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WESTERN UNION STANDARDIZES

THE WESTERN UNION TECHNICAL REVIEW

Cover: STANDARD SYMBOLS adopted by Western Union for drawings of circuitry—Printed Circuit Cards for AND and Flip-Flop circuits

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

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WESTERN UNION
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Volume 18
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Introducing Our Executive V.P.

The readership of the Western Union TECHNICAL REVIEW will be interested to know that our Executive Vice President is a technical man.

Mr. Russell W. McFall was elected Executive Vice President and member of the Board of Directors of Western Union on December 2, 1963.

He comes to us with vast engineering experience and technical management know-how. He has been Vice President of Litton Industries, Inc. where he was responsible for the design, manufacture and sales of radiation and communication equipment. He is particularly qualified in the management of engineers and scientists, since he was Manager of a staff of 3500 including 700 engineers and scientists, in the Missile and Ordnance Systems Department of General Electric. During these 15 years at GE, he was Manager of Education and Training and Manager of the Air-Force sections for Fire Control, Airborne Infrared and Countermeasures Systems. He was responsible for the execution of many government contracts.

Mr. McFall is a graduate engineer and a member of several leading professional societies. He received his degree of B.S.E.E. in Electrical Engineering from the University of Maryland in 1943. In his new post he will have general direction of all phases of the telegraph company's field operations and activities. This includes Plant and Engineering, Operating and Marketing, Purchasing, Employee Relations and the new department of Government Communications Systems.

The staff of the Western Union TECHNICAL REVIEW look forward to his inspiring leadership.

COMMITTEE ON TECHNICAL PUBLICATIONS

TECHNICAL ACCOMPLISHMENTS SERVE *Government Communications Systems*

W. H. FRANCIS

To the Readers of THE TECHNICAL REVIEW—Western Union employees and our host of technically-minded friends in Industry and Government—

A most cordial greeting from the newly created Government Communications Systems Department.

*During 1963, the two largest projects ever undertaken by the Telegraph Company—*AUTODIN *and the coast-to-coast radio beam system—have been placed in service. They represent technical accomplishments by the Plant and Engineering Department in which the Company takes great pride. While these projects are not completed, they are the beginning of a great expansion program in data handling, electronic switching and microwave systems.*

Western Union customers expect superior service and it is our responsibility to provide it. In securing new business, our greatest asset is the satisfied customer who in the past has received such service.

The TECHNICAL REVIEW *publication keeps employees informed of Western Union's technical progress, and is a means whereby Company experts on many complex subjects share their knowledge with others who have the need to know, in planning, engineering, installation and maintenance.*

I wish the staff of the TECHNICAL REVIEW *and its contributing authors continued success in their dedicated efforts on behalf of this valuable publication.*

W H Francis.

WILLIAM H. FRANCIS, VICE PRESIDENT
GOVERNMENT COMMUNICATIONS SYSTEMS

V. C. Kempf, Senior Project Engineer, Patrons Systems Div.—P & E Dept.

STANDARD SYMBOLS for DIGITAL LOGIC DESIGN

Need for Standard Symbology

The complexity of the business world requires that vast amounts of data need to be collected and processed automatically. Since many of the major business organizations are composed of diversified groups, separated geographically, they need to collect the data from distant points and assemble it in a form acceptable to a data processing machine. A variety of systems are made available to the business community for collecting, transmitting and processing of data through the marriage of "data processing" and "common carrier" equipment. The use of these composite systems creates a need for a universal logic language so that the manufacturer of one type of equipment can easily interpret other manufacturer's equipment.

Several sets of logic symbols have been developed to fill this need. The Department of Defense has published a set of graphical logic symbols to be used for all systems designed for the Departments of the Army, Navy and Air Force[1]. The American Standards Association, at the request of the Institute of Electrical and Electronics Engineers, has also developed a set of symbols to be used by every manufacturer of digital equipment[2]. The symbols developed by the ASA are in general agreement with those published by the Department of Defense and will be used by Western Union because of their advantages.

Advantages of Standard Symbols

- *Symbols are not restricted—*

The symbols used by Western Union define the logic operation of any system where the variables may assume only two discrete values. For example, these variables may be the collector voltage of a transistor, the current through a pair of relay contacts or the pressure of a fluid flowing through a pipe. Thus these symbols are not restricted to a specific method of implementing a logic function.

- *Few symbols need be learned—*

Each basic logic operation in digital logic design has a different symbol. Since any digital system contains only a few basic logic operations, it is only necessary to learn a few symbols to understand the logical operation of the most complex digital systems.

- *Input-outputs are specified—*

The standard symbols also specify the physical (voltage, current, fluid pressure, etc.) input-output characteristics of the circuitry used to perform the logic operation. Thus one need not understand the physical circuitry, used to implement the logic function, in order to understand the operation of the system.

- *Universal acceptance—*

These symbols have an almost universal acceptance among the major manufacturers of digital equipment. Thus, in order for one to understand the operation of a particular manufacturer's digital device, it is no longer necessary to first learn the symbols or the physical circuitry peculiar to that manufacturer.

- *Drafting templates—*

Another advantage of the standard symbols is the availability of drafting templates for these symbols. These templates are an aid to the rapid execution of logic drawings and make it possible to have symbols of uniform size which add to the appearance of the drawings.

Phase I and Phase II of System Design

In the design of any system it is first necessary to gather all the information pertinent to the input-output conditions desired by the customer. The Systems Engineer, a liaison between the customer and the design engineering staff, usually collects this information.

Secondly, it is necessary to interpret the input-output requirements set forth by the Systems Engineer and establish a set of logic functions to fulfill these requirements. The logic functions required are then illustrated on a Basic Logic Diagram by means of symbols which make no reference to physical circuitry or electrical characteristics. For this reason the symbols used at this phase of the design are slightly different from those used later in the Detailed Logic Diagram.

Basic Logic Symbols

● AND

The symbol for the AND function, shown in Figure 1, has two inputs although it may have any number of inputs more than two. The output of an AND function is true only when all of its inputs are true. Referring to Figure 1, output C is true only when input A and input B are true. If input A and/or input B is false, the output C will be false.

SYMBOL

TABLE

A	B	C
1	1	1
0	1	0
1	0	0
0	0	0

Figure 1—AND Function

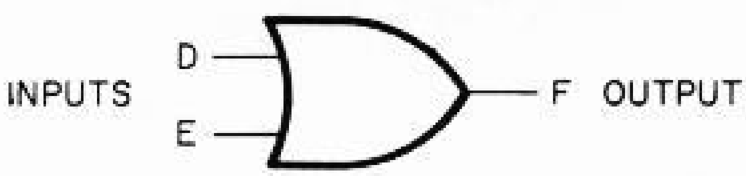
Instead of using the terminology—true and false, a shorthand terminology will be used.

The true state of an input or output condition will be referred to as the 1 state and the false state will be referred to as the 0 state. The 1 and 0 states are known as Logic States.

Referring to the AND symbol, output C will be in the 1 state, only if input A and input B are both in the 1 state. If input A and/or B is in the 0 state, the output C will be in the 0 state.

All possible combinations of input and output logic states may be listed in a table known as a Logic Truth Table. The Logic Truth Table for the AND function is shown in Figure 1.

SYMBOL



TABLE

D	E	F
1	1	1
0	1	1
1	0	1
0	0	0

Figure 2—OR Function

● OR

The symbol for the OR function shown in Figure 2, has two inputs although it may have more than two. The output of an OR function is true if one or more of its inputs are true. Thus, referring to Figure 2, output F is in the 1 state, if either input D or input E is in the 1 state. The basic OR function is sometimes known as the Inclusive OR function, because output F will also be in its 1 state if both inputs D and E are in the 1 state. If both inputs D and E are in their 0 state, the output F will be in its 0 state.

- EXCLUSIVE OR

The symbol for the EXCLUSIVE OR function, shown in Figure 3, has two inputs although it may have any number of inputs more than two. The output of a two-input EXCLUSIVE OR is true when one input is true and the other is false.

Thus, referring to Figure 3, output K is in the 1 state when input G is in the 1 state and J is in the 0 state or when input J is in the 1 state and input G is in the 0 state. The output is in its 0 state if both inputs are in the 1 state or both in the 0 state.

In the more general case, the EXCLUSIVE OR function may have any number of inputs. For the general case, the output of an EXCLUSIVE OR function will be in its 1 state if an odd number of inputs are in their 1 state. The output will be in its 0 state if an even number of inputs are in their 1 state or when all inputs are in their 0 state. The Logic Truth Table for a three-input Exclusive OR function is shown in Figure 4.

SYMBOL

TABLE

G	J	K
1	0	1
0	1	1
1	1	0
0	0	0

Figure 3—EXCLUSIVE OR Function

INPUTS			OUTPUT
0	0	1	1
0	1	0	1
1	0	0	1
1	1	1	1
1	1	0	0
1	0	1	0
0	1	1	0
0	0	0	0

Figure 4
Logic Truth Table
for a
3-INPUT EXCLUSIVE OR
Function

- FLIP-FLOP

A FLIP-FLOP is a logic device that stores a single bit of information. The symbol for the FLIP-FLOP, shown in Figure 5, has three possible inputs, Set (S), Toggle (T) and Clear (C) and two possible outputs 1 and 0.

When the Set input is first placed in its 1 state, the 1 output assumes the 1 state. When the Clear input is first placed in the 1 state, the 0 output assumes the 1 state. The outputs of the FLIP-FLOP are complementary. That is, if the 1 output is in the 1 state the 0 output is in its 0 state; or if the 1 output is in its 0 state, the 0 output is in its 1 state.

It is common to refer to "a 1 stored in the FLIP-FLOP" or "the FLIP-FLOP is in its 1 state," when the 1 output is in its 1 state. Conversely, "a 0 is stored in the FLIP-FLOP" or "the FLIP-FLOP is in its 0 state," if the 0 output is in its 1 state.

When the Toggle input is first placed in its 1 state, the outputs of the FLIP-FLOP change state; thus if the 1 output is in its 1 state, it will transfer to its 0.

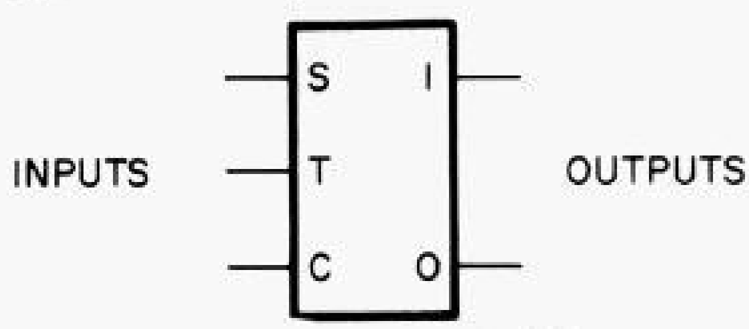


Figure 5—FLIP-FLOP Symbol

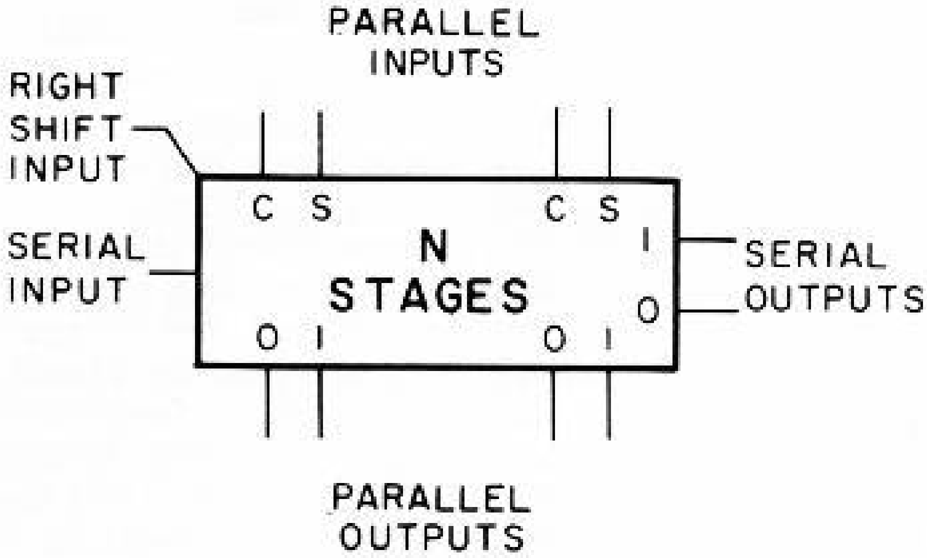


Figure 6—SHIFT REGISTER Symbol

• SHIFT REGISTER

A Shift Register is a combination of FLIP-FLOPS with a provision for shifting the information from one FLIP-FLOP to the next. The symbol for the Shift Register, shown in Figure 6, has N stages where N may be any whole number. The Shift Register has two basic modes of operation, one as a serial-to-parallel converter and the other as a parallel-to-serial converter. When the Shift Register is used as a serial-to-parallel converter, information is read in via the Serial Input Line and is read out on the Parallel Output lines. When the Shift Register is used as a parallel-to-serial converter, information is read in via the Parallel Input lines and is read out on the Serial Output lines.

Since the Shift Register is composed of a number of FLIP-FLOPS, the logic operation of the Set (S) and Clear (C) inputs and the 1 and 0 outputs is the same as previously defined for the FLIP-FLOP. The Serial Output lines are the 1 and 0 outputs of the last FLIP-FLOP in the Shift Register and are repeated at the right of the symbol to indicate the flow of information. The Right Shift input is used to advance, to the right, the information contained in any of the FLIP-FLOPS, one stage at a time. The Serial Input line, in conjunction with the Right Shift input, is used to read information into the first FLIP-FLOP of the Shift Register.

Only the logic operation of the Right Shift and Serial inputs will be described since the meaning of the other input and output lines were previously described in the section on the FLIP-FLOP. If a 1 state signal is placed on the Serial Input line and a 0 to 1 state transitional signal is then applied to the Right Shift Input, a 1 will be stored in the first FLIP-FLOP of the register. Conversely, if a 0 state signal is placed on the Serial Input line, a 0 to 1 state transitional signal on the Right Shift input will store a 0 in the first FLIP-FLOP. At the same time that information is read into the first FLIP-FLOP, the 0 to 1 state transitional signal on the Right Shift input will move the contents of the Shift Register one stage to the right. Thus if the first FLIP-FLOP contains a 1, this 1 will be shifted into the second FLIP-FLOP and if the second FLIP-FLOP contains a 0, this 0 will be shifted into the third FLIP-FLOP.

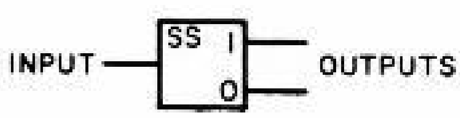


Figure 7—SINGLE SHOT Symbol

• SINGLE SHOT

The Single Shot, illustrated by the symbol in Figure 7, is a logic device that has only one stable state, called the 0 state. The terminology of the 1 and 0 states of the Single Shot is the same as previously defined for the flip flop i.e., when the Single Shot is in its 1 state the 1 output is in its 1 state. Conversely, the

Single Shot is in its 0 state, when the 0 output is in its 1 state.

When a 1 state signal is first applied to the input, the Single Shot will transfer to its 1 state, remain there for a time interval and then transfer back to its 0 state. The time interval that the Single Shot remains in its 1 state is indicated within the symbol.

● OSCILLATOR

The symbol for an Oscillator is shown in Figure 8. An Oscillator is a device with an output of a constant frequency, and is generally used as a time reference or clock. The frequency of the Oscillator will be indicated within the symbol. Since the oscillator does not have any inputs, it cannot make any logical decisions. Thus, the output of the Oscillator does not have a 0 or 1 state. Although the Oscillator cannot make a decision by itself, it is used in making logic decisions with the other functions.

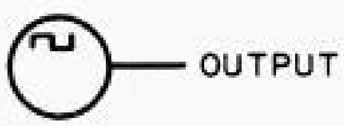


Figure 8—OSCILLATOR Symbol

● GENERAL SYMBOL

Any logic function which cannot be described by any of the above symbols is illustrated with the GENERAL symbol shown in Figure 9. The logic function represented will be described within the symbol.

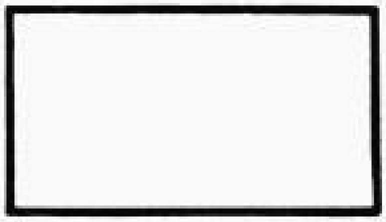


Figure 9—GENERAL Symbol

● LOGIC NEGATION

A Logic Negation operation is used when it is required to indicate that a given input condition must not be true. The output of a Logic Negation operation assumes the 1 state when the input is in its 0 state and vice versa. The symbol used to indicate a Logic Negation operation is a small circle and is always drawn at the point where an input or output line joins a logic symbol and is never drawn by itself. The Logic Truth Table for the Logic Negation function is shown in Figure 10.

INPUT	OUTPUT
0	1
1	0

Figure 10
Logic Truth Table
for the
LOGIC NEGATION
Function

● ALGEBRAIC NOTATION

It is common practice to indicate many of the logic operations in algebraic form in addition to their symbolic form.

1) The AND operation is represented as an algebraic multiplication sign. Thus referring to the AND symbol of Figure 1, this operation may be written algebraically as $C = A \cdot B$ or $C = AxB$ or $C = (A)(B)$. These expressions are read C equals A and B.

2) The OR operation is indicated in the same form as algebraic addition. Referring to the OR symbol of Figure 2 this operation may be written as $F = D + E$. This expression is read F equals D or E.

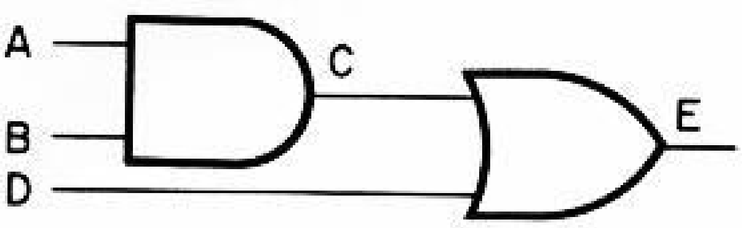
3) The Logic Negation operation is indicated by a bar (–) placed above the signal name or a prime mark (′) placed after it. Thus if the Logic Negation operation was performed on signal F, it would be indicated as $\overline{F}$ or F'. This expression is read not F.

Examples of Basic Logic Design

To aid in the understanding of these symbols a few typical applications of Basic Logic Design, follows:

Example 1

Assume it is required to produce an output condition E that is true when input conditions A and B are true or when input conditions D is true. This could be represented algebraically as $E = A \cdot B + D$. The representation of this operation symbolically is shown in Figure 11.

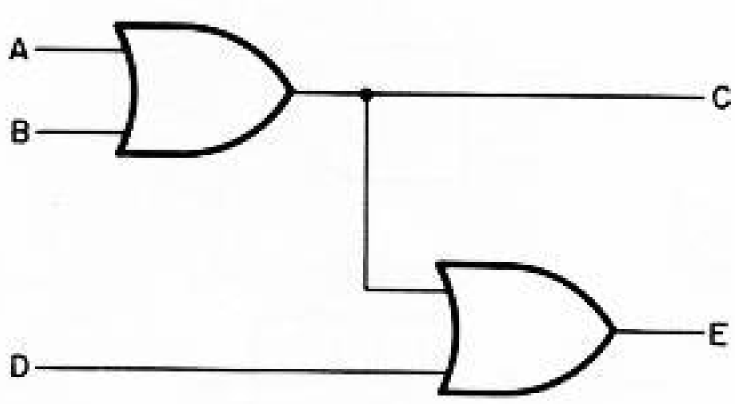


$$C = A \cdot B$$
$$E = C + D$$
$$E = A \cdot B + D$$

Figure 11—Example 1

Example 2

Assume it is required to produce two output conditions. One output condition C should be true when either input condition A or B is true. The other output condition E should be true when either input condition A or B or D is true. The first output condition could be represented algebraically as $C = A + B$ and the second output condition as $E = A + B + D$, as shown in Figure 12.

