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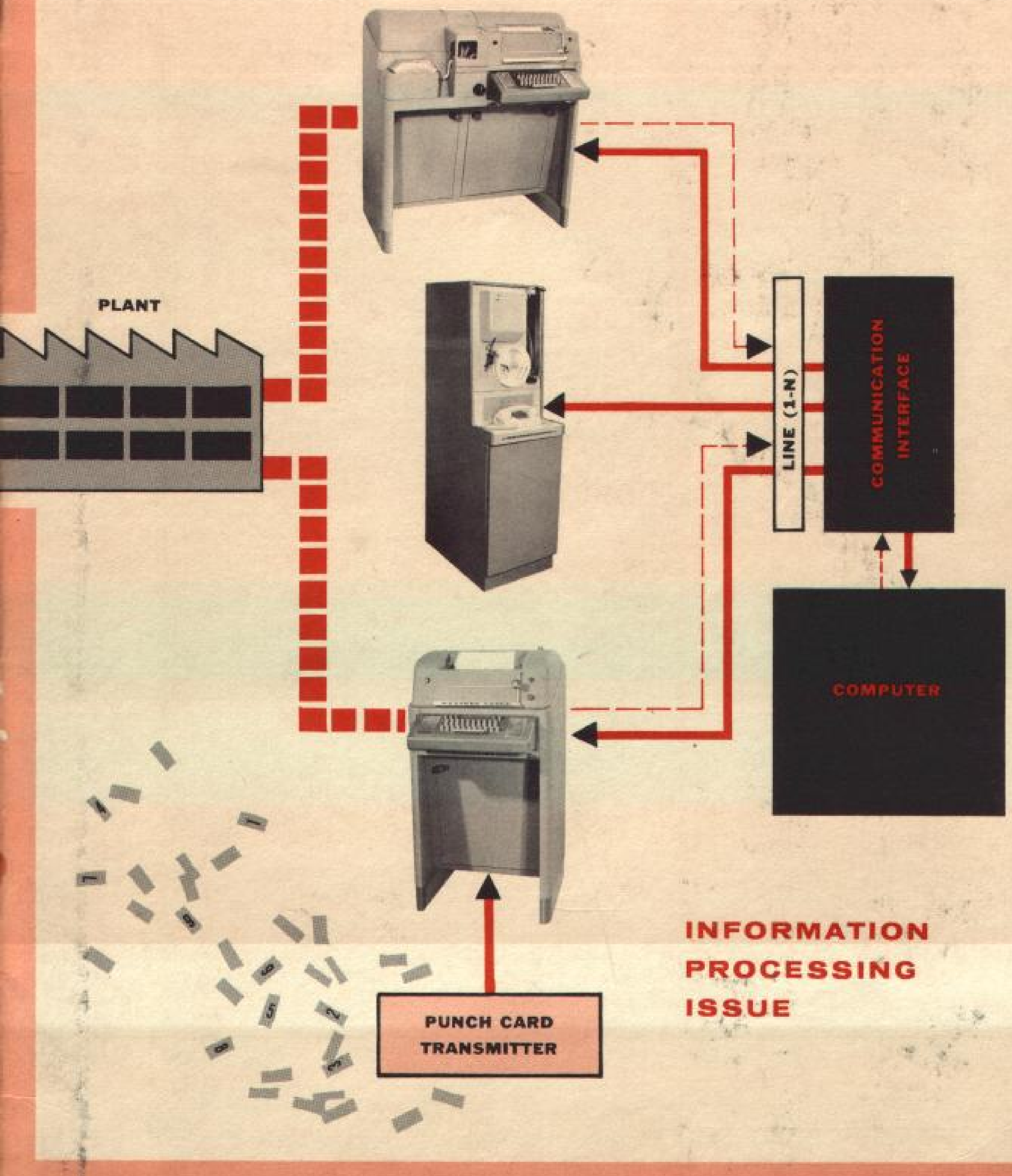

INFORMATION PROCESSING ISSUE

THE WESTERN UNION TECHNICAL REVIEW

Cover: Processing of Information
from Office Plant through

low-speed and high-speed teleprinters
and punched card transmitter

via Communications Interface
to a Computer

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

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WESTERN UNION

Technical Review

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N. L. Feld, Engineer—Telegraph Equip. Div.—Plant and Engineerng Dept.

New Punched Card Transmitter for Data Communications Systems

Part I— General Description and Applications

Western Union has added to its capacity for servicing the growing data communications field with the development of an economical and reliable punched card transmitter for use in low-to-medium volume card transmission applications. This article describes the principles of Punched Card Transmitter 11890-A and some typical applications of the unit in data communications systems.

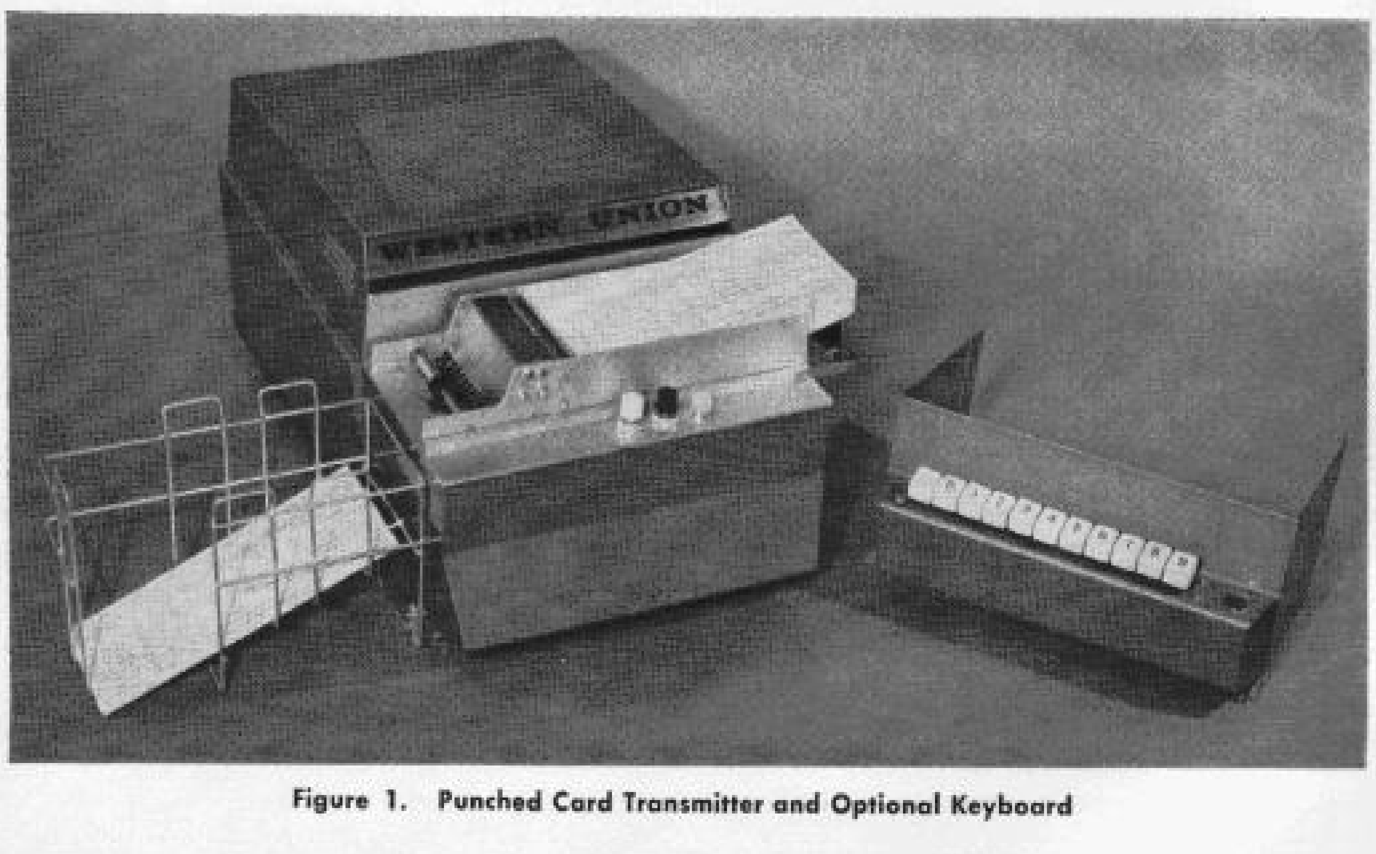


Figure 1. Punched Card Transmitter and Optional Keyboard

Punched Card Transmission

A basic characteristic of many data handling systems is their procedure of collecting data intermittently and in small quantities at many sources, and then transmitting this data to a central processing point. The data collection sources, or system terminal stations, usually require facilities that permit automatic transmission of the collected information. To permit automatic transmission, information is recorded on paper tape, magnetic tape or on cards. One or more of these media may be used in a system depending on which form will result in the most efficient handling of information.

Representing information in card form is advantageous because of the ease in sorting, storing, and random selection of individual cards from a stack. For example, discrete items, characterized by a short block of information, are generally represented on cards. Procedures such as rearranging adding, deleting, or updating data referring to such items may then be performed by rearranging the cards.

Of the many different types of card records, the one used extensively in data processing systems is the punched card. The reason is that a coded array of holes may be both recorded readily by card punching machines, and recognized readily by automatic card readers.

In systems which require communication between terminal stations and a processing center, and which record information in punched card form, the processing centers require equipment for automatically punching data on new cards from incoming line signals as well as for transmitting punched card information to the line. The terminal stations, in many cases, require only the capacity to transmit information from punched cards to the communication lines.

Design Objectives

Punched Card Transmitter 11890-A, shown in Figure 1, was designed, primarily, to meet the needs of terminal stations which have requirements for transmitting punched card information via an unattended machine, at any standard telegraph speed up to 100 words per minute. The unit will transmit data over telegraph facilities. Figure 2 illustrates the flow of information in a data collection network using the transmitter.

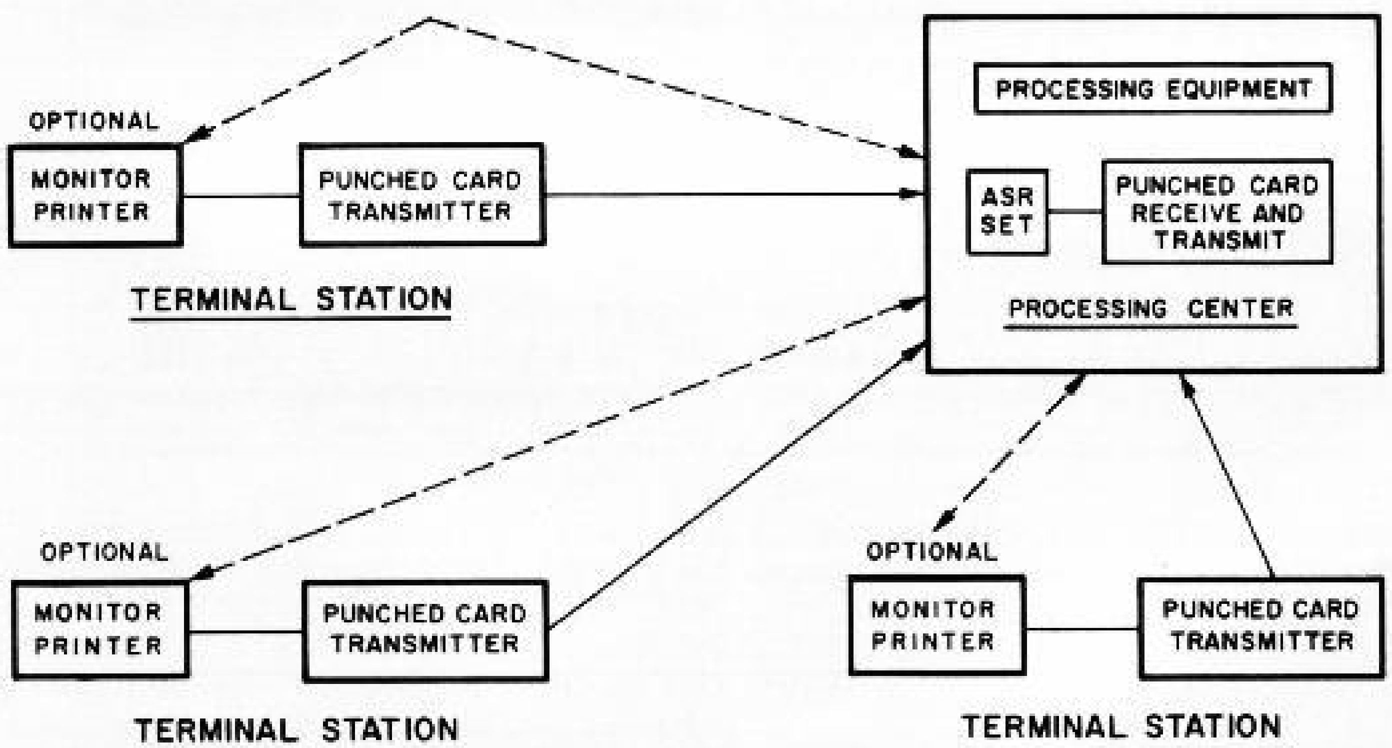


Figure 2. Information Flow in a Data Collection Network

Modes of Operation

Besides the basic mode of operation as an unattended reader of previously punched cards, the unit permits manual or automatic insertion of variable information. This is achieved by having an "auto-stop" character punched in a card which contains other pre-punched information. When the "auto-stop" character is sensed, the transmitter will stop feeding the card. Variable data may then be inserted from a keyboard, or from an auxiliary tape transmitter which has been automatically selected by an assigned character sequence preceding the "auto-stop" character. After the inserted keyboard data, or the auxiliary tape message is transmitted, the punched card transmitter may be reset manually or automatically. A reset button can be manually depressed, or "stunt-box" contacts of a monitor teleprinter may be actuated in response to signals from the auxiliary tape, and automatic feeding of the remaining cards is resumed.

The keyboard mode of insertion requires constant operator attention, whereas data insertion from the tape transmitter permits unattended machine operation. A mode of manual data insertion, which permits unattended operation, is the "port-a-punch" method.

Port-a-Punch Cards

Port-a-Punch cards are semi-perforated cards which are commercially available at low cost. Fixed information may be prepunched in these cards by machine. Using a hand-held card holder and stylus set, additional holes may be manually perforated in the cards, at the data collection source, in a manner somewhat similar to marking a mark-sense card with a pencil.[1] The combined port-a-punch and prepunched information may be transmitted from the punched card transmitter.

Auxiliary Equipment

The punched card transmitter was designed to operate as an independent device at a transmitting station. It may also be used with supplementary equipment to form a terminal outstation set, that permits transmission of data from a key-

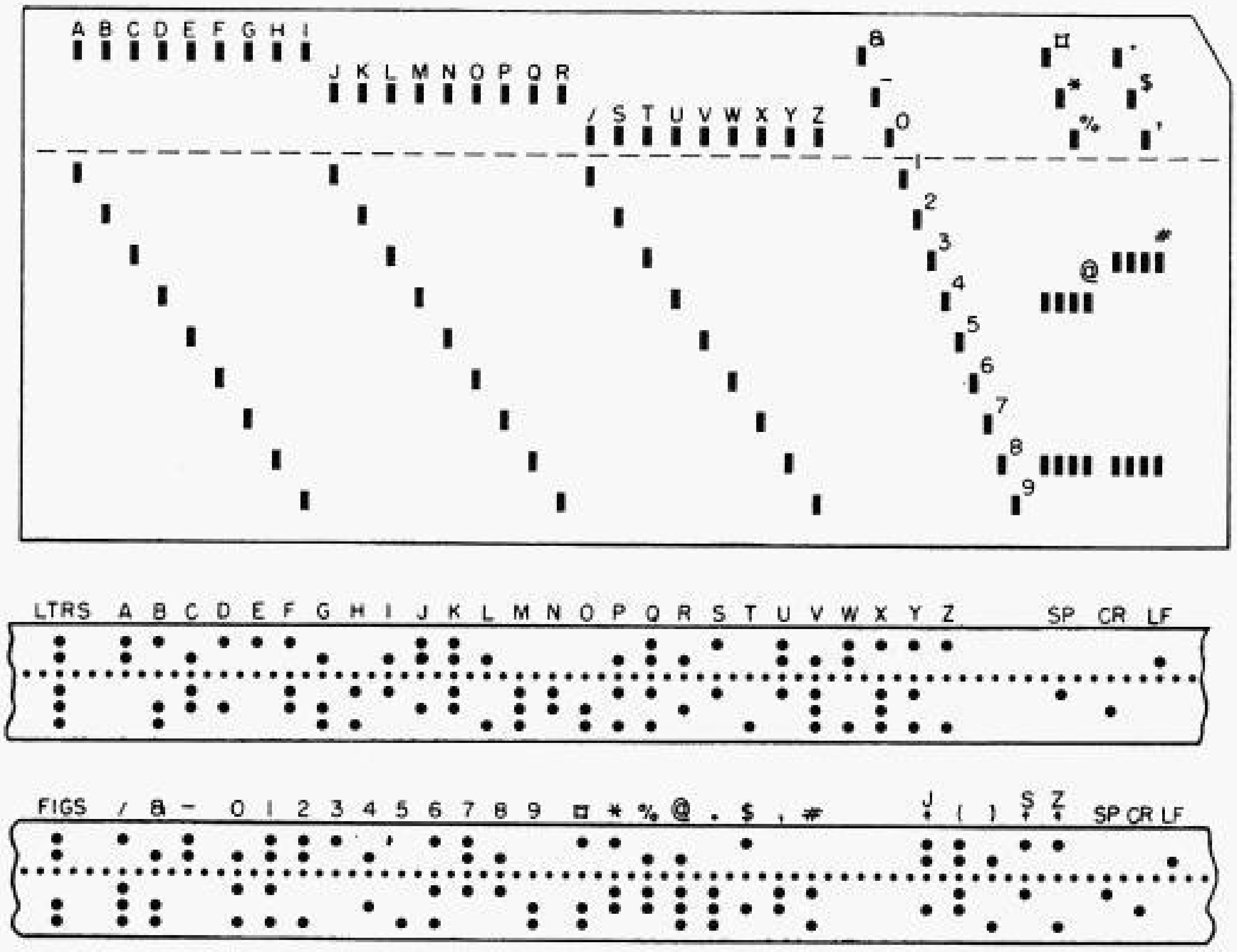


Figure 3. A 12-Level Card Code and A 5-Level Telegraph Code

board, from tape, or from cards and reception of data in the form of hard copy, tape, or punched cards. The output of the transmitter may be recorded at the receiving station on tape, as hard copy, or on punched-cards.

