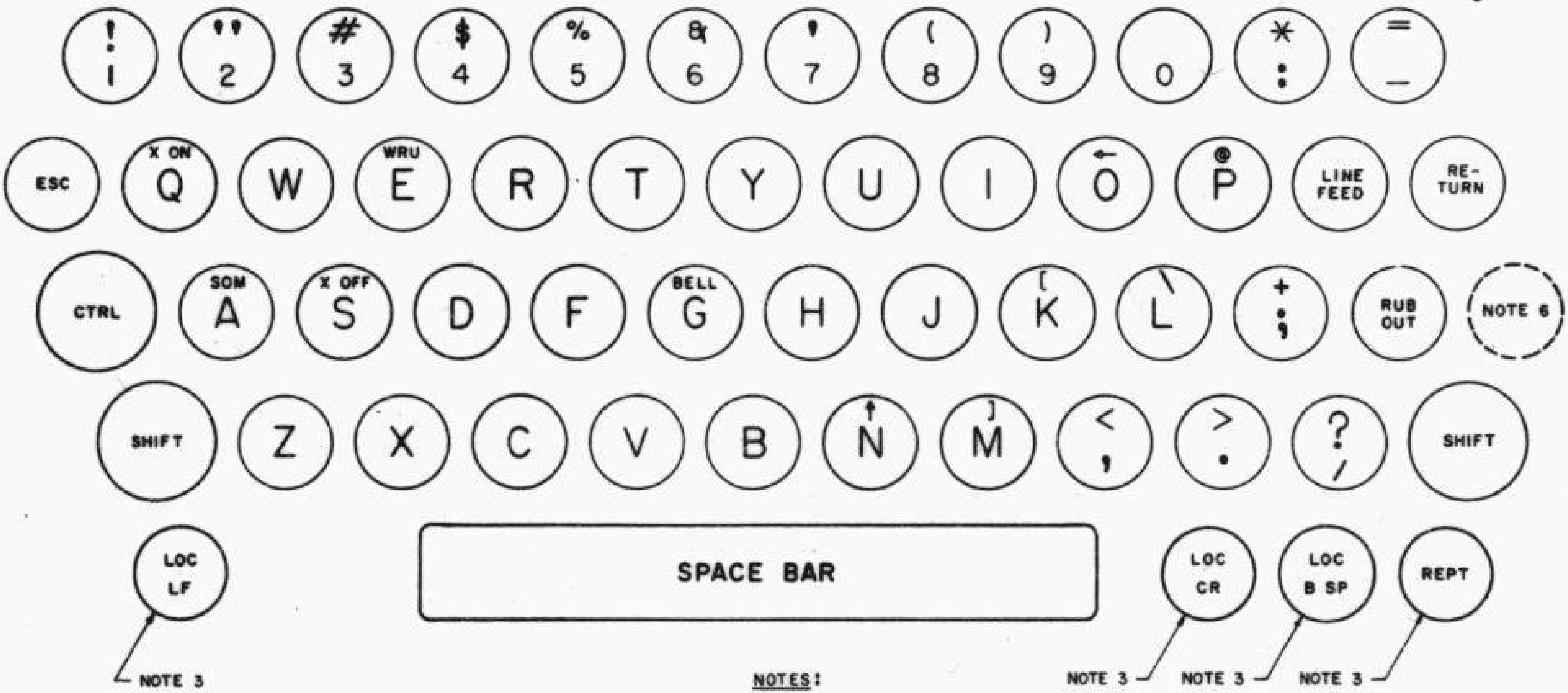
THE WESTERN UNION TELEGRAPH COMPANY

4-ROW, 8-LEVEL TELEPRINTER KEYBOARDS
MODELS 33 & 35 (ASCII CODE WITH PARITY CHECK PULSE)



NOTES:

1 CTRL KEY MAKES 7TH PULSE SPACING

2 SHIFT KEY INVERTS [illegible]TH PULSE.

3 THESE LOCAL KEYS ARE NOT ON THE MODEL 33.

4 OTHER CONTROL CHARACTERS, NOT SHOWN ON KEYTOPS, CAN BE GENERATED.

5 PULSE 8 IS EITHER AN EVEN VERTICAL PARITY CHECK PULSE OR IS ALWAYS MARKING (CUSTOMERS OPTION).

6 LOCATION OF REPEAT KEY ON MODEL 33

THE WESTERN UNION TELEGRAPH COMPANY

AMERICAN STANDARD CODE FOR INFORMATION INTERCHANGE (ASA X3.4–1963)

b_4	b_3	b_2	b_1	b_7 0 b_6 0 b_5 0	b_7 0 b_6 0 b_5 1	b_7 0 b_6 1 b_5 0	b_7 0 b_6 1 b_5 1	b_7 1 b_6 0 b_5 0	b_7 1 b_6 0 b_5 1	b_7 1 b_6 1 b_5 0	b_7 1 b_6 1 b_5 1
0	0	0	0	NULL	DC_0	b̸	0	@	P	UNASSIGNED	UNASSIGNED
0	0	0	1	SOM	DC_1	!	1	A	Q		
0	0	1	0	EOA	DC_2	"	2	B	R		
0	0	1	1	EOM	DC_3	#	3	C	S		
0	1	0	0	EOT	DC4 STOP	$	4	D	T		
0	1	0	1	WRU	ERR	%	5	E	U		
0	1	1	0	RU	SYNC	&	6	F	V		
0	1	1	1	BELL	LEM	' (APOS)	7	G	W		
1	0	0	0	FE_0	S_0	(	8	H	X		
1	0	0	1	HT/SK	S_1	)	9	I	Y		
1	0	1	0	LF	S_2	*	:	J	Z		
1	0	1	1	VTAB	S_3	+	;	K	[		
1	1	0	0	FF	S_4	, (COMMA)	<	L	\		ACK
1	1	0	1	CR	S_5	— (HYPHEN)	=	M	]		1
1	1	1	0	SO	S_6	. (PERIOD)	>	N	↑		ESC
1	1	1	1	SI	S_7	/	?	O	←		DEL

IN MODELS 33 AND 35, AN 8TH BIT IS USED EITHER AS A VERTICAL PARITY CHECK BIT (EVEN PARITY) OR IS ALWAYS MARKING (CUSTOMERS OPTION)

DC_1 IS X-ON AND DC_3 IS X-OFF IN MODELS 33 AND 35. DC_2 AND DC_4 CAN BE USED AS PUNCH-ON AND PUNCH-OFF CONTROLS.

Western Union
Technical Review
Volume 18 Number 2

APRIL 1964

ASCII	000	001	010	011	100	101	110	111
0000	NULL	DC_0 ①	ƀ	0	@	P		
0001	SOM	DC_1	!	1	A	Q		
0010	EOA	DC_2	"	2	B	R		
0011	EOM	DC_3	#	3	C	S		
0100	EOT	DC_4 (STOP)	$	4	D	T		
0101	WRU	ERR	%	5	E	U		
0110	RU	SYNC	&	6	F	V		
0111	BELL	LEM	'	7	G	W		
1000	FE_0	S_0	(	8	H	X	unassigned	
1001	HT / SK	S_1	)	9	I	Y		
1010	LF	S_2	*	:				
1011	V_{TAB}	S_3	+	;				
1100	FF	S_4	,					
1101	CR	S_5	-					
1110	SO	S_6	.					
1111	SI	S_7	/	?				

NEW
ASCII CODE

W

S 1 2 3 4 5 6 7 C R

U

S 1 2 3 4 5 6 7 C R

THE WESTERN UNION TECHNICAL REVIEW

Cover: New X3.4-1963 American Standard Code for Information Interchange

presents developments in Voice and Record Communications for the Western Union's Supervisory, Maintenance and Engineering Personnel.

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NEW
AMERICAN STANDARD CODE
for
INFORMATION INTERCHANGE

Introduction

On June 17, 1963 the American Standards Association (ASA) approved a new American Standard Code for Information Interchange.* The new code, commonly referred to as ASCII (usually pronounced *asky*), was developed after four years of work by a committee of experts in information processing and communications, at an estimated cost of more than three million dollars. ASCII is a 7-bit code intended for information interchange among data processing systems, communications systems, and associated equipments. Since it was developed to meet both message communications and data processing requirements, it represents a compromise between the needs of communicators and data processors, not ideal for either group but acceptable to both.

The use of centralized computers, connected to data originating points via communications facilities, is increasing rapidly, and the new code is expected to find wide application in future systems. In fact, the first two large-scale uses of the new code in Western Union will be in the AUTODIN overseas system, now being developed by Western Union for the Department of Defense, and the nationwide Advanced Record System now being built by Western Union for the General Services Administration. This article, therefore, is intended to explain the logic designed into the new code to telegraph-oriented engineers and other technical personnel.

* Copies of the "American Standard Code for Information Interchange—X3.4-1963" can be obtained from the American Standards Association, Inc., 10 E. 40th St., New York 16, N. Y. at $1.30 per copy.

Before developing the new code, ASA subcommittee X3.2 reviewed more than sixty existing codes, including the Baudot code, but decided that none of these were suitable for use as a standard for general information interchange.

History of the Baudot Code

The so-called Baudot code, used almost universally in printing telegraph systems today, is named for Jean Maurice Emile Baudot (1845-1903), an officer in the French Telegraph Service. However, Baudot did not invent the 5-level code, which had been used for cryptography by Sir Francis Bacon as far back as 1605. Neither did Baudot develop the code assignments for the letters, symbols and functions in use today. Nevertheless, it is fitting that the 5-level code be named for Baudot because of his many significant contributions to the telegraph art. Even today it is difficult to design telegraph apparatus without using one or more of the principles first conceived by Baudot.

Between 1899 and 1901, Donald Murray, an Australian newspaperman, developed and patented a high-speed one-channel printing telegraph. Murray developed his own code assignments for the 32 permutations possible with a 5-level code. He assigned the permutations containing the least number of marking pulses to the most frequently used characters, in order to keep the number of holes punched in perforated tape to a minimum. One apparent discrepancy in his code was the assignment of two marking pulses to the letter "Z," which is the least frequently used letter in the English alphabet. This may have been a concession to some European languages, in which "Z" occurs frequently.

Western Union purchased the American rights to Murray's patents and adopted his code assignments for the letters of the alphabet and the 10 digits. However, Western Union did change some of his code assignments for upper case characters. Murray's code differed from the Baudot code, then used in Europe, for every character except the letter "I." Telegraph engineers recognized the advantages of Murray's code in minimizing wear on perforating mechanisms, tape transmitters, and relays. Eventually it was adopted by Europeans and, again with changes in some upper case character assignments, became the standard CCITT (International Telegraph and Telephone Consultative Committee) No. 2 code.

The Baudot code has been used in telegraphy since 1874 and will undoubtedly continue to be used for transmission of the bulk of administrative messages for many years to come. However, it does have certain built-in disadvantages which make it unsuitable for general use in data communications systems. Although there are 32 possible permutations of the 5-level code, one of these (blank, or all-spacing) is not normally used and five other permutations are reserved for machine functions such as carriage return and line feed. This limits the number of possible graphics (printed characters) to 26 lower case and 26 upper case characters. Some data processing systems require more than these 52 graphics. In addition, it is necessary to use figures and letters shift to obtain the dual meaning for 26 characters. In data processing systems, there are disadvantages in using an ambiguous code in which the meaning of a frequently used character can depend upon a previous character. Also, the Baudot code is not structured so that collating and sequencing operations can be accomplished by simple binary arithmetic operations in data processing systems. (For readers not familiar with binary arithmetic, an explanation of the fundamentals is given in Appendix A).

Choice of a 7-Bit Code

ASA Subcommittee X3.2, which developed the new code, attempted to develop a 6-bit standard code, because many existing computers use a 6-bit code in their internal operations. (*Note:* In computer terminology, the word "bit" is a contraction of "binary digit" and is used in the remainder of this article instead of the word "unit" or "level," commonly used in telegraph terminology. Likewise, the terms "0" and "1" are used instead of "spacing" and "marking" pulses, respectively.) A 6-bit code would perhaps have been adequate for either data processing or message communications, but it was not possible to include all the alphabetics, numerics, special symbols, and control characters required for general information interchange within a 6-bit code. An 8-bit code was also considered, since this would permit transmitting two 4-bit binary-coded decimals (See Glossary) per 8-bits. However, it was decided that an 8-bit code would be too wasteful for most users, because 256 characters are seldom required even in data processing. Finally, 7 bits were chosen as the minimum number which would permit derivation of all the required characters. Thus, this code provides 128 possible characters, each represented by a discrete "bit pattern," or permutation.

Structure of the Code

In discussing the ASCII code, it is convenient to arrange the 128 bit permutations in 8 vertical columns, with 16 horizontal rows in each column, as shown in Table 1. The vertical columns are identified by the three high-order bits (7, 6 and 5, or b_7, b_6 and b_5) and the 16 horizontal rows by the four low-order bits (b_4, b_3, b_2 and b_1). The table is arranged in continuous increasing binary sequence, from top to bottom in the horizontal rows and from left to right in the vertical columns. The binary number "0000000" (decimal zero) thus appears in the top row in the left-hand column and the binary number "1111111" (decimal 127) appears in the bottom row in the right hand column. The bit pattern for any

TABLE I

b_7 →				0	0	0	0	1	1	1	1
b_6 →				0	0	1	1	0	0	1	1
b_5 →				0	1	0	1	0	1	0	1
b_4	b_3	b_2	b_1								
0	0	0	0	NULL	DC_0	b̸	0	@	P	UNASSIGNED	UNASSIGNED
0	0	0	1	SOM	DC_1	!	1	A	Q		
0	0	1	0	EOA	DC_2	"	2	B	R		
0	0	1	1	EOM	DC_3	#	3	C	S		
0	1	0	0	EOT	DC_4 STOP	$	4	D	T		
0	1	0	1	WRU	ERR	%	5	E	U		
0	1	1	0	RU	SYNC	&	6	F	V		
0	1	1	1	BELL	LEM	' (APOS)	7	G	W		
1	0	0	0	FE_0	S_0	(	8	H	X		
1	0	0	1	HT / SK	S_1	)	9	I	Y		
1	0	1	0	LF	S_2	*	:	J	Z		
1	0	1	1	VTAB	S_3	+	;	K	[		
1	1	0	0	FF	S_4	, (COMMA)	<	L	\		ACK
1	1	0	1	CR	S_5	- (HYPHEN)	=	M	]		①
1	1	1	0	SO	S_6	. (PERIOD)	>	N	↑		ESC
1	1	1	1	SI	S_7	/	?	O	←		DEL

NULL—Null/Idle
SOM—Start of Message
EOA—End of Address
DC_1—Device Control
DC_2—Device Control
DC_3—Device Control
DC_4 (STOP)—Device Control (Stop)
ERR—Error
EOM—End of Message
EOT—End of Transmission
WRU—"Who are you?"
RU—"Are you . . .?"
BELL—Audible Signal
FE_0—Format Effector
HT—Horizontal Tabulation
SK—Skip (punched card)
LF—Line Feed
VTAB—Vertical Tabulation
FF—Form Feed
CR—Carriage Return
SO—Shift Out
SI—Shift In
DC_0—Device control reserved for Data Link Escape
SYNC—Synchronous Idle
LEM—Logical End of Media
S_0-S_7—Separator (information)
b̸—Space (Word separator, normally non-printing)
<—Less Than
>—Greater Than
↑—Up Arrow (Exponentiation)
←—Left Arrow (Implies/Replaced by)
\ —Reverse Slant
ACK—Acknowledge
①—Unassigned Control
ESC—Escape
DEL—Delete/Idle

character is usually given in the high-order to low-order bit sequence. Thus, the bit pattern, or "code," for the letter R is:

Bit number:	7 6 5 4 3 2 1
Bit pattern:	1 0 1 0 0 1 0

This order may appear to be the reverse of that normally used in telegraph communications, where bits are usually given in the low-order to high-order bit sequence. But binary numbers, like decimal numbers, are given high-order digit first.

In developing the code, the ASA Subcommittee decided to place the 64 graphics in a "dense graphic subset"; that is, in a block of 64 consecutive binary numbers, preferably in four contiguous columns. First choice for the placement of this subset was either the first four or the last four vertical columns, since this would have permitted identifying the graphic subset with relatively simple circuitry by examining bit 7. However, the graphics could not be placed in the first four columns because the "all-zeros" character was reserved for the "null," or idle, character. This permits continuing the traditional use of blank perforated tape as a leader at the beginning of a message. It was also decided to reserve the "all-ones" bit pattern for the "delete" character in order to permit its traditional use as a "rub out" in punched tape. The four middle columns were finally chosen as the best compromise. In each of these columns, bit 6 is different from bit 7. This will permit identification of the graphic subset with relatively simple circuitry by a comparison of bits 6 and 7.

Most of the control characters were placed in the first two columns, and each class of controls was arranged in hierarchial order. At present, all of the characters in the seventh column and most of the characters in the last column are unassigned.

Structure of the Graphic Subset

The arrangement of the characters in the graphic subset was strongly influenced by considerations of the ordering, collating, and sequencing operations in data processing systems. The graphics are arranged so that a simple comparison of binary codes can be used to order information in a desired sequence. For example, conventional usage requires that the name "Johns" appear ahead of "Johnson" in an alphabetical listing. This requirement resulted in the word separator (space) being assigned to the lowest binary number in the graphic subset. Similarly, a name such as "West, W." should collate ahead of "Weston." This convention resulted in the comma being placed ahead of (or assigned to a lower binary number than) all letters and digits. Other commonly used punctuation marks were also placed in the first of the four graphic columns.

In order to permit a 4-bit numeric subset to be derived from the code. the ten digits were placed so that the four low-order bits represent the binary coded equivalents of their decimal values. The standard implies that the preferred characters to be included with the 10 digits in such a 4-bit subset are the asterisk, plus, comma, hyphen, period and slant. Since these six characters are not located in the same column as the digits, the 4-bit subset cannot be directly derived by merely dropping the three high-order bits. This will present no problem in contracting to a 4-bit subset, but will complicate the expansion of the 4-bit subset to a 6-bit or 7-bit set.

The colon and semi-colon, which are less frequently used than the other punctuation marks, were placed immediately after the ten digits because of international considerations. In areas where the pound sterling monetary system, with its 12 pennies in a shilling, is used, these two characters can be replaced by the "digits" 10 and 11.

Design of typewriter-like devices such as teleprinters was also considered in developing the standard. An effort was made to place characters which are normally paired on a typewriter keytop so that they differed by only one bit. This will simplify the design of keyboards using the new code by permitting a shift key to be used to invert one bit. However, not all of the traditional keytop pairings were retained, since other considerations conflicted with this requirement. For example, the digits 2, 3, 4 and 5 differ from the characters normally associated with them on a typewriter keyboard only in bit 5. The other digits are not as simply related to their corresponding "upper case" assignments.