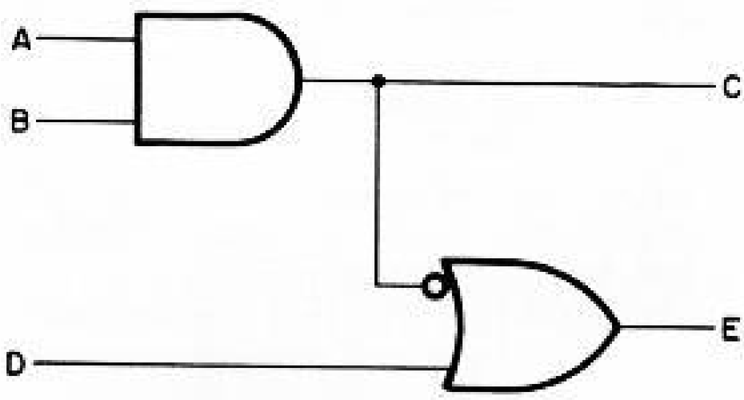


$$C = A + B$$
$$E = C + D$$
$$E = A + B + D$$

Figure 12—Example 2

Example 3

Assume it is required to produce two output conditions. One output condition C is to be true when input conditions A and B are true. The other output condition E is to be true when output condition C is not true or input condition D is true. This first output condition can be written algebraically as $C = A \cdot B$ and the second output condition as $E = \overline{C} + D$, as shown in Figure 13.



$$C = A \bullet B$$
$$E = \overline{C} + D$$
$$E = \overline{A \bullet B} + D$$

Figure 13—Example 3

Example 4

Assume it is required to produce an output D which is to be true from the time than an input condition A becomes true until the time that input condition B becomes true. The symbolic representation is shown in Figure 14.

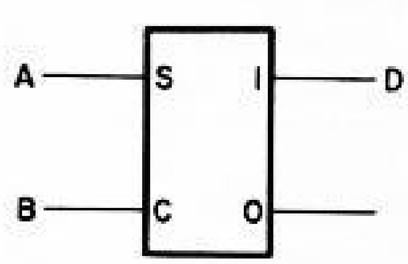


Figure 14—Example 4

Phase III of System Design

The third phase of the design requires implementing the logic function, with available circuitry, as specified on the Basic Logic Diagram. The designer must now take into account the electrical characteristics of the circuits used. Such problems as electric inversion and amplification require a few additional symbols. The end product of the system design is a Detailed Logic Drawing which illustrates the logic and circuit operation of the system. This drawing contains all the information necessary for the manufacture and maintenance of the finished system.

In any digital system each signal line has only two electrical levels or states, referred to as the more positive state and the less positive state. It is common practice to use mnemonic polarity notations instead of actual electric values, HIGH (H) meaning the more positive state and LOW (L) meaning the less positive state. The polarity notations are relative values; i.e., H may equal 0 volts and L may equal −12 volts or H may equal +12 volts and L may equal 0 volts.

Detailed Logic Symbols

- STATE INDICATOR ∘

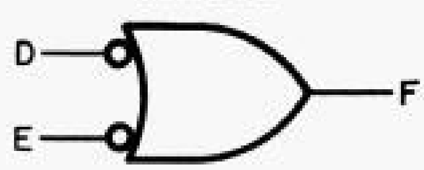
The presence of a small circle at the input or output of a symbol indicates the electric L state is associated with the logic 1 state. The absence of a small circle indicates that the electric H state is associated with the logic 1 state.

It should be noted that a small circle symbolizes logic negation on a Basic Logic Drawing but on a Detailed Logic Drawing it conveys electric level information.

Many variations of the following are possible depending upon whether the electric H or L state is assigned to the logic 1 state of each input and output line. In each case only one of the possible variations of the symbol will be described since all the others may be derived easily.

An electric truth table may be used in order to describe all the possible input-output electric states of the symbol.

SYMBOL



TABLE

D	E	F
L	L	H
H	L	H
L	H	H
H	H	L

Figure 15—AND Symbol

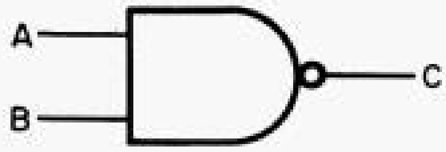
- AND

Referring to the symbol in Figure 15 output C is in its L state only when input A and input B are in their H state. If input A and/or input B is in its L state, the output C will be in its H state.

- OR

The output F, of the symbol in Figure 16, is in its H state if either input D or input E is in the L state. The Electric Truth Table of Figure 16 may be derived from the Logic Truth Table of Figure 2.

SYMBOL



TABLE

A	B	C
H	H	L
L	H	H
H	L	H
L	L	H

Figure 16—OR symbol

WESTERN UNION TECHNICAL REVIEW

Errata - Pg. 10 **January 1964 issue**

The symbol **and table in Figure 15 is for the** OR symbol.

The symbol **and table in Figure 16 is for the** AND symbol.

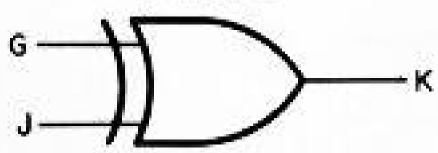
Only the **drawings and the tables should be** interchanged, **the captions for these figures remain** the same.

The L state is associated with the 1 state for inputs D and E in Figure 16; therefore, the polarity notation L may be substituted for 1 and H may be substituted for 0 in columns D and E of the Logic Truth Table. The H state is associated with the 1 state for output F in Figure 16; therefore H may be substituted for 1 and L substituted for 0 in column F of the Logic Truth Table.

• EXCLUSIVE OR

The Electric Truth Table for the EXCLUSIVE OR symbol may be derived from the Logic Truth Table in Figure 3. For the symbol of Figure 17 the H state is associated with the 1 state for both inputs and output. Thus if H is substituted for 1 and L for 0 in the Logic Truth Table, the Electric Truth Table, shown in Figure 17, will result.

SYMBOL



TABLE

G	J	K
H	L	H
L	H	H
H	H	L
L	L	L

Figure 17—EXCLUSIVE OR Symbol

• FLIP-FLOP

The FLIP-FLOP symbol in Figure 18, shows three inputs Set (S), Toggle (T) and Clear (C) and two outputs 1 and 0. When the Set input is first placed in its L state, the 1 output assumes the H state. When the 1 output is in the H state, the 0 output is in its L state.

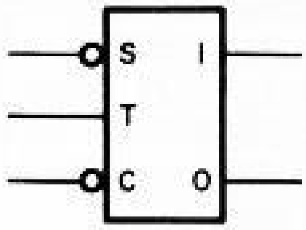


Figure 18—FLIP-FLOP Symbol

When the Clear input is first placed in its L state, the 0 output assumes the H state. With the 0 output in its H state, the 1 output is in its L state.

When the Toggle input is first placed in its H state the FLIP-FLOP will change state.

"A 1 is stored in the FLIP-FLOP" or "the FLIP-FLOP is in its 1 state" when the 1 output is in its H state. "A 0 is stored in the FLIP-FLOP" or "the FLIP-FLOP is in its 0 state" when the 0 output is in its H state.

• SHIFT REGISTER

The Shift Register shown in Figure 19 is a two stage register but it may contain any number of stages. Each stage of the register is shown as an individual block if it is necessary to indicate packaging and wiring information.

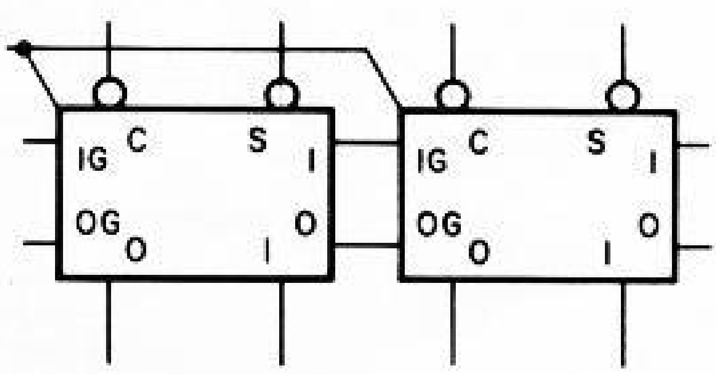


Figure 19—SHIFT REGISTER Symbol

The electrical operation of the Set and Clear inputs and the 1 and 0 outputs is the same as described for the FLIP-FLOP. The Serial Input lines, 1 Gate (1G) and 0 Gate (0G), in conjunction with the Right Shift Input are used to read serial information into the first FLIP-FLOP of the Shift Register. The Right Shift Input is shown as a diagonal input at the upper left-hand corner of the symbol. If the 1G line is in its H state, (0G line in its L state) an L to H state transitional signal on the Right Shift Input will store a 1 in the first FLIP-FLOP. If the 0G line is in its H state (1G line in its L state) an L to H state transitional signal on the Right Shift Input will store a 0 in the first FLIP-FLOP.

A L to H state transitional signal on the Right Shift Input will also move the contents of each FLIP-FLOP one stage to the right.

● SINGLE SHOT

For the Single Shot symbol of Figure 20, a H to L state transitional signal on the input line will transfer the Single Shot to its 1 state. When the Single Shot is in its 1 state, the 1 output is in its L state and the 0 output is in its H state. After the time interval of the Single Shot it will transfer back to its 0 state. When the Single Shot is in its 0 state, the 0 output is in its L state and the 1 output is in its H state. The interval of time that the Single Shot remains in its 1 state will be indicated above the symbol.

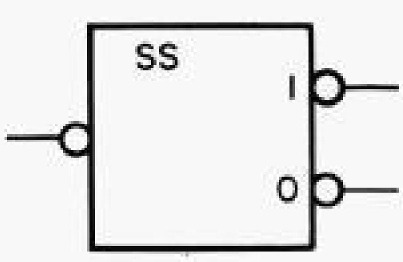
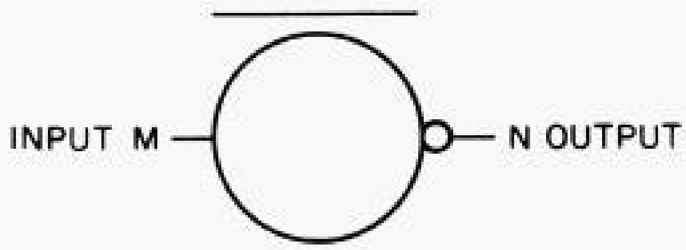


Figure 20—SINGLE SHOT Symbol

● ELECTRIC INVERTER

An Electric Inverter is a device that performs electric inversion but no logic inversion, that is, if the input is in its H state its output will be in its L state or vice versa. Since an Electric Inverter does not perform logic inversion, if the input is in its 1 state, the output will be in its 1 state or if the input is in its 0 state, the output will be in its 0 state. The symbol, shown in Figure 21, indicates that the H state as associated with the 1 state for input M and the L state is associated with the 1 state for output N. The Logic and Electric Truth Table are shown in Figure 21.



ELECTRIC

M	N
H	L
L	H

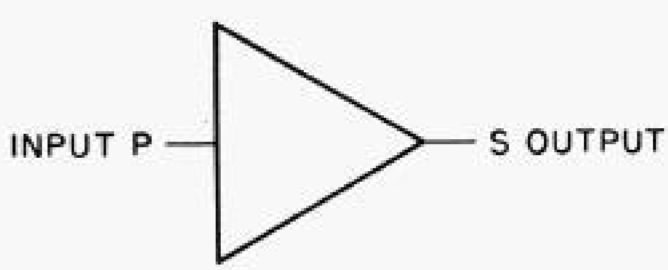
LOGIC

M	N
1	1
0	0

Figure 21—ELECTRIC INVERTER Function

● AMPLIFIER

An Amplifier is a device used to increase a current or voltage level; it does not produce logic inversion and may or may not produce electric inversion. The Amplifier symbol shown in Figure 22, does not represent electric inversion since the H state is associated with the 1 state for both input and output.



ELECTRIC

P	S
H	H
L	L

LOGIC

P	S
1	1
0	0

Figure 22—AMPLIFIER Function

• OSCILLATOR

Since the Oscillator does not make any logic decisions it does not have a 1 or 0 state associated with the output. Therefore a State Indicator would have no meaning if placed on the output line. The output waveform and its frequency is always illustrated above the symbol, as shown in Figure 23.

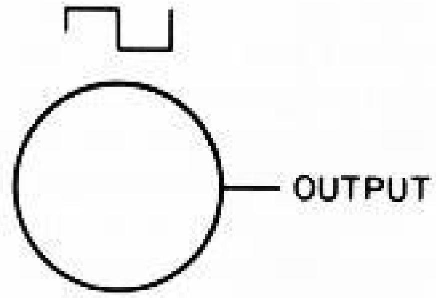


Figure 23—OSCILLATOR Symbol

• TIME DELAY

A Time Delay function illustrated by the symbol shown in Figure 24 is used when it is necessary to delay the application of a pulse. The TIME DELAY between input and output is generally indicated outside the symbol. If the input of a Time Delay function is placed in its 1 state, the output will transfer to its 1 state after the indicated time delay. If the input is then placed in its 0 state, the output will transfer to its 0 state after the same indicated time delay. For the symbol of Figure 24 the H state is associated with the 1 state for both input and output. Thus, if the input U is placed in its H state, the output W will transfer to its H state after the given time delay.

Figure 24—TIME DELAY Symbol

• SCHMITT TRIGGER

A Schmitt Trigger circuit is used to detect when a signal crosses a certain level and also to regenerate an edge distorted signal. Referring to the symbol, shown in Figure 25, when the input Y passes a certain threshold toward the H state the output Z transfers to its L state. When the input Y passes a threshold value toward the L state, output Z transfers to its H state. It should be noted that the two threshold values mentioned above may or may not have the same value.

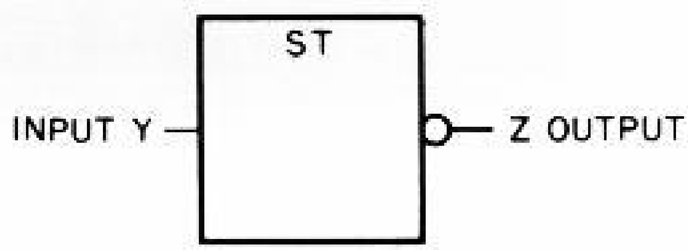


Figure 25—SCHMITT TRIGGER Symbol

• GENERAL SYMBOL

The symbol shown in Figure 26 is used to indicate any logic device that cannot be illustrated by any of the above symbols.

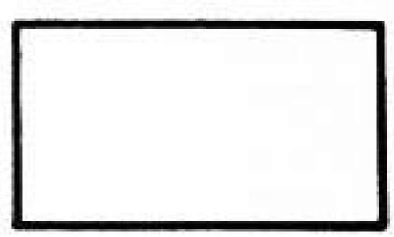


Figure 26—GENERAL Symbol

Signal Polarity Notations

If the electric state associated with the logic 1 state is not self evident on a Detailed Logic Diagram, an additional convention must be used. This convention, or polarity notation, modifies the signal so that if the H state is associated with the 1 state of signal A, the signal will be shown as A(H). If the L state is associated with the 1 state of signal A, it would be shown as A(L).

Examples of Detailed Logic Design

To understand the meaning of these symbols a few applications will be given. Each example given here corresponds to the example given previously for a Basic Logic Design. In each example it will be assumed that the available circuitry has the same electrical operation as the symbols shown in Figures 15 through 26.

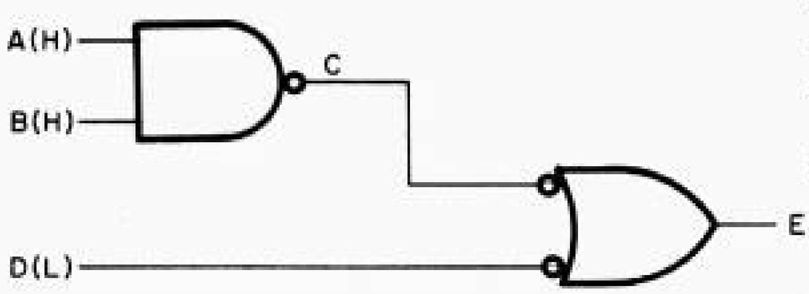
Example 1

Referring to Figure 11 assume that when input signals A and B are in their 1 state, that they are in their H state. Input signal D will be assumed to be in its L state, when it is in its 1 state. These signals, adding the Polarity Notations, will then be expressed as A(H), B(H) and D(L). If these assumptions were not true it would be required to electrically invert the input signals. The detailed logic representation of this example is shown in Figure 27. It should be noted that when signal C is true (in its 1 state) that its electric state is L and when signal E is true (in its 1 state) its electric state is H. A polarity notation for these signals is not indicated on the drawing since the State Indicator defines the electric states.

These signals may be represented algebraically in the same form as the algebraic expression for Basic Logic. Thus signal C may be expressed as $C = A \cdot B$ and signal E is expressed as $E = C + D$. Thus these expressions define both the logic and electrical operation of the symbol.

It should be noted that the 1 state is always true and the 0 state is always false; while either the H or L state may be true.

Thus in order to interpret these equations from an electrical viewpoint one must refer to the Detailed Logic drawing to determine the electric true state of each signal as defined by the State Indicator. In Figure 27 the true state of signal E is the H state, while the true state of the inputs to the OR symbol is the L state.



$C = A \cdot B$
$E = C + D$
$E = A \cdot B + D$

Figure 27—Example 1

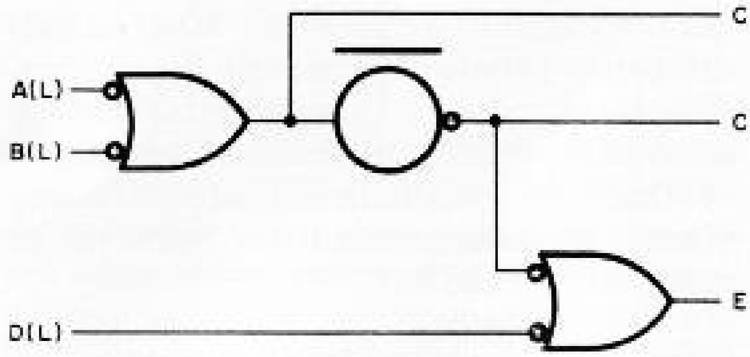
Example 2

Referring to Figure 12 assume that when input signals A, B and D are in their 1 state, they are in their L state. These inputs will then be expressed as A(L), B(L) and D(L), as shown in Figure 28.

It should be noted that output signal C appears electrically at two different points. When signal C is in its 1 state, the output of the OR symbol is in its H state and the output of the Electric Inverter is in its L state. Therefore either one of these signals may be used as an output depending upon which electric state is desired.

Note that the expression $C = A + B$ applies to both the output of the OR and

Electric Inverter symbol. When applying the expression $C = A + B$ to the output of the OR, the electric true state of C is the H state and when $C = A + B$ is applied to the output of the Electric Inverter, the electric true state of C is the L state. In both cases the electric true state of signals A and B is the L state.

