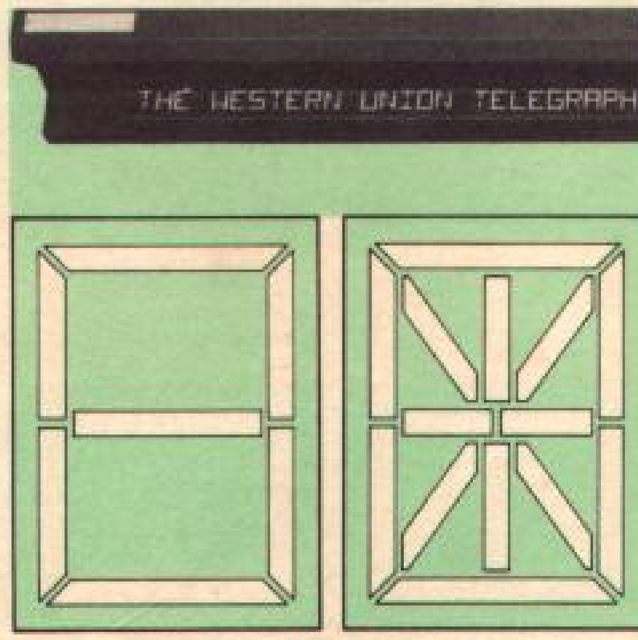
Western Union Technical Review

Volume 17 Number 1

JANUARY 1963

VARACTOR



ELECTRO-QUOTE

WESTERN UNION DIVERSIFIES

MICROWAVE SYSTEMS

DISPLAY DEVICES

TELECOMMUNICATIONS

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SENSOR FOR BOMB ALARM

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

Address all communications regarding the Western Union TECHNICAL REVIEW to:
The Editor
Western Union TECHNICAL REVIEW
The Western Union Telegraph Co.
60 Hudson St.
New York 13, N. Y.

Western Union TECHNICAL REVIEW, published quarterly in January, April, July and October.

Subscription Rates:	United States	— $2.00 per year
	Other Countries	— $3.00 per year
Single Copies:	United States	— 50¢ plus handling charge
	Other Countries	— 75¢ plus handling charge
	Handling Charge	— 50¢ per order
Checks:	Make check payable to: Western Union Telegraph Company (TECHNICAL REVIEW)	

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JANUARY 1963

VARACTOR DIODE PART 1

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ELECTRO-QUOTE

DISPLAY SYSTEM

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Data Card Transmitter

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BOMB ALARM

Display System 210-A

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Patents Recently Issued to Western Union

Volume 17

Number 1

THE WESTERN UNION TELEGRAPH CO.

60 HUDSON ST., NEW YORK 13, N. Y.

WESTERN UNION

Technical Review

Volume 17
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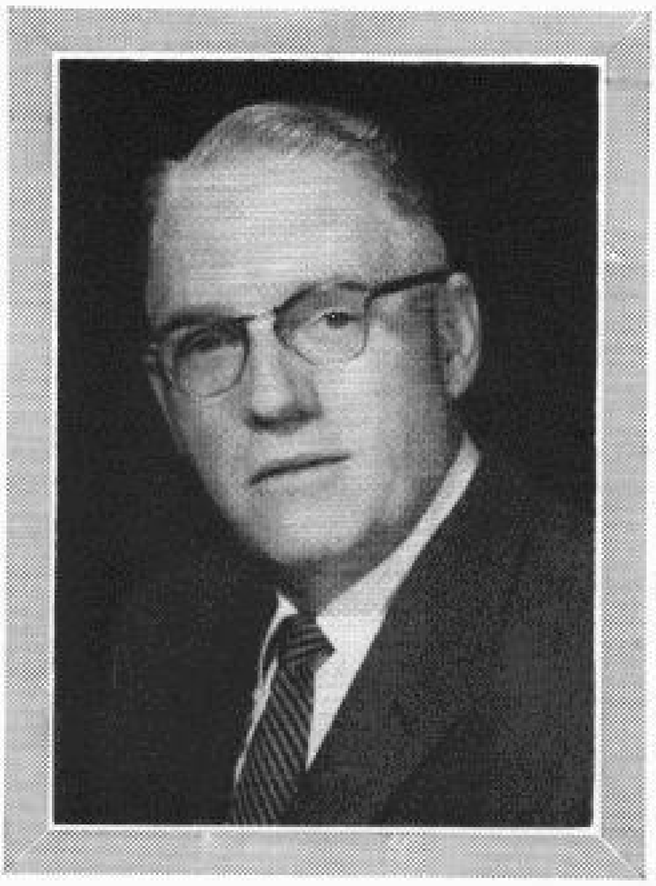
MARKETING our TECHNICAL KNOW-HOW

To the Readers of
The Western Union TECHNICAL REVIEW

It is with great pleasure that I greet you, the readers of the Western Union TECHNICAL REVIEW, *on this occasion of the first issue of the publication in 1963.*

Today, when diversification is the keynote in communications, technological improvements in transmission methods assume a more important role than ever before. Therefore, we have a responsibility to ourselves and to our company to keep informed on these advances, so closely associated with our own industry, and to be reasonably conversant about them. I can think of no better means of doing so than through TECHNICAL REVIEW, *the contents of which are prepared by men of achievement in their own right and who are well qualified to speak authoritatively on subjects in their particular field.*



The Marketing Department, is charged with the advertising, promotion, sale of all our present services, and with the development of additional ones. Understandably, we have a great deal more than passing interest in TECHNICAL REVIEW. *In order to effectively meet competition and obtain the best results from our efforts to secure additional revenue, we must keep ourselves up-to-date with all available information on the constantly changing developments in communications. We find the* TECHNICAL REVIEW *of great value for this purpose and I am sure that those of you in other departments, with other functions to perform, have also found this to be true.*

So, I commend the Western Union TECHNICAL REVIEW *and its staff for the consistantly excellent editorial standards maintained and, urge you, the reader, to avail yourself of each opportunity to thoughtfully read, and treat each of its issues as a source of future reference. The knowledge thereby gained will broaden your concepts of our industry, stimulate your thinking and interest, and, in turn, make you a more valuable representative of Western Union.*

VICE PRESIDENT-MARKETING

R. L. Ernst and J. K. Fitzpatrick, Engineers, Radio Systems Division

VARACTOR DIODE

Part 1*-Theory

MAINTENANCE costs are a controlling factor in evaluating the economics of present day microwave systems. Maintenance requirements for vacuum tube circuitry are necessarily high. Therefore, the ultimate objective of system designers, today, is to provide higher reliability and thus reduce maintenance.

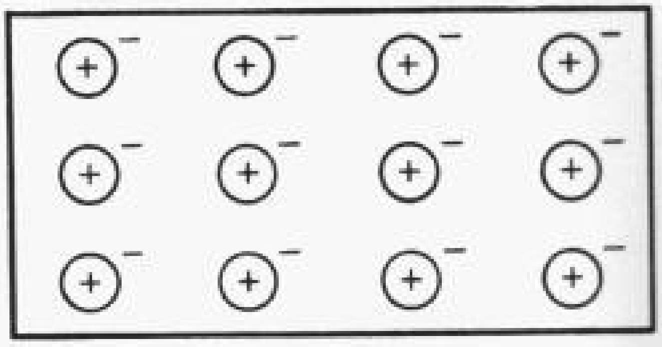
Many electron tube circuits can be replaced with compact transistorized equivalents, which require less power; yet, they provide higher reliability.

Recent development of a solid-state device, called the varactor, promises to advance microwave techniques. With the use of varactors, electron tube devices such as klystrons and traveling wave tubes may be eliminated in many microwave applications.

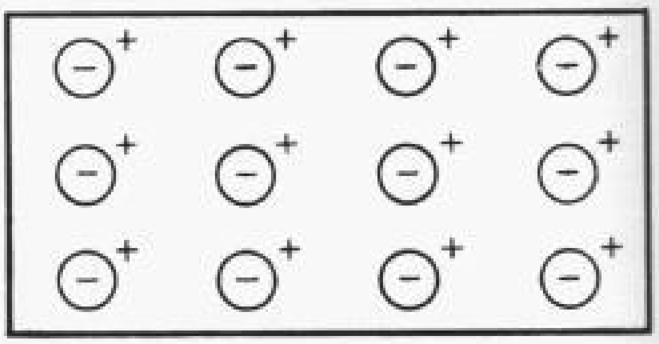
The varactor is a semiconductor junction or diode which acts as a variable capacitance. The term varactor is a contraction of variable reactor. Several typical varactors are shown in Figure 1.

Semiconductor Diode Physics

To understand the properties of the varactor it is necessary to review some semiconductor physics. Throughout this review a mnemonic scheme will be used to represent doped semiconductor materials.



(a) N-doped Semiconductor



(b) P-doped Semiconductor

Figure 2 Mnemonic Representations of Doped Semiconductor Material

Figure 2 illustrates two types of semiconductors, N-doped and P-doped. The mobile charges are represented as minus signs in Figure 2a and as plus signs in Figure 2b. These charges are electrons in Figure 2a and holes in Figure 2b. The

* Part II on Applications of the Varactor Diode will be published in the April 1963 issue of the Western Union TECHNICAL REVIEW.

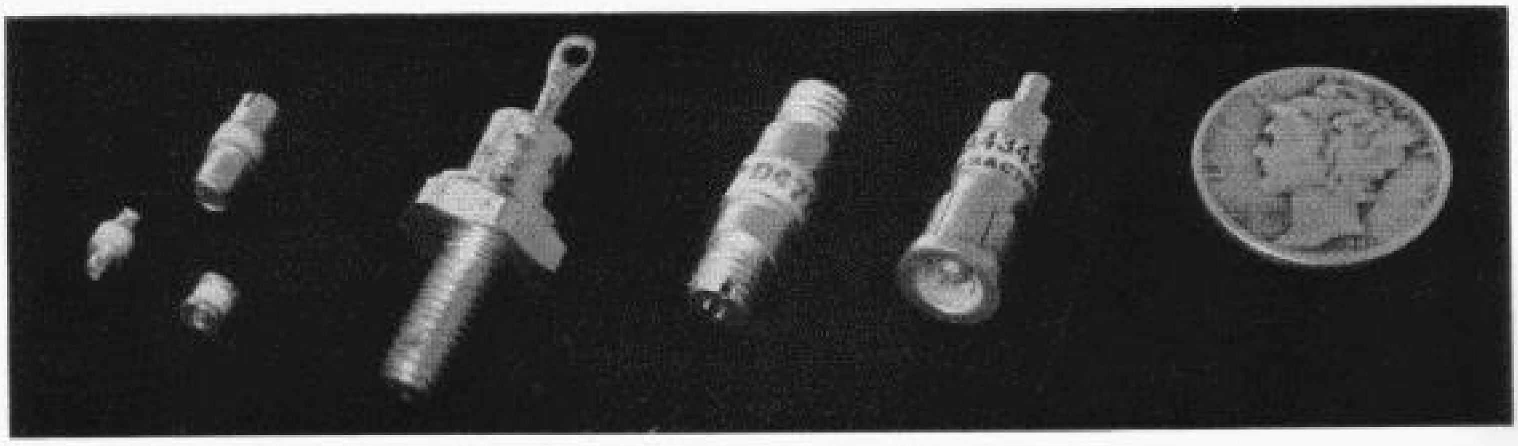


Figure 1 Typical Varactors

associated fixed charges of the semiconductor crystal lattice are represented by a sign of the proper polarity enclosed by a circle. As shown in Figure 3, when a p-n junction is formed, the holes and electrons combine so that there is an excess of positive or negative charges near the junction. Because there are no mobile charges, the area, known as the depletion layer, acts as an insulator. The net charge distribution across this depletion layer results in a potential difference between the terminals of the semiconductor crystal. This voltage, the contact potential, is represented by the symbol, ϕ. It can be seen from the above that increasing the voltage across the junction, V_j, by means of an external battery will increase the thickness of the depletion layer. Since $V_j = \phi - V$ (where V is the applied voltage), it can be seen that when V is made equal to ϕ, the depletion layer thickness approaches zero and the capacitance effect ceases for V in excess of ϕ.

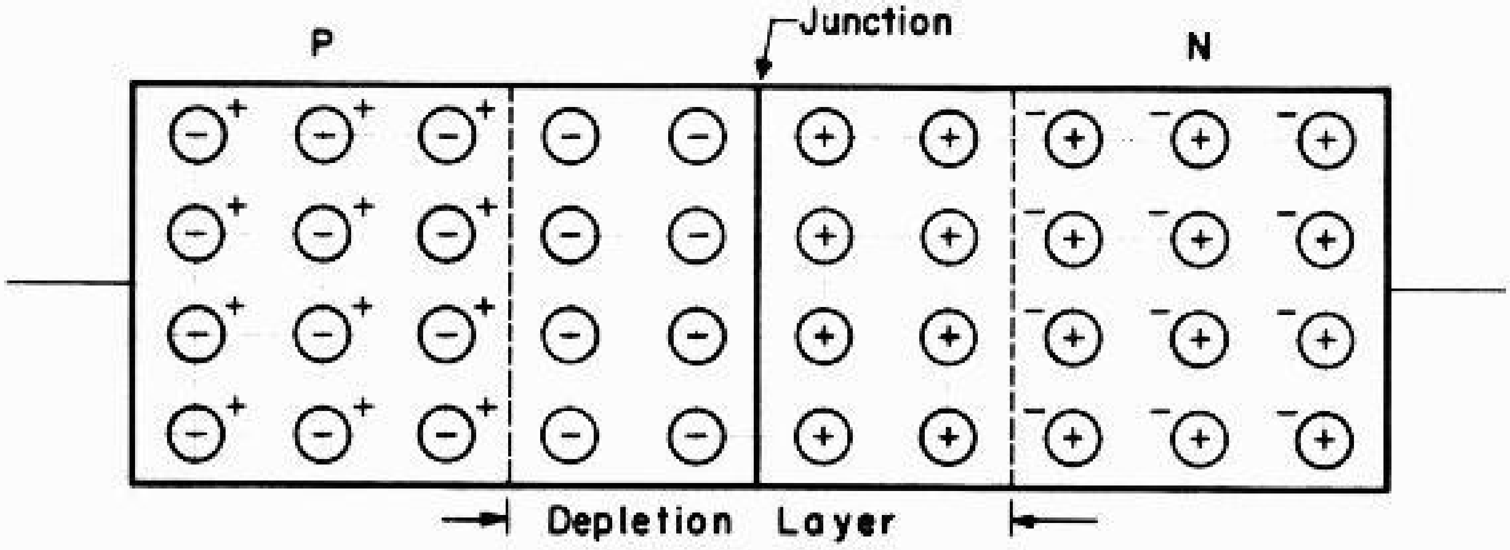


Figure 3 P-N Semiconductor Diode Model

Two typical fixed charge variations are illustrated in Figure 4a. If, on one side of the junction, the impurity density is constant, an abrupt junction diode is formed. However, it is also conceivable to make a diode with impurity density which varies linearly with the distance from the junction. This is called a linearly-graded diode. In Figure 4a, N(x) represents the doping density and x represents the distance from the junction, x being positive on the N side of the junction. The corresponding plots of carrier distribution are shown in Figure 4b. Here, p(x) represents the density of holes and n(x)-the density of electrons. The resultant net charge density is shown in Figure 4c. Here "e" represents the charge on one electron. Notice that the entire piece of semiconductor always has a net charge of zero.

Capacitance Voltage Characteristics

On a qualitative basis the reverse-biased semiconductor p-n junction has the property of a voltage variable capacitor because charges are being effectively stored. A quantitative expression, relating the capacitance per unit cross section area to the applied voltage V, is derived in Appendix I. There, the expression for the graded junction varactor is calculated as:

$$\frac{C}{A} = \epsilon \left[\frac{ea}{12\,\epsilon(\phi - V)} \right]^{1/3} \qquad (1)$$

In other words, a graded-junction diode has a capacitance which varies with the inverse cube root of the applied voltage.

A similar analysis reveals that an abrupt-junction diode has a capacitance which varies as the inverse square root of the applied voltage.

A typical varactor characteristic is given in Figure 5. This voltage variable capacitance properly occurs when the applied voltage, V, varies from a small forward voltage equal to the contact potential, ϕ, to a larger negative voltage, the breakdown voltage. At this breakdown voltage an avalanche process, typical of semiconductor diodes, occurs and

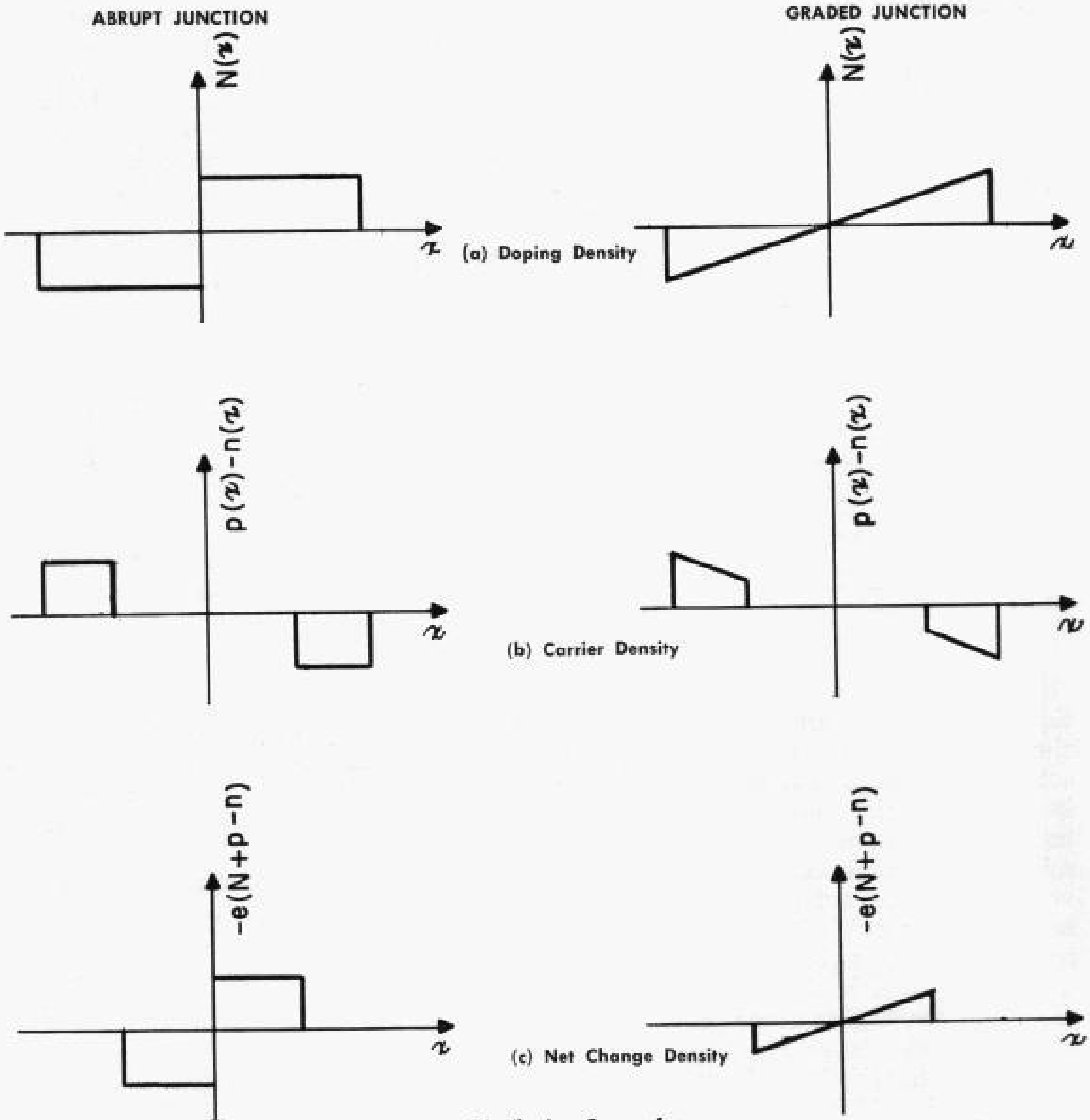


Figure 4 Distribution Curves for Abrupt and Graded Junction Diodes

the diode begins to conduct. Both the contact potential, ϕ, and the breakdown voltage, V_B, are determined by the semiconductor material and the manufacturing process used. Typically, ϕ varies from $+0.2$ volts to $+1.2$ volts and V_B varies from -3 volts to -120 volts.

As the voltage varies, the holes and electrons must migrate through all semiconductor material except the depletion layer. This results in a resistance mechanism in series with the variable or nonlinear capacitance.