The 26 letters of the alphabet were assigned to a continuous block of binary numbers in the 3rd and 4th columns of the graphic subset, and arranged in increasing binary sequence from A through Z. Five infrequently used symbols were placed in the fourth column immediately following the alphabet. These symbols can be dropped in order to accommodate foreign alphabets containing more than 26 letters.

A 6-bit graphic subset can be derived from the standard by dropping bit 6. The resulting subset will still retain the collating order used in the standard. In order to use such a code for communications purposes, it would be necessary to substitute carriage return and line feed for the asterisk and hyphen, or for two other infrequently used characters.

Control Characters

The controls included in the code fall into four classes: (1) transmission controls; (2) format effectors; (3) device controls; and (4) information separators. These four classes are grouped together and located in the first two columns of the table in the order given. Each class of controls is arranged in hierarchial order, but there is not intended to be a hierarchial relationship between classes. The first 8 characters, such as "start of message" and "end of transmission," are classed as "transmission controls," since they are used primarily in communications. The second group, format effectors, contains characters which are used to organize printed data on a page, such as carriage return, line feed, and vertical tabulation. The third group consists of device controls, useful in controlling the operation of auxiliary equipment. Use of these controls has not yet been standardized, but it is anticipated that they will be used for such purposes as turning an auxiliary reperforator on or off and starting or stopping a tape transmitter. The last group consists of information separators, used to identify boundaries of various elements of information. These controls, also called data delimiters, are machine-oriented controls used in data processing to serve a purpose similar to that of punctuation marks in message communications. Their exact usage has not yet been defined.

Several special controls which do not logically fall into one of the four classes previously described are also included in the code. The "shift out" character signifies that the graphic characters which follow have alternate meanings; that is, meanings other than those shown in the ASA code table. The "shift in" character denotes a return to the standard graphic subset. Use of these two characters is thus somewhat analogous to the figures and letters shift characters in the Baudot code.

The first character in the device control group (DC_0) has been reserved for "Data link escape." Use of this control has not been formalized as yet, but it is expected to serve a purpose similar to the "shift out" character. The latter character is intended primarily for communications use while the "Data link escape" is intended to provide supplementary controls in data transmission links.

The "escape" character also signifies an "escape" from the ASCII code. Exact use of this character has not been formalized either, but it is intended to modify the meaning of the following character or characters. This control is intended to provide a broad expansion of the code for special uses. For example, it could be used for communicating in those foreign languages which do not use the Roman alphabet.

The three remaining controls are the "error," "synchronous idle," and "logical end of media" characters. The "error" is for use in indicating an error in data. The "sync" is for use in achieving or retaining synchronism in synchronous transmission systems. The "logical end of media" is intended for use as an end-of-tape or end-of-card, etc. character. It does not necessarily occur at the physical end of the medium. For example, in perforated tape, it could be followed by blank tape.

The "acknowledge" character is intended for use as a single-character answer-back. Its position in the table was chosen to permit generation of the character by relatively simple means; that is, by generating an open line for 3 bit-lengths in a start-stop system. This choice was probably influenced by the use of automatically generated "V" answer-backs in many telegraph communications systems.

Some Shortcomings of the ASCII

The new ASCII code is a significant achievement in the field of standardization and its adoption as a standard may well mark the beginning of a new era of standardization in the communications and data processing fields. For the first time, a committee of experts representing many fields and many competitive companies worked together to develop from "scratch" a standard code; that is, the new code, unlike the CCITT No. 2 code, is not based on any code previously in use. This permitted the committee to base the code primarily on logical considerations, with historical convention being considered only where such considerations might influence future implementation of the code. In spite of this, however, the code does have some shortcomings.

For communications use, the new code has numerous disadvantages. Use of a 7-bit code for message communications is wasteful of transmission time, since a 5-bit code is adequate for most message communications. In addition, a 7-bit code results in a higher modulation rate for a given speed than does a 5-bit code. In some cases, this will require more expensive transmission facilities for use with the new code. For example, use of the new code with a unit-length start pulse, a parity check pulse, and a two-unit stop (or rest) pulse (11-unit code pattern) will result in a modulation rate of 110 bauds at a transmission speed of 100 words per minute. Thus, use of the new code at 100 words per minute over Western Union facilities will require use of Type 70 carrier terminals.

There is no error protection included in the 7-bit code. However, it seems probable that most communications systems which use the new code will use an 8-bit code, with the added bit used to provide an even vertical parity check. (This may eventually be adopted as part of the standard.) An even parity must be used in paper tape in order to preserve the validity of the "rub-out" and "blank" characters. In magnetic tape, other considerations dictate the use of odd parity. This discrepancy may someday prove to be a disadvantage.

Other error considerations were not entirely ignored in developing the new code. Most of the control characters were placed in the first two columns of the code in order to reduce the likelihood of generating a control code during idle transmission time by "hits," or short opens, on the line.

A conventional 3-row teleprinter keyboard cannot be designed to generate the ASCII code, because of the large number of characters used in the code. There is no simple relationship between the digits and the letters of the alphabet with which they are normaly paired on a teleprinter keyboard. For example, the code for the letter E is 1000101; the code for the digit 3, which is paired with E on teleprinter keyboards, is 0110011. A keyboard designed for use with the new code must therefore be more like a typewriter, or a standard expanded 4-row teleprinter, keyboard. Figure 1 shows the keyboard layout for the Teletype Model 35 teleprinter, designed to utilize the new code. To use this keyboard, a teleprinter operator must learn a new touch-typing system for all of the digits and punctuation marks.

From a communications standpoint, there are two other minor shortcomings in the ASCII code. First, the 7-bit code will be difficult for maintenance and supervisory personnel to memorize. Secondly, data processing considerations prevented assigning the permutations containing the least number of "ones" to the most frequently used characters. This will result in increased wear, and thus higher maintenance costs, on reperforators, transmitters, and relays.

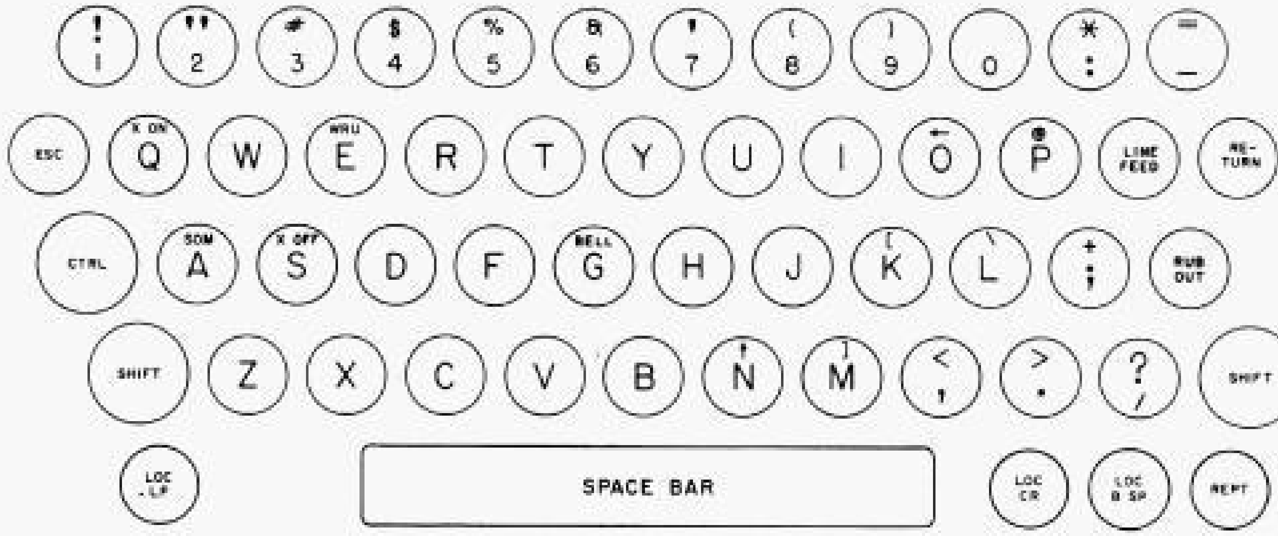

Figure 1. Model 35 Teleprinter and ASR Set Keyboard Layout

The Future of ASCII

The Teletype Corporation has already designed, and is now manufacturing, two lines of equipment which use the new ASCII code. Teletype's Model 33 teleprinters and ASR sets are basically the same as the light-duty Model 32 units, but designed for the new 7-bit code. The Model 35 teleprinters and ASR sets are basically heavy-duty Model 28 units redesigned for use with the new code. All of these units actually generate an 8-bit code, with an 11-unit code pattern. At present, there are two different types of keyboards available. In one type, bit 8 is always marking and, in effect, the rest, or stop, pulse is thus three units long. In the other type, bit 8 is used as a vertical parity-check bit (even parity).

A Teletype spokesman has been quoted in the public press (Business Week, June 15, 1963) as saying that Teletype expects half of their customers to be using the new code within five years. While this prediction may prove to be overly optimistic concerning the future of the 8-bit equipment, there appears to be little doubt that the new code will come into widespread use for data interchange in the years ahead. It appears doubtful that Western Union will ever adopt the new code for use in its public message service. Besides being wasteful of transmission time for message communications, its use would require extensive operator retraining. Also, it appears unlikely that existing private wire systems used primarily for message communications will be converted to the new code. Such an expensive conversion can only be justified where a private wire system is used primarily for data interchange.

The future of the ASCII code is enhanced by the revolution in data processing now in progress. As more and more companies and government agencies automate and centralize their data processing, the new code will almost certainly come into widespread use. New communications systems will be designed and built for use with the new code and perhaps some existing systems will be replaced by newer ones designed primarily for data interchange. A number of manufacturers of computers and data processing equipment are already providing "hardware" for use with the new code. Use of the new code will, for the first time, make possible the interchange of information between equipments made by different manufacturers.

Much standardization work remains to be done on the code itself and on implementation of the code. This work is proceeding at a rapid pace. By the time this article appears in print, it is possible that the code will have been modified to include a lower case alphabet in the unassigned area. Inclusion of the lower case alphabet will probably be followed by adoption of the code as an international standard by the International Standards Organization.

A standard for one-inch perforated paper tape will be issued in the near future. Work is continuing on standards for magnetic tape and punched cards using the new code.

GLOSSARY

Acknowledge .... A character generated at a receiving device to indicate to the sending device that information has been received successfully.

Are you? .... A request for a station to indicate if it is the station whose identification immediately follows the "RU" character.

Binary .... Consisting of two.

Binary-coded decimal .... A representation of a decimal digit by means of a binary code.

Binary digit .... Either zero or one, the only two digits used in binary counting.

Bit .... A contraction of "binary digit."

Bit pattern .... Any discrete permutation of the seven bits of the ASCII code.

Character .... The meaning, or interpretation, assigned to any discrete bit pattern.

Collate .... To examine and compare; to place in order.

Collating sequence ...... The sequence in which the characters acceptable to a computer are ordered.

Combinations .... Arrangement of things into groups so that each group has a certain number of things, without regard to the order in which they are arranged.

Data link escape .... A conditioning character which will change the meaning of one or more following bit patterns. It is intended to provide supplementary control in data transmission links.

Device Control .... A functional character used to control an ancillary device or devices, more specifically intended for switching devices "on" or "off."

End-of-address .... The character used to separate the machine-sensible address or routing part of a message from the following parts of the message.

End-of-message .... The last character of a message, except that in systems employing error control, there is a possibility the error control character or characters may follow the EOM character.

End-of-transmission ..... The character used to denote the end of a transmission. A transmission may include more than one message.

Error .... The character used to indicate that there has been an error in the information with which it is associated.

Escape .... A conditioning character used to change the meaning of one or more of the following characters. It is intended to provide supplementary characters in general information interchange.

Format effector .... A functional character which controls the layout or position of information in input/output media.

Graphic .... A written or printed letter or symbol.

Hierarchial .... Classified in order of higher and lower rank.

Information separator ... A character used to separate information in a logical sense. These characters are intended to be used in a hierarchial order.

Logical end of medium ... A functional character which identifies the end of information on a unit of physical material such as punched card or tape. This character is not necessarily located at the physical end of the recording material.

Order .... The way in which things are arranged.

Permutation .... The order in which a set of things is arranged.

Sequence .... To arrange objects or items in a given order.

Set .... Any collection of objects or things.

Shift-in .... The shift-in character means that all the bit patterns which follow shall be interpreted according to the ASCII code table.

Shift-out .... The shift-out character means that the graphic bit patterns which follow may have alternate interpretations until a shift-in character is received.

Start of message .... The first character of a message. "Message" includes *all* information, such as header, text, and preamble.

Subset .... Any collection of objects or items contained within a larger set.

Superset .... A collection of objects or things which contains a smaller set within it.

Synchronize .... A character transmitted by a synchronous transmission system in the absence of any other character to provide a signal from which synchronism may be achieved or retained.

Transmission control .... A functional character intended to control or facilitate transmission of information over telecommunication networks.

Who are you? .... A request for a station to identify itself.

APPENDIX A

FUNDAMENTALS OF BINARY ARITHMETIC

The decimal positional notation system of counting, commonly called the decimal system, is only one of many numbering systems developed over the past several thousand years. The ancient Mesopotamians developed a positional notation (or place value) system, in which the position of a digit determined its value, before 1700 B.C. This system was based on a count of 60 (sexagesimal system) and remnants of it survive today in our division of the hour into 60 minutes and the minute into 60 seconds. Other systems based on 3, 5, 12, 20, and so on, have been developed by civilized man over the centuries. The decimal system, with its base of 10, probably survives today because its convenience led European merchants to adopt it during the middle ages. The Hindus, who first developed the decimal positional notation system, were also the first to adopt a symbol for zero, to indicate the absence of a digit. This eliminated the confusion and ambiguity present in systems such as the sexagesimal system, which simply left a blank space to indicate absence of a digit.

The ten symbols used in our decimal positional system (0 and the digits 1 through 9) can be used to count any finite number of objects, no matter how large the quantity. When a count of nine is passed and no more digits remain, we write down a zero to indicate that this position represents "no objects." We then write a one to the left of the zero. In this position the "one" means "1×10." Similarly, when a count of 99 is passed, we write down two zeros and place a 1 to the left of them. In this position, the "one" means $1 \times 10 \times 10$. Thus, the number 9,373 means "$9 \times 10 \times 10 \times 10$ plus $3 \times 10 \times 10$ plus 7×10 plus 3.

In expressing quantities less than one, the postional notation system is also used, but the digits are divided by ten. Thus, the number 0.356 means "$3 \div 10$ plus $5 \div (10 \times 10)$ plus $6 \div (10 \times 10 \times 10)$."

The notation used in the two preceding paragraphs is satisfactory for use with small numbers. However, a shorthand notation was developed to reduce the labor of writing numbers, particularly large numbers. Instead of writing "$10 \times 10 \times 10$" we write 10^3, which means "$10 \times 10 \times 10$", or "10 raised to the third power." The three is called the exponent of ten.

In multiplying powers of ten, exponents are added. Thus, $10^3 \times 10^2$ equals $(10 \times 10 \times 10) \times (10 \times 10)$ or $10 \times 10 \times 10 \times 10 \times 10$, which in turn, equals 10^5. Similarly, in division, exponents are subtracted, so that $10^5 \div 10^3 = 10^2$. This is known as *the law of exponents*.

To express numbers less than 10, negative exponents are used. For example, $10^{-3} = 1 \div (10 \times 10 \times 10)$.

When the exponential notation was adopted, the question of the value of ten raised to the zero power, or 10^0, naturally arose. Since it obviously must lie between 10^1 and 10^{-1}, 10^0 was arbitrarily defined as one. Later, when the law of exponents was applied to any base number, it was discovered that *any* number raised to the zero power must equal one in order for the law to apply. Thus, $a^0 = 1$, regardless of what base number "a" represents.

It is believed that some primitive tribes used a numbering system based on two. Such a "binary system" is ideally suited for use with present day computers, which, perhaps, are in about the same state of development as the primitive tribes which first used a binary count. Much of the hardware used in today's computers can be in one of only two states. A switch can be open or closed, a relay can be operated or released, a diode or transistor can be conducting or not conducting.

The binary system used in computers is a positional notation, or place value, system. The only two digits used are zero and one. (The question of whether zero is a digit or a symbol used to indicate absence of a digit is debatable.) The same rules apply in binary counting as in decimal counting. That is, when a count of one is passed and no more digits remain, we write down a zero to indicate that this position represents "no objects." We then place a one to the left of the zero. In this position, the one means 1×2^1, or 2. Similarly, when a count of three, or binary "11," is passed, we write down two zeros to indicate that these two positions represent "no objects," then place a one to the left of them. In this position, the one means 1×2^2, or 4. A complete 3-place binary count is given in the following table.

BINARY NUMBER	DECIMAL EQUIVALENT
000	0
001	1
010	2
011	3
100	4
101	5
110	6
111	7

Table II shows a complete 7-digit binary count, from the decimal equivalent of 0 to the decimal equivalent of 127, arranged to correspond to the ASA code table shown in Table I.

The binary number "101" means 1×2^2 plus 0×2^1 plus 1×2^0, or $4 + 0 + 1 = 5$. Similarly, the binary point is treated exactly the same as the decimal point. The binary number 0.101 means 1×2^{-1} plus 0×2^{-2}, plus 1×2^{-3}, or $\frac{1}{2} + 0 + \frac{1}{4} = \frac{3}{4}$. In this explanation, decimal digits were used to simplify the principles involved. In purely binary form, the digit two would be replaced by "10," read "one-zero," *not* ten. For example, the binary number $10^{10} = 100$, or "one-zero raised to the one-zero power equals one-zero-zero."

