July 17, 1951 B. McMILLAN 2,560,585

CATHODE RAY SIGNAL TO VOLTAGE TRANSLATING DEVICE

Filed April 6, 1948

FIG. 1

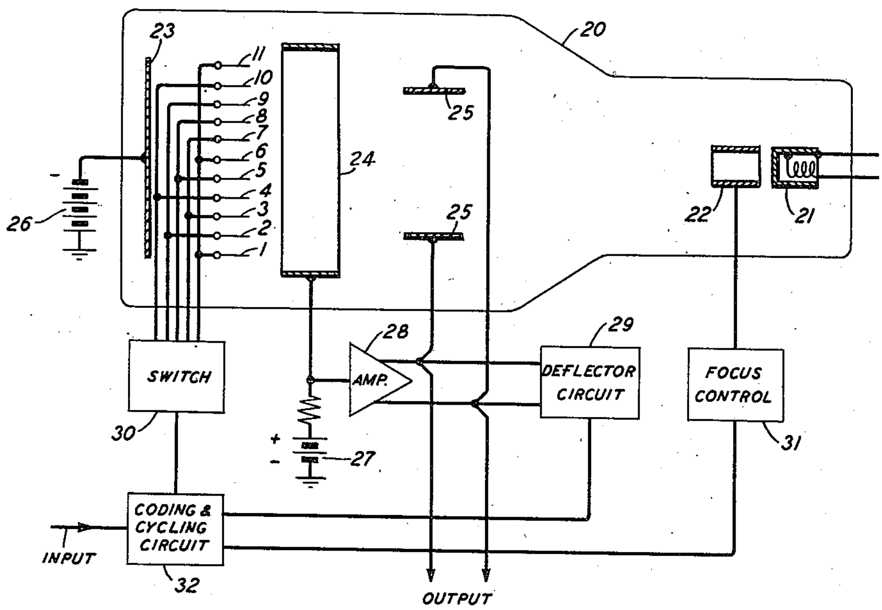


FIG. 2

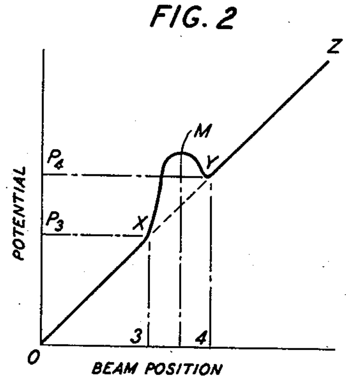


FIG. 3

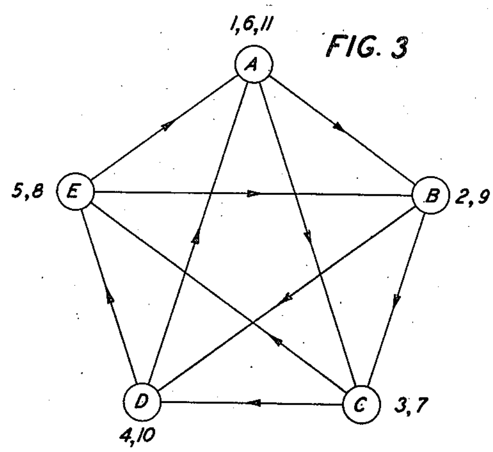
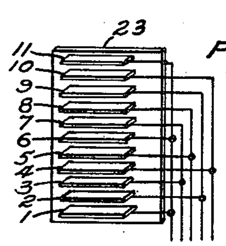


FIG. 4.



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CATHODE-RAY SIGNAL TO VOLTAGE TRANSLATING DEVICES

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9 Claims. (Cl. 315—21)

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This invention relates to cathode ray devices and more particularly to such devices of the general type disclosed in the application Serial No. 14,014, filed March 10, 1948, of J. R. Pierce, C. E. Shannon and J. W. Tukey, for translating signals into accurately reproducible voltages.

In devices of the general type to which this invention pertains, the beam of a cathode ray device is deflected in accordance with signals to be translated and the potential across the beam deflecting element, for example deflector plates, is precisely and automatically adjusted by action of a feedback circuit between the beam target and the deflecting element, so that each input signal of amplitude within a prescribed range is translated into an output voltage across the deflecting element of fixed and preassigned amplitude. This output voltage may be utilized to control the beam deflection in one or more associated cathode ray devices.

One general object of this invention is to improve cathode ray translating devices of the type above described.

More specifically, objects of this invention are to simplify such devices and apparatus of which they form a part, to facilitate the conversion of signals into voltages of prescribed amplitude and to improve the accuracy of resolution of signals into voltages.

