United States Patent Office 3,089,918 Patented May 14, 1963

3,089,918
TELEWRITING APPARATUS

Robert E. Graham, Chatham Township, Morris County, N.J., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Filed Sept. 9, 1960, Ser. No. 54,989
12 Claims. (Cl. 178—19)

This invention relates to the electrical transmission of information pertaining to graphic material and, more particularly, to apparatus for generating electrical signals that are indicative of the position of a moving stylus upon the face of a writing tablet. It has for an important object the elimination of mechanical restraints that fetter the free movement of ths stylus.

Various types of telewriting devices for indicating the "X" and "Y" co-ordinates of a moving stylus adjacent to the plane formed by a writing tablet are well known. Perhaps the most common of these involves the use of pantographic arrangements in which the stylus is coupled to, and thus restrained by, a series of mechanical linkages, the relative movement of which effects a change, for example, in the resistance of a variable resistor to which the linkages are connected. Electrical signals indicative of the position of the stylus are obtained by utilizing the variable resistor in an appropriate electrical circuit. Generally, however, the use of such pantographic arrangements in telewriting devices has been deemed undesirable, since the mechanical linkages associated therewith impede the completely free movement of the stylus and prevent a person who is using the device from writing with his normal and natural style and speed.

Telewriting devices are known, of course, in which the above-mentioned pantographic apparatus is eliminated. These generally utilize unrestrained conductive styli in conjunction with resistive surfaces as the writing tablets.

Typically, the resistive surfaces have applied to them electrical potentials that serve to create an electrical field in the writing tablet. However, extreme nonlinearities are often developed within the field which tend to reduce considerably the usable area of the writing surface.

Accordingly, another important object of the present invention is the elimination in a telewriting device of a resistive surface as the writing tablet and with it the electrical potentials required to create an electric field.

These objects and others are realized in this invention by departing from the usual type of telewriting device. Specifically, the invention utilizes a conventional cathode ray tube, whose face forms a writing tablet, and a special stylus that contains a photosensitive element, e.g., a photocell, at its tip. As the stylus is moved in front of the face of the cathode ray tube in forming cursive script, electrical signals obtained from the photocell, via a flexible conductive lead, for example, are operated upon and fed back to the beam deflection plates of the tube, and the electron beam in the tube is made to track the moving stylus. Since the beam tracks the stylus, the feedback signals are indicative of the "X" and "Y" co-ordinates of the stylus upon the face of the tube, and they may be transmitted to any remote location to indicate these co-ordinates.

To elaborate further upon the principles of this invention, the tracking of the stylus by the electron beam is accomplished by deflecting the beam in a circular scan of high rotational frequency and small radius. When

the circular locus of the beam is centered at a point on the face of the tube that lies opposite the center of the photocell contained in the tip of the stylus, the output from the photocell is essentially constant, i.e., it is a steady state potential. Decentering of the beam, on the other hand, produces a varying output potential from the photocell of a frequency equal to the frequency of the circular scan of the beam. The products of this signal and each of the signals applied to the horizontal and vertical deflection plates of the cathode ray tube to produce the circular rotation of the beam are related to the degree of decentering in the horizontal and vertical deflection directions, respectively. Accordingly, the output potential from the photocell is applied to a pair of multipliers to produce two "error" signals. These error signals are separately integrated to produce a pair of signals which, when applied to the deflection plates of the cathode ray tube, position the beam adjacent the tip of the moving stylus and which are indicative of the position of the stylus. In the present invention, the signals from the integrators are added, respectively, to the signals that create the circular scan of the beam, and the summed signals are applied to the deflection plates of the cathode ray tube both to create the circular locus of the beam and to center it on a point upon the face of the tube opposite the tip of the stylus.

As an additional feature of the invention, an alternative scanning mode is instituted should the beam become decentered beyond a certain predetermined amount. Decentering may be detected by noting the magnitude of the photocell output and generating an "out-of-contact" signal whenever the output falls below a predetermined threshold. In the alternative mode, the electron beam is made to scan the face of the cathode ray tube in normal line sweep and frame sweep fashion until the beam again commences to track the photocell. It may also be noted that the above-mentioned "out-of-contact" signal is generated whenever the stylus is withdrawn from the face of the tube. Thus, an indication is given of the formation of discontinuous traces such as, for example, the formation of individual alphabetic characters or individual words.

In another embodiment of the present invention, a special cathode ray tube is employed as the writing tablet. In this arrangement the cathode ray tube has a specially constructed face comprising, for example, a resistive film deposited on a thin dielectric layer. The stylus in this case is composed entirely of a conductive material that is grounded either directly, by the use of a flexible electrical conductor, or indirectly utilizing the self-capacity of the operator using the stylus. The electron beam is scanned in a circular locus, as described before, and is also intensity modulated. When the beam impinges upon a portion of the resistive film that is opposite the conductive stylus, the stylus shunts the majority of the varying beam current to ground. By detecting the beam current in the resistive film and producing a pair of signals proportional to the product of the envelope of the current and the potentials supplied to the deflection plates that create the circular scan, the stylus may be tracked and its "X" and "Y" co-ordinates upon the writing tablet noted in a fashion similar to that described above.