In binary arithmetic, the rules which apply are similar to the rules for decimal arithmetic. In adding, 1 plus 0 (or 0 plus 1) equals 1 and 1 plus 1 equals 10; that is 1 plus 1 equals zero, "with one to carry." Example:

BINARY ADDITION	DECIMAL EQUIVALENT
10101	21
+01101	+13
100010	34

TABLE II

DECIMAL EQUIVALENTS OF 7-BIT BINARY COUNT

b7 →				0	0	0	0	1	1	1	1
b6 →				0	0	1	1	0	0	1	1
b5 →				0	1	0	1	0	1	0	1
b4	b3	b2	b1								
0	0	0	0	0	16	32	48	64	80	96	112
0	0	0	1	1	17	33	49	65	81	97	113
0	0	1	0	2	18	34	50	66	82	98	114
0	0	1	1	3	19	35	51	67	83	99	115
0	1	0	0	4	20	36	52	68	84	100	116
0	1	0	1	5	21	37	53	69	85	101	117
0	1	1	0	6	22	38	54	70	86	102	118
0	1	1	1	7	23	39	55	71	87	103	119
1	0	0	0	8	24	40	56	72	88	104	120
1	0	0	1	9	25	41	57	73	89	105	121
1	0	1	0	10	26	42	58	74	90	106	122
1	0	1	1	11	27	43	59	75	91	107	123
1	1	0	0	12	28	44	60	76	92	108	124
1	1	0	1	13	29	45	61	77	93	109	125
1	1	1	0	14	30	46	62	78	94	110	126
1	1	1	1	15	31	47	63	79	95	111	127

In subtraction, 1 minus 0 equals 1, and 0 minus 0 equals 0. To subtract 1 from 0, it is necessary to "borrow one," as in decimal subtraction. Example:

BINARY SUBTRACTION	DECIMAL EQUIVALENT
10101	21
−01101	−13
01000	8

In multiplication, one times zero (or zero times one) equals zero and zero times zero equals zero. One times one equals one. Example:

BINARY MULTIPLICATION	DECIMAL EQUIVALENT
10101	21
×01011	×11
10101	21
10101	21
00000	231
10101	
00000	
011100111	

In binary division, the rules for addition, subtraction, and multiplication are used as in decimal division. Example:

BINARY DIVISION	DECIMAL EQUIVALENT
10.010	2.25
1100)11011.000	12)27.00
1100	24
11.00	3.0
11 00	2 4
00 00	60
	60
	00

In converting binary coded decimal numbers to "natural" decimal numbers, it is convenient to remember the following rule: The first position to the left of the binary point has a place value of one. Each succeeding place to the left represents a value twice that of the place to its right. Thus:

Place value:	64	32	16	8	4	2	1
Binary number:	1	0	1	0	1	0	1

means "64 + 16 + 4 + 1," or 85.

A similar rule applies to numbers less than one, except that the fractions ½, ¼, ⅛, etc. are used and the place value *decreases* as the position becomes farther from the binary point.

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Private Automatic Telephone Systems

PATS

Introduction

The first leased private automatic telephone system, PATS, was placed in service by Western Union, in February, 1964, for the Philadelphia-Baltimore-Washington Stock Exchange. This flexible system enables stock brokers to receive and execute buy and sell orders with greater speed and accuracy and thus provide better service to their customers. It provides members with immediate voice service for use in obtaining quotations and placing stock orders. Calls are placed by dialing 3-digit numbers. The average time between dialing and ringing is less than one second.

General Description

The PATS, private automatic telephone system, is of the Philips "UP" type. It is made up of one cabinet, as shown in Figure 1, for 100 lines and may be expanded to 450 lines by connecting 5 cabinets by means of cables with plug-in connecting strips.

The "UP" is an indirect system in which connections are established by means of registers and a common control circuit. A non-homing type high speed selector, which steps at 150 contacts per second, is used in all switching stages. The extensions are divided into groups of 50 for which a maximum of 6 connecting circuits can be provided. This system can operate with push button signals as well as dial pulses. To accomplish this it is necessary only to change the registers.

The number of extension lines may be increased by 10 at a time and connecting circuits by 2 at a time. Registers may be added, one at a time. Thus the exchange may be adapted to meet the customer's needs and provide for future growth.

Construction and Assembly

All components except the power supply are mounted in a steel cabinet, as shown in Figure 1. The double contact relays are combined into functional units which are easily mounted on special cross bars in the cabinet. The mounting brack-

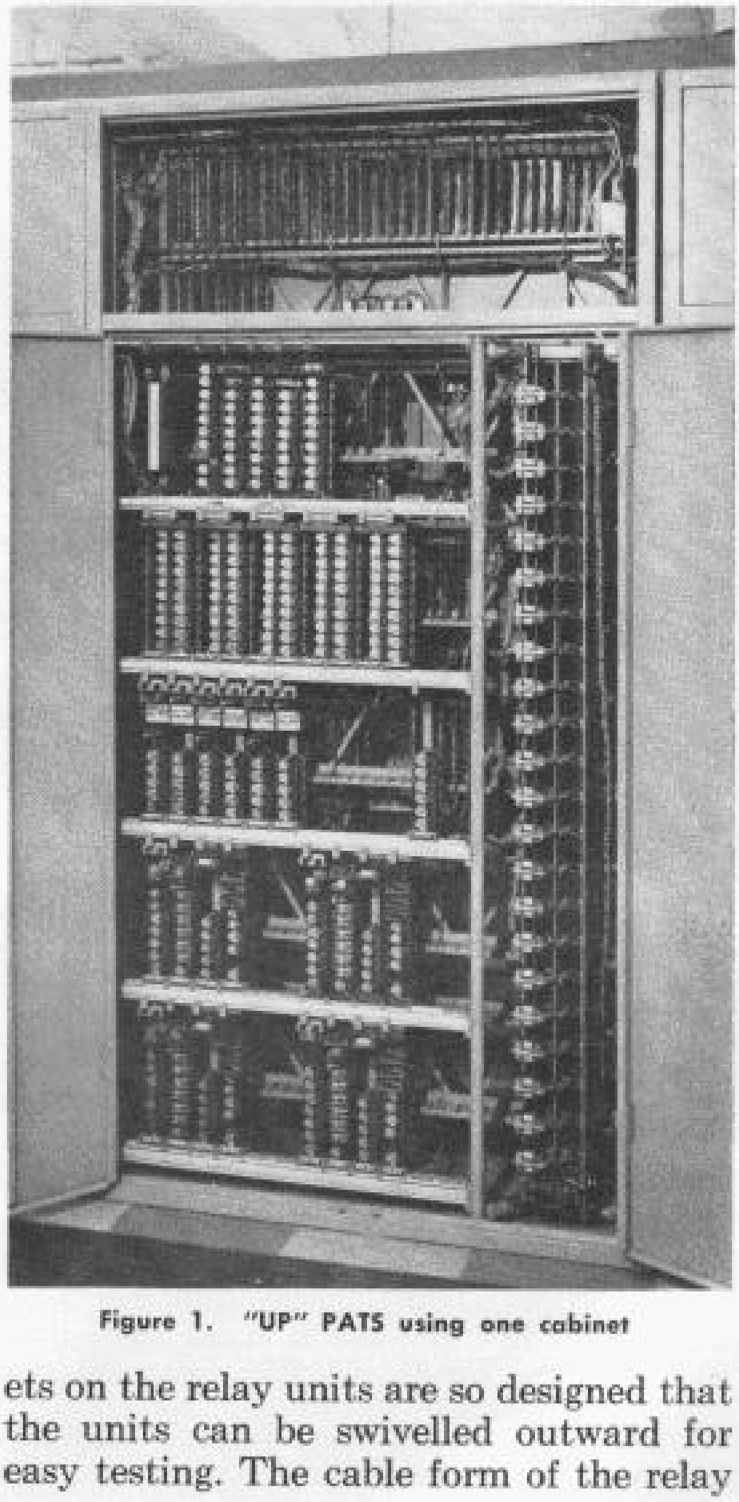
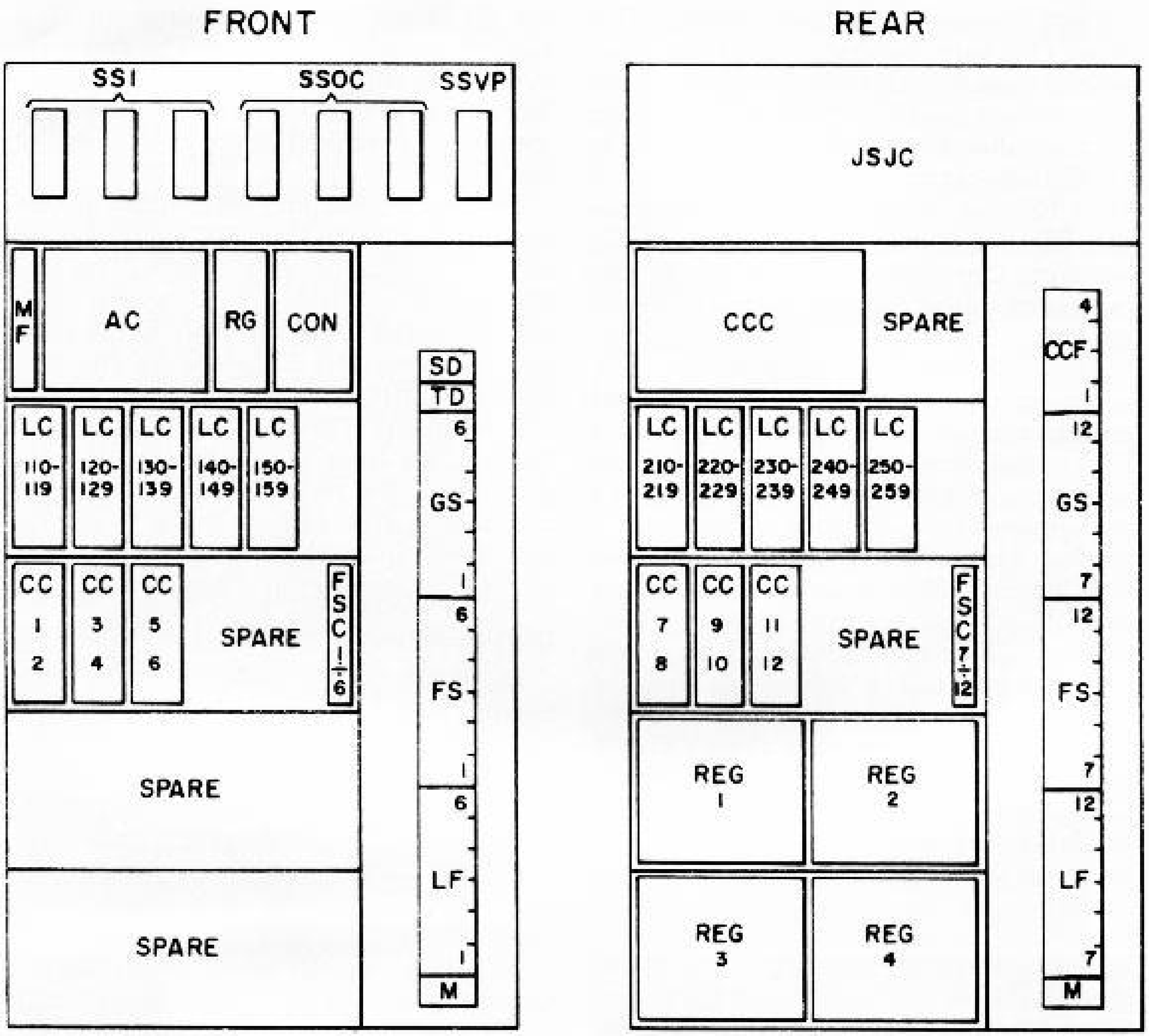


Figure 1. "UP" PATS using one cabinet

ets on the relay units are so designed that the units can be swivelled outward for easy testing. The cable form of the relay units terminate on plug strips which are inserted into socket strips mounted on the pre-wired frame.

Each selector bank column, into which the selectors are fitted, is driven by a small ac motor. The columns can be swivelled outwards on a vertical shaft to facilitate testing without interruption of operation.

Figure 2 shows the location of the equipment in the front and rear of the cabinet. The "spare" spaces can be used for mounting special equipment such as tie-line relay sets, paging system, staff locating units, group hunting units etc.



AC	alarm circuit
CC	connecting circuit
CCF	connecting circuit finder
CCC	common control circuit
CON	converter 48 V DC to 36 V AC 60 c
FS	final selector
FSC	final selector circuits
GS	group selector
JSJC	jumpering strips for junction cables
LF	line finder
M	motor
MF	main fuses
REG	register
RG	ringing generator
LC	subscriber's line circuit
SD	signal distributor
SSI	soldering strips for in-side wiring
SSOC	soldering strips for out-side cables
SSVP	soldering strips for various purposes e.g. operator set
TD	test distributor

Figure 2. Rack Layout of "UP" cabinet (Front and Rear views)

Operation

Positioning of the Connecting Circuit Finder (CCF)

The block diagram in Figure 3 illustrates the principle of the system. When a caller lifts his telephone off the cradle, a particular line relay in his line circuit operates. This causes a group relay in the caller's 50-line group to operate. This relay, in turn, operates another relay which then initiates the action to seize the common control circuit (CCC), along with an allotted register, if it is free. The CCC then starts rotating the wipers of the CCF associated with the seized register. When the connecting circuits (CC) are free, they will mark their respective outlets on one of the arcs of the CCF with battery.

When the rotating wiper of the CCF comes in contact with the first marked outlet, a path is set up to operate the high speed test relay in the CCC. The operation of this test relay (within 0.4 ms) immediately forces a detent into a ratchet wheel thus stopping it. This action immediately disengages the rotating gears.

The CCF is now positioned on a free connecting circuit, which means that the allotted register is connected to a CC.

In order to ensure that the CCC will be coupled only to one register with its CCF, the allotter makes the free registers available, one at a time.

Positioning of the Line Finder (LF)

The LF associated with the seized CC begins its positioning in about the same manner as the CCF. The marked outlet to the caller is identified because contacts of his line relay, which has operated, have closed a path to ground via the high speed test relay in the CCC. The wiper of the LF, which has battery applied to it from the CCC via the CC, rotates until it reaches the marked outlet. The test path is now closed for the test relay to operate immediately. The wipers stop in the same manner as described in the positioning of the CCF.

Because of the lockout feature of the register allotter in the CCC, only one LF can be positioned at a time. (The line finders are multipled.) If several calls are attempted simultaneously in the same 50-line group, the LF stops on the first marked outlet.

Continuous 450 cps dial tone is now transmitted from the alarm circuit (not shown) via the register to the caller's receiver. The average time taken to receive dial tone, from the moment the caller goes off hook, is about a half second.

Digit Selection

Digit selection is made by dial or push button.

(a) Dial

The standard "UP" is a 3-digit selection system. In a dial system pulses are

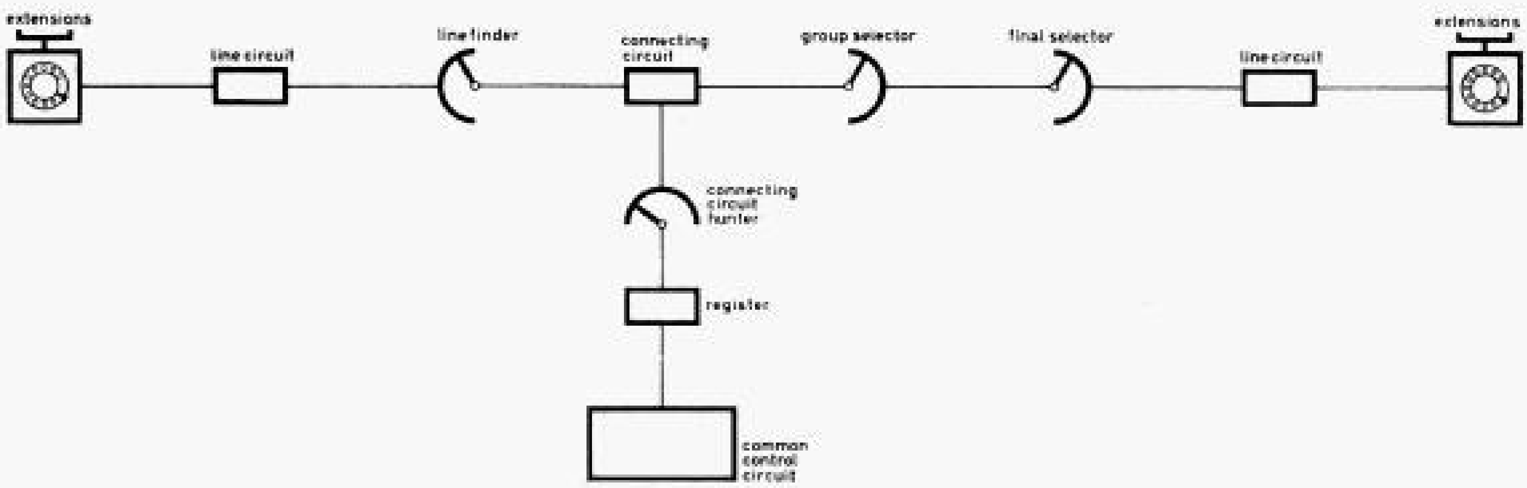


Figure 3. Block Diagram "UP" PATS

generated when the caller dials a required number. The pulses consist of a succession of loop interruptions with a ratio of 60 (break) to 40 (make) and a speed of 7 to 12 pulses per second. Wide tolerances are permitted. Every pulse implies two transitions, one from closed loop to open loop, the other from open loop back to closed loop. The counting circuit actually responds to the transitions.

In the register the number of transitions are first halved by a halving circuit consisting of two relays before applying them to a binary 10 counter consisting of 4 relays. Contacts of one of the halving relays controls the counter.

In addition to counting the number of pulses in each train the register also counts the number of pulse trains (digits). For the hundreds digit a relay operates at the beginning of each pulse train and another at the end. The same sequence follows for the tens digit except that different identifying relays are used. At the end of every pulse train the digit encoded in the counting relays is stored. For every digit there are four storage capacitors. When a digit has been dialed, one or more of these capacitors are charged. The last digit is stored by the counting relays which are held operated by a relay which operates at the end of the last digit.

The stored dial codes must now be converted into a form suitable for proper selector control. At the end of the last digit the register is immediately connected to the CCC.

(b) Push Button (Keyset)

The telephone set shown in Figure 4 has 12 push buttons, 10 for the digits 1 to 0, a "U" button and a "B" button. The "U" and "B" buttons are for special applications and will not be discussed here.

When a button is pressed, the loop current is interrupted. At the same time impedances are inserted between the now separated line wires and ground. These impedances may consist of a diode and a resistor, or of a resistor only. The following conditions may exist when a combination of diode and resistor are used for each wire:

- No current flow
- Current flow for negative voltage only
- Current flow for positive voltage only
- Current flow for both positive and negative voltage

Since the two wires are separated by the interruption of the loop, 16 different combinations are possible, which are sufficient for 10 push buttons plus a few for special purposes.

In the push button register four relays are arranged so that one or more will operate when a particular line condition is obtained by pressing the telephone key or button. The operation of these code relays initiate a counting circuit of four relays. The operation of one or more of the counting relays will indicate which digit has been selected. After each digit has been received, a relay will operate to indicate whether it is a hundreds or tens digit. Storage of the 3 digits is then accomplished in the same manner as the dial pulses.

The final condition of the register is such that the CCC will translate the codes in the same manner regardless of whether the system is push button or dial.

Testing the Selected Number

There are four relays used to decode the hundreds digit and four relays used to decode the tens digit; each of these relays is connected to one of the storage

Figure 4. Push Button (Keyset) Telephone Set

capacitors in the register. As soon as the CCC is connected to the register, the charged capacitors in the register discharge through the windings of the decoding relays in the CCC. The units digit is decoded by six main relays and two auxiliary relays. The contacts of the relays are connected together to form a relay tree. Each path in the hundreds relay tree corresponds to the first digit. The tens and units relay tree has a number of paths corresponding to the number formed by the last two digits. Another hundreds relay tree is used for testing the dialed number. As soon as the CCC receives the dialed number, the second hundreds relay tree will connect a path to one of two relays. If the CCC accepts the number as an accessible number, a "Go Ahead" relay will operate and the CCC will position the group selector.

