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Contents

Cover *Model of pinhead diode, shown here about 25 times life size, is symbolically surrounded by computer tapes, a field of application in which they will have wide use* *(See page 303).*

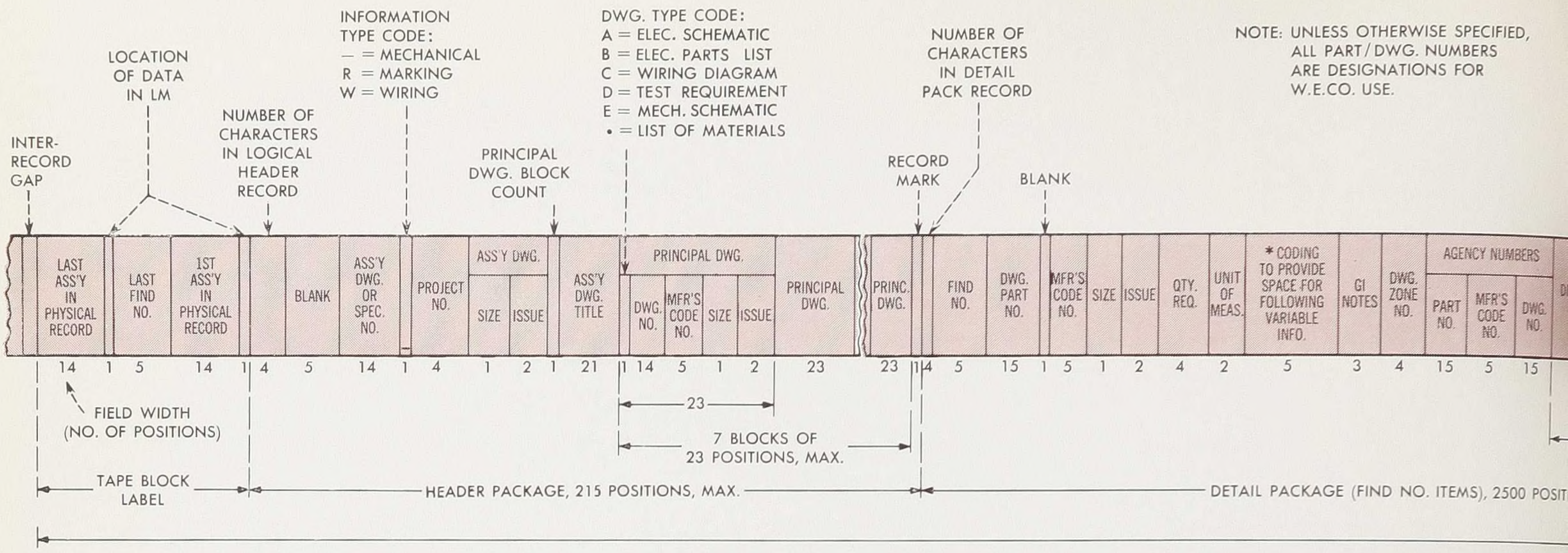
A Computer-Aide

T. J. O'Connor

arts Data Processing System

THE CONTINUED GROWTH OF THE BELL SYSTEM and the increasing complexity of the equipment being designed by Bell Laboratories for communications and military applications has stimulated investigation into new means for processing large volumes of engineering information more efficiently. Some measure of this volume can be gained from data on the drawing activity in the Laboratories Engineering Information Centers during the past five years. For example, during this time an average of 166,000 new sheets of drawings and 233,000 revised sheets of drawings have been produced annually, covering designs for both military and Bell System work. Not included in these figures are thousands of Specifications, Instruction Manuals, Catalogs and other documents also prepared and maintained by these Centers.

In the Bell System, where the telephone network represents the world's largest computer system, it seems natural to look to computers as machine aids in the design and manufacture of its products. For the past several years, the Engineering Information Centers in Bell Laboratories and a number of engineering groups in the Western Electric Company have been turning to computers for such aid.



The parts data file tape incorporates the assembly relationship information with information retrieved

Application of these machine aids is based on several basic principles. For one thing, if certain design criteria can be agreed upon before design begins, and if these criteria will have repetitive application, design rules for mechanical decision-making can be written into computer programs. The computer is instructed by the programs to act upon the basic incoming design data for a particular application, make calculations, combine related data, examine alternate possible solutions, make analyses and derive the optimum solution for that application. The designer is then offered the solution or is advised of incompatible or error conditions that preclude a solution.

In addition, once an item of design or manufacturing information is generated, analyzed and filed in the computer-oriented data processing system for a given application, it should never be necessary to repeat the complete cycle of manual generation, analysis and filing of the item for that or any other application. Computer programs, given a minimum of input data, will instruct the machine to extract one or more items of information from the files, modify it, combine it with other items of input or filed information, and supply the requested results in any desired combination of format and media (printed lists, pictorial presentations, punched cards, magnetic or punched tape, or microfilm).

Joint Efforts Desirable

The greatest returns, of course, will be realized from the Laboratories electronic data processing systems by developing them jointly with Western Electric so as to produce an integrated design and manufacturing information processing system.

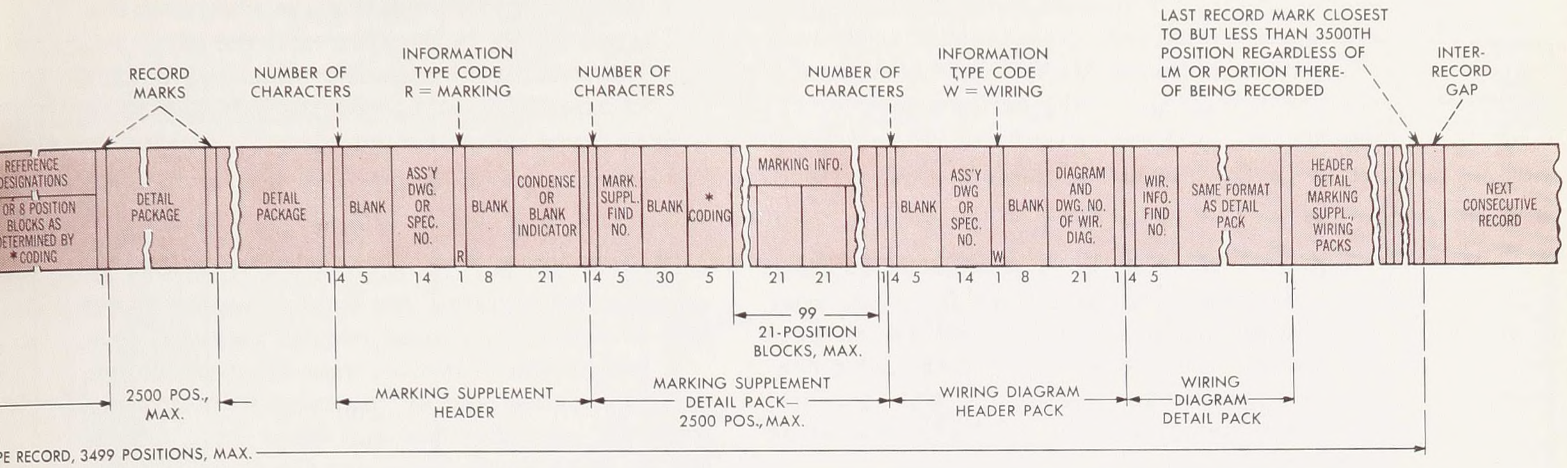
These principles are now being applied to an electronic data processing system that we might consider to consist of five areas of activity: (1) machine aids to assembly (part placement) and wiring design; (2) parts data processing; (3) wiring data processing; (4) pictorial data processing; and (5) management data processing. Discrete sets of programs have been developed in each of these areas. However, since much of the information handled is common or interdependent, further development is tending to merge the various sets of programs into one integrated information processing system capable of handling all the functions now handled separately.

Parts Data Processing System

The balance of this article will describe a Parts Data Processing System (PDPS) now partially in operation in the military areas of Bell Laboratories and Western Electric. Subsequent articles will cover several of the other areas mentioned above. The Parts Data Processing System is concerned with the preparation, storage, maintenance, and retrieval of information about parts and their assembly relationships.

As described in this article, PDPS is a man-machine system designed to relieve the designer, the manufacturing engineer and their support personnel from tedious, repetitive, clerical operations and from performing low-level, routine, decision-making functions associated with processing parts information. Because of the number of design and manufacturing changes, and the large volumes of data involved, the maintenance and transmission of accurate, up-to-date information by manual means has been difficult. A high-speed electronic data processing system such as PDPS promises relief from this problem also.

Some appreciation for the magnitude of the processing task can be gained through a brief look



from the screening file, and is grouped numerically as shown on the idealized tape above.

at some of the statistics involved. For example, more than 100,000 different, repetitive-use parts are currently included in Bell Laboratories military parts data files; various combinations of these parts are presently used in more than 21,000 assemblies of military apparatus and equipment. More than 20 discrete items of information are stored for each of the parts, including such data as part number, drawing number, title and status.

Some of these parts carry multiple numbers, assigned by different organizations such as the Laboratories, the Armed Forces, or vendors. One part may have as many as eight different part numbers: Given any one of these numbers, the system must be capable of selecting one or more of the other cross-referenced numbers and associated information as required by the requestor. Output format requirements for this information vary not only with application but also with customer requirements—even for the same parts and assemblies.

In addition to information retrieval for use, many other items of information must be added to the file and related to the original parts data as the information placed in the files by the designer moves to Western Electric engineers. Also, maintenance programs must be capable of updating the files without placing added burdens on individuals initiating the changes.

Method of Application

To explain better how the PDPS is being developed to aid the project engineer, the designer and the manufacturing engineer with these tasks, let us follow a hypothetical design from conception through manufacture, omitting details of development irrelevant to the use of PDPS.

During the early stages of design, the project engineer coordinates the development of basic design criteria to be used as guides by the designers. In addition to these criteria, he will include in the design guide recommendations for the use of certain parts, materials, finishes and processes. He may get assistance in selecting these parts from the combined Bell Laboratories-Western Electric parts data files, which contain information resulting from analyses made on parts used in previous designs.

Examples of questions that can be answered from these files include:

1. Have these parts been approved for general use?
2. If not, what are the approved substitutes?
3. Are these parts "high reliability" items?
4. What is the previous failure rate experience?
5. What are the acceptable part-drawing numbers, titles and descriptions for this application?
6. Where are the drawings for these parts located?
7. Which of these parts are stock items?
8. Where may they be procured?
9. Which are long-term procurement items?
10. If special tools are required to manufacture these parts, are the tools available?
11. What are the approximate cost data on these parts?

As the various pieces of apparatus and equipment for a design begin to take detailed form on the drawing boards, the designer begins to amass various items of information about the detailed parts and their assembly relationships on layouts and layout worksheets. Under a manual system it would be necessary for the designer (either the engineer or a draftsman) to look up and write out substantial amounts of detailed information on a formal list of materials. By using the PDPS files of information, however, this input effort is considerably reduced. He now uses a simplified layout worksheet such as the one for a converter sub-assembly shown in black on the top on page 299; the worksheet is passed on to the parts analyst who then does the necessary editing, preparatory to machine processing, as shown in color on the same table.

Any known part identification number could have been used; desired equivalent part numbers and associated information would then be machine selected.

This skeletal information is then processed through PDPS in the Data Processing Center. The result is the machine-printed parts list shown below on page 299. In addition to putting out this list, the system also has recorded the parts information in its files for future use.

A portable file in the Computation Center contains material for the PDPS run. This file, known as the "PDPS Cart" and shown on page 301 contains two files on magnetic tape—the parts data file and the screening file, as well as the necessary computer programs for updating and extracting information from these files and the input data.

The screening file tape incorporates part number records; at present there are 80,000 Bell Laboratories, 75,000 government agency and 67,000 vendor part number records in this file. As mentioned earlier, the same part may be recorded under several different numbers. However, these numbers are cross-referenced in the file so that a requestor, using any one of the numbers as input will receive as output the cross referenced numbers in any desired order of preference.

The screening program searches the file for the information with the highest available order of preference. If the input number is not found, or no equivalent is found in any order of preference, a "not-in-file" or "no equivalent identification available" indicator is printed out. If the desired part is not in good standing and a recommended substitute is available, this information is supplied. If the search is successful, the appropriate numbers, title, description and associated information are written on a revision data tape with input data for transfer to the parts data file.

In addition to the programs that perform the above screening, maintenance programs are available for loading and updating the screening files.

The second file in the PDPS cart, the parts data file, incorporates the assembly relationship information supplied as input with the information retrieved from the screening files. This parts list information is grouped numerically by assembly drawing or specification number. A summary of the magnetic tape format is shown at the top of pages 296 and 297. At the present time, this file contains information for approximately 21,000 lists of material on three reels of magnetic tape.

A maintenance program uses the revision data tape (mentioned earlier) containing information from the screening files and other input data to add to, delete from, or change the parts data file. Various diagnostic checks and precautions are taken to minimize contamination or destruction of information in the file.

With the file updated (this is presently done every-other-day), it becomes possible to extract a variety of combinations of current information. More than 1000 Lists of Materials are now being processed monthly.

Status Information Always Available

One important feature of the PDPS is its ability to provide the project engineer with a report on the current status of development of any level of equipment under his control. The table on page 300 shows a portion of a generation breakdown to the lowest detail level for a unit which is a small part of a larger equipment. Notice the computer has calculated the quantities required for each item in the unit covered by the generation breakdown. (Also notice that the Converter Sub-assembly parts called out on the opposite page are included.)

One very useful part of the report provides notification that certain parts lists for the unit are not yet in the file. This may be because the lists have been omitted by error, or, more likely, that the designs for those items have not yet been completed.

Another area in which the PDPS serves the designer is in the preparation and maintenance of spare parts reports. Heretofore, particularly during the period when design changes are relatively heavy, the task of preparing these reports manually was so time consuming that the spare parts lists rarely reflected the current design. Now, operational programs produce a generation structure for the equipment for which spares are to be determined. Each part and assembly is suitably identified and the total number of each item required for the equipment is specified. The designer designates items to be "spared" and their quan-

ASSEMBLY NUMBER	P	LM NUMBER	CODE IDENT NO.	SIZE	ISSUE	ASSEMBLY TITLE	PROJ NO.	ASSY DWG SIZE	ASSY DWG ISSUE	DATE	FRMT	CHG	CARD	LM NUMBER	SHEET
D9768567	-	LM9768567		B	-	CONVERTER, SUBASSEMBLY	RS190	D	-		I	A	-	LM9768567	1 OF

USED ON ASSEMBLY NUMBER	P	FIND NO.	SUF	AGENCY PART NUMBER	CODE IDENT NO.	AGENCY DRAWING NUMBER	PART NUMBER	SIZE	ISSUE	PART NAME AND DESCRIPTION	NO. REQD	UNIT	GI NOTE	ZONE	CODE CHG	CARD
D9768567	-	2					G205413-1 01714			~~TERMINAL~~ 9991	3				A	1
		4					BA10236-20 01714			~~SLEEVING FOR 22GA WIRE~~ 9991	1				A	1
		6					G205841-22 01714			~~WIRE 22 GA.~~ 9991	1				A	1
		14	B				9766745 00000	E	-	~~CONVERTER~~ CONVERTER, SUBASSEMBLY	1		b		A	1
		16					9768180 00000			~~PIN~~ 9991	2				A	1
		18	B				9768569 00000	C	-	COVER	1		b		A	1
		20					9768570 00000			~~BRACKET~~ 9991	1				A	1
		22	B				GS65341 01714			~~NETWORK~~ 9991 ~~Z~~1, 2, 3	3				A A	1 4
		8					G302433-52 01714			9991	8				A	1
		10					G302457-6 01714			9991	6				A	1
		12					G221439-11 01714			9991	14				A	1
		24					G302457-35 01714			9991	2				A	1
		26					GA9017MET P 01714			9991	@				A	1
		28					GA9070LI 01714			9991	@				A	1

OR @ DENOTES QUANTITY AS REQUIRED | E DENOTES PARTS NOT RECOMMENDED FOR GENERAL USE AT TIME OF INCLUSION IN THIS LIST | B DENOTES SUBASSEMBLY | C DENOTES SPEC OR SOURCE CONTROL DRAWING | D DENOTES PARTS TO BE SHIPPED LOOSE

As the designer amasses information on parts and their relationships, he inserts basic information (shown in black) on a simplified work form; the parts analyst adds more information shown in color. This skeletal information is processed by PDPS, *yielding the machine-printed tab list below.*

ASSEMBLY NUMBER	P	LM NUMBER	CODE IDENT NO.	SIZE	ISSUE	ASSEMBLY TITLE	PROJ NO.	ASSY DWG SIZE	DATE	LM NUMBER	SHEET
D9768567	-	LM9768567		B	$-	CONVERTER SUBASSEMBLY	RS 190	D	15 FEB 63	TAB LIST	2 OF