Special Features

The present operating prototype model of the Punched Card Transmitter 11890-A can:

(1) automatically feed punched cards from a stack of over 150 cards,

(2) sense recorded numeric information,

(3) translate this numeric information to 5-level Baudot code, and

(4) transmit this information serially, as make-break signals over a telegraph line, at speeds up to 100 words per minute.

Future versions of the transmitter are being designed to sense both alpha and numeric information and transmit the data in any 5-, 6-, 7-, or 8-level code.

It should be noted that the 5-level code may be rearranged to provide transmission error checking capability for numeric data, similar to that offered by the 7- and 8-level codes.[2]

The present model, shown in Figure 1, has been designed to sense and transmit the numeric portion of the input and output codes illustrated in Figure 3. In the card code, the digits 0 through 9 are represented as one hole per column, in levels 0 through 9 respectively. The hyphen (-) and ampersand (&) are represented by one hole per column, in levels 11 and 12 respectively. When any hole in levels 0 through 9 is sensed by the reading head of the transmitter, the electronic circuitry causes make-and-break pulses to be generated in accordance with the equivalent 5-level code of the sensed character. The 11 and 12 levels of the card are used for control functions in the present model. If the ampersand (&) hole is sensed, a 5-level code for "space" will be generated. Sensing of the hyphen (-) hole will cause the card to be automatically stopped, but no character will be transmitted. This is the "auto-stop" character. Transmission may be resumed by closing a "reset" switch manually or by means of the stunt box contacts of a monitor teleprinter.

Modular Design

The Punched Card Transmitter is of modular design and consists of three basic modules: a mechanical section, an electronic section, and a keyboard.

The mechanical section contains a motor-driven feed mechanism, the hole-sensing or read head, and a motor brake. It also contains the following controls: a "start" switch, which when initially depressed turns the power "on" and causes transmission of the carriage return, line feed and figures codes; a "card-out" switch which automatically shuts the machine "off" when the last card leaves the transmitter; a two-card switch may be provided to actuate an alarm if two cards pass through the card gauge simultaneously; and a line indicator light which indicates that data is being transmitted.

The electronic section, composed of Western Union standard circuit cards, contains its own power supply for converting 120v AC to 12v DC. When a hole in the card is sensed, an impulse from the stylus actuates a number of "nor gates" to electronically store the 5-level Baudot code equivalent of the sensed character. Simultaneously, an oscillator circuit is triggered and serial generation of the 5 level code is started. The transmission line is connected across the mercury-wetted contacts of a polar relay. When the relay is pulsed on and off by the electronic switching circuitry, make-break pulses, corresponding to the sensed character, are transmitted.

The keyboard is shown in Figure 1. When the "auto-stop" character is sensed in a card, a brake in the mechanical section is energized and the card stops. Characters 0 through 9 and "space" may be manually keyed in. Automatic transmission of punched data may be resumed by depressing the reset button.

Typical Applications

The punched card transmitter can serve as an economical tool for converting punched card information to paper tape or hard copy. However, its main application in data transmission systems is to be found at the initial data input stage, or, when the output of some previous stage is in punched card form, and where it is required to exchange data between terminal and processing stations. As previously indicated, the unit may be used at a terminal station with other equipment to prepare a local card or tape for transmission to another station. The type of auxiliary equipment used depends on the nature of the processing system.

The following areas represent the simplest types of application since little or no local card punching is required: A complete terminal station set consists of only a punched card transmitter and, if desirable, a monitor teleprinter:

- Purchasing—When stock of an item is depleted, its identification card may be selected from the file at the warehouse. The information on this card may be transmitted via the punched card transmitter to the processing center to initiate re-purchasing of the item.

- Shipping and Billing—Identification cards attached to packages they represent, are shipped to a warehouse having a punched card transmitter. Upon arrival at the warehouse, the arrival information is transmitted to the shipping and billing departments.

- Insurance Inquiry — An insurance agent at a branch office wishes to know the current status of a particular group of clients. A stack of client cards, selected from his files, is placed in the punched card transmitter. Identification information followed by a selection character sequence is transmitted to a processing center from the first card in the stack, and then the card automatically stops. Status information from the computer storage equipment at the processing center is transmitted back to a monitor printer at the branch office. Then, the monitor printer "stunt-box" automatically resets the punched card transmitter and the second client identification card is transmitted.

The next application illustrates how the recording of data in card form simplifies handling procedures. In this case, a card punch is used at each terminal station in addition to the card transmitter.

- Railroad Car Routing — Punched cards represent each car of a train. At each terminal station along its route, cars may be added or deleted from the train. Corresponding cards may be added to or deleted from the stack of cards representing the train. Advance arrival notice is given between stations by means of a card transmitter at the send terminal and a card punch at the destination terminal.

Other Possible Applications

Punched Card Transmitter 11890-A can be applied to other situations that require transmission of fixed identification information, at varying times or locations of transmission. It can also be used in applications which require the insertion of variable information related to the pre-punched fixed data, and which therefore may require the optional keyboard attachment.

The following areas are but a few applications possible with this unit:

- Trucking—for O S and D's—overages, shortages and damages
- Communications — for automatic multiple addressing of fixed messages
- Manufacturing — for production schedules
- Publishing—for updating of circulation records
- Hospitals—for out-patient billing

In all of these applications, the telegraphic output of the punched card transmitter permits automatic "stunt-box" selection of the final destination and format of the transmitted data.

Western Union's Increased Versatility

Western Union is currently expanding its transmission facilities. The new microwave system, the broadband switching system, Telex and private wire systems form a base for building a variety of networks that can satisfy the specific requirements of each potential patron. In addition to these facilities, however, a broad line of terminal equipment must be provided.

Punched Card Transmitter 11890-A may be offered to a patron as an independent piece of terminal equipment, or it may be designed for use with any of the various models of teleprinters and ASR sets to give 5- or 8-level output, and card, hard copy, or tape transmission. The unit can be used on private wire systems such as Plan 115 or on Telex, and it can be controlled by the automatic cut-in devices of these systems.[3] It can be designed to transmit the newly developed ASCII Transmission Code.[4] In short, it contributes to the increased versatility of the Western Union line of communications equipment.

References

1. Data Card Transmitter, P. F. Recca; Western Union TECHNICAL REVIEW, Vol. 17, No. 1 January 1963.
2. Punched Card Transmission in Telegraph Switching Systems R. Steeneck, Western Union TECHNICAL REVIEW, Vol. 15, No. 2, April 1961.
3. Plan 115 Switching System, H. Jorgensen, Western Union TECHNICAL REVIEW, Vol. 15, No. 4, October 1961.
4. New American Standard Code for Information Interchange, F. W. Smith, Western Union TECHNICAL REVIEW, Vol. 18, No. 2, April 1964.

Acknowledgements

The electronic circuitry for Punched Card Transmitter 11890-A was designed by Mr. R. Duswalt. Many helpful design suggestions concerning this unit were offered by members of the Telegraph Equipment Engineer's Staff.

The author wishes to express his appreciation to Mr. F. W. Smith for his assistance, so generously offered, in the preparation of this article.

MR. N. L. FELD, an Engineer in the Telegraph Equipment Division of the Plant and Engineering Department, has been concerned with the design and development of Punched Card Transmitter 11890-A since its inception.

He joined Western Union in 1961 and was assigned to the Ocean Cables Division where he was involved in the modification of Start-Stop Distributors 47-A. In 1962, he was assigned to the Telegraph Equipment Division where he has been concerned with the design of electro-mechanical mechanisms for use in teleprinter equipment. He participated in the conversion of the Model 19 ASR Set for Telex use.

Mr. Feld received a Bachelor of Mechanical Engineering Degree from the Cooper Union School of Engineering in 1960. He was a Teaching Fellow at the Polytechnic Institute of Brooklyn from 1960 to 1961, and he received a Master of Mechanical Engineering Degree from that institution in 1962.

J. J. Durachinski, Engineer—Data Systems Div.—Plant & Engineering Dept.

EDAC

A Simple Error Control

for a

Duplex Communication Network

Introduction

Error control has been a serious problem in data transmission for many years. Western Union's Data Systems Division has developed EDAC, an Error Detection—Automatic Correction system, that solves this problem simply and economically. EDAC detects errors in a transmitted teleprinter signal and automatically corrects them. These errors usually are due to a noisy transmission medium such as a HF radio circuit, where extreme fading and intense magnetic activity introduce numerous gaps in the transmitted information. Such conditions make meaningful communications almost impossible. To correct the effects of a noisy transmission medium, EDAC retransmits errored information until it is received accurately.

Basically, all systems performing the function of error detection resort to some form of redundancy within their framework. In EDAC, we obtain redundancy from a binary summation of stored information, and use this summation as a check criterion. To accommodate the binary summation process, and the subsequent check comparison, EDAC contains two memory units in both the send and receive terminal equipment from which stored information may be transmitted as often as required. Figure 1 shows an EDAC terminal.

It might be suspected, and rightly so considering the built-in redundancy, that a circuit with EDAC capabilities loses some transmission efficiency in a noisy or erratic medium. The amount of loss depends on circuit conditions. Good conditions allow information to be transmitted at teleprinter speeds. In fact, in a circuit free from errors, or where the error rate is comparatively low, such as land lines, one would not recognize the presence of EDAC in the circuit. System techniques inherent to EDAC permit the transfer of information as fast as circuit conditions allow.

Figure 1. EDAC Terminal

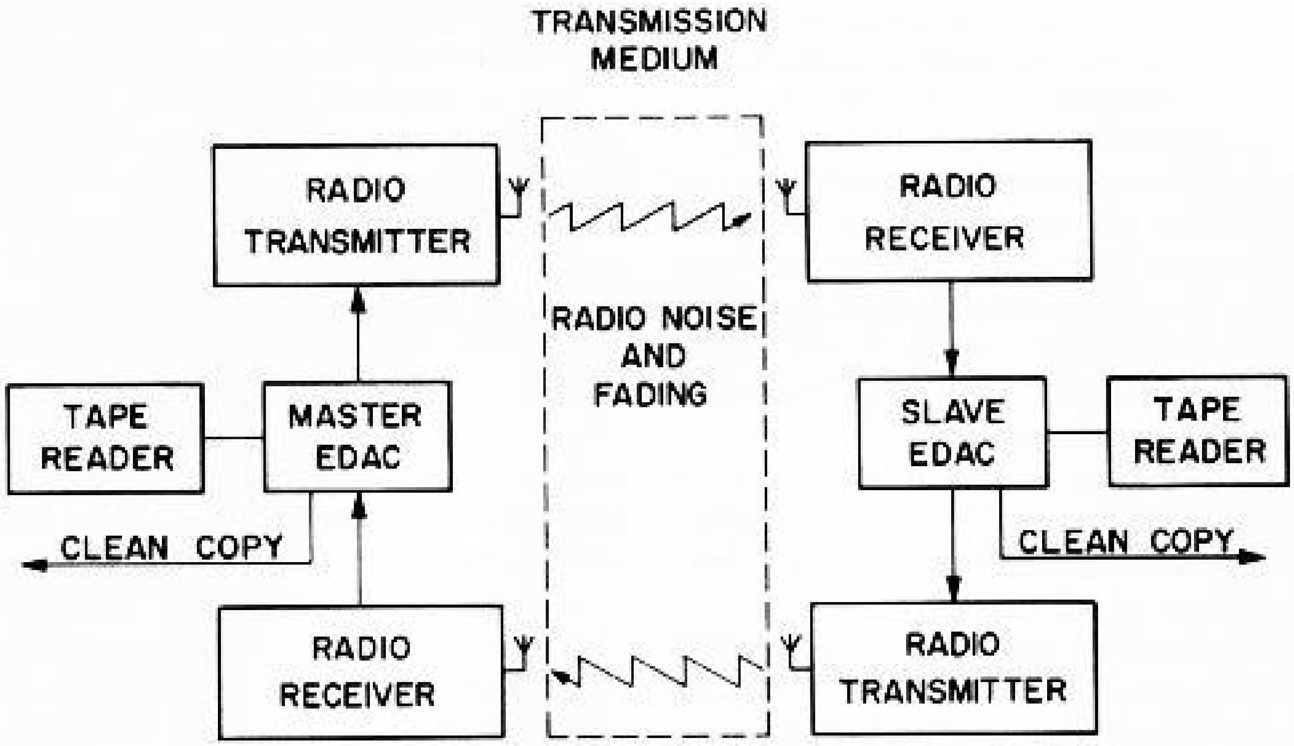


Figure 2. EDAC in a High Frequency Radio Circuit

Figure 2 shows the most significant application of the system—a HF radio circuit with one EDAC unit at each terminal. Here, the system operates on a duplex basis and thereby protects traffic in both directions. It must be emphasized, however, that the system eliminates only the errors generated in the transmission medium i.e., the errors generated between the output of one unit and the input of the other.

EDAC In A Duplex System

Figure 3 illustrates EDAC in a duplex system without including the elaborate HF radio transmitting-receiving equipment. In this arrangement, where one terminal serves as a master station and the other as a slave station, the system operates on a block synchronous basis. Phase correcting networks in the slave receiver as well as in the master receiver keep the distributors in synchronization. A phase lead or lag of either receiver results in a corrective measure on the distributor which tends to diminish the phase difference until synchronization is established.

To begin operation a start signal from the master-send station initiates the slave receiving distributor. Once this distributor is started it keeps pace with the send distributor by comparing the transition of the rest-start pulses. The slave send station, tied solidly to the receiving distributor, on a signal from the slave receiver, begins sending back to the master receiver. Thus, a complete communication loop with an available information channel in each direction is established. Separate and distinct information may flow in one channel of the loop without disturbing the information flow in the second channel, even though errors, which require retransmission, may exist in either channel. Hence, with two channels it is feasible to use each channel to accomplish a dual function. Both chan-

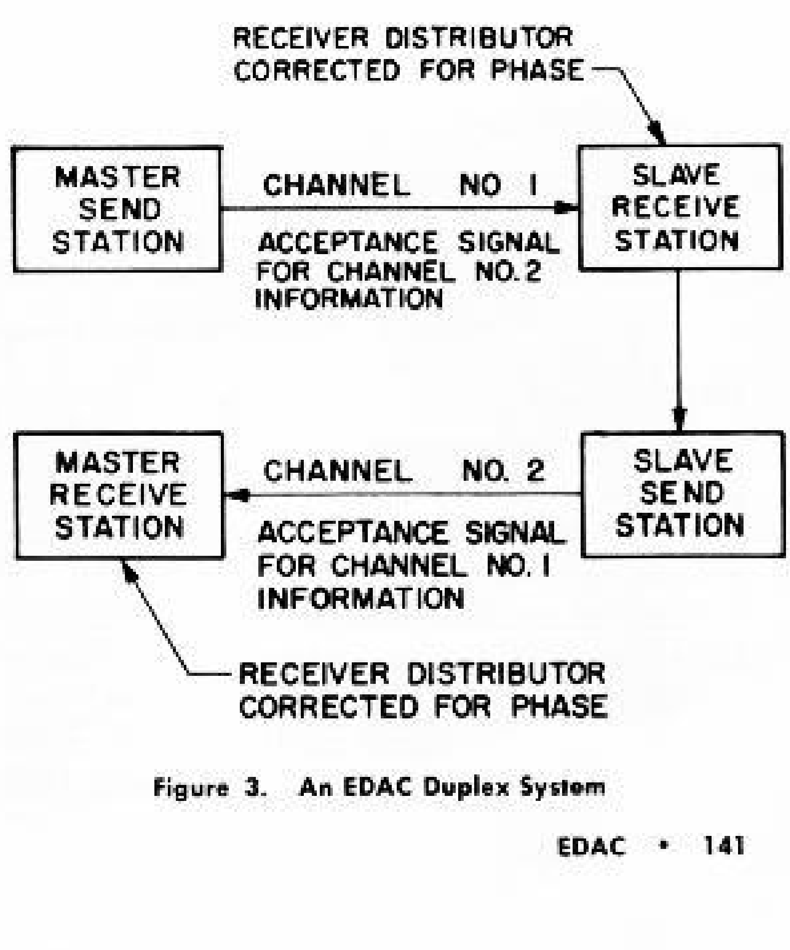


Figure 3. An EDAC Duplex System

nels function as prime information carriers as well as control carriers for information transmitted in the reverse direction. Specifically, we have a feedback channel for controlling errors in the system, where the control signal consists of a three-bit, block-acceptance pattern. It may be pointed out, however, that the acceptance signal in the feedback channels refer to information being transmitted in opposite directions.

Figure 4 shows a simplified master-slave timing diagram of the full duplex mode of operation and the relative starting positions of all distributors in the system. Notice the relative position of the acceptance signal in the feedback channel with respect to the prime information content. The separation between these two accounts for any propagation time encountered in the system. This aspect of the timing will be described later in this article, when the transposition of the check character and the acceptance signal is considered.

EDAC signal contains the same twenty information bits as the teleprinter signal, it also includes five bits for check information, three bits for the return acceptance signal, and two bits for synchronization. How is it possible to include these extra bits and still maintain the same length of block as the original teleprinter block? This question may be answered by observing that each rest-start combination in the teleprinter block occupies two and one-half bits, and by deleting the last three of these combinations it is possible to save a total of seven and one-half bits. These bits may be used for the check information and acceptance signal as outlined above. The additional half bit comes from the shortened first rest pulse. Incidentally, even though the EDAC block differs widely in some respects from the teleprinter block, the fact that both contain a total of thirty bits makes it possible to transmit the EDAC signal at the same speed as a standard teleprinter signal, without increasing the bit rate.