If the number dialed is not accessible, then the path set up in the hundreds relay tree will cause a "Reject" relay to operate. The CCC will then return to normal and the busy tone will be transmitted to the caller.

Positioning of the Group Selector (GS)

The hundreds relays that are operated form a marking path to the outlet of the group selector. When the "Go Ahead" relay operates, the wiper of the group selector starts rotating. As soon as the wiper (which has battery on it from the CCC via the CC) finds the marked outlet of the GS, the high speed test relay operates-thus stopping the selector in the same manner as the CCF.

Positioning of the Final Selector (FS)

The Final Selector is positioned in the same manner as the Group Selector. Marking takes place through a path completed by the contacts of the tens and units relays. The relay in the final selector circuit operates to make the physical connection between the GS and the FS. At the same time the FS is connected to the LC. The connections have now been completed and the ringing current is transmitted via the CC. The interrupters have been so arranged that when ringing current is generated to the called party's circuit, ringing tone is received by the caller at the same time. The CCC now returns to normal and is ready to assist in processing another call.

When the called party answers, the speech path is set up as follows:

From the caller's line circuit, through the LF, the CC, the GS, the FS, to the called party's LC.

The Gate Circuit

Some of the selectors are multipled by design. Because of this the possibility exists that two switches of the same selector could be rotated and marked on the same outlet at the same time. Thus double testing is possible. To eliminate this possibility a gate circuit is introduced.

Since every call is processed by the CCC, it is necessary that precautions be taken to ensure that there are no interruptions of the CCC while it is in operation.

The gate circuit, therefore, serves 3 purposes:

1. To decide which unit will use the CCC.
2. To control the order in which the units are allowed to use the common marking multiple. (This prevents double testing.)
3. To ensure that no units seeking access to the CCC are kept waiting too long.

Disadvantages

The major disadvantage of the "UP" system is that if the CCC should fail the complete system would become inoperative. Experience has shown, however, that failure of the CCC is very rare.

Advantages

- Since the units are of the plug-in type, defective units can be replaced in less than a minute. Thus no appreciable time would be lost should failure occur.
- Since the selector is "non-homing," there is less wiper movement per call. In addition the loads are evenly

distributed and wear on the contacts would be uniform and at a minimum.

- Mechanical noise and vibrations are reduced because the selector wipers move only a short distance and the method of stopping the selectors (detent and ratchet wheel) is such that there are no excessive vibrations transmitted to the shaft.
- The test relays have been reduced to one, thus lowering the initial cost of the high speed test relays and also there are less test relays to maintain.
- High flexibility and low maintenance cost has made "UP" PATS a very efficient and economical system.

Applications

To date Western Union has two "UP" systems in operation. The first system, a 200-line push-button system, was installed in 1962 at Western Union's Headquarters in New York City, with extensions to various parts of the Metropolitan Area and Jersey City. This system has been extremely reliable. In the last six-month period only three minor equipment troubles were reported while processing an average of 40,000 calls per month.

The second application, which is the first leased wire system, is in operation at Philadelphia - Baltimore - Washington Stock Exchange. This is a dial system operating over long distances. The special added features, modifications and operation of the system will be discussed in the July 1964 issue of the Western Union TECHNICAL REVIEW.

Acknowledgements

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* * *

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Mr. G. R. Chong is an Engineer in Broadband Switching division of Plant and Engineering since October 1963. He has prepared specifications on the operation and installation of Philips "UP" PATS and assisted in the installation and testing of first PATS for Philadelphia-Baltimore-Washington Stock Exchange. Prior to joining Broadband Switching group he was associated with the Facsimile division where he was engaged primarily in the applications of facsimile equipment and systems.

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AUTODIN

System Description—Part 11

Circuit And Message Switching Centers

Communication systems usually fall into one of two categories: Circuit switching or message switching. Circuit switching systems provide direct user-to-user circuit connections via circuit switching centers. Message switching systems relay messages from source to destination via message switching centers which store incoming messages until they can be forwarded to the next center or to the final destination. The particular application determines which of the two switching methods is used. If, for example, system traffic is traffic from a large number of like sources, each having a low message volume, then circuit switching may well prove to be the best system. If, on the other hand, the sources are unlike, the message load is large and the traffic distribution is such that long delays may be expected during "busy conditions," then message switching may prove to be the best approach.

In large systems where a variety of users are involved both switching techniques can be advantageously employed. AUTODIN, the Automatic Digital Network system, is an example of such an application. The circuit switching element provides direct point-to-point service between like circuit switching terminals; the message switching element provides service to large volume terminals and unlike terminals. Further, by providing a compatible interchange facility between the two switching elements the best features of each are attained. For example, circuit switching calls encountering extended busy conditions or those destined for unlike terminals can be routed to the message switching function for subsequent delivery to the addressee.

In Part 1 of the AUTODIN—System Description, the terminal equipment and network configuration were discussed.[1] This article, Part II, contains a general description of the switching center equipment.

Switching Centers

The present AUTODIN centers interface with the communication facilities at the audio or carrier side. Each center, as shown in Figure 1, comprises six distinct functional areas. The transmission facilities terminate in the Modem Area where the binary data signals are converted from frequency shift form to dc polar form and vice versa. From here the signals are passed through Technical Control where elaborate monitoring, patching, clocking, and signal level isolation and converting equipment is contained.[2,3] Encrypted lines are patched to the Crypto Area where government-furnished encryption and decryption equipments are located. The area to the left of the crypto area constitutes the "Black" or enciphered

Editorial Note: This is the third of a series of articles on AUTODIN.

signal area of the center; the area to the right of the crypto area carries deciphered or "in-the-clear" signals and therefore constitutes the "Red" or intelligible signal area of the center. The clear polar signals leaving Technical Control terminate in per line equipment associated either with the Message Switching Unit (MSU) or the Circuit Switching Unit (CSU). The MSU and CSU are also interconnected in Technical Control via MSU-CSU Interchange trunks. These trunks are local in-house channels and do not require use of cryptographic or modem equipment.

service messages. A separate small scale computer is also located in this area to search tapes written by the MSU and to retrieve messages specified in the search criterion. This unit is called the Tape Search Unit (TSU).

All the aforementioned equipments are in a controlled environment. Temperature, humidity and primary ac power are maintained within prescribed limits. Commercial power is the primary source of power for the switching center. However, no-break, back-up power is supplied from diesel driven generators in the event that the commercial source fails.

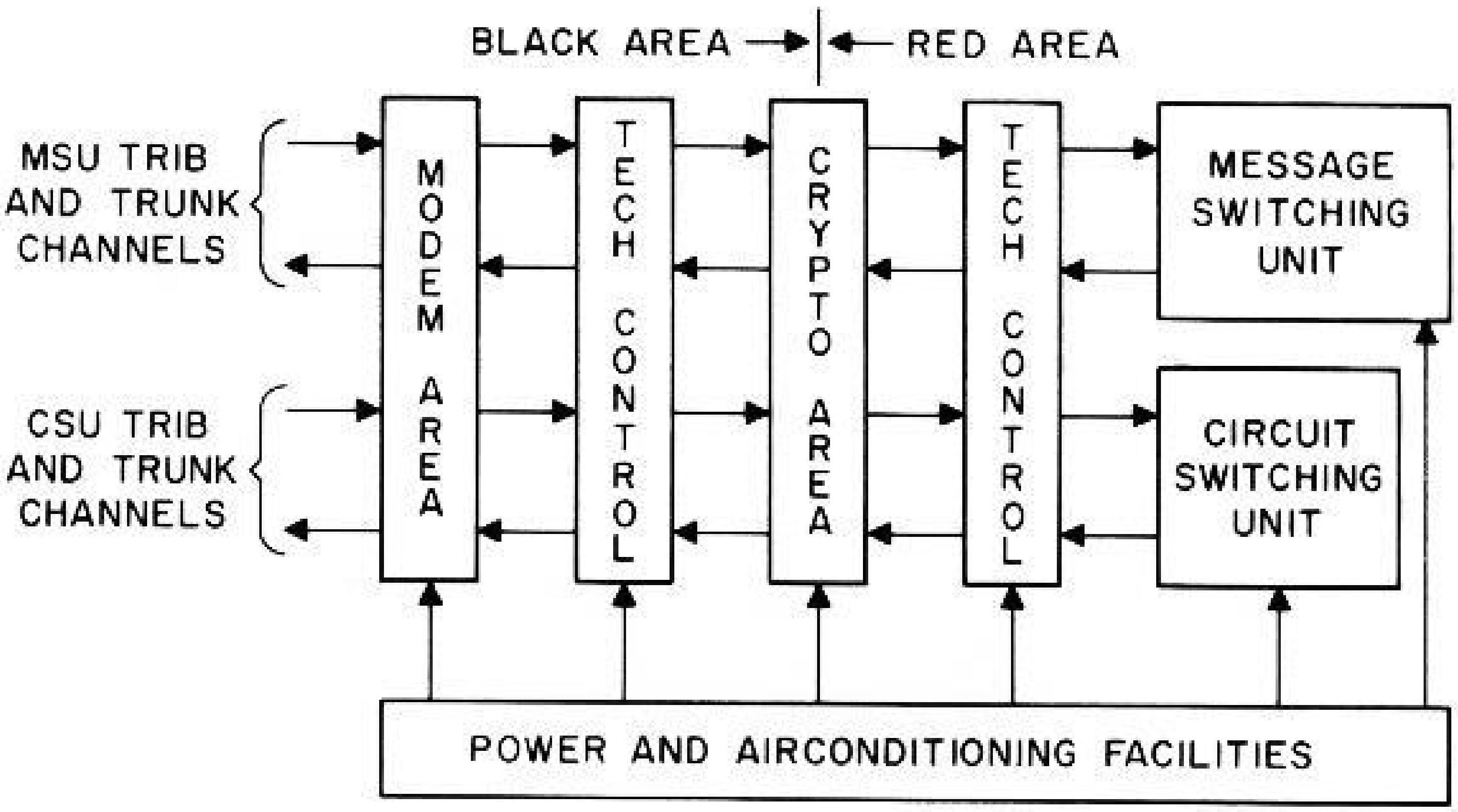

Figure 1. Switching Center Configuration

The MSU and CSU, located in the Center Operations Room, perform their respective switching and ancillary functions independently. This is where the bulk of the switching center equipment is located and the center operations are controlled and monitored. A systems console, which displays equipment and channel status and provides the means for controlling the center equipment, is the focal point of the operations area. Monitor printers adjacent to the system console receive operations type printouts. Two Compound Terminals, one connected to the MSU and the other to the CSU, serve as points for entering and receiving

The Circuit Switching Unit

The CSU performs the primary functions normally attributed to a circuit switch, i.e. it monitors the state of each incoming line to determine when a call requires service, processes incoming calls on a selective sequential basis, establishes and holds connections which are determined to be valid, and releases connections which are no longer required.

The manner in which these functions are performed and the means used to supervise and control the calling sequence are unique to the CSU. Rather than relying upon manual call generation techniques such as the telephone dial, the standard AUTODIN message header is used. This feature coupled with a supervisory control procedure akin to Mode I transmission procedures[1] permits calls to be automatically generated and messages to be transmitted immediately upon receipt of the connection.

the MSU is called. The next response expected from the CSU is either a Busy signal, a Disconnect signal, or a Connection Established signal.

Since the call is assumed for a terminal off CSU B, the next sequence of events involve seizing a trunk to CSU B and

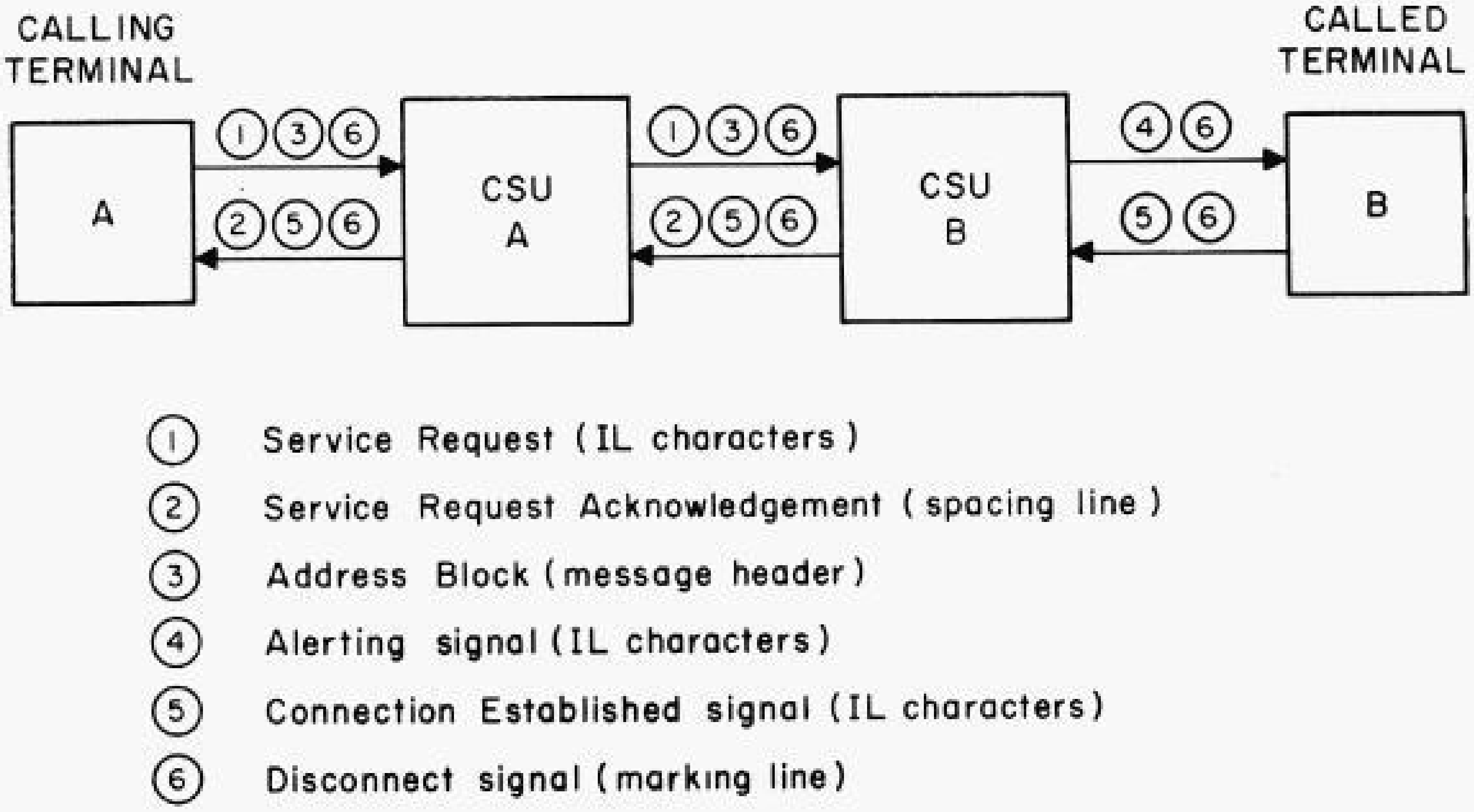

Figure 2. CSU Calling Procedure

Call Procedure

Figure 2 illustrates the normal calling procedure for progression of a call through two intervening CSU's. The procedure is as follows: The calling terminal initiates the call by sending (1) a Service Request to CSU A (continuous sequence of IL characters). The CSU recognizes the Service Request and connects a register-sender to the requesting line. The register-sender frames on the IL characters and sends (2) the Service Request Acknowledgement (steady space) to the calling terminal to acknowledge that it is ready to receive the address block. The calling terminal then sends (3) the Address Block followed by IL characters. The address block is the first line block of the message. It indicates the priority and security level of the call, the addressee and whether a circuit switching terminal or relaying the calling information from CSU A to CSU B. This procedure is a repeat of events (1), (2), and (3) previously described with the register sender taking the place of the calling terminal. The Address Block generated by the register sender at CSU A is in abbreviated form and also contains information specifying the speed and type of the calling station. When step (3) is completed, CSU A establishes a final connection between terminal A and the trunk to CSU B.

At CSU B the call is processed and found to be for local terminal B. The call is also determined to be for a compatible terminal (same speed, and type as the calling terminal and having a security clearance equal to or higher than the security level of the message) and a connection is established between it and the register-sender in CSU B. The register-sender then sends (4) an alerting signal to terminal B (continuous IL characters) and expects (5) a return of IL characters, if terminal B is ready to receive traffic. If this is the case, CSU B establishes the final connection between the trunk line from CSU A and terminal B, the IL characters generated by terminal B are recognized by terminal A as the connection established signal and terminal A initiates transmission of the complete message (including the header used as the address block in the calling procedure).

After the message has been completely transmitted and acknowledged, terminal A sends (6) a Disconnect signal (steady mark on line). CSU A and CSU B recognize the Disconnect signal within a ¼ to ½ second time interval, release their separate connections and return a disconnect signal on their respective send legs. The circuits are now free (steady mark condition) in both directions and available for a new call. If terminal A has another message to send, the procedure is immediately repeated for the next message.

Mechanization

The CSU employs a space-division switching technique. Solid state circuitry is used to the fullest extent practicable. The switching network and much of the relay logic is comprised of dry reed switches. Equipment in other parts of the unit is comprised of transistor resistor logic circuits for increased speed of operation.