FIND NO.	AGENCY PART NUMBER	AGENCY DRAWING NUMBER	PART NUMBER	SIZE	ISSUE	PART NAME AND DESCRIPTION	NO. REQD
2	7612728	B7612546	G 205413-1	A	GU	TERMINAL,LUG	3
4	8520063	B7619677	BA 10236-20	A	GU	INSULATION SLV,ELEC MIL-I-7444 BLK	1
6	8520890	A8520890	G 205841-22	A	GU	WIRE,ELECTRICAL,22AWG MIL-W-3861,TYPE S DR,ANLD & TIN COATED	1
8	9157788-52	C9157788	G 302433-52	A	GU	SCREW,MACHINE,PAN HD CRES,PASS 8-32NC-2A X 1/4	8
10			G 302457-6	A	GU	NUT,PLAIN,HEXAGON CRES,PASS,1/8 THK, 8-32NC-2B,11/32 AF	6
12	9157798-11	C9157798	G 221439-11	A	GU	WASHER,LOCK,SPLIT CRES,PAS[illegible]	14

LINE NO	NOMENCLATURE GENERATION 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	QTY REQ	SYS QTY	PART NO
0225	BRACKET,ANGLE	4	4	B9785944
0226	CONVERTER SUBASSEMBLY	1	1	D9768567
0227	TERMINAL,LUG	3	3	G 205413-1
0228	INSULATION SLV,ELEC	1	1	BA 10236-20
0229	WIRE,ELECTRICAL,22AWG	1	1	G 205841-22
0230	SCREW,MACHINE,PAN HD	8	8	G 302433-52
0231	NUT,PLAIN,HEXAGON	6	6	G 302457-6
0232	WASHER,LOCK,SPLIT	14	14	G 221439-11
0233	PIN,SHOULDER,HEADLESS	2	2	B9768180
0234	BRACKET,NETWORK	1	1	C9768570
0235	NUT,PLAIN,HEXAGON	2	2	G 302457-35
0236	SOLDER,LEAD-TIN ALLOY	a	1	GA 9017MET P
0237	SEALING COMPOUND	a	1	GA 9070L1
0238	NETWORK	3	3	GS 65341
0239	CAN	1	3	G 314745
0240	DISK	1	3	G 288875
0241	SCREW,TAPPING THREAD	1	3	G 272650-3
0242	SOLDER SN50 QQ-S-571	a	3	GA 9017MET P
0243	VARNISH MIL-V-173	a	3	GA 3087
0244	ADHESIVE PER A9726248	a	3	
0245	FIL,BAND PASS SUBASSY	1	3	G 314755
0246	BRACKET	1	3	G 314748
0247	PLATE	1	3	G 314749
0248	SPACER	1	3	G 314768
0249	CAPACITOR,FIXED,MICA,	1	3	G 334868F433D
0250	SCREW MACH FLAT HD	4	12	G 302066-237
0251	RIVET,TUBULAR	2	6	MS20450C885
0252	NUT,PLAIN,HEX BRS,TIN	2	6	MS35649-46
0253	WIRE ELEC 20 AWG	1	3	G 231720-2
0254	SOLDER SN50 QQ-S-571	a	3	GA 9017MET P
0255	ADHESIVE RUBBER RESIN	a	3	G 205548
0256	INDUCTOR ASSEMBLY	1	3	GA 11121
0257	COVER ASSEMBLY	1	3	G 314752
0258	TERMINAL FEEDTHRU,	4	12	GA 52178L1
0259	SOLDER SN50 QQ-S-571	a	3	GA 9017MET P
0260	COVER ASSEMBLY	1	3	G 314751
0261	BRACKET	1	3	G 314744
0262	BRACKET	1	3	G 314750
0263	SCREW MACH PAN HD	2	6	G 302531-2
0264	COVER	1	3	G 603901
[illegible]	...W MACH F HD	2	6	MS35245-18
[illegible]	...-SILVER CLASS 4	a	3	

Machine-printed "generation breakdown" provides project engineer with information on status of development of any level of equipment under his control, and quantities required for each item.

tities. This information is fed to output programs which produce the spare parts reports in the desired format. Spare parts maintenance programs also are available for advising the designer what has changed since the last report and for producing revised spare parts reports. A proposal is being studied for adding mortality formulae to the spare parts programs; this would further assist the designer in selecting and calculating the quantities of parts for which spares are needed.

PDPS will soon be serving another engineering area in the Laboratories. Programs are nearing completion that will combine component failure rate data with information from the parts data file to produce reliability predictions for various assemblies of equipment.

As mentioned earlier, the major gains are expected to accrue when the Western Electric Company implements its phases of the PDPS. During the past eight months, parts data files on magnetic tape have been delivered to Western Electric in North Carolina on a trial basis. Maintenance data on tape will be transmitted to update these files.

The flow of manufacturing information through the various functional areas in the North Carolina Works includes, in brief, these functions:

Engineering Analysis—determining what parts or materials are needed, "make or buy" decisions, source of items, where used, estimated costs, inspection and shrinkage requirements;

Ordering—summarizing quantities of like parts for the number of systems or subsystems on order, applications of schedule dates, checking against available material on hand, preparing purchase requisitions and interworks orders;

Purchasing—obtaining bids, selecting vendors, preparing and placing purchase orders;

Receiving—receipt of materials, verifying count and preparation of receiving reports;

Material Inspection—verifying conformance of received material to the requirements of purchase orders and associated drawings and specifications;

Storeroom Control—receipt and storage of material in the use area, preparation and maintenance of stock records, and selecting material for use by the assembly shops;

Manufacturing Layouts—detailed instructions to the shop on how to assemble and wire each assembly required to make up a product. Includes specifications of tooling and processes to be used;

Wage Incentives — establishment of standard time values, credit allowances, etc., against which to measure shop performance and to pay piece-work earnings;

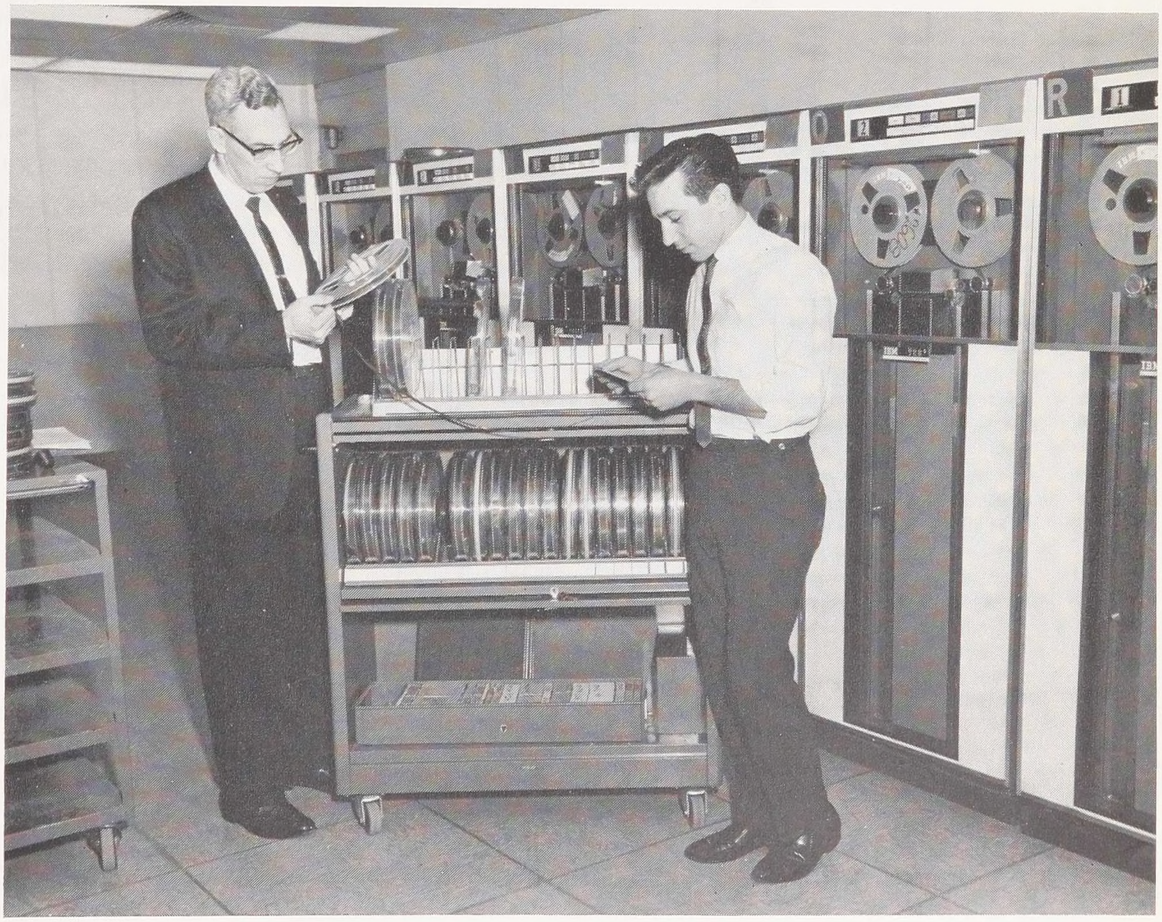
Assembly Scheduling—preparation of detailed schedules for the manufacture of assemblies at each generation level;

Shop Dispatching — daily implementation of schedules and recording progress.

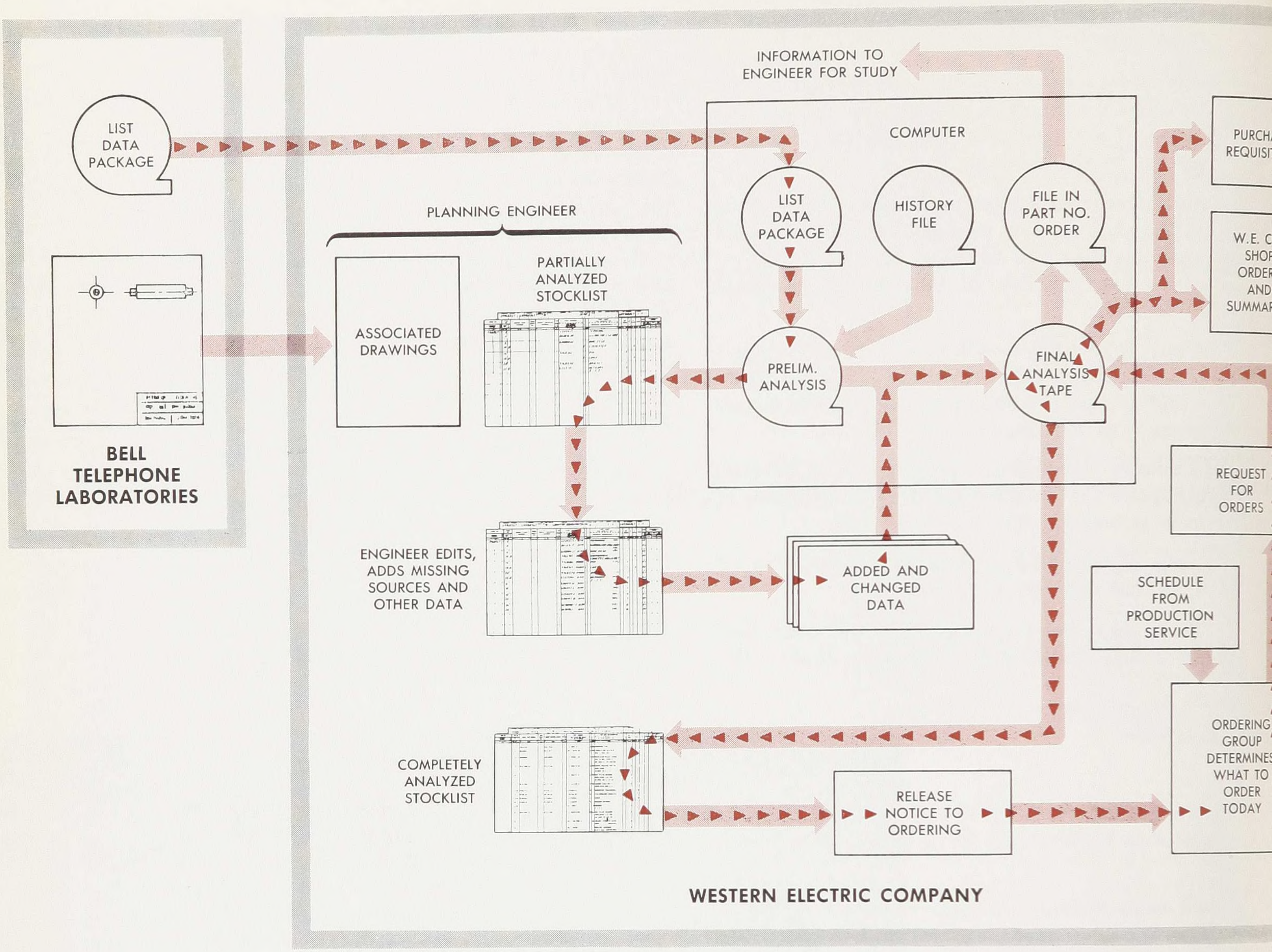
From these brief descriptions, it is clear that most of these functional areas have a direct interest in the information contained in Bell Laboratories parts data file. The Western Electric version of the file will contain a great deal of supplementary information needed by the functional groups listed above. As mentioned earlier, the Laboratories project engineers and designers will also find some of this information useful to them, so provisions for "feedback" are being incorporated in the integrated PDPS.

Programs are currently under development and test by Western Electric which make use of the tape files of parts data from Bell Laboratories to aid in the analysis and ordering functions. Some of the details of the proposed PDPS operations in the analysis and ordering areas are shown on page 302.

The flow of information processed by computer in the PDPS does not stop with the Western Electric Company. For central offices in the Bell System and for missile sites in the military services, great volumes of information concerning equipment and site configuration, and parts and assembly relationships, must be handled accurately and efficiently. Customers are making increasing use of computers for maintaining configuration con-



"PDPS Cart," shown in Whippany Computation Center, contains parts data file, screening file, and needed computer programs in its library of tapes.



Proposed use of PDPS in analysis function at Western Electric shows how program may be used.

trol and records of systems supplied by Western Electric.

From this it does not seem unreasonable to conclude that the transmission of information among the design, manufacture and field functions via volumes of paper is nearing an end.

Although much has been accomplished in the development of a computer-oriented parts data processing system, it is obvious that the system is still in its very early stages. New needs that the system can meet are continually becoming evident. Experience in operating the system is bringing to light new capabilities that weren't even thought of when programs were started several years ago.

As the systems analysts and programmers in this field build on their experience, improved procedures and programming techniques are developed. At the same time, new computer facilities bring new hardware capabilities to bear on the solution of problems in machine aids to design and data processing.

As development of the Parts Data Processing System continues, the project engineer, the designer, the draftsman, the manufacturing engineer and others will find new ways of making use of an increasingly powerful tool to free them from monotonous, low-level work that stifles creative effort. These uses, in turn, promise to enhance greatly the ability of the Bell System to serve its customers more effectively.

Modern technology has recently been intensively applied in the field of micro-miniaturization. The pinhead diode, a device much studied at Bell Laboratories, is well in the vanguard of this effort.

Pinhead Diodes

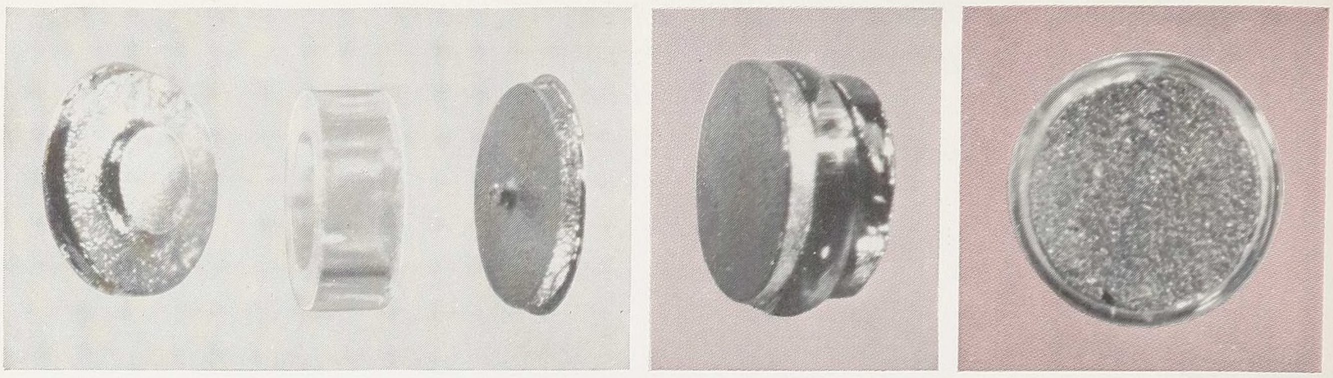
T. R. Robillard

ALTHOUGH TREMENDOUS STRIDES have been made in the semiconductor device art over the past decade, systems designers are increasing their demands for even smaller components. Having achieved true miniaturization of extremely complex electronic equipment through the use of lower power consumption semiconductor devices, systems engineers are now reaching toward the next goal of bread-box size computers and wrist radios—microminiaturization: The preferred way of achieving this goal—through integrated active and passive components, through individual microminiature components, or by using some form of hybrid integrated circuitry — has not yet been determined. The goal will be achieved in the near future, however, and the microminiature "pinhead" diode concept may well help to lead the way. Several types of pinhead diodes have been developed and are available for use in today's exploratory circuitry.