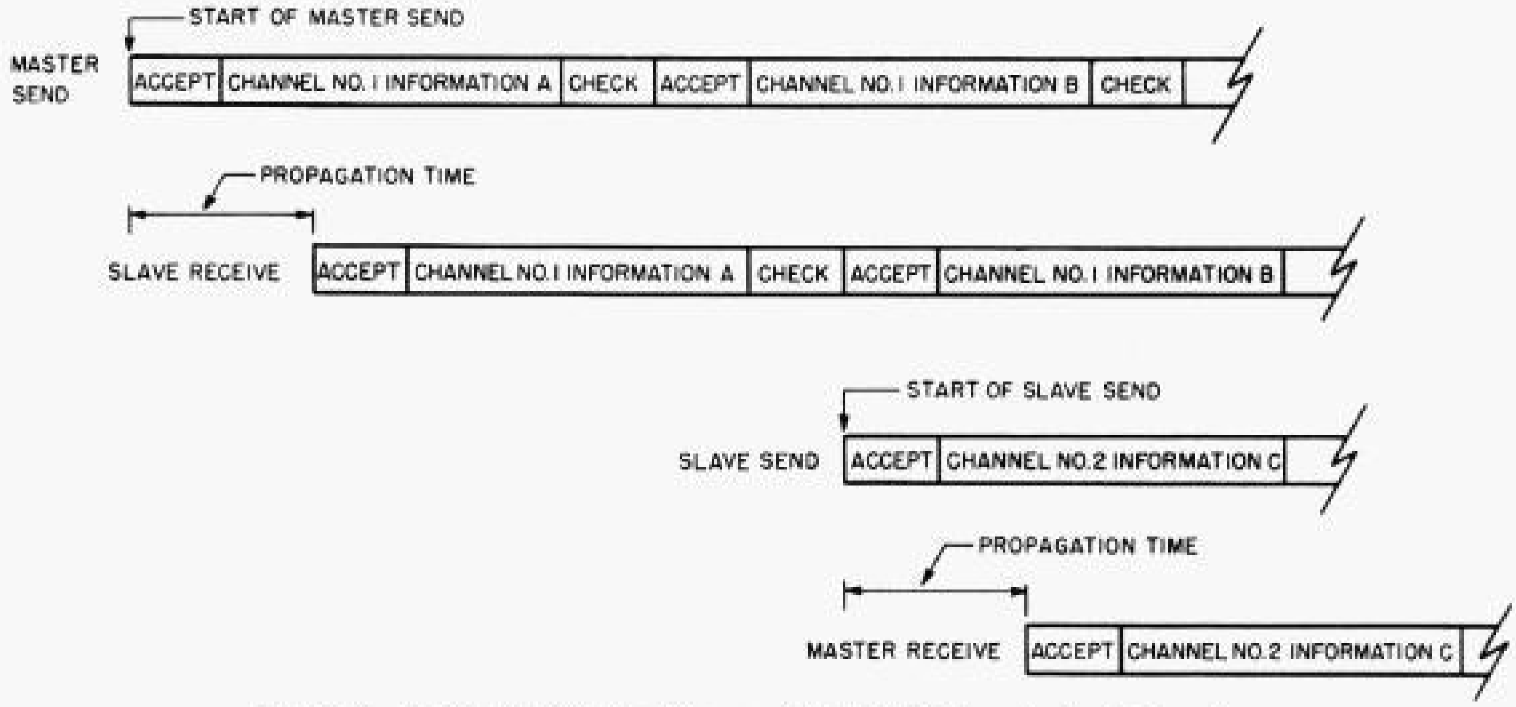


Figure 4. A Simplified Timing Diagram of the Full Duplex Mode of Operation

EDAC Signal

It might be advantageous at this point to examine the EDAC block and compare it with a teleprinter signal containing exactly the same number of bits. Figure 5 illustrates this comparison and establishes a relationship between four characters of a teleprinter signal and an EDAC block or signal containing six five-bit groups or characters. Although the

Operation Without Errors

Under normal operating conditions each block is transmitted in succession with a check character attached to the end of the block as shown in Figure 6.

The sequence of transmission never varies, first block A, then block B, followed by another block A and so on indefinitely. An acceptance signal from the receiver, accepting the first block A, must arrive at the send terminal before the transmission of the check character for in storage after having been checked correctly, are delivered as error-free copy.

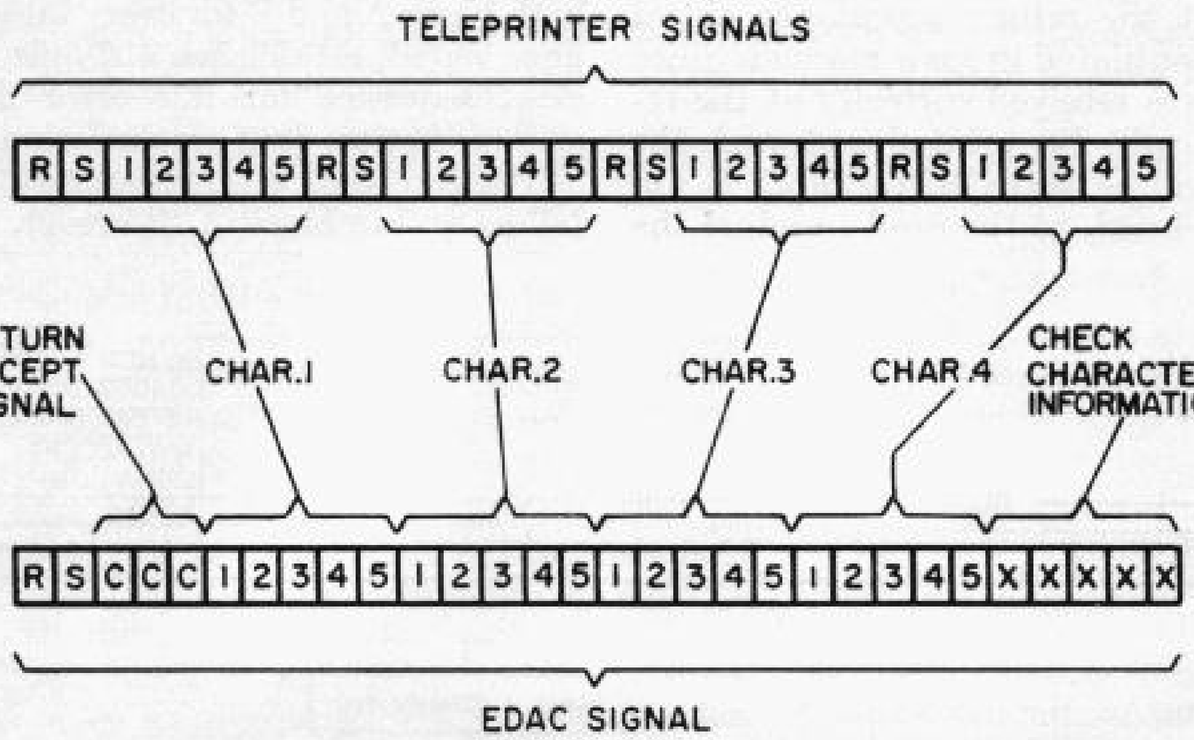


Figure 5. A Comparison of the EDAC Block and Four Teleprinter Characters

block B. The acceptance signal for block A may come at any time during the transmission of block B thus permitting the release of block A information from bank A sending storage and allowing new information to be stored in this bank. Likewise the acceptance signal for block B may come back at any time during the transmission of the next block A in sequence. Thus, an acceptance signal from the receiver certifies that a block of information has been received correctly, and directs the release of this block from the sending storage. At the receiver blocks of information, which have been placed

Operation With Errors

When errors are introduced into the transmitted signal, there are two instances when an acceptance signal may not be received and a retransmission of the information in storage is required:

(1) when the received information does not correspond to the transmitted information, and

(2) When an improper or incorrect acceptance signal arrives at the send terminal for a block of information that has been received and delivered correctly. Here the acceptance signal itself contains an error.

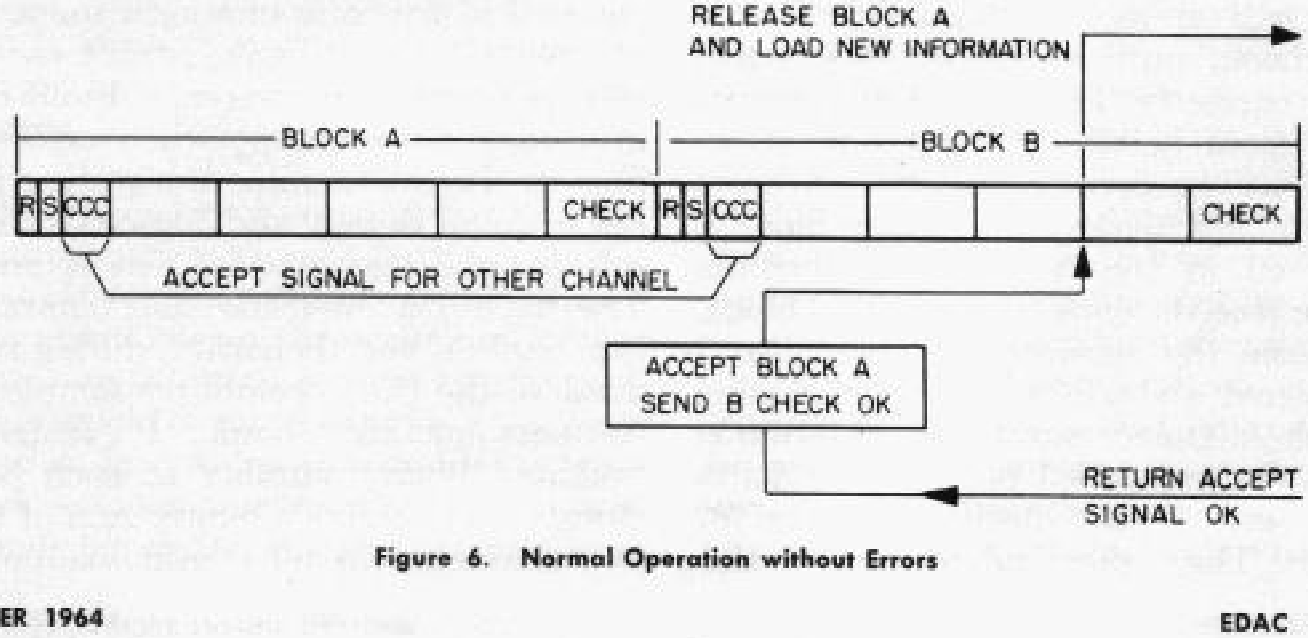


Figure 6. Normal Operation without Errors

The latter situation is illustrated in more detail in Figure 7. Suppose that block A is transmitted and received correctly but the return acceptance signal becomes mutilated in some manner. Since block A was received correctly at the receiver, it will be printed out and the receiver will be set to deliver block B. On the other hand, at the send terminal the mits both blocks over again. Strict adherence to the pattern, of erroring the check character of block B and retransmitting both block A and B for every false acceptance signal, establishes a simple and efficient sequence for this error detection and correction data transmission system.

The foregoing always assumed an error falling within block A. However, it might

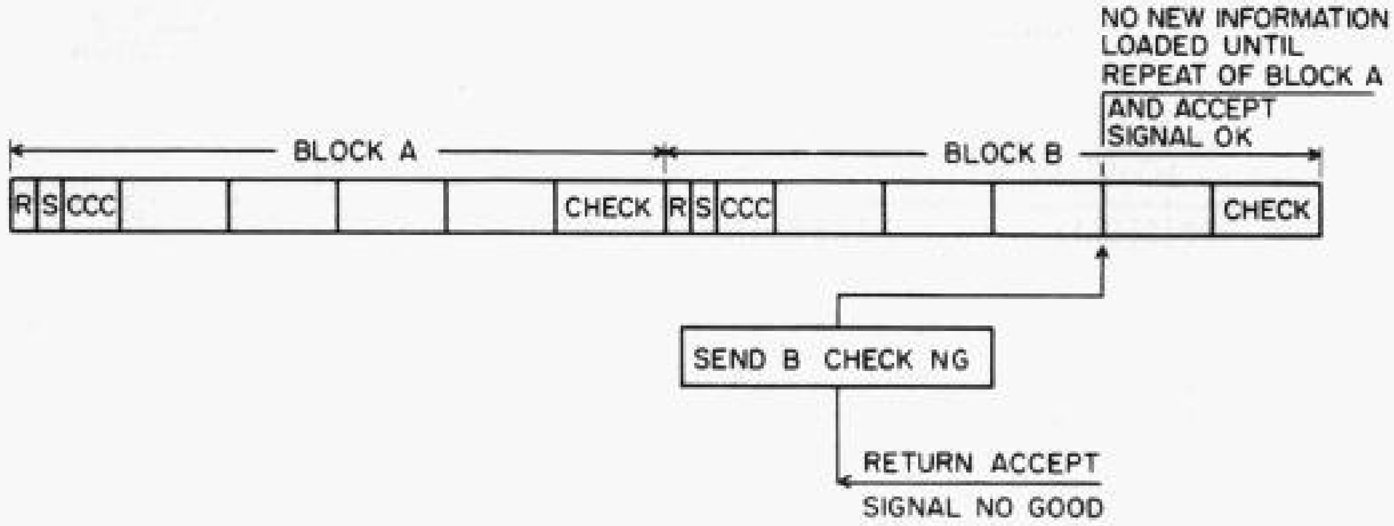


Figure 7. Operation with Errors

wrong acceptance signal for block A results in a transmission of a purposely errored check character for block B, so that this block will be rejected by the receiver. Both block A and B will be retransmitted until the proper acceptance signal verifies an error-free reception for block A. After an acceptance arrives for block A, the check character for block B will be transmitted correctly. For repeated retransmissions the check character for the block, following an errored block, will always be transmitted as a false check, until an acceptance signal returns correctly. This procedure prevents blocks from being delivered out of sequence at the receiver.

A similar situation exists when block A is errored in the transmission medium and the receiver detects the errored block. This time the receiver itself supplies a false signal and affects a retransmission of block A. Once again the send terminal follows the prescribed pattern and deliberately errors the check character for block B. Then, the send terminal trans- have fallen into block B since error generation is a random process. If this be the case, then, the preceding explanation applies with the letters A and B interchanged.

Storage and Check Computer

The introductory remarks briefly alluded to the two memory units used in EDAC to store information prior to transmission. These memory units or storage banks, each having a capacity of four characters, five bits in length for a total of twenty bits per bank, permit continuous operation of the system without delay in transmission except when errors are present. Let us examine the storing process in more detail, and for convenience, refer to the storage banks as A and B. The tape reader reads four characters into bank A, and thereafter, during transmission, the check computer samples the contents of this bank. It assigns a weighted binary number to each bit in storage and obtains a binary sum of these four characters. After transmission of the four characters, the five bits developed from the binary summation process serve as a check character for this block. Subsequently the tape reader loads four new characters into bank B; the binary sum of these characters is obtained by the check computer. Depending on whether the acceptance signal for block A returns correctly or incorrectly, the check computer inserts a true binary sum or a series of five space bits for the check character. If an incorrect acceptance signal arrives from the receiver, the computer purposely errors the check character with five space bits and this indicates to the receiver the unacceptable status of block B. These circumstances call for a repetition of both blocks A and B. The non-destructive readout characteristic of the storage banks allows block A and B to be repeated as often as necessary.

Check Character

The check character performs one of the most important functions of the system. It determines the effectiveness of the detecting capabilities. The choice of a suitable detecting method then becomes important. Moreover, we dismiss checking methods such as simple parity, block parity, cross parity and spiral parity as being either inadequate or cumbersome for our needs.

Let us consider a more fundamental approach and follow the development of the checking method used presently and how it came about. It must be remembered that the correction function in the EDAC system is performed by repeating a block of four characters until they are received correctly and acknowledged. Thus, it is not necessary to know where an error has taken place but only that an error has taken place in a specific block. The EDAC character allows five bits for error detection redundancy. As a first approach one might have assigned a parity bit for each character and then a parity character for the entire block. This requires an addition of nine bits to each block, which is far too large a number. In order to develop a redundancy that would detect numerous bit errors as well as single bit errors, an approach involving

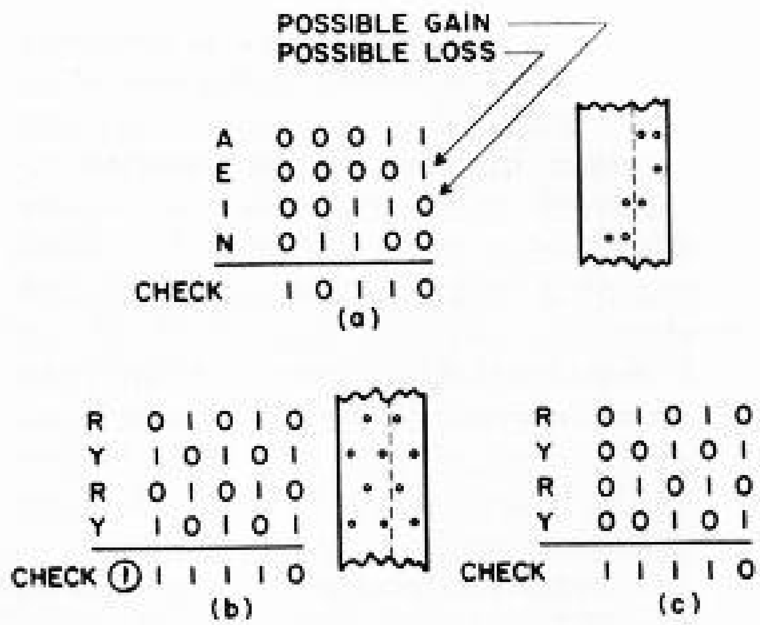


Figure 8. Development of a Check Character

a binary sum seemed to be a logical beginning. A check character could be developed by taking the binary sum of four characters as illustrated in Figure 8(a). Any loss or gain of bits would immediately affect this check character. This could fail only if an equal loss and gain of the same bit value occurs within a block giving an apparently correct check character generated from false information. Since most errors in a transmission

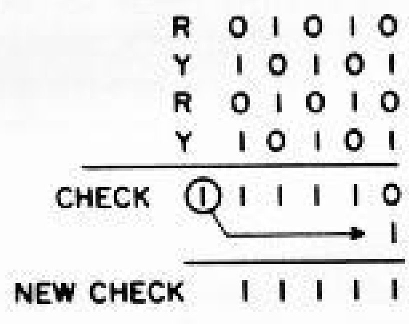


Figure 9. Use of the End-Around Carry

network are caused by drop outs, the probability of gaining and losing an equal number of bit values within the time span of four characters is extremely low. A second source of possible failure to this scheme is in the possible character combinations themselves. A check sum exceeding the five levels is fairly common. Figure 8(b) shows an example of the excess level. One approach would be to ignore this extra bit entirely; however, this presents some problems. If two drop outs occur in the fifth or highest level, as shown in Figure 7(c), the check character summation happens to be identical to the correct check character of Figure 7(b). Exactly the same situation exists if four drop outs take place in the fourth level.