Although the use of cathode ray tubes as writing tablets in telewriting devices is known, the present invention departs greatly from the principles of operation employed by such devices of the prior art. For example, in a telewriting device disclosed in Patent 2,553,245 granted to L. Espenschied on May 15, 1951, a source of light contained in a stylus is required to impinge upon a special photosensitive and electron emissive tube face to create a beam of electrons. The beam created thereby is passed through a set of plates and the potentials induced therein are indicative of the position of the stylus. In the present invention, however, an independently-formed beam of electrons is employed, and by utilizing the special tracking features outlined above, the beam is made to track exactly the moving stylus. With the precise tracking, potentials indicative of the exact position of the stylus are obtained from the deflection plates of the cathode ray tube.

The invention may be better comprehended by consulting the following detailed description of illustrative embodiments thereof taken in conjunction with the accompanying drawings in which:

FIG. 1 is a pictorial diagram, partially in block schematic form, of an embodiment of this invention utilizing a typical cathode ray tube as a writing tablet;

FIGS. 2 and 3 are graphical aids helpful in understanding the operation of the device depicted in FIG. 1; and

FIG. 4 is a pictorial diagram, partially in block schematic form, of an alternative embodiment of the invention utilizing a specially constructed cathode ray tube as the writing tablet.

Referring to FIG. 1, a typical cathode ray tube 10 is illustrated having a beam producing electrode 11, an intensity control grid 12, and sets of vertical deflection plates 13 and horizontal deflection plates 14. The signals responsible for the deflection of the beam within the tube are applied to the deflection plates 13 and 14 through the conductors 53 and 54. The beam of electrons is made to assume a circular scan of high rotational frequency and small radius by applying, for example, a signal of cosine wave form to the horizontal deflection plates and a signal of sine wave form to the vertical deflection plates. The apparatus for applying such signals to the deflection plates will be described in more detail hereinafter.

A stylus 20 is supplied for forming cursive script on the face of the tube. Conveniently, the tip of the stylus contains a lens 22 which images upon a photocell 21, contained within the stylus housing, the portion of the face of the tube in front of the stylus. When the circular locus of the beam upon the face of the tube is such that its image is centered on the surface of the photocell, the output from the photocell is essentially a steady state potential. However, when the image of the circular locus of the beam is not centered on the photocell, a sinusoidally varying potential is generated by the photocell of a fundamental frequency equal to the frequency of rotation of the beam. A better understanding of the theory behind the invention may be obtained at this point by consulting FIG. 2.

In FIG. 2, the center of the photocell, indicated at point C_P, may be considered to lie upon the face of the cathode ray tube. The electron beam's counterclockwise circular locus, of radius r, is shown with its center at C_L, the latter comprising the point of intersection of the two co-ordinates that represent vertical deflection and horizontal deflection. As pointed out above, the circular motion of the beam is created by applying a potential of cosine wave form, e.g., $a \cos \omega t$, to the horizontal deflection plates and a potential of sine wave form, e.g., $a \sin \omega t$, to the vertical deflection plates.

In the figure, the beam is shown in a decentered position as compared with the photocell, the amount of decentering being equal to the distance s between the points C_P and C_L. The line segment of length s joining these two points forms an angle φ with the horizontal deflection coordinate. Thus, $s \cos \varphi$ is the amount of decentering of the beam in the horizontal deflection direction, while $s \sin \varphi$ is the amount of decentering in the vertical deflection direction. In order to reduce the distance s to zero, a potential related to $s \cos \varphi$ must be applied to the horizontal deflection plates of the cathode ray tube, while a potention related to $s \sin \varphi$ must be applied to the vertical deflection plates. The present invention derives such potentials from the photocell's output signal, e_p, in the following fashion.

Still referring to FIG. 2, the instantaneous photocell potential, e_p, is related to the distance between the position of the beam at a given instant and the center of the photocell at point C_P. The beam's angular velocity ϖ is chosen to be sufficiently great in relation to the rate at which the stylus is moved across the face of the cathode ray tube that the point C_P may be considered fixed during several complete rotations of the beam around the point C_L. It may be seen that e_p is greatest when the beam is in position d. As the beam moves around to position e on its circular locus, the photocell potential gradually decreases to a minimum value; as the beam moves from e back to d, e_p increases from its minimum value back to its maximum value. Thus e_p varies with time in an approximate sinusoidal fashion about some positive potential K, at a frequency ϖ equal to the frequency of rotation of the beam, and with a maximum value at those times when the beam is in position d. Thus, for example, if the beam commences its counterclockwise circular locus at point c at time $t=0$ and is at point d at time

$$t=\frac{\varphi}{\omega}$$

the potential e_p may be expressed in the following form:

$$e_p=K+b \cos(\omega t-\varphi)+p \cos(2\omega t-2\varphi)+q \cos(3\omega t-3\varphi)+ \ldots z \cos(n\omega t-n\varphi) \quad (1)$$

where K, b, p, q . . . z are all related to the distance s. Only the term $b \cos(\omega t-\varphi)$, however, need be considered in this analysis, since subsequent multiplication and integration operations upon the photocell signal cause the contributions to the error signal from the constant term K and the higher harmonics to be zero.