The most commonly used microminiature diode is the so-called computer or logic diode. This is an extremely fast switching diode which forms the backbone of several high-speed electronic systems. The design objectives set forth at the outset of the microminiature diode development program were threefold: to design (1) an ultra-small semiconductor diode of (2) high reliability at (3) a low cost. The pinhead computer diode is rapidly approaching these design objectives.

The generic title of "pinhead" quite accurately describes the approximate size of the diode. As shown on page 304. The diode is cylindrical; it has a diameter of 0.032 in. and height of about 0.015 in. The completed device is fabricated from three parts: a low-resistivity silicon "end-cap," the encapsulating glass cylinder, and the "active" silicon wafer. These parts, and a completed diode are shown on page 304.

The active wafer is fabricated in a rather standard fashion. Phosphorous (an n-type diffusant) and boron (a p-type diffusant) are diffused into opposite faces of a slice of n-type silicon. A pn junction is formed approximately 0.0015 in. from the boron-diffused face, and a low-ohmic resistance contact is formed across the phosphorus-diffused face. In addition to phosphorous and boron, gold is also diffused into the slice to reduce the lifetime of the electrically active carriers in the device. This, in turn, decreases the



These greatly enlarged sections show (l to r) the silicon end cap, the encapsulating glass cylinder, and the active silicon wafer. Two views of the completed diode are shown at right.

switching time of the diode. Next, active wafers containing a mesa approximately 0.005-in. in diameter are cut out of this slice using ultrasonic cutting methods.

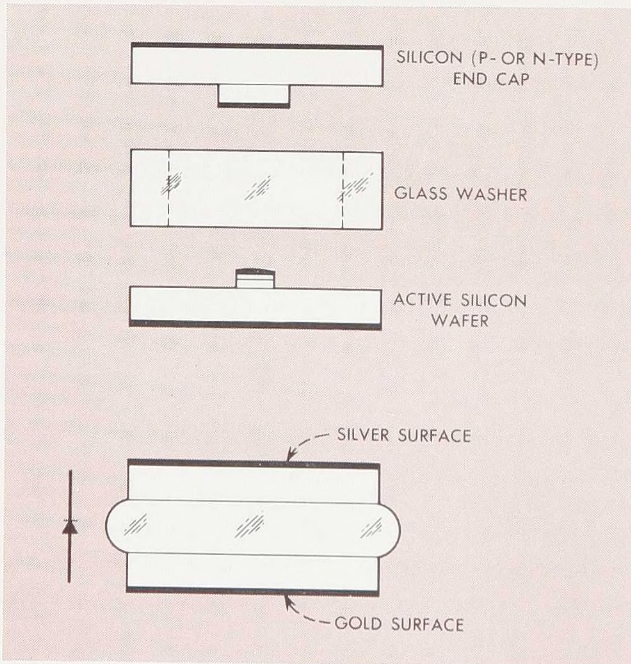
The end-cap is fabricated in a similar manner from very heavily doped silicon. A very high degree of doping insures that the end cap—which serves as part of the hermetically-sealed encapsulation—will have a negligibly small ohmic resistance. The hard glass cylinder is cut into 0.012-in. lengths from glass tubing, cleaned and is ready for use. To enhance the electrical properties of the device, the active region is chemically etched, and then the three cleaned parts are placed together on a magnetic susceptor in a radio frequency field. The radio frequency energy rapidly heats the susceptor and parts of the diode to approximately 800 degrees C; this, in turn, effects glass-to-silicon seals to both the end cap and active wafers. Simultaneously, an alloy bond is formed between the active mesa top and the opposite silicon end cap. Silver-plating one end (for polarity identification) completes the fabrication of the device.

Quite obviously, the device incorporates both the small-size and low-cost aspects of the initial objectives. The latter results from the minimal number of parts and operations required to complete the device. The typical electrical characteristics of this device are listed in the table on page 305.

Let us now consider the third and possibly the most important design objective: reliability. Synonymous with microminiaturization is the concept of a high density of components within a circuit module. Increasing the number of devices per module makes an increase in component reliability mandatory for successful circuit performance. The reliability of today's standard components will not be good enough for tomorrow's complex systems. Much of the burden for increased system reliability must be assumed by the semiconductor device designer.

Reliability means many things. True, it is of paramount importance how well the gross changes in the electrical characteristics are controlled under operating or storage conditions; but control of these changes does not, in itself, assure successful circuit performance. The overall properties (complete characterization) of any semiconductor device must insure mechanical and thermal operation of the device. The entire family of pinhead diodes has been designed to pass all of the environmental requirements outlined in the table on page 305.

It should be noted that these devices have been rated for extended high temperature storage at



Exploded cross-sectional and completed views of the pinhead diode. Overall dimensions are 0.032 in. in diameter and 0.015 in. in height.

250 degrees C. One way of rapidly determining the thermal reliability of this class of device is by resorting to the now well known technique of thermal step-stress aging (RECORD, *January*, 1962). To utilize this technique, a group of devices is held for a relatively short period of time (say, 2 hours) at an elevated temperature in excess of the long-term rating of the device. The number of failures at this stress level is recorded. The temperature is then increased and the same group of devices is held at this new stress level for the same length of time. The temperature is increased in steps until all of the devices are destroyed. This process is repeated for another group of devices from the same lot for a longer time (16 hours for example) and again with a third group of devices for a still longer time.

Reliability And Versatility

Proper interpretation of these data leads to an "acceleration curve" for a single class of devices as shown on page 306. This curve depicts the levels at which 50 per cent of each group of devices failed at each stress time. On this chart are plotted acceleration curves for three classes of diodes: Typical diodes with no form of surface protection, typical conventional package diodes protected with a planar layer of silicon oxide and pinhead diodes. It is quite obvious that the median failure temperature (50 per cent failure point) of the pinhead device is significantly higher than that of the other contemporary production device types. From the acceleration data, it is estimated that the time to median failure at a fixed temperature of 250° C is 3×10^6 hours and 5×10^{11} hours at 150° C. The basic reasons for this superior thermal reliability are: (1) sealing at extremely high temperatures which produces a dry, clean environment within the package, (2) scrupulous cleaning of parts prior to sealing, (3) the absence of all metal parts within the diode enclosure, and (4) the use of "hard" glass to enclose the device. It should be pointed out that thermal aging is only one of many tests used to evaluate device reliability.

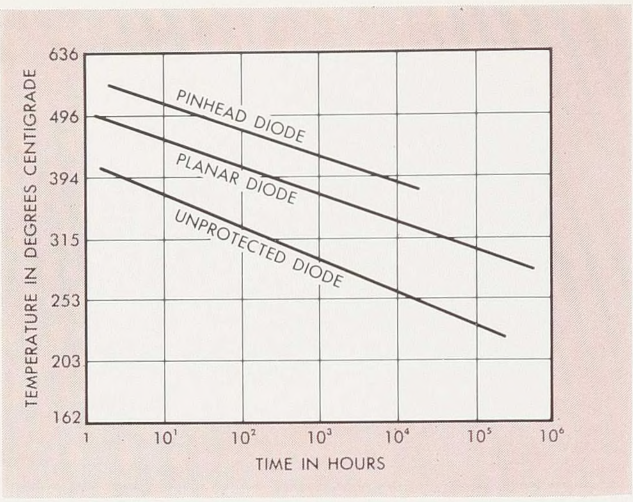
The pinhead diode approach is by no means limited to tiny high-speed diodes. Many types of devices—based on the design technology of the pinhead logic diode—have been fabricated. A medium-size, pinhead sandwich structure was used in fabricating medium-speed switching diodes, rectifiers, voltage regulator diodes, variable capacitor diodes and microwave parametric amplified devices. This structure is approximately 0.070 in. in diameter and 0.018 in. high. Another variation is shown on page 306; this triple-stacked sandwich structure is used in the design of a "level-shifter" device. The dimensions of this package are approximately 0.075 in. in diameter and 0.035 in. high. The application for such a device required a very slow diode with a controllably high forward voltage drop. This drop in voltage is achieved by stacking three diode wafers within a single package; the diode is made slow (large amount of stored charge) by suitably preserving the silicon bulk lifetime during the seal-

Reverse Recovery Time ($I_f = I_r = 10$ MA)	1.5 NS
Capacitance (Zero applied voltage)	1.4 PF
Forward Voltage ($I_F = 10$ MA dc)	0.86 V
Breakdown Voltage ($I_R = 5$ MA dc)	49 V
Reverse Current ($V_R = 20$ V dc)	3.6 NA

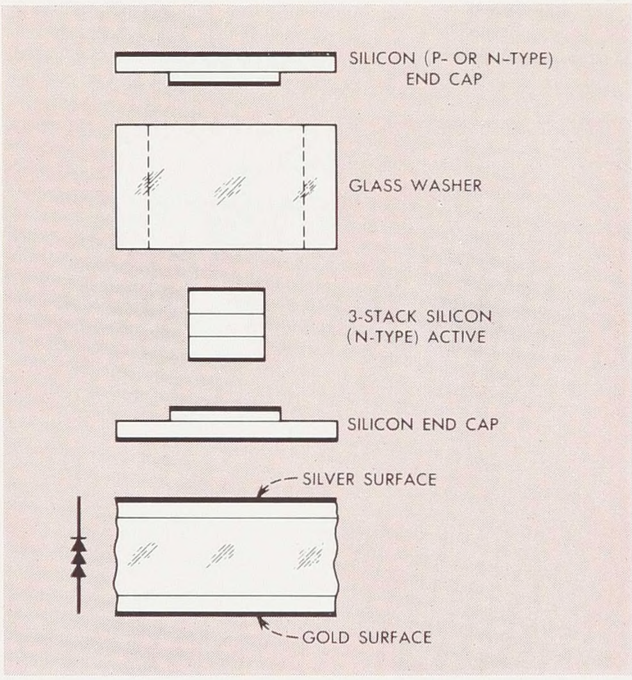
Typical electrical characteristics of logic pinhead diode.

Listing of the various environmental tests performed on pinhead diodes.

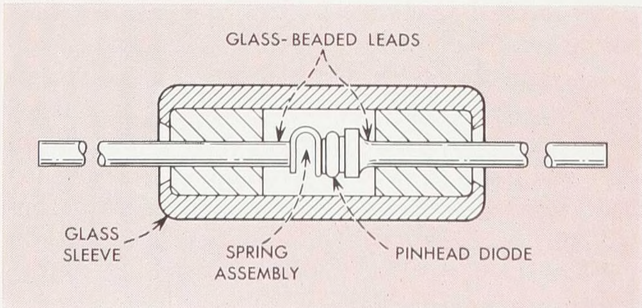
- Storage life (250°C)
- Operating life (100 MW, 100°C)
- Shock
- Constant acceleration
- Vibration fatigue
- Vibration variable frequency
- Temperature cycling
- Moisture resistance
- Salt atmosphere
- High temperature operation
- Surge current
- Dew point



Acceleration curves for three types of diodes. These curves show levels at which 50 percent of the devices failed at each stress level.



Exploded crossectional and completed views of pinhead level shifter. The use of triple stacked wafer results in high forward voltage drop.



Pinhead can be enclosed in small glass diode structure (above) for conventional applications.

in process. As might be expected the hot-glass seal-in technology is not particularly compatible with the design of both very high and very low-speed devices, and to effect the level-shifter design several fabrication procedures required extensive modification.

The versatility of the pinhead approach by no means stops with the fabrication of pinhead variations. Indeed, the basic pinhead lends itself readily to many possible mounting configurations. For conventional applications, the microminiature pinhead can be enclosed in a miniature glass diode package. This approach is shown at the bottom of this page. The basic pinhead device can also be used as a "passivated" wafer. Used in such a manner, this protected and stable element can subsequently be further enclosed—singularly or in multiple—in standard metal diode or transistor packages.

Device In Its Basic Form

Although these mounting configurations are practical, the true value of pinhead technology can be better appreciated when the device is used in its basic form. With such an approach, devices can be supplied premounted on various conducting or insulating substrates ready for interconnections at a systems level. In this manner, high-packing densities can be achieved and interconnecting wire circuitry can be simplified or eliminated. In addition, polarity reversal of a pinhead diode is a byproduct of the design.

Multiple assemblies also can be produced by "strip" mounting diodes on a common metallic substrate. To form such an assembly, the silicon end faces of the diodes are eutectic-bonded to a gold plated Kovar substrate at a temperature of approximately 400 degrees C. Soft soldering methods also can be used to attach lead wires to the diodes and to attach the diodes to equipment boards. Numerous other mounting arrangements are possible; and, indeed, many others have been tried. These two examples are illustrative, however, of a typical high-temperature multiple assembly supplied by a component manufacturer and of a multiple array which might be assembled at the equipment manufacturing location.

The pinhead diode represents a significant advance in semiconductor device technology. The basic device design offers potentially low cost and high reliability in a microminiature package. The basic pinhead approach as well as the possible mounting configurations are quite versatile and offer the systems designer greater latitude in equipment packaging. Further design and mounting arrangements are limited only by the imagination of device and systems designers.

To make connections between telephone offices, the T1 System uses not only a new method, but a new signaling language—binary pulses. Some unique circuit techniques were developed to adapt this language to the trunk signaling methods in present day exchange areas.

T1 Carrier System Signaling

A. L. Bonner and A. C. Longton

THE BASIC PURPOSE of every transmission facility in the Bell System is to provide a way for customers to exchange information. To set up the connections over which this can take place, switching systems themselves must exchange information. Signaling is the language of this exchange. It tells widely separated central offices how to establish connections, how to supervise them, and when to release them. The "alphabet" of the signaling language consists of only two letters—the two states of DC current. In systems using voice frequency circuits, any change in the DC condition is transmitted over wires which connect the transmitting and receiving ends of every circuit. In carrier systems there are no individual circuit connections and carrier signaling arrangements are designed, in effect, to replace them.

Signaling in analog carrier systems is performed by tones sent within, or just outside, the voice-band. The T1 Carrier System departs from the usual analog techniques. It uses pulse code modulation (PCM) for voice transmission. The unique nature of this technique has led to a new and quite novel method of signaling on carrier facilities—the transmission of signals in the form of pulses. Fundamentally speaking, the T1 System signals by extracting the DC conditions at one end of the circuit and transmitting them to the other end. At the receiving end, the signals that convey the DC conditions are reconstructed to appear just as they would if they had been transmitted by wire. Because DC signaling consists of only two states, any change in state is easily represented by one binary digit.

Binary pulses are the information content of the T1 System. The 24 speech channels of the system are sampled 8000 times a second and the samples are translated into seven-digit binary code groups. Thus there are 128 possible voltage levels, each one very closely approximating the amplitude of the voice sample it represents. It is a relatively simple matter to add an eighth, or signaling, bit to the seven-digit code group of each channel.

Adding this bit gives the T1 System an out-of-band signaling arrangement. This increases the required bandwidth slightly, but it has considerable economic advantage. An in-band signaling system (RECORD, *October,* 1960) transmits single frequency tones in the voice-band, and it must be designed so that speech does not interfere with the correct transfer of the signaling state. Complicated design steps are necessary to accomplish this and they are avoided with an out-of-band signaling system.

Actually, the nature of the existing telephone plant generated some of the most difficult problems encountered by the system designers. The T1 System was intended for metropolitan exchange areas. A number of trunk signaling methods are used in these areas and the system had to operate compatibly with them. However, some methods are not widely used and some may eventually fall into disuse. Therefore, the designers had to determine the most widely used methods, and decide on those they thought would prevail. Then, they examined the chosen trunk circuits for their similarities and their differences. On the basis of this information a design could be planned for the T1 System that would allow it to operate with many trunk circuits and with terminal equipment that could be adapted to these circuits.

Variations in Trunk Circuits

Trunk circuits vary widely even though interoffice signals are basically simple. Variations arise from many factors—the differences in the magnitude of the impedance that is required to open or close a loop, for example, or the variation in battery feed impedance due to the individual characteristics of the trunk relay circuits that supply battery voltage. One reason for the variety is simply the evolution of the telephone plant. Signaling was developed originally for short range circuits, then it was applied to intermediate range circuits, and finally to long range circuits. Trunk circuits changed as their applications changed. The number of them was further increased with the design of the various switching systems. This, in turn, led to signaling by dial pulsing, revertive pulsing, and E and M leads. These methods comprise almost all the signaling in metropolitan exchange areas.

Dial pulsing and revertive pulsing are two forms of loop signaling. In the forward direction of transmission (from the originating to the terminating office) these methods simply place an open or closure on the tip-and-ring conductors. In the opposite direction, the polarity of battery applied to the line indicates the status of a call. Revertive pulsing transmits, in addition, a ground pulse from the terminating to the originating end. This "revertive" pulse gives the method its name.

E and M lead signaling was developed to provide two like signaling paths, one in each direction of transmission, to make a two-way trunk. (A common mnemonic device to distinguish the direction of the flow of information over the leads is to call them trans*M*it and rec*E*ive leads.) The E and M leads are not a part of the transmission path, an arrangement that distinguishes this signaling method from loop signaling.