A combination of drop outs of both levels will also result in a false check character. By employing an end around carry when the binary sum exceeds five bits, an encouraging result is observed, namely—it now requires a total of 31 drop outs on any level to produce a false check sum.[1] Since four characters make it physically impossible for 31 drop outs to occur in any one level or a combination of levels, the check character becomes extremely error tight in relation to drop outs alone. Using the end around carry the check sum for Figure 8(b) would be as shown in Figure 9.

Another problem that arises in generating the check character concerns the binary adder itself. Since a five level adder with an end around carry can count to thirty-one and then repeats the cycle for additional pulses, a combination of characters such as all letters cause the adder to go through eight repetitions. A high rate of cycling leads to problems in the realm of probability theory and as such will not be considered here. The reassignment of the binary weights to each bit level affords a simple solution to this problem. Figure 10 compares the assignment of binary weights of the five level Baudot code. Figure 10(a) shows a normal assignment and Figure 10(b) shows the ones used in EDAC.

In laboratory tests in which different type of fade conditions were simulated, the check character has proven to be an extremely tight error check. In fact, in months of testing the EDAC system no information errored in transmission has been printed out.

Delivery Distributor and Control

After every block where the receiver check computer has given the correct sum, the information is readout from storage and delivered as error-free copy. In the readout process the delivery distributor inserts the rest and start bits for each character which, in effect, recreates the original teleprinter signal for use with a teleprinter.

Under some circumstances it is possible for a block of information to be transmitted correctly more than once for example, when a return acceptance signal itself becomes errored in transmission. In order to circumvent the possibility of a double delivery, a delivery control circuit remembers the sequence of delivery, first block A, followed by block B, etc. Thus, a delivery of block A causes the delivery control to anticipate block B. If block A happens to be repeated, it will not be printed out the second time because the delivery control is waiting for block B. The delivery control accomplishes the following functions: (1) it stops delivery in case of an error in the information, and (2) it keeps track of the block sequence. The latter function adds further assurance that blocks are printed out in correct sequence.

Transmission Rate

Operating on the concept of transmission upon the reception of an acceptance signal, EDAC is naturally limited by the transit time of this acceptance signal. The present operating principles of EDAC require that the acceptance signal for a specific block be received from the receiving terminal, before the check character of the following block is sent. It must be remembered that EDAC is a duplex system and the same functions occur in each channel. These functions require permanent time assignments in the two channels to accommodate the information bits, the check character and the acceptance

CODE LEVEL	1	2	3	4	5
DECIMAL WEIGHT	1	2	4	8	16

(a)

1	2	3	4	5
1	2	4	1	2

(b)

Figure 10. Comparison of Normal and EDAC Binary Weights

signal. Figure 11 shows the propagation times encountered in the transmission medium. The time delay is designated as T in the diagram. After the last bit of check character A is received, the slave receiver recognizes whether the received information is correct or not. A good or bad acceptance signal will then be generated

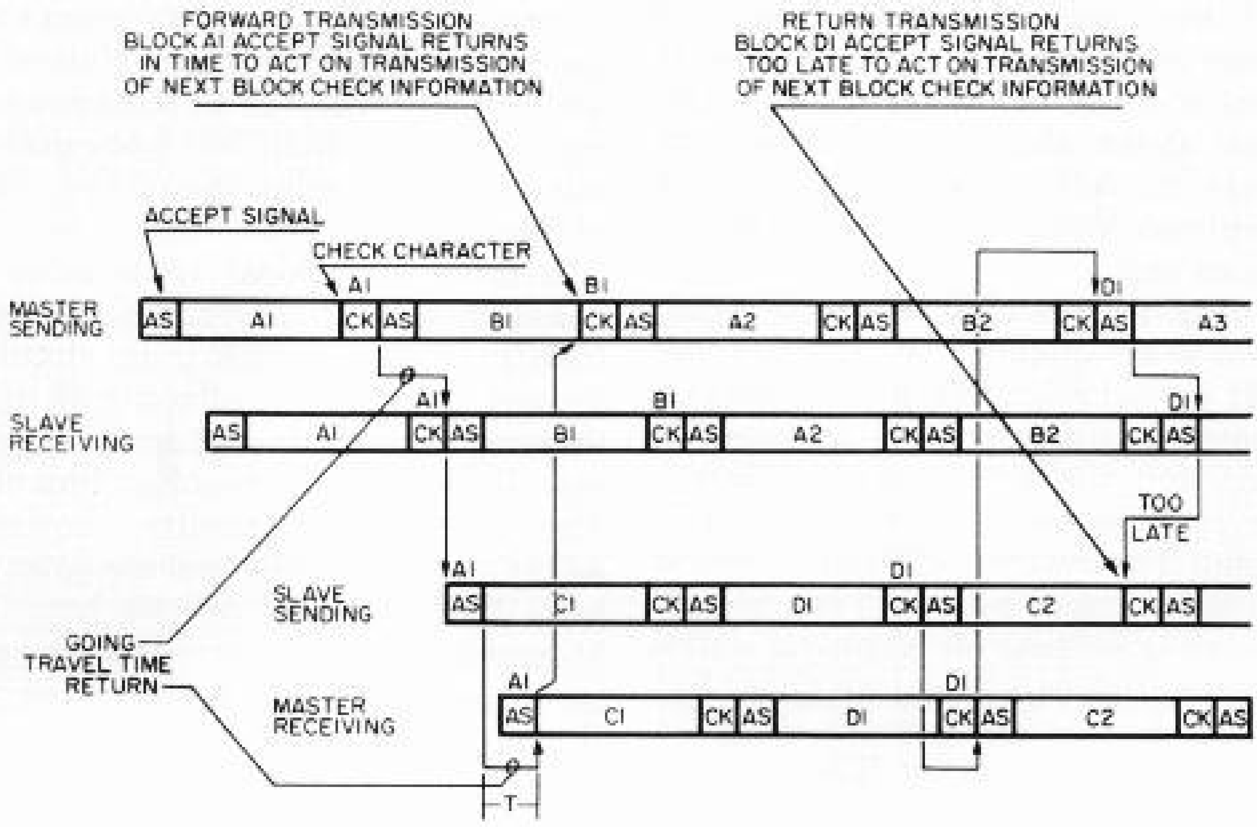


Figure 11. Maximum Propagation Delay Time without Interchange of Check and Acceptance Signal

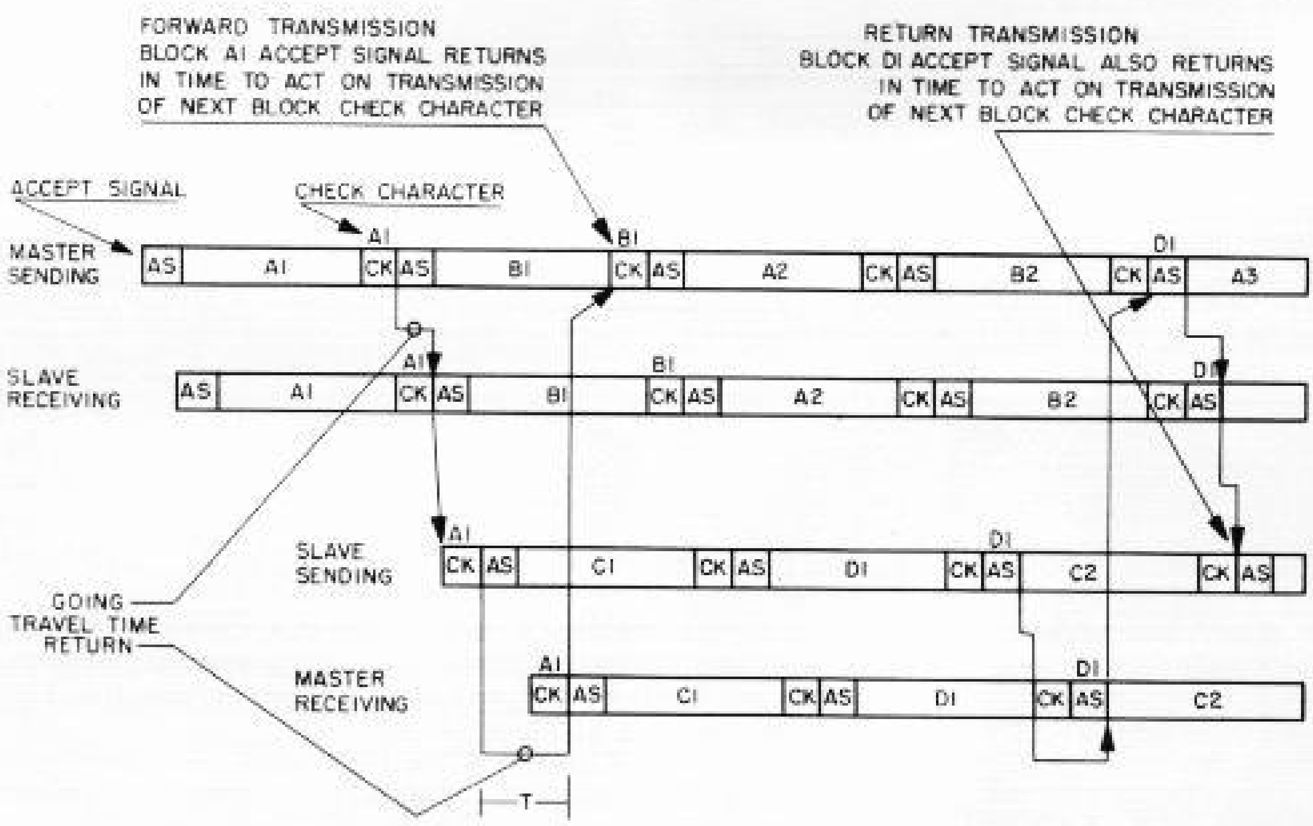


Figure 12. Maximum Propagation Delay Time with Interchange of Check and Acceptance Signal

and transferred to the send section of the terminal unit. The send section transmits the acceptance signal to the master receiver after a delay of T milliseconds. At this time the master send is in the process of sending B1. The master send must know if the reception of the previous block was correct or erroneous before it sends out a check character for B1. The maximum delay that this channel can tolerate is the delay involved in bringing the acceptance signal back before the B1 check goes out.

Following a typical EDAC character D1, in the other channel, the same procedure will be followed. We note, however, that the time delay in this instance is too great and the acceptance signal arrives beyond the check character for D1. As a result the system will not function because it is pushed past its capabilities. The system is waiting for a control signal which never arrives. Hence, we note that the system tolerates a greater delay in one direction than the other. The problem of equalization can be solved simply by interchanging the check and acceptance characters in channel number two as shown in Figure 12. Now the maximum allowable delay times are equal in each channel. The maximum overall time delay at which EDAC can operate at 100 wpm is 266 milliseconds. This corresponds to a distance of approximately 49,000 radio miles. As the transmission speed decreases this distance increases accordingly and vice versa.

Potential of EDAC

It is possible to operate the EDAC system at rates considerably in excess of 100 wpm by using faster flip-flops in the count-down chain of the timing clock. Faster flip-flops permit the system to operate at speeds up to 500 wpm over distances in the continental United States without any increase in storage capacity. Speeds greater than 500 wpm may be obtained by increasing the storage capacity of the system.

Recent operational tests using a terminal unit, such as shown in Figure 1, for a transoceanic H F radio circuit, have proved EDAC most effective in reducing transmission errors and in increasing the usefulness of the communication channel. The overall test results showed that EDAC increased channel usage anywhere from 2 to 3 hours per 24 hour period. Moreover, EDAC eliminated the necessity for repeating the same message two or three times thereby providing a more efficient communication channel.

• • •

Reference

1. Error, Detection, Correction and Control. Robert Steeneck Western Union TECHNICAL REVIEW Vol. 16, No. 3, July, 1962.

• • •

Acknowledgements

The author wishes to acknowledge the assistance of Mr. R. A. Derechailo for his significant contributions to the development of the check character and transmission rates. A special note of thanks is due Mr. Robert Steeneck for his valuable guidance and his contributions to this article.

Mr. J. J. Durachinski, an Engineer in the Data Systems Division of the Plant and Engineering Department, has been responsible for some of the major developments of EDAC and other digital type devices.

Before joining Western Union in 1961 he had a significant role in the development of a special purpose analog computer and ground support equipment for the F104 Fire Control System at General Electric.

He received his BSE in Electrical Engineering from the University of Michigan in 1960. He received his master's degree from New York University in 1964.

Patents Recently Allowed

Adjustable Stylus Holder for Facsimile Recording

D. M. Zabriskie

3,108,845—October 29, 1963

Since a static, spatial alignment of belt mounted styli in a facsimile machine is subject to change when the belt is in motion, this invention provides a readily adjustable stylus mount whereby the marks produced by the several styli can be dynamically aligned. Each stylus holder rests yieldingly against the belt but is attached thereto via a leaf spring, lying longitudinal to the belt, to a member which is slidably adjustable in a dovetail groove with respect to a block fixedlv attached to the belt. If the marking pattern indicates misalignment, removal of the styli one at a time will serve to identify misaligned styli and guide the adjustment process.

Electrically Conductive Coated Paper

C. M. Wiswell, F. L. O'Brien

3,118,789—January 21, 1964

To avoid the exposure of operators to unpleasant electric shocks which may accompany recording on electrosensitive papers having a non-conductive support or base, a pattern of perforations is pricked in the base layer so that in the coating process the electrosensitive conducting top coating is pressed through the base where it can make contact with the recording drum or platen. The process is applicable to electrosensitive recording papers generally whether by energized stylus, electrophotographic or zerographic recording processes.

Waystation Selection Network

G. G. Light, E. F. Manning, J. C. Parr, R. B. Wolfson

3,134,848—May 26, 1964

A waystation selection system particularly applicable to stock broker services where rapid and highly accurate handling of cryptic messages is required. The system is controlled by a terminal station over a duplex line which invites waystation transmission by first momentarily interrupting its own transmission for a precisely timed period, which throws all printers into non-print case so that control characters will not be printed, and then sends the single character selection and invitation code for the first waystation. If that station has messages waiting it will respond by starting transmission; if not, it will transmit an "X" character. The control station will again pause to start the cycle for the second and subsequent waystations. Or, when the terminal senses the end of transmission character from the first station, it will proceed to cycle the second and remaining stations. There is also provision for the automatic insertion of time on messages printed at the control station. For its own transmission, the terminal station activates only the desired waystation or waystations and proceeds with the transmission. For single station transmissions an answer back request character can be incorporated which stops other waystations to clear the way for transmission of an "X" character affirming that the waystation is in proper receiving condition.

J. A. Falkenberg, Project Engineer—Physical and Chemical Div.—P & E Dept.

New

TELEDELTOS Paper

Type 2AL and L-62

Western Union has been producing for some time versatile recording papers known as "TELEDELTOS" which have a variety of commercial applications. The two latest types 2AL and L-62 are described in this article.

TELEDELTOS papers are essentially electrically conductive base stocks coated with an opaque lacquer which is removed mechanically or by chemical decomposition when exposed to electrical signals. Though the paper is extremely sensitive electrically, it remains virtually indifferent to heat and light—an advantage over many other recording papers.

Western Union developed TELEDELTOS for use in its facsimile systems. Typewritten or handwritten messages are scanned by a photoelectric cell, creating electrical impulses which are transmitted and recorded. The transmitting and recording machines are synchronized, resulting in a clear, accurate reproduction of the original message.

Types L-39 and L-48

Two earlier types of TELEDELTOS have been produced commercially; they are called L-39 and L-48. These were introduced in 1939 and 1948, respectively. These tough, pliant papers are made from carbon impregnated base stocks. They have an opaque top coating and an aluminum lacquer coating on the back which reduces smudging and improves the appearance of the paper.

The L-39 paper has been produced and sold only to customers with certain types of chart recorders having unusual requirements.

The L-48 paper, which has been the Western Union standard for many years, has extensive commercial applications including those recorders where markings consist of event lines, analog lines and oscillograph traces.

New Types

More recently the chemical development has been directed toward producing a TELEDELTOS recording paper with improved recording qualities and is cheaper to manufacture. This resulted in two new types of paper, 2AL and L-62.

Type 2AL consists of a white paper-base stock coated with a conductive carbon formula and then top-coated with an opaque dispersion. Both coatings are made from aqueous media which are more economical to produce than the solvent systems which coat the L-39, L-48 and L-62 papers.

2AL Paper with Desk-Fax

The 2AL paper is currently used for Desk-Fax transceivers. Its applications is limited to recorders which make contact with the conductive coating along the edge of the paper or by penetrating the top coating of the paper to achieve a front surface ground. When high frequency A.C. is used, recording signals may be passed by condenser action also.

Type L-62 paper was developed to be used on Western Union recorders using L-48 paper and also for use on all types of chart recorders. It is equivalent to the L-48 paper. Recent improvements in the manufacture of black conductive paper have reduced the smudging tendency significantly, thus eliminating the necessity of the aluminum coating on L-62. This improves the ground between the paper and the drum, permits lower signal power levels for recording, and reduces the smoke and odor associated with the recording.

The L-62 paper, which has electrical properties identical to those of L-48 paper, will replace all L-48 paper used in Western Union recorders. It is also expected to replace most, if not all, commercial usage of L-39 and L-48 papers for chart recorders. The L-62 paper has a top coating which has a whiter surface than the green tinted coating on the L-48 paper. This makes for greater contrast in recording.