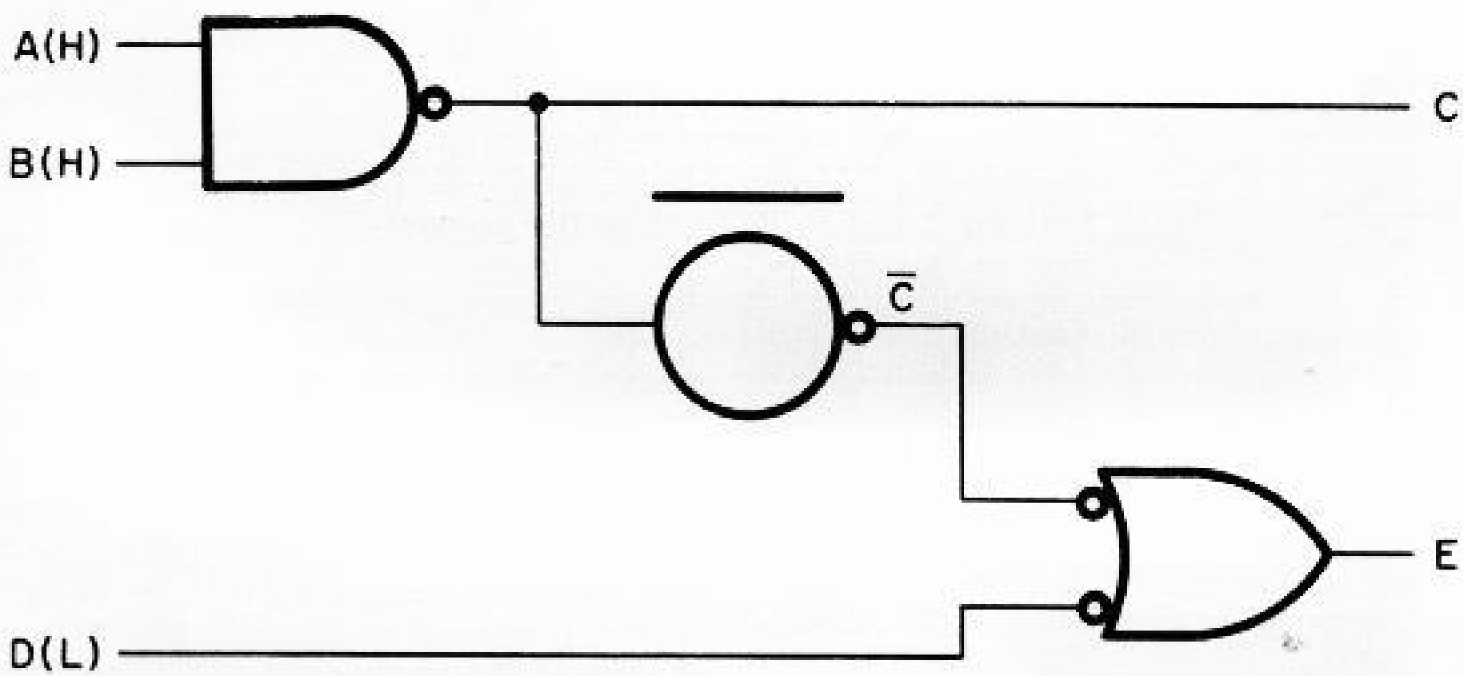


$C = A + B$
$E = C + D$
$E = A + B + D$

Figure 28—Example 2

Example 3

Referring to Figure 13, assume that when input signals A and B are in their 1 state, they are in their H state and when input D is in its 1 state, it is in its L state. These inputs may be expressed as A(H), B(H) and D(L) as shown in Figure 29. This example illustrates the use of an electric inverter to indicate logic inversion. It should be noticed that the electric level, associated with the 1 state, of the inverter input does not match the electric level, associated with the 1 state of the output of the AND symbol. In general, it can be shown that when the State Indicator of connected input and output lines does not match, logic inversion will take place.



$C = A \bullet B$
$\overline{C} = \overline{A \bullet B}$
$E = \overline{C} + D$
$E = \overline{A \bullet B} + D$

Figure 29—Example 3

Example 4

Referring to Figure 14 it will be assumed that inputs A and B are electrically L when in their 1 state. Thus they may be written as A(L) and B(L) and the detailed symbolic representation of this example is shown in Figure 30.

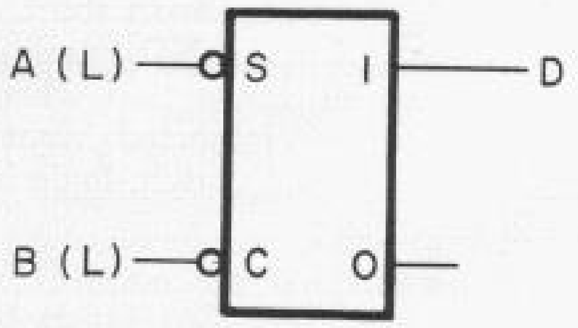


Figure 30—Example 4

Standardization Program at W. U.

The use of these standard symbols is only one of the many standardization programs in progress at Western Union. The design of standard logic circuits and associated hardware for use in low frequency digital equipment was recently completed.[3] The design of a family of standard power supplies and high frequency digital circuitry are other standardization programs currently in progress. The economics of these standardization programs promise to be most rewarding in that the production costs of many digital systems should be reduced as much as tenfold.

* * * *

References

1. Graphic Symbols for Logic Diagrams MIL-STD 806B, 26 February 1962.
2. Graphic Symbols for Logic Diagrams ASA-Y32.14-1962.
3. "Standard Circuit Cards for Data Switching Circuits" Marvin H. Gold (Western Union TECHNICAL REVIEW July 1963)

Acknowledgements

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Mr. Vincent C. Kempf is a Senior Project Engineer in the office of the Patron Systems Engineer. Since 1960 he has been actively engaged in the logic and circuit design of telegraph switching equipment, design of high speed terminal equipment and standardization of logic hardware.

Upon joining Western Union in 1957 he was assigned to the Automation Application Engineer. He assisted in the development and testing of Switching Systems 57, 57.1 and 59. He was responsible for the design of the electronic test equipment and the automatic intra-center routing equipment for Plan 59.

Mr. Kempf received his Bachelor of Electrical Engineering degree from Pratt Institute in 1957.

Patents Recently Allowed

Keypunch Jam Detector

R. Steeneck

3,101,893—August 27, 1963

A card jam detector for a key punch machine designed to be responsive to card transport malfunction from whatever cause in that, first, an alarm is potentially activated when a blank card to be punched is ordered from the supply stack and, second, the alarm is immediately deactivated when the punched card is added to the storage stack. Any interruption or delay in this sequence activates the alarm and shuts down the machine. Sensing means for the two actions comprise respectively a first switch which operates as a card ordering hole is sensed in the machine's program control card and a second switch which operates as the punched card is flipped onto the storage stack.

Perforator Chad Disposal Attachment

S. A. Kirkowski

3,104,804—September 24, 1963

For removing the chad and fuzz refuse from the punch block of tape perforator apparatus, a small piston-driven compressor driven from a convenient sprocket of the perforator provides an air stream through a tunnel which envelops the punch block. The refuse is thereby forced into a collecting tube leading to a suitable container which may be enclosed in or may be completely outside the machine.

Self-Regulating Two-Channel Time Division Telegraph System

H. F. Wilder

3,114,003 — December 10, 1963

A telegraph system which transmits signals in long "bursts" with means for automatic phasing (ranging) at the start of each burst. As illustrated for the multiplex case, at the transmitter a highly stable oscillator continuously drives a two channel 10-segment distributor which, when idle, sends spacing blanks of respectively opposite polarity to provide continuous long reversals at the character rate. To begin sending, slack tape in either channel changes the blank sending to AC for one complete revolution of the distributor to yield a receiver starting and aligning signal of 5 cycles length. At the same time a 402-step counting switch is released to time a burst of 400 characters each from the two channels alternately plus the AC start signal and a terminating signal of one long reversal. On subsequent revolutions the two channels cut in or out as released by slack tape, with intervening blanks, until at the end of the count of 400 characters the transmitters are stopped, regardless of whether messages are waiting, and a full revolution spacing reversal is sent as a terminating signal. At the receiving end a distributor, a multiplicity of counters and an automatic aligning, or ranging, device, all of electronic type, are driven by a continuously running bit rate oscillator of sufficient stability to maintain synchronism for the period of 400 characters. A counter recognizes the start signal, as distinguished from spurious line disturbances, and enables an automatic ranging device whereby the incoming signal pulses are sensed at their averaged midpoint despite fortuitous displacements caused by interference. For this ranging, a stationary multi-phase generator derives from each bit pulse of the local oscillator twenty equally spaced timing instants, or phases, which by means of a series of gating circuits determines which phase coincides with the averaged center of the arriving bits, and starts and aligns the receiving distributor accordingly. The burst length, number of channels, codes and other factors chosen for illustration may be varied.

Fred W. Smith, Senior Engineer, Telegraph Equipment Div.—P & E Dept.

A New Line of Light-Duty Teleprinters and ASR Sets

The Model 32 teleprinter, placed in service by Western Union in 1962, and the Model 32 ASR set, placed in service in early 1963, are the first American-made printing telegraph apparatus designed specifically for Telex service. Because the need for a low-cost, light-duty teleprinter had long been recognized by users of telegraph apparatus, Western Union designed the Type 100 teleprinter, during the 1930s, to fill a need for an economical page printing device. Thousands of these are still in service. The high cost of manufacturing and assembling this teleprinter after World War II, and its high maintenance cost, prohibited further quantity production after the late 1940s.

When Telex service was initiated in the United States in 1958, Western Union's need for low-cost, light-duty teleprinters and ASR sets increased considerably. At about the same time, it was learned that the Teletype Corporation was actively at work on the development of a low-cost page teleprinter. Western Union representatives discussed with Teletype engineers the need for low-cost, light-duty teleprinters and ASR sets for Telex service and proposed that Teletype develop and manufacture units specifically designed for this service. The design objectives established were based on the capabilities and limitations of corresponding European equipment used in Telex service.

The international standards developed by the CCITT (International Telegraph and Telephone Consultative Committee) were incorporated in the requirements, but with minor modifications in the standard CCITT No. 2 code and keyboard. The keyboard layout differed from the CCITT No. 2 keyboard only on the upper case V and Z characters. A 50-baud, 7.5-unit transmission pattern and a speed of 400 characters per minute were specified. Other standard teleprinter speeds, for service other than Telex, were not, of course, precluded. The standard Telex 69-character line length was also specified.

Design Objectives

The design objectives for the ASR set were based on operating characteristics of the Siemens and Halske ASR set, which had just been adopted by Western Union as the standard Telex ASR set.[1] All the capabilities of the latter set were to be incorporated into the new ASR set. However, no additional features or added versatility were to be provided if this increased the cost of the unit. The operating characteristics were specified in detail by Western Union, but the implementation of the design to achieve low cost and reliability was left entirely to Teletype.

Western Union defined "light duty" to mean a total of not more than two hours of operation per day. The teleprinter was to be considered "in operation" when the motor was turned "on." Further, Western Union advocated, as one goal, a "1000-hour" teleprinter and defined this as one which would require very little maintenance during the first 1000 hours of operation, but could normally be expected to require replacement of numerous worn parts after 1000 hours. A statement of Teletype's position regarding "light duty" is given in the box on page 19.

The method used to achieve the light duty goal was to build and test substantial numbers of prototype teleprinters. Parts which wore excessively or broke on a significant number of test models during the designated period of operation, were redesigned to increase their life. Parts which were appreciably worn but still serviceable after this period were not redesigned. This approach contributed importantly to the achievement of the low-cost objective.

The definition of "low cost," from a Western Union viewpoint, was less exact. Initially it was hoped that the cost of the teleprinter alone would not exceed $300, but it was recognized that this would be very difficult to achieve. It was generally agreed that a cost of $500 or less would satisfy the low-cost requirement.

How Low Cost Was Achieved

Teletype achieved the low-cost design objective by careful attention to design, by using manufacturing techniques not common in the manufacture of telegraph apparatus, and by deliberately limiting the versatility of the Model 32[2]. Wherever possible, mechanisms were simplified and a single part made to combine the functions of many parts. Extensive use was made of die castings and molded plastic parts.

In the manufacturing process, parts were hardened only when necessary and local hardening was used when required in order to avoid costly straightening operations that are frequently necessary after hardening. Assembly of the unit was simplified. For example, the entire keyboard is assembled without the use of a single screw or washer. Snap-together parts and retaining rings were used liberally to reduce assembly costs.

One exception to the low-cost design objective was the use of the Model 28 all-metal clutch. Although this clutch is comparatively expensive, its use was recommended by Western Union because of its excellent quality and low maintenance cost.

In addition to the low initial cost, the installation cost has also been kept down, as compared to other teleprinters and ASR sets. The entire Telex teleprinter (or ASR set) is shipped from the factory in one carton and can be unpacked and assembled in less than one hour.

The following statement of Teletype's position regarding "light-duty" application of the Model 32 was made by a company spokesman:

"Initially it was agreed that 'light duty' would mean an average of not more than two hours of operation per day, which for a five year calendar life requires a total machine operating life of about 2500 hours. Assuming that the machine is actually typing 50% of the time it is turned on, this results in a life requirement of 30 million character cycles.

"The life of a machine with fully interchangeable and replaceable parts is, of course, theoretically unlimited and this applies to the Model 32. For practical purposes, Teletype defined machine life as the point where trouble begins due to worn parts. The machine may be kept in service beyond this point but, 'or maintenance economy, the manuf icturer recommends that it be withdrawn and rebuilt. This can be done on a standardized production line basis, following which the machine should be ready for another almost equally long tour of duty. While this rebuild procedure is good for any such product, it is especially important for the Model 32 in order to keep maintenance costs and initial costs in balance.

"Proving Laboratory tests on production machines running at Telex speed (400 characters per minute) indicate that this rebuild point is reached at about 100 million character cycles, well beyond the 30 million design objective. If the machine is operated at 100 words per minute, the rebuild point occurs after about 50 million character cycles. The machines are not necessarily limited to two hours of usage per day—they may be run continuously if desired, the effect being merely to approach the rebuild point in a fewer number of weeks."

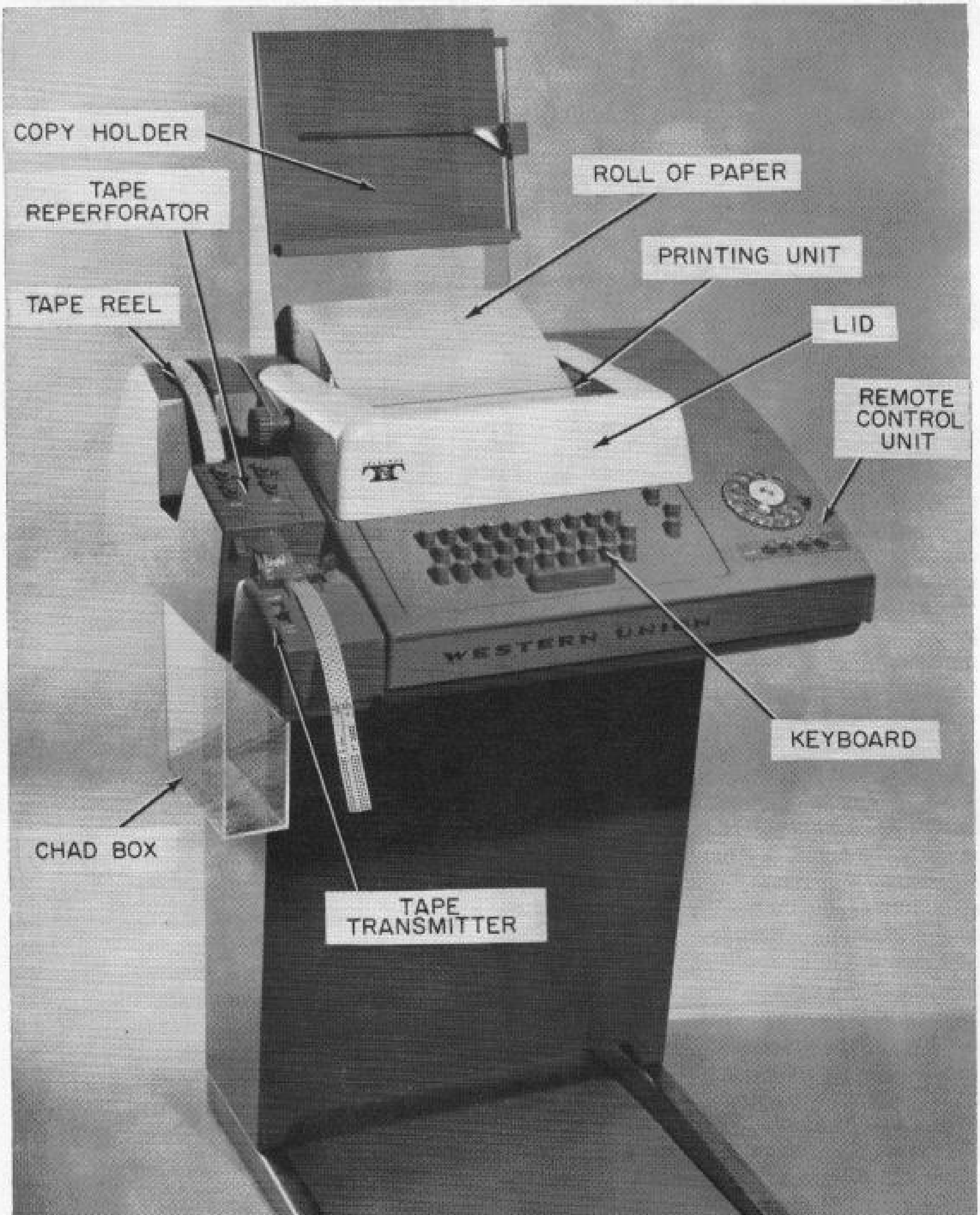


FIGURE 1. The Model 32 ASR Set

General Description

The basic components of the Model 32 teleprinter are the typing unit, keyboard, distributor, answer-back unit, motor, remote control unit (RCU) for Telex operation, and a selector magnet driver unit mounted in the same compartment as the remote control unit. A cover and a copy holder with a line guide are also provided and the entire printer assembly is mounted on a stand, or pedestal. The Model 32 ASR set, shown in Figure 1, also includes a tape transmitter and reperforator attachments, and a chad box. In addition, a rectifier is mounted in the stand to furnish power for operating the transmitter. The same stand is used for either unit; space is available in it for mounting relay racks and other special equipment, when required. Both units are small in size and light in weight, as compared to other Western Union teleprinter sets; but this is a logical consequence of the design for low cost and light duty, rather than a specific design objective. The overall dimensions of the teleprinter, without the stand, are shown in Figure 2. When the tape transmitter and reperforator attachments are added, the overall width of the unit is increased by approximately 3½ inches. The stand on which the teleprinter or ASR set mounts is 17¾ inches wide and 24½ inches high.

A front view of the teleprinter with the cover removed is shown in Figure 3. The remote control unit, located in a compartment at the right of the teleprinter, is an electronic unit which performs the same functions as the Siemens and Halske remote control units widely used in our Telex system[3]. An electronic selector magnet driver, which normally receives make-break (neutral) signals from the line and transmits 500 milliampere make-break signals to the selector magnet, is also located in the same compartment. A polar adaptor plug-in circuit card is available which enables the teleprinter to receive polar signals. The control unit is the area of convergence for the wiring from the various other components; electrical connectors are provided at the rear of the unit for interconnecting these components.