T1 Signaling Circuits

The task of adapting to the various kinds of trunk circuits and the different signaling methods rests with the signaling circuits of the T1 System channel units. A system terminal contains 24 of these units. Each has signal scanning and reconstructing circuits as well as circuits to terminate voice signals. Because the system has one cable pair for each direction of transmission, a four-wire terminating circuit is used to merge the paths for local switching. For four-wire toll switching the paths remain distinct, and voice amplifiers match the system transmission levels to toll levels. The table on page 309 shows the fundamental characteristics of the signals that the channel units were designed to extract and reconstruct and the similarities between them.

The similarities of these signals was one point of departure for the design of the channel units. The question was: What basic circuit configurations can be designed that will be adaptable to the different signaling methods? Clearly, the answer to this question lies in what is common to many techniques. For example, the drawing on page 310 shows how the system conveys dial pulses from an originating to a terminating office. A diode scanning gate placed across the loop detects open and closed conditions. When the gate detects an open loop, the diode conducts current. When the loop closes, the voltage across it keeps the diode from conducting. Channel pulses can pass to the output side of the gate only when the diode is conducting. The gate pulses are converted to a form suitable for transmission. At the terminating office a signaling amplifier produces a continuous current in response to regenerated pulse signals. The current supplied by a signaling amplifier controls a relay that operates each time the loop closes, thus reproducing the dial pulse condition at the terminating office.

TYPE	SIGNAL	ORIGINATING OFFICE		DIRECTION	TERMINATING OFFICE	
		Condition Office to Line	Condition Line to Office		Condition Line to Office	Condition Office to Line
E & M LEAD	On Hook	Ground on M		→	Open on E	
	Off Hook	Battery on M			Ground on E	
	On Hook		Open on E	←		Ground on M
	Off Hook		Ground on E			Battery on M
LOOP DIALING	On Hook	Open Tip & Ring		→	Open Tip & Ring	
	Off Hook	Close Tip & Ring			Close Tip & Ring	
	On Hook		Normal Battery	←		Normal Battery
	Off Hook		Reverse Battery			Reverse Battery
REVERTIVE PULSING	Start	Close Tip & Ring		→	Close Tip & Ring	
	Stop	Open Tip & Ring			Open Tip & Ring	
	Ground Pulse		Close Tip & Ring			Close Tip & Ring
	On Hook		Normal Battery	←		Normal Battery
	Off Hook		Reverse Battery			Reverse Battery

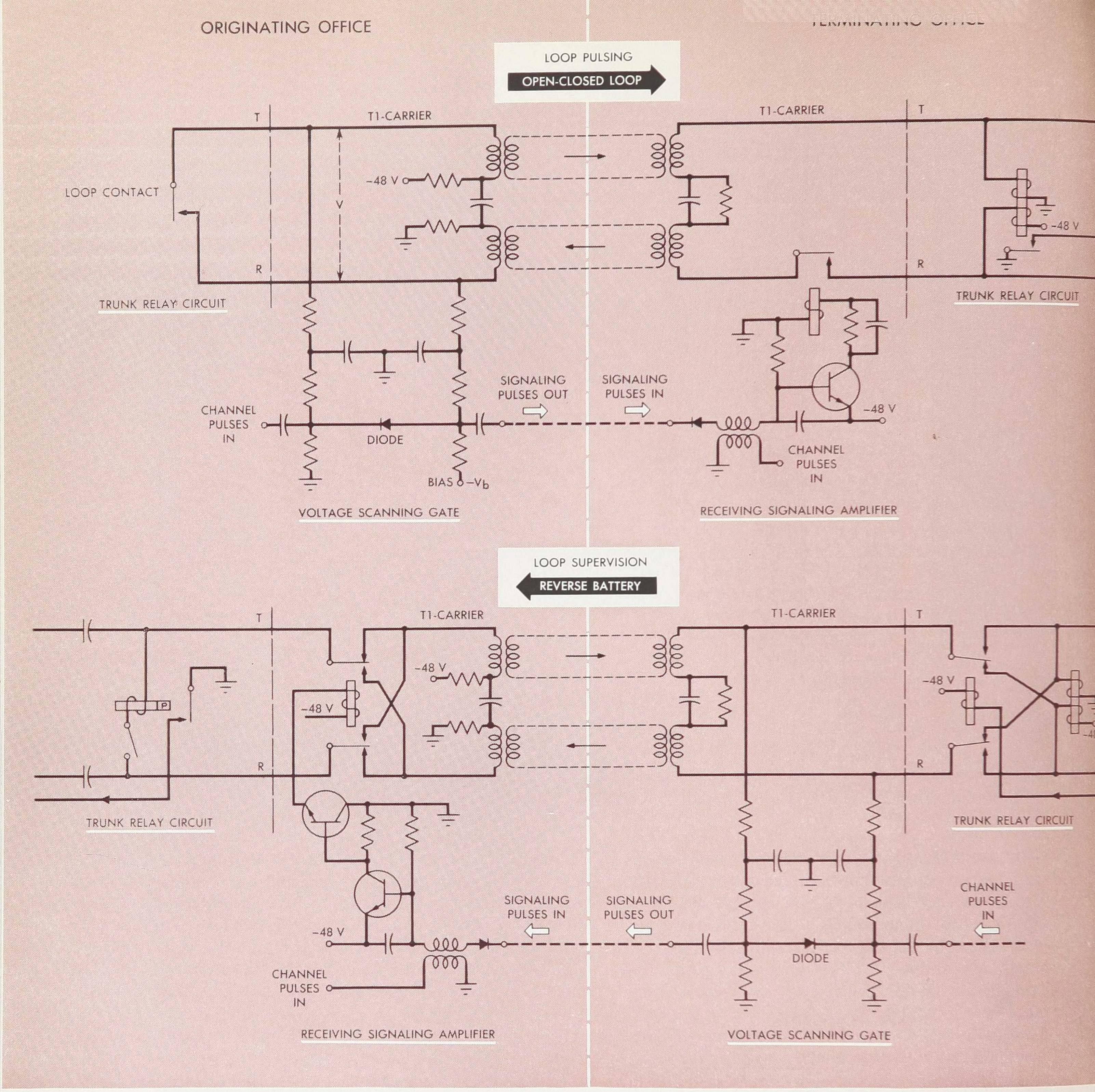
Fundamental characteristics of signals by which central offices communicate with each other.

The same techniques are used for reverse battery supervision, as shown in the lower drawing on page 310. In this case, the voltage scanning gate has no bias control. The gate will not pass pulses when the battery is reversed; that is, when voltage is applied to the tip conductor of the channel unit. When the battery polarity is normal, however; pulses appear on the output side of the gate in the terminating office channel unit. Corresponding pulses appear at the input to the signaling amplifier in the originating office. The channel unit circuits reconstruct the normal battery indication at the originating office.

T1 Signaling Scheme

These techniques are readily adaptable to the scheme of T1 System signaling (page 310). In this scheme, binary signaling pulses fit into the transmission pattern of the PCM speech pulses. An incoming PCM pulse train is composed of the eight-digit codes for the 24 channels. The signaling pulse—one digit in the eight—is separated from the voice code digits and regenerated by a signaling circuit common to all units in a terminal. Regeneration gives the pulse sufficient gain to operate an "AND" gate in the receiving part of the channel unit. Channel pulses time the gate at a rate of 8000 per second. When a signaling pulse and a channel pulse coincide, a pulse signifying the coincidence is fed into the receiving amplifier where it is stored during the time between adjacent pulse positions. The receiving amplifier controls a relay which reconstructs the signaling on the office side of the hybrid circuit that, in turn, separates the transmitting and receiving parts of the speech signals. When pulses arrive at the proper rate, the amplifier holds the relay released. If the pulses stop, and do not continue after a specific interval, the relay operates.

ON and OFF binary pulses that carry the signaling information are transmitted to the common signaling circuit in two groups—each group represents 12 channels. The duration of the pulses—fixed by the speech sampling process—is four PCM digits. The common signaling circuit



The T1 method of signaling. Top half of the drawing shows how the system signals with the dial pulses from an originating to a terminating office. The bottom half shows how reverse battery supervision is carried in the opposite direction from terminating office to originating office.

translates any channel pulse at its input to a single digit positioned to fit into the pattern of the PCM digits that convey speech information.

This is the basic scheme for T1 System signaling. Its pattern is duplicated and expanded, as shown in the drawing on page 312, to perform all the necessary system signaling functions at both the originating and terminating ends of exchange trunks.

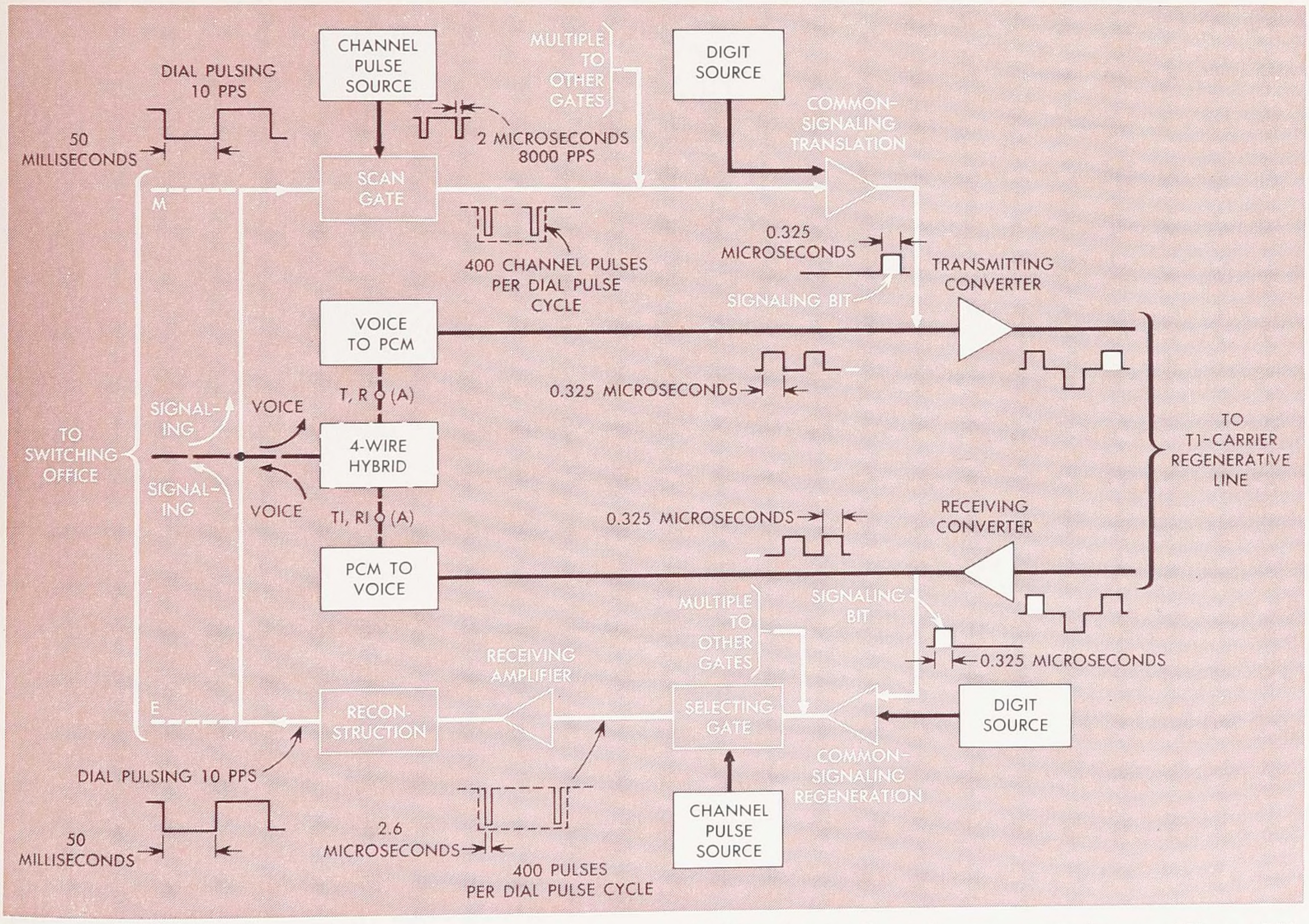
Additional signaling information must be transmitted for revertive pulsing. To handle it, another binary channel with scanning and reconstruction circuits is added to the T1 System terminal. Revertive pulse systems (panel switching systems, for example) store the dialed digits in a sender. The sender gives the scanning gate a closed loop indication to send forward. As it receives this indication, the panel equipment at the terminating end begins to move over a bank of contacts. As it moves, the equipment sends backward ("revertive") pulses to mark its position for the sender. The sender opens the loop as a stop signal when the equipment has reached the correct contact. The revertive pulsing phase is completed before the called party answers and, therefore, before reverse battery supervision exists. Thus, the T1 System does not need an additional binary digit for revertive pulses; it merely "borrows" the least significant speech digit, uses it to transmit revertive pulses, and returns it to the PCM train when reverse battery is present.

E and M lead signaling is handled almost exactly like dial pulsing and revertive pulsing. The only difference is that the switching office and the carrier signaling systems exchange information over separate E and M leads instead of over the voice channel tip-and-ring leads. Therefore, the scanning gate is connected to the M lead and biased so that ground on the M lead results in the transmission of pulses. When battery is placed on the lead, pulses are not transmitted. These two conditions are reconstructed at the terminating office as an open or a grounded E lead, respectively.

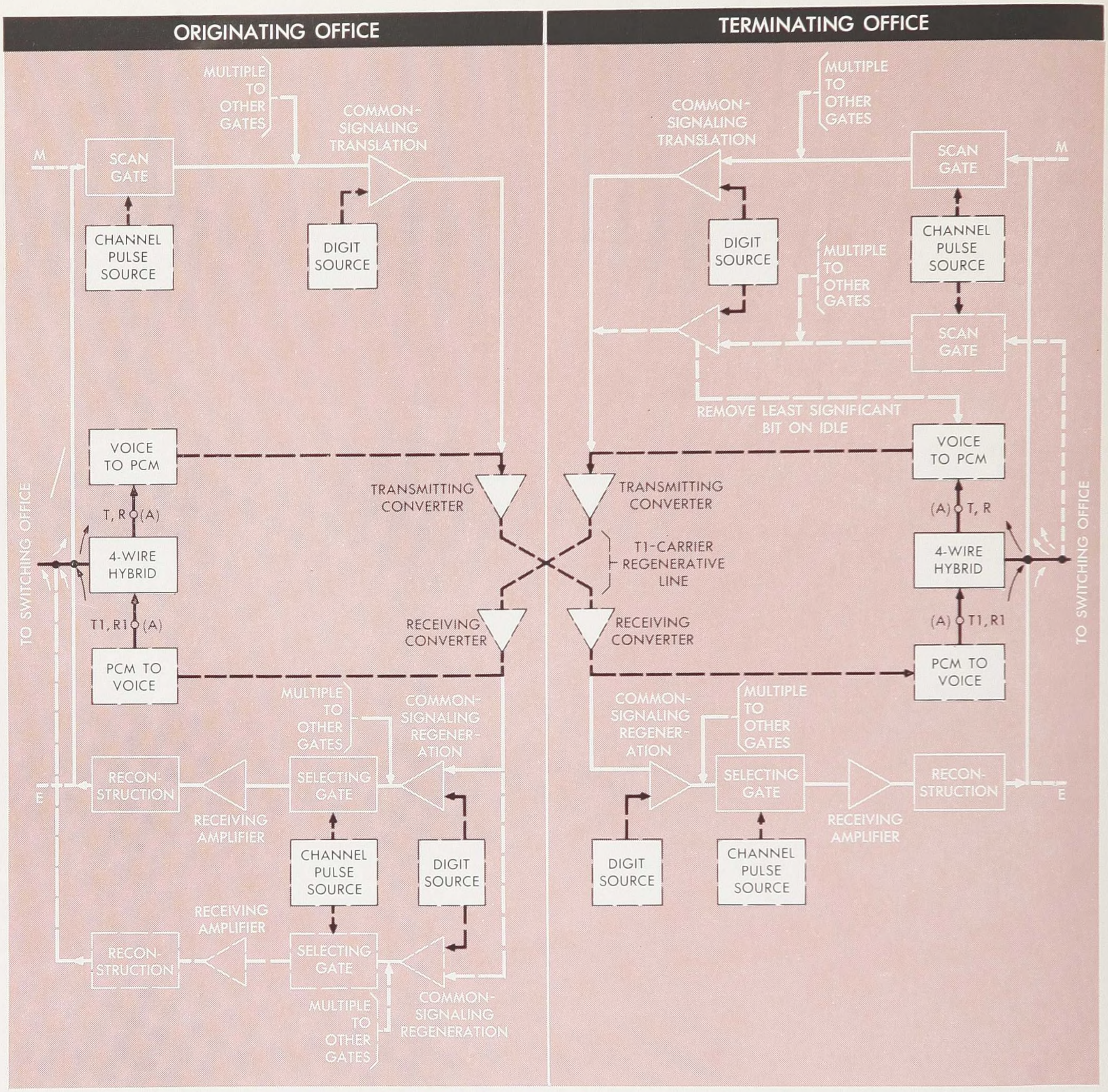
Multifrequency pulsing for the T1 System is merely a special case of dial pulsing. Tones used to transmit the dialed number are coded in the same way voice is coded. The DC loop voltages which control and supervise the connection are handled by the dial pulsing channel unit.