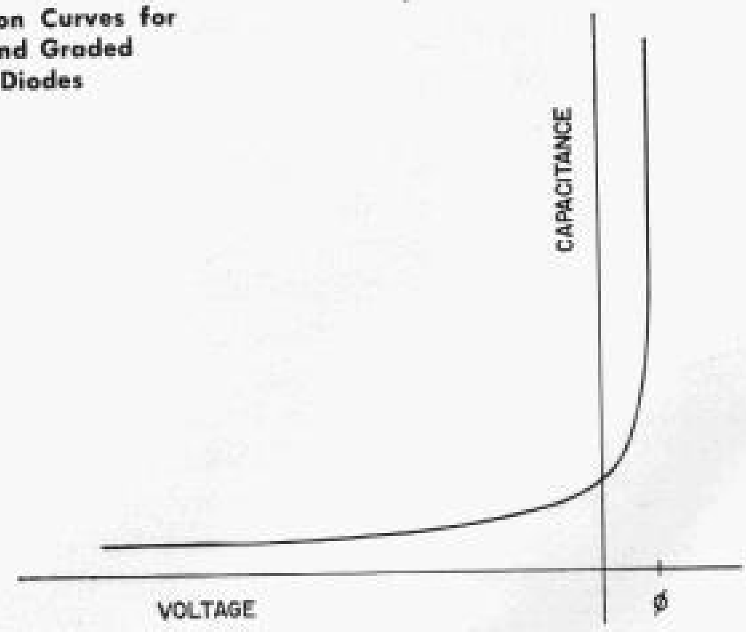
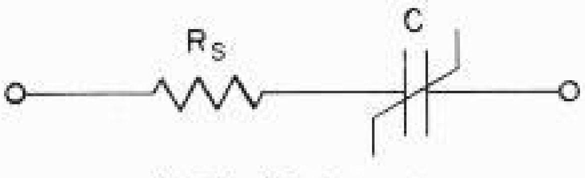


Figure 5 Capacitance vs. Voltage for a typical Varactor

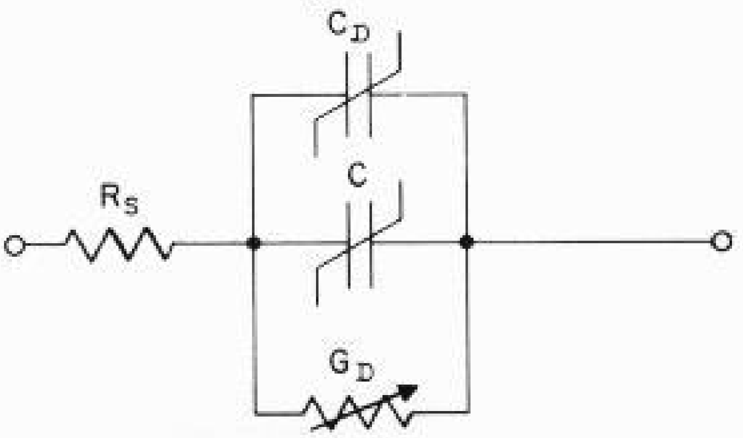
Equivalent Circuit

An equivalent circuit for the varactor is shown in Figure 6a. This circuit is valid only at high frequencies and at voltages between ϕ and V_B. A more complete equivalent circuit is shown in Figure 6b. Here G_D, conductance, takes into account the voltage-current characteristic associated with a typical diode. C_D, the diffusion capacitance, occurs only at extremely high frequencies. When the applied ac voltage drives the varactor slightly positive, holes and electrons cross the junction, become minority carriers, and combine with majority carriers to cause conduction. However, a finite time is required for this combination process; this time is called the lifetime of the minority carrier. If the frequency of the applied voltage is high enough, a large number of minority carriers will be pulled back across the junction before recombination. This periodic storage of minority carriers is responsible for the diffusion capacitance effect.

In most applications of varactors the effects of G_D and C_D are negligible, so that the equivalent circuit, shown in Figure 6a, is sufficient for analysis.



(a) Simplified Circuit



(b) Complete Circuit

Figure 6 Equivalent Circuits for a Varactor Diode

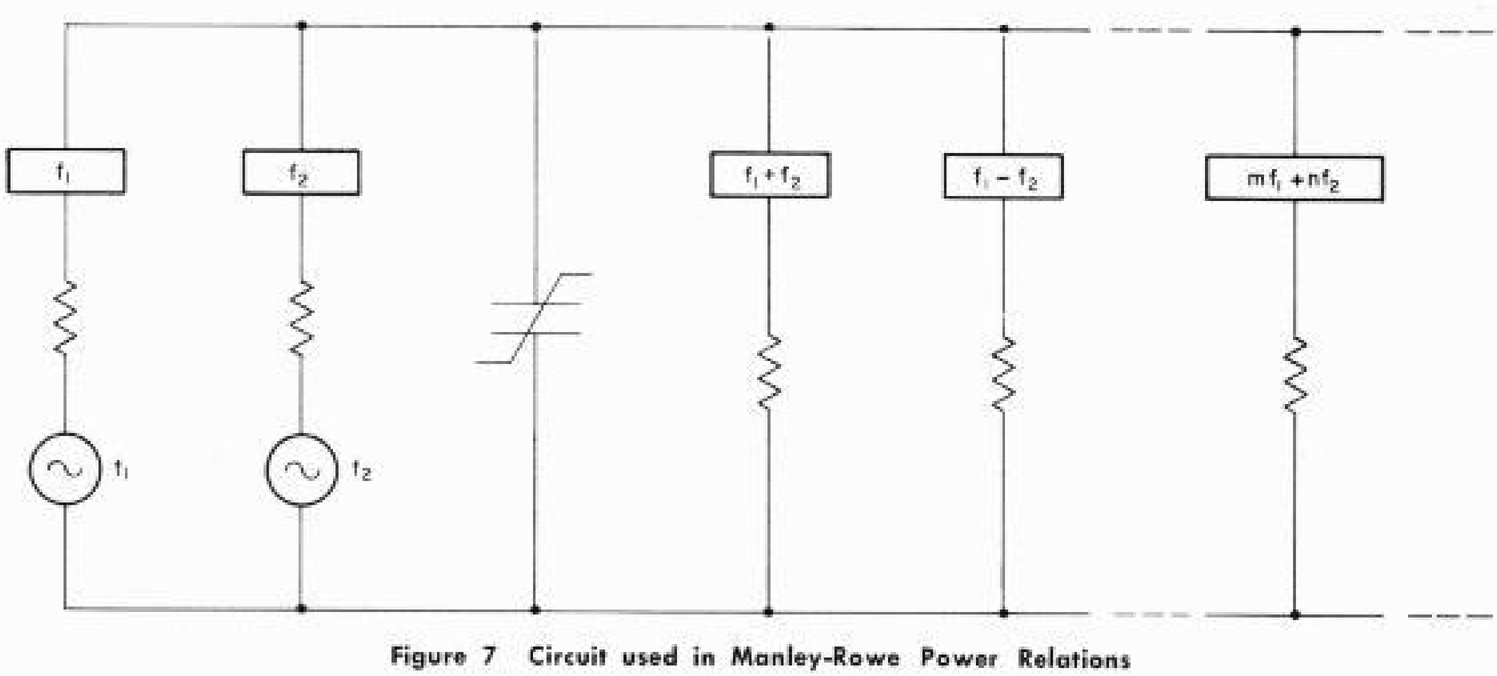


Figure 7 Circuit used in Manley-Rowe Power Relations

Manley-Rowe Power Relations

It has been shown that the actual varactors behave as lossy, nonlinear capacitors. A guide to an initial understanding of the applications of such devices is a pair of equations known as the Manley-Rowe power relations. These expressions relate the power levels at the various frequencies, when the nonlinear capacitor is inserted in a general circuit. This "ideal" nonlinear capacitor is lossless and exhibits the property of nonlinear capacitance at any applied voltage. The circuit in which this nonlinear capacitance is inserted is shown in Figure 7. The blocks are ideal bandpass filters which pass only the frequency designated within the block.

The power, $P_{m,n}$, at each frequency, $mf_1 + nf_2$, is then given by the equations:

$$\sum_{m=o}^{\infty} \sum_{n=-\infty}^{\infty} \frac{m P_{m,n}}{mf_1 + n f_2} = o \quad (2a)$$

$$\sum_{n=-\infty}^{\infty} \sum_{m=o}^{\infty} \frac{n P_{m,n}}{mf_1 + n f_2} = o \quad (2b)$$

To illustrate the use of these equations, consider a circuit in which only power at frequencies f_1, f_2, $f_1 + f_2$, and $f_2 - f_1$ is allowed to be dissipated. This circuit is represented schematically in Figure 8. The letters s, p, i, and u stand respectively for signal, pump, idler, and upper sideband.

To use the Manley-Rowe relations it is necessary to select the proper values of m and n. Because of the manner in which the equations were derived [1], both positive and negative components of each frequency must be used. Table I lists typical values of m and n for this device as follows:

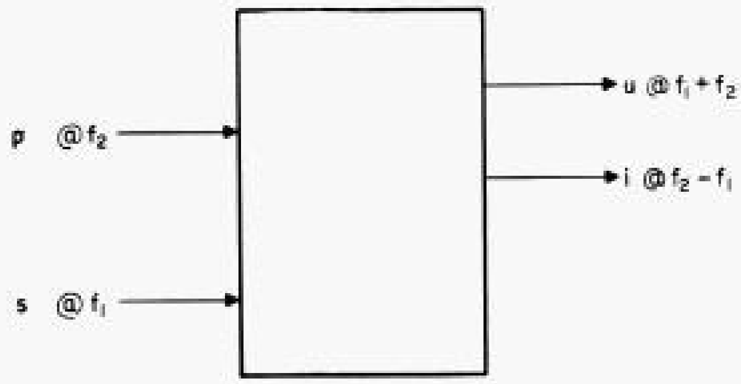


Figure 8 Schematic Representation of Manley-Rowe Power Relations

The equation (4a) is used to determine the ratio of output power to input power, i.e., P_u/P_s. If the convention, that power flowing into the nonlinear capacitance is positive, is used, P_s becomes positive and P_u, negative. The gain of this device can therefore be defined as the negative of this ratio, which is positive.

$$g = -\frac{P_u}{P_s} = \frac{f_u}{f_s} - \frac{P_i}{P_s}\frac{f_u}{f_i} \quad (5)$$

TABLE I

Circuit Frequency	m	n	Manley-Rowe Frequency
f_s	1	0	f_1
f_p	0	1	f_2
f_u	1	1	$f_1 + f_2$
f_i	−1	1	$f_2 - f_1$
$-f_s$	−1	0	$-f_1$
$-f_p$	0	−1	$-f_2$
$-f_u$	−1	−1	$-f_1 - f_2$
$-f_i$	1	−1	$f_1 - f_2$

Substituting each value of m and n into the Manley-Rowe formulas yields:

$$\frac{P_{1,o}}{f_1} + \frac{P_{1,1}}{f_1 + f_2} + \frac{P_{1,-1}}{f_1 - f_2} = o \quad (3a)$$

$$\frac{P_{o,1}}{f_2} + \frac{P_{1,1}}{f_1 + f_2} + \frac{P_{-1,1}}{f_2 - f_1} = o \quad (3b)$$

Expressing this in terms of the actual circuit frequencies yields:

$$\frac{P_s}{f_s} + \frac{P_u}{f_u} + \frac{P_i}{-f_i} = \frac{P_s}{f_s} + \frac{P_u}{f_u} - \frac{P_i}{f_i} = o \quad (4a)$$

and

$$\frac{P_p}{f_p} + \frac{P_u}{f_u} + \frac{P_i}{f_i} = o \quad (4b)$$

Since the term f_u/f_s is greater than unity, it represents a conversion gain. The second term of Equation (5) is likewise positive, because P_i is negative when P_s is positive. This second term is an additional gain to the upper sideband caused by the dissipation at the lower sideband. This additional gain is due to a regeneration effect. Because the power at the lower sideband is dissipated without performing a useful function by itself, it is called the idler power. The mere dissipation of power at the idler frequency is all that is required for gain from the regeneration effect. This device is known as a four-frequency upconverter or as an upper-sideband upconverter with a single idler.

Varactor Parameters

The Manley-Rowe power relations are valuable tools because of the extreme simplicity with which they predict gains and losses in a frequency converting device. However, these devices must use ideal nonlinear reactances. At present, one of the best approximations to this ideal nonlinear capacitor is the lossy voltage-limited varactor diode. It is therefore necessary to develop a design theory which will indicate how to best utilize the varactor characteristic.

Using the capacitance characteristics shown in Figure 5 and the simplified circuit of Figure 6a for a semiconductor diode, theoretical relations have been derived for many types of varactor circuits. In the derivations, certain expressions occur so frequently that it has become convenient to use new varactor parameters for these expressions.

In performing the derivations[2], it was found that the mathematics could be simplified if many relationships were expressed in terms of elastance, S, rather than its reciprocal, capacitance.

At this point it is important to compare the variation of elastance and capacitance with voltage and charge. Charge is considered an independent variable because a sinusoidal charge variation occurs during a sinusoidal current variation. The equations for elastance variation are:

ABRUPT JUNCTION

$$\frac{S}{S_{max}} = \left(\frac{\phi - v}{\phi - V_B}\right)^{1/2} \qquad (6a)$$

$$\frac{S}{S_{max}} = \left(\frac{q_\phi - q}{q_\phi - Q_B}\right) \qquad (7a)$$

$$\left(\frac{\phi - v}{\phi - V_B}\right) = \left(\frac{q_\phi - q}{q_\phi - Q_B}\right)^{2} \qquad (8a)$$

GRADED JUNCTION

$$\frac{S}{S_{max}} = \left(\frac{\phi - v}{\phi - V_B}\right)^{1/3} \qquad (6b)$$

$$\frac{S}{S_{max}} = \left(\frac{q_\phi - q}{q_\phi - Q_B}\right)^{1/2} \qquad (7b)$$

$$\left(\frac{\phi - v}{\phi - V_B}\right) = \left(\frac{q_\phi - q}{q_\phi - Q_B}\right)^{3/2} \qquad (8c)$$

The plots of the elastance and capacitance are given in Figures 9 and 10. The elastance versus charge curve in an abrupt junction varactor is a straight line. This means that maintaining a sinusoidal current through the varactor will cause a sinusoidal elastance variation. The significance of this fact will become clear in the discussion of harmonic generators, which will be presented in Part II of this article.

Some varactors will be neither perfectly abrupt nor perfectly graded, but will vary somewhere between these two conditions. Mathematically, this is equivalent to saying that the exponent of elastance variation in Equations 6a and 6b is somewhere between 1/2 and 1/3. A sketch of the distribution of the net charge density for such a varactor is given in Figure 11.

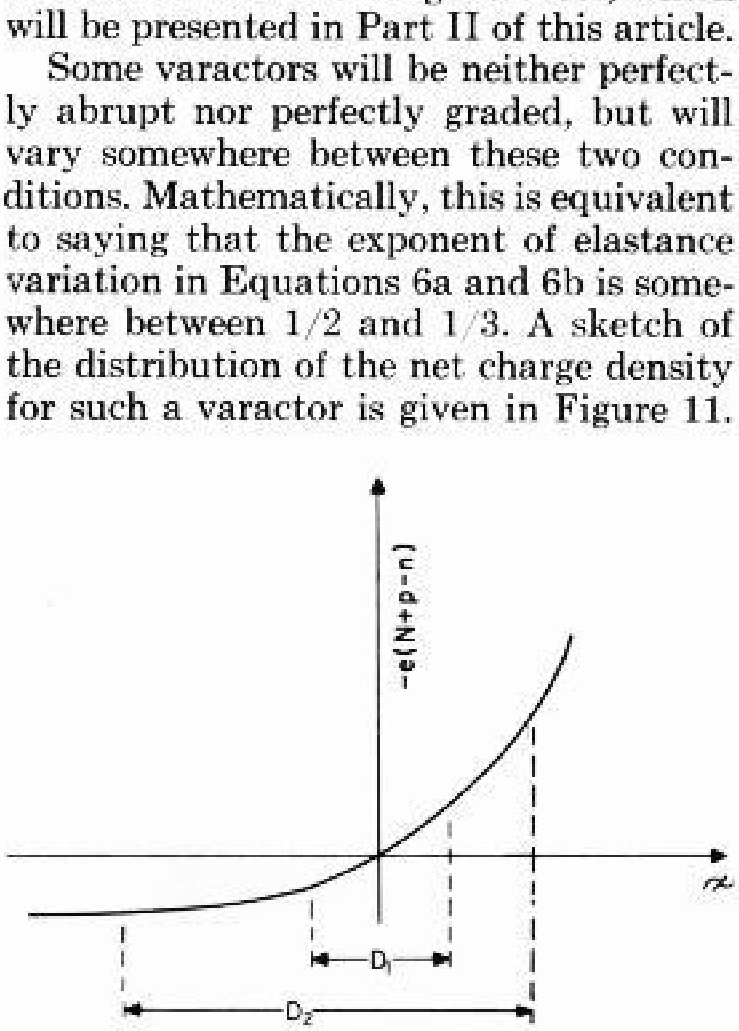


Figure 11 Density Distribution Curve for a Diffused Junction Varactor

For small applied voltages the varactor behaves as a graded junction as shown by the corresponding depletion layer thickness D_1. For larger applied voltages, corresponding to a depletion layer thickness of D_2, the left-hand edge of the depletion layer is in a region where the doping is uniform, and the right-hand edge does not vary appreciably with voltage. Thus, for large voltages, the varactor appears as an abrupt junction.

A convenient varactor parameter, called the "cutoff frequency," f_c, is defined as:

$$f_c = \frac{S_{max} - S_{min}}{2\pi R_s} \qquad (9)$$

In many cases S_{min} is much less than S_{max} so that it becomes correct to say:

$$f_c = \frac{1}{2\pi R_s C_{min}} \qquad (10)$$

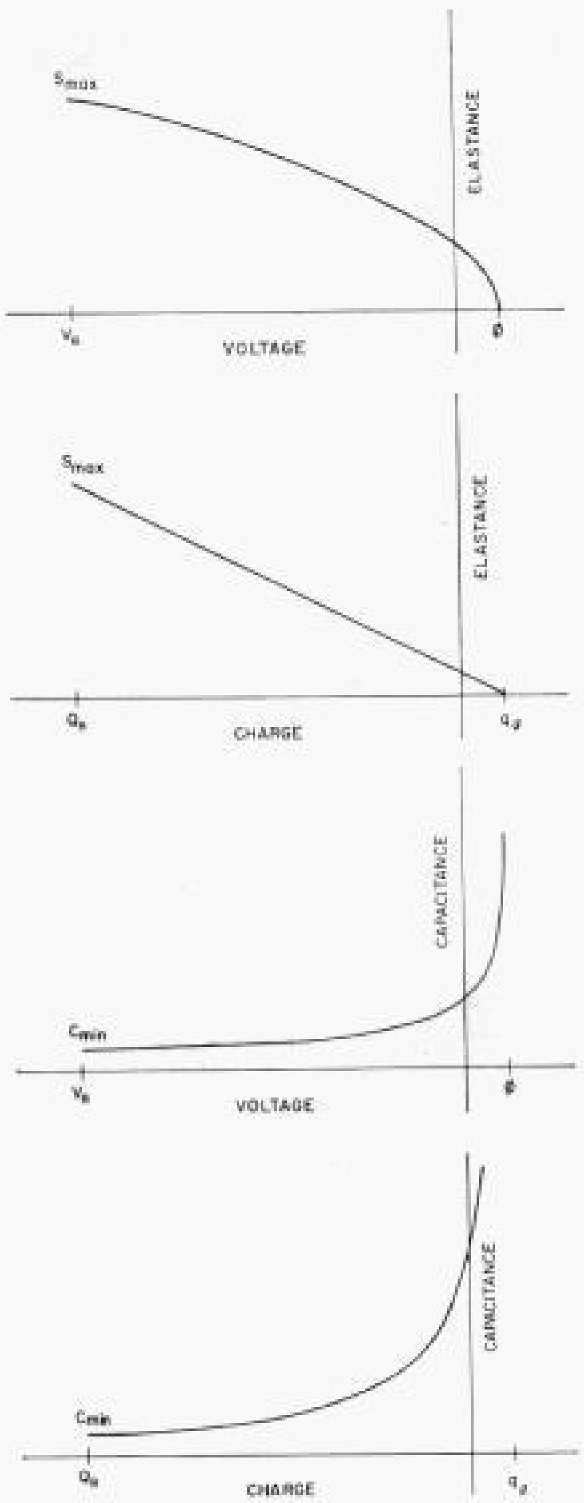


Figure 9 Elastance and Capacitance Curves for an Abrupt Junction Varactor

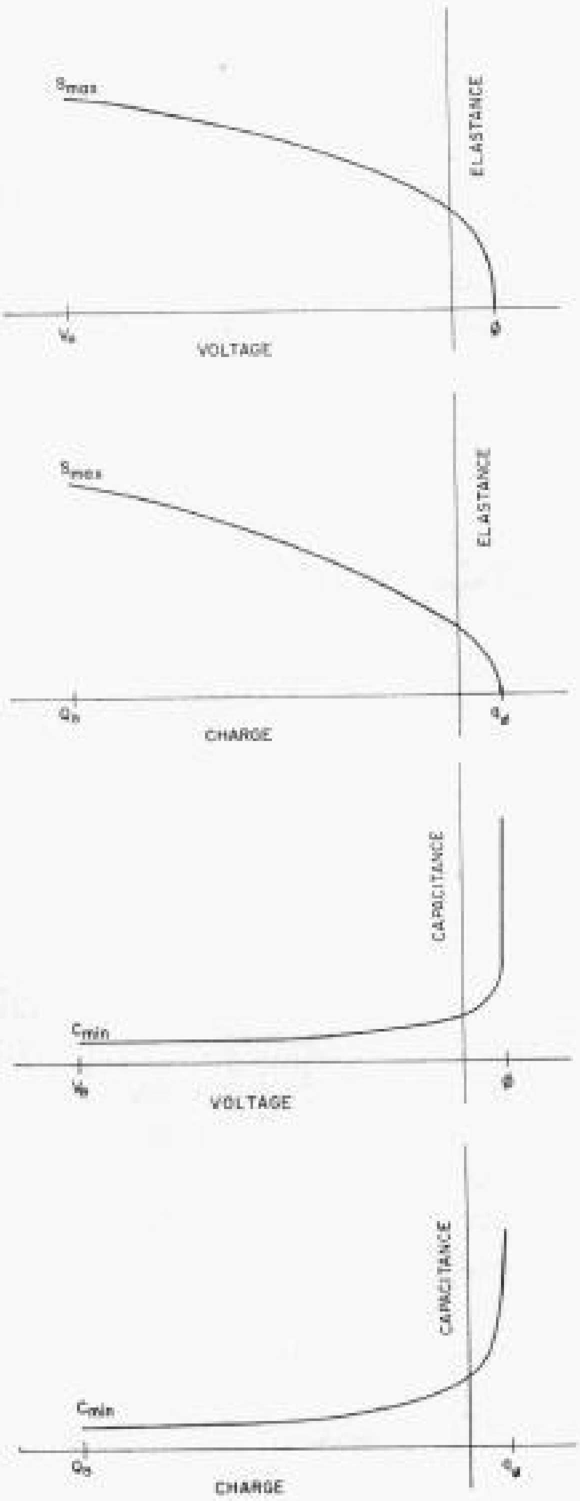


Figure 10 Elastance and Capacitance Curves for a Graded Junction Varactor

This parameter may be physically interpreted as that frequency at which the quality factor of the varactor at breakdown voltage, Q, is equal to one. From this the Q of the varactor at any given frequency, f, may be obtained from the relation:

$$Q = \frac{f_c}{f} \qquad (11)$$

Another parameter called the "modulation ratio" is given by the expression:

$$m_k = \frac{|S_k|}{S_{max} - S_{min}} \qquad (12)$$

Here $|S_k|$ is the magnitude of the kth component of the Fourier exponential series expansion of the elastance variation. The significance of the quantity $m_1\omega_c = m_1\,(2\pi f_c)$ will become clear, when various varactor applications are discussed in Part II of this article.