Applications

TELEDELTOS papers have many unique commercial applications. They are used on naval instruments aboard ships to indicate echo soundings. Sound waves from schools of fish may be recorded on fathometers to enable fishermen to determine their depth and bearing. The paper may be used in the medical field, also, to record heartbeats and brain reactions, in the aircraft industry to record engine performance; and in the railroad industry to record traffic, to mention only a few.[1]

Currently TELEDELTOS is being used in the computer and data processing fields for readout of dot-pulse type recordings. Satisfactory recordings have been obtained from signals as short as 50 microseconds, and speeds of over 500 inches per second have been attained on certain recorders. Stringent requirements for new uses make it necessary to exercise close control over the paper uniformity, both mechanical and electrical and the pigments, binders, lacquers and top coating weights.

TELEDELTOS paper has many military applications. It is incorporated in the Distant Early Warning (DEW-LINE) radar system. At Cape Kennedy, TELEDELTOS records information transmitted from missiles and satellites as they progress in space. Field artillery ranging equipment employs TELEDELTOS to record echos and thus pinpoint exact ranges.

Today, over 40 thousand Western Union customers send and receive close to 50 million messages a year by facsimile machines located in their own offices. Western Union uses TELEDELTOS for all of these messages.

Wherever electrical signals are used to provide a written record, Western Union's TELEDELTOS paper may be used to obtain greater speed, accuracy and permanency.

• • • •

Reference:

1. Recording on TELEDELTOS, F. L. O'Brien and J. H. Hackenberg, Western Union TECHNICAL REVIEW Vol. 16, No. 2 April 1962.

Mr. J. A. Falkenberg, a Project Engineer in the Physical and Chemical Division of the Plant and Engineering Department, has assisted in the development of L-62 and 2AL recording papers. He is currently active in the chemical phase of the Western Union Data Card project.

Mr. Falkenberg joined Western Union in July 1951, and served 2 years in the United States Army Airborne Division. He later received a B.S. degree in Chemistry from C.C. N.Y. in 1961.

G. H. Ridings, Facsimile Engineer—Facsimile Div.—Plant & Engineering Dept.

Facsimile Imaging Systems

Part I

While Facsimile, a form of record communications, is much older than Television, it is infinitely less familiar to most people. Facsimile and Television are similar in many respects but quite different in others. In some respects Facsimile attempts to do what photography does. However there is quite a difference between producing a facsimile locally by photographic processes and producing one at some remote location, perhaps hundreds of miles from the original or "subject copy" as we call it.

A photograph taken by anyone with a little basic knowledge in the handling of his camera is usually a pretty good facsimile; by comparison a copy reproduced by Facsimile can be and often is a pretty poor facsimile, yet adequate for the purpose. In fact the quality of many of our facsimile reproductions is more comparable to the quality of copies produced by an inexpensive office copier. One reason for this is that it is necessary to dissect the subject copy into thousands of small areas in accordance with a definite pattern, generate a signal proportional to the density of each area, transmit it to the distant recorder, and in accordance with the same pattern apply this series of signals to a "record sheet" to reproduce a facsimile of the subject copy. In the process, distortions of one kind and another can and do take place but the major factors which limit the quality of the reproduction are economic rather than technical. The reasons for this will be evident as we become more familiar with the Facsimile process itself.

This article is Part I of a paper delivered to the New York Chapter of the Society of Photographic Scientists and Engineers on February 19, 1964 at the Chemist's Club in New York City.

Principles of Facsimile

To better understand this process, let us consider the analogy of reading a letter or a book. In reading, the eye does not glance at a page and relay its contents to the brain with a single setting of the eye. Even if the field of vision were adequate the copy must be "scanned" by the eye in an orderly manner, making repeated trips line by line across the page. Of course, the gaze might be fixed and the page moved back and forth across it; or the page could be mounted on a drum and steadily revolved so that it would only be necessary for the gaze to shift down to a new line once per revolution.

Now fortunately the field of vision of the human eye is more than adequate to cover the height of a character and the brain has been taught to recognize each individual character and distinguish between them. It is also capable of recognizing groups of characters and so it is possible for the eye to scan a whole line of print in each sweep of vision and together with the brain to obtain the full intelligence conveyed by the series of characters constituting the line of print.

In the Facsimile process a photocell or "electric eye" is used to scan the subject copy. However the field of vision of the photocell or phototube as it is more accurately called is purposely restricted to a mere point rarely larger than 1/100 inch in each dimension and sometimes much smaller than this. During each trip across the subject copy, which we call a "scanning line" either the paper is advanced or the scanning spot is moved down a distance equal to the width of the scanning line so that the scanning lines are contiguous and the entire area of the page is viewed as the scanning process continues.

It is necessary to limit the view of the phototube in this manner because this device cannot distinguish one character from another; it can only distinguish between degrees of light. If it sees the unmarked white or light-colored paper surface it passes a relatively high current and it ceases to pass current (or passes a very low level) when it sees a black area. In other words, its output is proportional to the level of light striking it (within certain limits) or inversely proportional to the density of the area being viewed. Now in order to obtain signals which are capable of forming reasonably sharp, clearly defined characters when properly reassembled we must limit the view of the phototube to an area whose dimensions are no greater than the width of the narrowest stroke of the characters we wish to reproduce—about 1/100 inch for most typewritten subject copy. Obviously if the area viewed were wider than the width of the character strokes the phototube would never see an all-black area in scanning across the characters and therefore would never generate a signal corresponding to an all-black area. In addition the transition from white to black or from black to white would be a very gradual one. Under these conditions the recorded character strokes would not have sharply defined edges, would be broadened and would not be full black but a gray corresponding to the average density of the area viewed.

On the other hand if the area viewed were made say 1/10 the width of the character strokes the phototube would be generating a full black signal after its view had passed across 1/10 the width of a stroke and the signal would remain full black until it began viewing the opposite edge of the stroke at 9/10 of the way across. Here the transitions from white to black and from black to white would be quite steep and the recorded character strokes would be full black and would have sharply defined edges. Obviously a machine scanning at 1000 lines per inch would produce a much better facsimile than one scanning at 100 lines per inch. Unfortunately the bandwidth required to transmit signals generated by the 1000-line machine is just ten times that required by the 100-line machine and the transmission time for a page of copy is ten times as great. Or if the available bandwidth were fixed as is generally the case, the scanning speed would have to be reduced by a factor of ten and the transmission would take 100 times as long. So except in extremely rare cases circuit charges and other costs dictate that the viewed area which we call an "elemental area" be as large as possible, that is, approximately equal to the stroke width which for ordinary typewritten material is about 1/100 inch. This means that there are about ten scanning lines across upper-case typewritten characters and seven or eight across lower-case letters (depending upon whether they are elite or pica) which is entirely adequate to reproduce these characters. Some telephoto equipments operate at 300 lines per inch and there are a few special-purpose equipments with scanning as fine as 1000 lines per inch, but the vast majority are from 96 to 120 lines per inch. When we compare this to the grain structure of photographic materials it is easy to see why our facsimiles are poor seconds to photographic ones made locally.

Recording

Now in order to convert this series of facsimile signals generated by scanning the subject copy into a facsimile copy a small marking point of approximately the same dimensions as that of the elemental area viewed by the phototube of the transmitter is caused to execute the same scanning motion across a record sheet in exact synchronism with the transmitting scanner. This marking point produces marks on the record sheet under control of the phototube signals transmitted over the circuit and in the same relative positions as they are found on the subject copy. This process, greatly oversimplified, is illustrated in Fig 1. The characters are thus built up in narrow strips which blend together so well under most conditions that minute inspection is required to see where one fits against the other. A magnified portion of a recording is shown in Figure 2.

A number of different kinds of mate-

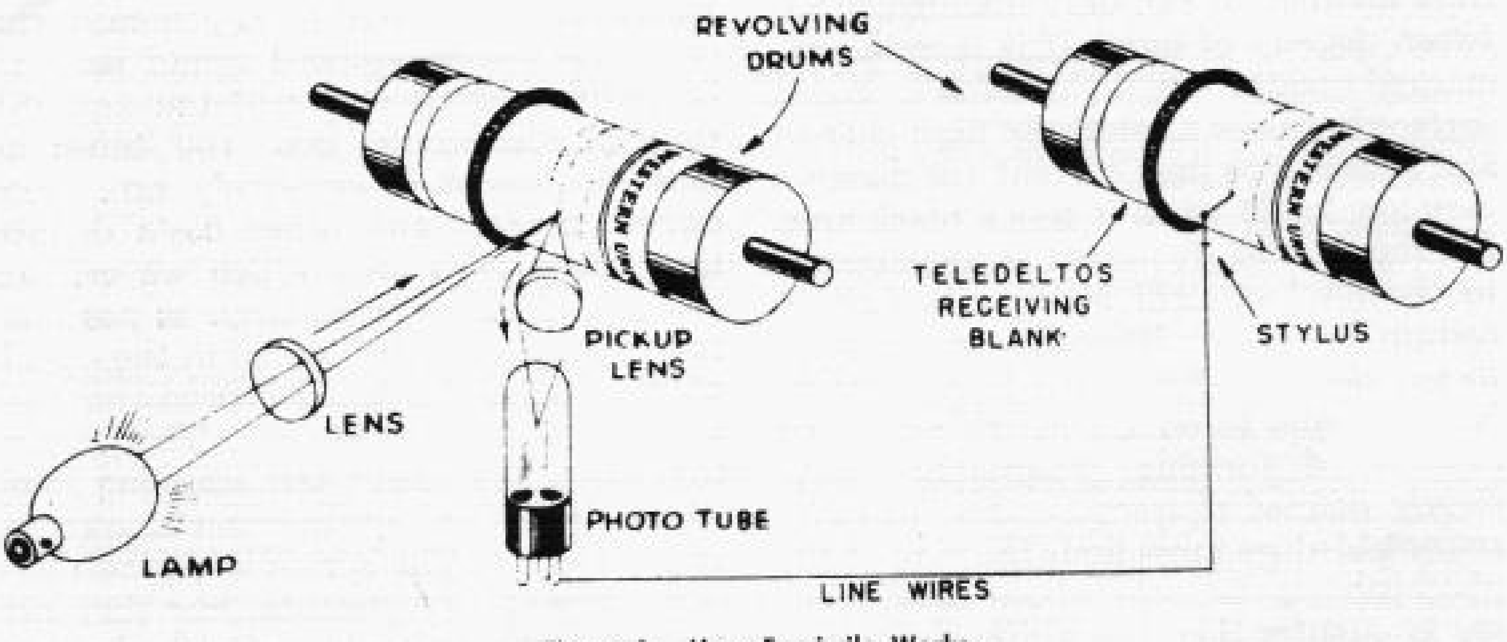


Figure 1. How Facsimile Works

Figure 2. Section of a Recording (magnified)

rials are commonly used as record sheets for Facsimile and these will be described later. For the reproduction of news pictures photographic film is generally used. A typical telephoto recorder consists of a drum which is rotated (within a light-tight compartment) synchronously with that of the transmitter. Upon this drum is mounted a sheet of unexposed film. The film is scanned by a light spot of the same size as the elemental area viewed by the phototube at the transmitter. The brilliance of this spot is made to vary in proportion to the amplitude of the received facsimile signals thereby producing a "negative" of the subject copy, from which positive prints are made by conventional photographic printing techniques.

Telephoto equipments, particularly the recorder, must be constructed with utmost precision so that the scanning lines are exactly contiguous at all times. Even the slightest overlap of the scanning lines will cause dark strips to appear in gray areas due to the double exposure of the film. Likewise failure of the scanning lines to touch each other throughout their entire length will cause light strips (where the film remains unexposed) to appear in dark areas. Great care must be taken in designing the optics and electronics of telephoto equipments so that the density response curve for the particular film used is properly matched for the speed of the recorder and the over-all density response from phototube to final print is as linear as possible.

The quality of reproduction possible with 100-line scanning is shown in Figure 3. This photograph was reproduced on equipment manufactured by Muirhead of England. It would be very hard to distinguish this facsimile from the orignal photograph. The reason of course is that there is very little fine detail, no sharply defined transitions between white and black or vice versa. On the other hand Figure 4 has considerable fine detail and although a 100-line picture might be considered adequate for reproduction in newspapers, it is definitely inferior to the 300-line reproduction, which we see here. As you can see it is difficult to distinguish

Figure 3. Wire Photo—100 lines per inch

the 300-line facsimile from the original photograph. Can you tell which is the original? It is on the left in the figure below.

Unfortunately the cost of photographic film or even printing paper and the processing time and expense, etc., preclude the use of photographic recording except for special applications as, for example, the one just cited. For almost all applications in which typescript is to be reproduced much cheaper so-called direct recording methods are employed. Most common of these are the conductive and capacitive dry electronsensitive papers and the moist electrolytic papers which I shall describe later. Electromechanical methods employing ink or carbon paper have been used but these methods have serious speed limitations. In all of these methods the over-all white-to-black density range is less than in photographic recording and relatively nonlinear, especially near the ends of the range. In addition the electrolytic papers tend to "bleed" and the dry electrosensitive papers are not completely homogenous so that edge sharpness suffers in both cases. These degradations as well as that due to the coarse scanning are the major factors which limit the quality of reproduction in the usual facsimile system and as I said before are economic rather than technical.

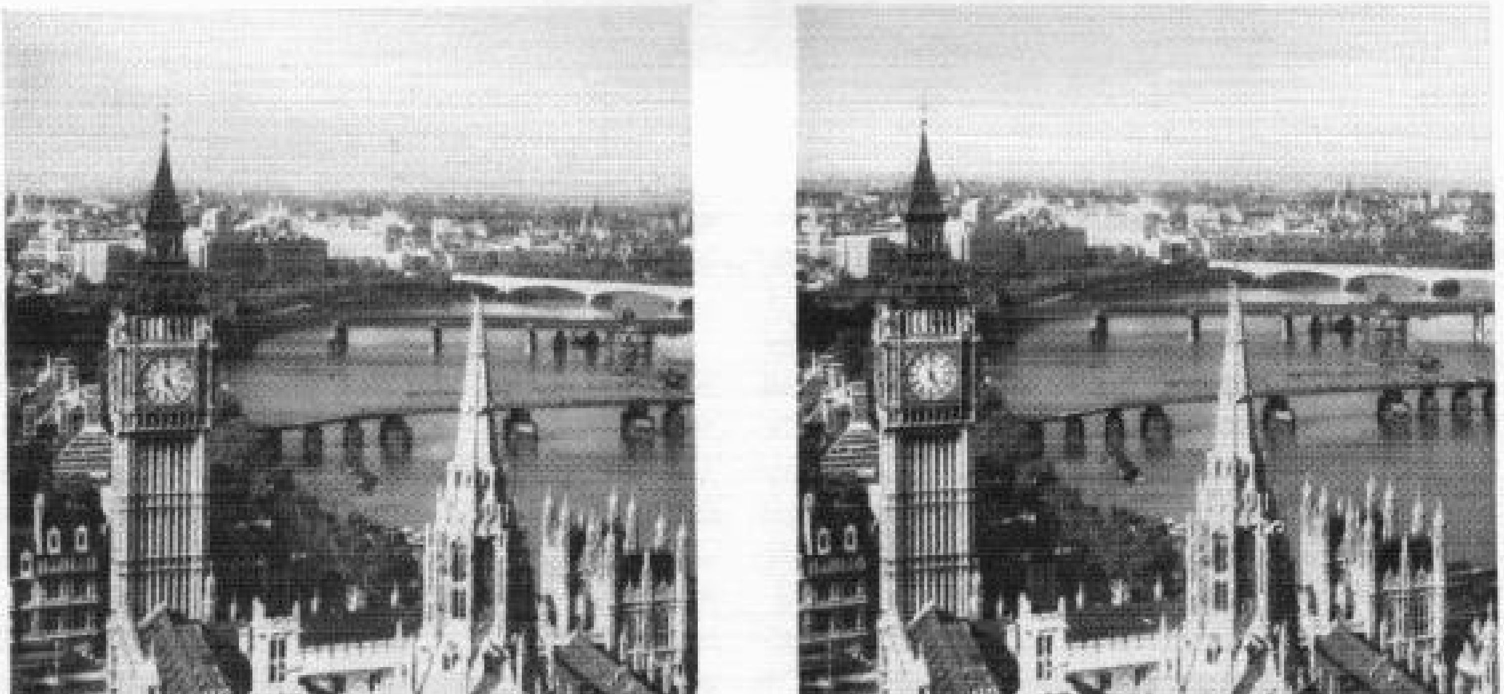


Figure 4. Wire Photo—300 lines per inch and Original Photo

Signal Inversion

When using the direct recording methods it is necessary to introduce a "signal inverter" somewhere into the system. This follows from the fact that the output of the phototube is maximum when viewing white areas of the subject copy and minimum when viewing black areas, whereas maximum current through the record sheet produces the densest mark. An inverter would also be required in photographic recording if we wished to record directly on printing paper to avoid the intermediate film processing. The signal inverter can be located in the transmitter or receiver, whichever is most convenient. Inversion is usually accomplished in the modulator which converts the signals from the phototube into a modulated carrier for transmission.

separate commercial power sources. Figure 5 shows what might be expected if we tried to do this. Where the power at the two terminals is not from the same source a sample of power from one terminal can be transmitted to the other and used to control the speed of the other machine. Or if this is impractical both machines can be driven from individual precision power supply units whose frequencies can be adjusted to match each other. The precision required is of the order of one part in 100,000. A maximum skew of ⅛ inch in an 8½ x 11 document would result from this amount of frequency difference and this is considered tolerable. Another method, the transmission of a pulse at the start of each scanning line to synchronize a local oscillator, is also sometimes employed.