The CSU has seven major parts, as shown in Figure 3: the Per Line Equipment, the Line Scanner, Register Senders, Translator, the Switching Network, Network Control, and Central Control. Central Control is the heart of the switching unit. Generally, it sequences the performance of each task involved in establishing and holding connections; it also provides the means by which information is passed from one unit to the next, and verifies that the information exchanged is valid and that the sequence of events are properly executed and terminated. The per line equipment recognizes Service Requests and Disconnect signals, stores the state of the line (idle, busy high, or busy low) and indicates the type, speed

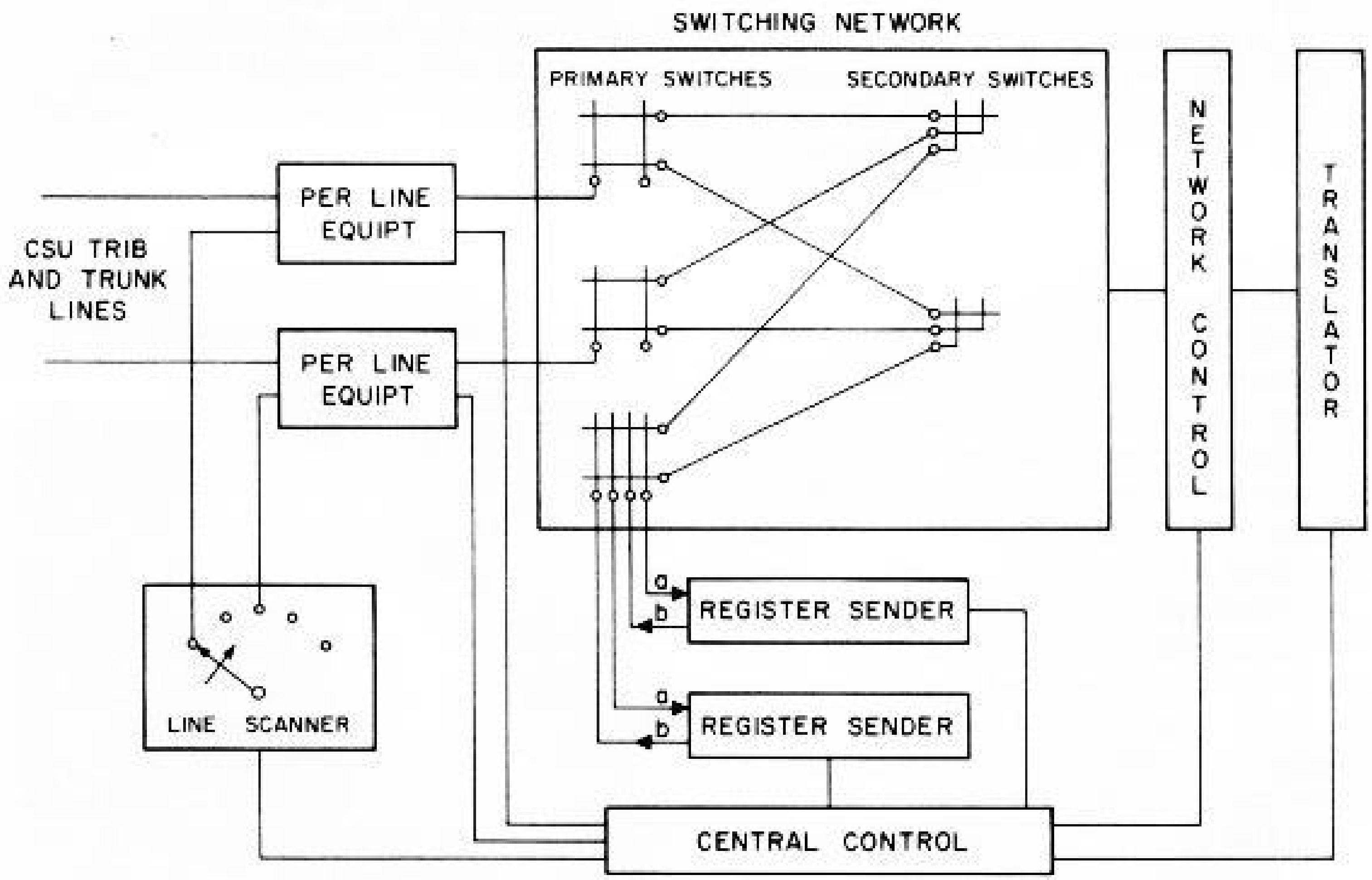

Figure 3. CSU Block Diagram

and security level of the line. The line scanner sequentially scans the lines to determine the presence of a Service Request and stops to indicate to central control the equipment location of the line requesting service. The register senders are called into play to receive and store the address block from the calling station and to relay this information as well as the speed and type of the called station to the next CSU, if a tandem connection is requested. In the event that the call is for a local CSU station, it alerts the called station and waits for a response before requesting a "final" connection. The translator and network control cooperate in determining and establishing the required connection through the switching network. The switching network is used to establish calling line to register sender connections (A appearance connections), register sender to called line or trunk connections (B appearance connections), and calling-to-called line or trunk connections (final connections).

The switching network is a three stage, four-wire, non-blocking array, as shown in Figure 3. The primary switches, serving a group of lines, are square switch arrays. Each vertical-horizontal crosspoint represents a dry-reed switch. Coincident excitation of a horizontal and vertical coil of the switch will cause it to operate. A separate hold coil in series with a make contact of the switch is used to hold the switch operated. The crosspoint switches are independently operable thus permitting all lines to be accessed through the switch.

The secondary switches, which interconnect a pair of primary switches, are triangular switch arrays. The vertical-horizontal cross points of this switch also represent dry reed switches. The operate and hold arrangement for these switches are identical to those in the primary switch arrays. Use of a triangular switch array reduces the number of cross point switches required to a minimum, without affecting accessability between the primary switch arrays.

In the event that a connection is desired between two lines on the same primary switch, two crosspoint switches are energized on the same horizontal and a line reversal relay is operated in the per line equipment to connect the called station's receive line to the calling station's send line and vice versa.

Central control determines, from the class relay in the per line equipment, whether the called line or trunk is of a compatible line speed and type and that its security level is equal to or greater than the security level indicated in the originated call. In the event that the checks are not satisfied, the call is rejected and disconnected. Other reasons for generating disconnects may be due to invalid address blocks, parity errors, or high priority preempt sequences.

Network control selects the first idle line in a multichannel group and controls the selection of the first available trunk route from the set of primary, first alternate and second alternate trunk groups. If all lines in the group are busy and the call is high priority, a low busy line is preempted and seized by the high priority call. If all routes are unavailable, central control informs the register sender to return a busy signal to the calling station.

Figure 4 shows a front view of the 50-line CSU. A trouble indicator panel appears on the face of the end rack in the second row of the unit. It is used primarily as a maintenance aid and includes facilities to indicate the state of certain critical points in the CSU. Key switches associated with the panel permit test calls to be manually controlled, certain ele-

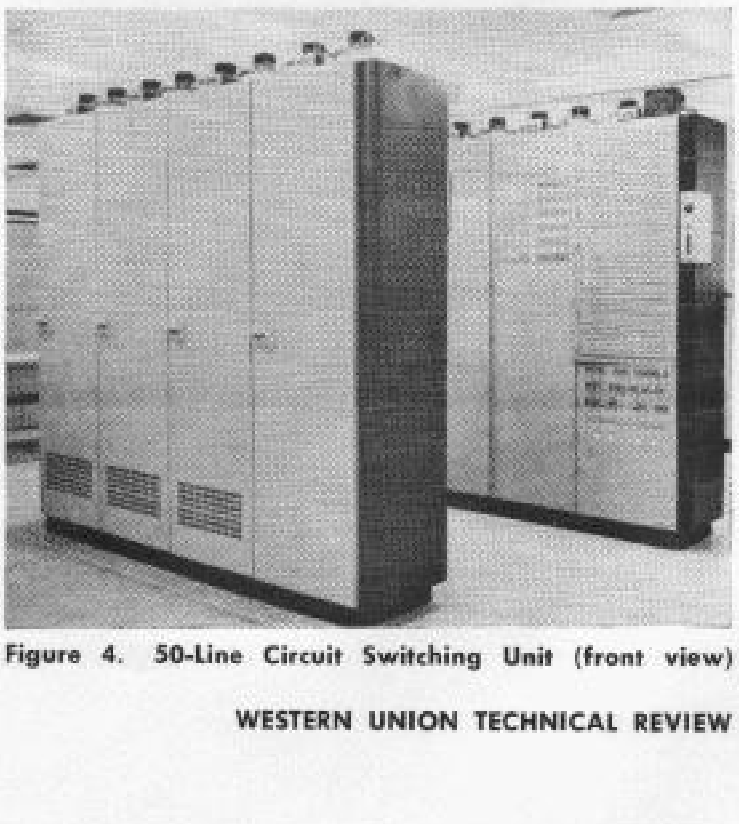

Figure 4. 50-Line Circuit Switching Unit (front view)

ments of the CSU to be activated or made to appear busy, and redundant circuit elements to be selected manually or automatically.

The panel to the left of the trouble indicator panel contains switches and lights for tracing connections established through the switching network, and making lines appear busy to the CSU.

The Message Switching Unit

The MSU employs the store-and-forward concept of transmission and consequently is much larger and more complex than the CSU. Each message switched by the MSU is received in its entirety before it is relayed to the next destination. Thus, the MSU has all the functions normally associated with a station receiving and transmitting messages. These functions in the MSU are time-shared among the input/output channels to the fullest extent practicable. In addition to these functions, the MSU is also provided with extensive random access message storage for received messages and with the logic and memory necessary to recall and transmit these stored messages to the output channels in the required order, code, and format. These functions are performed by a computer and its associated peripheral devices under the control of a stored program specifically designed for the AUTODIN application.

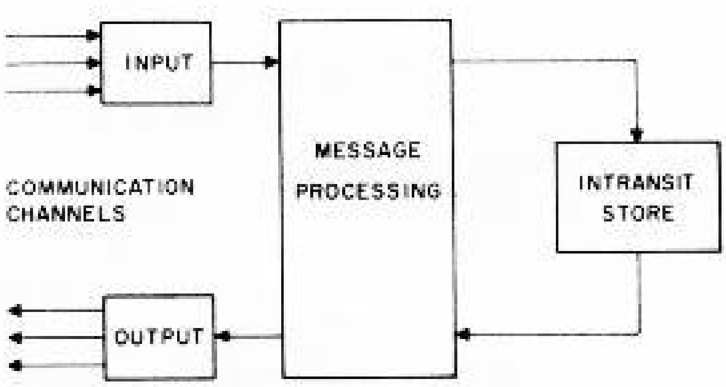

Figure 5. Functional Block Diagram of Message Switching Unit

A simplified functional block diagram of the MSU appears in Figure 5. The input and output functions provide buffering between the communication channels and the message processing function. The input function accumulates bit-serial message data into characters, code-converts input characters into common language Fieldata characters, accumulates input characters in allocated per line message storage, and transfers accumulated characters (line blocks), on demand, to the message processing function. The output function performs the inverse function of accepting line blocks from the message processing function, storing them in per line allocated storage, and distributing them to the output lines, a character at a time, in bit-serial form and in the required line code.

Message Processing

The message processing functions fall into two parts: input processing and output processing. Input processing accumulates incoming message segments (line blocks) into messages, checks each segment received for accuracy, processes the message headers to determine the precedence, type, security, and routing requirements of the message, stores the message segments in intransit store, maintains a multiplicity of records which specify where the messages are stored, the destinations to which they are to be delivered, the format in which they were received, the time received in the center, etc., writes a complete reference copy on tape of each message received, and records journal information on tape for each message indicating when and from what channel the message was received and whether or not it was completely received and accepted by the center. Output processing determines when channels are free to accept additional message data, selects the message segments which are to be transmitted next over these channels by examining the contents of tables prepared by input processing, retrieves these message segments from intransit store, converts them to the format required by the output channel, deletes routing indicators that are not pertinent to the given transmission, transfers the message segments to the output function, updates tables pertaining to the messages as required, and records journal entries for each message transmitted to indicate when and to what channel the message was transmitted and whether or not it was accepted by the receiver.

Intransit store is used for temporary storage of messages received by the MSU. Only one copy of the message is kept in intransit store. As soon as the message has been completely transmitted and acknowledged the space is made available for a new message.

tables, and storage of channel status information. Common logic is time-shared by all channels of the ADU. A maximum of 25 full-duplex lines, each operating at any standard speed up to 4800 bauds and controlled by either Mode I or teleprinter procedures, can be associated with each ADU. The 50-line and 100-line MSU centers are presently equipped with two and four ADU's, respectively.

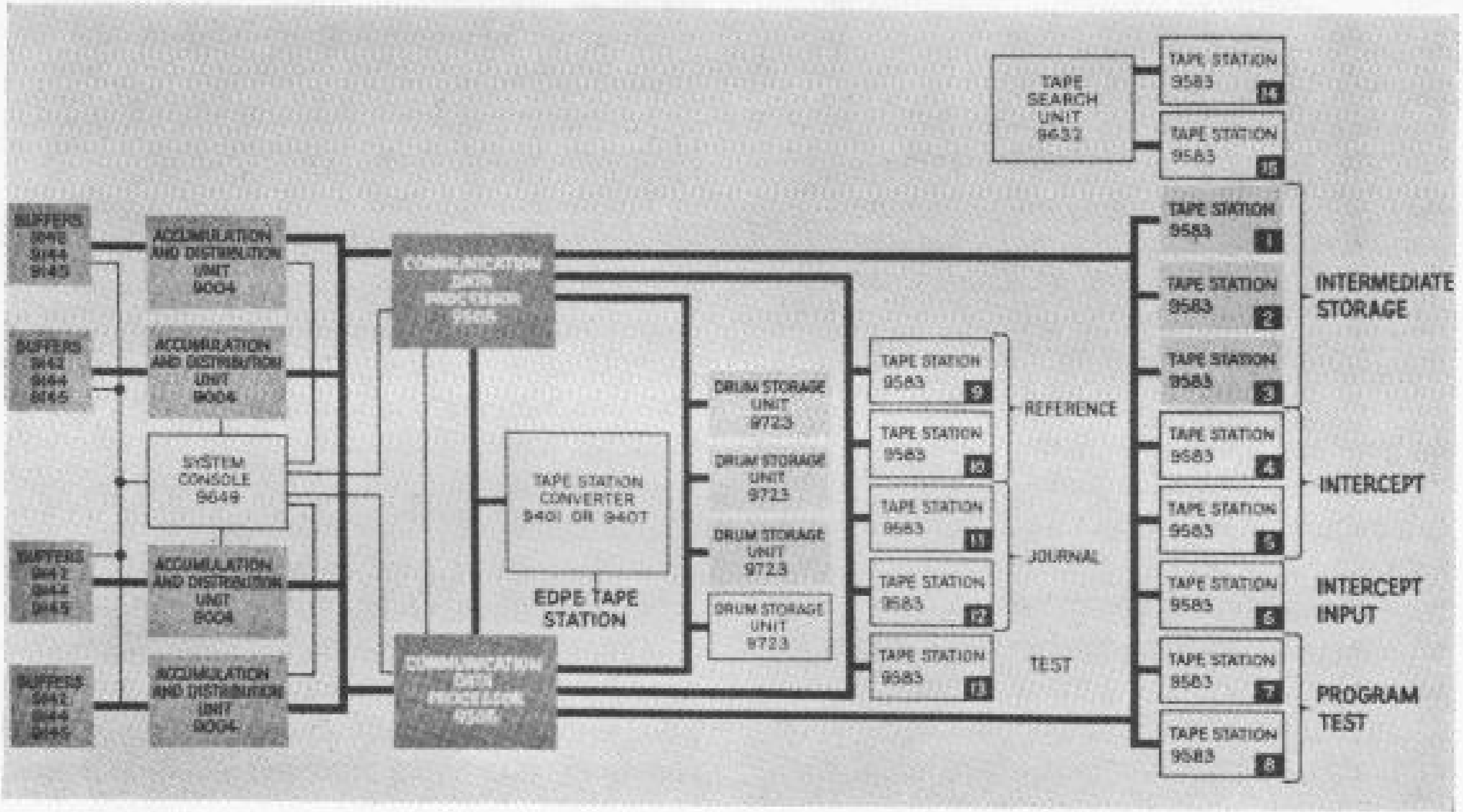

Figure 6. Equipment Block Diagram of Message Switching Unit

Figure 6 is an equipment block diagram of the MSU. The input/output functions previously described are accomplished by the Buffers and the Accumulation and Distribution Units (ADU). Communication channels terminate in buffers which accumulate incoming bits into characters and distribute out-bound characters bit serially to the line. Three buffer types are used: Mode I high speed buffers (4800 bauds max.), Mode I low speed buffers (600 bauds max.) and teleprinter buffers (60, 75, and 100 wpm). The ADU performs the balance of the input/output functions. Core storage in the ADU is used for accumulating characters into line blocks, code conversion

Communication Data Processor

The message processing functions are performed by the Communication Data Processor (CDP) which is a large scale computer designed primarily for data handling and logical operations. It uses an extensive magnetic core memory for storing the operational program and other related information. Buffer areas in core are also used for temporary storage of information being transferred to and from peripheral devices. Simultaneous operation with many peripheral devices is possible while the computer is executing internal routines, thus permitting the full capabilities of the computer to be used most efficiently.

The bold lines eminating from the CDP represent transfer channels; the units at the end of the transfer channels are called peripheral devices. The two tape transfer channels are each capable of being written to and read from simultaneously—thus permitting up to four tapes to be in use at the same time. The other transfer channels must be used alternately for reading and writing.

Note that two CDP's are provided and that each has access to the same peripheral devices through its own set of transfer channels. Normally, one CDP is "on-line" and processing traffic while the other is in "standby." Should the "on-line" CDP fail, the "standby" CDP takes over automatically without loss or mutilation of messages and with minor or no noticeable effects upon traffic handling.

The intransit message store function is represented by the Drum Storage Units (DSU) and the three Tape Stations designated as Intermediate Storage. The 50- and 100-line MSU centers are equipped with 3 and 4 DSU's, respectively. Each DSU has one drum capable of storing approximately ¼ million 8-bit characters. Messages are normally stored on the drums. When the drums become overloaded, the messages most likely to experience long waiting time on drum are transferred from drum to intermediate tape. These messages are returned to drum when the overload condition no longer exists.

Messages for stations which are closed out or inoperable are directed to Intercept tape to prevent such messages from occupying drum space unnecessarily. When a station is reopened for traffic, the Intercept tape is read back into the system and onto the drum. A maximum of three magnetic tape stations are required for the Intercept function: one each for receiving and transmitting messages and the third station serving as a spare.

The Reference and Journal information generated by the message processing function are written to two separate tapes. These tapes are never read into the "on-line" system. They are used either by the Tape Search Unit or the "standby" CDP to accumulate statistics and recover messages lost because of equipment failure. A maximum of two stations must be assigned for each function, one actively being written to and the other serving as a spare.

At some sites, messages for colocated data processing facilities are received and transmitted via EDPE tapes which are fed directly into the MSU via a Tape Station Converter (TSC). A maximum of eight EDPE tape stations can be connected to the TSC, one used for input to the MSU and seven used to receive messages destined for the Electronic Data Processing (EDP) activity.

Modular Design

The MSU consists of an integrated set of units constructed on a modular basis. Failures of single units of equipment will in no case result in a complete center outage and in many instances are fully protected by standby equipment. A single buffer failure, for example, affects only the line which it serves. An ADU failure, which is one of the more serious types of single failure conditions, affects up to 25 lines. At present, an additional ADU is being installed at each site to serve as a spare unit and to permit preventive maintenance routines to be scheduled on each unit without loss of service to the customer. Failures of the on-line CDP are automatically detected by special automatic monitoring equipment and protected by the standby CDP. Drum failures cause a proportionate reduction in the intransit storage capacity and may require messages to be recovered from Reference tape but in most cases do not adversely affect the center operation. Tape failures are automatically handled by closing out the affected tape and switching to a spare tape.

Many multiple failure conditions are also tolerated. Failure of such functions as Intercept, and Intermediate Tape Storage, for example, may cause some degradation in MSU service, but do not affect the basic message switching functions. The minimum complement of equipment required by the MSU to perform useful work is one ADU, one DSU, one CDP, and one Reference and Journal Tape.