Five Channel Units Designed

In both the economic and the engineering sense, these arrangements have been highly successful. Only five kinds of channel units have been designed, and with them, or combinations of them, the T1 System can be equipped to handle essentially all exchange area methods of signaling



Basic scheme for T1 System signaling: Incoming pulse in the signaling position is separated from PCM pulse train and regenerated; providing additional gain to operate selecting gate.



In the T1 System, the basic signaling scheme is duplicated in both originating and terminating offices. The one basic design is used to perform all signaling functions at either end of a circuit.

independent of the type of switching center. Two of the five units serve the originating end of the system; there is one for each of the two loop signaling methods. Two others serve the terminating end; there is one for dial pulsing and one for revertive pulsing. On one-way trunks, the units at the terminating end simulate the DC conditions of the originating switching office; at the opposite end, they terminate the outgoing trunk equipment as a terminating office would. Because loop signaling methods are used on local direct trunks, these four units are equipped with four-wire terminating circuits.

The fifth unit was designed to be used with E and M lead signaling and it provides standard four-wire toll transmission and impedance levels. It does not have the four-wire terminating circuit. Instead, the four-wire tip-and-ring voice frequency leads are connected to the channel unit amplifiers and the E and M leads are connected separately to the "built-in" signaling circuits. This unit provides the flexibility that is needed to connect the T1 System to E-type signaling units and to other circuits such as those used for foreign exchange signaling.

Common to all five channel units is the basic scanning gate and signal amplifier circuits. As a matter of fact, the diode scanning gate is a unique characteristic of T1 System signaling, one that distinguishes it from voice frequency signaling systems. The gate is designed with a low shunting loss to speech signals and it is connected across the loop in a balanced configuration so that it does not disturb the voice circuit. In operation, the gate continually changes from a forward to a reverse biased state according to the pulsing speed on the loop. If the gate is to cope with the different methods of signaling, its operating point must be shifted for each one. This is effected merely by changing its bias voltage so that the scanning process can take place over various DC voltage ranges.

Economy of the Design

One of the major system objectives was economical terminals. The design of the channel units, of course, had to contribute to this objective. Toward this end, the units consist of semiconductor devices integrated with relays. Semiconductor devices conserve space and power; relays are inexpensive and their contacts will serve to isolate the control action from the loop. For example, a mercury relay reconstructs the open or closed loop condition of an originating circuit. The signaling channel is designed so that the operate and release time of this relay are approximately equal. This yields a signaling channel that is virtually free of pulse distortion. On the other hand, for reverse battery supervision low pulse distortion is not much of a factor, but an adequate number of contacts to effect the reversal of the battery is important. For this function, a wire spring relay was completely suitable.

The first applications of the T1 System have proved the economy of this design. Easy maintenance has been one feature of the signaling system, because channel units are rapidly and easily interchanged. The units use only -48 volts and only those signals generated internally by the system terminal. Their small size allows three terminals (72 system channels) to be installed in an eleven and one-half foot bay. This is not only an economical arrangement, but one that has proved well suited to the engineering of central office equipment for carrier transmission.

New Wall Phone Joins TOUCH - TONE Family

One of the newest members of the Bell System's TOUCH-TONE telephone family is a streamlined wall model that can also solve tight wall space problems.

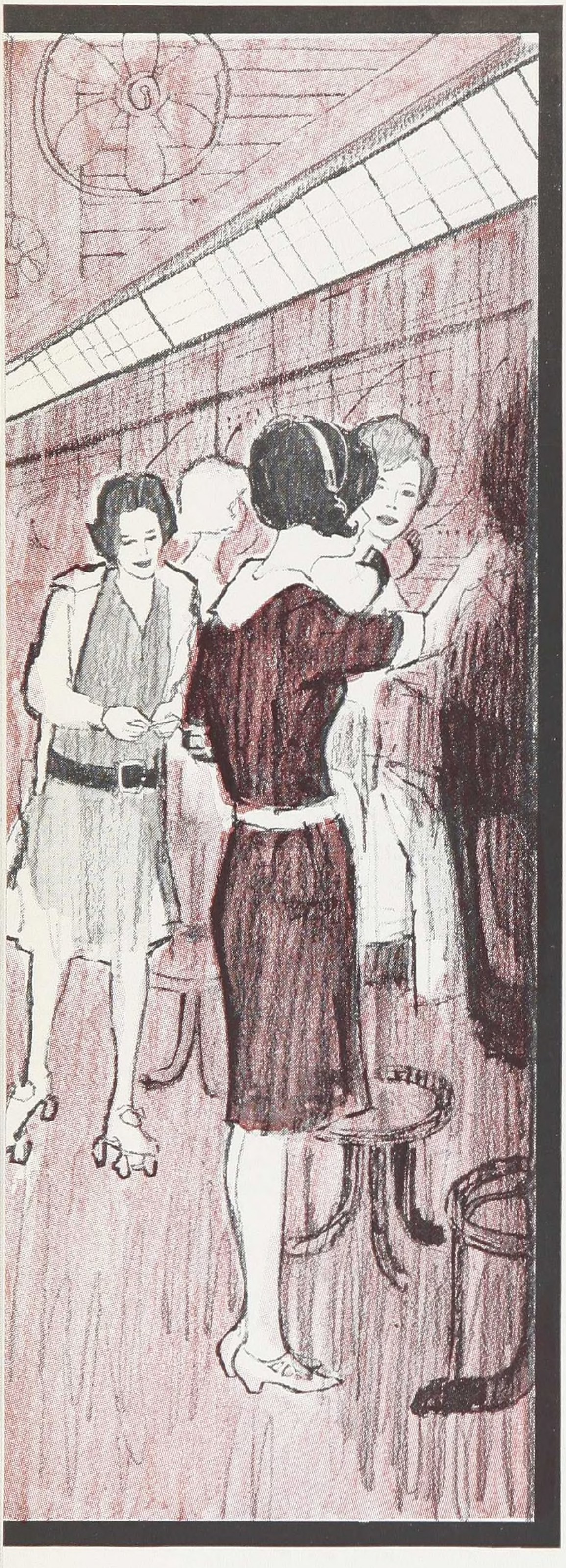
Set for production in the fall at Western Electric's Indianapolis Works, this pushbutton phone has all the virtues of other newly-developed TOUCH-TONE models and some that are distinctly its own.

Its main advantage, of course, is the new pushbutton method of calling. The new wall telephone is also smaller in every dimension than its predecessor, the rotary dial wall set. Its width is $4\frac{1}{4}$ inches, length, $8\frac{3}{4}$ inches, and depth, including handset, $4\frac{1}{2}$ inches—reductions of an inch or more in each case.

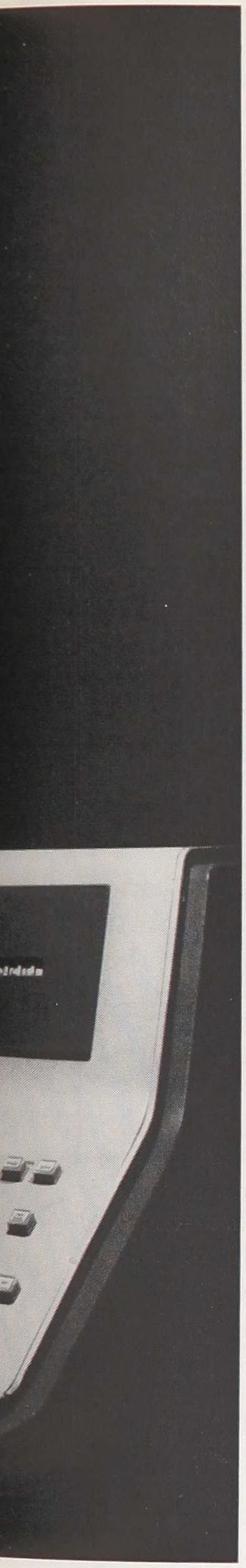
Bell Laboratories' engineers at Indianapolis used the reduced size of the pushbutton caller and the use of a smaller internal network and ringer in designing the new unit for production.

Advanced model shop samples for the new wall telephone are now being tested for public response in Findlay, Ohio, and Greensburg, Pa. About 5,000 of the new wall phones are expected to roll off the production line by the end of the year.

A new member of the Bell System's TOUCH-TONE line is this streamlined wall model.



Operator training, casual in decades past, is as modern today



R. D. Kroning and D. H. Gale

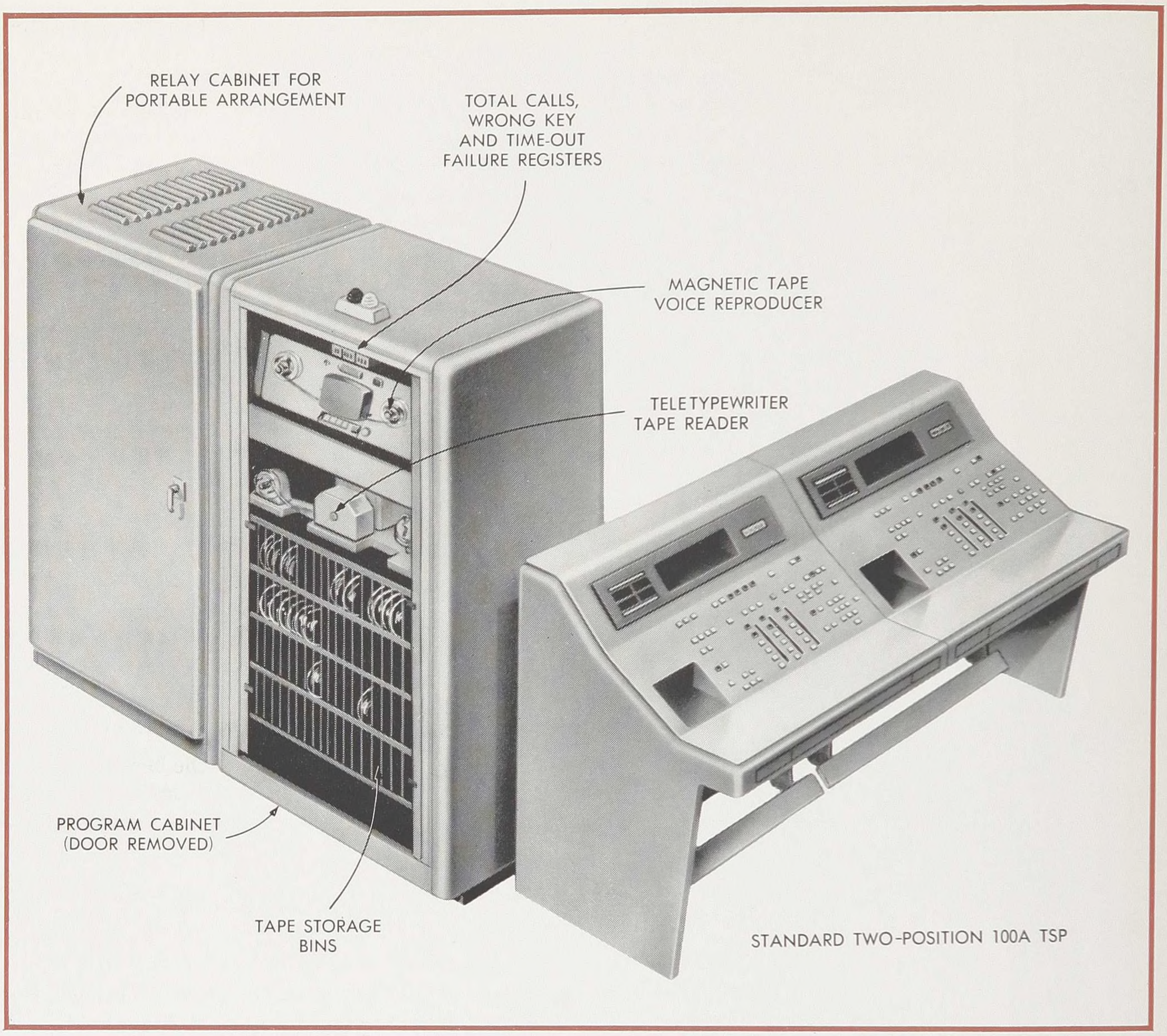
Automatic Training

For Operators of the 100A TSP

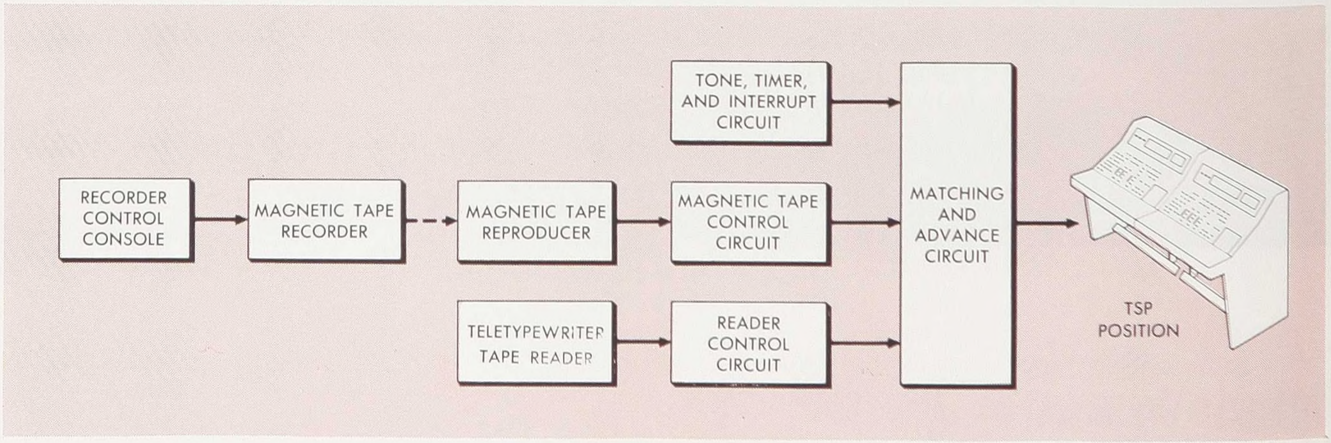
JUST A FEW DECADES AGO visitors to a busy toll operating room might have mistaken it, at first glance, for a skating rink. Girls on roller skates glided back and forth carrying toll-call tickets between the operators at the recording switchboard positions and the operators at the positions used to complete calls. It is unlikely that the girls were given formal training in roller skating, but training operators in the specialized skills of operating a switchboard is undoubtedly as old as the first switchboard itself.

Since the times of those youthful wheeled messengers, operator training in the Bell System has taken many forms, probably beginning with a trainee simply watching and listening in on an operator at a working switchboard position. Later special training equipment was developed; it usually included a modified operating position and a special instructor's position or control console. The instructor could originate practice calls to the student operator by sending lamp signals and tones over the training circuits to the training position. The instructor also played the part of the customer and the distant operator on a toll call, observed the student's responses, and offered help and assistance on her operating technique and efficiency.

ment now in use.



The layout of a typical installation of the 100A TSP automatic training equipment. Drawing shows the two-position action and the program unit and control unit for the left-hand position—the only one in use in this situation. When the right-hand position is used a second set of cabinets, back-to-back, is added to the layout.



The block diagram shows the circuit elements which constitute the automatic training equipment. This is a permanent installation. A power-supply is added for a portable installation.

The development of automatic training equipment for the 100A Traffic Service Position (TSP) introduces the use of a stored program to control training calls. The program, contained on punched paper tape, controls training circuits which, in turn, control lamps, number displays, and audible signals for the student at the training position. The circuits also recognize the student's operating errors and inform her when she makes one. Voices of customers and distant operators are simulated as they would occur on actual calls and recorded on magnetic tape that is played back to the trainee in conjunction with the lamp and tone signals controlled by the paper tape. An instructor will be needed only on occasions where she can present new material or practice more effectively or efficiently than the stored program, or when the student has unusual difficulty, as might occur in the very early stages of training. For these occasions, the instructor will probably work with the student while the equipment operates automatically. In certain instances, special tapes for manual use will be prepared, with the instructor controlling the advance of the paper tape and assuming the role of the customer and the distant operator.

This technique is a major advance in the training process. Economically, the advantages are obvious. There are other marked advantages: The student is more relaxed than she is with an instructor auditing her performance and can concentrate more fully on the task. The automated "teacher" has infinite patience, is tireless, immune to distraction, and can have—through careful programming—as thorough a knowledge of the subject matter as any expert in the field.

The 100A TSP

The 100A TSP is not a switchboard—only calls that require operator assistance are routed through it, such as person-to-person, collect, and other special types of toll calls (RECORD, *August* 1960), as well as all types of coin long-distance calls and Centralized Automatic Message Accounting calls. It is designed so that the operator need be in on the connection only for the minimum time necessary. The position has three "loops" or call channels, the functional counterparts of the cord circuits on a cord switchboard. Ten NIXIE* lamps in two groups of three lamps each and one group of four lamps, are mounted in the upright part of the position. They display 7-digit calling numbers, 7 or 10-digit called numbers, 2 or 3-digit charge amounts, 2-digit minutes quantities, and 3-digit rate codes.