FIG. 3 depicts the variation in the value of b for various amounts of decentering s. Positive values of s indicate that, with regard to FIG. 2, the center of the photocell lies to the right of the center of the circular locus of the beam. Similarly, negative values of s indicate that the center of the photocell lies to the left of the center of the beam's locus. It may be noted, if the response of the photocell is monotonically related to the distance from the beam, when the center of the photocell is circumscribed by the circular locus of the beam, i.e., when the absolute value of s is less than r, b varies monotonically with s. When the center of the photocell is not circumscribed by the locus of the beam, i.e., when the absolute value of s is greater than r, the monotonic relationship between s and b no longer exists. However, the algebraic signs of b and s are always the same whether or not the center of the photocell is circumscribed by the locus of the beam. Since b is related to s as shown in FIG. 3, $b \cos \varphi$ and $b \sin \varphi$ are related in the same fashion, respectively, to $s \cos \varphi$ and $s \sin \varphi$, the latter comprising the components of decentering in the horizontal and vertical deflection directions. Accordingly, the apparatus of FIG. 1 resolves the potential e_p into two components proportional to $b \cos \varphi$ and $b \sin \varphi$, and these potentials are utilized by virtue of their relationships to $s \cos \varphi$ and $s \sin \varphi$, to center the locus of the beam on the photocell.

Referring once again to FIG. 1, the signal developed by the photocell, the fundamental component of which is given as $b \cos(\omega t-\varphi)$, is coupled to a tracking unit 30 by means of lead 23. Conveniently, lead 23 is a flexible electrical conductor which neither fetters the free movement of the stylus nor hampers the writing style of a person using the device. An amplifier 31 may be utilized, if required, to increase the magnitude of the photocell signal.

The signal from the amplifier 31 is applied to two multipliers 37 and 38 and also to a peak rectifier 32. Two signals from sources 36 and 39, $a \cos \omega t$ and $a \sin \omega t$, respectively, are also applied to the multipliers 37 and 38. Since the fundamental component of the amplified signal from the photocell 21 may be designated as $b \cos (\omega - \varphi)$, the output from multiplier 37, i.e.,

$$(a \cos \omega t)(b \cos [\omega t - \varphi])$$

may be expressed as:

$$\frac{ab}{2} \cos \varphi + (\cos 2\omega t)\left(\frac{ab}{2} \cos \varphi\right) + (\sin 2\omega t)\left(\frac{ab}{2} \sin \varphi\right) \quad (2)$$

Similarly, the output from multiplier 38, i.e.,

$$(a \sin \omega t)(b \cos [\omega t - \varphi])$$

may be expressed as:

$$\frac{ab}{2} \sin \varphi + (\sin 2\omega t)\left(\frac{ab}{2} \cos \varphi\right) - (\cos 2\omega t)\left(\frac{ab}{2} \sin \varphi\right) \quad (3)$$

In the above multiplications, the constant term K and the higher order harmonic components of the photocell signal have been neglected, since they produce product terms that are sine and cosine functions of time, and, such functions are filtered out by subsequent integration operations.

As shown by Equations 2 and 3, each multiplication produces a component of voltage that varies only with φ. In Equation 2, that component is $ab/2 \cos \varphi$; in Equation 3 it is $ab/2 \sin \varphi$. From the prior analysis, it may be seen that these components of voltage are related to the degree of decentering, in the horizontal and vertical deflection directions, respectively, of the circular locus of the beam from the center of the photocell. Accordingly, to isolate these components, the signals from multipliers 37 and 38 are applied to the summing integrators 44 and 45, respectively. The summing integrators depicted are of conventional form, for example, as described in Korn and Korn, Electronic Analog Computers, 143–45, 288–92 (1st ed., 1952). Each of the integrators provides an output potential that is proportional to the integral of the sum of the inputs applied thereto. For the present, it will be assumed that the other inputs to the summing integrators, i.e., the input from pulse gate 41 and the input from the scale of n frequency divider 42, are each zero, since they apply to an alternate scanning mode to be explained later. Summing integrators 44 and 45, are provided with a reset mechanism similar to the reset apparatus as shown in the Korn and Korn reference, supra. Conveniently, each may comprise a relay energized by a signal from its reset lead, 46 or 47. Upon energization, the relay connects the output of its associated summing integrator to a common reference potential, e.g., ground. Since, however, the resetting operations pertain to the alternate scanning mode just referred to, no signals are present on the reset leads, and accordingly, the only active leads to integrators 44 and 45 are from multipliers 37 and 38, respectively.

Because the integrals of terms of the form $\sin n\omega t$ and $\cos n\omega t$ are zero over a time long as compared with $2\pi/\omega$, the integrated signals from multipliers 37 and 38 represent the integrals of only the terms $ab/2 \cos \phi$ and $ab/2 \sin \varphi$, respectively. Thus, the error potentials $ab/2 \cos \varphi$ and $ab/2 \sin \varphi$ are integrated themselves to provide a pair of signals which, when applied to the deflection plates of the cathode ray tube, result in the circular locus of the beam becoming centered on a point upon the face of the tube opposite the tip of the stylus. In this respect it should be noted that integration of the signals $ab/2 \cos \varphi$ and $ab/2 \sin \varphi$ always produces deflection signals of the proper polarity to reduce the error s. This may be seen from the fact that, since the deflection voltages are proportioned to the integrals of the terms $ab/2 \cos \varphi$ and $ab/2 \sin \varphi$, the terms themselves represent the rate of change of the beam's deflection and, therefore, the velocity of the center of the rotating beam. From FIG. 3 it may be seen that the algebraic sign of b is always the same as that of s. Thus, as the beam becomes centered, i.e., as s approaches zero, the velocity of the center, C_L, of the circular beam locus is always in the proper direction independent of whether or not the beam circumscribes the stylus. If, however, the signals $b \cos \varphi$ and $b \sin \varphi$ are derived by the use of low pass filters and applied directly, without integration, to the deflection plates of the cathode ray tube, the rate of change of these terms would represent the velocity of the center of the locus of the beam. In this case it is apparent from FIG. 3 that, as s approaches zero, the rate of change of b with respect to time changes algebraic sign. The change in sign occurs at $s=r$; and such a change in sign indicates a change in the direction of the movement of the center of the locus of the beam. Thus, without integration, operation of the invention is readily achieved in the range of s where b and s vary monotonically with each other, i.e., in the range where the circular locus of the beam circumscribes the center of the photocell.