The maximum value of m_1 depends on the variation of elastance with time. Maximum m_1 values are of the order of 0.25.

It is convenient to define another quantity known as the normalization power, P_{norm}, as:

$$P_{norm} = \frac{(V_B - \phi)^2}{R_s} \qquad (13)$$

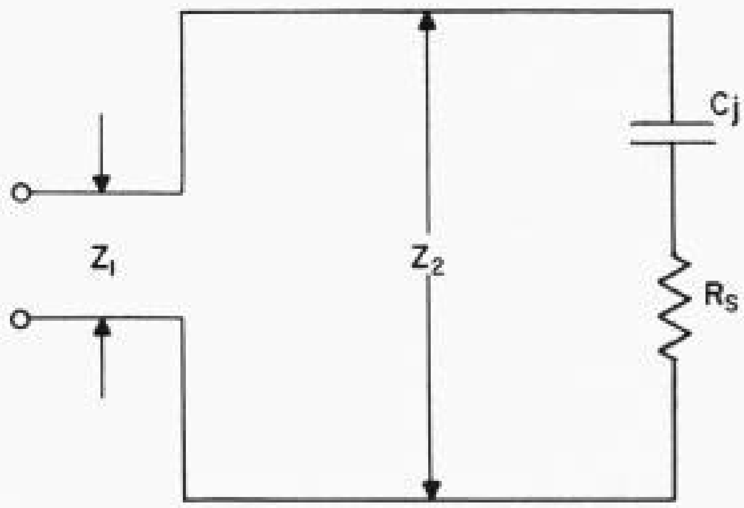
There is no practical physical interpretation of this quantity. P_{norm} ranges from watts to kilowatts; but it must be remembered that this is not an actual value of power existing at any point within the circuit. Actual values usually range between .1 and 1 percent of this quantity.

Varactor Packaging

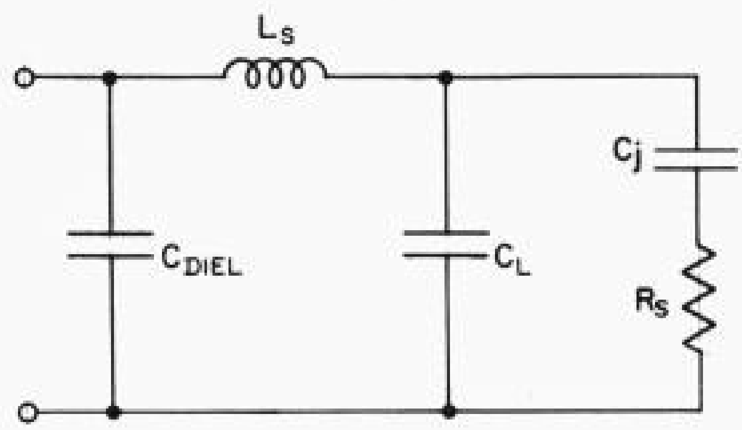
Due to the extremely small size of the semiconductor crystal, it is necessary to enclose the varactor in a case, similar to those shown in Figure 1. Such a package usually consists of a cylindrical or tapered contact to the semiconductor, surrounded by a ceramic or glass dielectric as shown in Figure 12. The resultant exact equivalent circuit for the packaged varactor thus becomes that shown in Figure 13a. The impedances, Z_1 and Z_2, of the line are not constant throughout its length.

Because the length of the varactor is much smaller than a wavelength, a lumped component equivalent network may be drawn as in Figure 13b. The junction capacitance and series resistance associated with the semiconductor material are C_j and R_s respectively. C_{DIEL} represents capacitance through the dielectric, L_s represents the series inductance associated with the case or package, and C_L is a shunting capacitance or that portion of the case capacitance associated with the series inductance. The package parameters do not affect the theory of the varactor diode and its applications. These parameters are merely considered as parasitic elements in the circuit into which the varactor is inserted. The complete circuit must therefore be designed by including the package parameters and adjusting for their effects.

In general, as the varactor package becomes smaller, the residual elements become smaller and the ability of the



(a) Exact Equivalent Circuit



(b) Lumped Parameter Approximation

Figure 13 Equivalent Circuit of a Packaged Varactor

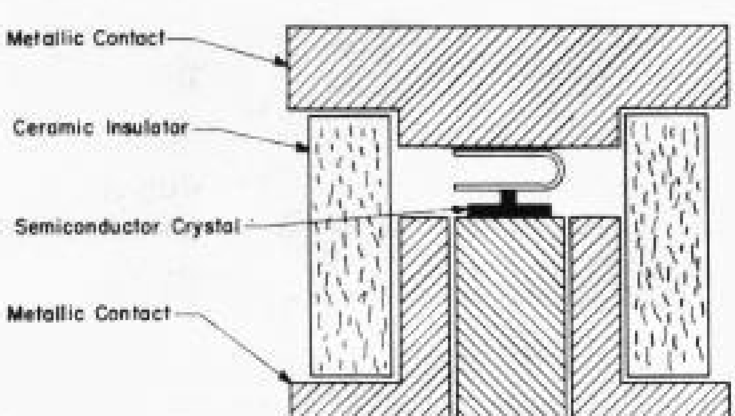


Figure 12 Cross Section of a Typical Packaged Varactor

package to dissipate heat generated within the semiconductor is less. Therefore, at low frequencies, a large package will be commonly used because the effects of the parasitic residual elements will be small and the heat dissipation requirements for the large input powers will be large. At high microwave frequencies, the package is usually very small because the effects of the parasitic elements will be severe if the package is too large. Also, the amount of power to be dissipated is usually much less.

Applications

Western Union is presently using voltage variable capacitors in the WLD-6 cross-country radio beam equipment. Most future microwave systems will include the use of the varactor.

These and many other applications of the varactor will be described in Part II of this article which will appear in the April 1963 issue of the Western Union TECHNICAL REVIEW.

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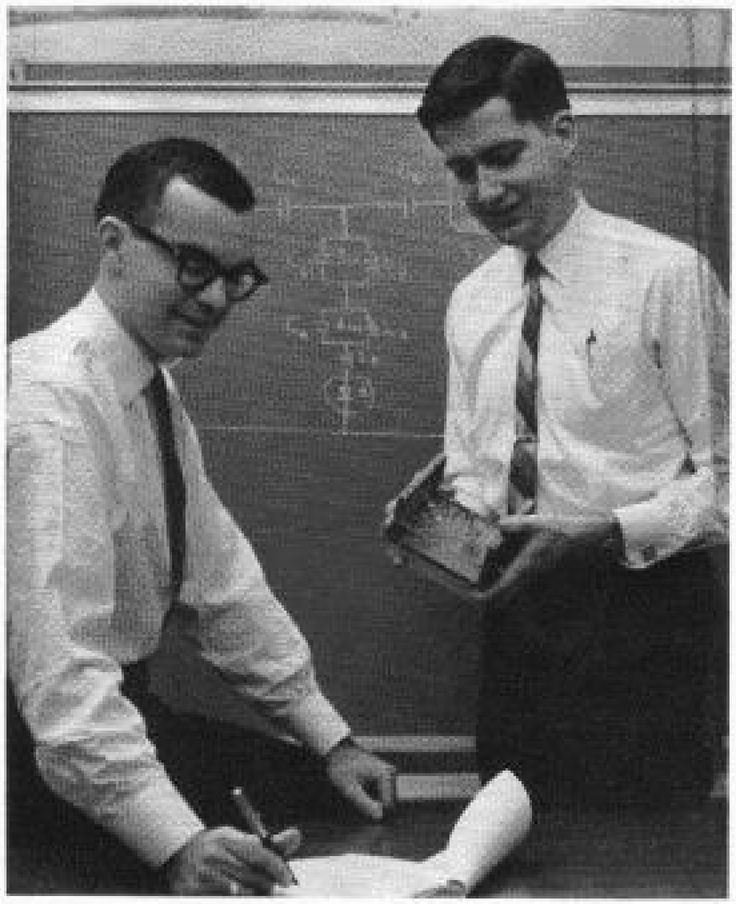


Mr. R. L. Ernst, right, an engineer in the Radio Systems Division, is currently involved with the development of parametric devices for application in telegraphy.

Since joining Western Union in 1961, he has designed an upconverter for use in delay measuring equipment and has also participated in the study of the effects of long waveguide runs on microwave system performance.

He received a B.E.E. degree from Manhattan College in 1961 and is currently studying for a M.S.E.E. Degree at Polytechnic Institute of Brooklyn. He is a member of the IEEE and Eta Kappa Nu.

Mr. J. K. Fitzpatrick, left, also an engineer in the Radio Systems Division, is currently specializing in the design of varactor multipliers. Previously he had been concerned with the development of microwave components, TWT amplifiers and audio and switching circuitry.

Mr. Fitzpatrick joined Western Union after receiving his B.E.E. degree from Manhattan College in 1960. He is studying for his Master's Degree at Newark College of Engineering. He is a member of IEEE and Eta Kappa Nu.

APPENDIX I

Capacitance Voltage Characteristic of a Graded Junction Varactor

Consider the graded junction diode. Here

$$N(x) = ax \tag{I-1}$$

where a is the concentration gradient. The net change distribution becomes:

$$\rho = -eax, -\frac{d}{2} \leq x \leq \frac{d}{2}, \tag{I-2}$$

where d is the depletion layer thickness. Applying Poisson's equation,

$$\nabla^2 \Phi = -\frac{\rho}{\epsilon}, \tag{I-3}$$

to this one dimensional case gives

$$\frac{d^2 \Phi}{d x^2} = -\frac{\rho}{\epsilon} = \frac{eax}{\epsilon} \tag{I-4}$$

where Φ (x) is the electrical potential and ϵ is the permittivity of the semiconductor. Integrating,

$$\frac{d\Phi}{dx} = \frac{eax^2}{2\epsilon} + K_1 \tag{I-5}$$

is obtained. Inserting the boundary condition that:

$$\frac{d\Phi}{dx} = o \ at \ x = \pm\frac{d}{2}, \tag{I-6}$$

yields:

$$o = \frac{ea}{2\epsilon}\left(\frac{d}{2}\right)^2 + K_1 \tag{I-7}$$

and

$$K_1 = -\frac{ead^2}{8\epsilon}. \tag{I-8}$$

Therefore;

$$\frac{d\Phi}{dx} = \frac{ea}{2\epsilon}\left(x^2 - \frac{d^2}{4}\right). \tag{I-9}$$

Integrating this gives:

$$\Phi = \frac{ea}{2\epsilon}\left(\frac{x^3}{3} - \frac{d^2x}{4}\right) + K_2. \tag{I-10}$$

Inserting the boundary condition:

$$\Phi = o \ at \ x = o, \tag{I-11}$$

results in:

$$o = \frac{ea}{2\epsilon}(o) + K_2, \tag{I-12}$$

and

$$K_2 = o.$$

Therefore:

$$\Phi = \frac{ea}{2\epsilon}\left(\frac{x^3}{3} - \frac{d^2x}{4}\right) = \frac{eax}{2\epsilon}\left(\frac{x^2}{3} - \frac{d^2}{4}\right) \tag{I-13}$$

The total potential difference across the junction, V_j, consists of the sum of the contact potential and the applied negative bias voltage, or

$$V_j = \phi - V. \tag{I-14}$$

Equating this to the above expression gives:

$$\phi - V = \Phi\big|_{x=-\frac{d}{2}} - \Phi\big|_{x=\frac{d}{2}} \tag{I-15}$$

which becomes:

$$\phi - V = \frac{ead^3}{12\epsilon} \tag{I-16}$$

The total charge, Q, on either side of the junction is found to be:

$$\frac{Q}{A} = \int_o^{d/2} eax\, dx = \frac{ead^2}{8} \tag{I-17}$$

By combining with the above expression this becomes:

$$\frac{Q}{A} = \frac{ea}{8}\left[\frac{(\phi - V)\, 12\epsilon}{ea}\right]^{2/3} \tag{I-18}$$

The resulting capacitance per unit area is then:

$$\frac{C}{A} = \frac{d\,(Q/A)}{d\,(\phi - V)} = \epsilon\left[\frac{ea}{12\epsilon\,(\phi - V)}\right]^{1/3} \tag{I-19}$$

H. F. Burroughs, Project Engineer, Electronics Division

ELECTRO-QUOTE*

DISPLAY SYSTEM

THE Electro-Quote Display System translates telegraphic code into an alpha-numeric display composed of matrix-type indicators which produce and store letters of the alphabet, numerals or symbols. The indicators are adjacently set in a display panel to permit viewing a block of information. Each block or information is erased and renewed in accordance with the received telegraph signals.

Alpha-Numeric Readouts

An alpha-numeric readout is an indicator which is capable of forming all the letters of the alphabet as well as all of the numerals 1 through 0. A numeric readout is an indicator capable of forming numerals only. The principle involves an arrangement of elements or segments such that any letter and/or numeral can be formed by selection of the appropriate segments. All numerals can be formed by selecting from the seven-segment pattern of Figure 1. All alphabet characters and the numerals can be formed from selections from the fourteen-segment pattern of Figure 2.

Most alpha-numeric readouts presently available use lamps, electroluminescence or electromechanical motion as a means of energizing the segments. The alpha-numeric readout used in the equipment to be described is of the electromechanical latching type.

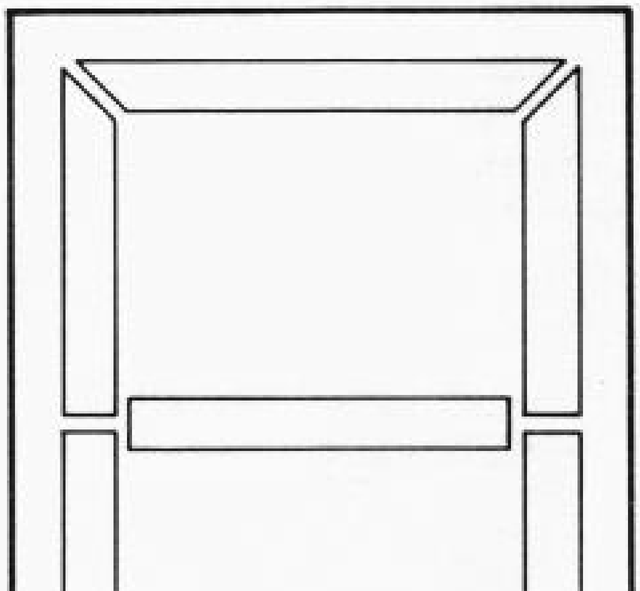


Figure 1 7-Segment Pattern (Numeric)

* The Electro-Quote Display System was developed and constructed at Western Union's Water Mill Laboratory under a development contract with the Trans-Lux Corporation.

Each of the metallic segments is fastened to a ferrite rotor mounted between the pole pieces of an electromagnet. The segments are aligned behind glass, which is masked in the pattern of Figure 2. Magnetically induced rotation of the rotors causes the segments to turn either into the viewing area of the mask or out of it. The segments operate in response to a dc pulse and thereafter remain operated until pulsed again. This built-in storage aids in reducing the amount of supporting circuitry. The readout operates at speeds of 25 milliseconds or less.

The Prototype

The phototype system developed by Western Union comprises a Display Panel and a Control Cabinet. The Display Panel contains all the readouts or indicators. The display may be made up of one panel, as shown in Figure 3, or several panels.

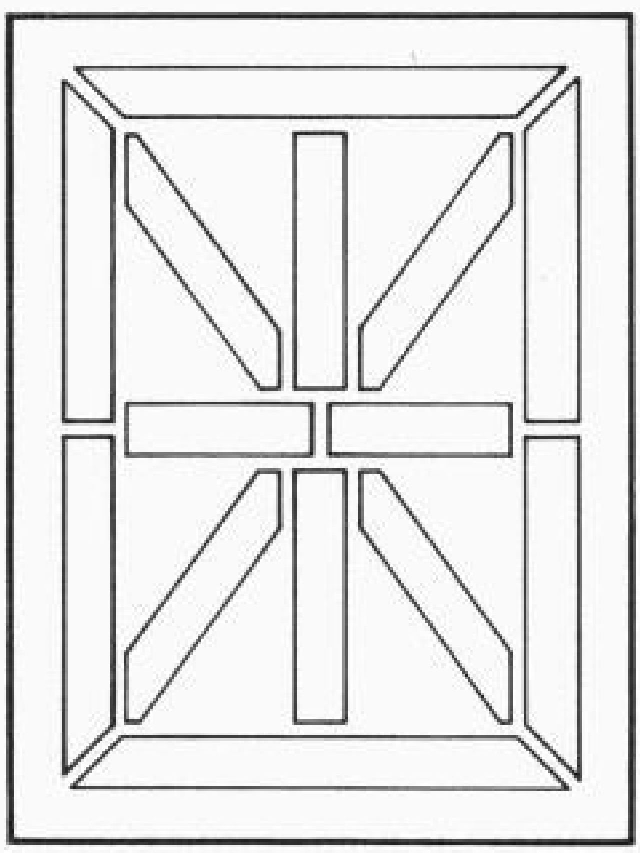


Figure 2 14-Segment Pattern (Alpha-Numeric)

Figure 3 Display Panel

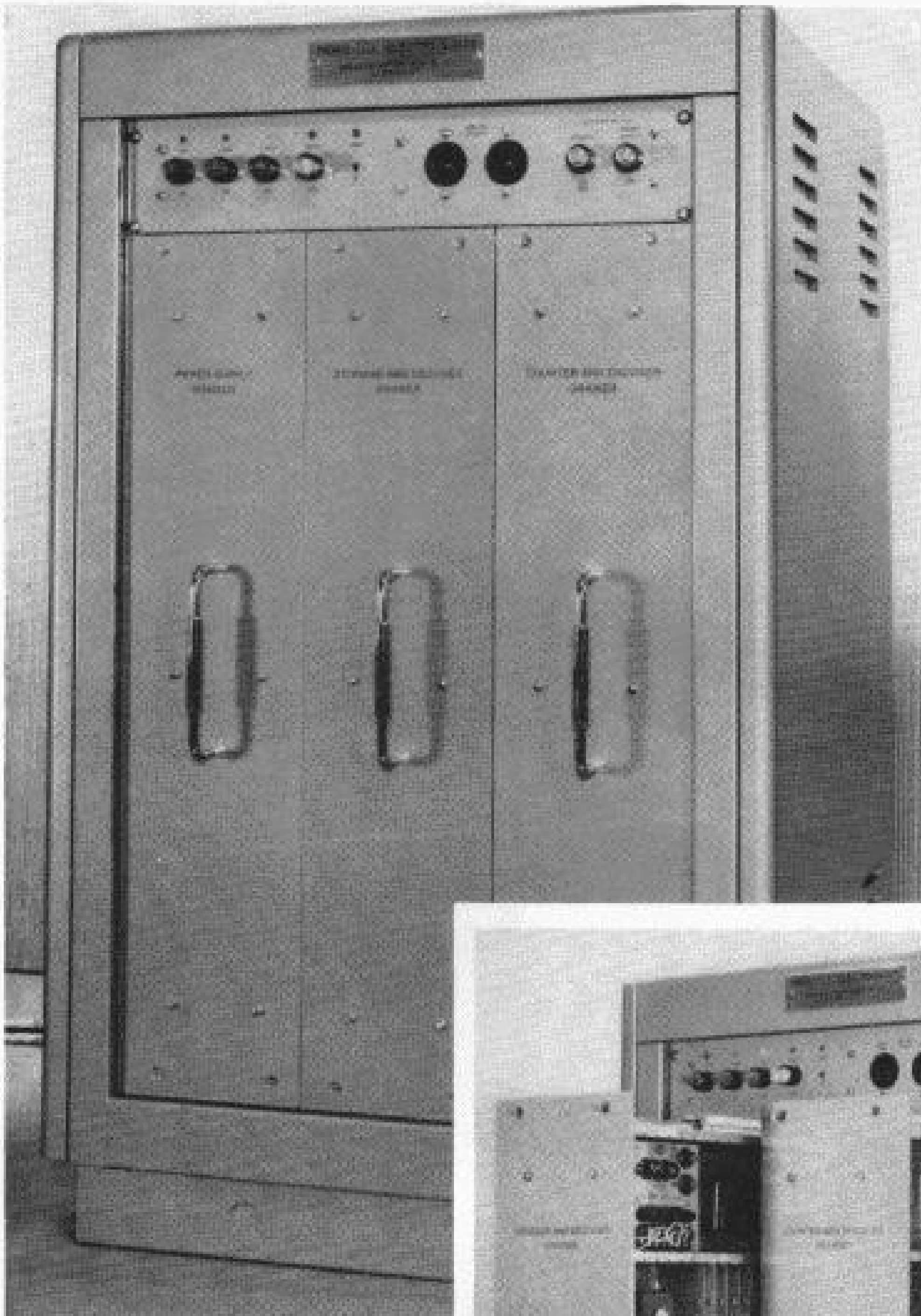
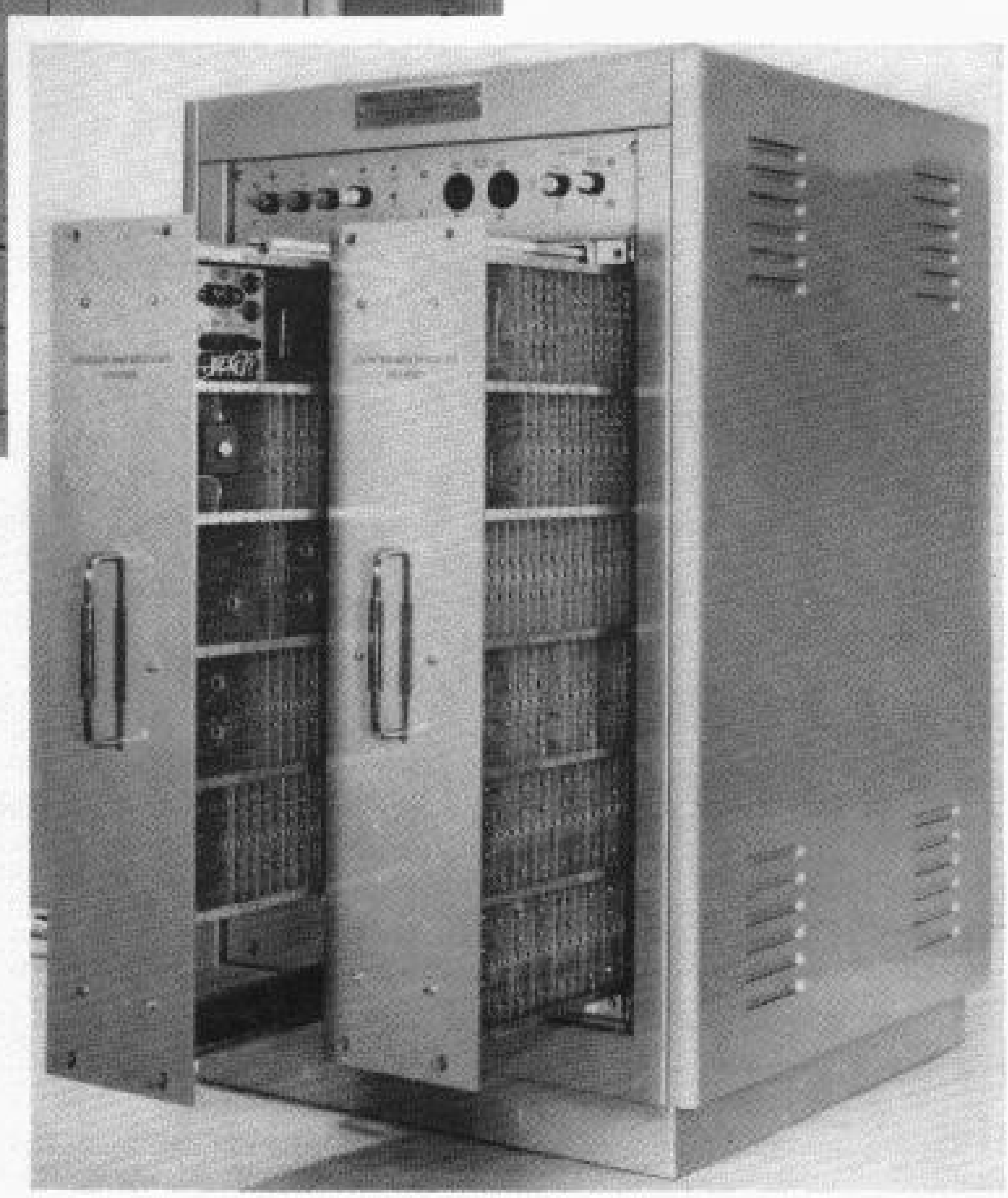


Figure 4. Control Cabinet
(a) drawers closed



(b) two drawers opened

Translation Equipment

The translation equipment, contained in the Control Cabinet of Figure 4, employs all solid state circuitry mounted on printed cards. The cabinet is composed of three vertically-mounted drawers: (1) Power Supply, (2) Storage and Decoder and, (3) Counter and Encoder. The Display Panel, shown in Figure 3, is twelve feet wide and contains seventy-five alphanumeric readouts, each measuring 1½ inches wide by 2½ inches high. The individual readouts plug into a series of printed circuit boards.