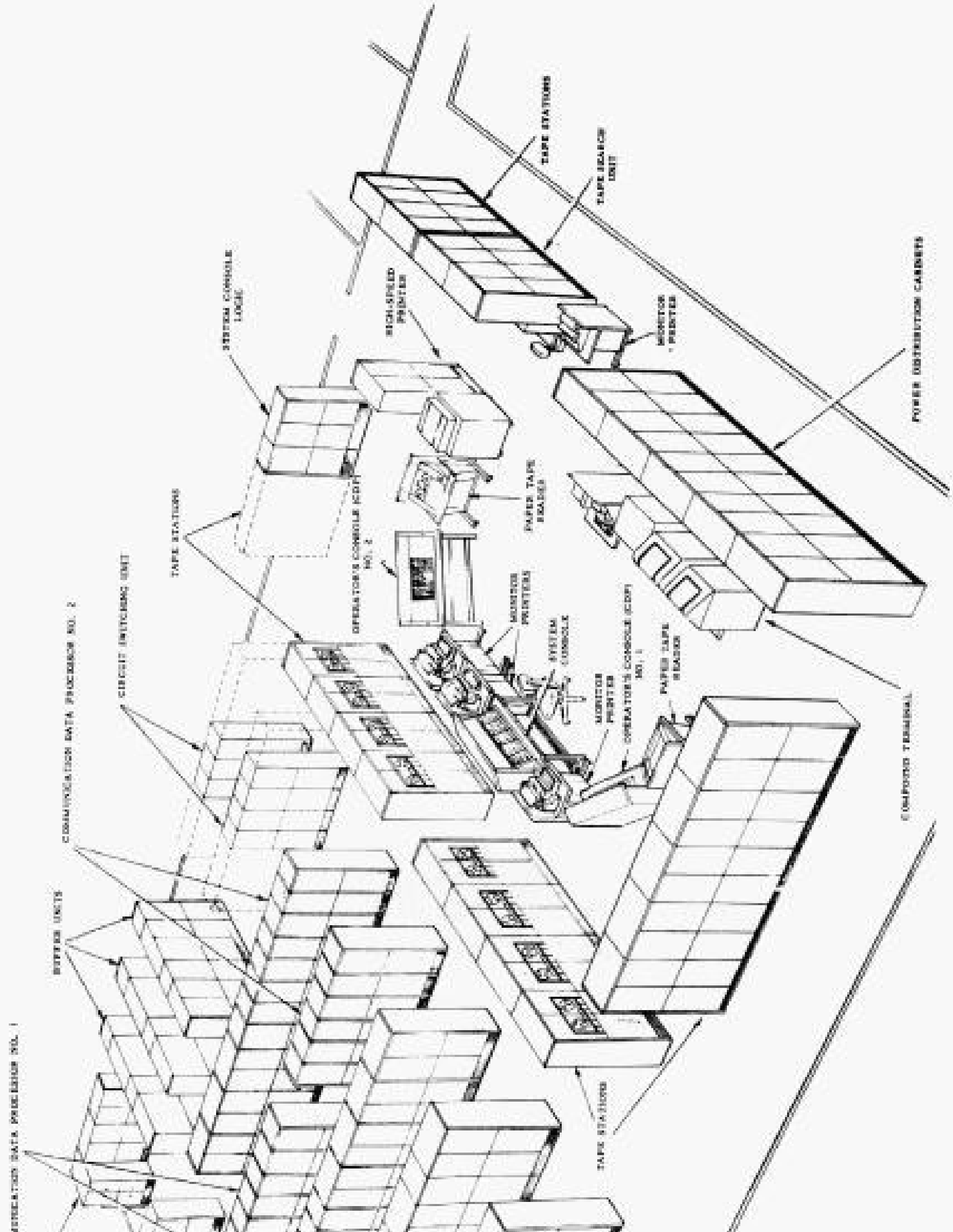

Figure 7. Floor Plan of a 50-Line AUTODIN Center

Figure 7 is a layout of the operations area of a typical 50-line AUTODIN center. The major units of equipment are indicated. The Circuit Switching Unit appears at the top center of the figure. Most of the remaining units belong to the MSU.

Figure 8 is a view of the operations area of a typical AUTODIN center. Most of the equipment shown is part of the MSU. The console in the center of picture is the System Console.

Figure 8. A Typical AUTODIN Center

Reliability of the System

The complete five-center AUTODIN has been in operation for some time. While the usual problems associated with a new system have occurred, its performance has been gratifying to date and is steadily improving. The system performance is continually monitored and improvements are being made both to hardware and software as the needs arise.

As an indication of customer acceptance, an order has been received recently to expand the present MSU centers to 250 full duplex lines and to provide four additional centers which will have a 250-line MSU capability and a 50-line CSU capability.

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1. AUTODIN—System Description, Part 1—Network and subscriber terminals—H. A. Jansson, Western Union TECHNICAL REVIEW, January 1964, Vol. 18 No. 1.
2. AUTODIN—Switching System—Technical Control Facility—F. B. Falknor, Western Union TECHNICAL REVIEW, October 1963, Vol. 17, No. 4.
3. Digital Phase Corrector for Synchronous Transmission—E. J. Chojnowski, Western Union TECHNICAL REVIEW, October 1962, Vol. 16, No. 4.

MR. H. A. JANSSON, Senior Engineer in the AUTODIN Project Group, has been associated with the AUTODIN project since its inception. His prime responsibility has been in the area of system and switching center design and analysis.

Previously he was associated with the Automation Group where he was concerned with data communication and the application of computer techniques in the design of message switching centers. While in the Switching Systems Group he was engaged in the design of several telegraph switching systems including Plan 55.

Mr. Jansson entered Western Union in 1950. He received his BEE, Bachelor Degree in Electrical Engineering, from Pratt Institute in 1950 and his MEE, Master's Degree in Electrical Engineering, from Stevens Institute of Technology in 1957.

He is a Member of the IEEE and has several patents credited to him on telegraph switching systems.

Part I—System Description—Network and Subscriber Terminals was written by Mr. Jansson in the January 1964 issue of the Western Union TECHNICAL REVIEW.

Raffaele Ascione, Senior Project Engineer—Cable Equipment Div.—P & E Dept.

A Solid-State Teleprinter/Multiplex Translator

The Solid-State Translator is a code converter designed by Western Union to be used as an interface between asynchronous teleprinter channels and synchronous multiplex channels in transatlantic cable operations. This interface equipment performs the dual function of teleprinter-to-multiplex and multiplex-to-teleprinter code conversion. Code conversion had been obtained previously by means of punched tape repeaters or channel repeater relay banks and electromechanical start-stop distributors.

Introduction

A considerable volume of cable traffic, originating in Montreal, Canada and neighboring cities and destined for overseas points, was formerly routed via New York facilities of the Western Union International. To comply with a Canadian Department of Transport request, that routes for such traffic be confined to Canadian territory, an "All-Canadian Route" was established. The voice frequency (VF) circuit from the cablehead at Bay Roberts, Newfoundland to New York was rerouted through the Montreal office of the Anglo-American Telegraph Company and a special narrow-band telegraph carrier repeater was provided to make available six narrow-band carrier channels from Montreal to Bay Roberts. These channels, in conjunction with a rearrangement of the Montreal office equipment, enabled the majority of circuits between Montreal and Bay Roberts to be operated on a teleprinter basis thereby streamlining and improving message handling at Montreal.

However, at Bay Roberts, the interface between the teleprinter channels and the synchronous time-division multiplex channels used for transatlantic cable traffic required teleprinter-to-multiplex and multiplex-to-teleprinter code conversion.

In converting teleprinter to multiplex signals, the teleprinter "Start" and "Rest" impulses or code bits which are redundant in the multiplex code, serve to provide teleprinter synchronizing information only and must be deleted before the intelligence code bits may be retransmitted on a multiplex channel. Conversely the Start and Rest impulses must be added to the signal output of a multiplex channel to permit transmission over a teleprinter facility.

Previously code conversion has been obtained through the use of tape repeaters, or channel repeater relay banks and electromechanical start-stop distributors.

Design of Translator

Solid-state Translator Type 11594, which utilizes Western Union Standard Logic cards, was designed to eliminate any need for tape reperforation and to obviate the considerable amount of maintenance associated with electromechanical start-stop distributors and switching relays used in channel repeater banks. This resulted in a more reliable interface between the teleprinter and the multiplex systems, requiring little or no maintenance.

The PXMX portion, which converts teleprinter to multiplex signals, features several functional blocks including an Input Line Filter, a Receiving Start-Stop Distributor and a Channel Repeater. The output from a multiplex channel is converted to teleprinter signals by a Sending Start-Stop Distributor in the MXPX section of the translator.

Timing pulses for both sending and receiving start-stop distributors are obtained from a common stable local oscillator, Type 11084. A dual output ± 12 volt, 2 ampere Power Supply Type 11591 provides all the power necessary for the logic circuit elements in the translator.

Teleprinter to Multiplex Conversion (PXMX)

The basic functions involved in translating an asynchronous teleprinter signal to a synchronous multiplex signal are:

(a) Signal Regeneration
(b) Serial-to-Parallel Conversion
(c) Channel Repeater Coupling

A somewhat more detailed breakdown of the function blocks in the PXMX translator is illustrated in Figure 1. For convenience the teleprinter signalling speed has been fixed at 45.45 bauds.

Polar teleprinter signals from the output relay of a narrow-band carrier channel at $\pm$ 120 volts DC are connected through simple voltage dividers to limit the voltage swing appearing at the input of the Input Line Filter to appropriate values. Within the filter a dc flip-flop responds as a line relay. Other NOR logic elements, in conjunction with a delayed action flip flop, serve to eliminate any signal "breaks" caused by fortuitous impulse noise which may occur at any time during the reception of a teleprinter character, provided that such noise "hits" have a duration of less than the built-in time delay of the flip-flop, (in this case set at two milliseconds). In effect, incoming signals of less than two milliseconds duration are not reproduced at the output of the filter. As a consequence the output is a "filtered" signal which follows the input signal with a delay of two milliseconds. In addition, the polar input signals are normalized to yield an output signal varying between ground potential and a negative voltage level, suitable for use with the logic elements of the system.

The square-wave output of the free-running oscillator is connected to the input of the Frequency Divider through the Oscillator Gate. Normally, under "idle line" conditions, the oscillator signal is "blocked" at this gate by a control or inhibit potential emanating from the Gate Control. The various inputs of the Gate Control are, at this time, in an "all-ground" condition. When the leading edge of the Start impulse appears at one of the Gate Control inputs, the block is removed—thus passing the oscillator signals to the Frequency Divider chain and initiating the counting cycle. During the counting cycle one or more Gate Control inputs derived from several points in the Frequency Divider and the Sample Pulse Generator chains preclude the establishment of an "all-ground" condition until the end of a prescribed count interval.

The Frequency Divider is a four-stage binary counter which divides the oscillator frequency by a factor of 16. For the indicated frequency of 727.2 cps the Divider output is a series of timing or "step-

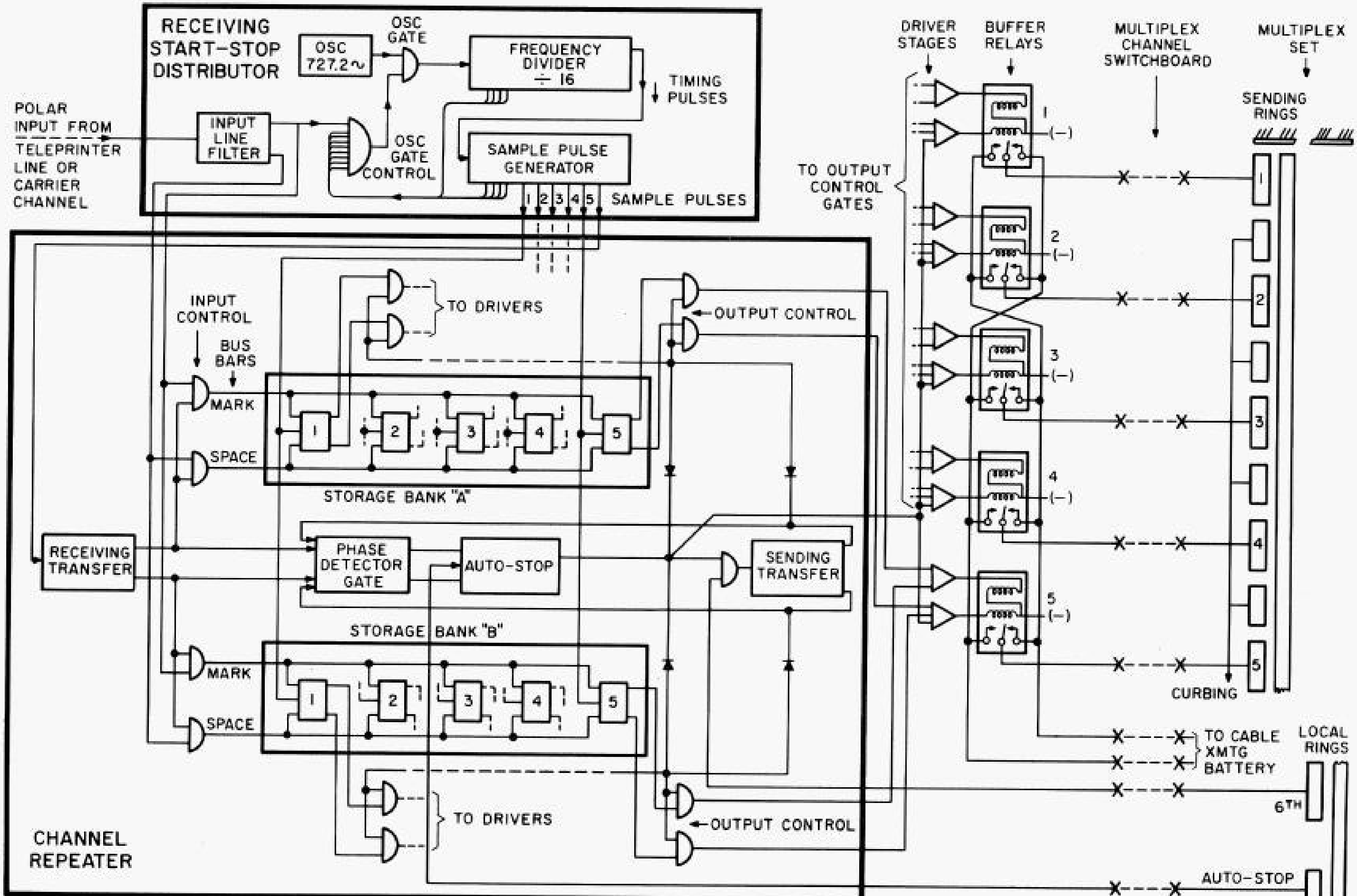


Figure 1. Block Diagram of Teleprinter-to-Multiplex Translator

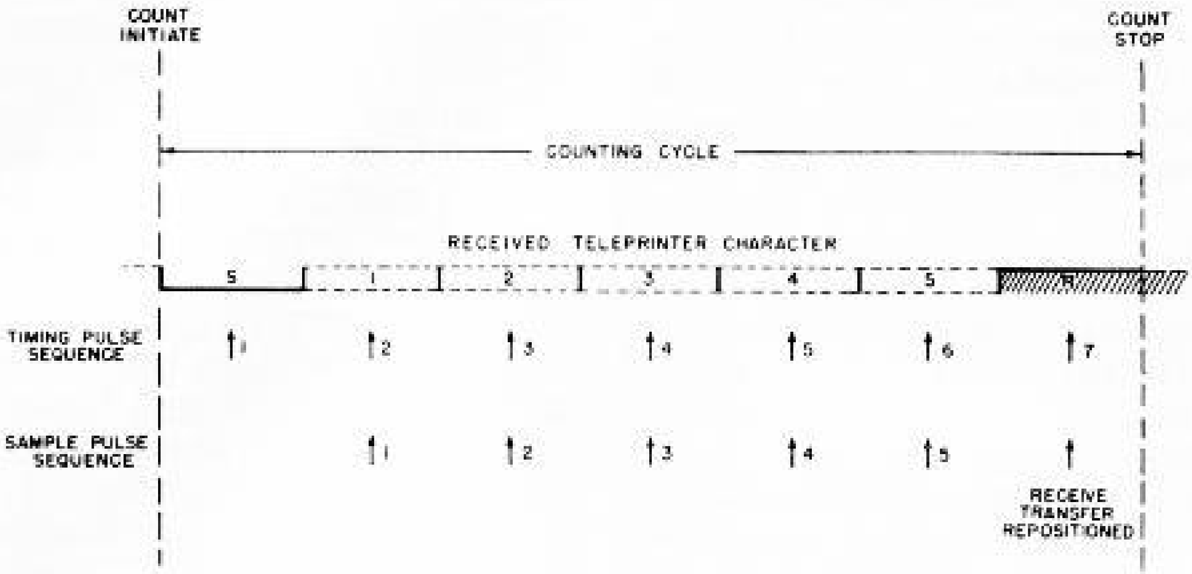


Figure 2. Timing Sequence for the Receiving Start-Stop Distributor (PXMX)

ping" pulses which occur at precisely 22 millisecond intervals. The first of these pulses occurs one-half a bit length or 11 milliseconds after the leading edge of the Start impulse appears, and corresponds to the center of the Start impulse.

The Sample Pulse Generator is a four-stage shift register which counts a specific number of the "stepping" pulses and in turn generates the individual sampling pulses used to store the teleprinter character intelligence bits in one or the other of the two five-unit storage banks of the Channel Repeater. The first of these sample pulses occurs one and one-half bits after the initiation of the Start impulse and corresponds to the center of the first intelligence bit. Since the "marking" and "spacing" bus bars of the storage banks are conditioned in response to line signal polarities appearing at the output of the Input Line Filter, the first storage flip-flop in the bank will respond to and store the first signal impulse. In a similar manner subsequent signal impulses are stored in successive flip-flops by the sample pulses. This technique effectively "strips" the Start and Rest impulses from the teleprinter character.

The result is serial-to-parallel conversion and the stored signal may be considered a fully reconstituted signal that can be conveniently retransmitted at a bit rate determined by the synchronous multiplex set. In a sense this type of regeneration is analogous to terminal regeneration.

The combination of the Input Line Filter, the Frequency Divider and the Sample Pulse Generator constitutes a Receiving Start-Stop Distributor which filters, regenerates and distributes the intelligence portion of a received teleprinter character to several storage flip-flops, accomplishing in this manner serial-to-parallel conversion. The timing sequence for the start-stop distributor is shown in Figure 2.

A channel repeater is a useful adjunct when it is desired to couple a start-stop system to a synchronous system. It may be considered as a "loose" coupling which absorbs any variations in teleprinter motor speeds occasioned by power supply frequency fluctuations. The theory of operation is briefly described by the following discussion. Assume that the multiplex speed is arbitrarily set at 300 operations per minute (opm).