Referring again to FIG. 1, the signals from integrators 44 and 45 are passed to the adders 34 and 35 where they have added to them, respectively, the signals $a \cos \omega t$ and $a \sin \omega t$. These last-named signals are added at this point to provide the sinusoidal signals that produce the circular rotation of the beam. The signal from each of the adders is thus composed of two components; first a sinusoidal component that produces circular rotation of the beam, and second a component that positions the beam opposite the tip of the moving stylus. Accordingly, these signals are applied directly to the deflection plates 13 and 14 of the cathode ray tube by leads 53 and 54, respectively.

Since the beam tracks the movements of the stylus, the signals from the integrators 44 and 45 are indicative of the "X" and "Y" co-ordinates of the stylus upon the plane formed by the face of the cathode ray tube 10. These signals are obtained from the leads 51 and 52 and are applied to a utilization device 55 where they may be utilized in any fashion, e.g., to effect a reproduction, at a local monitor or at a remote point, of the graphic material then being "written" on the face of the tube 10.

The present invention contemplates an alternative scanning mode that effects a "search scan" of the face of the tube by the beam whenever the beam is not tracking the stylus. Such a scan, which may be, for example, a typical line by line sweep of the entire face of the tube by the beam, continues until the beam once again tracks the stylus. This scanning mode is useful to permit automatic orientation of the beam near the stylus, so that tracking may commence, for example, when the stylus is returned to the face of the tube in a writing position after it has been withdrawn therefrom. The alternative scanning mode is effected in the following fashion.

The output from amplifier 31 is passed through a peak rectifier 32 which develops a signal that is indicative of the peak output potential produced by the photocell 21. The signal from rectifier 32 is supplied to one input of a comparator 33, the other input of which is energized by a reference potential, for example, a fixed potential designated $V_{Ref.}$. Whenever the signal from the peak rectifier falls below the reference potential, the output potential of the comparator changes from, for example, 0 volts to some positive value. Thus, whenever the output of the photocell falls below some predetermined magnitude, which indicates that the beam is neither tracking the stylus nor in close proximity thereto, a signal is supplied by comparator 33. The signal from the comparator energizes pulse gate 41 which passes a series of pulses that are formed, for example, from the output of the sine wave generator 39 by the pulse former 40. Accordingly, a series of positive pulses, for example, are applied to one input of the summing integrator 44. These pulses are added to the signal from multiplier **37**, and the sum is integrated. However, since the photocell signal is extremely small at the time during which tracking is not taking place, the output of multiplier **37** is virtually zero. Thus, the pulses from gate **41** are alone integrated to produce an output potential from integrator **44** that increases with time as a series of step voltages.

After each series of *n* pulses from the pulse gate **41**, a scale of *n* frequency divider **42** produces an output pulse which serves to reset the summing integrator **44** and which is applied to one input of the summing integrator **45**. Summing integrator **45** integrates the series of pulses from the scale of *n* frequency divider **42** in a fashion similar to that of integrator **44**. After each series of *m* pulses from the frequency divider **42**, the scale of *m* frequency divider **43** produces a pulse which resets the summing integrator **45**. The net effect of the integrations by the summing integrators **44** and **45** is to produce outputs that resemble sawtooth functions, although each sawtooth is composed of a series of step voltages. The output from the summing integrator **44** thus provides a sawtooth output potential which builds up during every *n* pulse from pulse gate **41** and which is applied through the adder **34** to the horizontal deflection plates **14** of the cathode ray tube. This in effect causes the beam within the tube to sweep the face of the tube in normal line sweep fashion. Similarly, the output from the summing integrator **45**, which also is of a sawtooth wave form that builds up during every *n* times *m* pulses from pulse gate **41**, is applied through the adder **35** to the vertical deflection plates **13** of the cathode ray tube. In this fashion, the beam is made to sweep across the face of the tube in typical frame sweep fashion in the vertical direction.

Since the line sweep and frame sweep scanning raster may commence at any point upon the face of the cathode ray tube **10**, the sawtooth waves should be of sufficient magnitude to ensure that the beam scans an area of at least twice that of the face of the tube. In this fashion, the line sweep and frame sweep scanning raster effectively encompasses the entire face of the tube, regardless of the potentials previously supplied by the integrators.

Alternatively, the resetting of the integrators may be effected by means of deflection voltage comparisons with predetermined voltage values corresponding to maximum required horizontal and vertical deflections, respectively. By utilizing such comparisons and eliminating both the scale of *n* divider **42** and the scale of *m* divider **43**, when the horizontal deflection voltage reaches its maximum value, the summing integrator **44** is reset and a pulse is applied to the summing integrator **45**. At maximum vertical deflection, the vertical integrator is reset. In this alternate arrangement the double-amplitude deflection voltages are not needed.