The segments of the readouts are treated with a phosphorescent paint which glows when illuminated by the ultraviolet light supplied by three coated fluorescent tubes. A dimmer control provides adjustment of the intensity of ultra-violet light to permit viewing the display over a very wide range of ambient light levels. The present equipment is limited to the operation of three display panels in parallel.

Operation

The equipment will accept 7.5-unit telegraphic codes at rates of 60-, 75-, or 100 words per minute. It is presently programmed to process symbolic weather messages. Upper case characters are those of the standard weather keyboard, exclusive of the period, (.). The primary weather message is fifty-six characters maximum, followed by varying amounts of secondary supporting information. Therefore, the text of a message may be of any length but the number of displayed characters in any one panel is limited to seventy-five.

Selection of the equipment is made by a three-character address. Characters are then posted sequentially on the Display Panel from left to right with simultaneous erasure, of the previous message at a point two characters ahead of the character being posted. For any message less than seventy-five characters, the remaining portion of the Display Panel is erased automatically. No functions other than *space* are posted and only one is posted regardless of the number received in sequence. An *end-of-message* condition is generated by either a three-character *received end-of-message* or, automatically, by any text exceeding seventy-five characters in length.

Circuitry

The block diagram of Figure 5 illustrates the intelligence or signal path through the equipment. The series train of intelligence pulses is stored, in parallel, by means of an electronic start-stop receiving distributor. Code rates of 60-, 75-, or 100 words per minute can be processed by merely plugging in the printed circuit card containing the appropriate tank circuit for the start-stop oscillator.

The storage section is of the flip-flop register type, sufficient to store three characters. Decoding gates are provided for all twenty-six characters as well as for *letters shift*, *figures shift*, *space* and the unique three-character sequences corresponding to *start* and *end-of-message*. Any three-character sequence may be wired into the equipment by a simple strapping arrangement. Two gate paths to the Encoder, corresponding to *upper* and *lower case*, are provided for each of the decoded characters. These gates are controlled by a flip-flop, which switches in accordance with the shift functions. Each time a character is decoded, a pulse is furnished to the Character Counter which, in turn, controls the sequential posting of characters across the Display Panel.

The Character Counter consists of a units counter and a tens counter. Each section is a ring counter of the flip-flop shift register type. Combining gates provide seventy-eight sequential outputs, each isolated from the others.

The Encoder is a diode matrix having fifty inputs corresponding to the fifty decodable *upper* and *lower case* characters and fifteen outputs corresponding to the fifteen segments in the alpha-numeric readout. The fifteenth segment is used for the purpose of underlining certain characters. Each output of the matrix is coupled to the coil of a dry reed relay. Each relay has one "make" contact with an operate time of approximately three milliseconds. Four relays are mounted on a printed circuit card. When energized, the relays supply battery to one side of the "set" coils of the alpha-numeric readouts.

The operation of the Display Panel is as follows: For any given character, battery is supplied to the appropriate "set" coils of all seventy-five readouts. However, it finds a path-to-ground only through that counter amplifier (power switching transistor) which has then been made to conduct, by the appropriate output of the character counter. In addition, the transistor which provides a "set" path through one alpha-numeric readout also provides a simultaneous "reset" or erase path through the readout located two characters ahead of it.

Following receipt of the address, the first two readouts are erased by the second and third address characters shifting Message Control circuit so that pulses fed to the Character Counter are derived from a free-running multivibrator (F.R. MVB) instead of from the decoded characters. The remainder of the board is then erased. The frequency of the free-running multivibrator is chosen so that erasure proceeds at a rate slightly greater than one-hundred words per minute. If the text exceeds seventy-five characters in length, the Character Counter supplies a pulse to the Message Control circuit equivalent to that of the *received end-of-message* and also locks itself on the 78th count. The cycle is repeated only when the next selection characters are received.

Maintenance features

Jacks are provided for local monitoring of the telegraph signals and testing of the equipment. Insertion of the sixty

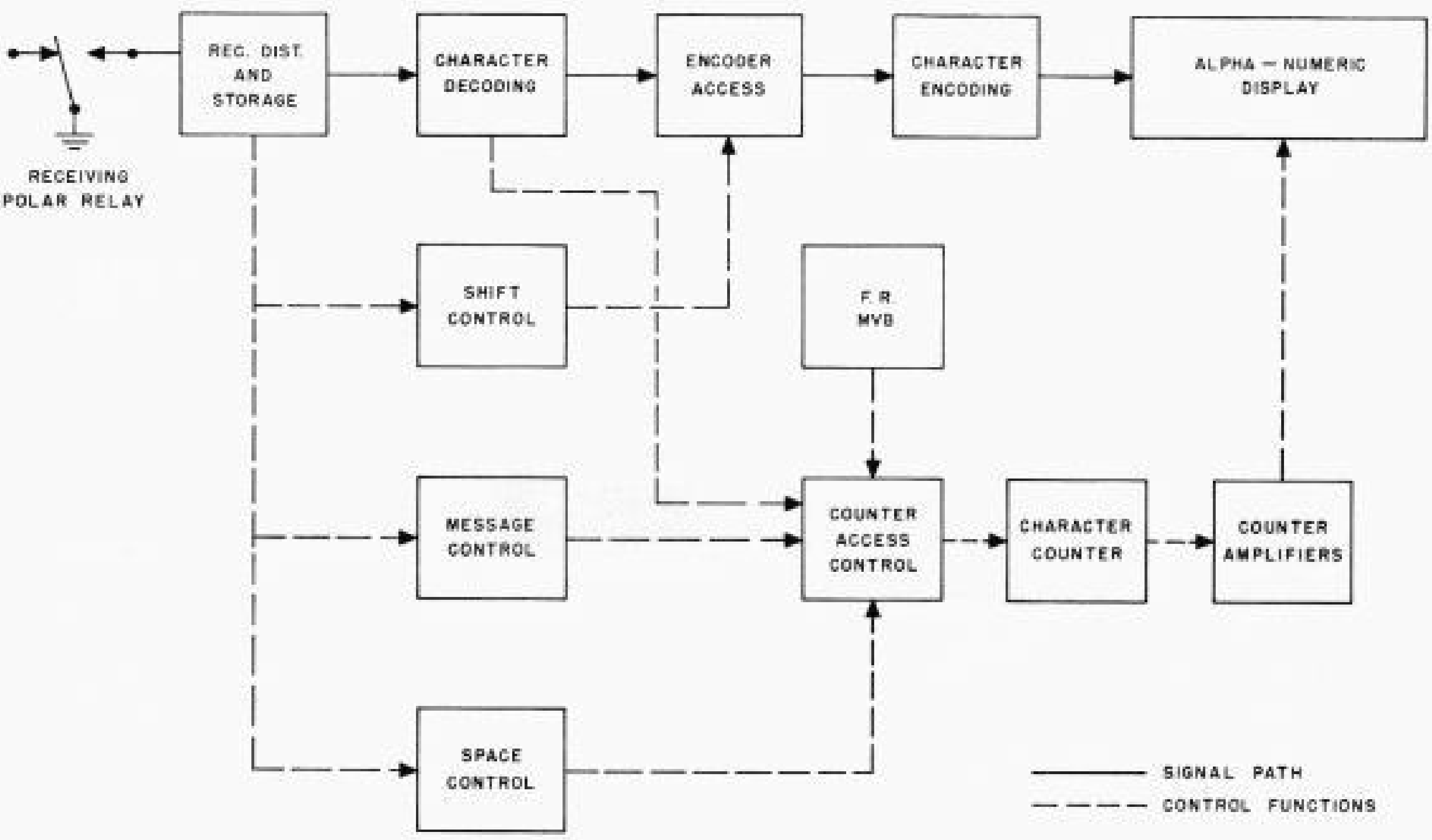


Figure 5 Block Diagram of Intelligence Path

out of storage. The first character of the text is then posted in the first position of the display, while the third position is erased, etc. If the text is less than seventy-five characters long, the three-character *received end-of-message* conditions the words-per-minute oscillator card allows complete testing with a 2B printer. To facilitate testing the Display Panel, two push-button switches are provided. One switch serves to operate, sequentially, all the segments of each alpha-numeric readout while the other switch serves to erase them. The switches provide a rapid means of checking all the readouts as well as some of the circuitry. The circuits are arranged so that, if testing or erasure is in progress when live traffic is received, the testing or erasing operation is preempted and the traffic is posted in the normal manner.

Applications

The Electro-Quote Display System has a wide potential application. It can be used wherever there is a need for a rapid, automatic display of intelligence. The prototype was designed for posting weather messages in aircraft control centers. It can be adapted for posting any telegraphic data.

Any number of parallel display panels located in remote areas and operated from a single, central control unit are possible.

The readouts can be large enough to be viewed from appreciable distances and, therefore, readable to many people simultaneously.

Indicators, with either colored or fluorescent segments, can be grouped into a multi-line display to accommodate various types of information.

Satellite display boards can be provided to duplicate or select the information of any one display panel.

Mr. Harry F. Burroughs has been most recently associated with the development, production, installation and testing of the nationwide Display System 210-A (Bomb Alarm). Some of the techniques developed in that program have been embodied in the design of the Electro-Quote Display described in this article.

The author's previous experience in facsimile systems prompted an article on eddy current speed control published in the January 1960 issue of the Western Union TECHNICAL REVIEW.

Prior to joining Western Union, Mr. Burroughs received a B. S. degree in Electrical Engineering from Brown University in 1950. Since then, he has been a member of the staff of the Electronics Research Engineer at Western Union's Water Mill Laboratory.

P. F. Recca, Senior Project Engineer, Telegraph Equipment Division

Data Card Transmitter

Today, many companies are devoting much effort toward the development of more sophisticated and faster computers. However, little attention has been given to the problem of data collection for eventual transmission via telegraph facilities.

For some time, Western Union has been acutely aware of the need for a device which could automate data at the collection source. It has developed the Data Card Transmitter 11313-A as a means of satisfying this need.

The Data Handling Problem

Most business data originate in handwritten copy and usually include very basic information. In a data communication system data processors and telegraph operators have the task of accurately transcribing this data for telegraphic transmission. Also, they must follow a prescribed format designated by the data system. Such formats vary according to the system used and are frequently so complex that much skill is required in the preparation of the data for transmission to the processing center. The format is usually as essential as is the primary data itself and, for this reason, many data centers cannot accept data unless the format is correct. Ultimately, the data is received at the destination where it is finally processed for such purposes as warehouse shipping, inventory control, payroll, billing, etc. At each of these data collection points skilled personel are required. In addition there is considerable delay in the preparation of the data for transmission.

The Data Card Transmitter 11313-A was designed primarily to eliminate the manual transcription of original data for a typical data handling problem, as shown in Figure 1. With proper application, this unit can effectively reduce costs and save valuable time at many points in a data processing system. In some cases it can be used to obtain the end product directly from a hand-marked card.

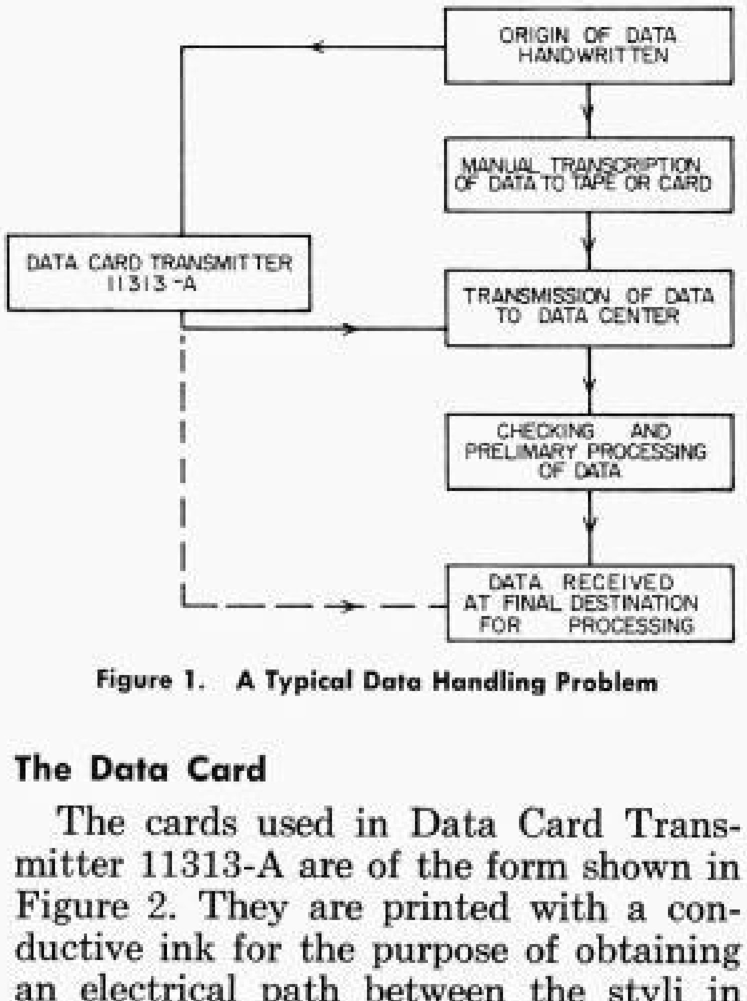


Figure 1. A Typical Data Handling Problem

The Data Card

The cards used in Data Card Transmitter 11313-A are of the form shown in Figure 2. They are printed with a conductive ink for the purpose of obtaining an electrical path between the styli in the unit and the information entered on the card. The cards are specifically designed for the particular needs of the data system in which they are used.

On the upper portion of the card shown in Figure 2, are nine columns of ten mark-sensing boxes for numeric data entry; each box has been assigned a digit from 0 to 9. Left of each column of boxes is a vertical line. The offset projection of this line below the column is a control mark.

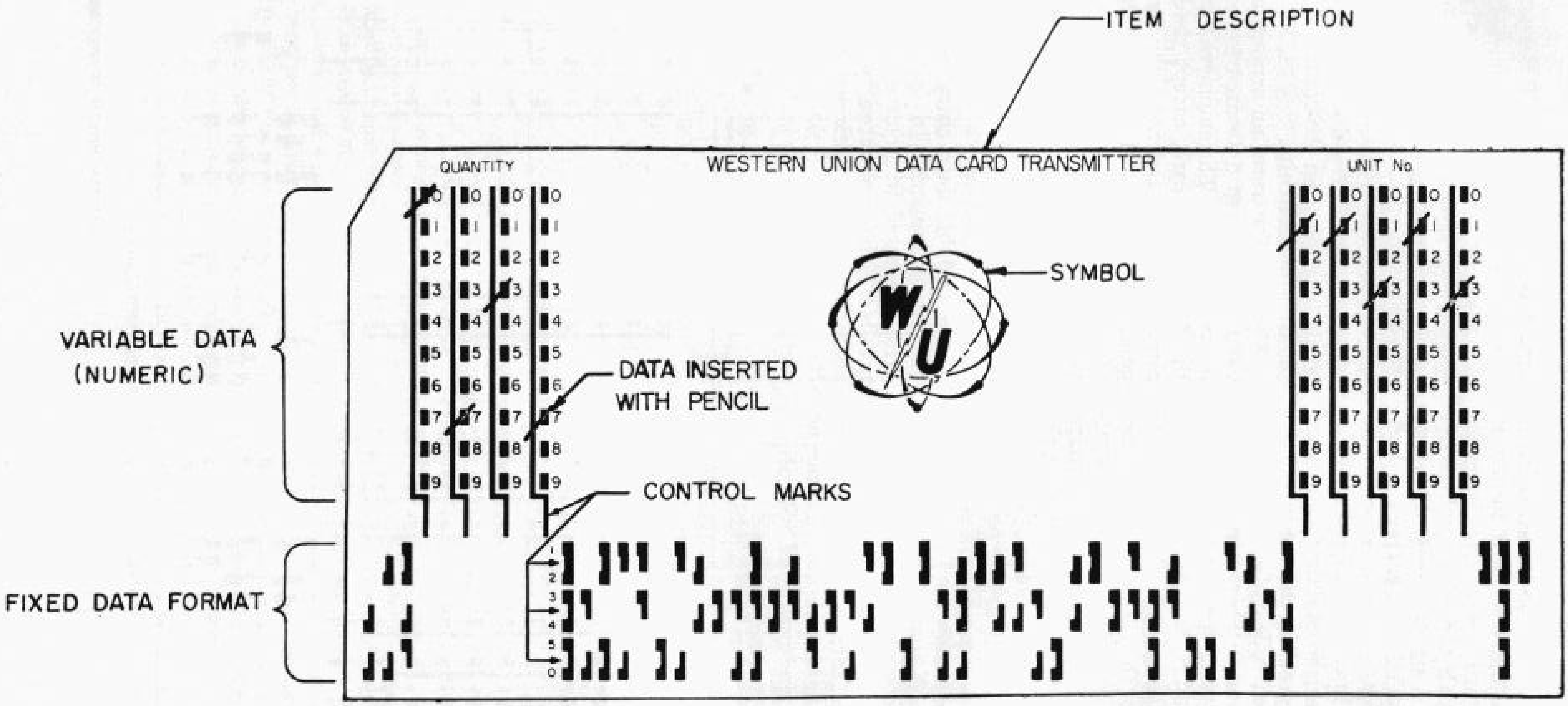


Figure 2. Data Card

The lower portion of the card is reserved for fixed alpha-numeric data format in standard Western Union five-unit teleprinter code with the additional unit, a zero, used for a parity check. This zero position is included for checking the card-reading function only and is not transmitted to the line.

In the lower, fixed-data-format area three rows of possible control marks are located between code pulses 1 and 2, 3 and 4, and 5 and 0. These control marks are connected with their respective code pulses.

The control marks, in the upper and lower portion of the card, trigger the electronic circuits contained in the transmitter and permit the card to be fed through the unit, at a constant speed, without the need for punched feed holes.

The item description may be typed at the top of or at the side of the card, so that it may be easily read when placed in a card rack. A symbol, or other information not intended for transmission, may also be printed in the same conductive ink on the card without interfering with the data to be transmitted, since no control marks are associated with it.

Data Entry

To insert the variable information on the card, it is merely required that a single, firm stroke, of an ordinary soft pencil, be placed so that it connects the desired box to the vertical line to the left. Since pencil lead is a conductor, the stroke completes the electrical path through the conductive ink from the control stylus to the electronic circuits.

Figure 3 illustrates an arrangement of variable and fixed data used for processing payroll data. The employee enters all the data on the card, except the hourly rate. This is entered manually by other personnel or obtained from a designated place in a computer memory or storage. With proper programming of the card and an associated computer, the final products of the process will be the employee's check, ledger sheets, and other statistical reports.