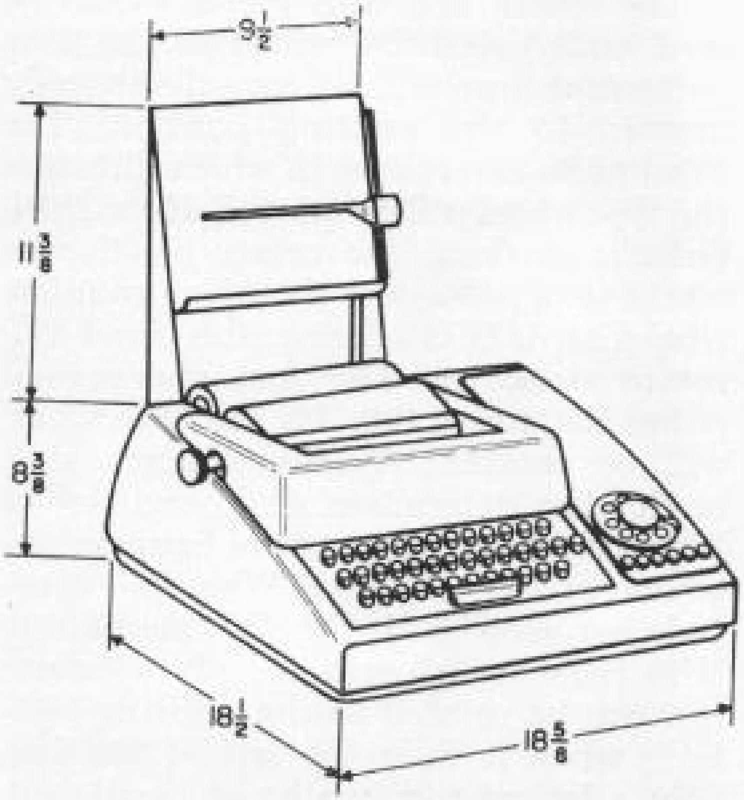


FIGURE 2. The Model 32 Teleprinter without Stand

The Typing Unit

The low-cost objective dictated the use of a type wheel in the printing unit, shown in Figure 3. The type wheel consists of 16 vertical rows, with four characters in each row, as shown in Figure 4. Each vertical row contains either upper case or lower case characters. In the left half of the type wheel drawing, upper case characters appear in the row immediately to the left of their corresponding lower case characters. In the right half, the upper case characters appear in the row to the right of their equivalent lower case characters. The printing area, as shown, is just above the home position of the type wheel.

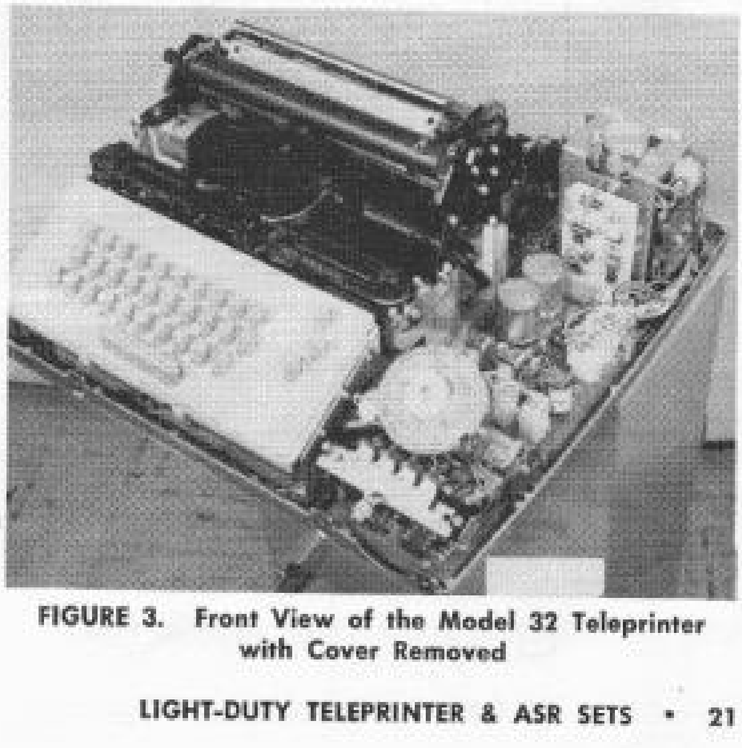


FIGURE 3. Front View of the Model 32 Teleprinter with Cover Removed

The fourth and fifth pulses in the 5-level code determine which of the four horizontal rows will be moved vertically upward to the printing position. The third pulse determines in which direction the type wheel will be rotated. If the third pulse is marking, the rotary positioning mechanism will rotate the wheel counter-clockwise; if it is spacing, the wheel will rotate clockwise. The first and second pulses determine how far the type wheel will be rotated. A letters-figures shift mechanism determines whether a row of letters characters or a row of figures characters will be selected. When a "zero" code bar associated with this mechanism is in the figures position, only a figures row can be rotated to the printing position; when it is in the letters position, only a letters row can be so positioned.

After the type wheel has been positioned, a print hammer strikes it and causes the type wheel assembly to rotate about the lower end of its shaft, driving the print hammer and ribbon against the paper to print the selected character. Since there are only 51 graphics (printing characters) on the type wheel and 64 possible printing positions, there are 13 positions which do not contain raised printing characters. These positions, such as line feed, carriage return, bell, etc., are indicated by rectangles in Figure 4, and printing is suppressed in these positions.

A timing belt is used to space the type wheel assembly from left to right as a line is printed. In Figure 3, the pulley at the left is fastened to the upper end of a shaft. At the lower end of this shaft there is a ratchet which is stepped once by a feed

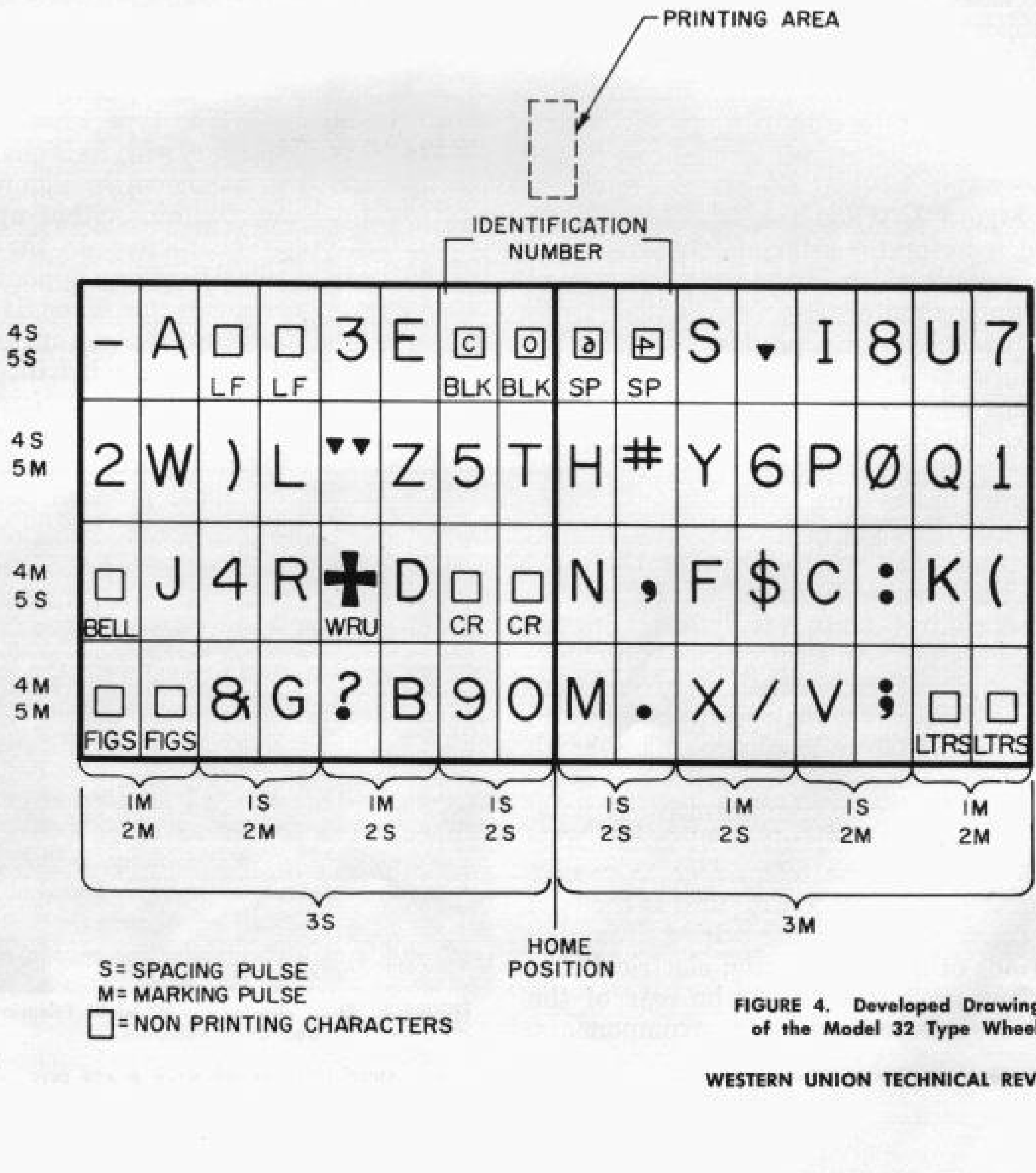


FIGURE 4. Developed Drawing of the Model 32 Type Wheel

pawl after each printing character or space. A check pawl detents the ratchet. This design contributed to the low cost of manufacturing, but at some sacrifice in accuracy of printing alignment. As compared to the Model 28 teleprinter, for example, the horizontal spacing between printed characters is somewhat uneven. However, the copy produced has proven to be acceptable to our Telex subscribers.

The selector magnet operates on 500 milliampere make-break signals, supplied by the selector magnet driver (SMD) in the remote control unit. The SMD unit, which is a single printed circuit card, converts the 60-ma line signals to 500-ma "driver" signals. The non-inductive input of the SMD results in an inherent marking bias when the teleprinter is used on long loops with high distributed capacitance. The reason for this is that high capacitance causes a considerable delay in the decay of current on mark-to-space signal transitions, but there is no corresponding delay in the build up of current due to high inductance on space-to-mark signal transitions. On long loops, it is frequently necessary to add inductance to the loop, either at the Telex exchange or at the teleprinter end of the loop, in order to compensate for this unbalance. On short loops and on properly balanced long loops, the teleprinter can tolerate distortion of 40 percent transmitted from a Telex exchange test transmitter.

The typing unit is mounted to the base by means of four rubber shock mounts; there is no rigid mechanical connection between the typing unit and the base. There is only one non-rigid mechanical connection between the typing unit and the keyboard. This results in a slight vibration of the typing unit during printing. However, the resulting "jitter" of the copy being printed is not particularly objectionable to most operators.

The selector mechanism positions five blocking levers to their marking or spacing positions, depending upon the code combination received. A cam on the selector assembly then trips a code bar clutch, which allows the code bars to move diagonally upward and to the left where they are either blocked or allowed to continue their motion, depending on the marking or spacing positions of their associated blocking levers. The upward component of motion of the code bars is used to control the positioning of the type wheel. The sideways movement is used to determine which function, if any, will be performed. The underside of each code bar is coded by means of notches and projections. After the code bars have been positioned, a function clutch is released to provide power for printing and for actuating the special functions. Function levers are allowed to move upward and sense the notches on the code bars. If a function lever is not blocked by a projection on a code bar, it continues to move upward until it is latched by an associated function pawl. A drive bail then pulls the selected lever and function pawl downward. The motion of the pawl is used to perform the desired function. Universal function levers which can be coded for any desired character are available.

The function mechanism on the Model 32 is not a separate removable "stunt box" subassembly as on the Model 28[4] teleprinter and the versatility of the function mechanism is comparatively limited. For example, sequential selection, latch-unlatch, and latch-release function mechanisms are not available as yet. However, a function contact can be operated by any predetermined character. Twelve function mechanism slots are available, but at present only 8 of these can be used in conjunction with function contacts.

There are four clutches used in the Model 32 and three of these (the selector, code bar, and function clutches) are associated with the typing unit. The fourth clutch is used to drive the distributor shaft.

The Keyboard

Unlike conventional teleprinter keyboards, the Model 32 keyboard does not contain a mechanism for distributing signals to the line. Depressing a keylever operates five parallel output contacts corresponding to the marking and spacing pulses for the character represented by the depressed keylever. Start-stop teleprinter signals are distributed to the line by a separate faceplate-type of distributor mounted on the base. The keyboard contains two code bars for each of the five code levels. Each pair of code bars is complementary coded by means of slots in the top of the bar, so that when one of the pair has a slot beneath any keylever, the other has a projection beneath this keylever. When a key is depressed, one code bar in each pair moves up and the other moves down, as in the Type 19 set keyboard. The code combination for the character corresponding to the depressed key determines which bar in each pair will move up and which will move down. Each pair of code bars is interconnected by means of a T-lever at each end of the bars, and each pair of T-levers is interconnected by means of a tie link, as shown in Figure 5. The motion of the code bars rotates these T-levers. A wire-type contact is associated with each of the right hand T-levers and the motion of the levers determines whether a contact will be allowed to close or will be held open. This is illustrated in Figure 6. When a right hand T-lever is rotated to the marking (clockwise) position, the end of the lever which engages the wire contact moves downward and unblocks the contact. All contacts are held open, however, by the contact bail. When any keylever is depressed, a universal code bar is depressed, as on any conventional teleprinter. On the Model 32, this universal bar initiates the motion which ultimately results in downward rotation of the contact bail.

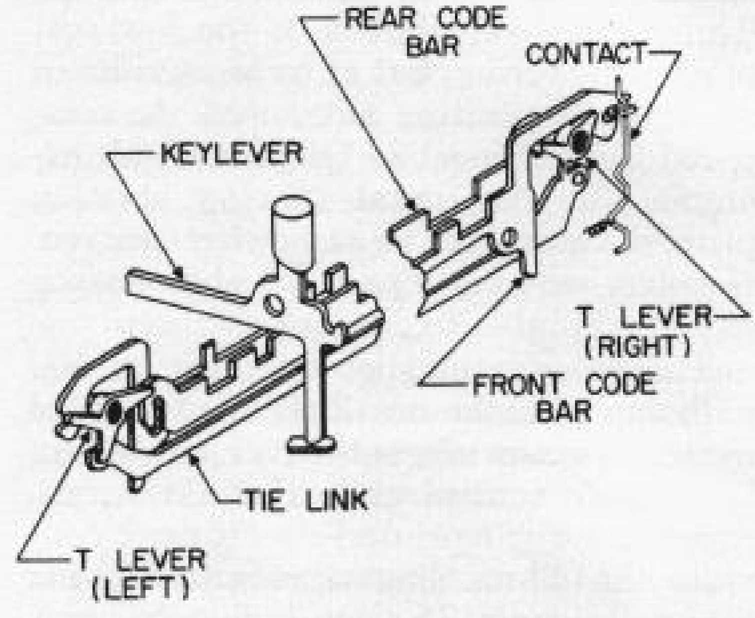
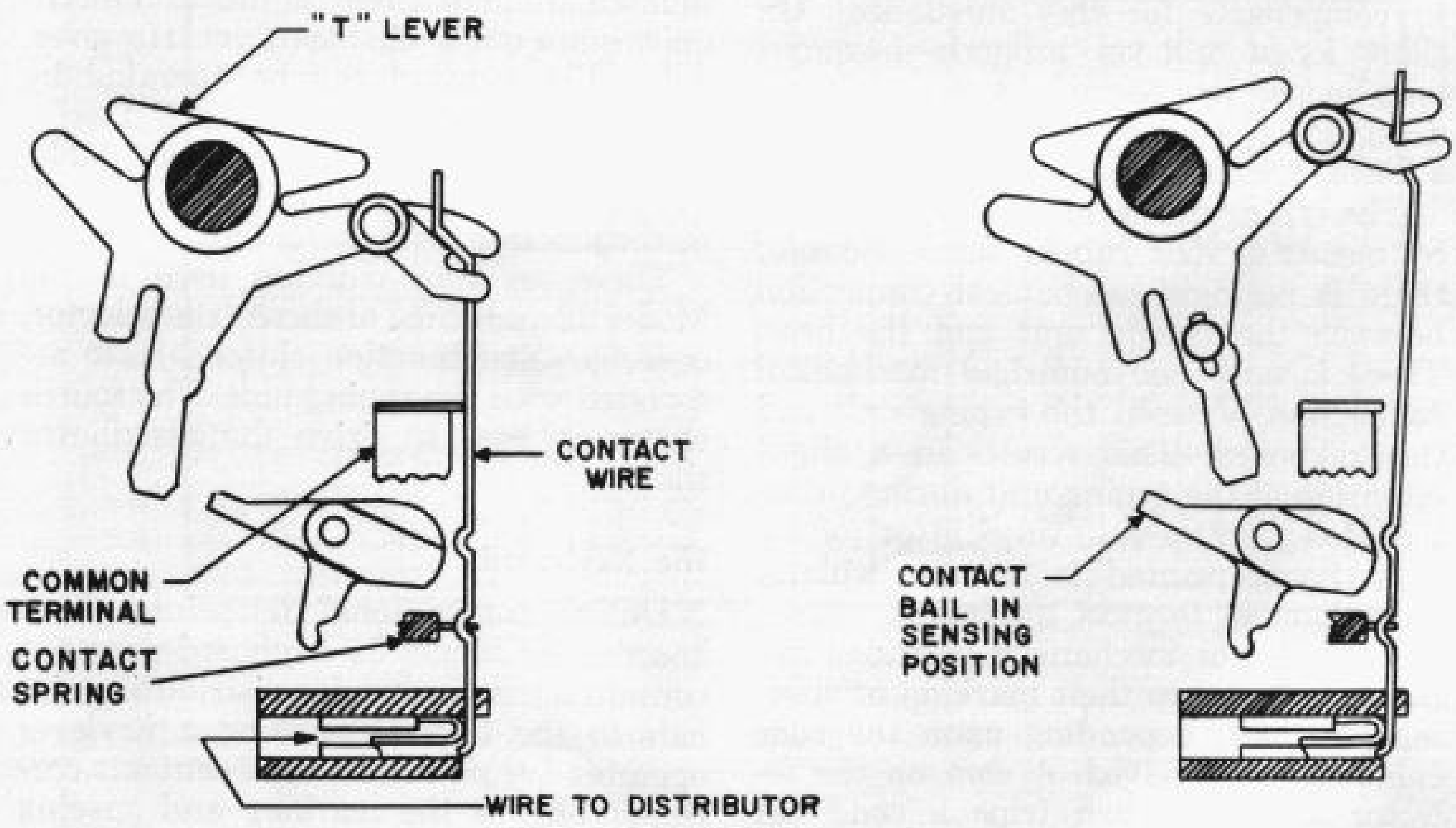


FIGURE 5. Keylever and Code Bar Mechanism of the Model 32 Keyboard, showing One Pair of Code Bars



6-A—Marking positions.

6-B—Spacing Positions

FIGURE 6. The Right T-lever And Its Associated Contact.

As the bail moves downward, away from the projections on the contacts, those contacts which are not blocked by T-levers will be pulled against a common bus bar by their contact springs, as shown in Figure 6-A. T-levers which are in the spacing position will, of course, block their associated contact springs, as shown in Figure 6-B. The T-levers and the contact bail are made of nylon, since these parts must be of insulating material.

The keyboard is equipped with a non-repeat mechanism which prevents a character from being transmitted to the line more than once when a keylever is held depressed. It is also equipped with a repeat key which overrides the non-repeat feature and allows a character to be transmitted repeatedly to the line when the repeat key and any character key are held depressed simultaneously. A T-lever locking feature locks the code bars in their selected positions when a key is depressed and prevents depressing another key until near the end of the distributor cycle.

the right half. The upper halves of the F, G and H keys are similarly "split." Since the upper case codes for these three characters are reserved for domestic use and their use is prohibited by the international Telex standards, the right halves of these keys are blank.

The Distributor

The distributor faceplate, shown at the left in Figure 8, is used to distribute to the line the parallel output signals generated by the keyboard. It also distributes signals generated by the answer-back unit and, in the ASR set, the tape transmitter attachment.

When the teleprinter is idle, the brush arm remains at rest, with the outer brush resting on the stop (rest) segment. When a keylever is depressed, the distributor clutch stop lever is momentarily disengaged and the brush arm is driven through one revolution to transmit the selected character.