During the search scan, the beam sweeps across the entire face of the tube **10** in typical line sweep and frame sweep fashion until the beam is in proximity to the tip of the stylus **20**. At this time, the amplified and peak rectified potential from the photocell **21** is slightly greater than the reference potential $V_{Ref.}$ that is applied to comparator **33**. The output potential of comparator **33** thus changes from the above-mentioned positive value to 0 volts, and the pulse gate **41** is no longer energized. Thus, the summing integrators **44** and **45** no longer have applied thereto the voltage pulses from gate **41** and frequency divider **42**, respectively. However, since the beam in the cathode ray tube **10** is now adjacent the tip of the stylus **20**, the normal tracking mode takes over by virtue of the error signals developed by multipliers **37** and **38**, and the beam once again tracks the stylus. It should be noted that by adding the "error" signal from one of the multipliers to the associated pulse signal for the "search" mode and applying the sum to one integrator, the embodiment depicted can switch smoothly and permanently from the searching mode to the tracking mode. If a common

integrator was not utilized, such a transition most likely could not take place, since it would be mere chance that the integrated multiplier signal alone would be equal to the search signal when the beam was opposite the stylus. Thus, as the device switched back from the searching to the tracking mode, the beam would be deflected away from the photocell, which would cause the searching mode to start once again. The present arrangement overcomes this problem.

The signal from the comparator **33** is also used to generate an "out-of-contact" signal, as from the lead **50**, which is applied to the utilization device **55**. In this fashion, whenever the electron beam in the tube **10** assumes a search raster and is sweeping the face of the tube in line sweep and frame sweep fashion, a signal is generated. This signal is present whenever the stylus is either withdrawn from the face of the tube or whenever the beam has become decentered from the photocell by a predetermined amount. Such an "out-of-contact" signal may be utilized to indicate that the "X" and "Y" signals from leads **51** and **52** are not indicative of information pertaining to the tracing, upon the face of the cathode ray tube, of an alphabetic character, a numeral, or other graphic material.

In the embodiment illustrated in FIG. 1, no mechanical restraints are placed upon the stylus. A conducting flexible lead **23**, which connects the photocell **21** and the amplifier **31**, is the only form of coupling that joins the photocell wtih the rest of the circuitry. It may be appreciated that this does not hinder or cramp a writing style to any appreciable degree. However, alternative arrangements may be employed to lessen even further the restraint placed upon the movement of the stylus, such as, for example, a radio transmitter contained within the stylus to transmit a signal indicative of the photocell potential to the amplifier **31** and thence on to the rest of the circuitry of FIG. 1.

Turning now to FIG. 4, there is depicted another embodiment of the present invention. In this case, a special cathode ray tube **10** is employed that is similar in all respects to conventional cathode ray tubes except that it has a specially constructed face **17**. This face comprises an outside dielectric layer **16** which conveniently may be of glass. Deposited upon the inside of the layer is a thin resistive film **15**. An electrical connection is made by the lead **19** to the thin resistive film at a point **18** on the inside of the face of the cathode ray tube. Lead **19** is connected to a demodulator **24**, the output of which is connected to a tracking unit **30**, corresponding to the tracking unit **30** of FIG. 1.

A conductive stylus **20** is employed in this embodiment in place of the stylus containing the photocell as depicted in FIG. 1. The stylus **20** may be grounded directly, for example, by the use of a flexible conductive lead connected between it and ground, or it may be grounded indirectly through the self-capacity of the operator writing with the stylus.

The beam in the cathode ray tube, produced by the electrode **11** that is connected to a suitable energizing potential, not shown, is given a circular scan of high rotational frequency and small radius, as in the embodiment of FIG. 1. In addition, the beam is intensity modulated by a radio frequency signal from the source **9** that is applied to the beam intensity control grid **12**. Intensity modulation of the beam is provided, since a varying signal is required to pass current from the resistive film **15** to the metal stylus **20**, both of which may be considered to comprise opposite plates of a capacitor. When the electron beam impinges upon the resistive film **15** at a point opposite the tip of the metal stylus **20**, a majority of the varying beam current passes through the film to the stylus and thence to ground. On the other hand, when the beam impinges the resistive film at a point that is not opposite the tip of the metal stylus, a majority of the varying beam current flows within the resistive film to the demodulator

24. Accordingly, by examining the current flowing in the resistive film, one may obtain an indication of the flow of current to the metal stylus.

It thus may be seen that when the locus of the circular scan of the beam is opposite the center of the tip of the metal stylus, the demodulator has applied to it a signal that is small and whose envelope is non-varying. However, when decentering of the beam occurs, i.e., when the beam is not spinning around an area directly opposite the center of the tip of the metal stylus, the demodulator has applied to its a signal of radio frequency containing a varying or modulated envelope. The frequency of the envelope will be equal to the frequency of rotation of the beam within the cathode ray tube. As in the embodiment of FIG. 1, the products of this envelope and the potentials applied to the plates of the cathode ray tube that cause the circular scan are indicative of the magnitude and direction of decentering of the beam. Accordingly, the signal from the resistive film is demodulated and applied to a tracking unit **30** which is virtually the same tracking unit as depicted in FIG. 1. The only differences in the units are that, for the present embodiment, the inputs to multipliers **37** and **38** from oscillators **36** and **39** are $-a \cos \omega t$ and $-a \sin \omega t$, respectively. Further, the comparator **33** is altered to energize the pulse gate **41** when the amplified and peak rectified signal from demodulator **24** is greater than $V_{Ref.}$. These changes are required since the fundamental component of the signal from the resistive film may be expressed as $-b \cos (\omega t - \varphi)$, whereas the fundamental component of the signal from the photocell is

$$b \cos (\omega t - \varphi)$$

and also because decentering of the beam results in an increase in the signal from the resistive film, whereas decentering causes a decrease in the photocell signal. With these changes, the apparatus operates as that of FIG. 1, and the beam tracks the movements of the metal stylus. Thus, three signals are obtained, namely, an "out-of-contact" signal from lead **50** indicating when the stylus is being tracked, and "X" and "Y" signals from leads **51** and **52** indicating the co-ordinates of the stylus with respect to the writing tablet.