The variable data entry need not be exclusively numeric. In fact, using the card illustrated in Figures 2 or 3, it is possible to have nineteen variable alpha characters in the mark sensing area. If the card is made a little wider, the complete alphabet may be included, as shown

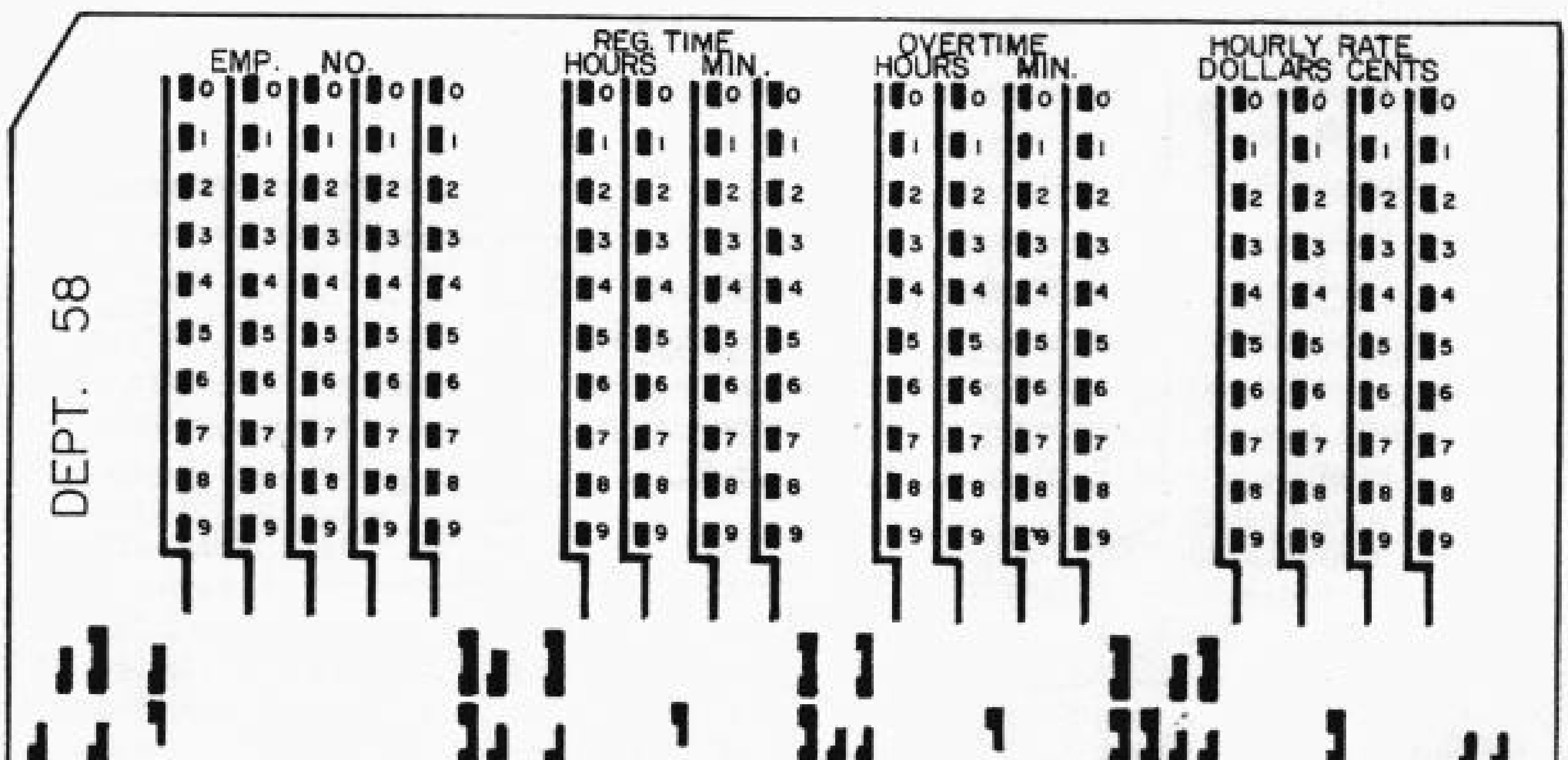


Figure 3. Data Card for Payroll Processing

in Figure 4. This card illustrates another feature important to specific data systems. Below each column of variable alpha data an additional box may be marked "omit," when it is desired that no information be transmitted. This ensures that there always be one mark in every variable data column, to retain the protective readout feature of the Data Card Transmitter.

with a non-conductive writing implement, such as a ball point pen, the error will be electronically detected and further transmission of the card will be stopped. Similarly, if two or more marks are erroneously placed in a single variable-data column, the error will be detected and the transmission stopped.

The fixed data format at the lower section of the data card is also protected in

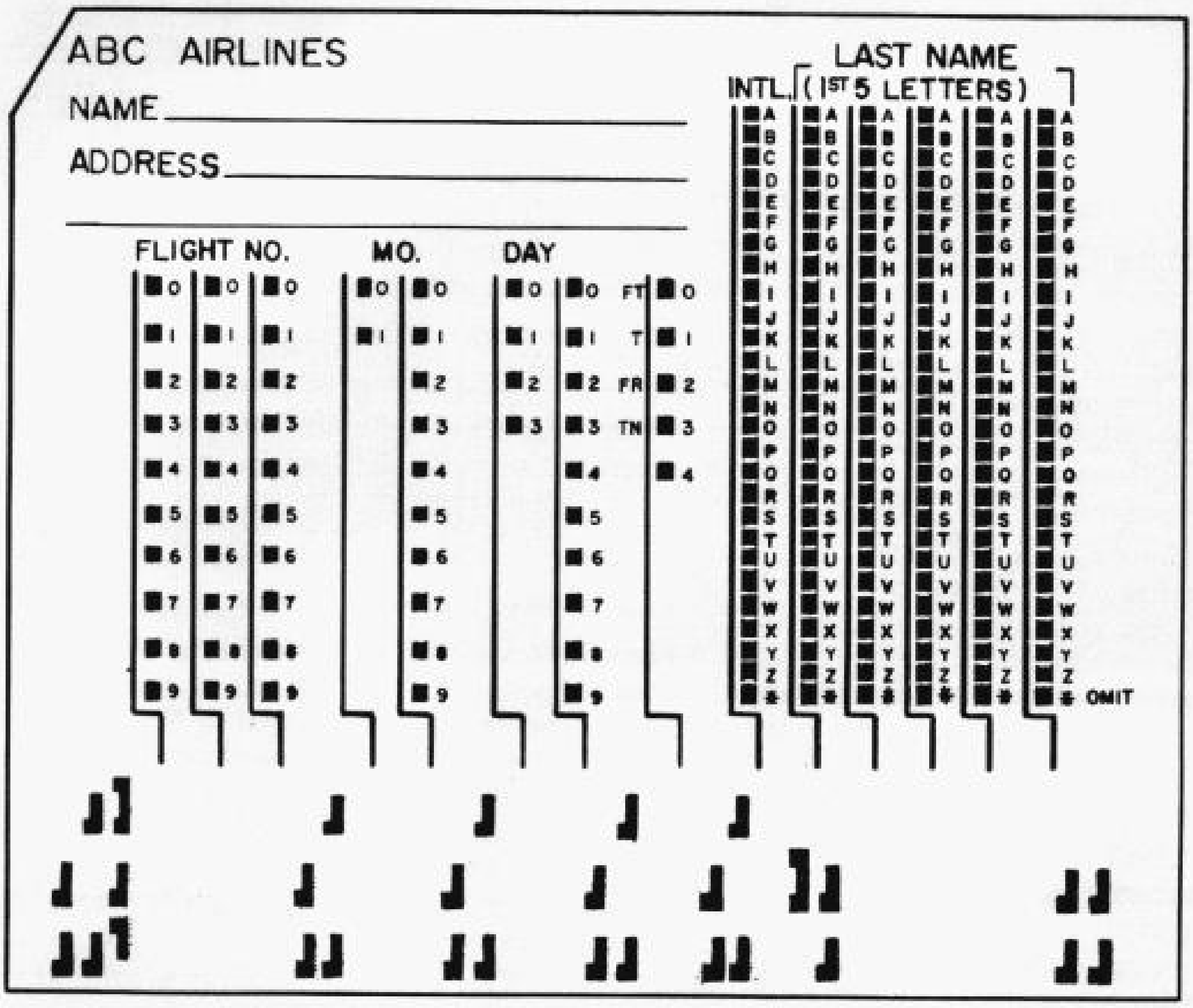


Figure 4. Data Card for Variable Alpha Data

Protected Readout

The reliable transmission and reception of information is essential to all data systems. The transmission of data from Data Card Transmitter 11313-A is electronically and mechanically protected so that the rechecking of the data or the format at the processing point is unnecessary.

All data cards are designed so that only one mark is required in every variable-data column, even if no information is to be transmitted in that column. If a column is not marked, or marked improperly

its readout by the addition of a parity unit to the five-unit code. This parity unit is added to all code combinations which add up to an odd number of pulses, so that the total of all code combinations is an even number of pulses. When using standard five-unit code receiving equipment, this "even parity" is checked internally to ensure accurate transmission. However, the parity unit is not transmitted to the line. If improper parity is detected, further transmission of the data on the card is stopped.

To further guarantee the transmission of data, electronic and mechanical protection is provided to prevent two or more cards being fed through the mechanism at one time. Although such a malfunction is not likely to take place when the mechanical unit is properly adjusted, this protective feature is still advisable for accurate transmission of data.

To protect against placing a card upside down, backwards, or otherwise incorrectly into the machine, the Data Card Transmitter provides a mechanical means which prevents the card from being fed under the reading styli.

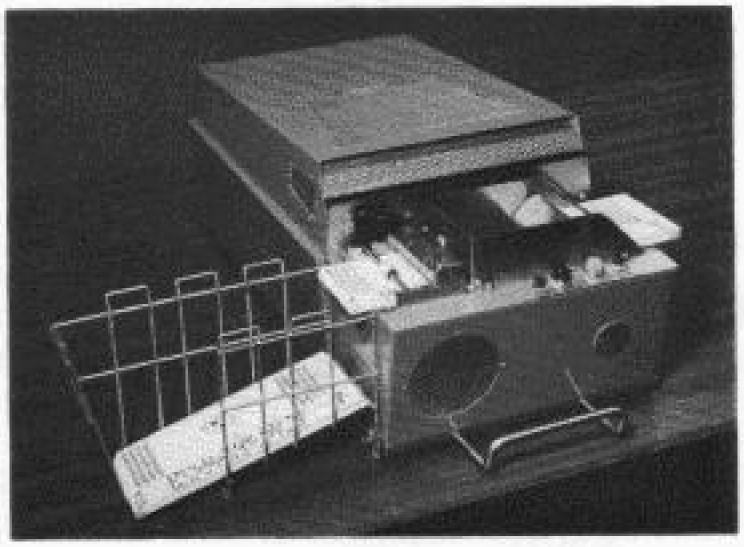


Figure 5. Data Card Transmitter—11313A

Mechanical and Electronic Sections

Data Card Transmitter 11313-A is a complete unit, having its own self-contained power supply. It may be physically separated into two parts; a Mechanical Section and an Electronic Section. One mechanical section may serve a number of different types of electronic sections depending on the needs of the customer.

Figure 5 shows the machine completely assembled. The base of the unit measures 9⅝ in. wide, 20 in. long and 8 in. high. The unit rests on five rubber feet, weighs approximately 33 pounds, and is made portable by means of the front handle.

Figure 6 illustrates the machine separated into two sections.

The ***mechanical section*** of Data Card Transmitter 11313-A consists of the sensing styli and a motor-driven, card-loading-and-feeding mechanism. The card-loader is capable of holding approximately 100 cards and feeding them, one at a time, from the bottom of the stack between two sets of pressure rollers. These rollers feed the card under the styli, out of the unit, and into a basket. The design of the card loader is such that cards of varying length may be fed through the machine at random without the need for any readjustment of the loader. This permits the data card to be as long as is required by the data printed on it. Thus blank areas in the cards are eliminated and transmission time is fully utilized.

The information sensed by the styli in the mechanical unit is transferred to the ***electronic section*** of Data Card Transmitter 11313-A where it is read and translated into the line signals required by the specific system. The fixed data on the card is read into the electronic "flip-flop" storage and then transmitted via an electronic distributor located in the machine. The variable data is first translated into the same code as the fixed data and then stored and transmitted via the same circuits as those used for fixed data.

Figure 7 is a functional block diagram of a model unit showing all the basic components. The output to the line is via a polar relay contained in the machine, but it may also be a multiwire output if the application requires it. A Polar Relay Type 202 is provided to operate from the electronic circuitry and to pass the generated start-stop signals to the telegraph line.

The electronic unit is a solid state device employing mostly flip-flop and nor-gate circuitry, mounted on printed circuit cards. These printed circuit cards may be easily removed and replaced if maintenance tests indicate this to be necessary.

The power supply for the unit is contained in the electronic section. Both negative and positive potentials of 12 volts are developed for the solid state circuitry.

A potential of 120 volts is also developed for the four control styli to provide adequate tolerance to the electrical resistance of the pencil markings on the data card.

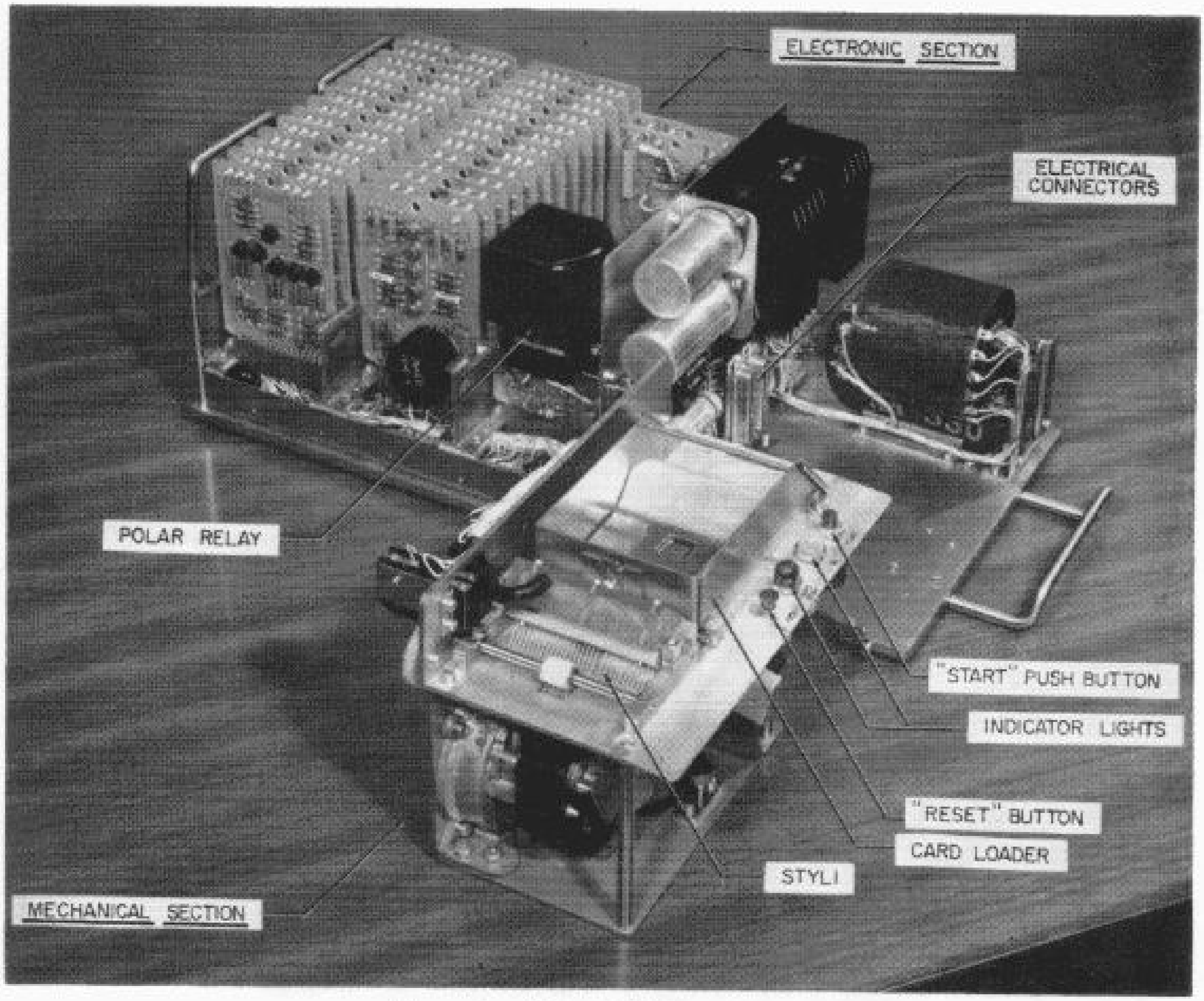


Figure 6. Data Card Transmitter
Component Parts of Electronic and Mechanical Sections

Included in the mechanical section of the machine are five micro-switches, one pushbutton switch, and two indicator lights which function as follows:

- *Loader Switch*—Operated whenever cards are in the loader.
- *Card-Out Switch*—Operated by a card shortly after it passes the sensing styli and released as a card leaves the unit.
- *Two-Card Switch*—Operated only if more than one card is inadvertently fed through the machine.
- *Reset Switch*—Operated to reset all the alarm circuits.
- *Line Blind Switch*—Operated when the "*RESET*" switch is depressed to prevent any information subsequent to an error from being transmitted to the line.
- *Start Button*—When the "Loader" switch and the "Card-Out" switch are simultaneously unoperated, all power to the machine is removed by means of a relay contact. In order to restore power, the "*Start*" button must be depressed. The power will remain "on" as long as either the "Loader" or "Card-Out" switch is operated.
- *"On" Light*—Lights "white" to indicate that power is "on."
- *Auto-Stop Light*—Lights "red" to indicate that the unit has detected an error, caused by an improperly marked card, a parity error, or the operation of the "Two-Card" Switch.

Other switches and lights may be included at the customer's request to suit his particular requirements.

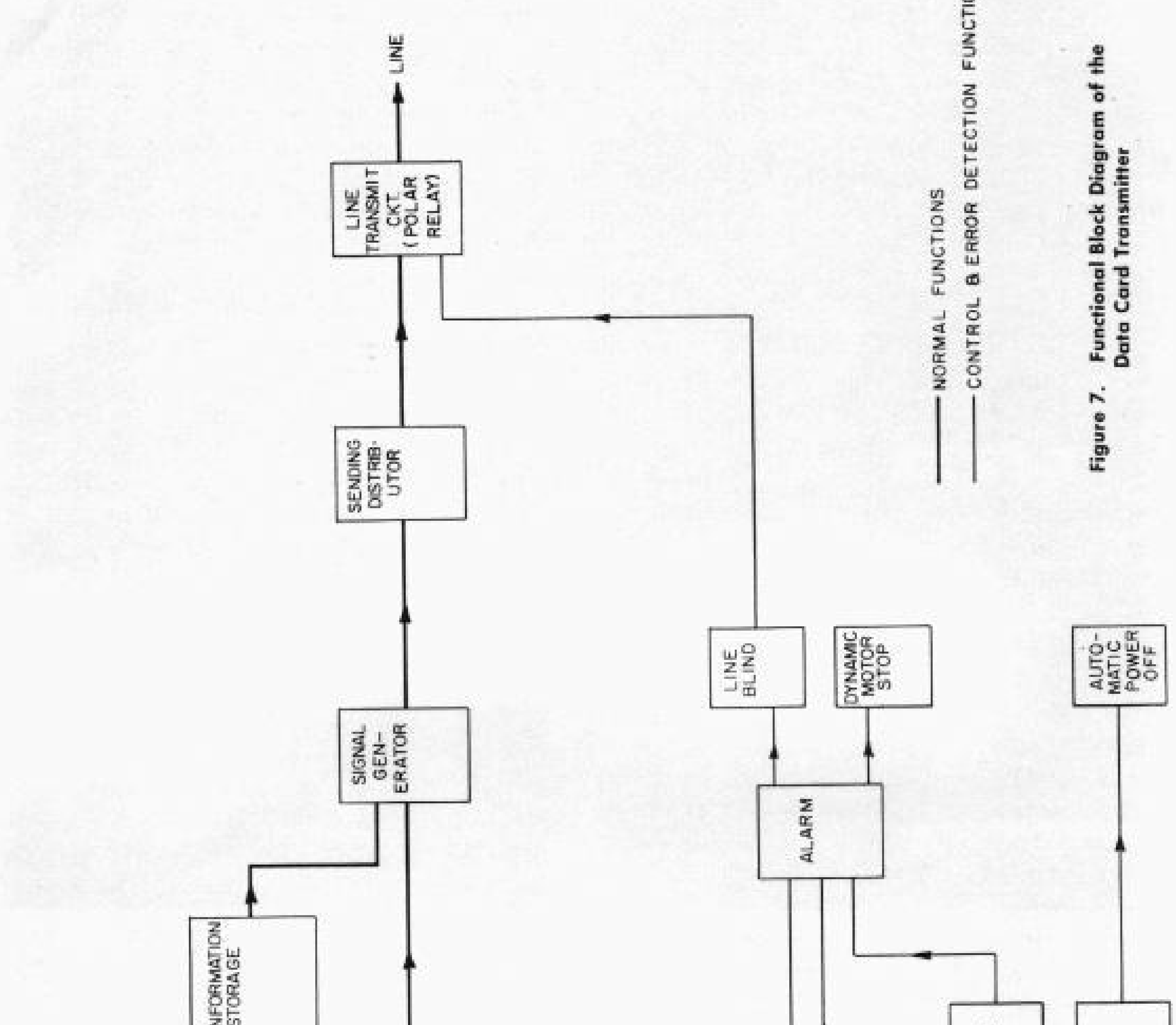


Figure 7. Functional Block Diagram of the Data Card Transmitter

The electronic and the mechanical sections are connected together with a multicontact plug and receptacle, thus allowing the two units to be completely separated if necessary. With the mechanical unit removed, it is now possible for a maintenance man to plug in a test device especially constructed to stimulate card reading functions.

Operation

Only a few minutes of instruction is required to teach one to operate the Data Card Transmitter. It is only necessary to place the cards in the card loader and depress the "*Start*" button, which initiates the power to the unit. Cards will then feed automatically, one at a time, through the machine. When the last card in the loader has been fed out of the machine, the power will return to its normally "off" condition.

In some applications, the depression of the "*Start*" button may be deferred until a circuit connection is established. For example, when this machine is used in conjunction with Western Union's Telex network, the operator can dial the desired destination before transmitting the data information.

The only other need for an operator is to reject and correct errors in the card information.

Reject of Card Information

Whenever an improperly marked card or a parity error is detected anywhere on a data card, the entire card information must be invalidated to ensure the proper operation of the data processing center. The procedure necessary to reject a card will vary according to the requirements of the data system.