In one illustrative embodiment of this invention, a cathode ray discharge device comprises a secondary electron emissive target, a collector electrode for receiving secondary electrons emanating from the target, an electron gun for projecting an electron beam against the target, and deflection means, for example deflector plates, effective when energized to deflect the beam in one dimension along the target. A feedback coupling is provided between the collector electrode and deflection means for controlling the deflecting potential in accordance with the position of the beam.

In accordance with one feature of this invention, means are provided for selectively establishing any one of a plurality of paths for flow of secondary electrons from the target to the collector electrode, in accordance with the ultimately desired beam position, whereby the feedback coupling is effective only when the beam is at or in immediate proximity to the desired position.

More specifically, in accordance with one feature of this invention, a plurality of parallel members, extending normal to the direction of beam deflection, are provided adjacent the target electrode to define a row of openings or windows

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through which secondary electrons from the target may pass to the collector electrode. Each opening or window is controllable to permit or prevent passage of secondary electrons therethrough, by control of the potential of the two parallel members bounding the window. Furthermore, each opening or window corresponds to a respective one of a plurality of possible beam positions and, consequently, is associated with a respective output voltage across the deflection means.

In accordance with another feature of this invention, the several window bounding members are associated electrically in groups so that any opening or window may be opened to permit passage of secondary electrons by application of an appropriate potential to two of the groups. This permits selective individual opening of the windows by application of potentials to the groups in accordance with a preassigned code.

In accordance with a further feature of the invention, deflection of the beam in response to a signal is effected solely by operation of the feedback circuit. In one specific embodiment, the beam is directed initially beyond one end of the row of windows and is defocussed so that it spreads over the row but is sufficiently focussed so that any motion thereof toward an open window results in an increase in the feedback and, consequently, in the potential across the deflection means whereby the beam is deflected toward the window to pass therethrough. Concomitantly with the motion of the beam, the concentration of latter may be increased so that during the final adjustment of the beam position, the beam is sharply focussed.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a diagram, partly schematic, of electron discharge apparatus illustrative of one embodiment of this invention;

Fig. 2 is a diagram illustrating the relation between beam position and deflecting potential in the apparatus shown in Fig. 1;

Fig. 3 is another diagram showing the interconnection of the elements of the window defining assembly and the leading-in conductors therefor in the device shown in Fig. 1; and

Fig. 4 is a perspective view illustrating the construction and association of the target electrode and the window-defining elements.

Referring now to the drawing, the cathode ray device illustrated in Fig. 1 comprises an evacuated enclosing vessel 20 at one end of which an electron gun is mounted. For simplicity of illustration, the gun is shown as comprising an indirectly heated cathode 21 and a cylindrical focus control electrode 22. Mounted at the other end of the vessel is a secondary electron emissive target electrode 23, which may be a plate the surface of which toward the electron gun is coated with a material having a secondary electron emission coefficient of greater than unity. A cylindrical or rectangular frame-like collector electrode 24 is positioned opposite and in axial alignment with the target 23. Between the gun and collector electrode are a pair of parallel deflector plates 25.

Flow of secondary electrons from the target electrode 23 to the collector electrode 24 is subject to selective control by an assembly of a plurality of electrically individual, parallel plates or strips of electrically conductive material which extend normal to the target electrode and define a group of substantially identical windows between the target and collector electrodes. In the specific device shown, eleven plates or strips 1 to 11, inclusive, forming ten windows are provided. Adjacent plates or strips are spaced a distance somewhat greater than the diameter of the focussed beam projected from the electron gun and all the strips are positioned immediately adjacent the target electrode 23.

The operation of the plates or strips will be understood from the following considerations. The electron beam from the gun upon impinging upon the target causes the release of secondary electrons. These electrons, if the plates or strips were absent, would flow to the collector electrode 24. However, these plates or strips, depending upon the potential thereof relative to the target electrode 23, serve to either permit or prevent passage of the secondary electrons to the collector electrode. Consider any pair of adjacent strips. If the potential of either strip or of both strips in this pair is substantially different from that of the target electrode, secondary electrons cannot pass through the space or window bounded by this pair. For example, if either strip or both strips of this pair are highly positive relative to the target, secondary electrons will be collected by the strip or strips. If either or both strips are highly negative relative to the target, secondary electrons emanating from the target will be repelled thereto. If, however, two adjacent strips or plates are at substantially the same potential as the target, these together with the target bound a substantially field free region through which secondary electrons can pass to the collector electrode 24. Thus, by proper energization of the strips or plates any window may be opened to permit flow of secondary electrons therethrough, while all other windows are, in effect, closed and passage of secondary electrons is prevented.

It is evident that individual excitation of the multiplicity of plates or strips to effect selective control of the windows would entail use of a large number of leading-in conductors. In accordance with one feature of this invention, the number of such conductors requisite is substantially minimized. In the specific device shown in Fig. 1, the plates or strips are grouped in accordance with a two out of five code with five leading-in conductors A to E, inclusive. The specific connections are illustrated clearly in Fig. 3 wherein the lettered circles designate the leading-in conductors and the numbers adjacent these circles designate the plates or strips connected to the respective conductor.