Theory of Operation

Once the multiplex speed has been assigned, it is necessary to establish an incoming teleprinter character rate which is less than the multiplex rate by some fixed percentage, approximately 1 to 2 percent. At the distant teleprinter sending position, the transmitter is released at a rate such that the characters do not exceed 295 per minute, but the signal baud rate is left unchanged from the normal rate. The received teleprinter signals, after being regenerated as previously described, are distributed and stored in one of two Storage Banks. The switching of signals into one or the other storage positions is controlled by the Receiving Transfer Flip-Flop which is operated to a new state, at the end of each received teleprinter character, by a pulse from the Sample Pulse Generator.

The outputs of these storage banks are alternately connected through sets of control gates to pairs of driver amplifier stages which position five mercury-wetted contact polar relays. Control of the storage bank output is exercised by the Sending Transfer Flip-Flop, which is repositioned once per revolution by a local 6th pulse segment on the multiplex distributor.

For proper operation, the Receiving and Sending Transfers must be out-of-phase. Stated in other words, if the Receiving Transfer switches a character into Storage Bank "A," the Sending Transfer must be switched to utilize the output of Storage Bank "B" and vice versa. Recalling that the multiplex speed has deliberately been made effectively higher than the teleprinter speed, it can be seen that the Sending Transfer will gradually accumulate phase with time or will "creep" ahead until it is in-phase with the Receiving Transfer. Since this results in a simultaneous attempt to store in, and to transmit from the same storage bank, which would cause errors in retransmission, corrective measures must be instituted immediately. The in-phase relationship is detected by the Phase Detector Gate which conditions the control inputs of the Auto-Stop Flip-Flop. This Flip-Flop, driven by an auto-stop segment on the multiplex distributors, is normally in the SET or inactive state. When the in-phase condition is established the Auto-Stop Flip-Flop will be positioned to the RESET or active state. This will immediately apply a "blocking" or "inhibit" potential to all Storage Bank Output Control Gates, to the input of the Send Transfer and to various inputs of the Driver stages which position all the Buffer Relay Tongues to their spacing contacts causing a "blank" or spacing signal to be sent on the multiplex. The output of both Storage Banks and the 6th pulse drive to the Sending Transfer is thus "blocked," preventing the next 6th pulse from repositioning this flip-flop.

Since the Receiving Transfer will be repositioned during the next character interval, while the Sending Transfer is inactive, an out-of-phase condition is reestablished and the Phase Detector Gate reconditions the control inputs of the Auto-Stop Flip-Flop. The next auto-stop pulse will reposition this flip-flop to the normal SET state, removing the "block" from the Storage Bank outputs, the input of the Sending Transfer and the inputs of the Driver Gates. This permits the relays to be repositioned by the character stored in the Storage Bank selected by the particular state of the Sending Transfer. The following 6th pulse repositions the Sending Transfer thus switching to the alternate Storage Bank. Operation is then normal, but the auto-stop process repeats periodically, with the total number of inserted blanks per minute equal in number to the difference in speed, between the teleprinter and the multiplex signals, in operations per minute (opm) or revolutions per minute (rpm).

It should be noted that the mercury-wetted contact relays serve as buffers or isolating devices between the low-level voltages of the logic elements and the high potentials necessary for cable transmission. "Split-channel" operation, required for the multiplex, is conveniently obtained by appropriate wiring of the relay contacts. Correct channel polarities are obtained at the multiplex distributor set.

Multiplex to Teleprinter Conversion (MXPX)

The translation of signals, delivered from a multiplex set in parallel form to a serial stream of bits representing a teleprinter character, is accomplished by the MXPX circuit. This consists primarily of a solid-state start-stop distributor which generates a series of timed intervals representing the start, the five intelligence intervals and the rest impulses of a teleprinter character. The polarity of each of the five intelligence intervals is made to correspond to the mark or space polarities delivered from the multiplex.

Figure 3 is a block diagram of the MXPX. Signals from the multiplex are delivered on five individual wires. After passing through appropriate voltage dividers to limit the $\pm$ 120-volt excursions to $\pm$ 12 volts, they are stored on five dc flip-flops. By choosing the proper output of each flip-flop the "split-channel" multiplex character is normalized to a "straight-channel" character. Contacts of a channel selector switching relay are interposed at this point to select the dc flip-flop complementary outputs when a multiplex channel having polarities of the opposite sense is used.

Each stored bit is then applied to one input of respective Time Interval Gates. With pulses from the Code Generator at other inputs, each Time Interval Gate reflects the stored signal impulse polarity at its output for a specified interval. The gate outputs are then combined in a six-input Combiner Gate, whose composite output drives a differentially-connected, mercury-wetted contact polar relay. The contacts of this relay provide a polar $\pm$120-volt output suitable for connection to a teleprinter line or a carrier channel input.

For "spacing" or idle line conditions, Time Interval Gates 1 through 5 are all inactive, i.e., the outputs are all at ground potential. Gate 6, however, has a negative voltage output which establishes the output of the Combiner at ground potential. This positions the tongue of the output relay, TOR, to its marking contact, keeping the teleprinter line closed.

The time base for the Sending Start-Stop Distributor is provided by the common free-running local oscillator connected through an Oscillator Gate to a Frequency Divider which reduces the oscillator output frequency by a factor of 16 and generates a series of timing pulses, in much the same manner as the PXMX, described previously. These pulses are applied to the drive bus of the Code Generator, to step this four-stage shift register. During an idle period, the output of the Oscillator Gate Control applies a blocking potential to the Oscillator Gate thus maintaining both counter chains in a quiescent state.

The counting cycle which generates the required teleprinter character is initiated by a local segment on the multiplex set. This is called the MXPX pulse and follows, in time sequence, immediately after the delivery of the 5th intelligence impulse from the multiplex channel segments. When the multiplex is idle (spacing), the Mark Detector Gate monitoring each of the signal impulse polarities has an "all-ground" input condition which results in a blocking potential being applied to the MXPX Control Gate. This is then unresponsive to pulses from the MXPX segment. If at least one of the signal impulses is a "mark," denoting the reception of a character other than a "blank," the inhibit potential is removed from the MXPX Control. Thus, the next MXPX pulse conditions the Oscillator Gate Control to remove its blocking potential from the Oscillator Gate, passing the oscillator output signal to the Frequency Divider and initiating the counting sequence.

At the output of the Frequency Divider the timing pulses, spaced at 22 millisecond intervals, begin to step the Code Generator chain. The first timing pulse coincides with or is within a few milliseconds of the leading edge of the MXPX pulse. At the same time an output from the Code Generator, appearing at the input of Time Interval Gate 6 causes the gate output to go to ground potential, deactivating Gate 6 and resulting in a negative potential at the Combiner output. This drives the output relay to the spacing contact, and so generates the leading edge of the "Start" impulse.

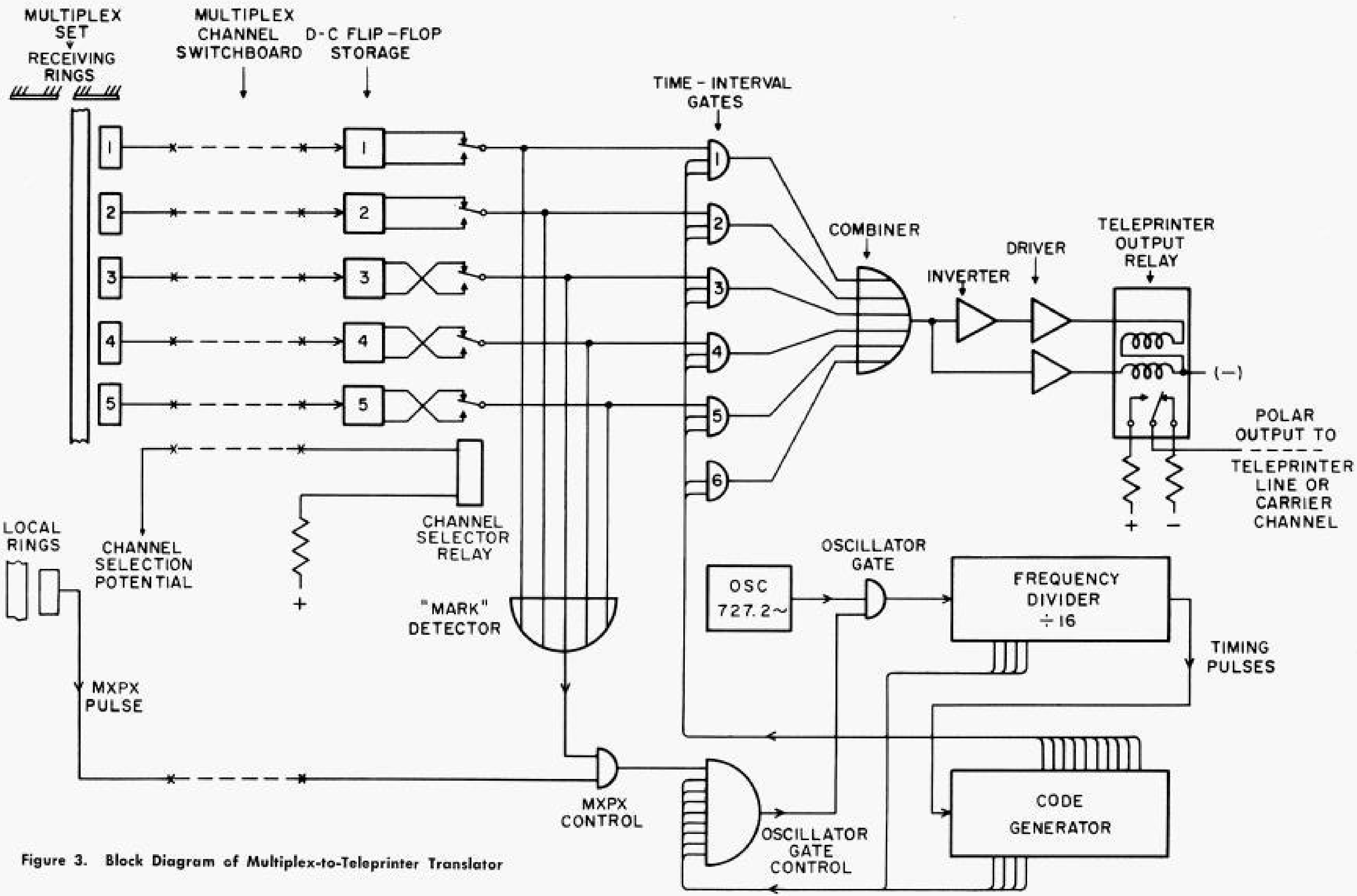


Figure 3. Block Diagram of Multiplex-to-Teleprinter Translator

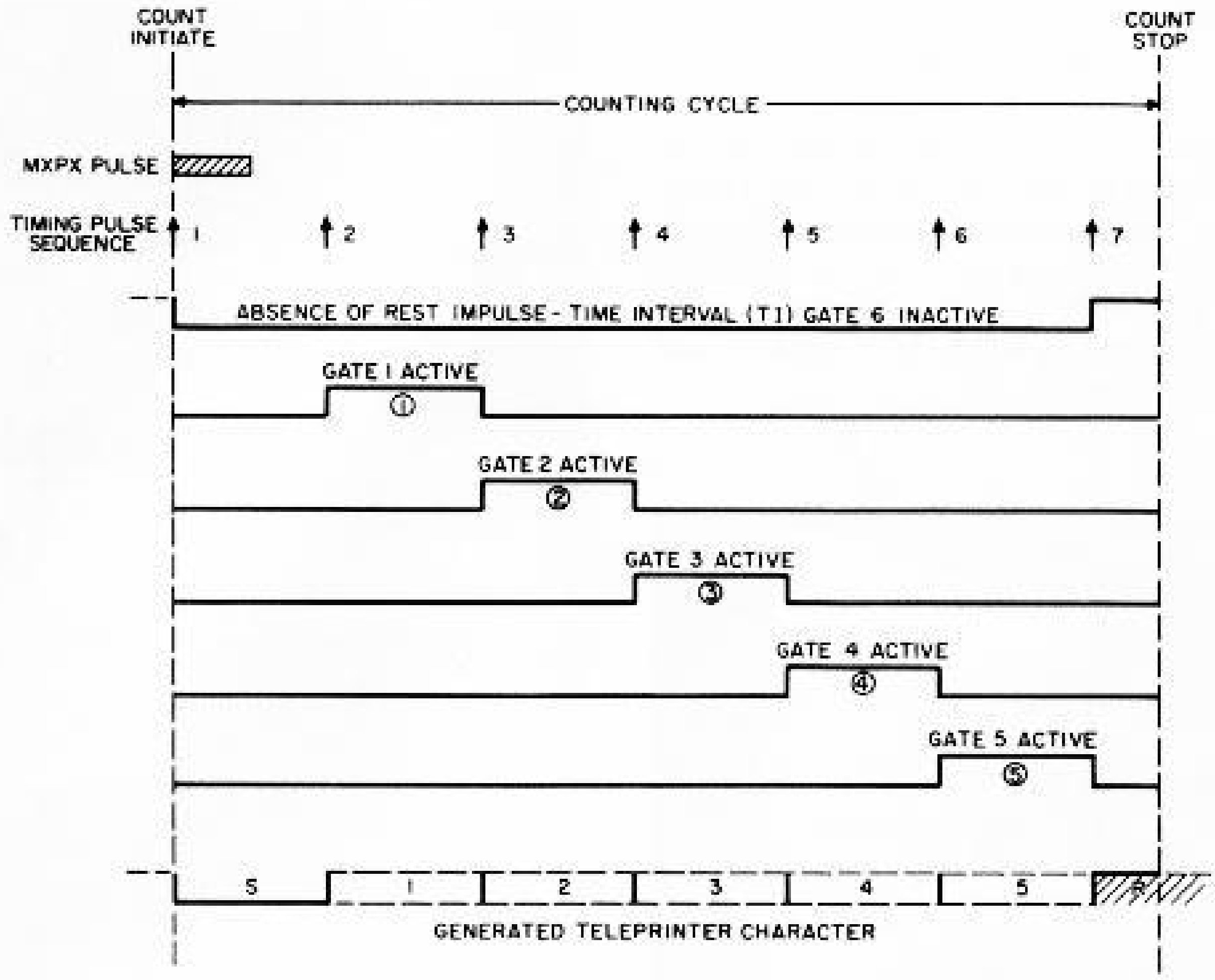


Figure 4. Timing Sequence for the Sending Start-Stop Distributor (MXPX)

One bit length later, a second timing pulse yields a Code Generator output which is applied to Time Interval Gate 1 to "activate" it. Assuming that the 1st signal impulse is a "mark," the Gate 1 output becomes negative, establishing a ground at the Combiner output which drives the TOR to marking. This generates the trailing edge of the "Start" impulse or the leading edge of the 1st signal impulse, depending on one's viewpoint. After another bit-time interval, an output from the Code Generator "deactivates" Gate 1 and "activates" Gate 2, thus generating the trailing edge of the 1st impulse.

The cycling continues in this manner until six bit-time intervals have elapsed at which time Gate 6 is again "activated," causing TOR to mark and yield the beginning of the "Rest" impulse. One half-bit-time later the counter chain outputs establish an all-ground input condition on the Oscillator Gate Control which blocks the oscillator signal, stops the count and restores idle conditions.

A timing sequence for the Sending Start-Stop Distributor is shown in Figure 4. The "active" interval for each gate is indicated with respect to the timing pulse sequence, as well as the resulting teleprinter character. It can also be seen from the chart that the Code Generator has been arranged for a 6.5-unit code. This implies that the Rest impulse has been so shortened that it is only one-half bit in length.

While this appears, at first glance, to be a very detrimental condition, it must be understood that the actual length of the Rest impulse is determined by other factors. As previously noted, the sending start-stop distributor is controlled by a local pulse from the multiplex such that the maximum character rate is determined by the speed of the multiplex in operations per minute. This was assumed to be 300 opm. At this speed, the time for one revolution is 200 milliseconds. For a teleprinter signal speed of 45.45 bauds, the time duration of the start impulse plus the five intelligence impulses of a teleprinter character is $6 \times 22 = 132$ milliseconds. The actual Rest impulse transmitted by the start-stop distributor is then $200\text{-}132 = 68$ milliseconds or 3.1 units in length. Similarly, if the multiplex speed is increased to as much as 400 opm, the Rest impulse will be $150\text{-}132 = 18$ milliseconds, which is slightly under 1 unit in length but this will still permit satisfactory teleprinter operation.

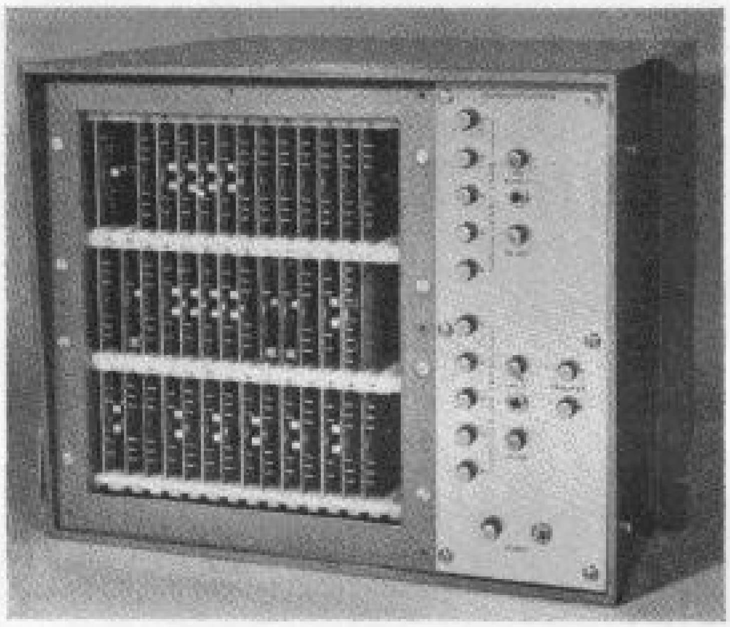


Figure 5. Translator Type 11594 (Front View)

Implementation

The resulting design of a translator based on the foregoing concepts is illustrated in Figure 5. The cabinet is equipped with side flanges suitable for mounting on a standard 19-inch repeater rack. A dust cover, not shown, permits access to the printed circuit cards. All other equipment is accessible from the front when the hinged door is open, as shown in Figure 6.