Printed circuit techniques are used in

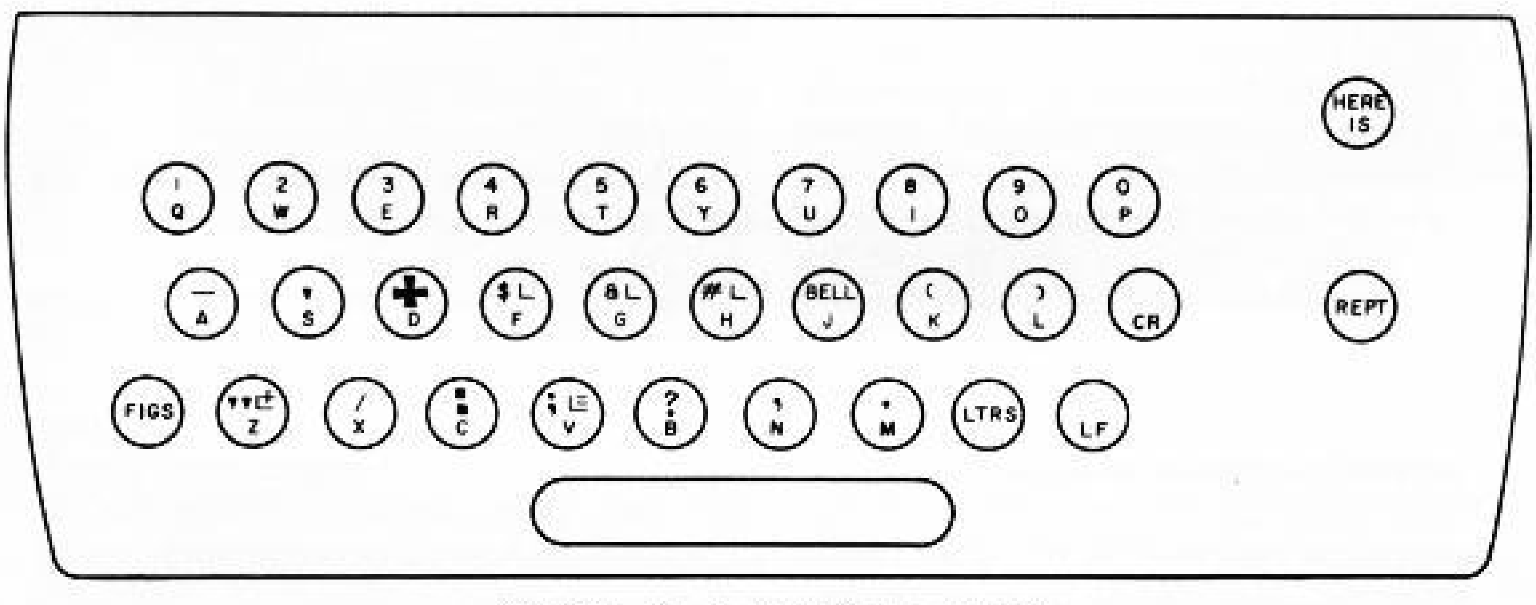


FIGURE 7. The Model 32 Keyboard Layout

The keyboard layout is shown in Figure 7. As previously stated, this layout and the corresponding type wheel layout correspond to the CCITT No. 2 standard except for the upper case V and Z. The upper halves of these two keys are divided into two parts by a right angle mark. The character printed by Western Union Telex printers is imprinted on the left half of each key and the character printed by foreign Telex teleprinters is imprinted on

the manufacture of the faceplate and the resulting cost of this unit is so low that it is not economical to repair worn or damaged faceplates. The cost of this unit is actually less than the cost of resurfacing a faceplate used on Model 14 distributor transmitters. (The faceplate can be removed by removing three screws and seven push-on connectors.) The molded brush arm used on the distributor is also inexpensive to manufacture. The torsion

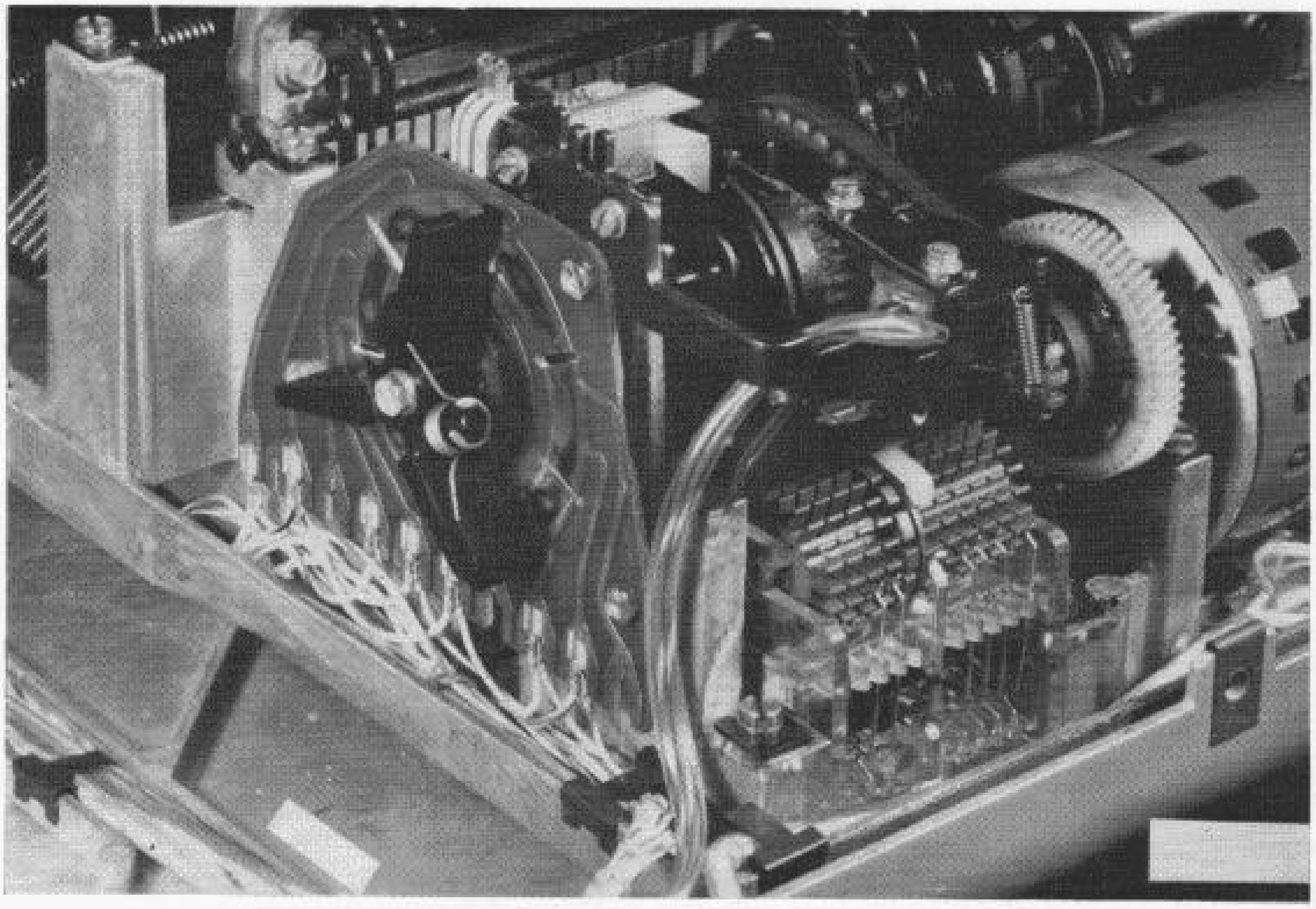


Figure 8. Rear View of the Model 32 Teleprinter with the Cover Removed

spring used to hold the brushes in contact with the faceplate rings is designed to give almost constant tension on the brushes until the latter wear to the point where replacement is necessary.

The low cost of the faceplate and its multi-purpose use were important factors in reducing the cost of the Model 32 ASR set.

Western Union's laboratory tests and actual service results with the Model 32 indicate that the low-cost design of the faceplate has not resulted in higher maintenance cost, as might be expected. However, there has been some sacrifice in signal quality. In order to prevent chipping of the brushes, which might be caused by the brushes striking the edge of a segment as they pass from one segment to another, the leading edge of each segment is bent slightly away from the adjacent segment as shown in Figure 9. (The insulating material on which the segments are "printed" is slit, for about ¼-inch, to permit this.) As the brush rotates, it remains in contact only with the segment on which it is resting until the trailing edge of the brush passes over the trailing edge of this segment. The brush then drops, under spring tension, until it comes to rest on the following segment. During the brief transition period, the brush is in contact with neither segment. This condition causes a momentary break between two successive marking pulses. Western Union's bias and distortion meters sometimes misinterpret this break as a very large marking bias. However, the amount of actual signal distortion introduced by this break is less than 5 percent.

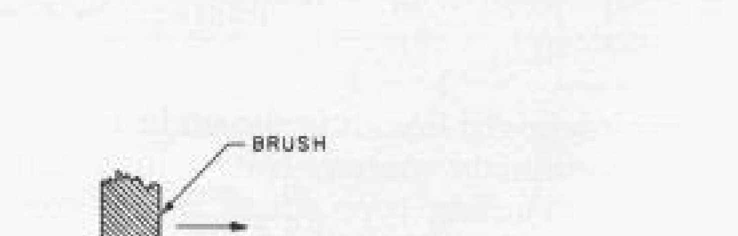


Figure 9.
Sectional View of Distributor Segments

The Answer-Back Unit

The answer-back unit, which can be seen just to the right of the distributor faceplate in Figure 8, performs the same functions as the answer-back units used on other Western Union Telex printers[1]. However, it does have several novel features. The coding drum is a one-piece molded plastic part with 21 rows of tines around the periphery. The drum is coded for the answer-back characters to be transmitted by breaking off tines in each position which must correspond to a marking pulse. There are eight coding levels across the width of the drum, instead of the usual five, because the same drum is used in the 8-level Model 33 teleprinter. In the Model 32, three of these levels are not used and the wire spring contacts corresponding to these three levels are omitted. Each of the other five levels is associated with a contact which is held open when it is opposite a tine on the drum, but is allowed to close when it is opposite a space from which a tine has been removed.

In addition to the eight coding levels, there is a feed ratchet, a control cam and a suppression level molded into the periphery of the drum. The feed ratchet is stepped by means of a feed pawl which is actuated by a cam roller on the distributor cam clutch. The control cam and an associated control lever determine the stop position of the drum. When the control cam drops into an indent in the drum, it causes the distributor clutch to disengage at the end of its revolution and the answer-back drum stops rotating. Normally, there is only one indent in the control cam and the drum makes one complete revolution each time the answer-back is tripped. However, there are removable tabs in the control cam which can be broken off to provide either two or three stop positions of the drum. This feature is useful when it is desired to send an answer-back code less than 20 characters in length.

Since the answer-back contacts are connected to the distributor segments in parallel with the keyboard contacts, the answer-back contacts must be held open in the home position to avoid interference with transmission from the keyboard. This would normally result in transmission of a blank as the first character in the answer-back code. However, blanks are undesirable in Telex. In order to suppress this blank, a tine is removed from the suppression level in the home position. The suppression contact, opposite the suppression level, is normally prevented from closing by the answer-back trip link. When the trip link moves forward to trip off the answer-back, the suppression contact is allowed to close, if it is not opposite a tine. The contact is wired so that it shorts the line when closed and therefore prevents the first character from being transmitted to the line. After the answer-back steps from the home position, the tines on the suppression level prevent this contact from closing. The suppression level also serves another useful function. Since the drum is a one-piece molded part, it cannot be recoded. However, if an error is made in coding a character, the suppression tine at this level can be broken off so that the errored character will be deleted from the answer-back transmission. Because of the low cost of the answer-back drum, the inability to recode it is not an economic burden.

The here-is key on the keyboard trips the answer-back by means of a mechanical linkage. When the upper case D (who-are-you) character is transmitted from the keyboard, a mechanical interconnection, operated by a blocking cam on the distributor shaft, prevents the answer-back from being initiated.

The Motor and Driving Gears

The ac synchronous motor used on the Model 32 teleprinter is a miniaturized capacitor-start, capacitor-run motor which can develop 25 millihorsepower (1/40 h.p.) at 3600 rpm. The motor used on the ASR set is similar, but is a 33 mhp motor. The motor, capacitor and start relay are mounted on the left rear of the base. At present, no dc motor is available for the Model 32 and it is not anticipated that one will be provided in the future.

The motor pinion drives a gear which is part of a gear and pulley assembly. The pulley on this assembly drives an internal tooth belt. This belt in turn drives a gear pulley on the distributor shaft. A gear fastened to this pulley drives a mating gear on the main shaft. Motion and power for driving all of the teleprinter mechanisms are obtained from these two shafts. The gear and pulley assembly which is driven by the motor is mounted on a bracket which fastens to the die-cast end bell on the pinion end of the motor. In order to change speeds it is only necessary to replace this one assembly.

The ASR Set

The ASR set consists of the basic teleprinter plus a tape transmitter attachment and a tape punch attachment. A compact power supply, mounted inside the stand, is also included to provide electrical power for stepping the tape transmitter. In addition, a control magnet and a cam-operated set of contacts is provided in the printer to furnish timed stepping pulses for the transmitter. Both attachments are mounted on the left side of the teleprinter, as shown in Figure 1. The tape transmitter is mounted near the front of the teleprinter and the reperforator is mounted behind it, with about 1¼ inches of space between them. In both cases, tape feeds from rear to front, so that continuous tape operation is possible. Except for the very early production units, it is possible to convert a teleprinter to an ASR set by adding the tape attachments, power supply, and transmitter step mechanism to the basic unit.

Motion for setting up selections in the reperforator is supplied by extensions on the typing unit code bars. For this reason, tape cannot be prepared off-line while a message is being received on-line.

The Tape Reperforator Attachment

The tape punch, which is mounted to the base of the teleprinter, produces fully perforated tape with in-line feed holes, using 11/16″ tape. Sensing levers in the tape punch-sense the positions of the code bars in the teleprinter and translate this into motion which determines whether a hole will be punched in each of the five levels of the tape.

Friction feed is used to feed tape through the punch by means of a knurled feed roller and a mating pressure roller. Tape gauge (number of holes per inch) is adjusted by means of the tension spring used to hold the pressure roller in contact with the feed roller. One end of this spring is anchored in one of a series of notches in an arm. The tape gauge is adjusted by moving the spring loop to another of the notches, thereby changing the extended length of the spring and the spring load on the pressure roller. In order to reduce variations in the load on the feed roller as the diameter of the tape roll varies, and thus minimize variations in the 10-per-inch hole spacing, a tape "nudger" is used to unwind tape from the supply reel. While the punch pins are penetrating the tape to perforate the selected code combination, the nudger strikes the tape and causes a short length of tape to unwind from the roll. When the feed wheel subsequently feeds the tape forward one step, it has only to feed slack tape.

Rotation of the function shaft in the teleprinter provides motion for operating an oscillating power bail assembly in the tape punch. The bail, in turn, provides motion and power for operating the tape punching and feeding mechanisms and the tape nudger.

Since the who-are-you character (upper case D) should not be punched in tape to be transmitted via Telex, the Model 32 punch is designed to prevent perforating this combination in the tape. (The reason for this is that an upper case D transmitted via Telex would actuate the distant answer-back unit and result in "garbling" of the next 20 characters in the tape.) When the letters-figures code bar is in the figures position and a "D" combination is set up in the punch, an ingenious mechanism in the punch inserts the 2nd and 5th pulses so that a figures combination is perforated in the tape. Thus, a figures-D sequence is converted to a figures-figures sequence.

Four control buttons are provided on the reperforator. Two of these are used to turn the reperforator on and off and a third one is used to back space the tape for the purpose of correcting conscious errors. The fourth button, when held depressed, releases the feed mechanism to facilitate inserting and removing tape from the reperforator.

magnet located in the distributor area of the teleprinter. This magnet closes the transmitter step contacts in the teleprinter and releases the distributor clutch, allowing the distributor shaft to start

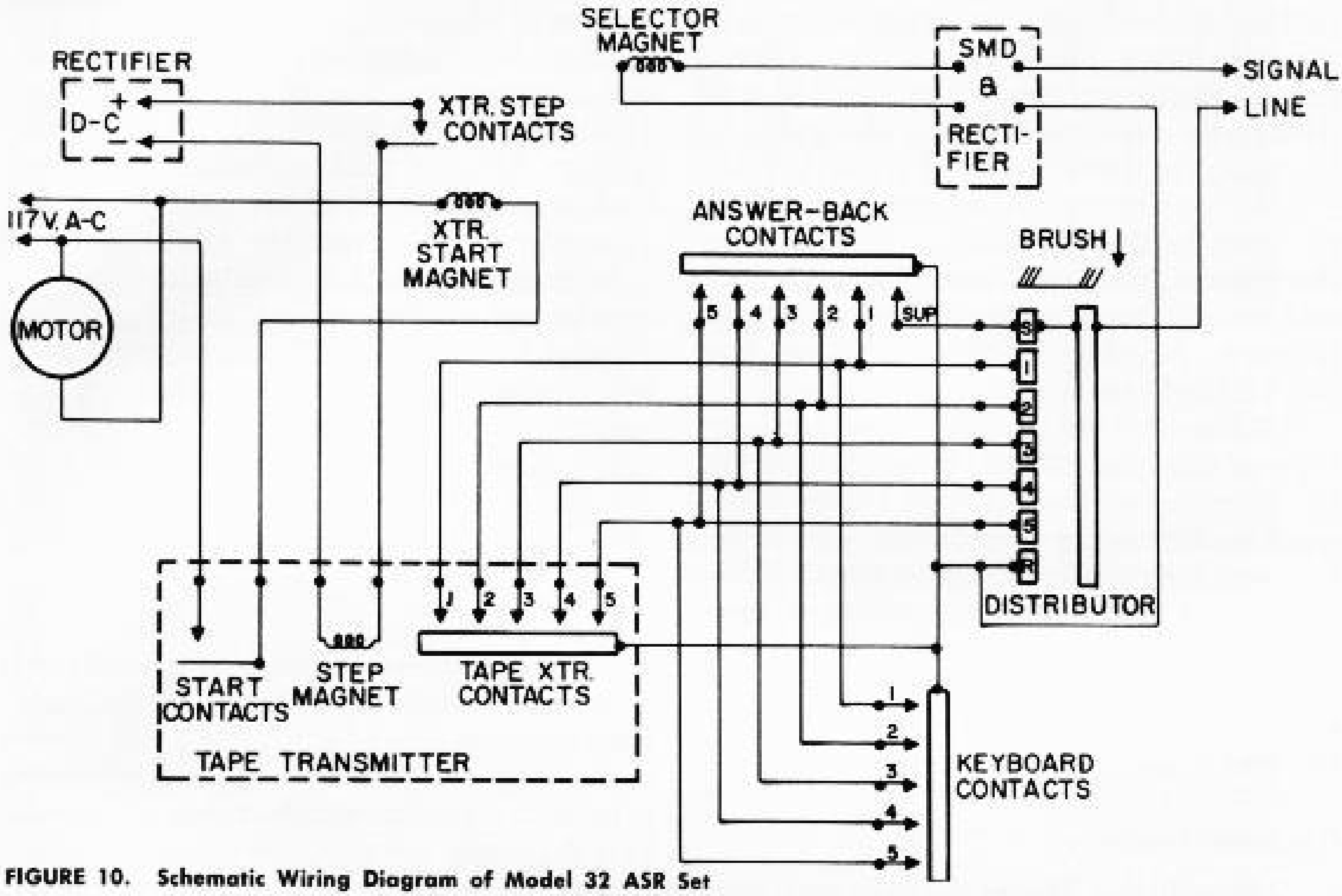


FIGURE 10. Schematic Wiring Diagram of Model 32 ASR Set

The Tape Transmitter Attachment

The tape transmitter attachment is fastened to the teleprinter base, but there is no mechanical interconnection between the two units. Electrical connections from the transmitter enable the distributor to transmit to the line the code combinations set up on the reading pins and also provide an electrical path from the power supply in the stand, via contacts on the base, to the tape transmitter step magnet. In addition, a control circuit is provided from a set of start contacts in the transmitter to a control (trip) magnet on the base. A simplified schematic wiring diagram of the Model 32 ASR Set is shown in Figure 10.