For this embodiment, a special stylus containing a photocell is not required. Any metal stylus will suffice; an ordinary metallic fountain pen or ballpoint pen may be used.

Although specific embodiments of the present invention have been depicted, it is obvious that numerous additions and substitutions may be made without departing from the spirit and scope of the invention. Accordingly, the invention should be deemed limited only insofar as it is restrictively defined in the following claims.

What is claimed is:

1. Telewriting apparatus comprising a cathode ray tube, means for producing a beam of electrons within said tube, means for deflecting said beam in response to input signals, means for supplying an oscillatory signal to said beam deflection means for rotating said beam about a reference axis, a photocell, means for detecting an output from said photocell as it is moved in closed proximity to the face of said cathode ray tube, means supplied with the output of said photocell and said oscillatory signal for producing a potential corresponding to the difference in phase therebetween and of a magnitude dependent on the distance between said photocell and the point of impingement of said beam on the face of said tube, means for integrating said potential, means for applying said integrated potential to said beam deflection means for deflecting said beam so that said reference axis passes through said photocell, means for applying a signal to said beam deflection means to deflect said electron beam in a search raster across the face of said tube whenever the magnitude of said photocell output is less than a predetermined threshold, and means for utilizing the aforementioned integrated potential to indicate the "X" and "Y" co-ordinates of said photocell.

2. Apparatus for transmitting electrical signals indicative of the position of a photocell adjacent the face of a cathode ray tube in which said tube includes means for creating a beam of electrons and a first means for deflecting said beam in a first direction and a second means for deflecting said beam in a second direction; said apparatus comprising means for applying a first signal to said first deflection means and a second signal to said second deflection means, said first and second signals exhibiting a phase difference sufficient to impart to said beam a rotational movement about a reference axis, a photocell, means for detecting an output signal from said photocell, means supplied with said photocell signal and said first signal for producing a first potential proportional to the component in said first direction of the distance between the point of impingement of said beam upon said face and said photocell, means supplied with said photocell signal and said second signal for producing a second potential proportional to the component in said second direction of the distance between the point of impingement of said beam upon said face and said photocell, means for producing an out-of-contact signal whenever said output signal from said photocell is less than a predetermined magnitude, means responsive to said out-of-contact signal for producing a first search signal, means responsive to said out-of-contact signal for producing a second search signal, said first search signal and said second search signal, when separately integrated and applied to said first and second deflection means, respectively, imparting to said beam a movement that effects a searching raster covering the entire face of said tube, means for adding said first potential and said first search signal to produce a first summed signal, means for adding said second potential and said second search signal to produce a second summed signal, means for integrating said first summed signal, means for integrating said second summed signal, means for applying said integrated first summed signal to said first deflection means, means for applying said integrated second summed signal to said second deflection means, and means for utilizing said integrated first summed signal, said integrated second summed signal and said out-of-contact signal to indicate the movements of said photocell.

3. A telewriting device comprising a cathode ray tube, means for producing a beam of electrons within said tube, a first deflection means responsive to an input signal for deflecting said beam in a first direction, a second deflection means responsive to an input signal for deflecting said beam in a second direction displaced 90 degrees from said first direction, a stylus capable of being moved about the face of said tube, a photosensitive element positioned in said stylus, means for detecting an output signal from said photosensitive element, means for multiplying said output signal from said photosensitive element by a signal of cosine wave form to produce a first product signal, means for multiplying said output signal from said photosensitive element by a signal of sine wave form to produce a second product signal, means for producing an out-of-contact signal whenever the magnitude of said output signal from said photosensitive element is less than a predetermined value, means responsive to said out-of-contact signal for producing a signal of a first pulse wave form, means responsive to said out-of-contact signal for producing a signal of a second pulse wave form, means for adding said first product signal and said first pulse signal to produce a first summed signal, means for adding said second product signal and said second pulse signal to produce a second summed signal, first means for integrating said first summed signal, second means for integrating said second summed signal, means for resetting to a first reference value the output of said first integrating means after each series of n pulses from said first pulse wave form means, means for resetting to a second reference value the output of said second integrating means

after each series of *m* pulses from said second pulse wave form means, means for adding said integrated first summed signal and said signal of cosine wave form to produce a first control signal, means for adding said integrated second summed signal and said signal of sine wave form to produce a second control signal, means for applying said first control signal to said first deflection means, means for applying said second control signal to said second deflection means, and means for transmitting said integrated first summed signal, said integrated second summed signal, and said out-of-contact signal to any location thereby to provide signals indicative of the movement of said stylus.

4. A device for the transmission of graphic information comprising a cathode ray tube, the face of said cathode ray tube comprising a conductive film placed upon a layer of dielectric material, means for producing a beam of electrons within said tube to impinge upon a portion of said conductive film thereby to produce a flow of current therein, means for modulating the intensity of said beam in accordance with an applied signal to cause intensity variations of said current, control means for deflecting said beam in response to an input signal, a conductive stylus coupled to a source of reference potential and capable of being freely manipulated adjacent said dielectric layer to thereby produce an amplitude modulation envelope on the intensity variations of said current, demodulating means responsive to the flow of current in said conductive film for developing a signal whose wave form follows the envelope of said current flowing in said conductive film, means responsive to the signals from said demodulating means and to said input signal for supplying a control signal to said control means for positioning said beam to impinge the portion of said face of said tube opposite said stylus, and means for utilizing said control signal to indicate the movement of said conductive stylus.