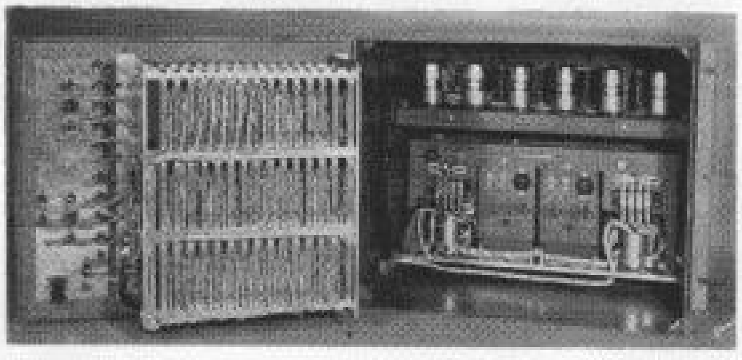


Figure 6. Translator Type 11594 (Interior View with hinged door assembly open)

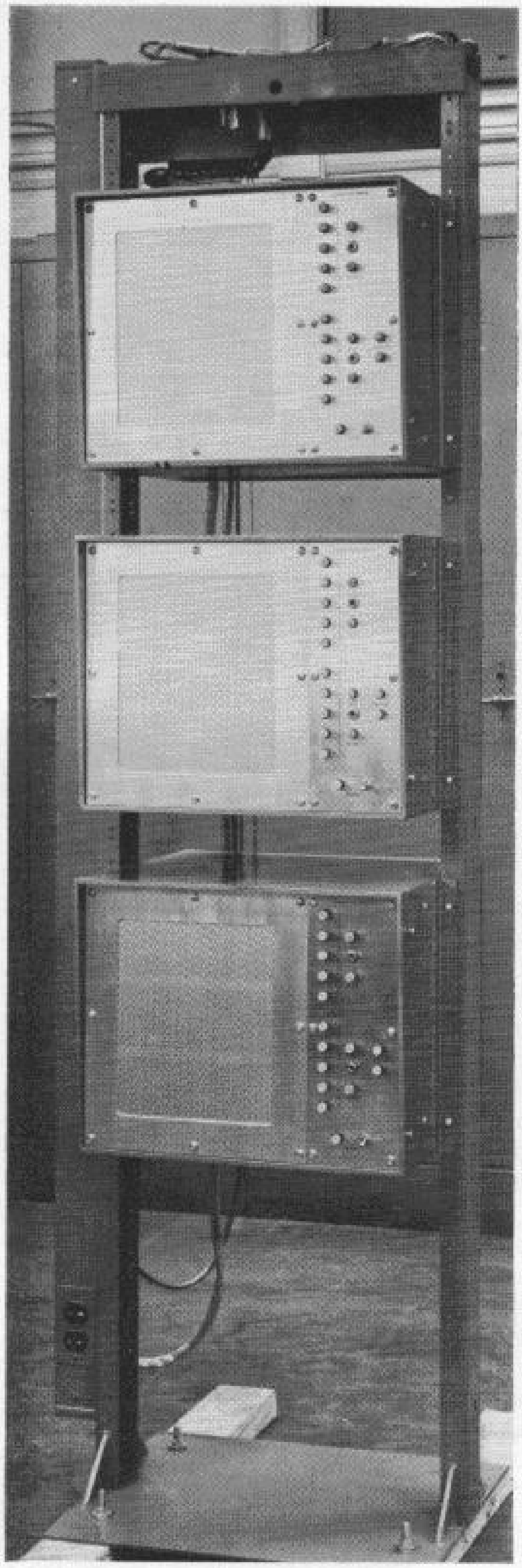


Figure 7. Translator Rack Type 11592 showing 3 mounted Translators

Two groups of lamps are shown on the right panel in Figure 5—one associated with the MXPX and the other with the PXMX. These clearly indicate the particular character passing through each portion of the device at any one instant, (an "on" lamp indicates a mark impulse and an "off" lamp a space). Flashing IN-USE lamps confirm that the unit has been assigned to a working multiplex channel; such connection being made through a multiplex channel switchboard. Teleprinter lamps show the status of incoming and outgoing teleprinter lines and the constant switching action of the Send and Receive Transfer flip-flops may be observed on the TRANSFER lamps.

Three translators mounted on a rack, as shown in Figure 7, constitute Translator Rack Type 11592. A wiring duct equipped with signal and power outlets permits all connections to each translator unit to be made on a plug-in basis. Installation is facilitated by a multiconductor block at the top of the rack which terminates all the required signal wire connections.

Translator Reliability

A Translator Rack 11592 was installed in the cable station at Bay Roberts, Newfoundland in December of 1963. The equipment was immediately placed in service as part of the "All-Canadian Route" requested by the Canadian Department of Transport. Continuous satisfactory operation since that time attests to the attainment of a reliable, maintenance-free interface between the teleprinter and the multiplex systems.

MR. RAFFAELE ASCIONE is Senior Project Engineer in the Cable Equipment Division of the Plant and Engineering Department. He has been active in the development of signal amplifiers, carrier apparatus, time-division multiplex, submerged repeater power supplies, and other shore-based equipment pertaining to submerged repeaters for ocean cable telegraphy. In the course of this work, he has supervised the installation of various equipments at cable stations in the United States, Newfoundland, Eire, Italy, Spain, Portugal and the United Kingdom.

Currently, he is engaged in work related to the establishment of high-speed data service for both voice-coordinated point-to-point use and high-speed tape relay applications.

Prior to joining Western Union in 1946, Mr. Ascione was a Signal Corps officer assigned to the telegraph operations of the Alaska Communication System, and is presently associated with U. S. Army Reserve Research and Development activities in the grade of Major.

Mr. Ascione received his BEE degree from Cooper Union in 1949 and has completed all requirements for an MSEE degree at the Brooklyn Polytechnic Institute. He is an associate member of the IEEE.

AUTODIN System to be Expanded

Western Union has signed a contract with the Department of Defense, involving capital expenditures in excess of $55,000,000, to expand its AUTODIN communications system, world's largest and most advanced automatic digital data nework.

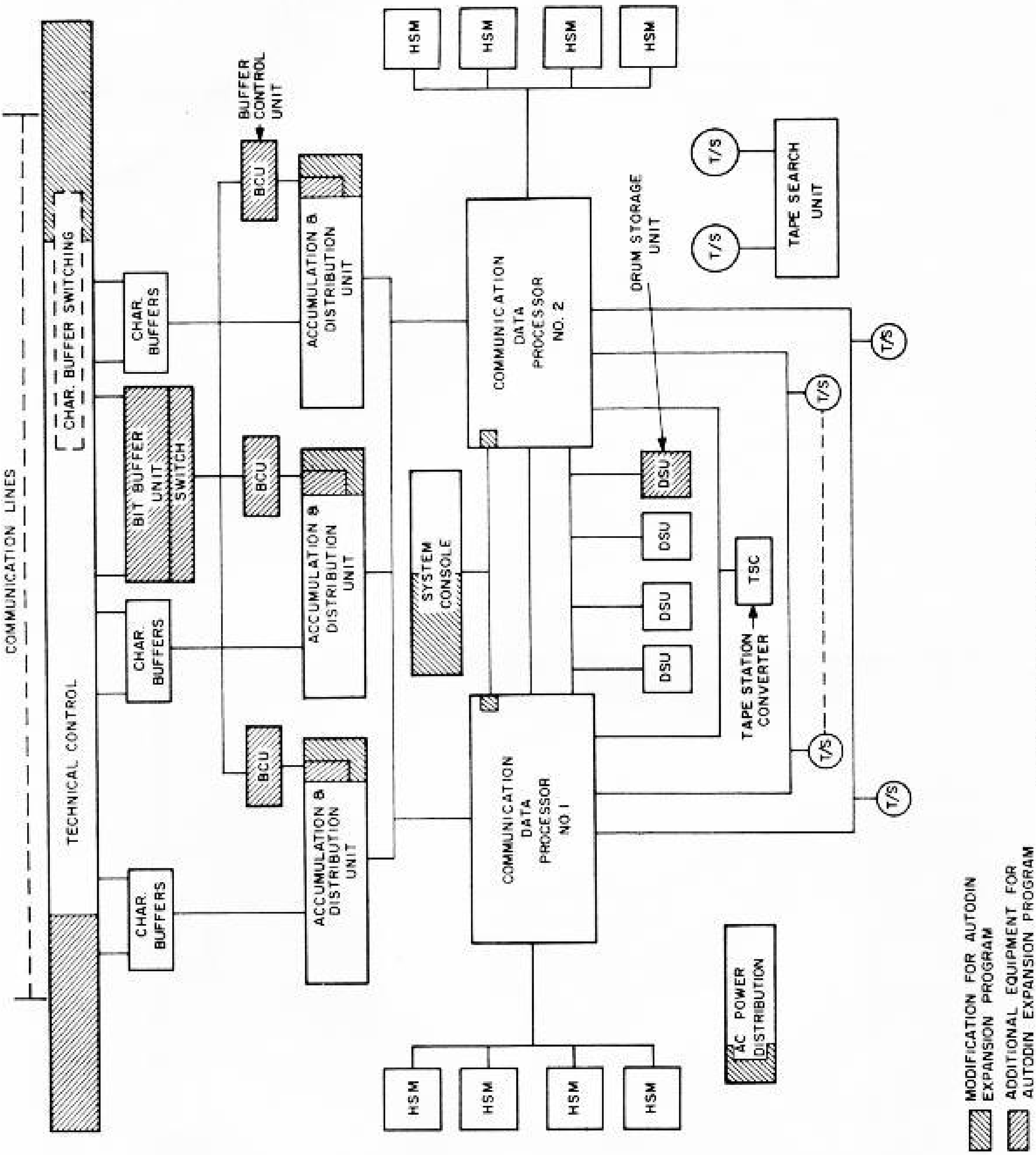
Scheduled for completion by mid-1966, AUTODIN's expansion, when additional outstation equipment and circuitry is installed, will provide Western Union with additional private wire revenues approximating $25,000,000 annually.

The present AUTODIN system, completed by Western Union for the Department of Defense early in 1963, and already being expanded, consists of five major switching centers and more than 350 outstations. The new contract will add four new switching centers, bringing the total in the United States to nine. Capacity of the five existing centers will be increased and the enlarged system will have a capacity of more than 2,000 outstations. The present switching centers at McClellan and Andrews serve as the gateway stations, or connecting links, to the overseas segments of the system.

Western Union has also been retained by the Department of Defense, under a separate contract, to assist in engineering additional overseas AUTODIN centers.

AUTODIN is being developed into a global system for the high-speed interchange of vital telecommunications for the Department of Defense, not only between military installations but also with industrial plants which provide direct support for weapons systems. Completely automatic and compatible with other military communications systems, it is capable of handling, at high speed, enormous quantities of narrative, data, and other digitalized information. Circuit switching engineered into the system permits certain outstations to be directly connected with others for volume transmission. Expansion of the system as planned will greatly enlarge its present daily capacity of 12,000,000 punched cards, equivalent to more than 160,000,000 words.

With the completion of the expanded system all arms of the Department of Defense will be users of the AUTODIN network. This will replace the existing military electromechanical and manual teletypewriter switching centers in the continental United States, as a major contribution to the overall economy program of the Department of Defense.



Additional Equipment for AUTODIN Expansion.

PAPERS RECENTLY PRESENTED
by
WESTERN UNION ENGINEERS

AUTODIN: A new Concept in Data Communications

presented by E. C. Chamberlin, Vice President of Eastern Division, before the Data Processing Management Association in Westchester, N. Y. on February 19, 1964

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Transcontinental Microwave System and Broadband Switching Service

presented by Don Finter to the Communications Managers Association in New York, N. Y. on March 11, 1964

Fundamental Technical Aspects of Data Transmission Over Communications Channels

presented by J. Z. Millar, Assistant Vice President, Plant and Engineering Department to American Management Association—Seminar on Data Communications Systems in New York, N. Y. on April 9, 1964

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Facsimile Imaging Systems

presented by G. H. Ridings to the Society of Photographic Scientists and Engineers at the Chemists Club in New York, N. Y. on February 19, 1964

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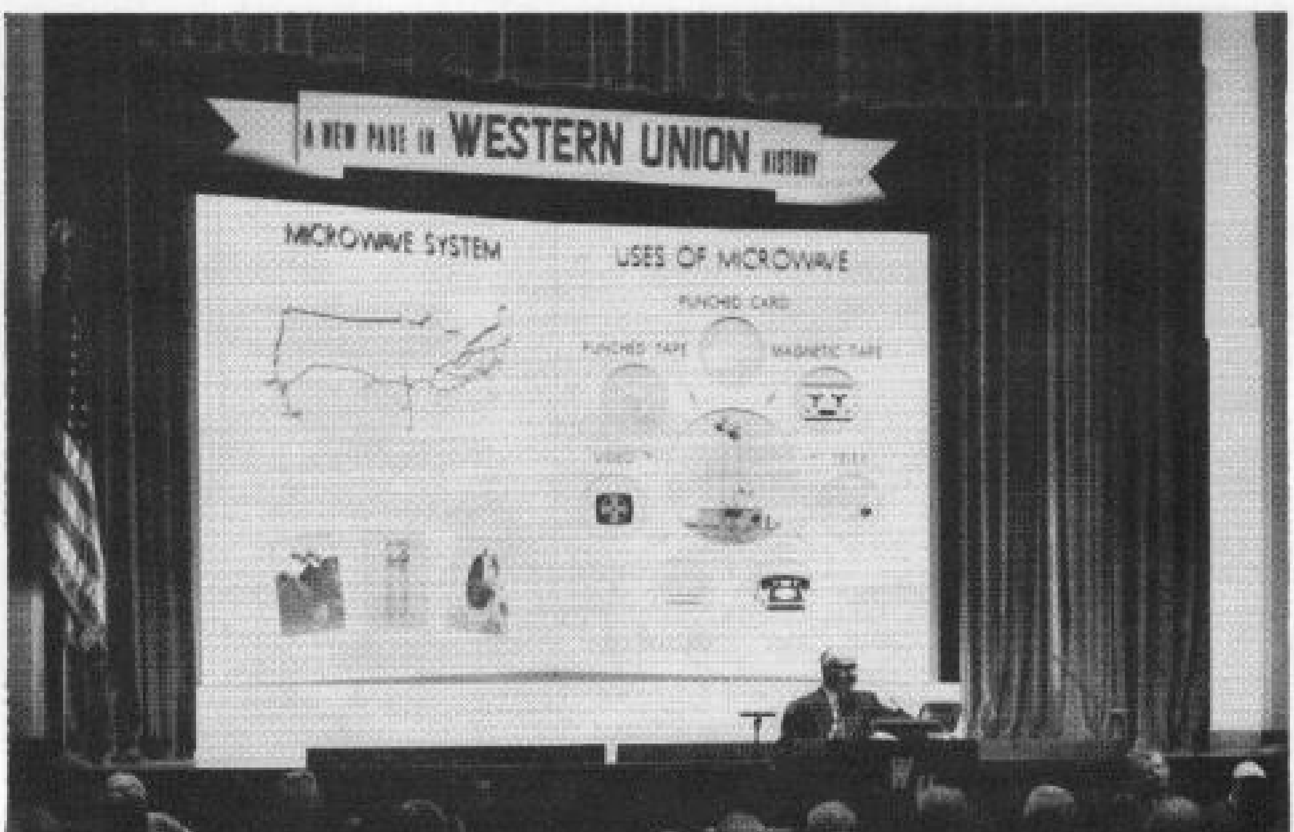
Western Union Stockholders' Meeting
Western Union Auditorium
April 8, 1964



Mr. T. F. McMains, Vice President and Assistant to the President, addresses the Stockholders' Annual Meeting, in the auditorium at Western Union's Headquarters Building, 60 Hudson Street, New York City.

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Codes
Data Communications
Data Processing
Standardization

Smith, Fred W: New American Standard Code for Information Interchange

Western Union TECHNICAL REVIEW, Vol. 18, No. 2 (April 1964) pp 50 to 61

This article describes the logic designed into the new ASCII (Asky) code for telegraph-oriented engineers. It covers the history and structure of the code developed by the ASA Subcommittee and points out the possible future applications.

Private Automatic Telephone Systems
Telephone Switching Systems
Voice Circuits
Dial and Keyset Operation

Chong, G. R.: Private Automatic Telephone Systems PATS

Western Union TECHNICAL REVIEW, Vol. 18, No. 2 (April 1964) pp 62 to 67

This article describes the operation of the basic Philips Type "UP" private automatic exchange. Its advantages are discussed.

Subscriber Terminals
Switching Systems
AUTODIN
Digital Networks

Jansson, H. A.: AUTODIN—System Description
Part II—Circuit and Message Switching Centers

Western Union TECHNICAL REVIEW, Vol. 18, No. 2 (April 1964) pp 68 to 77

This is the second part of the article on System Description of the Automatic Digital Network. It covers the Circuit and Message Switching Centers. The functions and mechanization of the CSU and the MSU are described. A typical layout of the combined CSU and MSU is included.

Code Translator
Solid-State Devices

Ascione, R.: A Solid-State Teleprinter/Multiplex Translator

Western Union TECHNICAL REVIEW, Vol. 18, No. 2 (April 1964) pp 78 to 87

The coupling of a start-stop teleprinter channel to a synchronous time-division multiplex channel requires translation or conversion between the codes used in the two systems. Solid-States Translator Type 11594, described in this article, obviates the usual tape relay or electromechanical interface devices with attendant greater reliability. A presentation of basic design concepts theory of operation and actual implementation are included.

Microwave System in Test Operation
Linking JPL with Goldstone Tracking Station

A specially-designed microwave system for deep-space communication, with unmanned spacecraft on the next flight to the moon, has been completed by Western Union and leased to Jet Propulsion Laboratory of the California Institute of Technology under contract to the National Aeronautics and Space Administration.

The new 164-mile, five-hop, microwave system is now in test operation linking the JP Laboratory in Pasadena with the Goldstone deep-space tracking station in California's Mojave Desert near Barstow. The microwave towers between Goldstone and Pasadena are located on the summits of Shadow Mountain, Bailey Peak, Montana Mines, and Sierra Peak in Southern California.

When the United States launches its next unmanned spacecraft on a flight to the moon, the space vehicle will "talk" with earth computers and receive flight and landing orders over the Western Union microwave system.

Scientists at Jet Propulsion Laboratory in Pasadena will guide, and command the spacecraft by remote control. Goldstone, the only station in the United States designed and constructed for deep space tracking of unmanned spacecraft, will act as the spacecraft's earth link.

Data gathered by the spacecraft will flash automatically and directly through the receiving antenna at Goldstone to Pasadena over Western Union's system, for quick analysis by computers. Commands to the spacecraft from Pasadena will travel directly by microwave to the spacecraft via Goldstone's high-powered transmitter. All spacecraft control activities will be centered at the Jet Propulsion Laboratory in Pasadena.

Western Union's microwave network will handle two types of data transmission from the lunar spacecraft: engineering telemetry, which measures the spacecraft's response to its environment and scientific telemetry, which reads the scientific instruments aboard the spacecraft.

The new Western Union microwave system will play a key communications role in the nation's future deep-space exploration including unmanned probes of the Moon, Venus, Mars, and other planets. In order to handle the large volume of data sent to and received from the spacecraft, while in flight and on the moon's surface, the microwave system will provide bandwidths up to six million cycles, which is much more than the 4.2 million cycles bandwidth required in a microwave video channel for television.