed wiring boards (PWBs) and the printed wiring backplanes (the backplanes into which the PWBs connect). The PWBs are about the size of a page of this magazine, a size that was influenced by the desired characteristics of the line and trunk circuits. For example, the more circuits per PWB, the lower the cost per circuit. However, this factor had to be balanced by a concern for the number of circuits taken out of service when a PWB is removed to clear trouble. In this case, the best answer was four line circuits packaged per PWB.

The PWBs are constructed by a photographic, chemical-etching process. This produces a pattern of copper conductors overlaid on an insulated support plane and interconnected by plated-through holes. Component leads are inserted into the holes and soldered to the PWB to form a functional circuit pack. At one end are gold contact fingers for interconnection to a printed wiring backplane to form a "carrier," or shelf, of the Dimension PBX equipment cabinet.

The carrier backplane is also a two-sided printed wiring board with copper conductors etched on epoxy glass. The backplane measures about 8 by 22 inches. Coaxial and tape cable interconnect the carriers, and 26-gauge connector-ended cables connect the carriers to the external cross-connect field.

Line, trunk, and processor carriers are used in the system, and each cabinet contains up to five carriers. Fully equipped line carriers contain enough circuit packs for about 60 lines. Fully equipped trunk carriers handle about 30 trunks. Line and trunk carriers may be assembled in various combinations to furnish 60, 120, or 180 lines in a single cabinet, or 240, 360, or 420 lines in two cabinets, depending upon traffic (the number of trunks needed) and customer requirements.

Adding to the capacity of an installation is a simple matter of rolling in a second cabinet, uncrating it, and placing it in location. A loaded cabinet weighs a maximum of 750 pounds and can be handled easily on its own rollers. By interconnecting 25 cables, installation personnel can double the capacity of the system in less than an hour.

The packaging density resulting from the use of high-level integrated circuits caused one concern in cabinet design. Could the system operate at the required maximum external ambient temperature of 120° Fahrenheit? Both thermal analysis and simulation were used to assess the rate of heat accumulation and to determine the combination of fans, baffles, and cabinet openings required to dissipate the heat. Final tests verified the proper operation of the PBX in an external ambient of 120° Fahrenheit.

Transportation and handling tests were also conducted in the laboratory. Results of these tests were incorporated into the structural design to ensure that the PBX would arrive factory-fresh at the customer's premises.

Maintenance

The long-range maintenance objective of a highly reliable, easy to maintain PBX called for the following:

• Built-in maintenance aids to help craft personnel understand machine operation.

• Methods of isolating faults so that circuit packs would be replaced only as a repair procedure with 90 percent accuracy on the first replacement.

• A coordinated package of maintenance hardware, software, documentation, and training that allows a craftsperson to solve 95 percent of the problems encountered in an average of one-half hour or less.

The Alarm Panel on the cabinet contains alarm and fault indicators and associated controls. Major and minor, fuse, over-temperature, and functional alarms are displayed on the panel. The functional alarms indicate faults in the processor, memory, network, and facility (such as tone generators and consoles). Specific off-line programs associated with these alarms are paged in from the tape

Feature presentation. Bob Dybevik (left) and Tony Krzmarzick (right) of Northwestern Bell Marketing explain a novel feature of the Dimension PBX to Jim Wasserman, vice president of Twin City Bottle Company—the product's first customer.

Planning session. John Lees (seated), test engineer at Western Electric's Denver plant, goes over details of a Dimension PBX test with (left to right) Rick Klosterman, Jim Wetsel, and Felix Garcia, also of Western Electric.

cartridge with the aid of the Maintenance and Administration Panel. The Alarm Panel also contains switches for a number of manually operated processor diagnostics and for control of emergency power transfer.

The Maintenance and Administration Panel functions in conjunction with the Alarm Panel and supporting TOP (Task Oriented Practices) documentation. Observing fault indications on the alarm panel, a craftsperson consults the TOP documentation to determine which MAAP procedures to use. Equipped with flip-charts corresponding to specific procedure numbers, the MAAP unit directs the craftsperson in carrying out the procedures and helps interpret results.

Additional maintenance aids include fuses for system and circuit protection, visual lamp displays indicating system and circuit status, circuit test points, and access points for making test calls. Audit programs and error recovery procedures are also used to minimize the effect of ac power disturbances, low voltage conditions, transient electrical disturbances, and many other potential sources of trouble.

The best insurance of trouble-free operation, however, is the thorough program of manufacturing tests instituted at the Western Electric plant in Denver, where the Dimension PBX is made (see right-hand photo, this page). Specific tests cover circuit packs, wiring, and software and include the use of "x-ray" programs to self-test hardware and diagnose faults. Customized system tests cover all the features specified on each customer's order. As these tests continue to improve in speed and thoroughness, they should help ensure even more that Bell System customers receive the best and most reliable service that is economically feasible.

To date, about 100 systems have been shipped from the Western Electric factory in Denver, and the field experience has been good for all concerned. Customers are discovering that the Dimension PBX's comprehensive package of features offers them new ways of using the telephone, and Operating Company people are finding that the systems are easy to install and use. The Dimension PBX promises more satisfied customers as shipments increase in the coming months. □