5. A device as recited in claim 4 further comprising means responsive to said signal from said demodulating means for supplying a varying potential to said control means to cause said beam to be deflected in a search raster across the face of said tube whenever the magnitude of said demodulated signal is greater than a predetermined threshold.

6. Telewriting apparatus comprising a cathode ray tube, the face of said cathode ray tube comprising a thin resistive film and a layer of dielectric material, means for producing a beam of electrons within said tube, said beam producing a current flow in said resistive film upon impingement therewith, means for modulating the intensity of said beam in accordance with an applied signal thereby causing intensity variations in said current, means for deflecting said beam in response to input signals, means for supplying an oscillatory signal to said beam deflection means for oscillating said beam in a locus about a reference axis, a source of reference potential, a metal stylus capable of being moved freely about the face of said tube adjacent said dielectric layer and coupled to said source of reference potential, means for detecting the flow of current in said resistive film as said stylus is moved in close proximity to said face of said tube, said stylus producing an amplitude modulation envelope on the intensity variations of said current when proximate to a point on said face which is closer to one part of the locus of said beam than to another part of the locus, demodulating means for developing a signal whose wave form is the envelope of said current flowing in said resistive film, means supplied with said last-named signal and said oscillatory signal for producing a potential corresponding to the difference in phase therebetween, means for integrating said potential, means for applying said integrated potential to said beam deflection means for deflecting said beam so that said reference axis passes through said stylus, means for applying a signal to said beam deflection means to deflect said electron beam in a search raster across said face of said tube whenever the magnitude of said demodulated signal is greater than a predetermined threshold, and means for utilizing said integrated potential to indicate the position of said stylus adjacent said face of said tube.

7. Apparatus for transmitting electrical signals indicative of the position of a conductive stylus adjacent the face of a cathode ray tube in which said tube is characterized by a face comprising a resistive film, said tube being further characterized by means for creating a beam of electrons, said beam producing a current flow in said resistive film upon impingement therewith, means for cyclically varying the intensity of said beam, a first means for deflecting said beam in a first direction, and a second means for deflecting said beam in a second direction; said apparatus comprising means for applying a first signal to said first deflection means and a second signal to said second deflection means, said first and second signals exhibiting a phase difference sufficient to impart to said beam an oscillatory movement about a reference axis, wave form developing means for developing a signal whose wave form is the envelope of the current flowing in said resistive film, means supplied with the signal from said wave form developing means and said first signal for producing a first potential proportional to the distance in said first direction between the point of impingement of said beam upon said face and said stylus, means supplied with said signal from said wave form developing means and said second signal for producing a second potential proportional to the distance in said second direction between the point of impingement of said beam upon said face and said stylus, means for applying said first potential to said first deflection means, means for applying said second potential to said second deflection means, and means for utilizing said first potential and said second potential to indicate at any location the movements of said stylus.

8. Apparatus for transmitting electrical signals indicative of the position of a conductive stylus adjacent the face of a cathode ray tube in which said tube is characterized by a face comprising a resistive film, said tube being further characterized by means for creating a beam of electrons, said beam producing a current flow in said resistive film upon impingement therewith, means for cyclically varying the intensity of said beam thereby producing cyclical variations of said current, a first means for deflecting said beam in a first direction, and a second means for deflecting said beam in a second direction; said apparatus comprising means for applying a first signal to said first deflection means and a second signal to said second deflection means, said first and second signals exhibiting a phase difference sufficient to impart to said beam an oscillatory locus about a reference axis, said stylus producing an amplitude modulated envelope wave form on the cyclical variations of said current whenever any part of the locus of said beam on said resistive film is closer than any other part of the locus to a point at which said stylus is proximate to the resistive film, wave form developing means for developing a signal whose wave form is the envelope wave form of the current flowing in said resistive film, means supplied with the signal from said wave form developing means and said first signal for producing a first potential proportional to the distance in said first direction between the point of impingement of said beam upon said face and said stylus, means supplied with said signal from said wave form developing means and said second signal for producing a second potential proportional to the distance in said second direction between the point of impingement of said beam upon said face and said stylus, means for integrating said first potential, means for integrating said second potential, means for applying said integrated first potential to said first deflection means, means for applying said integrated second potential to said second deflection means, and

means for utilizing said integrated first potential and said integrated second potential to indicate the movements of said stylus.