Automatic training equipment for this position, shown opposite, consists of a standard 2-position TSP section with minor modifications; a program unit containing a two-channel tape reproducer and a teletypewriter tape reader; and a control unit consisting of a large relay circuit, a fuse panel, and a cross-connecting field. There are two design versions—a portable arrangement to be moved between different locations as it is needed for pre-cutover training, and a fixed arrangement for replacement training at one location. In the portable arrangement the relay equipment is mounted in a cabinet and connected by plug-ended cables; in the fixed arrangement it is mounted in relay racks in the terminal room of a central office and permanently cabled. Relatively simple modifications make a standard 100A TSP into a training position. Only the left hand and middle of the three "links" are used in a training position. They are represented by the sets of keys and lamps adjacent to the ticket slots which are cut vertically into the lower center section of the key-shelf. A combined key and lamp, designated Position Transfer Left, is redesignated Failure, and is used to indicate a trainee error. A second key-lamp, designated Position Transfer Right, is redesignated Advance, and is used to advance the program and magnetic tape at the beginning of a training exercise or after any error or failure. Three message registers, mounted in the upper section of the program unit cabinet, count completed training calls as well as wrong key or time-out failures the trainee may make.

Each numerical display on the "NIXIE" lamps is controlled by a special training code in the program. The specific digits for each display are determined by cross-connection assignments locally wired into a "NIXIE" display cross-connection field. The equipment can produce for display a total of ten called numbers, four calling numbers, six charge amounts, four minutes quantities, and three rate codes.

Training Equipment Circuits

The teletypewriter tape is the source of all signals to light, flash, and extinguish position lamps and to start signal tones and stop them when they are not self-limiting. It also contains signals to start simulated customer or distant operator speech, and to set-up checking conditions for all key operations and vocal responses by the trainee. The tape also controls certain functions of the training circuits, such as stopping its own advance and switching between checking (read) functions and simulated circuit action (write) functions. However, the teletypewriter tape codes that control the signals for these equipment functions

* Trade Mark, The Burroughs Co.

must first be translated into a form acceptable by the training equipment circuits.

The translation is performed by the Reader Control Circuit (see page 316). Its first step is to change the standard teletypewriter code into a 1-out-of-26 characters code designated by the letters of the alphabet. These are then grouped in pairs and transmitted to the Matching and Advance circuit which effects the lighting or flashing of all keyshelf and "NIXIE" display lamps and the connection or generation of the interrupter pulsing signals and the audible signals and tones produced by the Tone, Timer, and Interrupter circuit. The Matching and Advance Circuit also checks the trainee's responses and, in conjunction with the Reader Control Circuit, starts and stops the teletypewriter tape at certain checking points in the program and when the trainee has made an error.

Customer and distant operator speech is recorded on one of the two channels of the magnetic tape. Pulses of two different levels of amplitude are impressed on the second channel. The smaller signal stops the tape at the end of each voice message, and the greater one is used as an end of program mark to synchronize the teletypewriter and magnetic tapes at the start of a new program (i.e. one training call) and after any accelerated advance to the next program which may occur, for instance, after a trainee error or translator alarm. Audible signals and tones are generated within the training circuits rather than recorded on the magnetic tape because when the equipment is operated manually the instructor simulates customers' and operators' voices and the magnetic tape is not used.

Supervisor of the control unit merely loads tapes into the cabinet to prepare the equipment for a training session. Here, she adjusts magnetic tape reels. Teletypewriter tape is in the tape reader just above the storage bins.

Training Position Prepared

A training position is prepared for a training session simply by loading the teletypewriter and magnetic tapes into the teletypewriter tape reader and magnetic tape reproducer machines. The trainee then plugs her headset into the telephone jacks and operates the Advance key. This causes the magnetic tape to advance to its beginning; the teletypewriter tape also advances to its beginning and starts its first activities.

Each call program is divided into discrete parts, or segments. At the beginning of a training call, the teletypewriter tape sets up checking conditions for the trainee responses required for the first segment, then it activates the various lamp and audible signals that occur at the beginning of the call. These signals appear on the position, and the tape stops at the end of the segment. If the trainee makes the correct key operations and vocal responses, the checking circuits of the Matching and Advance Circuit signal the teletypewriter reader to advance the tape into the next segment.

This alternating situation-and-response by-play between the program and the trainee continues smoothly through one call and into the next unless the trainee makes an error. If she operates a wrong key, or fails to operate a key or make a vocal response within a prescribed time, the circuit action stops immediately, a failure lamp lights or flashes, and a failure register scores the error. The trainee then operates the Advance key and the tapes are skipped over the rest of the incorrectly handled call and then advance normally into the next call on the program tape.

Ideally, the program must present the trainee with a training situation that exactly duplicates an actual working situation. A call can be analyzed as a number of natural groups of events that occur between its initiation and its completion. For example, a group of lamps light on the position accompanied by an audible signal to the operator

SPL TOLL LAMP LIGHTS	ACS LAMP LIGHTS	CLD LAMP LIGHTS	ZIP TONE	TSP OPR SPEAKS: ("MAY I HELP YOU?")	CLG CUST REPLIES: ("MR. BROWN, PLEASE")	TSP OPR SPEAKS: ("THANK YOU")	TSP OPR HITS PERS PAID KEY
1	2	3	4	5	6	7	8

PERS PAID LAMP LIGHTS	AUD RING STARTS	AUD RING STOPS	CLD LAMP OUT	DISTANCE PBX OPR SPEAKS: ("FIRST NATIONAL BANK")	TSP OPR SPEAKS: ("MR. BROWN, PLEASE, LONG DISTANCE CALLING")	PBX OPR, CLD AND CLG CUSTS SPEAK: ("ONE MOMENT, PLEASE"... "BROWN SPEAKING"... "HELLO, MR. BROWN, THIS IS RICHARD SMITH"... "HELLO, DICK"...
9	10	11	12	13	14	15

TSP OPR HITS ST TMG KEY	ST TMG LAMP LIGHTS	TSP OPR HITS POS RLS KEY	SPL TOLL LAMP OUT	ACS LAMP OUT	PERS PAID LAMP OUT	ST TMG LAMP OUT
16	17	18	19	20	21	22

The actions that constitute a typical person-to-person paid call that will be handled by the TSP.

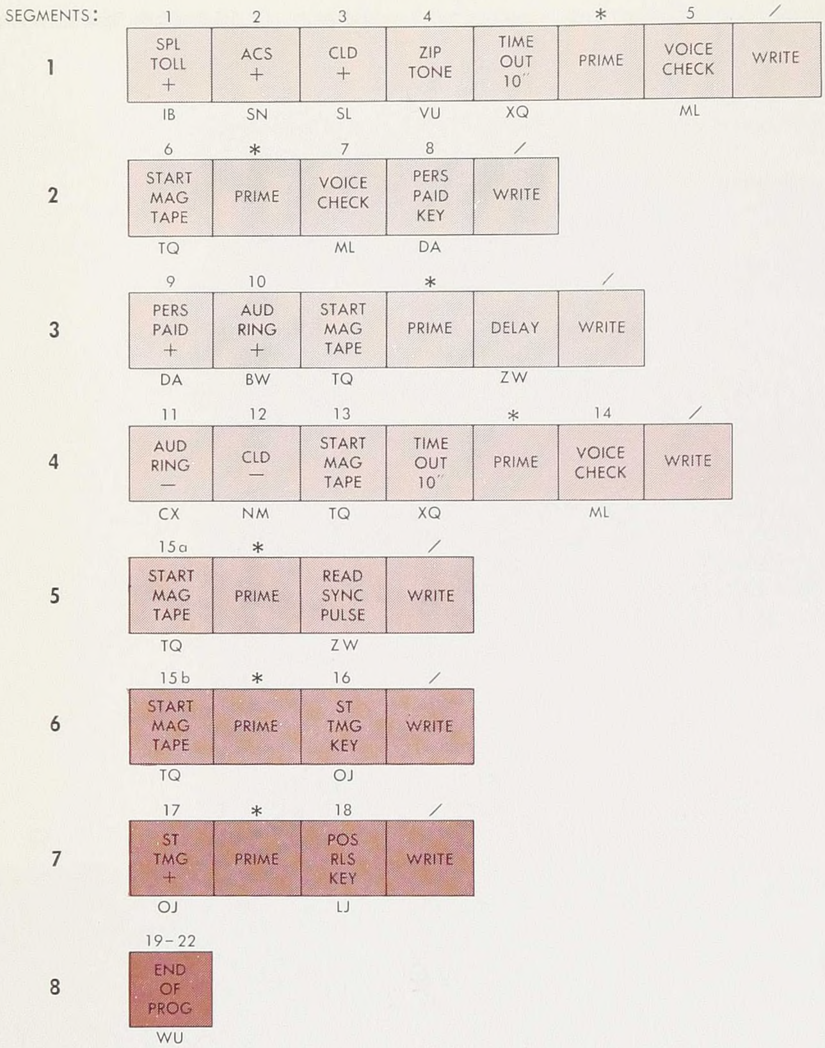
indicating that a customer has initiated a call, and the operator offers assistance. Each program segment constitutes one such group of events. The program tape is stopped at the end of each segment. If the trainee has properly performed the actions required in the segment, the tape is restarted and the next segment is run.

Each segment, then, controls one function, or one group of functions, performed by the equipment and it also checks the trainee's response. "Write" or control codes are assigned to the equipment functions, and "read" or checking codes to the trainee's responses. These codes are the alphabetic pairs from the Reader Control Circuit. Actually, the circuit yields only 185 separate codes—not enough to meet all training requirements. Therefore, many of the alphabetic pairs are used both as a "read" function code and a "write" function code. Most of the double-purpose codes are assigned to functions related to the combined key-lamps in the position; as a "read" function they serve as checking codes on the operation of the keys, as a "write" function they control the lighting of the built-in lamps. They are differentiated on the tape as "read" or "write" functions according to whether they precede or follow a transfer code known as *prime* (teletypewriter code *space*). *Prime* is one of two control codes included in every program segment. The second control code, called *write,* stops the tape at the end of each segment. Both of these control codes are single-character codes.

Principles of Programming

Let's examine the principles involved in programming for TSP training by designing the actual program for a person-to-person paid toll call. For this call, the customer will dial "0" followed by the seven or ten digits of the called number. During the few seconds in which the call is being connected through the switching network, the calling customer is connected to the TSP operator who ascertains from the customer the assistance he requires. She then prepares the charging equipment for the particular type of call by operating a class of charge key. After the talking connection is established to the desired called party, she operates another key to start the charge timing equipment, and then disconnects her position from the call.

The first step in programming this call is to list all the separate events that occur. These can be determined simply by directly observing and monitoring an operator as she actually handles a



The segmented program. The numbers above the boxes correspond to the equivalent events shown on page 319. The letter pair under each box is the teletypewriter code pair that is assigned to it.

call. The separate events occurring in a typical call of this type are listed above. Each event is numbered so that it can be easily followed through the remaining programming steps.

The next step is to group the events into segments. Into the numerical listing of the events we insert slant symbols (/) to indicate the segment divisions, and asterisks to separate the events within each segment into "write" and "read" groupings, respectively, thus: 1 2 3 4*5/ 6*7 8/9 10 11 12 13*14/15*16/17*18/19 20 21 22.

Timing Intervals

The next step is to program the proper timing intervals as they are required between the events of the call. Such intervals apply, for example, to the length of time a continuous equipment function, such as audible ringing, should be allowed to continue. Other examples are the time-out intervals allotted for the responses by the trainee, which, if exceeded, result in failures scored on the time-out register. Also, at this time, the program is examined and amended as needed in other ways to make the simulation of the call and the desired responses more realistic and in accordance with operating practices. This usually results in the addition of more codes and segments.

Amended Program

The amended program with the added codes and segments is shown at left. The asterisk and slant symbols are replaced by the equivalent code designations *prime* and *write,* and the wording of the events, as expressed on page 319, is changed to standard code terminology. To illustrate, the code for verifying a vocal response by the trainee (e.g., events on page 319 is called "Voice Check," and the code corresponding to customer or distant operator speech is called "Start Mag Tape."

The changes over the original program are now easily seen. In segment 1, the code "Time-Out 10" has been added to give the trainee ten seconds to recognize the type of call and make the proper response. In segment 4, a similar 10 second time-out allows sufficient time for a relatively long response to be made by the trainee.

Segments 3 and 4 have been derived from the original segment 3, and include two new codes, "Start Mag Tape" and "Delay." These codes are added to control a time interval between the start and end of audible ringing.

Both the audible ringing generator and the magnetic tape are started in segment 3. This time, however, the tape contains only a blank or unrecorded segment with the usual end-of-segment tone pulse at the end. This pulse stops the magnetic tape automatically. The running time of the blank segment is made equal to the time it takes for the called customer to answer.

In addition, a special "read" code called *Delay* is added in segment 3, while the code that stops the audible ringing is placed in segment 4, as are the codes for other events that occur when the called customer answers. Just as a regular "read" code holds up the advance of the teletypewriter into a new segment until it is cleared by the proper trainee response, the *Delay* code prevents the teletypewriter tape from advancing into segment 4 and cutting off the ringing until the magnetic tape reaches the tone pulse at the end of the blank segment. In other words, this "read" code is cleared, not by any action of the trainee, but by the tone pulse on the magnetic tape.

Segments 5 and 6 are the result of splitting the original segment 4 into two to meet a requirement of the operating practice for this type of call. A number of conversational interchanges take place to determine that the proper party has answered, as shown at event 15 on page 319. The proper operator response, after this event, is to operate the ST TMG key to start charge timing. However, in this situation timing must not be started on the initial response by the called party ("Hello", or "Brown speaking") but only after an indication that the proper called party has been reached and that the conversation will continue. Therefore, the checking code on the operation of the ST TMG key must not be fed into the matching circuitry until the magnetic tape reaches the desired point in the conversation. Thus if the trainee prematurely starts charge timing on the call, she will be charged with an error because she has operated a key whose corresponding "read" code has not yet been transmitted.

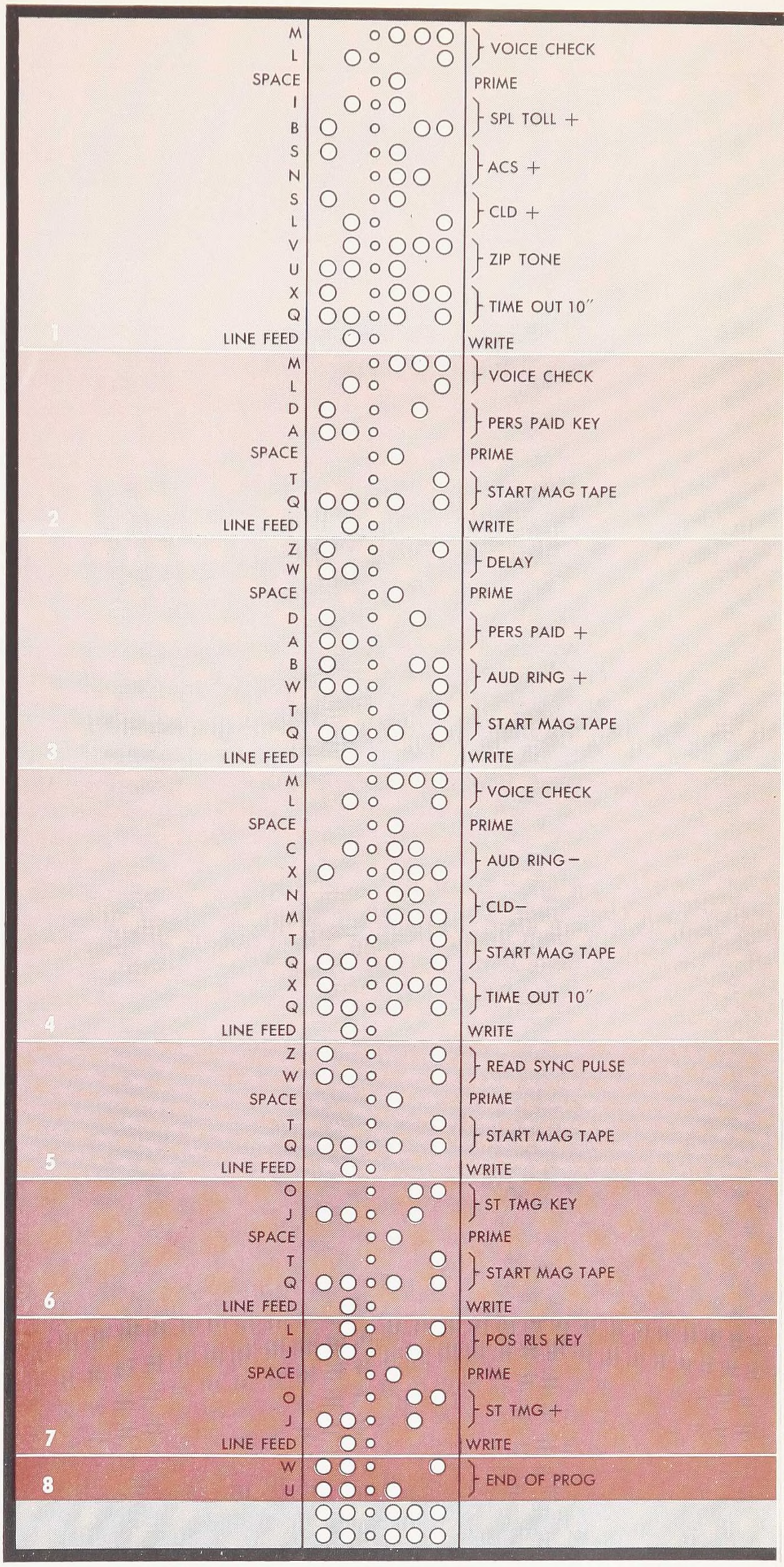
Segment 5, therefore, contains the initial conversational exchanges, plus the *Read Sync Pulse* code, which holds up the advance of the program tape until the magnetic tape stops. Segment 6 contains the remainder of the conversation, plus the "read" code for the ST TMG key.