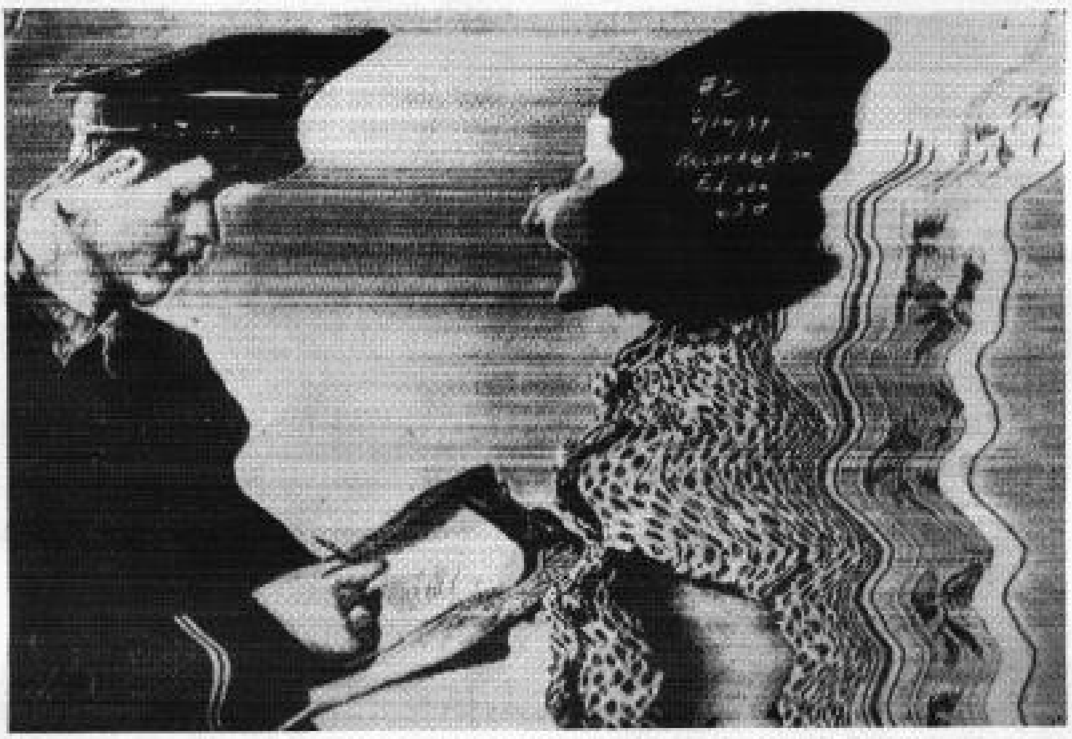


Figure 5. Lack of synchronization

Synchronism

The requirement that the transmitter and recorder scan the subject copy and record sheet, respectively, at the same rate and in synchronism is most easily met by using synchronous motors to drive each unit and by operating them from the *same* alternating-current power source. Although the frequency of commercial power sources is constant enough over the long term to make electric clocks sufficiently accurate timepieces for all ordinary purposes, short-term frequency variations make it impossible to operate ordinary facsimile transmitters and receivers from

Another requirement of any facsimile system is that some arrangement be provided to insure that the reproduction of the subject copy is properly located on the record sheet. Location in the vertical direction which we call "Framing" is accomplished manually for drum-type equipments by proper positioning of the subject copy and record sheets on the drums with respect to the start positions of the scanning head and recording head. In the case of continuous or "flat-bed" scanners and continuous recorders "Framing" is accomplished by the transmission of appropriate "start" and "end-of-message" signals.

Positioning of the copy in the horizontal direction—that is, along the scanning line—which we call "Phasing" can be accomplished in several ways. The simplest of these employs a commutator on one machine (usually the transmitter) and a clutch on the other. The commutator is arranged, for example, to generate a pulse as the scanning phototube views the left-hand edge of the subject copy mounted on the transmitter drum. The clutch of the recorder holds the drum in such a position that the marking point is at the left-hand edge of the record sheet mounted on it. The clutch is triggered by the received pulse and the marking point moves across the record sheet in step with the motion of the scanning phototube. Phasing need only be done once at the start of each message. Another arrangement commonly used does not require a clutch. Both machines have means for generating pulses at the edge of the page. But one, usually the recorder, is caused to run at a speed slightly higher or lower than the other. The two pulses are fed into a coincidence circuit and when they coincide the drifting arrangement is immediately disabled and the machine allowed to run synchronously with the other. Other arrangements may be used but I believe these will suffice to acquaint you with this last requirement of a facsimile system and we can proceed with a discussion of the various mechanisms and optical configurations employed to perform the scanning and recording functions.

Scanning and Recording Mechanisms

Scanning of the subject copy and the corresponding motion of the recording spot or point across the record sheet can be accomplished mechanically or electronically. Because the desired linearity of the scanning motion is more easily achieved mechanically, because mechanical scanners are generally less costly to construct and to maintain and because of certain problems in the use of "flying-spot" and image tubes at low scanning rates electronic scanners are used only in high-speed applications. These are relatively few and will be touched on after we have covered the mechanical arrangements.

There are two ways in which we can analyze the subject copy and derive the phototube current which is representative of the light being reflected from it at any instant. First we can create a light spot on the subject copy of the exact size of the elemental area we wish to view, and pick up by means of a phototube or phototubes the light reflected from it. We call this "spot projection." A typical arrangement consists of a light source, a condenser lens, an aperature plate to delineate the size of the scanning spot and an objective lens to focus the light from the aperture onto the surface of the copy. A second condenser lens picks up as much light from the subject copy as can conveniently be collected and focuses it upon the cathode of the phototube. A typical configuration is shown in the top half of Figure 6. Or we can floodlight a relatively large area of the subject copy, focus an image of this area onto the aperture plate and pick up by means of a phototube the light passing through the aperture. We call this "flood projection" or "image dissection." A typical arrangement consists of a light source, a condenser lens to floodlight a limited but relatively large area of the subject copy, an objective lens to focus an image of this area upon the aperture plate and sometimes a second condenser lens to focus the light passing through the aperture upon the cathode of the phototube. A typical configuration is shown in the lower half of Figure 6.

In either method sharply defined images are not required of the condenser lens assemblies, may in fact be undesirable as this would increase the problem of aligning the optics and maintaining this alignment. Therefore cheap molded glass or plastic lenses are generally acceptable and at best two simple plano-convex lenses are used. However, since the objective lens (together with the aperture) in each method defines the elemental area of the subject copy being instantaneously view-

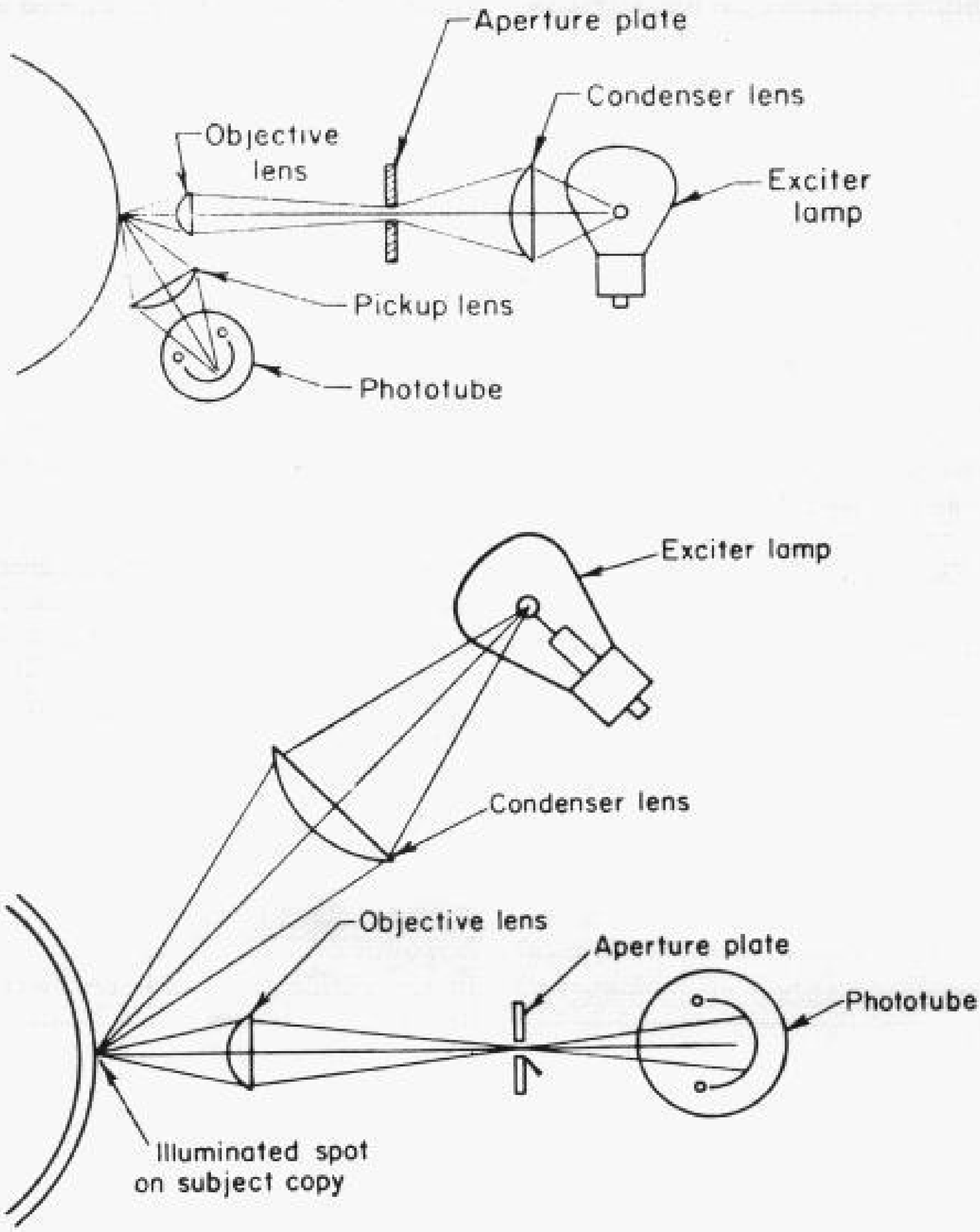


Figure 6. Spot Projection and Flood Projection

ed by the phototube it is important that this area be sharply defined. Any blurring or halo at the outline of this tiny area reduces the sharpness of the transitions from white to black or black to white. And because (as explained previously) in most systems the area being viewed is of the same general dimensions as the strokes of the characters on the subject copy, lack of sharpness in the outline of this tiny area will reduce the contrast between the character strokes and the paper background.

In drum-type equipments we are imaging only a very small (elemental) area on the optical axis and so we need only concern ourselves with minimizing longitudinal aberrations. In the simplest of coarse-scan drum-type equipments a doublet consisting of spaced plano-convex lenses is sometimes employed as the objective but better quality and fine-scan equipments almost always employ a cemented doublet or triplet corrected for both spherical aberration and longitudinal chromatic aberration. Of course in so-called "flat-bed" scanners where we are imaging an entire scanning line rather than just one elemental area all of the aberrations and distortions encountered in photography are involved and a high-grade photographic lens is required.

Part II of this article will appear in the January 1965 issue.

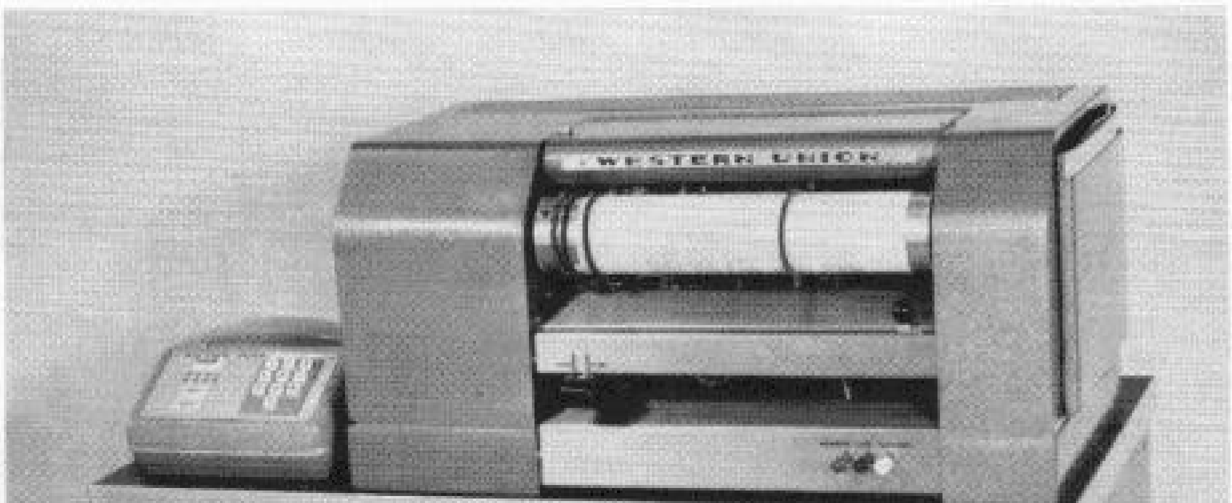
Mr. G. H. Ridings, Facsimile Engineer in the Plant and Engineering Department, was invited to speak at the Chapter Meeting of the Society of Photographic Scientists and Engineers, on the basic principles and requirements of Facsimile systems. He has been engaged in the design of facsimile systems and equipment for thirty years.

Mr. Ridings was awarded the d'Humy Medal in 1960 "for his dedicated effort and notable accomplishments in the development of facsimile telegraph instruments and circuitry." Much of the company's facsimile apparatus for central offices and for customers has been designed by Mr. Ridings. He has been particularly responsible for the fully automatic devices.

Mr. Ridings holds about 53 patents in the field of facsimile and has been responsible for many of Western Union's early developments in this area. Most important of these is the Desk-Fax; over 40,000 units of which are in service in the United States.

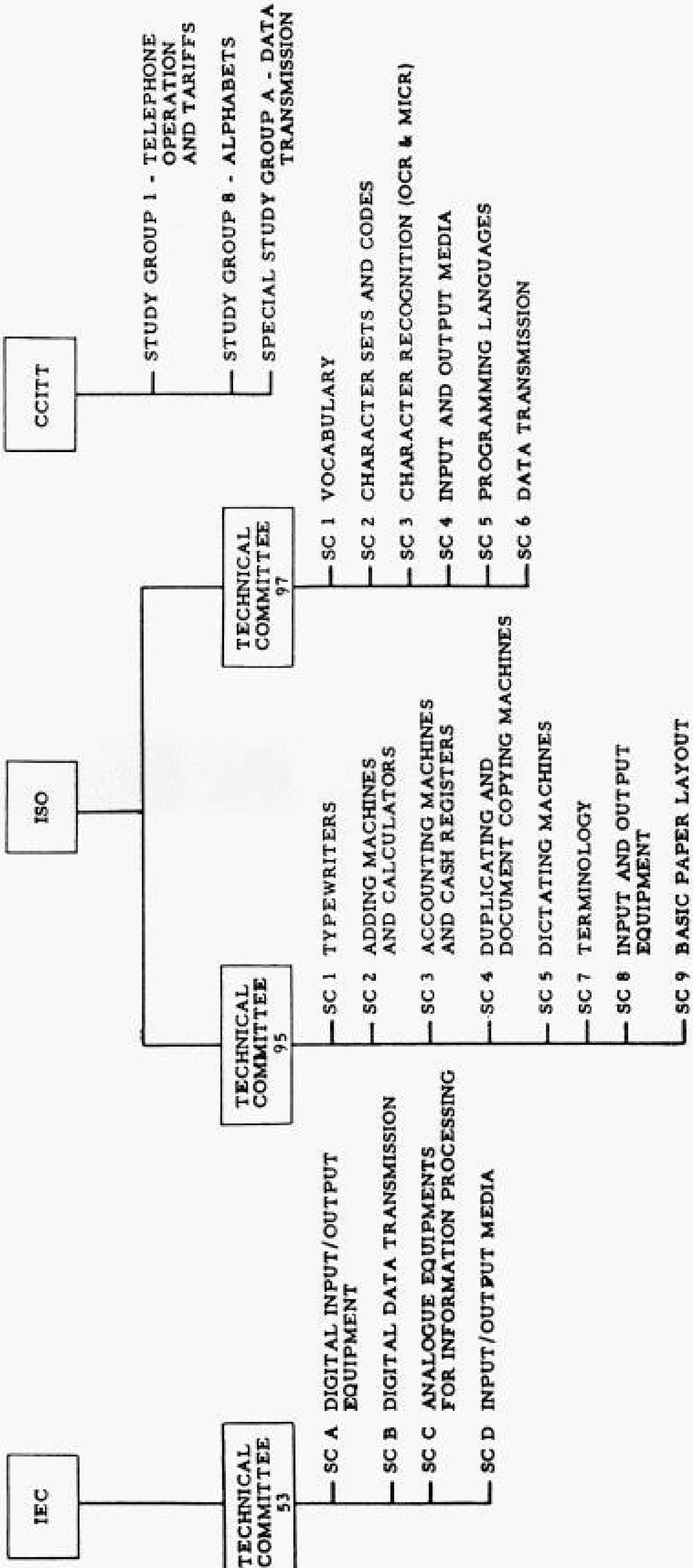
Mr. G. H. Ridings received the 1960 d'Humy Medal from Mr. W. P. Marshall, our President, in September 1960 while Mr. W. H. Francis, now Vice President of Government Relations, looks on.

New Facsimile Transceiver



An article covering a new Facsimile Transceiver used in connection with Broadband Exchange Service has recently been developed by the Facsimile Division and will be described in a future issue of the Western Union TECHNICAL REVIEW.

INTERNATIONAL STANDARDS ORGANIZATIONS



Philip R. Easterlin, Planning Engineer (Retired)—Planning Department

CCITT Sets New Standards at the Third Plenary Assembly

The Western Union Telegraph Company was represented at the Third Plenary Assembly of the CCITT which met in Geneva, Switzerland, May 25-June 26, 1964.

Over 400 delegates from 70 nations comprised the various study groups. A number of new and revised recommendations were formally adopted.

Mr. Philip R. Easterlin, of the Planning Department, represented The Western Union Telegraph Company at the Third Plenary Assembly in Geneva as he had previously at the Second Plenary Assembly in New Delhi, India, in 1960. Mr. Easterlin retired from The Western Union Telegraph Company on September 1, 1964 to become Vice President—Plant and Engineering of Western Union International, Inc. However, Western Union representation on this Committee will be maintained. Mr. J. Z. Millar, of the Plant and Engineering Department will represent The Western Union Telegraph Company on the CCITT and CCIR (Consultative Committee International Radio) at all future meetings.

CCITT Standards

CCITT, Consultative Committee International Telegraph Telephone, is the organization within the ITU (International Telecommunications Union) responsible for making recommendations which become standards for all facets of international telegraph and telephone operation. It is world-wide in scope. Except in instances of bi-lateral agreement, the CCITT recommendations are accepted by national administrations and the telegraph and telephone carriers in the USA, for the operation of their international telecommunications services with other countries.