9. Apparatus for transmitting electrical signals indicative of the position of a conductive stylus connected to a source of reference potential as said stylus is moved in close proximity to the face of a cathode ray tube, said tube being characterized by a face comprising a resistive film and said tube including means for creating a beam of electrons, said beam producing a current flow in said resistive film upon impingement therewith, means for cyclically varying the intensity of said beam thereby producing cyclical variations of said current, a first means for deflecting said beam in a first direction, and a second means for deflecting said beam in a second direction; said apparatus comprising means for applying a first signal to said first deflection means and a second signal to said second deflection means, said first and said second signals exhibiting a phase difference sufficient to impart to said beam an oscillatory locus about a reference axis, said stylus producing an amplitude modulated envelope wave form on the cyclical variations of said current whenever any part of the locus of said beam on said resistive film is closer than any other part of the locus of said beam to a point at which said stylus is proximate to the resistive film, wave form developing means for developing a signal whose wave form characterizes the envelope wave form of the current flowing in said resistive film, means supplied with the signal from said wave form developing means and said first signal for producing a first potential proportional to the distance in said first direction between the point of impingement of said beam upon said face and said stylus, means supplied with said signal from said wave form developing means and said second signal for producing a second potential proportional to the distance in said second direction between the point of impingement of said beam upon said face and said stylus, means for producing an out-of-contact signal whenever the magnitude of said signal from said wave form developing means is greater than a predetermined magnitude, means responsive to said out-of-contact signal for producing a first search signal, means responsive to said contact signal for producing a second search signal, said first search signal and said second search signal imparting to said beam a searching pattern which covers the entire face of said tube when said signals are each integrated and applied to said first deflection means and said second deflection means, respectively, means for adding said first potential and said first search signal to produce a first summed signal, means for adding said second potential and said second search signal to produce a second summed signal, means for integrating said first summed signal, means for integrating said second summed signal, means for applying said integrated first summed signal to said first deflection means, means for applying said integrated second summed signal to said second deflection means, and means for utilizing said integrated first potential, said integrated second potential, and said out-of-contact signal to indicate the movements of said stylus.

10. A telewriting device comprising a cathode ray tube having a face composed of a layer of dielectric material upon which has been deposited upon one side thereof a thin resistive film, means for producing a beam of electrons within said tube, said beam producing a current flow in said resistive film upon impingement therewith, means for cyclically varying the intensity of said beam thereby producing cyclical variations of said current, first and second deflection means, means for applying a potential of cosine wave form to said first deflection means and a potential of sine wave form to said second deflection means for rotating said beam in a circle on said resistive film, a source of ground potential, a grounded conductive stylus capable of being moved freely about the face of said tube adjacent said dielectric layer, said stylus producing an amplitude modulated envelope wave form on the cyclical variations of said current when a part of said circle is closer than another part of said circle to a point at which said stylus is proximate to said dielectric material, means for producing a signal proportional to the amount of current in said resistive film, means for detecting the envelope wave form of said proportional signal, means for multiplying said envelope wave form of said signal by the potential of cosine wave form to produce a first product potential, means for multiplying said envelope wave form of said signal by the potential of sine wave form to produce a second product potential, means for producing an out-of-contact signal whenever the magnitude of said envelope wave form is greater than a predetermined magnitude, means responsive to said out-of-contact signal for producing a potential of a first pulse wave form, means responsive to said out-of-contact signal for producing a potential of a second pulse wave form, means for adding said first product potential and said first pulse potential to produce a first summed potential, means for adding said second product potential and said second pulse potential to produce a second summed potential, first means for integrating said first summed potential, second means for integrating said second summed potential, means for resetting to a first reference value the output of said first integrating means after each series of *n* pulses from said first pulse wave form means, means for resetting to a second reference value the output of said second integrating means after each series of *m* pulses from said second pulse wave form means, means for adding said integrated first summed potential and said potential of cosine wave form to produce a first control signal, means for adding said integrated second summed potential and said potential of sine wave form to produce a second control signal, means for applying said first control signal to said first deflection means, means for applying said second control signal to said second deflection means, and means for transmitting said integrated first summed potential, said integrated second summed potential, and said out-of-contact signal to any location thereby to provide signals indicative of the movement of said stylus.

11. Telewriting apparatus comprising a cathode ray tube, means for producing a beam of electrons within said tube, means for deflecting said beam in response to input signals, means for supplying an oscillatory signal to said beam deflection means for rotating said beam about a reference axis, a photosensitive element, means for detecting an output from said photosensitive element as it is moved in close proximity to the face of said cathode ray tube, means supplied with the output of said photosensitive element and said oscillatory signal for producing an error potential corresponding to the difference in phase therebetween, means for applying said error potential to said beam deflection means for deflecting said beam so that said reference axis passes through said photosensitive element, means responsive to the output of said photosensitive element for supplying a varying potential to said deflection means to deflect said beam in a search raster across the face of said tube whenever the magnitude of said photosensitive element output is less than a predetermined threshold, and means for utilizing said error potential to indicate the "X" and "Y" coordinates of said photosensitive element.

12. A device for the transmission of graphic information comprising a cathode ray tube, means for producing a beam of electrons within said tube, control means for deflecting said beam in response to an input signal, means for supplying an oscillatory signal to said beam deflection means for rotating said beam about a reference axis, stylus means positioned in a nonfixed fashion adjacent the face of said tube, means responsive to the location of said stylus means relative to the location of said beam on the face of said tube for producing a control current,

means supplied with said control current and said oscillatory signal for producing an error potential corresponding to the difference in phase therebetween and of a magnitude dependent on the distance between said stylus and the point of impingement of said beam on the face of said tube, means for supplying said error potential to said control means to position said beam upon the portion of said face of said tube opposite said stylus means, means responsive to said control current for supplying a varying potential to said deflection control means to deflect said beam in a search raster across the face of said tube whenever the location of said stylus means relative to the location of said beam on the face of said tube is greater than a predetermined distance, and means for utilizing said error potential to provide information relevant to the movement of said stylus means.

References Cited in the file of this patent

UNITED STATES PATENTS

2,455,532	Sunstein	Dec. 7, 1948
2,487,641	Denk	Nov. 8, 1949
2,849,707	White	Aug. 26, 1958