It is evident from inspection of Figs. 1 and 3, that application of a potential substantially equal to that of the target electrode to any two of the conductors A to E will result in opening of only one of the windows to permit passage of secondary electrons. For example, if the proper potential is applied to conductors A and C, strips 1, 6, 11, 3 and 7 will be energized. Of these, only strips 6 and 7 are adjacent, and, consequently only the window bounded by these two strips will be opened. Similarly, if the potential is applied to conductors A and D, strips 1, 6, 11, 4 and 10 are energized and only the window bounded by strips 10 and 11 will be opened. Thus, any one of the windows may be opened alone by application of the requisite potential to the two conductors connected to the strips bounding that window.

Although in the specific embodiment illustrated in Fig. 1 eleven strips forming ten windows are included, a different number may be employed. The grouping of the strips with the leading-in conductors to enable selective opening of any window by energization of two conductors will be in accordance with the following. If the number of windows w can be expressed generally as $k(2k+1)$, where k is a whole number, then $(2k+1)$ leading-in conductors will be required. Let the vertices of a polygon having $(2k+1)$ sides represent the conductors. Draw all possible chords of the polygon. Clearly, each chord represents a possible combination of two out of $(2k+1)$. Connect the linear graph the nodes of which are the vertices of the polygon and the branches of which are the chords. Beginning at any node, traverse the graph on a closed unicursal path. Consider the strips numbered serially, i. e. 1, 2 . . . $(w+1)$, in the order of their physical position. Strip 1 then is connected to the conductor corresponding to the starting point (vertex) in tracing the path and successive strips are connected to the lead conductors as the respective vertices are encountered in traversing the path until the sequence is closed by connecting strip $(w+1)$ to the starting conductor.

The process above outlined may be illustrated by reference to Fig. 3. Start at conductor A. The unicursal path then is traced over the vertices in the order A, B, C, D, E, A, C, E, B, D, A, and the strips are connected to the conductors in the manner heretofore described and as indicated in the figure.

If the number of windows w is not of the form $k(2k+1)$, where k is a whole number, a similar process of connecting the strips to the leading-in conductors is employed. Specifically, the smallest number w_1 larger than w which is expressed in the form $k(2k+1)$ is selected. The process above set forth is then followed for the number w_1 of windows. After the first $(w+1)$ strips, bounding w windows have been accounted for, the construction is stopped. The connections thus indicated are employed for the strips bounding the desired w windows.

The selective opening of the windows is utilized to control the position of the electron beam and thereby the voltage appearing across the deflector plates 25. As shown in Fig. 1, the collector electrode 24 is maintained positive with respect to the target electrode 23, as by batteries 26 and 27, and is connected in feedback relation to the deflector plates 25 by way of an amplifier 28.

Also connected between the plates 25 is a source 29 of deflecting potential. The plates or strips 1 to 11, inclusive, are connected to a source through a switch 30 whereby the several groups of strips may be brought selectively to the potential of the target electrode. The electron beam may be controlled from a focus control 31. The latter, together with the source 29 and switch 30, may be controlled from a cycling circuit 32.

Assume that a potential is impressed between the deflector plates 25 and that the beam is focussed, i. e. that it is of a diameter somewhat less than the spacing between adjacent plates or strips. If the feed back circuit through the amplifier 28 were open, the beam deflection would be linearly proportional to the deflecting voltage so that the beam position versus deflecting potential graph would be a straight 45-degree line as O X Y Z in Fig. 2. However, if the feedback circuit through the amplifier 28 is closed, the graph is altered. Consider the case where a potential having a value between P_3 and P_5, such as to cause the bear to pass through the window between plates or strips 3 and 4, is applied between the deflector plates 25, and the strips 3 and 4 are at the potential such that secondary electrons flow from the target through the window noted to the collector electrode. Assume that the amplifier is so poled that the potential component due thereto impressed between the plates 25 is additive with respect to that due to the source 29. Then, if the beam moved across the window in question, the potential between the deflector plates would vary as illustrated by the curved part XMY of the graph in Fig. 2.

Some points between M and Y, however, represent stable beam positions whereas points between X and M are unstable beam positions. This will be apparent from a consideration of the relationship involved. If the beam is centered at a position corresponding to a point, say midway between M and Y, and the deflecting forces thereon are somehow disturbed so that the beam would move to the right, in Fig. 2, it is evident from this figure that such movement would result in a decrease in the deflecting potential. Hence, the beam would return to its initial position. Similarly, if the beam were disturbed and moved to the left, the deflecting potential would increase so that the beam would return to its initial position. For points between X and M, however, a disturbance of the beam would result in a change in the deflecting potential of such sign as to move the beam in the direction initiated by the disturbance. For example, if the beam were deflected to a position near and to the right of that corersponding to point X, it would not be in equilibrium, for a slight move to the right would result in an increase in the deflecting potential and consequently a further motion of the beam to the right.