In general, Western Union's domestic Telex system conforms to CCITT recommendations. Thus, Western Union's system is completely compatible, for fully automatic through-dialing operation, with those systems in Canada, Mexico and, through the facilities of the three U.S. International Carriers (WUI, RCAC and AC&R), with overseas Telex networks.

Developments at the Third Plenary Assembly

During the Third Plenary Assembly, the CCITT approved the reports of 19 study groups and numerous special working parties. It also assigned further questions for study for the next plenary to be held in Argentina, in 1968.

Among the various actions taken by the Plenary Assembly of prime concern to the U.S. telegraph carriers are the following:

1) A new Type C Telex signalling system for intercontinental transit working was adopted.
2) Action on the new telegraph alphabet, comparable in purpose to the ASCII (American Standard Code Information Interchange) code, was deferred to a special working party for further study.
3) International Telegraph Alphabet No. 2 was modified to provide two additional upper case combinations for national use.

   This was accomplished as follows:

   abandonment of upper case C (:)
   abandonment of upper case K (()
   replacement of upper case L ()) by [illegible]

4) Revisions were made in the International message format to allow for the re-transmission of messages through computerized and other

types of automatic message handling systems.

5) Optional use of time, date, register numbers and automatic request of answer back sequence was prescribed for intercontinental Telex circuits. This also dealt with the need for reducing the time for establishing connections.

6) Provisional recommendations were adopted covering two new multiplex systems, 5 and 6-unit codes respectively, which have improved features for handling the Telex signalling criteria and the sub-division of 50-baud telegraph channels. The chief use of the new multiplex systems will be on VF (voice frequency) carrier telegraph systems operated over the TAT (Trans-Atlantic Telephone type cables.

Recommendations for Data Transmission

Special Study Group A, dealing with data transmission, also met at Geneva and submitted its report to the Plenary Assembly which approved the recommendations of the group on the following:

1) Use of the Telex network for data transmission at the modulation rate of 50 bauds.

2) 200-baud data transmission on telephone-type circuits.

3) Standardization of modulation and data signalling rates for synchronous data transmission in the general switched telephone system. So far this covers 600 and 1200 baud operation.

4) A 600/1200 baud modem for use in the switched telephone network.

5) Standards for the type and form of signals exchanged at the interface between data processing terminal equipment and data communication equipment. This recommendation is similar to the U.S. standard interface, EIA (Electronic Industries Association) RS-238, but the number of control conductors across the interface has been increased.

6) A recommendation outlining the procedure for cooperation with other International organizations on the matter of standards for data transmission. This step was taken to clearly define the point that CCITT is responsible for the standards on transmission channels and modems, including the transmission bit order for the new telegraph alphabet being developed for data transmission.

CCITT Working Procedure

New CCITT recommendations, or the revision of existing recommendations, are developed by means of a three-stage procedure involving "questions," "contributions" and finally "recommendations." Because of the diversified national interests of the many countries involved, the above procedure normally requires 2 or 3 years and sometimes longer.

Briefly summarized, CCITT members or associate members (industrial and scientific organizations) may submit a question for study. If the Plenary Assembly deems that the study is warranted, participating organizations may then express their views on the question in the form of a contribution. Suitable action is then taken by the study group and the reply to the question may result in a draft recommendation which is formally adopted or rejected at the next Plenary Assembly meeting.

Administrations or private operating agencies, feeling the need for additional standardization or revision in existing international tariff, operation and technical practices, may also submit the matter in the form of a question for study. After review by the Plenary Assembly the question is then assigned to the appropriate study group. Some questions are rather broad in scope and are not always within the competence of a single study group and these may require the setting up of a special working party jointly comprised of members of the several interested study groups. Typical of such questions are the special working parties for the new telegraph alphabet and message re-transmission.

Study Group Meetings

The actual spade work in CCITT is done at the study group or special working parties meetings, each of which meets on an average of once or twice yearly. These meetings are usually held at ITU headquarters in Geneva and an attempt is made to schedule several consecutive study group meetings of a contiguous nature, such as telegraph apparatus, telegraph switching, etc., so as to minimize the travel requirements of participants. In general, study group meetings dealing with technical matters are usually provided with consecutive interpretation in the required languages in order to convey the more precise meaning.

The study group meetings are presided over by a Chairman and Vice Chairman who are representatives of either an administration or private operating agency and are selected for these posts by the preceding Plenary Assembly because of their experience in CCITT work and overall background in each specialized area. The Chairman and Vice Chairman are assisted in the conduct of the meeting by a Senior Counsellor from the CCITT Secretariat, who is well versed in CCITT procedures and the background of the recommendations. They also help in clarifying the various viewpoints raised during discussions.

Prior to the scheduled study group meetings, the CCITT Secretariat circulates copies of all contributions on various questions under study to each member of the study group. These contributions are thoroughly studied, discussed at the study group meetings and used as a basis for the group's reply to certain questions.

It is interesting to note that the United States' approach to the CCITT is completely different from that of any other country. On all matters pertaining to regulatory questions, such as tariffs and cost of services, the FCC establishes the U.S. position in meeting with representatives of the U.S. carriers and/or manufacturing representatives, in which case the U.S. carriers are expected to adhere to these positions in their discussions with any other delegations. In the case of non-regulatory (technical or operating) questions, the U.S. carriers can jointly present the common position and even have one common spokesman in study group meetings. On the other hand, each individual carrier can express divergent views on the floor of the study group meeting.

The study group summarizes the work on individual questions in a preliminary report which is presented in final form to the next Plenary Assembly. The reply to various questions often forms the basis for new or revised recommendations or the reply may state the reasons why a recommendation should not be issued.

The United States delegation, headed by M. H. Woodward of the Federal Communications Commission, included representatives from the Department of State, Western Union International, ITT International Communications, RCA Communications, American Telephone and Telegraph and General Telephone and Electronics. ***Mr. P. R. Easterlin, second from left, faces the camera.***

Steeneck, R., Data Systems Engineer—Data Sys. Div.—Plant and Engineering Dept.

Development of Error Correcting Codes

Part I—Modulo 2 Arithmetic

In 1950 Dr. E. W. Hamming introduced a binary code that could not only detect errors but could also correct them provided only one bit of the code was in error.[1] This simple code was based on the principle of using more than one parity bit per block and then assigning each parity bit to a different combination of information bits. Thus, each possible single-bit error produces a particular combination of non-checking parity bits.

As an example, if bit 7 in Figure 1 were in error, it would produce non-checks on parity bits P_1, P_2 and P_4. This is the only single-bit error that can produce such a non-check pattern and therefore the pattern indicates the location of the error. The code is relatively simple and requires no complex mathematics in its explanation or its operation.

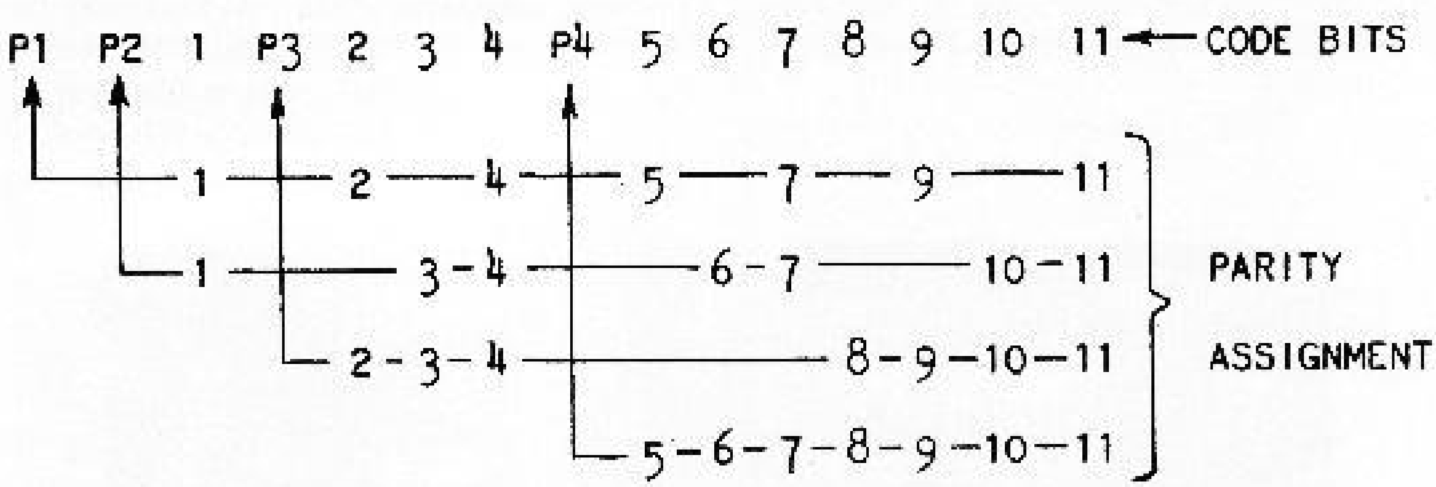


Figure 1. Hamming Single-Bit Error Correcting Code

Dr. Hamming's breakthrough triggered off a relentless search for codes which do more than just detect and correct one-bit errors. Several much more complex codes appeared later. These codes not only corrected one-bit errors but also corrected two-bit errors. The search finally culminated in a general mathematical solution which was published in 1960 by R. C. Bosé and D. K. Ray-Chaudhuri. This disclosure indicated that codes which correct beyond the two-bit range were possible.

It is not the purpose of this article to repeat the mathematical disclosures given by those introducing multiple-error correcting codes, but instead to view the field from a broad angle, avoiding as much as possible the confusion, associated with complex mathematical terms, that seems to engulf the basic simplicity of the subject of binary digits.

Most explanations of multiplex error correcting codes first refer to polynomials; such as the general polynomial:

$$A+BX^1+CX^2+DX^3+EX^4+FX^5 \ldots$$

etc.

At this point one might logically ask: "What have polynomials to do with digital codes"?

Digital Codes

To answer this we must first review some of the history of digital codes. For many years the characters in digital codes were described in terms of "marking" and "spacing" pulses. The advent of computer technology, however, changed marking and spacing pulses into bits, such as "1" and "0." So today each character in a digital code may be considered as a binary number. The mathematician considers that all numbers are polynomials—and thus all digital codes are polynomials.

Figure 2 shows how the number, "101, 011" can be expressed as a polynomial. A polynomial such as $1(10)^0+1(10)^1+1(10)^2$ . . . etc., reads from left to right while a number in Arabic form reads from right to left.

"Addition"

In Modulo 2 "Addition," digits are never carried over into adjacent columns. For instance, in binary addition, 1 plus 1 equals 10 while in Modulo 2 addition 1 plus 1 equals 0. The second digit of the answer is dropped.

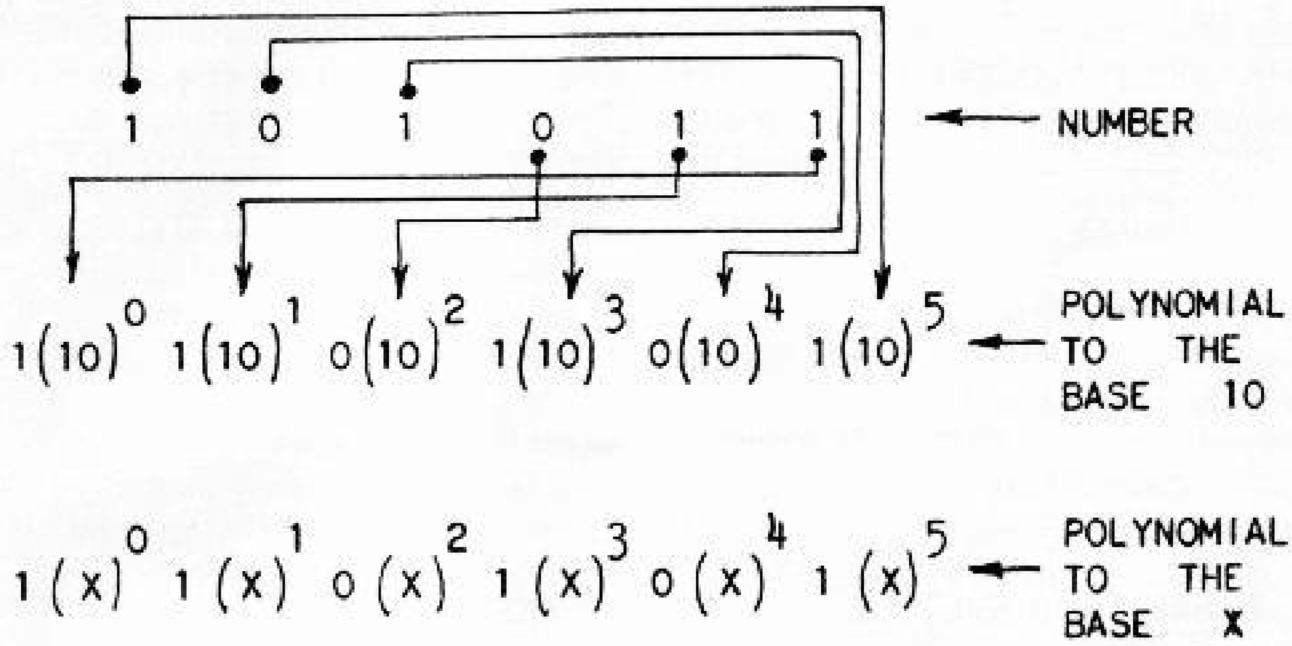


Figure 2. A Number in Polynomial Form

Since polynomials are general expressions of numbers, they are most useful in solving general problems involving numbers which are not necessarily limited to the binary or decimal system of notation.

However, since digital codes are concerned only with binary notation, there is no need to use general polynomials in explaining their operation. The process of error correction may be illustrated by simple binary arithmetic.

Unfortunately one cannot do this without first becoming familiar with a somewhat simpler form of binary arithmetic called Modulo 2 arithmetic.

Modulo 2 Arithmetic

Modulo 2 arithmetic may be considered a somewhat random system of binary addition, subtraction, multiplication and division in which operations are performed on a odd-even basis. In other words, there is no "carry over" to or subtraction from adjacent columns. It might be better described as parity arithmetic. The following explains Modulo 2 arithmetic by comparing it with binary arithmetic.[3]

Figure 3 shows the sum of two binary numbers in binary arithmetic and in Modulo 2 arithmetic. The rule is "simply add—but don't carry digits to the adjacent columns." A quick way of performing Modulo 2 addition is to examine each column. If it contains an odd number of 1's, the Modulo 2 sum is 1. If the column contains an even number of 1's or no 1's at all the Modulo 2 sum is zero.

Modulo 2 "Subtraction"

In Modulo 2 "Subtraction" the process again is similar to that of binary subtraction, except that "one" can be subtracted from "zero" by borrowing a hypothetical second digit, thus making the subtraction possible by changing the "zero" into 10, as shown in Figure 4. If a comparison is made between the addition shown in Figure 3 and the subtraction problem shown in Figure 4, it will be noted that both problems use the same digits and both produce the same answer.

In Modulo 2 arithmetic one can subtract a large number from a small number, without getting a negative answer.

BINARY ADDITION

$$1 + 1 = 10$$

$$\begin{array}{r} 110110 \\ +101111 \\ \hline 1100101 \end{array}$$

BINARY SUM

MODULO 2 ADDITION

$$1 + 1 = 0$$

SECOND DIGIT DROPPED

$$\begin{array}{r} 110110 \\ +101111 \\ \hline 011001 \end{array}$$

MODULO 2 SUM

Figure 3. Comparison of Binary and Modulo 2 Addition

BINARY SUBTRACTION

$$10 - 1 = 1$$

$$\begin{array}{r} 110110 \\ -101111 \\ \hline 000111 \end{array}$$

BINARY DIFFERENCE

MODULO 2 SUBTRACTION

$$0 - 1 = 1$$

SECOND DIGIT BORROWED FROM NOWHERE TO CHANGE 0 TO 10 TO COMPLETE SUBTRACTION.

$$\begin{array}{r} 110110 \\ -101111 \\ \hline 011001 \end{array}$$

MODULO 2 DIFFERENCE

Figure 4. Comparison of Binary and Modulo 2 Subtraction

One can also produce the same answers in subtraction as one does in addition. Although Modulo 2 addition and subtraction may seem to have no practical function, electrical circuits performing these functions have been in practical use for some time. A pair of two-way switches, both controlling one light circuit, is perhaps the best example of a Modulo 2 "adder." The position of one switch is in effect added to the position of the second switch. If the sum of the addition is "1," the lamps light; and if the sum is "0," the lamps go out.

Before proceeding with an explanation of Modulo 2 division and multiplication, it might be well to examine the possibilities of using addition and subtraction alone to produce error correcting codes.

Error Correcting Codes

If during transmission of a message, every bit to be sent is repeated, errors can be detected but not necessarily corrected. Figure 5 illustrates that the location of errored bits cannot be pinpointed by a single repetition of each bit transmitted. A double repetition to provide error correction is required unless the repeated bit can be tied in with other bits. This may be done by using Modulo "2" addition, as illustrated in Figure 6.

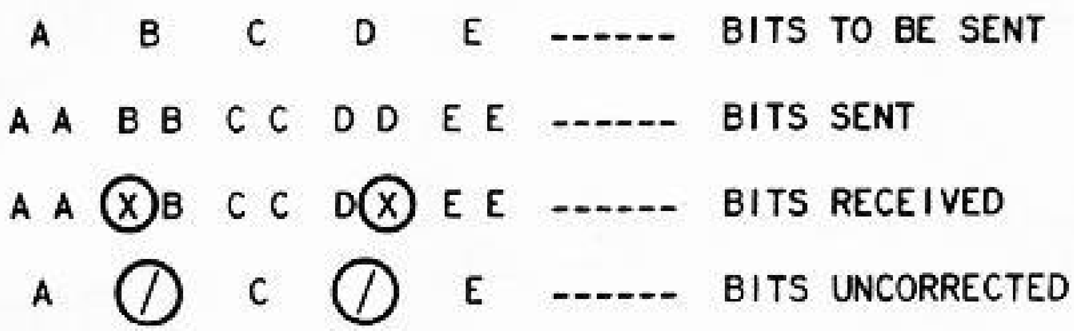


Figure 5. Double Transmission Provides No Correction

In this method a protection bit is transmitted after every information bit. The protection bit is generated by adding the two previous information bits together. At the receiving end the same process is repeated. If all bits are correct, the error correcting sum following each information bit will be zero.