Whenever an error is detected in the Data Card Transmitter 11313-A, the motor is electro-dynamically braked, card motion is stopped, and the "red" AUTO-STOP light is illuminated. A visual inspection of the card in the machine by the operator indicates which tie-up condition caused the unit to stop. When the RESET button on the mechanical unit is held depressed, the card is fed out of the machine and into a basket without transmitting any further information on that particular card. If there is more than one error on a card, the card will stop at each error, even if the RESET button is held depressed, so that the card may be properly and completely corrected before rerunning. Since the depression of the RESET button also stops the loading of subsequent cards, an operator may, by means of a teleprinter keyboard or a special "Bust This" data card, eradicate the information sent from the errored card before the next card in the loader is transmitted.

The routine for retransmission of the errored card will vary in different data systems. In systems which require the cards to be in consecutive order, it will be necessary to restack the cards, thus placing the corrected card on the bottom of the stack before resuming transmission.

In systems where the order-of-card transmission is not vital, much time may be saved by setting the improperly marked cards aside and retransmitting them after the entire stack has passed through the machine.

These procedures of retransmission are predicated upon the ability of the operator to correct errored information in the cards. In some cases it is necessary that the operator refer back to the data source.

Another method of eradicating the information transmitted is one in which a given character sequence, such as two or three "Xs," will be transmitted when the "*RESET*" switch is depressed. The receiving equipment is programmed to recognize this sequence as a card "reject."

In other versions of the unit, it is possible to eliminate the necessity of stopping the card when an error occurs and instead, mark the card so as to indicate it is faulty. In this type of application each card has a character sequence which indicates the beginning of a card and another character sequence signifying the end of the card. When an error occurs, no further information is transmitted on that card including the "end of card" sequence. The receiving equipment must necessarily be programmed to recognize this as a "reject."

Typical Applications

The versatility of the Data Card Transmitter makes it suitable for not only existing data systems, but those data handling systems where the output of the data card may be a teleprinter, perforated tape, business machine cards, or all three at the same time. The fixed data area of the card permits the use of more sophisticated formats which segregate the card information through the programming of the receiving equipment.

A system utilizing this capability is illustrated in Figure 8. This sales order system processes data efficiently using only telegraph equipment. The output of the Data Card Transmitter is transmitted over regular telegraph facilities to four different receiving areas: (1) Order Department for completion of records, (2) Billing Department for pricing, (3) Inventory Control for stock records, and (4) Shipping Department for shipping papers. Each teleprinter, at these four areas, is programmed by means of its "stunt box" to receive only that portion of the data information pertinent to that area. For example, the shipping papers are produced only at the warehouse station which fills the sales order. Except for the pricing operation, all equipment shown is automatic and unattended.

In addition to payroll and sales order applications, the Data Card Transmitter may be applied in many other areas, such as:

- Stock broker reports of sales and purchases.
- Production schedules for manufacturing plants and steel mills.
- Transmission of meter readings for utility companies.
- Bills of lading for freight handling.
- Transportation and hotel reservations.
- Invoicing charge accounts.
- Billing labor charges.
- Inventory control.
- Data storage retrieval.
- Encoding and decoding.

Besides the commercial applications, the Data Card Transmitter has many military applications in the communications and supply areas where message format is a major factor.

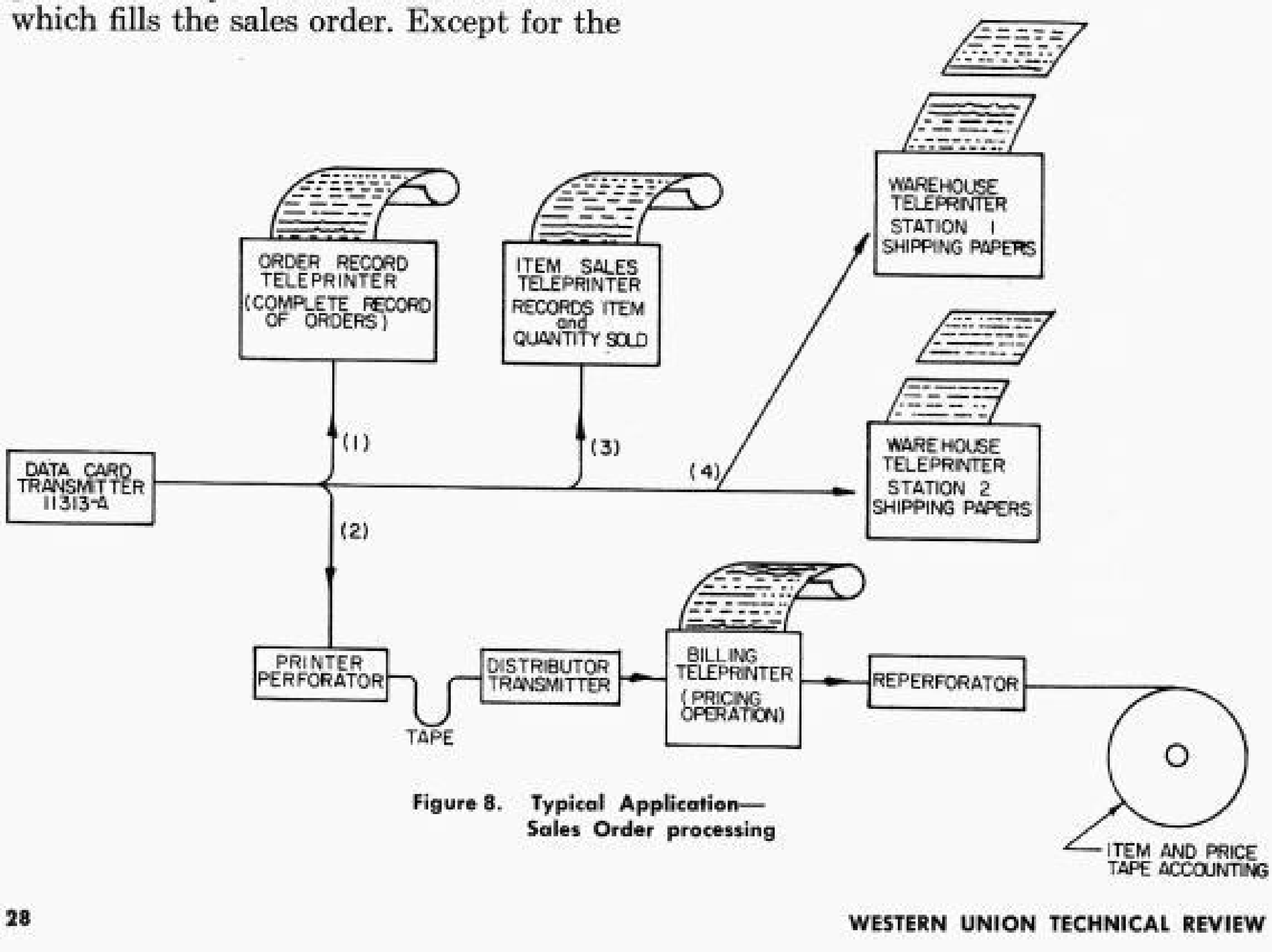


Figure 8. Typical Application—Sales Order processing

Acknowledgments

The basic operating principles for the Data Card Transmitter were conceived by Mr. R. Steeneck, Acting Data Systems Engineer at Western Union. The electronic circuitry was designed by Mr. R. Duswalt, Project Engineer.

The author wishes to express his appreciation to these engineers and others who participated in the success of this unit.

Mr. Recca, left, Mr. R. Duswalt in the middle, and Mr. R. Steeneck on the right, examine the latest model of the Data Card Transmitter—11313A

Mr. P. F. Recca is a Senior Project Engineer in charge of the design of the Data Card Transmitter 11313-A.

Since his employment with Western Union in 1948, he has been primarily engaged in the design and improvement of electromechanical telegraph equipment. He was responsible for the design of the Tape (Loop Gate) Transmitter 7595 and the Bias and Distortion Test Set 7399. He has participated in numerous components and system designs, such as those used in Telex, where his teleprinter knowledge was used in the selection and application of all outstation equipment.

Mr. Recca received his Bachelor of Mechanical Engineering degree from the Polytechnic Institute of Brooklyn.

Third AF DATACOM Station Begins Operation at Tinker AFB

Communication Data Processor operator's console of a type made operational on December 17, 1962 at McClellan AFB, California. This is the second center of five such centers accepted by the Air Force for the AF DATACOM network designed by Western Union.

A third center was made operational at Tinker AFB, Oklahoma on January 9, 1963.

Patents Recently Issued to Western Union

Facsimile Transmitter

W. D. Buckingham, N. R. Lane, G. H. Ridge, F. T. Turner

3,056,034—September 25, 1962

An optical scanning system for a flat-sheet facsimile scanner of the type described in Patent No. 2,903,512 designed to blank out transmission when the scanning beam moves offside on narrow message blanks. Light from a single source passes via a folded path including an oscillating spherical mirror to the message sheet and is there reflected to an enclosing cylindrical reflector bearing elongated apertures for passage of the oscillating beam. It is then reflected to a message photocell. When the beam passes offside the message sheet it reaches a blanking mirror and is reflected instead to a blanking photocell which controls circuitry to interrupt signal transmission. Dimensional design of optical path lengths, conjugate foci of the cylindrical reflector and optical center of curvature of the oscillating mirror, all are integrated to provide selectivity between the two photocells.

Telegraph Switching System

M. D. Adams, C. W. Johnson, E. J. Chojnowski, A. M. Eisner, H. Glick

3,057,956—October 9, 1962

A telegraph automatic switching system employing a number of switching centers wherein each incoming line position is provided with a storage printer-perforator, and directors under allotter control process message routing indicators to direct the messages cross-office to reperforators at outgoing line positions. Multi-address messages up to a predetermined number of addresses are switched directly but if the number is exceeded the message passes to a multi-address position for handling. Also, a single address code may direct a message to several different addresses via successive switching centers and means are provided for preventing transmission of the message to addresses handled by previous centers. A parity check assures accuracy of cross-office transmission for all characters.

Ticker Tape Projection System

P. L. Myer

3,060,799—October 30, 1962

Since a single ticker tape projector can project on the screen only a few inches of tape a coordinated system of a number of projectors handling adjacent sectors of tape is used for projecting a long continuous length of tape on an elongated screen. Each projector employs a separate ticker, together with its tape puller, taut tape loop contacts, and a relay type of tape snubber each of the latter located at a respectively increasing distance from its ticker for maintaining proper registration of the tapes. The tickers and, by means of a system of relays, the tape pullers all start simultaneously when slack tape allows all of the taut tape contacts to close. The snubbers stop all tapes simultaneously when the first taut tape contact opens.

Telegraph Pole Line Insulator

W. F. Markley, J. L. Slater

3,061,667—October 30, 1962

A rubber line insulator embodying in its formulation a heat cured mixture of substances providing improved qualities at high frequencies and comprising, in addition to fillers and pigments, an elastomeric rubber compound and a hydrocarbon polymer both of low dielectric constant and together providing elasticity and resiliency to support the line conductor without bending and abrasion, and a wax compound to provide long-lasting non-wetting surface characteristics. Some carbon black is added to provide resistance to ageing but not sufficient to impair the dielectric properties.

C. R. Deibert and W. D. Buckingham, Electronics Division

BOMB ALARM

Display System 210-A

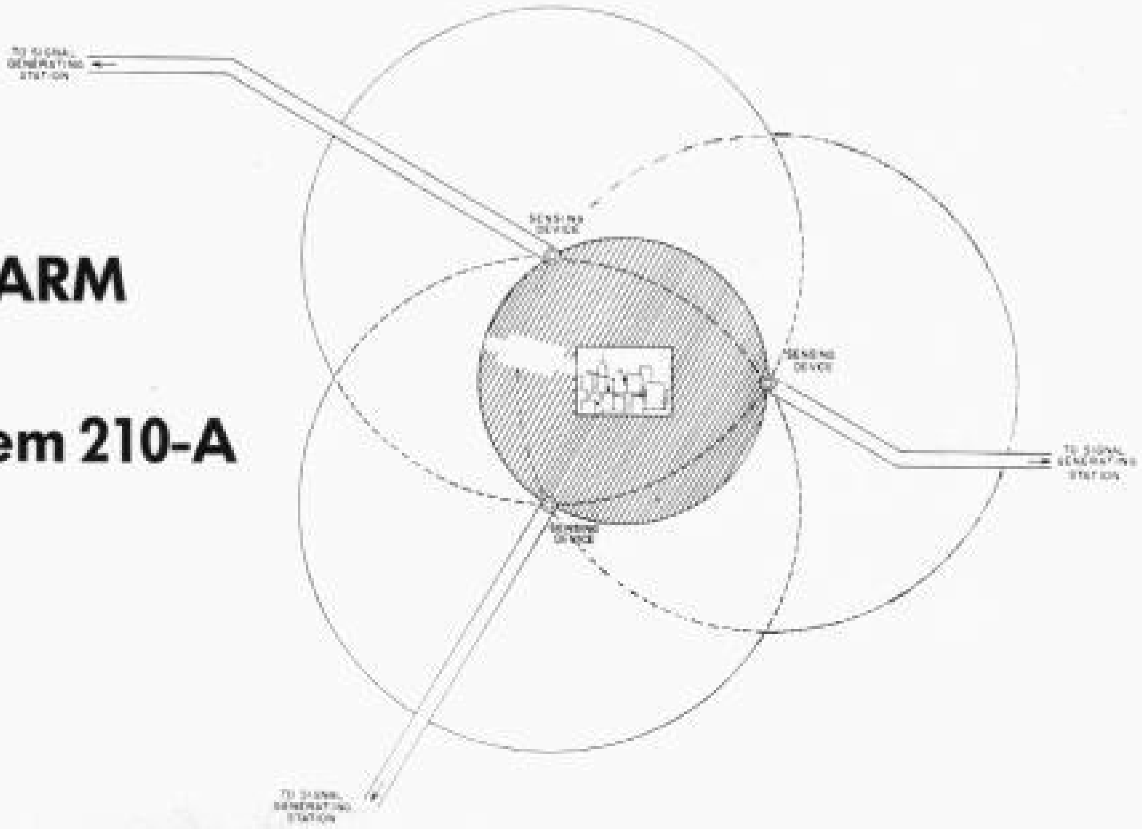


Figure 1. Configuration of Sensing Devices

THE prime requisite of any alarm system is maximum reliability coupled with safeguards which insure that the system "fail safe" in event of trouble. A nuclear-bomb alarm system has the added special requirement that it never send a false alarm. The Western Union Display System is designed to these specifications.

Energy Produced by Bomb

A nuclear bomb produces three main types of energy which might be used as a basis for detecting a blast. About one third of the total energy is emitted in the form of light and heat,—generally referred to as "thermal radiation." This intense radiation travels almost instantaneously and can start fires or cause skin burns at considerable distances from the point of detonation.

The second type of energy known as "initial nuclear radiation" consists of gamma rays and neutrons. This comprises only three percent of the total energy and its intensity decreases sharply with distance. At a distance from the blast where exposure to thermal radiation could produce serious skin burns, initial nuclear radiation would not cause any obvious injury.

The third type of energy, and that which is responsible for the largest part of the destructive action of the bomb, is the "blast wave." While this is intense, it is relatively slow, and its arrival time depends upon the energy yield of the explosion and the distance involved. At a distance of one mile from a one-megaton blast, the blast wave will arrive about four seconds after the thermal radiation.

Any one of these three forms of energy could be used as basis for detection; but, considering available methods, the high intensity and the high speed of transmission of the thermal radiation energy make it best suited to operate a bomb-explosion detecting device. In addition, the thermal radiation from a nuclear blast has a unique wave shape which distinguishes it from all natural sources of thermal radiation. The nuclear flash wave consists of two pulses of thermal energy, a fast-rising short-duration pulse followed by a comparatively slow-rising long-duration pulse.

Western Union Design

Detectors or sensing devices used in the Western Union Bomb Alarm System are designed to detect the thermal radiation from nuclear blasts. They have an adequate foggy weather range and observe a field extending from 0 to 360° in azimuth. They are used in groups of three, spaced at intervals 120° apart and several miles distant from the center of the area under observation. Figure 1 illustrates an ideal configuration of three sensors.

If a blast occurs near the center of the area, it is reported by all three detectors, since there is ample time for each detector to report the event before the arrival of the blast wave, which might destroy the detector or its connecting wires. The connecting wires and other system elements are located outside the central area. If the blast occurs sufficiently close to one of the three detectors to destroy it before it can report, then the other two detectors in the group will send the alarm. While all events are reported to central information points, simultaneous reports from at least two detectors will normally be required to record a bomb alarm on the system display map, at each central information point.

The detector, which is transistorized, receives its operating power from the telegraph signal generating station, over a pair of telegraph wires. Signals from the detector to the signal generating station pass over the same wires as audio-frequency tones. Three tones are used: one indicating the normal or "green" condition, the other two, used in sequence, indicate an alarm or "red" condition. The detector may be located some distance away from the signal generating station, depending on the line resistance and the permissible line voltage.

The detector, shown in Figure 2, is housed in a heavy, air-tight, aluminum, cylindrical container, about 9 inches in diameter and one foot high, which is surmounted by a cylindrical Fresnel-type marine lens. Within the lens is a cylindrical perforated-metal shield, which has a light-attenuation factor of 100; within the shield are the photocells, mounted at the focal point of the lens.

■ Western Union was asked, in May of 1959, to submit a proposal to the Air Force for a nuclear-bomb alarm system. It was required that this system should observe a group of about one hundred selected possible target areas in the United States and continuously report their condition on display boards located at a number of different military command centers. Plans for such a system were presented to the Air Force in June 1959, Western Union was given instructions to proceed early in August 1959, and a prototype system was developed and in operation by March of 1960.

■ This prototype display system observed fourteen potential target areas in the eastern portion of the United States. It consisted of thirty-seven Detectors and Signal Generating Stations, one Master Control Center, and one Display Center located in the Pentagon. After a series of engineering tests, the U.S. Air Force accepted the prototype system on February 10, 1961. From that date until February 6, 1962 when the prototype was integrated into a nationwide system, performance was satisfactory, with no false alarms and with 98.1 percent normal responses out of a total of 18,600,000 responses.

■ Nationwide expansion of the system was completed early in 1962. Following a series of tests, which included the successful reporting of an actual nuclear detonation, the system was declared "fully operational" by the Air Force. This system is known as Western Union Bomb Alarm—Display System 210-A.

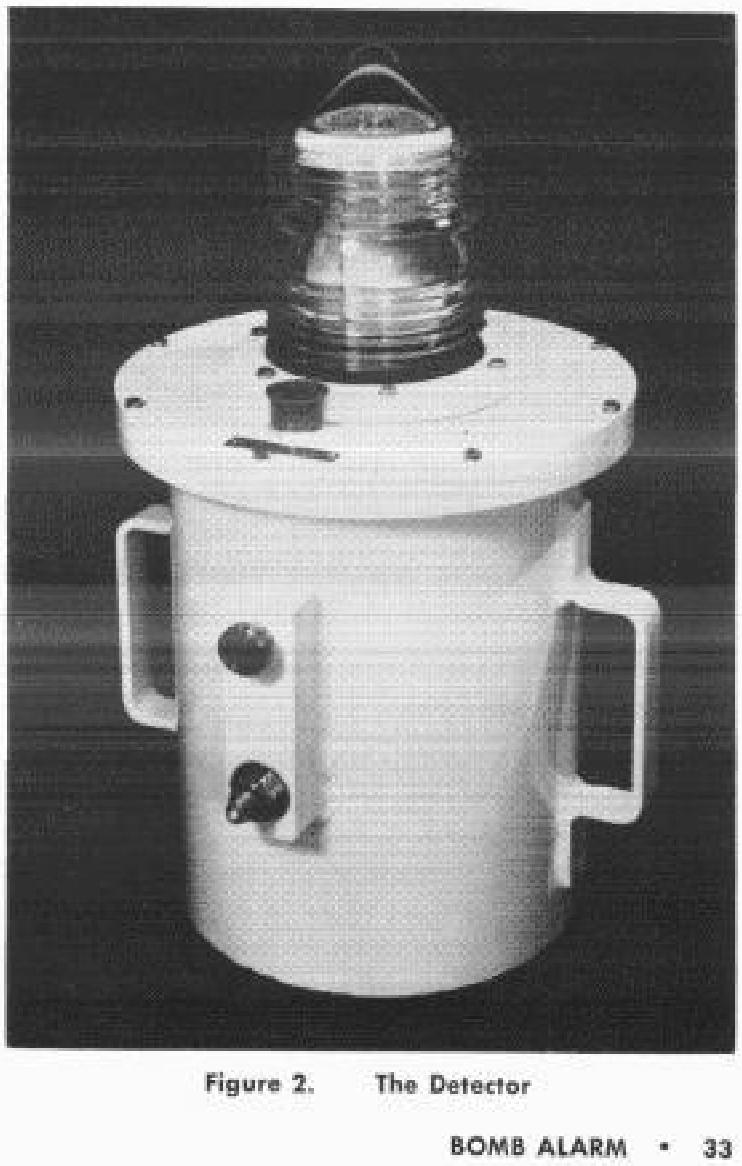


Figure 2. The Detector

Operation of the Detector

The photocells are the silicon "sun battery" type. The individual cells are thin plates 1 by 2 centimeters. Three plates are mounted in a triangular structure, 2 cm high and 1 cm on a side, with the sensitive surface on the outer face. These photovoltaic cells respond to the visible and infrared energy produced by a nuclear flash. Their response time is only a few microseconds.

A double-peaked electrical pulse, illustrated in Figure 3, is generated in the photocells by a nuclear blast. This pulse is amplified by two separate amplifiers and fed into two separate discriminating circuits. The first discriminator requires a fast-rising, high-amplitude pulse to cause it to trigger and shift the oscillator in the detector to its intermediate warning frequency. The second discriminating circuit is designed to respond only to pulses of sufficient magnitude and of a shape unique to a nuclear blast.

Thus a series of tests is applied, to assure that an alarm will be given only in the event of a nuclear flash and not because of lightning or other natural causes.

Lightning does have a fast rise time, but its intensity is low and its spectral distribution is such that much of its energy falls outside the acceptance range of the photocell. Lightning also does not last long enough to produce sufficient energy to satisfy the discriminator. Even multiple lightning flashes fall far short of satisfying the energy requirement of the alarm system.