In Segment 8, the end-of-program code extinguishes all lamps that are still lighted.

Completing the Program

The limitation of the operating speed of the tape reader necessitates one final manipulation of the program. If the individual "read" and "write" code groups of each segment were set on the teletypewriter tape in the true time sequence of the corresponding groups of events in the actual call, the trainee could respond to an indication in a "write" grouping before the tape had advanced far enough to transmit the "read" or checking code for the response. To prevent this, the checking codes must be programmed before the "write" codes. The completed teletypewriter tape program for the call is shown at right, with the "read" and "write" portions of each segment transposed with respect to their positions in the segmented program.

The two disciplines of teaching and training are closely related, especially in their practical applications. Operator training in the Bell System includes a certain amount of straightforward transfer of information. In fact, the 100A TSP automatic training equipment, especially when it is operated in the manual mode, will be used in teaching or demonstrating operating practices. However, its primary purpose is to help develop highly skilled TSP operators by providing one means for concentrated practice under realistic conditions.



A rendering of the teletypewriter paper tape containing a completed program for a person-to-person paid call through a 100A TSP. Right side of the tape lists the call actions; on the left are the teletypewriter code letters assigned to each one.

news in brief

J. B. Fisk to Serve on Governor's Committee

James B. Fisk, Laboratories President, has accepted an invitation to serve on the Governor's Committee on New Jersey Higher Education. The announcement was made recently by N. J. Governor Richard J. Hughes.

Chairman of the new committee is Dr. Carroll V. Newsom, vice chairman of the Board of Directors for Prentice Hall, Inc. and former president of New York University.

Other committee members are Dr. James Hillier, Vice President of RCA Laboratories and Director of Research for the David Sarnoff Research Center; Dr. Millicent C. McIntosh, President-emeritus of Barnard College; and Dr. James A. Perkins, Vice President of the Carnegie Corporation and President-elect of Cornell University.

The committee will make a broad study of New Jersey's resources of higher education, both public and private, and evaluate their effectiveness in providing quality education to an ever-increasing number of students.

According to Governor Hughes, one of the principal aims of the study is to determine the facilities needed to produce trained personnel for New Jersey's business, industrial, scientific, and cultural development.

Antenna for Space Communications Developed

William Steier of the Guided Wave Systems Research Center is the codeveloper of an unusual gas-discharge antenna for spacecraft. The antenna is designed to prevent disruption of high-frequency radio signals as spacecraft re-enter the earth's atmosphere. Such signals are disrupted by gas discharge from the hull of the satellite as it heats up in collision with the air. Working with Irving Kaufman of the Space Technology Laboratories at Los Angeles, Mr. Steier discovered that the gas itself can be used as an antenna, thus maintaining communications.

When gas isn't present, as in space, Mr. Steier says an antenna could be created by a gas discharge from the satellite. This would eliminate the necessity of building metal antennas on the satellite with the attendant construction problems and the damages resulting from the extremes of heat and cold.

Mr. Steier was first interested in the antenna problem in the summer of 1961 while he was a consultant at the Space Technology Laboratories. He was also a member of the electrical engineering faculty of the University of Illinois at that time.

Award to Bell Labs Employee

Edwin P. Felch, director of the missile and guidance laboratory for Bell Telephone Laboratories, has received the "Commander's Award" of the U.S. Air Force's Ballistics Systems Division.

The presentation was made to Felch at Norton Air Force Base, San Bernardino, California, by Brig. General John L. McCoy, deputy commander of the ballistics systems division.

The award cited Felch for his work on the design and development of the Bell Labs command guidance system and technical direction of the Remington Rand Univac computer effort for the Titan I weapons system.

New Cable Ship Completes First Assignment

The Cable ship *Long Lines* completed laying a 1,300-mile section of a transatlantic telephone cable that will link the U. S. mainland directly with England. This was the first project for the Bell System's new cable ship.

C. S. *Long Lines* is now proceeding towards Southampton, England, where she will pick up 1,600 miles of cable for the final segment.

The single cable system—to extend from Tuckerton, N. J., to Widemouth in Cornwall, England—is a joint project of the Long Lines Department of A.T.&T. and the British Post Office. It is scheduled for service in October and will be able to transmit 128 simultaneous conversations. The *Alert*, a British Post Office ship, placed the shore-ends both in England and the U. S.

Plans for two new underseas telephone cables were announced recently by A.T.&T.

One cable will stretch 1,500 miles under the Pacific Ocean between Guam and the Philippine Islands. The other will link Florida with St. Thomas in the Virgin Islands. Both systems, which will be laid by C. S. *Long Lines*, will be able to transmit 128 simultaneous conversations.

The Pacific project, scheduled for completion by late 1964, is a joint undertaking of A.T.&T. and the Philippine Long Distance Telephone Co. The Hawaiian Telephone Co., Radio Communications, Inc., and Kokusai Denshin Denwa Co., Ltd. also will participate.

A.T.&T. and ITT Communications, Inc. will jointly participate in the completion of the Caribbean cable. The Service date is set for 1965.

The new Caribbean cable will be the main route for United States-Virgin Islands telephone traffic. It will be connected to a St. Thomas-Puerto Rico microwave radio system. The cable also can be extended to other points.

J. F. Poole

The demand for telephone service grows constantly. To meet it, the Bell System is often engaged in the task of modifying older systems, such as the panel switching offices, for new features and services.

The New Numbering Plan In Panel Switching Offices

New telephone switching techniques, while they improve service for customers, may necessitate changes in the telephone network that create a new set of problems for the Bell System. The new numbering plan is such a change. It brings Direct Distance Dialing (DDD) facilities to telephone customers, and makes possible other new services. At the same time, it presents the Bell System with the problem of how to modify existing equipment for the new features without interrupting telephone service on this equipment. A case in point is a Bell Laboratories project to adapt panel switching offices to the new numbering plan.

The present numbering plan, a combination of letters and numbers, yields only 540 central office codes and 152 area codes. These are not enough to meet the continually increasing demand for telephone service. The new numbering plan will increase the possible central office codes to 792 and area codes to a theoretical 800 (Record, *March* 1962). It will accomplish the first by All Number Calling (ANC) and the second by permitting any number to be used in the second digit of the area code where the present numbering plan permits only "0" or "1". Office codes and area codes will be interchangeable in the new numbering plan, and a feature will be added to panel switching offices to indicate which use of a code is intended. The new numbering plan also introduces a new form of prefix dialing to panel offices — prefix "1" will be used for sent-paid station-to-station toll access and prefix "0" will be used to increase the mechanization of certain toll calls such as person-to-person, credit card, and collect calls which will be routed through a new traffic service position. Most of the changes to adapt panel offices to these new numbering plan features will consist of modifying the sender, the decoder-connector, and the decoder.

A panel office subscriber sender is equipped with a register circuit that can record eight digits. On DDD calls, ten digits are dialed and the other two are recorded in an auxiliary sender circuit (Record, *June* 1957). The sender transmits the first three digits it records—the area or office code—through the decoder-connector to the decoder which translates them and returns routing information to the sender. On the basis of the information from the decoder, together with the remaining digits it has registered, the sender controls the routing of the call to the called telephone. When a customer dials "0" for operator assistance, the decoder translates the "0" as an instruction to the sender to complete the call to an operator.

Modifications for Prefix Dialing

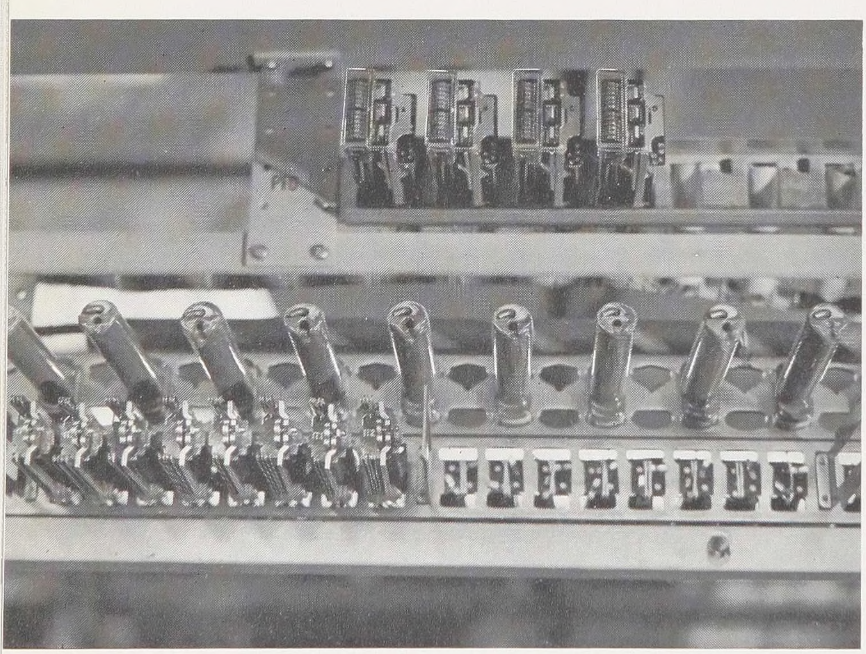
To adapt panel offices for prefix dialing, new relays will be added to the sender and decoder to record and translate these prefixes. Special registers or prefix counters, that will record a first-dialed "1" or a first-dialed "0", will be added to panel senders. Under the new numbering plan an "0" dialed as the first digit may be either a prefix indicating a special toll call, or it may be the familiar operator-assistance signal. The sender must distinguish which it is. To do this, the sender will divert an "0" from the A (first digit) register and record it on the prefix counter. Then, the sender must wait to see if other digits follow the "0". The intersender timing circuitry, a part of the sender, will be modified to time for a three-to-six second waiting period. If other digits are recorded during this period, the "0" will be treated as a prefix.

A further consequence of prefix dialing is that the panel sender must tell the decoder whether a prefix "0", a prefix "1", or no prefix has been dialed. Existing connecting leads through the decoder-connector will be reused to transmit this information. The leads will be designated LA (Local Area) and PF (prefix). The plan for use of LA and PF signals is shown in the chart opposite.

This chart also shows conditions registered in the sender and the decoder action requested. Included in these conditions are those for the recycle feature which has been provided in panel offices to allow continued use of existing routes to adjacent numbering plan areas. The recycle feature pretranslates an area code so that the sender can release these adjacent area code digits and complete the call on the existing seven digit routes. The recycle feature also signals on compressed code (CC) leads to the decoder that this function has been accomplished.

Let's take a more detailed look at how the modified system will process prefix calls. A "0" dialed as the first digit will be stored in the prefix register which immediately will begin to time the waiting period for additional digits. If the "0" is for the operator, the decoder will be seized at the end of the timeout period and signals will be transmitted over the PF and LA leads. If the "0" is a prefix, the timer will stop as soon as the A digit is dialed. The decoder will be seized when the C digit is registered. The sender then will transmit LA and PF signals and the A, B, and C digits; at the same time it will place a signal on a presently unused lead to the auxiliary sender to indicate a prefix "0" call. The auxiliary sender, in turn, will change the multifrequency start pulse to a new frequency combination which is a signal to the traffic service position that this is a special toll call. In this way, the same trunks can be used for both prefix "1" and prefix "0". For prefix "1" calls, the "1" will be transferred to the prefix register. When no prefix is dialed, the sender merely will record the first three digits on the A, B, and C registers. The decoder then will be seized and the three digits will be transmitted to it along with the LA lead signal.

Another problem arising from prefix dialing is how to arrange "route screening". These calls cannot be screened through the existing class-of-service relays, because the decoder cross-connection field is densely wired in panel systems and it cannot be easily expanded. Furthermore, the route relays in the decoder circuit are not arranged for "route advance" in panel systems as they are in crossbar systems. If the prefix "1" is dialed when it is not needed, or if it is not dialed when it is needed, the call must be diverted to an announcement trunk and not completed over the route that the actual dialed digits indicate. If the prefix "0" is dialed, the call must be routed to



The prefix counters that will be added to the top of a bay of four senders in the panel system to handle prefix "1" and prefix "0" calls. Existing intersender timing relays (below the resistors) were reused and additional relays (above the resistors) were added for this function.

CONDITION REGISTERED IN SENDER										SIGNALS FROM SENDER TO DECODER			DECODER ACTION REQUESTED							
													Use translator for:							
													Local area				Area code ‡		Adja-cent area	
													Screen for prefix				Screen for prefix		Screen for prefix	
First decoder seizure	Second decoder seizure	"0" operator	No prefix-X11 or 7 or 10 digit code	Recycle CC plus 7 digit code	Prefix "0"	Prefix "1"	11X code (Service or test)	10 digit code	7 or 10 digit code	Prefix information	Compressed code information	Code digits	None	"0"	"1"	Not screened	"0"	"1"	None	"1"
X		X								LA, PF										
X				*	X				X	LA, PF		A-,B-,C-		X						
X			X							LA		A-,B-,C-	X							
X						X			X	PF		A-,B-,C-			X					
X				X		X			X	PF	CC0-8	A-,B-,C-			X					X
X							X			PF		A1,B1,C-				X				
X				X		†			X		CC0-8	A-,B-,C-	X						X	†
	X					X		X		PF	CC9	A-,B-,C-						X		
	X				X			X		LA, PF	CC9	A-,B-,C-					X			

* Dialing of prefix "0" cancels the recycle feature

† An option permits the decoder to complete recycled calls without prefix "1"

‡ This translator is used when a 10 digit toll code and a 7 digit toll code are interchangeable

Plan for signals through decoder-connector to introduce prefix dialing to panel switching offices.

the traffic service position and not completed to the original route. This will be accomplished by a technique called route group screening in which the decoder uses prefix screening relays to control the battery supply of groups of route relays.

Under the present numbering plan, the "0" and "1" in the B (or second digit) position control the request for an auxiliary sender on DDD calls. Under the new numbering plan any code can be an area code and the control of the auxiliary sender will be a function of the decoder which will instruct the sender to call in an auxiliary sender.

Interchangeable Office and Area Codes

Before the system can handle interchangeable area and office codes, the decoder must be arranged to transmit special information to the sender. Generally, the decoder will be able to translate and select a route from the prefix and the A, B, and C digits. However, with prefix "1" dialing within an area, identical office and area codes may be preceded by the same prefix, though they require different routes. In this case the decoder may not be able to determine if the three digits are an office code or an area code.

If the decoder is unable to determine the routing of a call from the prefix and the code, it will signal the sender to count the digits for that call. With this feature, on every call, the decoder will tell the sender to (1) complete the call after seven digits, or (2) complete the call after ten digits, or (3) count the digits. If the last order is given, the sender will count the digits and tell the decoder if the A, B, and C digits are to be translated as an office code or an area code. There are no spare leads through the decoder connector to pass these signals and it would be difficult to add new leads. Therefore, an analysis was made of all existing leads to determine if there were any that could be reused for the new function. The analysis showed that the existing stations

SD SIGNALS FROM DECODER TO SENDER								
Station Delay		Previous application (X Denotes features no longer used)					New application for new numbering plan	
Designation	Indication	Manual office	Step-by-step, panel, or crossbar local office	Operator 1 & 3 digit permanent signal or 3 digit vacant code	Multi-frequency tandem	5 digit vacant code	Release decoder & count digits; call auxiliary sender	Expect 10 digits; call auxiliary sender
A	None	Numbers over 9999; party letters					✓	
B	SD	Numbers over 9999; no party letters						✓
C	SD SD1	No numbers over 9999; no party letters	7 digits dialed	None 1, 3, 7 or 10 digits dialed	7 digits dialed (Decoder operates 7 DG relay)			
D	SD1	No numbers over 9999; party letters	High 5 Incoming group "B" office		8 or 10 digits dialed	7, 8 or 10 digits dialed		

Station delay signals and their applications in various types of offices and systems.

delay leads would suit the purpose.