In Figure 6, bit C is shown as received in error. Under this condition, the two error correcting sums following the errored bit B will each be "1." This condition is used to point back to bit C as being the bit in need of correction.

If a check bit is errored, only one error correcting sum will be "1" and this condition will not call for correction of an information bit.

It should be noted, however, from this illustration, that if bit C were received in error and a second error occurred during the reception of the next three bits, the error correction function will fail. Under such a condition the error will either be ignored or the wrong bit will be "corrected."

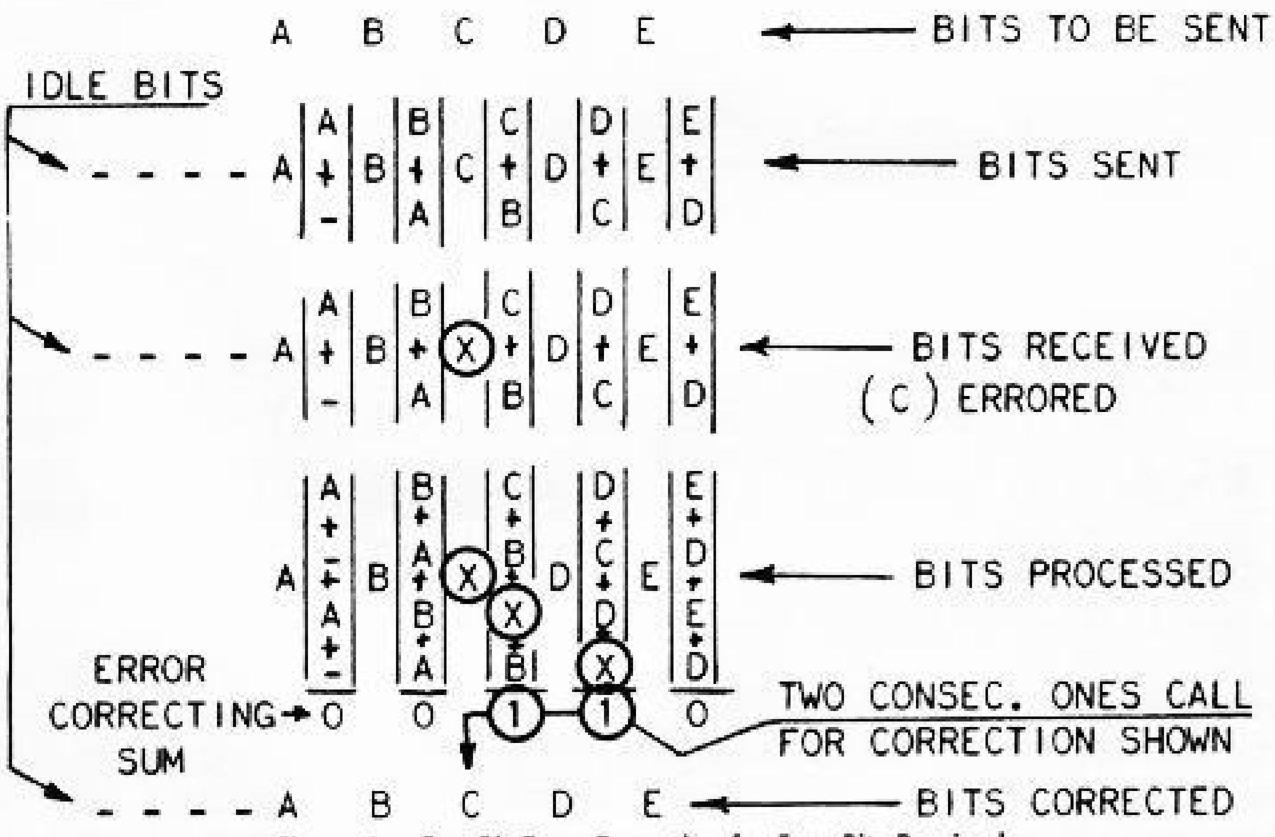


Figure 6. One-Bit Error Correction for Four Bits Received

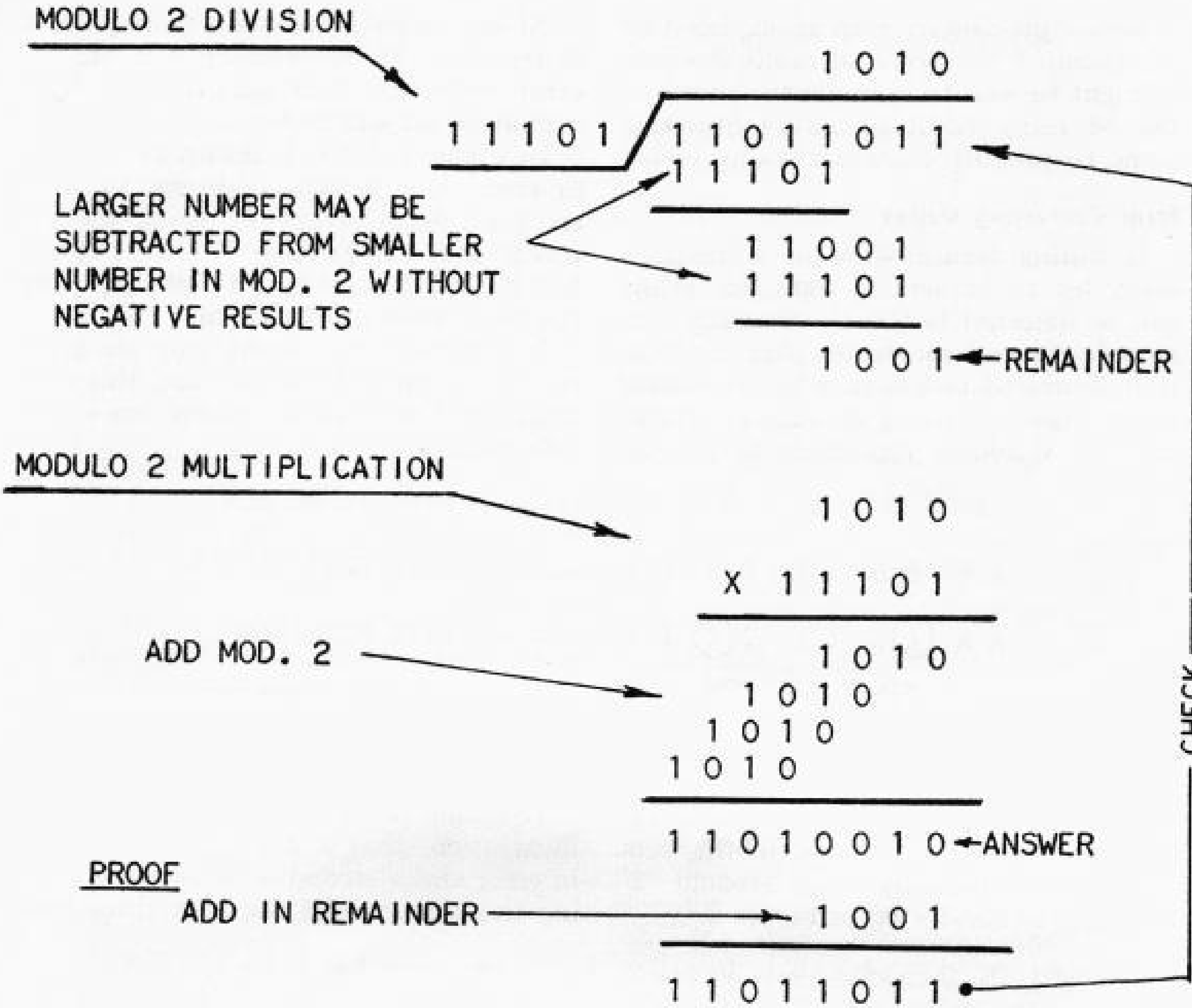


Figure 7. Modulo 2 Division and Multiplication

However, all error correcting codes are subject to definite limitations and cannot be assumed to correct all transmission errors. Although this simple code is limited to correcting single bit errors, it must only wait 3 bits after every single bit error before it is in condition to correct another single bit error.

Continuously generated error correcting codes may be devised in many more complex ways to gain some advantage over the system shown. The basic principle, however, is the same in that protection bits are generated from an interlace of other bits in order to form a code structure that can correct as well as detect errors.

Continuously generated error correcting code systems have some advantages over error correcting codes system generated in block form. Although "block" error correcting codes require less redundancy than the "continuously generated" error correcting code shown, in general they require more complex circuiting in both the generation and correction operations. Continuously generated codes generally fit in well with shift register and flip-flop techniques.

While Modulo 2 "Addition" is practically the same as Modulo 2 "Subtraction," Modulo 2 "Division" is very different from Modulo 2 "Multiplication" both in operation and result.

"Division"

Figure 7 illustrates Modulo 2 "Division." The dividend, 11011011, divided by the divisor, 11101 is recognized as a common procedure in arithmetic, yet in operation is quite strange.

The first five digits of the dividend, 11011, are shown as divisible by the divisor once, even though the divisor, 11101, is larger than the first 5 digits of the dividend 11011. This is possible since, in Modulo 2 "Subtraction," it has been shown that a larger number may be subtracted from a smaller number, without getting a negative result.

"Multiplication"

Modulo 2 "Multiplication" is illustrated in the lower half of Figure 7. The number 1010 is multiplied by the multiplier, 11101 which was the divisor in the Division above. Using Modulo 2 Addition, it may be seen that the "answer" is 11010010, which when added to the "Remainder" produces the final figure 11011011. This checks with the "dividend" above in the Division problem.

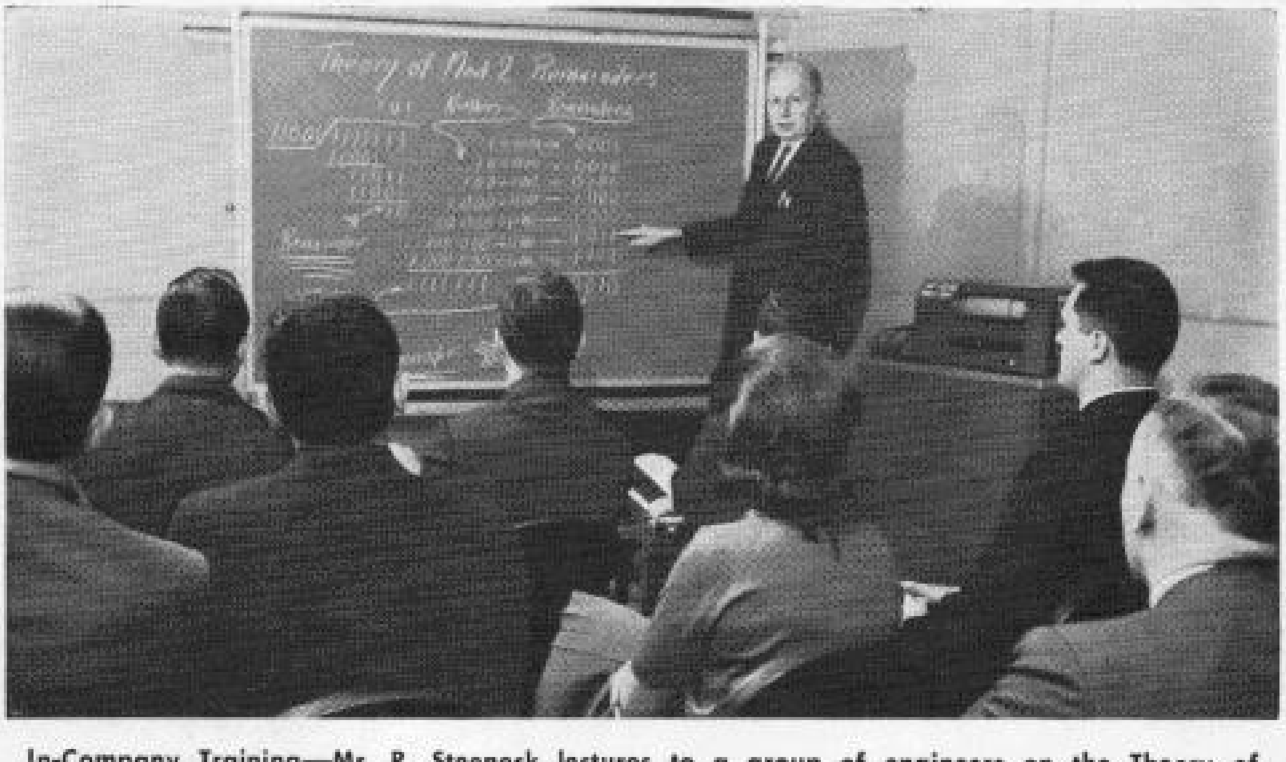
It is obvious that Modulo 2 Multiplication uses the same procedure used in standard multiplication, except that all addition processes are performed in Modulo 2 addition.

* * *

References

1. R. W. Hamming, "Error Detecting and Error Correcting Codes", The Bell System Technical Journal, Vol. XXVI, April 1950.
2. R. C. Bosé—D. K. Ray Chaudhuri, "Error Correcting Codes", Information & Control, Vol. 3, No. 1, March 1960.
3. Fred W. Smith, New American Standard Code for Information Interchange, Western Union TECHNICAL REVIEW, Vol. 18, No. 1, April 1964.

Part II of this article will describe the development of Error Correcting Codes which correct more than one-bit errors. Error Correcting Codes in Block Form will be published in the January 1965 issue of the Western Union TECHNICAL REVIEW.



In-Company Training—Mr. R. Steeneck lectures to a group of engineers on the Theory of Modulo 2 Arithmetic.

Data Transmission
Data Processing
Electro-Mechanical Devices

Feld, N. L.: Punched Card Transmitter

Part I—General Description and Applications

Western Union TECHNICAL REVIEW, Vol. 18, No. 4 (Oct. 1964)
pp 134 to 139

The Punched Card Transmitter is an electro-mechanical device for transmitting cards in data processing systems at 5 to 6 cards per minute.

The unit automatically feeds cards from a stack, translates the Hollerith to Baudot code, and transmits the information serially over a single telegraph channel.

This article describes the features of the unit and shows how it may be applied in data communications systems.

The card feed and read mechanisms will be described in Part II of this article.

Information's Processing
Error Detection Device
Error Correction Device
Data Transmission

Durachinski, J. J.: EDAC

Western Union TECHNICAL REVIEW, Vol. 18, No. 4 (Oct. 1964)
pp 140 to 148

This article describes an error detecting and automatic retransmitting device called EDAC—Error Detection Automatic Correction—designed by Western Union. The design concept, including the general theory of operation and method of error detection, is included. Application and effectiveness of the device are pointed out.

Facsimile Papers
Recording Media

Falkenberg, J. A.: New TELEDELTOS Paper—Types 2AL and L-62

Western Union TECHNICAL REVIEW, Vol. 18, No. 4 (Oct. 1964)
pp. 150 to 151

Two new types of TELEDELTOS, 2AL and L-62, have been developed at Western Union, for use in its facsimile systems. Using these papers, typewritten or handwritten messages are scanned by means of a photoelectric cell, creating electrical impulses which are transmitted via telegraph. The papers are described in this article and some of their applications in recording instruments, computers and in military use are enumerated.

Principles of Facsimile
Photographic Recordings
Facsimile Processes

Ridings, G. H.: Facsimile Imaging Systems—Part I

Western Union TECHNICAL REVIEW, Vol. 18, No. 4 (Oct. 1964)
pp. 152 to 159

This is Part I of of series article on the fundamental principles of facsimile. It was extracted from a paper delivered to the Society of Photographic Scientists and Engineers in February 1964 at the Chemists Club in New York City. Parts II and III will appear in the January and April 1965 issues of the Western Union TECHNICAL REVIEW.

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Telex
Codes
International Standards
Technical Meetings

Easterlin, P. R.: CCITT Sets New Standards at the Third Plenary Assembly

Western Union TECHNICAL REVIEW, Vol. 18, No. 4 (Oct. 1964) pp. 160 to 163

During the 3rd Plenary Assembly of the CCITT in June 1964 in Geneva, Switzerland, recommendations for U. S. telegraph carriers were approved. Of these, actions on a new type C Telex signalling system for intercontinental transit was adapted, action on a new telegraph alphabet was deferred, International Telegraph Alphabet No. 2 was modified, etc. This article points out the highlights of this meeting and summarizes the working procedure of the Committee.

Codes
Modulo 2 Arithmetic
Error-Correcting Devices

Steeneck, R.: Development of Error Correcting Codes—Part I

Western Union TECHNICAL REVIEW, Vol. 18, No. 4 (Oct. 1964) pp. 164 to 169

Part I of this article is an introduction to the development of error correction codes. It briefly covers the history of such codes, explains the functions of Modulo 2 Arithmetic in the design of such codes and describes a simple continuously generated, error-correcting code.

New Products
Facsimile
Broadband Service

Facsimile Transceiver

Western Union TECHNICAL REVIEW, Vol. 18, No. 4 (Oct. 1964) pp. 159

A new Facsimile Transceiver for Broadband Exchange Service has been developed.

Announcements

Management Information Systems Group

Western Union TECHNICAL REVIEW, Vol. 18, No. 4 (Oct. 1964) pp. 172

This announcement of a new organization points out the objectives of the Management Information Systems Group in providing a "Complete System Management" capability.

Management Information Systems Group

Offers New W. U. Service For

Information Processing Systems

Western Union has established a Management Information Systems organization to provide customers with a total management capability. Since the company has the capability for furnishing data transmission services for all types of information processing systems, the new MIS group will arrange to design, procure and install all necessary hardware required for a fully mechanized system—and provide the total management service of such a system.

The engineering disciplines offered by the Management Information Systems group are:

Systems Analysis	—	*determining the total information and data transmission requirements,*
Communications Engineering	—	*engineering the communications requirements of the system,*
Systems Procedures	—	*preparing procedures for information processing,*
Development of Systems	—	*developing the hardware to meet the system's needs,*
Programming	—	*preparing programs for customer's data processing system,*
Implementation	—	*installing the total information system,*
Operation of System	—	*providing the total system's management for leased or customer-owned services.*

Western Union can provide complete system management from system concept through operation of the total system.