Environmental Conditions

A desiccant is mounted in the sealed aluminum container to maintain a low-humidity atmosphere for the detector components.

The aluminum can is painted white on the outside to reflect solar heat. The detector circuits are designed to operate over a wide temperature range.

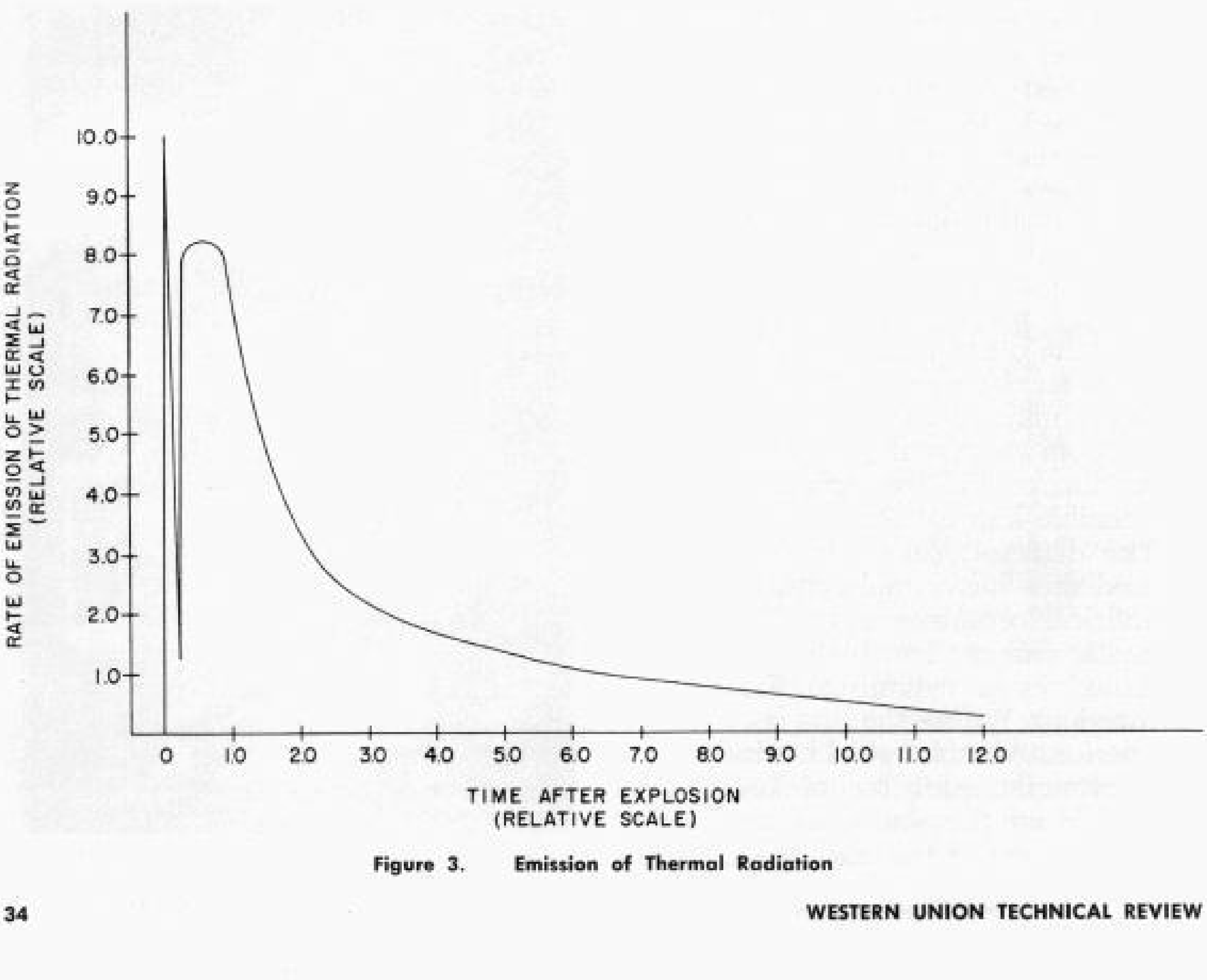


Figure 3. Emission of Thermal Radiation

Remote Control Tests

The detector includes a built-in test simulator which can be triggered remotely. It operates to produce a flash from a group of small neon and tungsten filament lamps which are mounted inside the attenuating metal screen and around the photocells. This flash is similar in shape to a nuclear flash. The detector will report an alarm upon the receipt of such a test flash.

A test of the complete system is possible from the photocell and the detector, the signal generating station, the Master Control Center, and all the interconnecting telegraph network to the Display Centers.

Signal Generating Station

The signal generating station shown in Figures 4 and 5, is located at some convenient point within approximately twenty miles of the detector. It supplies power to the detector and receives signals from the detector as a steady "green" or all-clear-and-operating signal or as the "red" sequence of two tones which constitutes the nuclear alarm.

The signal generating stations, connected in series loops, together form a system for reporting the status of detectors. When queried, each signal generating station will report "green" or not report at all. The "green" report indicates that the normal tone is being received from the detector and that the signal generating station is in working order. No report indicates trouble; either a detector is not

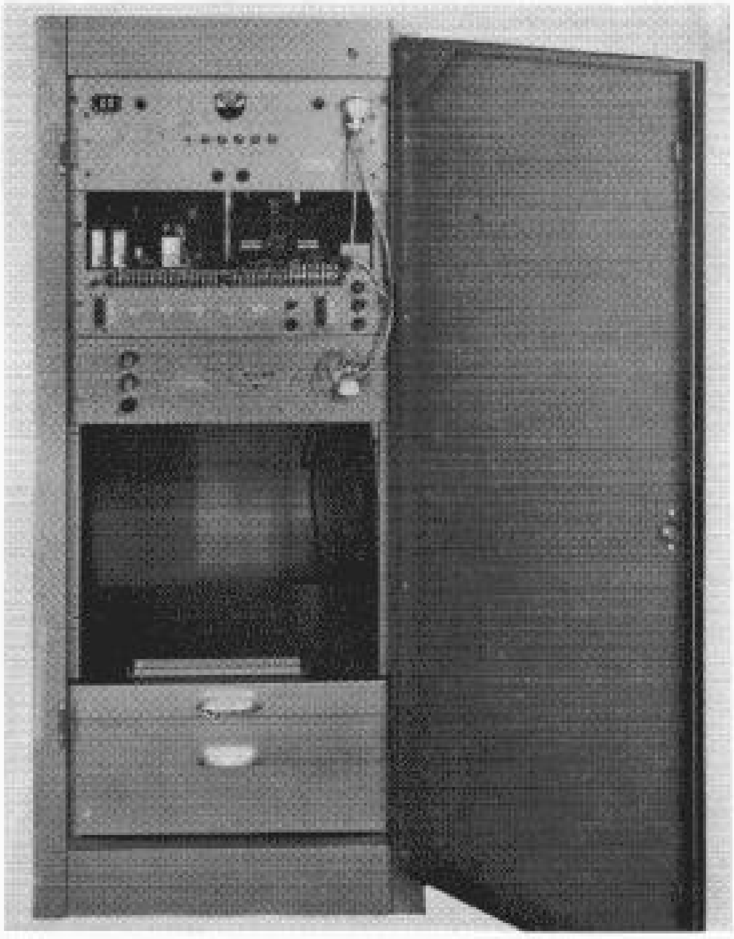
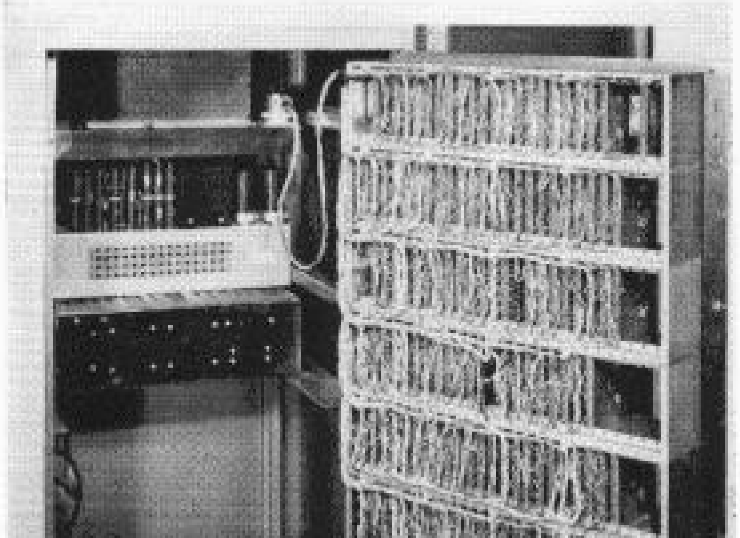
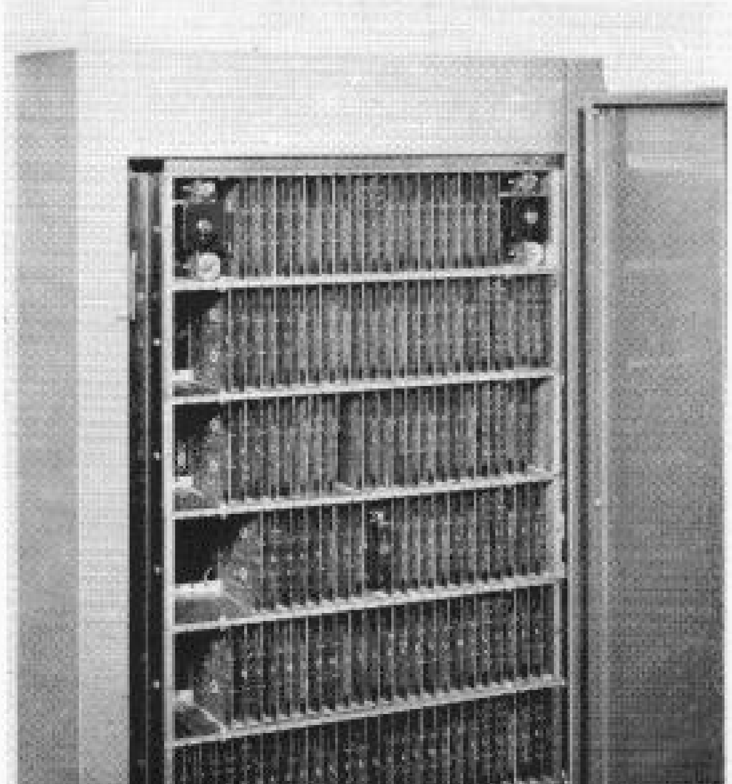


Figure 4. Signal Generating Station—Front View



a) Logic Assembly Swung Open



b) Back Door Opened showing Logic Assembly

Figure 5. Signal Generating Station—Rear View

working, the line to the detector is faulty, or the signal generating station itself is not in perfect working order.

Message Transmission

Each signal generating station is a regenerative repeater and is capable of retransmitting perfectly, even badly distorted signals. Each station can receive only from the next preceding station and can send only to the next succeeding one. Each such loop is under the direct control and supervision of a Master Control Center. Under normal conditions the Master Control Center will periodically send to all loops connected to it a polling signal in the form of five-letter word. The first signal generating station on each loop receives this signal and repeats it to the following station with an 11 millisecond delay. At the same time the message is decoded within the signal generating station and, on decoding, causes a probe to be made on the detector line. If the green tone is present, the signal generating station will transmit its green report directly following the poll message. If no green tone is found, no local report will be made.

The second signal generating station will receive and repeat the poll request and, on decoding the poll message, will prepare to send its answer as the first station did with the exception, that now there is further traffic on the line in the form of the reply of the first station. The second station will have to wait until it sees an idle incoming line before it inserts its reply. This procedure is followed all the way down the line, each station relaying all incoming traffic and appending its report at the end. The last station on a loop will relay back to the Master Control Station, the original poll request and the reports of all the other previous stations and append its own report as the last message.

If the signal generating station fails to receive a polling message for an interval of 2½ minutes, it will send its green report automatically. This feature aids attending personnel to locate breaks in the series loops, if they occur, and informs them as to the number of stations still capable of reporting red alarms under such conditions.

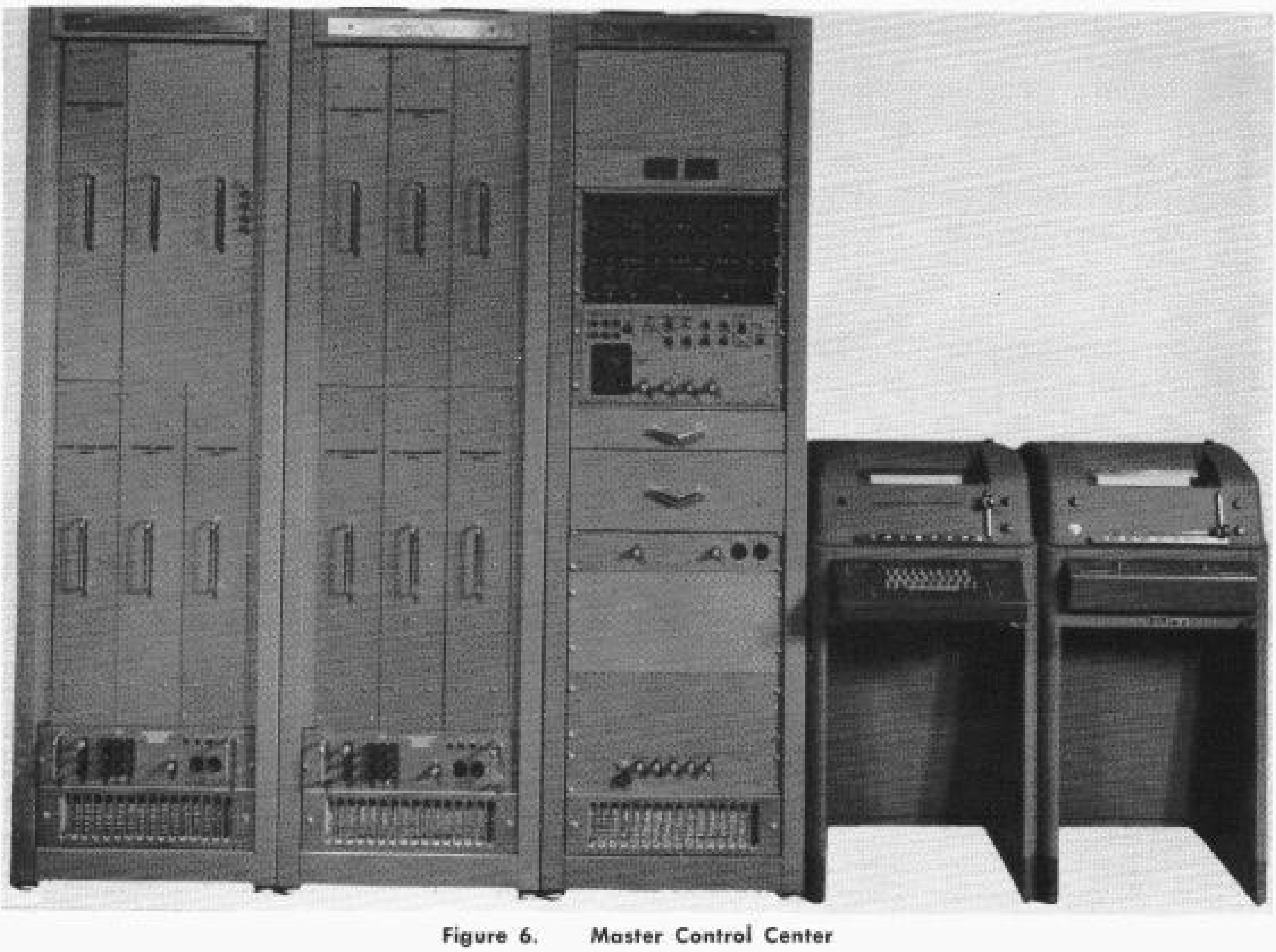


Figure 6. Master Control Center

Should the incoming tone from the detector shift to the alarm sequence, the signal generating station will generate its characteristic alarm signal and, if the line is idle, immediately transmit it down the line. Should the signal generating station be busy when an alarm is detected, the transmission of the alarm is delayed until the end of the message then being relayed.

After receiving an alarm from the detector, the signal generating station then inserts the alarm message and shunts any further incoming traffic into storage. The traffic in storage is retransmitted directly following the local alarm report. Handling traffic in this manner assures that an alarm can be handled with a minimum of delay and that no traffic is lost. It is important that the incoming traffic, which is stored when the local alarm is inserted, be preserved and retransmitted, for it, too, may be an alarm message.

Master Control Center

The Master Control Center, shown in Figure 6, is the automatic control center for the system. All the signal generating station loops begin and end in Master Control Centers. Loop polls are initiated from this point and all answers are received here. The Master Control Center knows the number of signal generating stations which should report and recognizes their call letters. On completion of a poll, all the stations reporting are checked off and the "green" reports are relayed to the Display Centers. The Master Control Center generates an out-of-order or "yellow" report for any station not reporting. On completion of the report to the Display Centers, the poll request is again sent out to all signal generating station loops, thus beginning a new cycle. Figure 7 is a functional block diagram of a Master Control Center.

On receipt of an alarm message the Master Control Center immediately ceases all normal functions. All "green" reports in storage are erased making the storage register available for recording "red" reports as they are received. At the same time the function of the storage register is changed, the Center begins a high speed scan of the register and within a millisecond it begins the transmission of the "red" reports to the Display Centers. After all "red" reports have been cleared out of the storage register and all incoming traffic has ceased, the Master Control Center initiates a poll. On completion of this poll the storage register is scanned for "yellow" reports only and a corresponding report is made to the Display Centers. At the end of this report the Master Control Center reverts to a normal status and initiates a normal polling sequence.

"Red" Test

In addition to the continual testing and reporting program which the Master

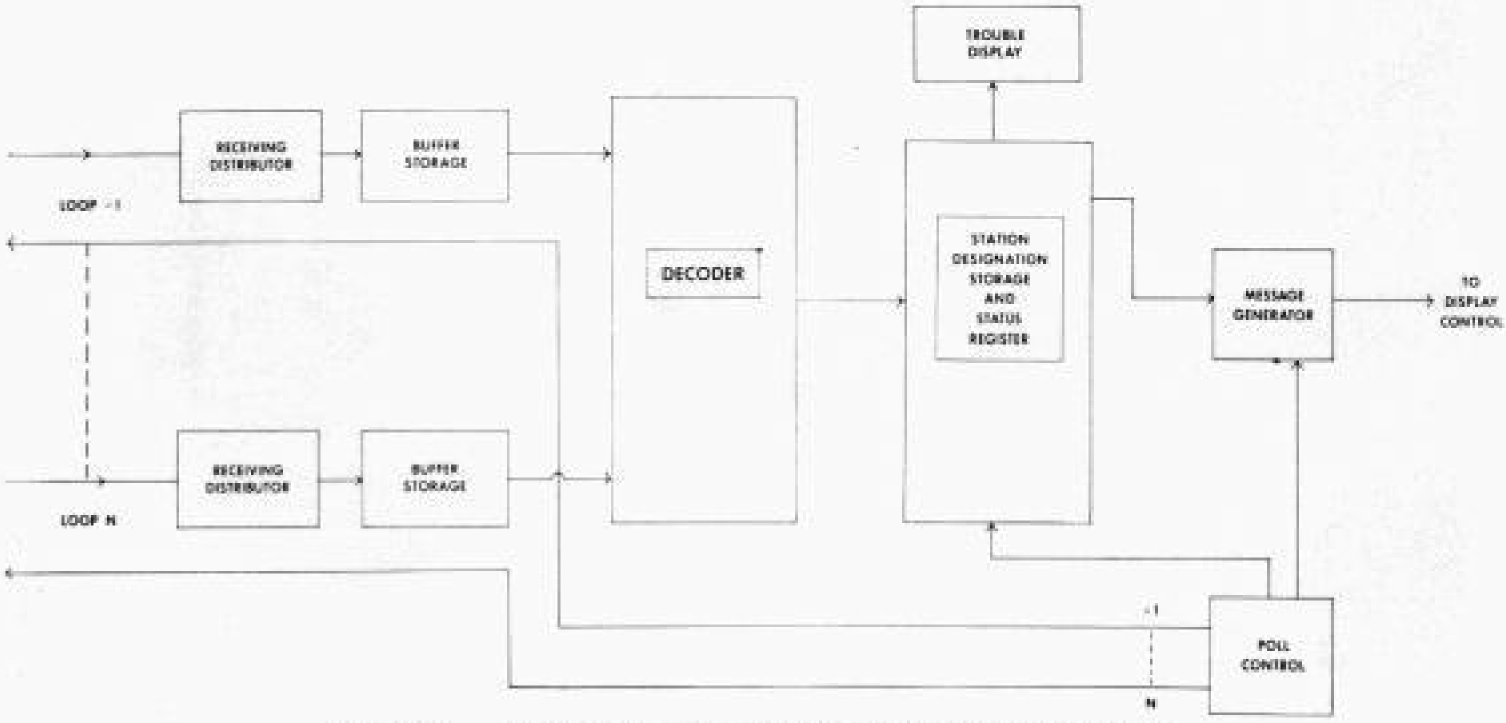


Figure 7. Functional Block Diagram of Master Control Center

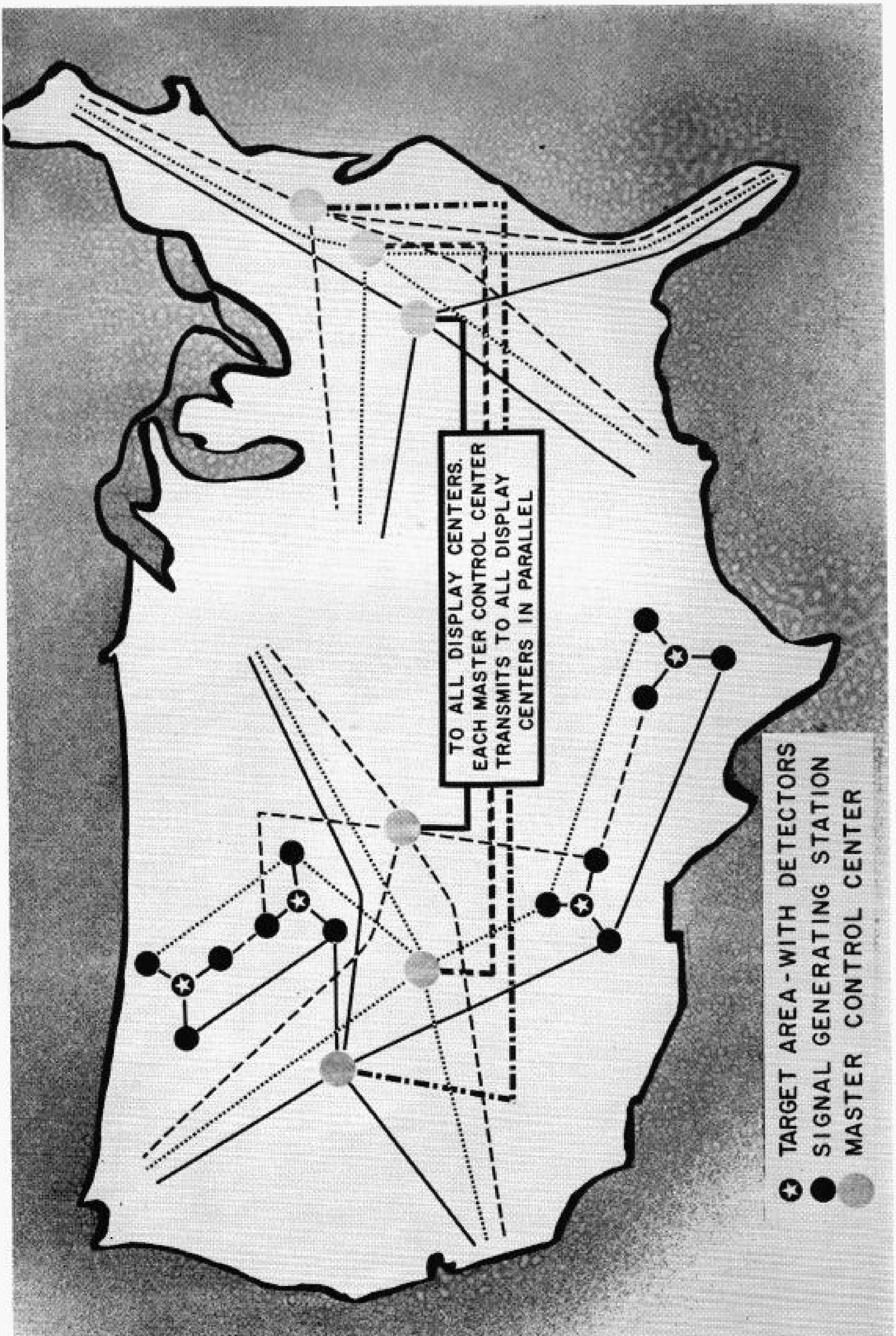


Figure 8. Theoretical System Layout

Control Center performs automatically, provision is made for the attendant at the Center to perform a complete test of the "red" reporting circuitry, loop by loop, or for the entire center at once. On insertion of the proper message on a loop, each signal generating station will trigger a built-in simulator in its associated detector and cause a "red" test to be made. Loops are normally taken out of service to make such tests and the "red" reports merely appear on a test printer and are not relayed to Display Centers. Messages originating in this manner are modified so they are easily identified as test messages and if inadvertently they are relayed to the Display Center, they will not be decoded as alarm messages. Full over-all tests can be made when properly authorized and initiated.