A three-position handle on the transmitter provides on, off, and free-wheeling positions for controlling the transmitter. When this handle is moved to the "on" position, it closes a contact which completes a circuit to the transmitter trip rotating. When the step contacts close, the reader magnet is energized and its armature raises the reading pins and allows them to read the code holes punched in the tape. As the distributor brushes rotate, they distribute to the line the code combinations set up on the pins. Near the end of the distributor cycle, the step contacts are momentarily opened by a camming roller on the distributor shaft. The step magnet is de-energized, the reading pins are retracted, and the tape is stepped forward one character by a pawl and ratchet. Tape feeding and pin retraction occur simultaneously and the reading pins are pivoted at their lower ends so that they move with the tape until they are withdrawn from the holes in the tape. The feed ratchet is engaged by both a detent and a blocking pawl. The detent serves the usual purpose of defining the rest position of the feed wheel and the blocking pawl prevents overfeeding.

One of the novel features of the tape transmitter attachment is that the entire sensing pin guide assembly is moved upward to read the holes in the tape. Each pin is biased to its upper position in the guide by a tension spring. If a pin is opposite a hole in the tape it continues to rise with the guide. If it is not opposite a hole in the tape, the pin is blocked and the spring stretches to allow the guide to continue its upward travel while the pin is held stationary. Wire spring contacts are used in the transmitter as well as in the answer-back unit and the keyboard, and an extension on each sensing pin determines whether its associated contact will be held open or allowed to close.

A tape-out pin is held depressed by tape in the transmitter. When the end of the tape passes over this pin, it moves upward under spring tension and opens the transmitter start contacts to stop further feeding of the tape. A tight-tape arm, which snaps onto the molded plastic tape latch, performs the same function when the tape feeding from the reperforator to the transmitter becomes taut.

Optional Features

Although the Model 32 does not have the versatility of the Model 28 line of equipment, many standard optional features are available for it. Such features as automatic carriage return and line feed, unshift on space, low paper contacts, and speeds of 60 or 100 words per minute can be added at relatively low cost and with little installation time required. A simple directory holder is also available as an accessory for mounting on the right side of the stand.

A sprocket-feed typing unit is also available for the Model 32. This unit includes a form feed-out mechanism which normally feeds out a form, 11 inches long, under the control of a form-out disc which makes one revolution per 11-inch form. Two stop lugs can be installed on the disc to limit its rotation to one-half of a revolution per form-out cycle in order to feed out 5½-inch long forms. Three stop lugs can be used to form-feed 3-2/3-inch forms. At present, these are the only three form lengths available. However, other sets of gears for use in the form-feed mechanism could be designed to provide other form lengths if the need arises. Horizontal and vertical tabulation are not available and it is not anticipated that these features will be provided in future models of the unit.

Converting a friction feed Model 32 to sprocket-feed involves so much labor that Teletype does not plan to offer a conversion kit for this purpose. Sprocket feed teleprinters or ASR sets must be ordered complete from the factory.

It is expected that limitation on the number of legible copies which can be printed on a Model 32 (an original and one carbon) will restrict the use of sprocket-feed units and it is not anticipated that the ratio of sprocket-feed to friction-feed printers in use will ever approach that of the Model 28 teleprinter.

Future Potential

Laboratory test results and actual field experience with the Model 32 indicate that this new line of equipment will prove to be very satisfactory in the light-duty type of service for which it was designed. It is definitely not suitable for heavy duty service, however, since maintenance costs would be prohibitive in this type of service.

An elapsed timer for measuring the "on" time of the Model 32 was not provided because it was felt that the added cost of such a unit could not be justified. Certain wear points in the teleprinter can be used, however, as guides in determining when a Model 32 should be overhauled in a repair shop. In addition, the range of the teleprinter also serves as an excellent guide to the amount of wear present. As previously stated, a teleprinter in good condition will tolerate 40 percent distortion. However, when parts in the selector mechanism begin to wear, the signal distortion tolerance drops sharply. Maintenance personnel have been instructed to dial the distortion test set at the Telex exchange and note the amount of distortion tolerated on each maintenance visit to a Model 32 outstation.

The Model 32 has not yet been in service long enough to determine how well the

"1,000-hour" objective has been met. However, laboratory tests indicate that, with a few exceptions, the parts subject to wear can be expected to last for this period of operation. As further experience is acquired, design changes and improvements in manufacturing techniques will undoubtedly be made to assure achievement of this goal.

At present, all of the Model 32 units purchased by Western Union are being used in Telex service. It appears likely, however, that this low-cost equipment will find wide usage in such applications as intra-plant message distribution for industry and on-base message distribution for the military services. The low cost of a receiving-only Model 32 teleprinter, without the Telex remote control unit, could open up markets previously closed to teleprinters for economic reasons.

Compared to Teletype's Model 28 line of equipment, the Model 32 sets are relatively simple and require less maintenance training. Adjustment of the Model 32, however, is somewhat more difficult, partly because some of the parts are not readily accessible and partly because the black finish used on many of the parts—for reasons of economy—make many of the clearance requirements between parts difficult to see.

• • •

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3. *Telex in Canada*, Mr. C. J. Colombo, Western Union TECHNICAL REVIEW, Vol. 12, No. 1, January, 1958.
4. *Function Mechanisms of the Model 28 Teleprinter*, Mr. E. Louis Parkington, Western Union TECHNICAL REVIEW, Vol. 10, No. 2, April, 1956.

Fred W. Smith has been in charge of the Mechanical Equipment Group in the Telegraph Equipment Engineer's office since 1951. In this capacity, he was responsible for establishing Western Union's engineering requirements for the Model 32 teleprinters and ASR Sets.

He joined the Applied Engineering Division of Western Union in 1946, after having served four years as a radar maintenance and repair officer in the U.S. Army Signal Corps. His responsibilities include the design and field application of mechanical equipment used in start-stop printing telegraphy and in reperforator switching.

Mr. Smith received a degree of Bachelor of Science in Electrical Engineering from the Georgia Institute of Technology in 1938. He is a member of the Institute of Electrical and Electronics Engineers and past Chairman of both the American Institute of Electrical Engineers Committee on Telegraph Systems and the Committee on Standardization of Perforated Tape.

K. M. Jockers, Senior Project Engineer, TELEX Division-P & E Dept.

Traffic Evaluation
For Western Union Telex Network
Part II—Switch Stages

Switch Stages

The preceding sections dealt with trunk analysis; however, in each teleprinter connection in the Telex network there are many switch stages that are used within an exchange to link various combinations of subscribers and trunks. The sections discussed under Busy Hour, Probability, Grade of Service and Accessibility in Part I are also applicable to the calculation of the quantities of the switch stages. However, switch stages are unidirectional, more subject to uniform grouping, and in general much less costly than trunks.

In order to discuss the traffic considerations involved in determining the quantity and grouping of switch stages, the exchange layout as indicated in Figure 5 will be used as an example. This exchange layout is a simplified TWM-2 Exchange in San Francisco serving 300 subscribers with trunk connections to New York, Chicago and Los Angeles. Each subscriber is connected to its own Terminating Set (TS) and the subscribers are treated in groups of 100. In order for a subscriber to initiate a call, he must seize an Input Set (VUS) that is also shared by the other subscriber in his 100 group. As indicated, there is a group of 20 VUS units per 100 subscribers and with a $B = 1\%$ these units can carry 12.13 Erl. during the Busy Hour. If this was 20% of the total daily traffic, then this switch group can handle an average sent traffic per subscriber of 36 minutes a day. If traffic studies indicate that more than 12.13 Erl. are being offered by this 100 group of subscribers, then, the number of VUS units must be increased or the number of subscribers actually served by the group should be decreased. The type of busy given a subscriber requesting a VUS unit is also very important. The subscriber requesting a VUS unit is given a delay type busy. In other words, the busy results in depressing the "Start" button on his Remote Control Unit until a VUS unit becomes idle.

In order to connect to a subscriber, an Output Set (VDS) must be seized and like the VUS units, the VDS units also are shared by a 100 group of subscribers. As indicated there are 24 VDS per 100 subscribers and using the Erlang Table it can be determined that with a $B = .2\%$ the group of 24 VDS units can carry 13.19 Erlangs. An improved grade of service is indicated for VDS over the VUS units because the type of busy received on failure to seize a VDS unit results in a redialing by the calling party, or a loss call type busy. Now using this information the three groups of VDS units are seized through a IV Group Selector (IVGS) and this switch must be capable of passing 3 x 13.19 or 39.57 Erl. Calculated at a $B = .2\%$ this stage would require 57 IVGS units, if all input units had full accessibility. If the accessibility to the IVGS was $K = 10$ then 81 IVGS units would be required, and a mixing plan would have to be developed in order to get the maximum utilization of the 81 IVGS unit. The development of a mixing plan, which is a subject in itself, will not be covered by this article. However, in general, a mixing plan is a method of equally distributing the offered traffic to any group of switches or trunks in order to obtain the most efficient use of the group of switches or trunks. For example, during the peak traffic period between New York and San Francisco each input trunk from New York should be able to seize an idle IVGS unit. If all input trunks from New York only shared IVGS units with other New York input trunks, this would be a very unsatisfactory mixing plan. The New York input trunks should, as far as practical, share IVGS units with input trunks or VUS units that have their peak requirement for IVGS units at a different time.

Common Equipment

In establishing a path through an exchange or many exchanges, certain units of equipment are encountered whose functional use is of short duration and limited to, in some cases, the establishment of only one link. Units of this type usually

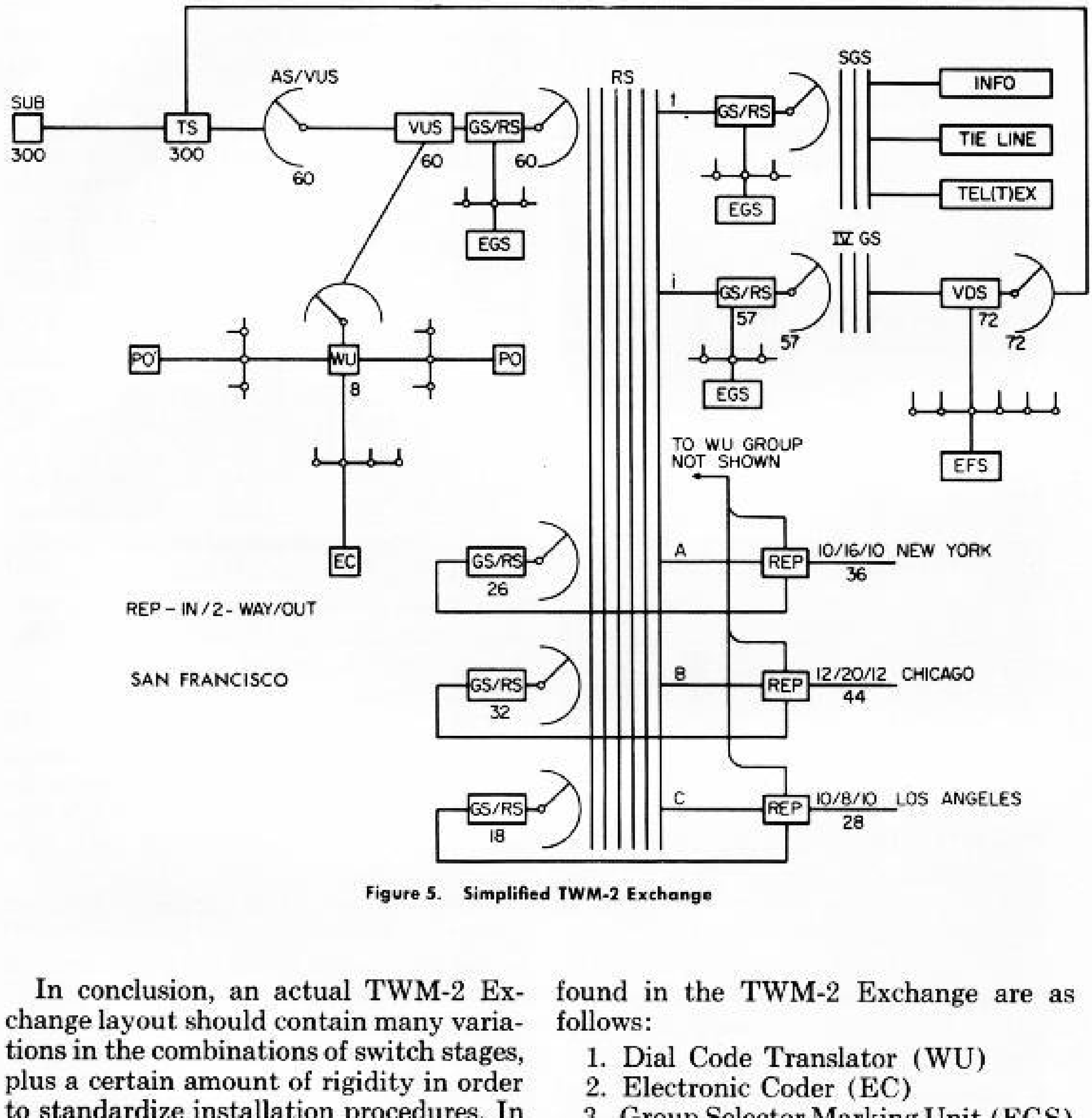

Figure 5. Simplified TWM-2 Exchange

In conclusion, an actual TWM-2 Exchange layout should contain many variations in the combinations of switch stages, plus a certain amount of rigidity in order to standardize installation procedures. In most cases a compromise is sought between economy and standard arrangements in order to obtain a more manageable exchange configuration; however, at no time are any compromises made that will tend to degrade the overall service in providing a path through the exchange.

found in the TWM-2 Exchange are as follows:

1. Dial Code Translator (WU)
2. Electronic Coder (EC)
3. Group Selector Marking Unit (EGS)
4. Final Selector Marking Unit (EFS)
5. Group Selector Allotter (PO)
6. Final Selector Allotter (PO)
7. Mechanical Storage Device (IS)

Each unit listed above performs a specific function in the processing of a call through that portion of the exchange to which it is assigned. The quantity of these units required is dependent upon the load it carries during the busy hour; which is governed by the following formula:

$$Y_{ce} = \frac{Y_t \, x \, T_{hce}}{T_{ht}}$$

where Y_{ce} = Load carried by the common equipment during the busy hour (Erlang).

Y_t = Total load carried by the group using the common equipment (Erlang).

T_{hce} = Average holding time of common equipment (seconds).

T_{ht} = Average holding time of units in the group using the common equipment (seconds).

An example of the use of this formula is demonstrated by a calculation of the number of Dial Code Translators (WU) required to serve Input Sets (VUS) as indicated on Figure 5. Each group of 20 VUS units can carry a Busy Hour load of 12.13 Erlangs. There are three such groups; therefore, the total Busy Hour load, Y_t can be assumed to be 36.39 Erlangs. Each VUS unit is held for the entire length of message and if this is found to be an average of three minutes then T_{ht} equals 180 seconds.

The WU is used to store incoming dial information, and it is held by a VUS until the dial information defines a chargeable rate which normally takes four dial digits and connects to an output unit, VDS or Repeater. The holding time of a WU serving VUS units is the sum of the following factors:

2 sec.—Initial hesitation on the part of the subscriber after he sees the precede to dial lamp light.

7.5 sec.—The average number of dial digits stored is 5 and the average duration of each is 1.5 secs.

2 sec.—Disconnect time of the WU.

Therefore, T_{hce} is equal to 11.5 seconds. Substitution of these quantities in the formula yields a Y_{ce} equal to 2.33 Erlangs. Using this figure in an Erlang Table with grade of service B = 0.1% indicates that 9 WU units are required to serve the 60 VUS units.

Dial code translators are also used to serve Repeaters from other Junction Exchanges, District Exchanges and Sub-district Exchanges and in each case the Y_{ce} is different due primarily to a different value of T_{hce}.

The other listed units of common equipment are also subject to the same type of calculation in order to ensure the proper functioning of each TWM2 Exchange; however, in this article it will suffice just to give a brief description of each unit.

The Electronic Coder (EC) is used by a specific group of Dial Code Translators (WU). Each WU will request the EC after each dial digit is in storage until the EC evaluates a route for the RS switch stage, and if required, a chargeable rate for the call. If the EC was used by the group of WU just described in the example serving VUS units, then the EC will be requested four times in the processing of each message and each time it will be held for approximately .12 second.

The Group Selector Marking Unit (EGS) is used to position a group of 16 switches. The load carried by a group of 16 switches depends primarily upon the overall size of the switch group. In the example, Fig. 5, the 57 IVGS units carried 39.57 Erl.

Final Selector Marking Unit (EFS) is used to position a specific group of 24 FS switches serving usually a maximum of 100 subscribers.

Group Selector Allotter (PO) is provided for each main switch group, for example, RS, IVGS etc. This allotter is used by each Dial Code Translator when it requires the service of an EGS; therefore, it prevents dual seizures of EGS units.

Final Selector Allotter (PO) is used by each Dial Code Translator when it requires the service of an EFS; therefore, it prevents dual seizures of EFS units.

Mechanical Storage Device (IS) is usually shared in a group of five by twenty incoming and two-way repeaters from a TW39 exchange. This unit will store dial digits coming from the TW39 exchange until a Dial Code Translator (WU) can be seized, and it will be held until the WU releases.

Traffic Evaluation Equipment

The preceding sections dealt with the principles and importance of a traffic analysis. This analysis however, is dependent upon the tools used to gather pertinent information and to verify or adjust the results of an analysis. The traffic evaluation equipment presently employed in the Western Union Telex Network is as follows:

- Erlangmeter
- Traffic Recorder
- T_m Meter
- Over Flow Counters
- Seizure Counters

The first three items are shown on Figure 6 as they appear in a TWM-2 Exchange along with a jack panel that terminates registration points for all repeaters, switch stages and common equipment.

The Erlangmeter is a volumetric traffic meter designed for registering the sum of the holding time on a single unit or a group of units with similar functions. The maximum number of units that can be recorded in any group is 500. The Erlangmeter also provides a pulse which is used by the Traffic Recorder to plot on chart paper with a time index, the amount of traffic that is carried in a 15-minute interval. From this chart paper the Busy Hour is determined.

The T_m meter is used to determine the average holding time of any unit. It consists of two counters, one of which counts the number of seizures and the other registers the total holding time. If the number of seizures on a particular unit in a group is 1800 or more, then the results can be considered as representative of the entire group.