Stations delay (SD) information is part of the route information derived from the contacts of the route relays. In existing panel offices, SD information helps the sender determine: (1) if it must wait for a digit to be dialed into the station register; (2) the order of out-pulsing panel call indicator signals over a trunk to a manual office; (3) if—on calls to crossbar offices—additional revertive pulses should be transmitted for incoming group selections to indicate the called office. Revertive pulses will select between two offices of a combined crossbar terminating unit when both are served by one common trunk group. They will also indicate that a theoretical designation is being called for rate discrimination when one trunk group serves both the physical and theoretical designations.

Some station delay information for manual offices will no longer be needed because the plan for DDD eliminates central office numbers above 9999 and party letters. Thus, of the four combinations of station delay signals — designated A, B, C and D — transmitted to the sender over the SD and SD1 leads, two will no longer be useful. It was decided to reuse signals A and B for the new numbering plan as shown above. The A signal will be used as a request from the decoder to the sender to count digits on seven and ten-digit calls when area and office codes are interchangeable. The B signal will be used as a request from the decoder to the sender for an auxiliary sender. On both seven and ten-digit routes, the auxiliary sender will provide MF outpulsing; on ten digit calls it will also handle the additional digits.

Routing procedure for interchangeable codes will require a rather complex series of actions in the decoder. If the decoder can identify the routing of a call from the code and prefix, it will give the sender routing information immediately. If the code is ambiguous, the decoder will give the sender routing information for a seven-digit route and simultaneously command it to count digits. The sender will start timing after the seventh digit to see if more digits will follow. It will also select an auxiliary sender to handle the additional digits. If an eighth digit is not registered in the three to six second timing interval, the auxiliary sender will be released and the call will be completed to the seven-digit route. If an eighth digit is registered, the sender will immediately release all route information recording relays and makes a second connection to the decoder. The decoder will then call in an ambiguous (interchangeable) code translator to translate the A, B, and C digits as an area code. There is one translator in the decoder of existing panel systems; the additional area code translator will be added to the system to handle ambiguous codes. Both are necessary because different translations of the A, B, and C digits are required depending on whether the codes are to be translated as an office or an area code.

With these changes, panel switching systems, although they are old in the Bell System, will bring the new numbering plan features to the customers they serve. To the telephone customer, the Bell System network may seem a finished thing, its shape and structure settled for today and for the future. Actually, as this article illustrates, it is constantly growing and changing. This growth and change is directed toward one end—improved telephone service.

Author J. F. Poole makes tests on a bay of Laboratory panel equipment that has been modified to accommodate the new numbering plan features.

Computer-made Movies Aid Satellite Research

Perspective movies, computed and drawn by an electronic data processing system, are helping scientists at the Laboratories in visualizing the motions of an orbiting communications satellite.

The computer-made animated movies not only enable scientists to see the complex motions of a satellite tumbling through space, but also provide a way of communicating the results of mathematical research with far greater clarity than possible with a written report.

Dr. E. E. Zajac, of the Mathematics and Mechanics Reseach Center, described the new technique last month at a meeting of the Association For Computing Machinery in Denver, Colorado.

Dr. Zajac has been studying the angular motions of a satellite oriented by gravity gradient torques and containing an attitude control system consisting of two single-axis gyros. Control of a satellite's attitude is desirable so that the satellite's antenna can be kept pointing towards the earth. The computer-made movies enable Dr. Zajac to see, more easily than by inspecting the plots of satellite axis angles versus time, how the control system works.

He programs an IBM 7090 digital computer to generate a magnetic tape containing the data necessary for describing sequential perspective drawings of the satellite's position and attitude.

The tape is given to a General Dynamics/Electronics SC 4020 Recorder, which converts the digital data into line drawings on the face of a special type of cathode-ray tube. Images on the face of the tube are photographed by a motion picture camera. When the film is developed, a movie is obtained, with each frame an accurately-drawn perspective picture of the satellite.

The cost of the computer-made movies depends on how complicated the picture is. Objects whose shapes are easily described mathematically are simplest to depict and least expensive. Complicated shapes and several objects require more complicated programming. The movie of the satellite required about three to eight minutes of IBM computer time for computing the drawings for one minute of movie at 16 frames per second.

Dr. Zajac said that in addition to depicting satellite motions, computer-made movies are useful for depicting other sequential events, such as simulation of shock waves and explosions, missile trajectories, wave propagation and flow processes.

New Cable Wards Off Gophers

Telephone cables buried in certain areas of the country west of the Mississippi River are now coated or wrapped in steel. The reason for the protective covering: gophers.

The gopher, about a foot long, somehow knows that its incisors will grow and soon pierce its brain if not periodically filed down. Buried telephone cables offer the perfect file.

Before Western Electric designed the new extra-strength cables, the unarmored lines—thick as a man's arm—could be stripped to their wire cores in just a few weeks by these rodents. Short circuits, phone disruptions and costly repairs were the results.

One species—the pocket gopher—is so prevalent that farmers often attack it with poison or rifles. These gophers are extremely hard to find since they seldom appear above ground. Their sharp hearing, to compensate for near blindness, can detect a man's footsteps yards away. The gophers may desert a spot temporarily but they return—often to the same spot where they were burrowing or stropping their teeth on telephone cables.

The need to protect telephone cables from these small creatures was apparent as early as the 1930's. For example, a 15-mile section of cable, connecting Grand Island and North Platte, Neb., was stripped of its covering in 2,500 places. Some holes measured a few feet, others only a few inches; but each was large enough to let in moisture and interfere with reliable communications.

After several such incidents Bell Telephone Laboratories began a defense study using live gophers. They obtained the animals from the Iowa State Agriculture Department through the Northwestern Bell Telephone Company. The gophers were shipped to the Laboratories in metal cans that could serve as test bins. The bottoms of the cans were perforated and covered by samples of cable. They were arranged like branches on the floor of a woodbox with light showing between them.

The theory was that the gophers, unable to get up the cans' high slippery sides would seek freedom by gnawing their way down through the cables. The gophers, apparently, would mistake the light for an escape route and the time required to chew through the cable barricade would point out what kind of armor and how much would be needed to protect telephone cables in the field.

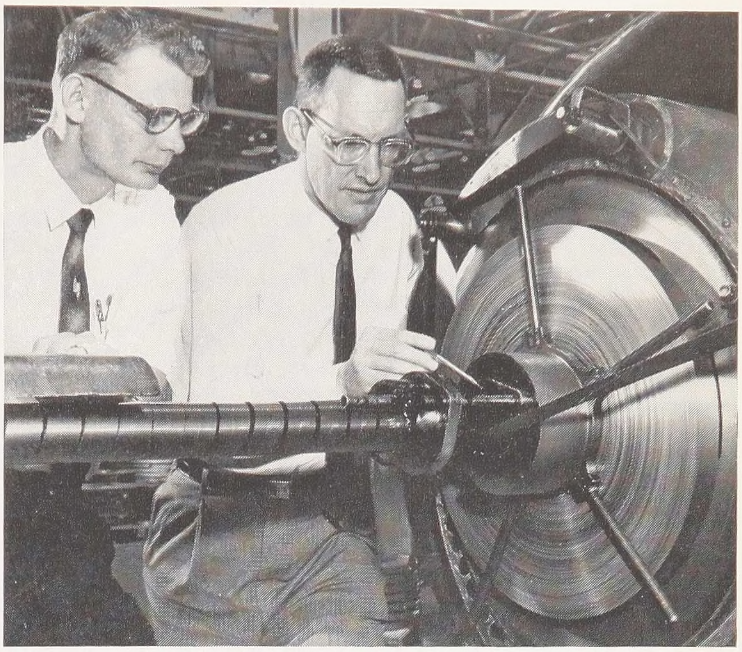
For some gophers it took only one week to tear up the cables while for others it required seven. The average time to shred up a variety of copper and lead shielded samples was three weeks. The test proved that if gophers were not really hungry—and hunger doesn't seem to be the prime motivation for gnawing cables—they were at least persistent and only steel could stop them.

Western Electric is now producing several varieties of steel-coated cables. One of these cables, manufactured at the Western Electric plants in Omaha, Neb., Baltimore and Chicago, relies mainly on steel tape wrapped like barber stripes on top of the cable's inner plastic jacket. A layer of jute "twine" is then woven around it and sealed with pitch to cushion the cable in hard rocky ground.

Another cable is designed to ward off lightning as well as gophers. Steel and aluminum are applied in one sheathing operation like two sleeves over the cable's inner plastic covering to shield against lightning and other electrical disturbances. An outer jacket of black polyethylene plastic is then applied for added protection. This cable is made at the Western Electric plants in Baltimore, Chicago and Kearny, N. J. and will soon be made at Omaha.

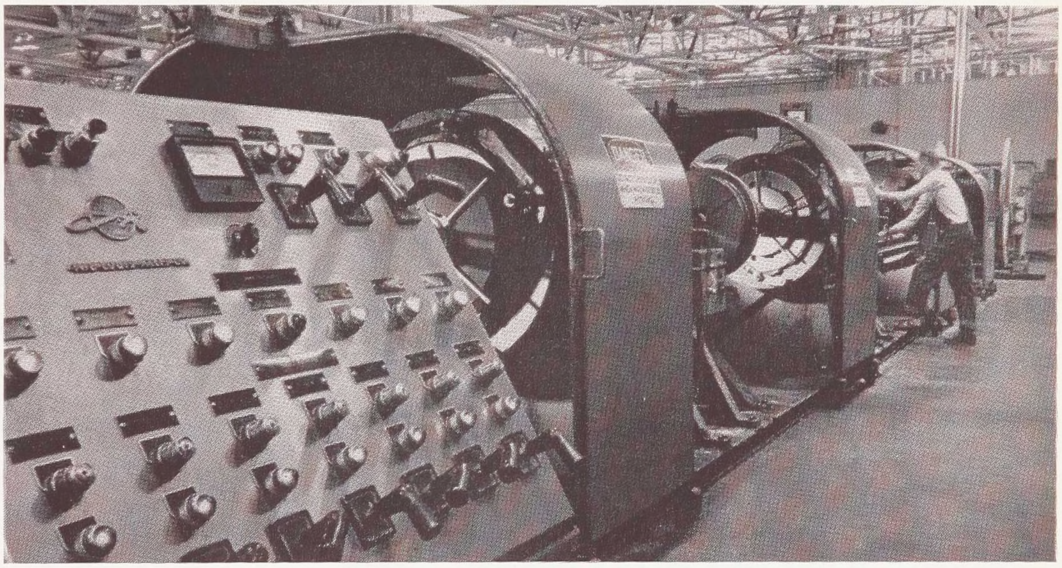
So far the cables are holding up well, giving promise that gophers are now a problem of the past.

These copper and lead shielded sample cables were easily penetrated by the gopher's sharp teeth.

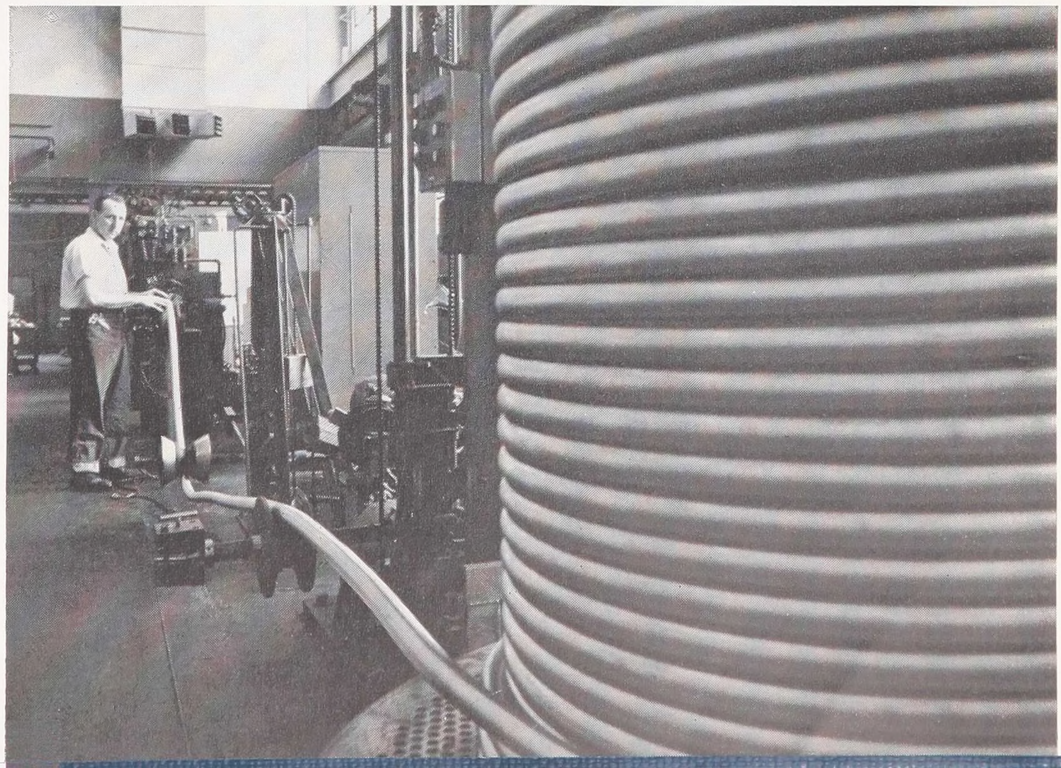


An armoring machine wraps steel tape over the phone cable's plastic jacket to protect against gophers.

The control panel in the foreground monitors operations on the cable armoring line at Western Electric's Omaha plant.



Steel jacketed cable is wound on a reel before receiving a final coating of black polyethylene.



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Following is a list of the inventors, titles and patent numbers of patents recently issued to members of the Laboratories.

Bailey, G. C.—*Electrical Drive Circuit*—3,089,960.

Barnes, D. H.—*Traffic Measurement Apparatus*—3,099,819.

Bishop, W. M.—*Stowage Apparatus for Cable Instrumentality Housings*—3,093,333.

Bobeck, A. H.—*Electrical Information Handling Circuits*—3,090,946.

Bobeck, A. H.—*Magnetic Core Flip-Flop*—3,090,745.

Bouton, G. M. and Heiss, J. H., Jr.—*Press for Tubular Extrusion*—3,095,089.

Cioffi, P. P.—*Magnetic Circuit Using Semiconductor Properties*—3,098,181.

Cremin, J. D.—*Microwave Switching Circuit*—3,092,789.

Cutler, C. C.—*Attitude Control for Satellite Vehicles*—3,088,697.

Dacey, G. C.—*Negative Resistance Device Modulator*—3,090,014.

DeFina, A. L. and Keller, A. C. *Preset Call Transmitter* — 3,089,003.

Dunn, F. A.—*Variable Gyromagnetic Wave Transmission Device*—3,090,930.

Engelbrecht, R. S. and Mumford, W. W.—*Noise Figure Improvement in Radio Receivers*—3,090,009.

Fredericks, G. W. and Lamneck, W. J.—*Parallel-To-Serial Converter Apparatus*—3,090,034.

Garrett, C. G. B. and Pfann, W. G. —*Field Effect Parametric Amplifier*—3,094,671.

Gerbore, A. E., Plyer, R. A. and Steger, W. C., Jr.—*Private Branch Exchange Telephone System Including Conference Facilities*—3,099,719.

Gotthardt, M. R. — *Translator Checking Circuits for Telephone Switching System*—3,099,720.

Graham, R. E.—*Telewriting Apparatus*—3,089,918.

Gruenz, O. O., Jr.—*Number Comparison and Display Circuits*—3,090,942.

Haring, H. E. and Taylor, R. L.—*Manufacture of Solid Electrolytic Capacitators*—3,093,883.

Harr, J. A. and Lowry, T. N.—*Line Concentrator System*—3,099,717.

Heiss, J. H., Jr., see Bouton, G. M.

Hines, M. E.—*Multiplex Message Transmission*—3,089,921.

Hutson, A. R.—*Piezoelectric Devices Utilizing Aluminum Nitride*—3,090,876.

Hutson, A. R.—*Piezoelectric Devices Utilizing Cadmium Sulfide* —3,093,758.

Jacquier, J. H.—*Diversity Communication System*—3,099,716.

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Karnaugh, M.—*Pulse Repeating System*—3,093,815.

Karnaugh, M.—*Logic Circuit Employing Magnetic Cores*—3,094,611.

Keller, A. C., see DeFina, A. L.

Ketchledge, R. W.—*Optical Storage System*—3,099,820.

Kibler, L. U.—*Solid State Diode Surface Wave Traveling Wave Amplifier*—3,094,664.

Kleinman, D. A. and Schawlow, A. L.—*Hall-Effect Apparatus* —3,089,995.

Kretzmer, E. R.—*Information Storage Arrangement*—3,098,996.

Krom, M. E.—*Telephone Line Concentrator System*—3,093,708.

Kroning, R. D. and Orost, J.—*Intercepting Trunk Circuit*—3,090,835.

Lamneck, W. J., see Fredericks, G. W.

Lander, J. J. and Morrison, J.—*Process for Coating with Silicon Dioxide*—3,093,507.

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Ligenza, J. R.—*Photo Sensitive Gas Phase Etching of Semi-Conductors by Selective Radiation*—3,095,341.

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Williford, O. H.—*Telephone Ringing Circuit*—3,089,001.

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