All trouble reports and "red" alarms are automatically printed out on a second printer at the Master Control Center. All maintenance functions can be initiated from this point immediately at the first appearance of trouble.

Regional Layout

The prototype system included only one Master Control Center. In the system covering the entire country, six such centers are employed in two groups of three; each group covering about one half the country. Figure 8 is a theoretical layout of the nationwide system. Each Master Control Center transmits to all Display Centers. The system is designed so that each of the three detectors, associated with a given target area, is tied into a separate Master Control Center by way of separate facilities. Reliability and continuity of coverage is improved by this triple diversification. Each Master Control Center polls all associated circuits every two minutes.

Display Center

The Display Center consists of the decoding equipment, shown in Figure 9 and two display panels illustrated in Figures 10 and 11. The decoding equipment decodes the telegraph traffic so that the designated lamps light up on the display panels. This equipment also keeps track of the mistakes it makes as well as those caused by a faulty circuit to the Display Center. Attendants are called in case of trouble. Figure 12 is a block diagram of the display control equipment.

The display panels consist of a map, shown in Figure 10 and a tabular listing of the target areas, shown in Figure 11. On the map display only the "red" status report can be made and this, only, if two or more Detectors in a given target area have sent in "red" reports, or if a single "red" report is received while the other two circuits, to a given target area, are inoperable or "yellow." A red lamp lights up behind a translucent panel, which has a map outlined on its front surface, so that the area under attack may be located. The locations of target areas are visible only when alarm situations exist or are simulated.

On the tabular listing, referred to as the communicator's panel in Figure 11, three lamps are provided for each detector; red, yellow and green. One of these lamps is lit at all times. Ideally, only "green" lights should appear indicating all equipment and circuits are in working order. A "yellow" light indicates that equipment or facilities associated with a particular de-

Figure 9. Display Control Cabinet and Printer

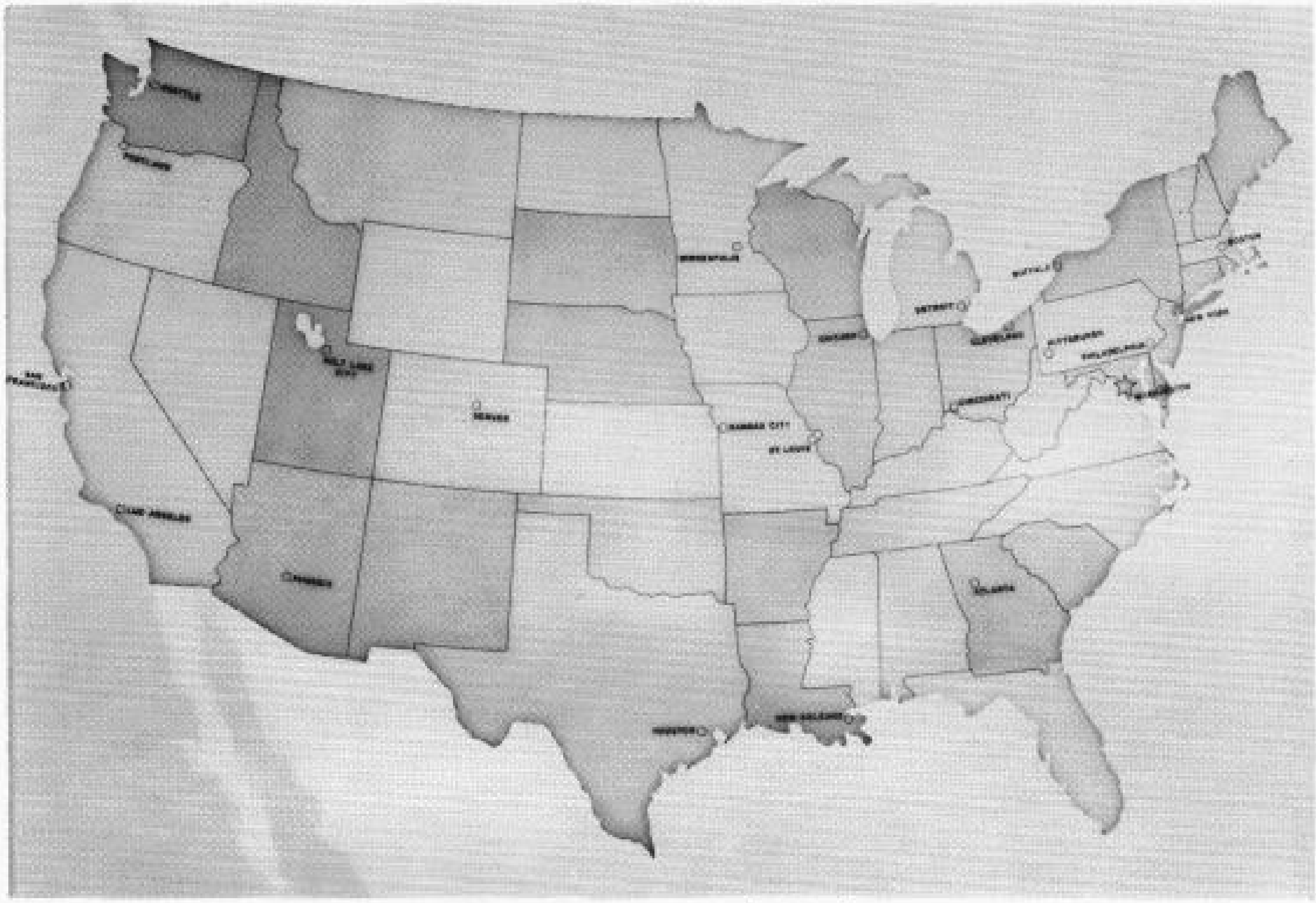


Figure 10. Map Display Panel

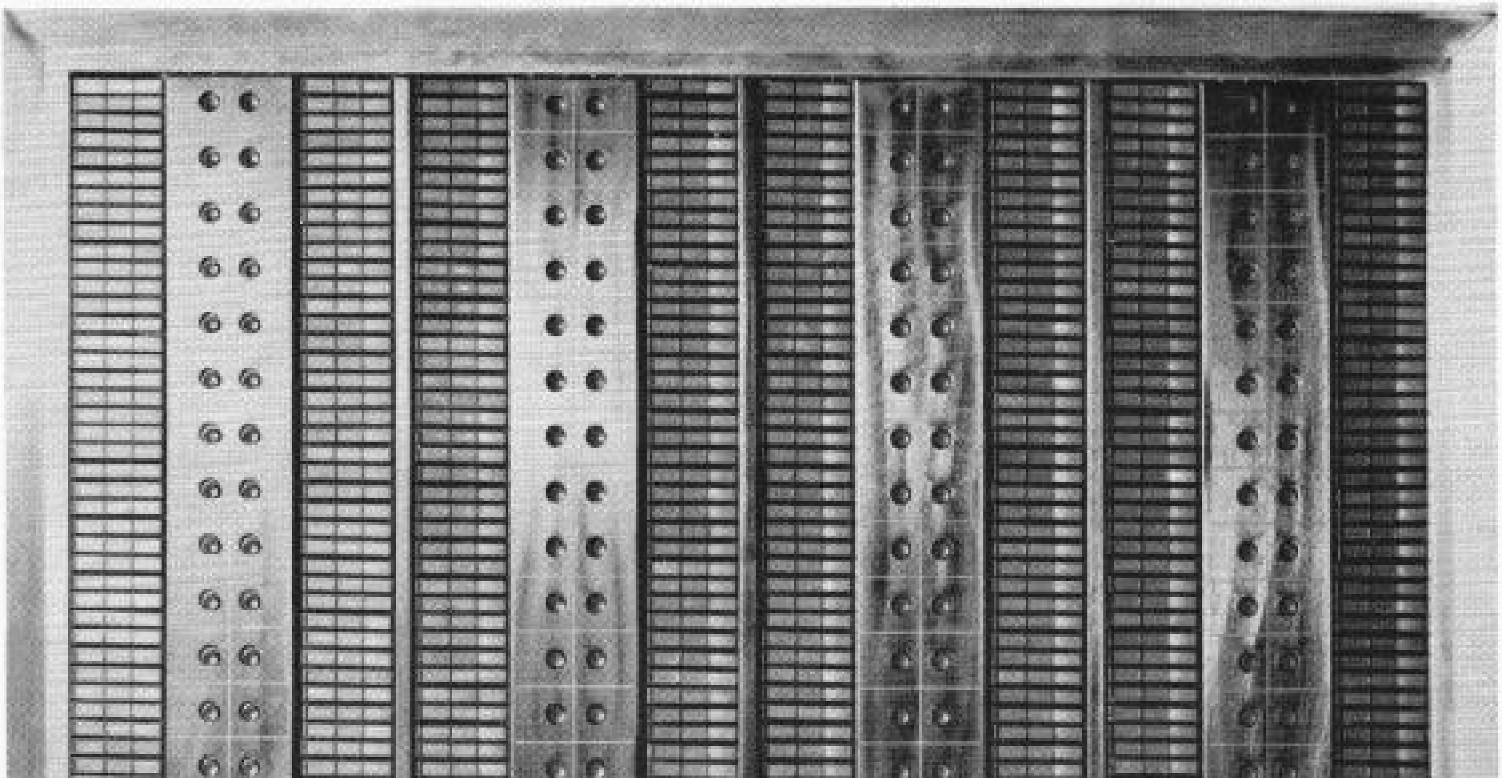


Figure 11. Communicator's Display Panel

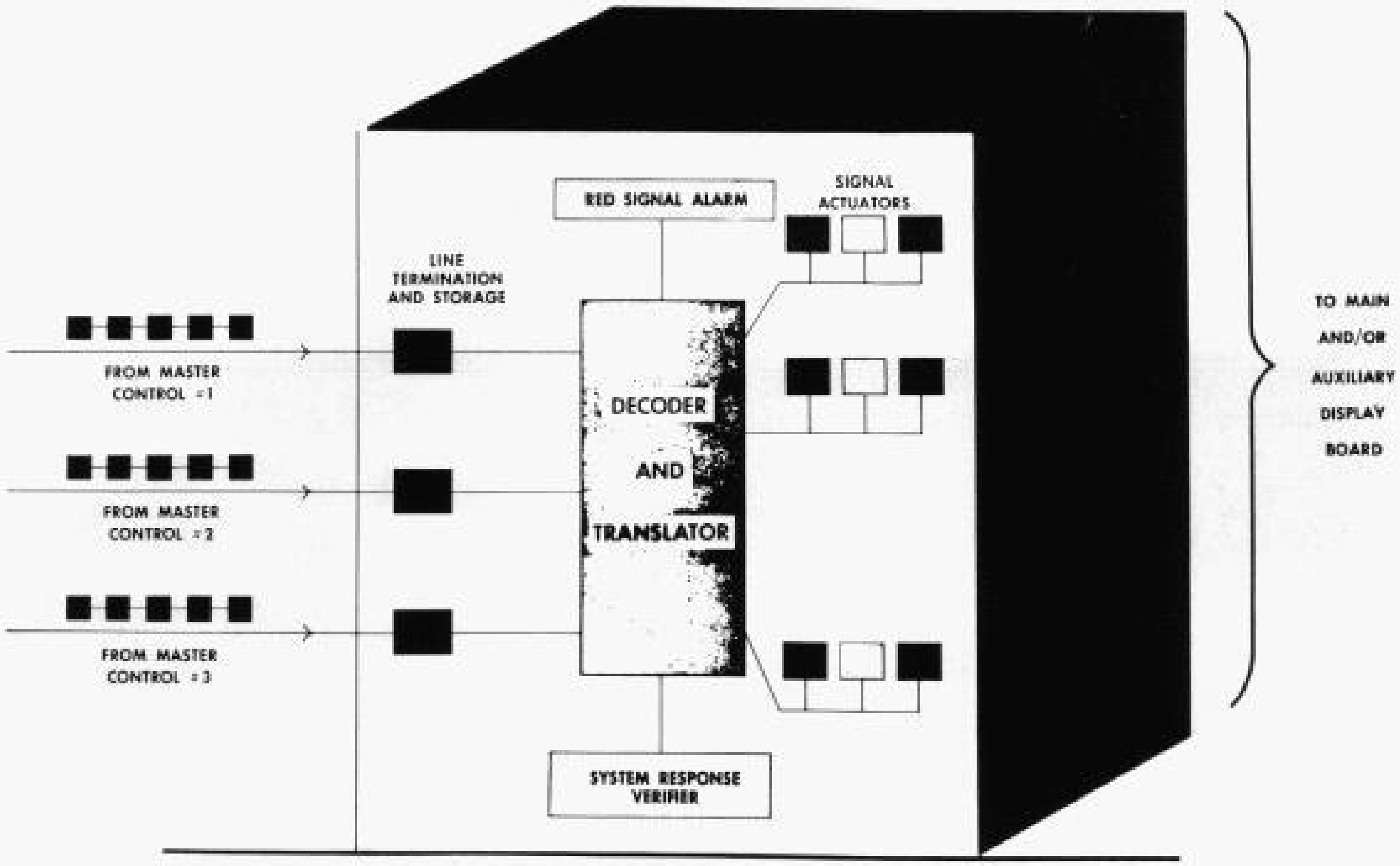


Figure 12. Display Center Control—Block Diagram

tector are faulty and are incapable of responding to the test sequence but may still be able to respond to an alarm sequence, depending on the type of fault. The "red" light indicates an alarm sequence has been detected. A target area name becomes readable only when an alarm situation exists or is simulated for that area. The attendant at the communicator's panel knows the status of all detectors at all times.

System Reliability

The Western Union Nuclear Bomb Alarm System has been designed with many safeguards to insure continuous operation. This system will maintain a constant watch over the selected locations with maximum reliability assured by continuous testing. If a nuclear explosion should occur within any of the observed areas, instant notice would be flashed to the important military posts.

MR. CLARENCE R. DEIBERT, Senior Engineer, is in charge of the Water Mill Laboratory Staff who designed and developed the component equipments of the Western Union Display System 210-A. He has been a member of the Water Mill engineering staff since 1941; was appointed Assistant to the Electronics Research Engineer in 1947.

On joining The Western Union Telegraph Company he was assigned to research in the field of infra-red signalling, first for Western Union, later under contract to the NDRC. Since 1947 he has directed the development of the High Speed Facsimile Terminal, of Telegraph Terminal AN/FGC-29, and most recently the design and development of the Bomb Alarm System.

Mr. Deibert is an Electrical Engineering graduate of Northeastern University. Before joining Western Union he was an employee of the General Radio Company and a research assistant in the nuclear physics laboratories at MIT. He is a co-inventor of the concentrated-arc lamp, holds several patents in the facsimile field, has contributed to the technical literature in both these fields and is a member of the IRE.

To a Western Union engineering, research, scientific or technical worker who has made a most significant contribution to the telegraph art

Mr. Buckingham receives the 1962 d'Humy Award from Mr. W. P. Marshall, President of The Western Union Telegraph Company

MR. WILLIAM D. BUCKINGHAM, Senior Engineer in the Electronics Laboratory at Water Mill, New York has had a major role in developing the sensor for the Bomb Alarm system. He received the 1962 D'Humy Award for "his original ideas, fruitful research and inventions in many areas of communications and national defense."

He joined Western Union in 1925 and since then has designed the optical system for a facsimile scanner, the concentrated arc-lamp, the depthometer, equipment for night fighter trainers, and character recognition equipment amongst others. He won the Franklin Institute Medal for his development of the Concentrated Arc-Lamp.

Mr. Buckingham is a graduate of Case Institute of Technology where he received his degree in Electrical Engineering. He is the author of numerous technical papers and is a member of the IRE.

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Varactors
Semiconductor Devices
Variable-Capacitance Diodes

Ernst, R. L. and Fitzpatrick, J. K.: Varactor Diode Part 1—Theory

Western Union TECHNICAL REVIEW, Vol. 17, No. 1 (Jan. 1963). pp 4 to 13

This is a tutorial article introducing the fundamental characteristics of varactor diodes. The Manley-Rowe power relations for nonlinear reactances are explained and illustrated with a practical example.

Part II will appear in the April, 1963 issue of the Western Union TECHNICAL REVIEW and will be concerned with the applications of this device.

Display Systems (Alpha-Numeric)
Data Communication Systems
Electro-Mechanical Devices

Burroughs, H. F.: Electro-Quote Display System

Western Union TECHNICAL REVIEW, Vol. 17, No. 1 (Jan. 1963). pp 14 to 19

Western Union developed and constructed ELECTRO-QUOTE for the Trans-Lux Corporation. This article describes the prototype system which translates telegraphic code into an alpha-numeric display of information received over telegraph facilities.

This method of data transmission has many potential applications such as brokerage houses, aircraft control centers or other places where a rapid automatic display of intelligence is required.

Data Transmission
Data Processing
Electro-Mechanical Devices

Recca, P. F.: Data Card Transmitter

Western Union TECHNICAL REVIEW, Vol. 17, No. 1 (Jan. 1963). pp 20 to 29

The Western Union DATA CARD TRANSMITTER 11313-A was designed to automate data transmission at the source. This article describes the problems in handling such data for telegraph transmission and suggests a few of the many applications of the unit such as: billing, shipping, stock trading, hotel reservations and others.

Data Communications Systems
Optical Sensors
Display Systems

Deibert, C. R. and Buckingham, W. D.: Bomb Alarm—Display System 210-A

Western Union TECHNICAL REVIEW, Vol. 17, No. 1 (Jan. 1963). pp 32 to 42

This article describes the system philosophy of Bomb Alarm—Display System 210-A and discusses, in general terms, the operation of the major units of equipment. A brief history of the development of the system by Western Union, in conjunction with the U.S. Air Force, is also included.

TECHNICAL REVIEW FOR '63

EDITORIAL

Perhaps you have noticed the changes in the cover and in the format of articles of the TECHNICAL REVIEW which occurred in 1962. Many of our readers have, and have commented favorably upon these changes. You may not know, however, that the magazine has had a new Editor for the past year and that, in large measure, the new Editor has been responsible for what has taken place.

The plans for 1963 include a series of special issues relating to particular subjects of interest, i.e., a Communications Switching issue, a Microwave issue, and others which will document Western Union's developments in advanced telecommunications.

Western Union's new services such as Private Wire Alternate Record Voice Service, Broadband Switching Service, AF DATACOM, TELEX, and others are subject matters to be reported and published in the near future. The advancing field of Data Communications is of continuing interest, also. We know that our readers—the employees of Western Union and our customers and friends in industry—are eager to keep abreast of the new developments in these fields.

Since this is a magazine primarily concerned with changes in the state of the art relating to fields in which the Telegraph Company is interested and particularly with Western Union accomplishments, most of our articles are prepared by members of the R&E Department and Plant Department on the solicitation of the Committee on Technical Publications, based upon the knowledge of committee members of current engineering projects and impending changes in our Public Message System or Private Wire Services. In addition to these solicited papers, articles in keeping with the objectives of the magazine are invited for consideration from all employees regardless of department.

COMMITTEE ON TECHNICAL PUBLICATIONS