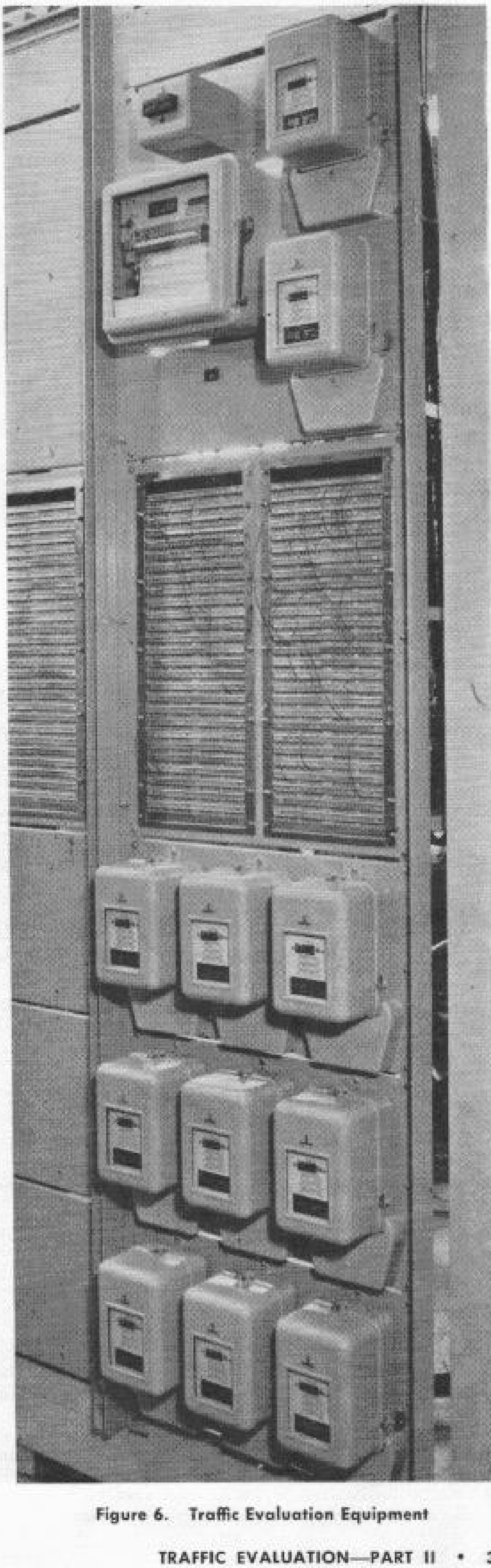

Figure 6. Traffic Evaluation Equipment

Over flow counters, as the name implies registers a count each time all units in a group are busy and a request comes in to seize a unit. The information gained from these counters plus the number of seizures, which are provided by seizure counters, provide a continuous check on the exchange to point out probable areas of traffic congestion.

Central Traffic Evaluation Personnel

At present, the traffic readings taken by each exchange are under the control and direction of Central Traffic Evaluation Personnel. This organization assigns time periods for traffic readings and evaluates the information obtained. From this evaluation and information obtained from marketing research, the following areas of the Telex Network are affected:

- Future equipment requirements
- Trunk Changes
- Alternate Route pattern changes
- Equipment arrangements
- Mixing plan arrangements
- Network number assignments
- New exchanges to be added

The future of the Western Union Telex Network is dependent upon network revisions that keep it abreast of its growth. Traffic evaluation and its proper implementation is essential to meet this goal.

Part I of this article, on Trunk Analysis, appeared in the October 1963 issue of the Western Union TECHNICAL REVIEW.

Kenneth M. Jockers, Senior Project Engineer in the Research and Engineering Department, is presently assigned to the Project Manager—TELEX Division, where he is in charge of a group entitled "Special Switching Arrangements." In this capacity he is concerned with circuit switching system concepts; engineering problems associated with TWM-2 Equipment and its application.

Mr. Jockers participated in the design, development, installation and testing of Switching Systems 57 and 59. In 1960 he joined the staff of the Project Manager—TELEX.

He joined Western Union in 1954 and was assigned to the Patron Systems Engineer. He was involved in the design and development of Data Processing System 201, and the conversion of Plan 51.3 for operation with Plan 55.

In 1955 he was called to active duty for two years as an Officer in the Army's Corps of Engineers.

Mr. Jockers received a Bachelor of Electrical Engineering Degree from The Polytechnic Institute of Brooklyn in 1954. He has previously written an article on the Type 600 Switching System for the Western Union TECHNICAL REVIEW.

PAPERS RECENTLY PRESENTED
by
WESTERN UNION ENGINEERS

AUTODIN—A New Beginning in Communications

presented by G. Stewart Paul, Vice President before National Convention
National Association of Railroad and Utilities Commissioners
Oklahoma City, Oklahoma on Oct. 10, 1963

"EDAC Solution to the Problem of Error Control in Telecommunications"

presented by Robert Steeneck at the AFCEA meeting of the Scott St. Louis Chapter in Belleville, Illinois on Nov. 1, 1963

"The Application of Computers to Automatic Electronic Communications Systems"

presented by J. Z. Millar, Asst. V. P. before Institute of Electrical and Electronic Engineers
Boston Chapter, PGCS
Bedford, Mass. on Dec. 11, 1963

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WESTERN UNION EXHIBIT
AT
1963 AEROSPACE PANORAMA

Western Union's latest development, The Optical Character Reader (shown to the left of middle in the above picture), was exhibited at the Air Force Association's 1963 Aerospace Panorama in Washington, D.C. The Character Reader worked through a Model 28 Transmitter into a Model 28 KSR set at 100 words per minute. The Electro-Quote Display Board, mounted at the top of the Western Union backdrop was operated from a DATA Card Transmitter through a Computer in New York City. Readout from the Computer appeared on the Electro-Quote Display Board and on printed copy on the Model 28 Send. & Rec. Teleprinter at 100 words per minute.

An article on The Optical Character Reader will appear in the April 1964 issue of the Western Union TECHNICAL REVIEW.

H. A. Jansson, Senior Engineer — AUTODIN Project Group, P. & E. Department

AUTODIN

System Description—Part I

Network and Subscriber Terminals

In 1958, Western Union was selected to develop and lease to the United States Air Force an advanced electronic switching system, intended for rapid and accurate communication of data and narrative messages among a variety of users. It was called COMLOGNET, *Com*bat *Lo*gistics *Net*work, to indicate that its primary function was for communication of logistics data. However, as the system developed and was further defined, its function was broadened to include all *A*ir *F*orce *Data Com*munication requirements and thus renamed AF DATACOM. In February 1962, when the system was made operational, it became the first increment of the *Auto*matic *Di*gital *N*etwork, controlled by the Defense Communication Agency and operated by the Air Force Communications Service (AFCS) for the purpose of data communication among the armed forces. The system was renamed AUTODIN.

System Requirements

While the AUTODIN Program has been expanded to overseas operation, the first step in the overall planning concentrated on continental United States, where manual data relay centers were replaced by an automatically operated network. Five automatic electronic switching centers were established as the basic network. They are located at Norton AFB in San Bernadino, Calif., McClellan AFB Sacramento, Calif., Gentile DSC at Dayton, Ohio, Andrews AFB near Washington, D. C. and Tinker AFB, Oklahoma City, Oklahoma.

The system requirements encompassed both a message switching and a circuit switching facility. The general characteristics of the switching centers, planned for the early and mid 1960's, presupposed the use of solid state computer techniques. Techniques previously applied in the design of electromechanical message and circuit switching systems had to be extended and modified. New equipment and procedures had to be developed not only for the centers, but for the terminal (out station) and modem areas as well. A set of transmission control procedures and a family of data terminals were designed to meet the data source, speed and accuracy requirements; message formats and rules for conversion from one format to another were established for the message switching centers; and high speed modems were developed to operate with voice facilities to mention only a few of the many tasks associated with the AUTODIN development.

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

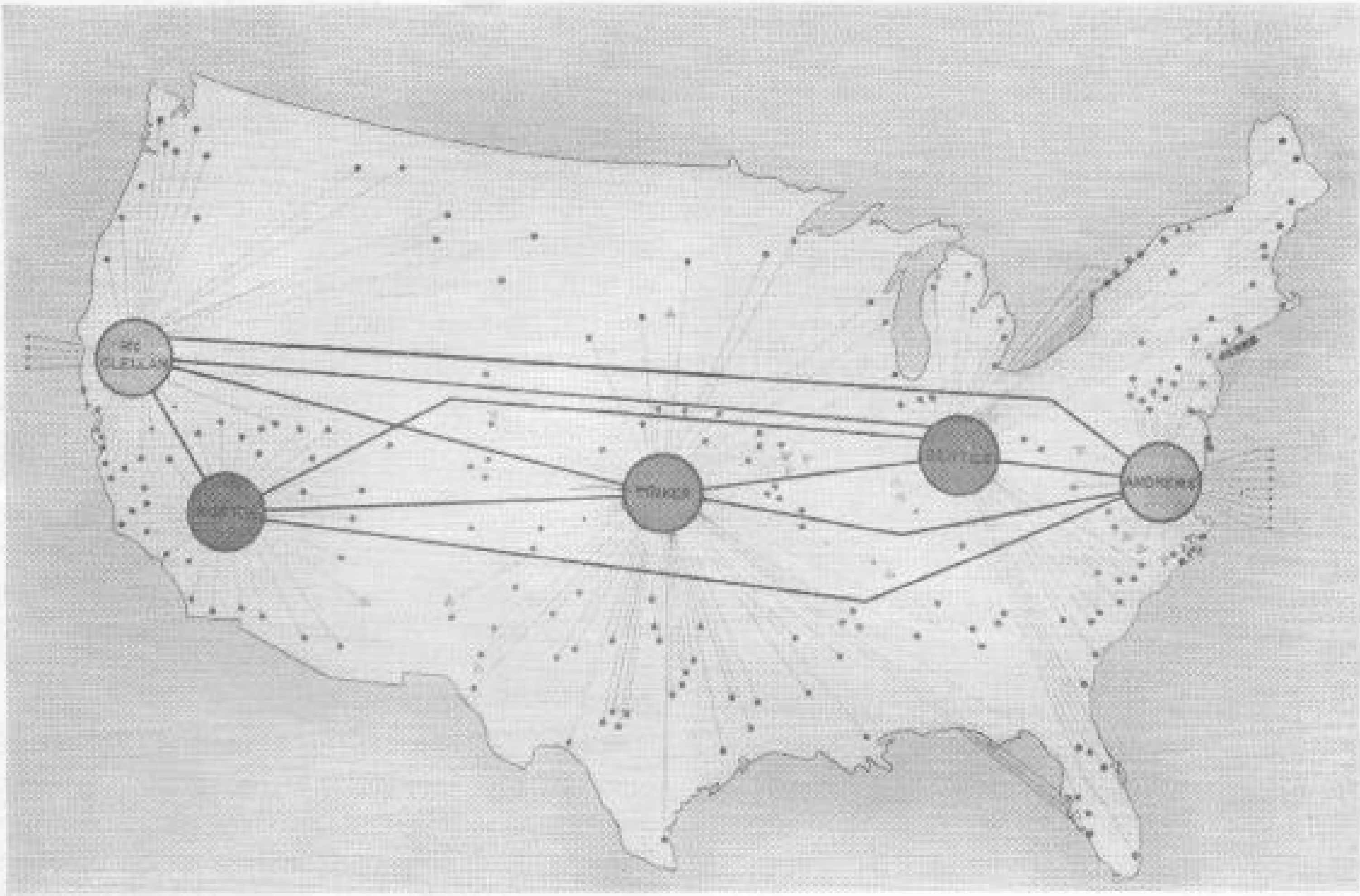


Figure 1. AUTODIN Network in Continental United States

Some of the major functional requirements initially imposed on the system by the Air Force were:

- Messages initially accepted by the system must be on IBM cards, magnetic tape, and teleprinter tape. (Other forms of input would be accommodated as required.)
- Codes must include an AF card code, an AF teleprinter code, and a variety of magnetic tape codes characteristic of the computer generating the tape (RCA, IBM, Univac, NCR, etc.)
- Transmission rates must be adapted to the data source and transmission facility and should initially adhere to one of the following standards: 75-, 150-, 300-, 600-, 1200-, 2400-, and 4800 bauds and established teleprinter signal modulation rates
- Exchange of messages must be permitted among all terminal devices in the network
- Special security protection features must be included to insure against system compromise of message security
- Compatibility with government-furnished link-encryption equipment must be assured
- Routing facilities must include unlimited multi-address capability, group code addressing, and routing by precedence, security and message type
- Automatic error detection and correction features must be provided for data terminals
- Messages must be processed and released independently in the order of their priority and time of arrival at the center
- Flash and emergency messages must preempt lower priority transmissions, if other circuits are not available
- Statistics of various types must be accumulated by the message switching center

Design Approach

A computer-based message switching center was developed to meet the above diverse requirements. A stored-program-controlled message processor was selected for the basic switching functions to provide the flexibility required to meet the new requirements. Modular design of the center equipment into functionally independent units or subsystems permitted test and maintenance routines to be performed on each unit and also enhanced the flexibility of the equipment. In 1959, RCA was selected as the major subcontractor for the message switching center equipment and its set of operational programs.

A solid state 4-wire circuit switching center, designed according to Western Union specifications, having its own common control facility and using dry reed relays for the switching network was also procured from RCA, in 1960. A unique supervisory signal and control procedure was established for this center which permits the terminals to automatically call the desired destination using the "header" or address portion of the message.

Solid state terminal control equipments were designed according to Western Union specifications and procured from IBM and RCA for the high-speed card-teleprinter, and magnetic tape terminals. Special control procedures, designated as Mode I, were specified to attain the high accuracy and speed required by the customer.

Western Union designed and built the modem equipment and Technical Control Facilities in the switching centers, and as prime contractor had a major role in determining the system design of the center and terminal equipment. Close liaison with the customer and the subcontractors was maintained throughout the project.

Network Configuration

The Western Union leased AUTODIN centers are located at five points in the continental United States as shown in Figure 1. Each center has a co-located Message Switching Unit (MSU) and Circuit Switching Unit (CSU). Four of the centers, located at Norton AFB, McClellan AFB, Gentile DSC and Andrews AFB, contain a 50-line MSU and a 50-line CSU. Tinker AFB has a 100-line

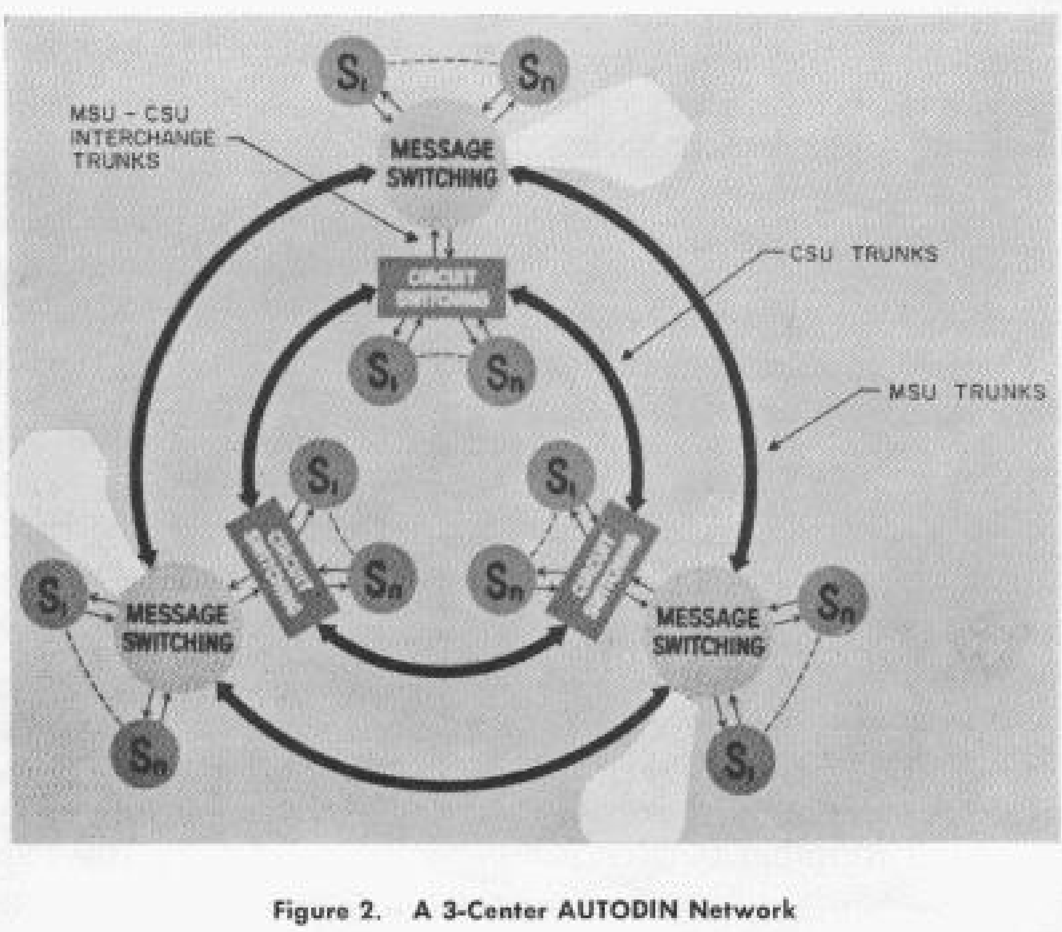


Figure 2. A 3-Center AUTODIN Network

MSU and a 50-line CSU. The message and circuit switching units operate independently and thus can be remotely located from one another. However, a reduction in the number of operating and maintenance personnel and a decrease in building costs were realized by co-locating these units.

Separate trunk circuits are provided for the MSU and CSU. Figure 2 illustrates a hypothetical three-center AUTODIN network. CSU trunks are used only by the CSU terminals for direct CSU-CSU connections; MSU trunks are allocated full time for MSU use. MSU-CSU interchange trunks, as shown in Figure 2, interconnect the MSU and CSU at each Automatic Electronic Switching Center (AESC) and thus provide means for interchanging traffic between the local circuit switching terminals and the message switching network.

MSU trunks are operated at 2400 bauds, the maximum standard rate now attainable on a voice circuit. CSU trunks are operated at the data rate of the connected terminals. For economic reasons the CSU trunks are grouped into unique speed groups. At present, 150- and 2400 baud CSU trunks are used to match the speed of the terminals now connected to the CSU. Two additional trunk speeds may be assigned to meet the speed requirements of future CSU terminals. The CSU trunk selection process determines which one of four speeds is to be assigned for each call.

Alternate routing facilities are provided on both the MSU and CSU trunks. For the CSU trunks, there may be up to two alternate routes associated with each primary route. Calls, which cannot be served because all channels in the primary route are busy, are automatically routed to the first or second alternate route depending upon circuit availability. Flash and emergency calls proceed on the same basis, but will automatically preempt lower priority connections, when all trunk routes are busy.

Messages for the MSU trunks normally remain in queue and await their turn to be transmitted over the primary route. However, should delays due to traffic backlog become excessive for a given MSU, an alternate trunk route can be designated for the MSU for each of the six message precedence levels. Messages so designated will automatically proceed via the new route until they are again changed by the MSU operator.

Direct terminal-to-terminal communication is provided for the CSU subscribers, thus permitting a means for fast, mass exchange of data at a minimum cost. However, transmission is limited to single-address traffic and between two subscribers having the same speed, code, and format characteristics. If multi-address traffic, group code addressing, or other special routing features are required, the MSU is called in, via the CSU-MSU interchange trunks, to receive and process the messages. Likewise, other CSU messages may be sent to the MSU because the terminal possesses a different transmission speed, code, or format or because the destination terminal is busy with another transmission.

The MSU provides a full-time, full-duplex connection to all its connected terminals. Multipoint or waywire operation is not provided because of cryptographic considerations. Any of the standard speeds, codes and formats are handled, although a given terminal may operate in only one speed and code. The MSU will process all messages accepted by the system, convert the input code and format to the code and format required by the output terminal, and independently process and release each copy of the message as the output lines become available.

Link encryption is planned for use on all trunk and terminal channels. Bit synchronous clock signals for the crypto devices and means for resynchronizing the send and receive cryptographic equipment are provided at each end of the channels.[1,2]

Subscriber Terminals

Four types of subscriber terminals are utilized in AUTODIN: Compound Terminals, Magnetic Tape Terminals, High Speed Teletype Terminals and Teleprinter Terminals. The first three are data terminals requiring high transmission accuracy and utilizing elaborate closed-loop control procedures (Mode I) to assure that all transmitted data are received correctly by the receiving terminal. The Teleprinter Terminal is a standard 5-channel paper type, full duplex terminal operating with no return control procedures (Mode II) and using channel sequence number checks as the primary means for maintaining message continuity.

- **Compound Terminal**

The Compound Terminal (CT), designed by IBM and illustrated in Figure 3, transmits and receives teletype messages via a modified ASR Set and card messages via two type 536 card punches (sending and receiving). Transmission is synchronous and in 8-bit common-language Fieldata code of which 7-levels are used for information and the 8th level for odd parity check. The line rate is 150 bits per second requiring twice the bandwidth of a standard teletype channel.

Data are transmitted in 80-character groups, preceded and followed by two unique block control characters called framing characters, thus making the unit of transmission (line block) 84 characters. The first three framing characters refer to the type of block (first block of message, intermediate block of message, or last block of message) and type of message being transmitted (card message or teletype message). The last framing character, used solely to verify the accuracy of the transmitted block, is called the Block Parity character. It is so configured that even longitudinal parity is maintained for all 8 bits of the characters in the line block. The first framing character is excluded from the longitudinal check.

Each data block must be correctly acknowledged before the next block is transmitted. If an error is indicated by the reply (ER code), the block is retransmitted. If no answer is received, a REP code is generated by the transmitter to recall the last reply sent by the receiver. Alternate acknowledgement codes ACK-1 and ACK-2, are used to uniquely identify to which of the two consecutively transmitted line blocks the acknowledgement pertains. If the wrong ACK is received in response to REP, the block is repeated; if the correct ACK is received the next block is transmitted.

Other unique control codes to halt transmission (WBT) or reject a message (RM) may be generated by the receiver in reply to a line block or REP. Transmission of a discard message signal (DM)

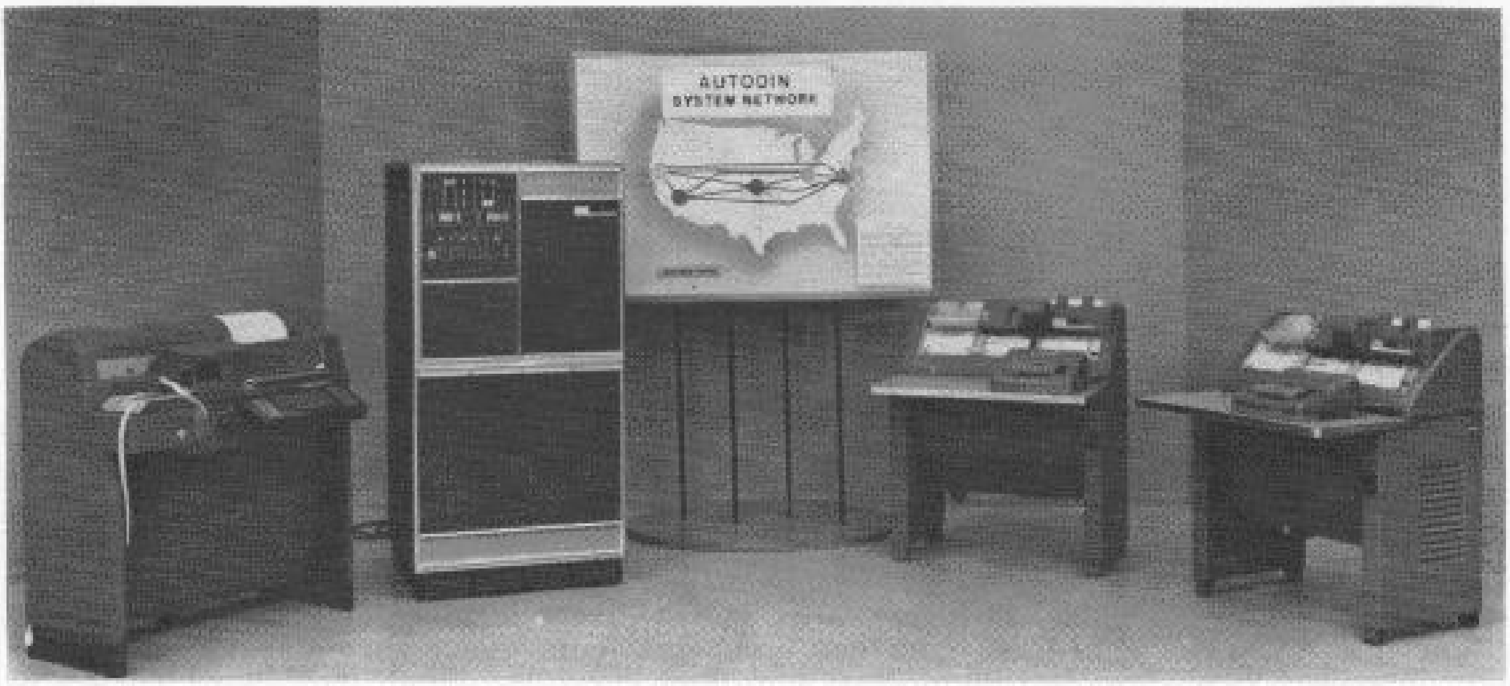


Figure 3. The Compound Terminal

by the transmitting station instructs the receiver to ignore the incomplete message and sets up both terminals to process a new message.

Note that the line block format is chosen to coincide with the 80-character IBM card. Teletype messages are blocked similarly into line blocks by the control section of CT. In the special case of the end-of-message block, where the last character of the message may appear anywhere in the block, the block is filled with a special throw away character called Ignore (i).

minal for Teletype to/from Fieldata, and Hollerith to/from Fieldata conversions.

The CT operates either as a message switch or circuit switch terminal. For circuit switching use, the terminal is equipped with additional facilities required for supervisory signaling with the CSU.

Magnetic Tape Terminal

The Magnetic Tape Terminal (MTT), designed by RCA and illustrated in Figure 4, serves as the input-output communication device for computer installa-

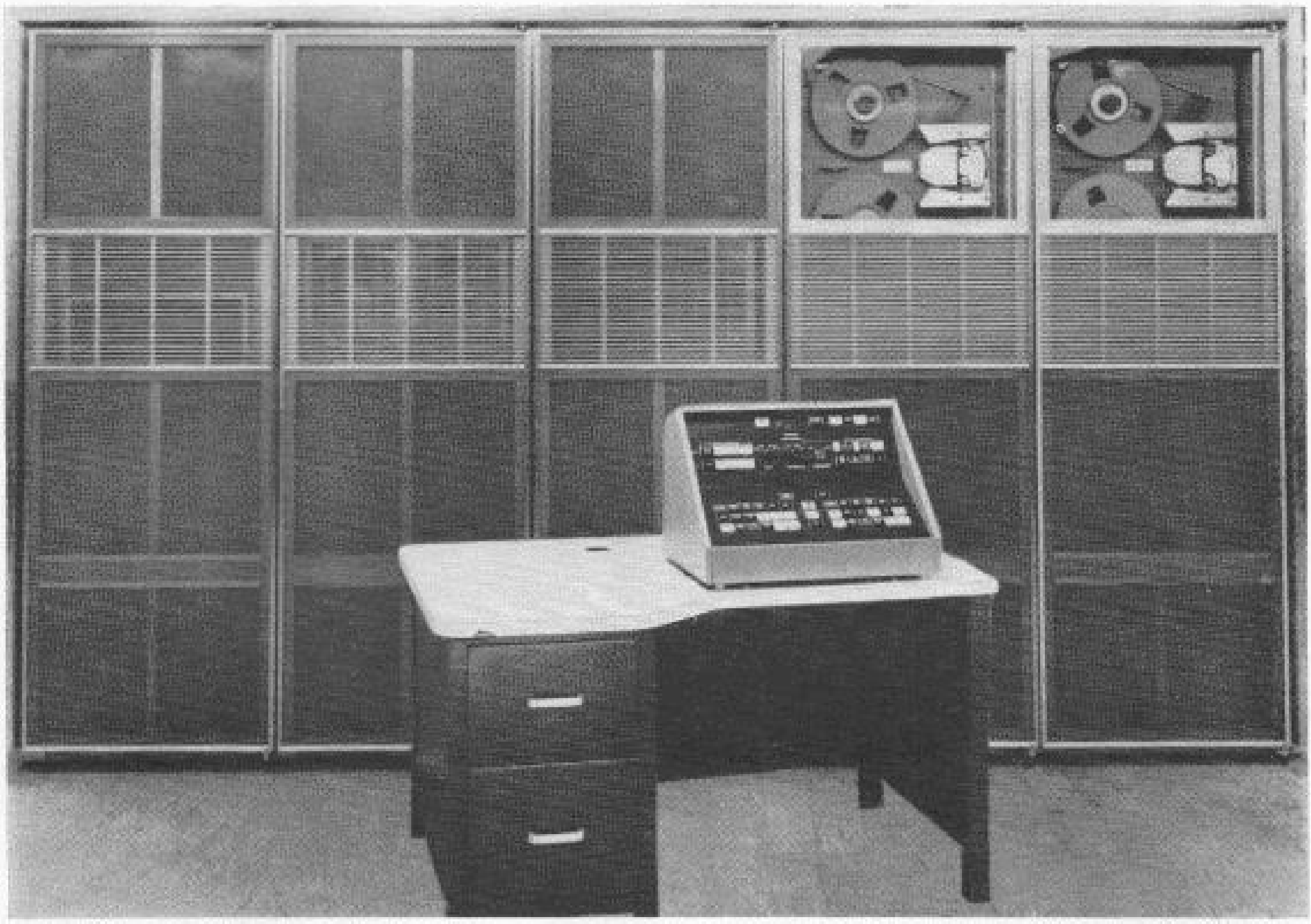


Figure 4. The Magnetic Tape Terminal

Core storage of two 84-character blocks is provided for both the transmit and receive side of the terminal to permit blocks to be retransmitted automatically when errored and to overlap line transmission with device input/output.

Code conversion is included in the ter-

tion. It reads and writes tapes which are compatible with the computer being served. Code and format conversion is performed by the MTT to permit it to communicate with other MTT's serving other computer types.

Transmission is full duplex at 2400

bauds. Special Mode I procedures (continuous mode) are used to reduce the effects of reply times. Rather than wait for an answer to a transmitted block, the terminal proceeds to transmit the next block while waiting for an ACK to the previous block. Assuming that the acknowledgement arrives before the succeeding block is completed the process continues into the next line block. If an ACK is not received before the next block is ready for termination (sending the last two framing characters), the terminal sends a special character, called Idle Line, repeatedly until ACK or ER is received to the line block. If an answer is not received within a certain specified time, REP is sent to recall the last answer. Once an answer is received, transmission may resume. If the correct ACK is received, the line block is terminated by sending the last two framing characters and then followed by the next block. If the incorrect ACK or ER is received, the previous line block is retransmitted. Since at most one complete block is allowed to be unacknowledged, the answer can only apply to it when it arrives.

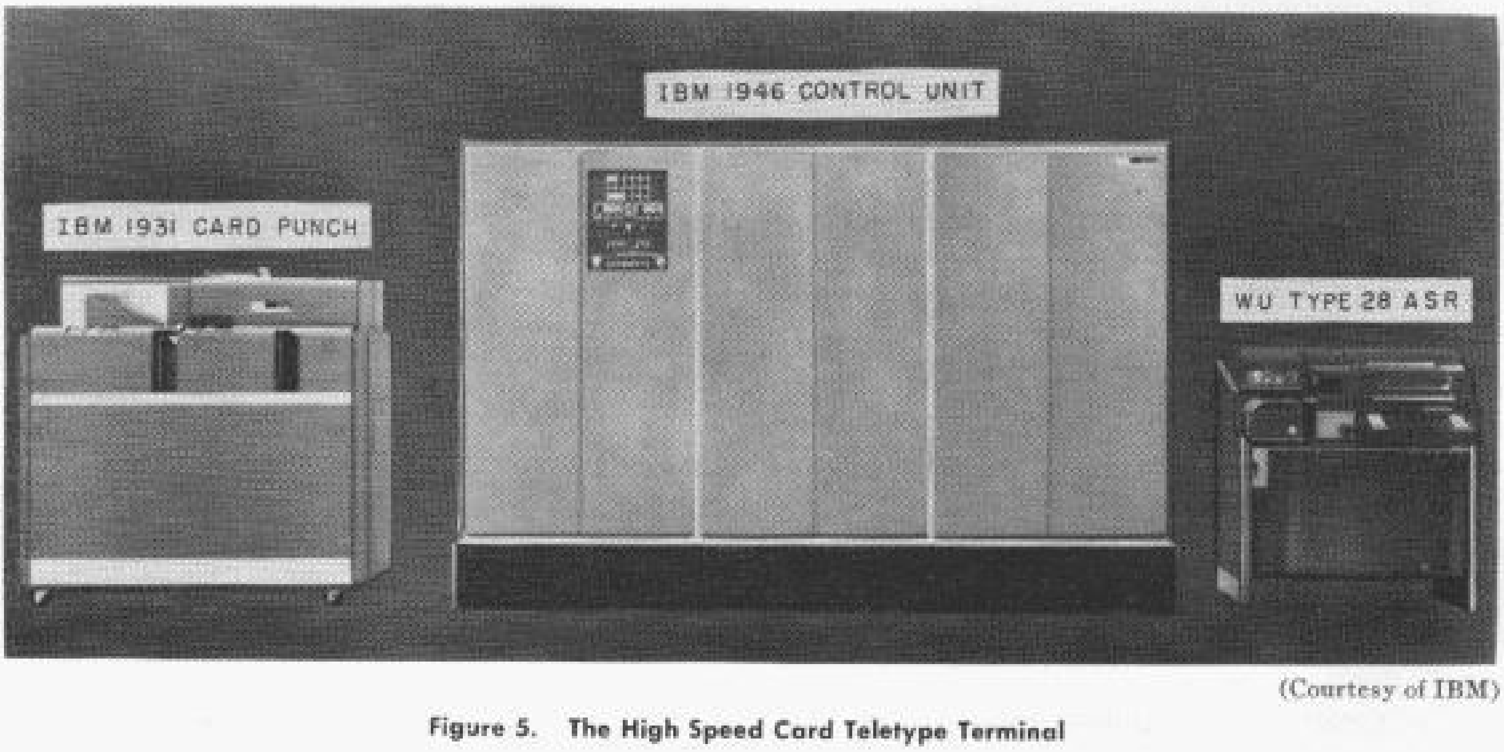
The MTT provides up to two tape blocks (1200 characters each) of storage for the send and receive sides of the terminal to overlap line transmission with input/output. Line blocks in error are automatically retransmitted from storage.

The terminal functions either as a message switching or circuit switching terminal. Sufficient hardware has been included with all MTT's to permit them to operate either with the MSU or the CSU.

The tape stations (one for sending data and another for receiving data) are designed to operate with any of the computer tapes presently programmed for the system. Conversion kits are available for permitting the tape units to operate with any of the presently identified computer types.

High Speed Card Teletype Terminal

The High Speed Card Teletype Terminal HSCTT, designed by IBM and illustrated in Figure 5, functions in a manner identical to the CT except that the line rate is 1200 bauds and additional buffering is provided to operate with the card reader punch. The modem for this terminal requires the bandwidth of a voice circuit. The card input/output device operates at 100 cards per minute (cpm) as compared to the 12 cpm rate of the CT.



(Courtesy of IBM)

Figure 5. The High Speed Card Teletype Terminal

Teleprinter Terminal

The Teleprinter Terminal transmits and receives messages in the 5-channel Baudot code. Transmission is by standard telegraph means. Characters are sent asynchronously in bit serial form. Start and stop bits indicate the start and end of each character.

The terminals may operate either as one-way (simplex) or full-duplex MSU terminals. No provisions are included for error detection and correction. The messages processed by this terminal appear in the same format as that now used in all the military teleprinter networks.

At present, AUTODIN interfaces with existing military teleprinter networks by this means. As this is the standard mode of operation in these networks no modifications need be made at the teleprinter centers to interconnect AUTODIN with these systems.

References:

1. AUTODIN—Technical Control Facility—F. B. Falknor, Western Union TECHNICAL REVIEW, October 1963.
2. Digital Phase Corrector for Synchronous Transmission—E. J. Chojnowski, Western Union TECHNICAL REVIEW, OCtober 1962.

Part II of this article, entitled "Circuit Switching and Message Switching Centers in the AUTODIN Network", will appear in the April 1964 issue of the Western Union TECHNICAL REVIEW.

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.

G. S. A. System

Improved Communications

for the Government

Western Union has received an order from the General Services Administration for the Advanced Record System a part of the Federal Communications system which will serve the civilian agencies of the Federal Government. This new system, scheduled for operation early in 1965, parallels the AUTODIN *(Automatic Digital Network) which provides communication between the military agencies of the Federal Government.*

*The Advanced Record System provides over 1600 outstations coast-to-coast, and represents the second largest W. U. Private Wire System. (*AUTODIN *is the largest.) The system uses computers for automatic routing of messages and is designed to handle printing telegraph, and highspeed data communications. It features both circuit and message switching, and direct-dial, station-to-station connections.*

Computers and associated equipment at the junctions will be provided by UNIVAC Division of Sperry Rand Corporation; while the circuit switching equipment will be furnished by International Telephone and Telegraph Corporation.

The main junction centers in the system will be located along the route of Western Union's new transcontinental microwave radio beam network, which is routed to avoid any known target areas. Buildings to be constructed at these points will be fallout-protected, providing for extended stay by personnel in an emergency.

In commenting on the Western Union contract, GSA's Administrator Bernard L. Boutin said: "This is a dynamic step in GSA's progress in providing improved communications for the government in the most economical manner." He said further that the system will provide full communications for continuity of government in times of emergency.

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Digital System Design
Drafting Symbols
Standardization Program

Kempf, V. C.: Standard Symbols for Digital Logic Design

Western Union TECHNICAL REVIEW, Vol. 18, No. 1 (Jan. 1964)
pp 4 to pp 16

Western Union has adopted the standard symbols developed by the American Standards Association for use in drawings of standard logic circuits for low frequency digital equipment. The article points out the advantage of standardization of symbols and describes the most important Basic Logic symbols and Detailed Logic symbols.

Telegraph Equipment
Light-Duty Teleprinters
ASR Sets

Smith, Fred W.: A New Line of Light Duty Teleprinters and ASR Sets

Western Union TECHNICAL REVIEW, Vol. 18, No. 1 (Jan. 1964)
pp 18 to pp 31

This article describes the low-cost Model 32 Teleprinter and automatic send-receive set. Available optional features of the unit are suggested.

Laboratory tests and field experience indicate that the Model 32 Teleprinter will prove to be very satisfactory in the light-duty type of service for which it was designed.

It is expected to have wide application in intra-plant message distribution for industry and on-base message distribution for the military services.

Telex
Traffic Evaluation Technique
Circuit Switching

Jockers, K. M.: Traffic Evaluation for Western Union Telex Network
Part II—Switch Stages

Western Union TECHNICAL REVIEW, Vol. 18, No. 1 (Jan. 1964)
pp 32 to pp 36

This is the second part of the article on Traffic Evaluation techniques which describes the Switch Stages used within an exchange to link various combinations of subscribers. Switch stages are more subject to uniform grouping and in general are much less costly than trunks.

Traffic evaluation and its proper implementation is essential to meet the growth of the Western Union Telex Network.

Subscriber Terminals
Switching Systems
AUTODIN
Digital Networks

Jansson, H. A.: AUTODIN—System Description

Part I—Network and Subscribers Terminals

Western Union TECHNICAL REVIEW, Vol. 18, No. 1 (Jan. 1964)
pp 38 to pp 45

This is the second in a series of articles on AUTODIN (Automatic Digital Network). It describes the subscriber terminals and the AUTODIN network design. The major functional requirements proposed by the Air Force are tabulated.

Featured in the April 1964 issue:

The Optical Character Reader

Standard Codes for Telegraph Transmission

Route Selection for Microwave Systems

AUTODIN—System Description

Part II—Circuit Switching and Message Switching Centers in the AUTODIN Network