Hence, it will be seen that for an applied potential between P_3 and P_4 between the deflector plates 25, the beam will come to rest at a position corresponding to a point between M and Y. Now, inasmuch as each beam position corresponds to a certain potential between the deflector plates, it will be appreciated that for an applied potential in the relatively large range between P_3 and P_4, the resulting potential appearing across the deflector plates will be within a much narrower range. The exact extent of the latter range will be determined by the amplitude of the feedback. In general, the greater the feedback the smaller is the range of resulting potential. In a well designed system, the potential appearing between the deflector plates may be constant within ± one per cent for a range of applied deflecting potentials varying by of the order of ten per cent.

In one manner of operation of the apparatus illustrated in Fig. 1, the input is in the form of pulses. Each pulse is resolved into a potential of corresponding amplitude applied to the deflector plates 25 by way of the deflector circuit 29. Also at the circuit 32, each pulse is coded to operate the switch 30 whereby the proper plates or strips are energized to open the window corresponding to the pulse amplitude. By virtue of the feedback action heretofore described, the beam position is adjusted automatically and the corresponding potential is established across the deflector plates 25. In other words, each input pulse is resolved into an output potential of amplitude determined by the amplitude of the input pulse.

In another manner of operation of the apparatus, feedback alone is utilized to produce a deflecting potential across the deflector plates 25. In this case, initially the beam is directed to one end, e. g. the lower, of the array of strips and is somewhat defocussed so that it is spread over the target 23 but is sufficiently forcussed that any motion of the beam toward an open window causes an increase in the secondary emission. The input, then, comprises code groups of two pulses each. For each group, a corresponding window is opened and as a result secondary electrons flow to the collector electrode and a deflecting potential is produced across the deflector plates 25. Consequently, the beam moves toward the open window and the secondary electron current and, hence, the effective deflecting potential increases. Thus, the beam is moved to the open window and adjusts itself to equilibrium position thereby to produce a potential, of amplitude corresponding to the input pulse group, across the deflector plates.

Advantageously, concomitantly with the deflection of the beam in response to an input pulse group, the focus control is operated to increase the beam concentration whereby the final adjustment of beam position is obtained with the beam sharply focussed, i. e. is of a diameter somewhat less than the spacing between adjacent strips. Such focus control may be effected, for example, by triggering of an RC circuit controlling the potential of the electrode 22, upon application of each input pulse group to the circuit 32.

Although specific embodiments of the invention have been shown and described, it will be understood, of course, that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. Electron discharge apparatus comprising a secondary electron emissive target, means opposite one face of said target defining a row of windows, means for projecting an electron stream against said one face of said target, a collector electrode opposite said one face, means for deflecting said stream along said row of windows, a feedback coupling from said collector electrode to said deflecting means, and input means connected to said window defining means for energizing said window defining means to selectively open said windows individually for passage therethrough of secondary electrons from said target to said collector electrode.

2. Electron discharge apparatus comprising a secondary electron emissive target, means for projecting an electron stream against one face of said target, a collector electrode opposite said face, a plurality of electrode members adjacent said face and spaced to define a row of openings each of which is bounded by two adjacent electrode members, means for deflecting said stream in the direction to pass along said row of openings, a feedback coupling between said collector electrode and said deflecting means, and input means connected to said electrode members for selectively biasing any two adjacent electrode members at such prescribed potential relative to said target and collector electrode as to permit passage of secondary electrons from said target through the opening bounded thereby, to said collector electrode.

3. Electron discharge apparatus in accordance with claim 2 wherein there are $k(2k+1)$ openings, k being a whole number, and wherein said biasing means comprises means connecting said members electrically into $(2k+1)$ groups in such manner that upon application of said prescribed potential to any two groups only one pair of adjacent electrode members will be at said potential.

4. Electron discharge apparatus comprising a target one face of which has a secondary electron emission coefficient greater than unity, an electron gun for projecting an electron stream against said one face, a collector electrode opposite said one face, a plurality of parallel strip electrodes between said target and said collector electrode and defining a row of windows, each window being defined by two adjacent strip electrodes, means for deflecting said stream in the direction along said row of windows, a feedback coupling between said collector electrode and said deflecting means, and input means connected to said strip electrodes for energizing said strip electrodes to selectively open any one of said windows for passage of secondary electrons from said target to said collector electrode.

5. Electron discharge apparatus in accordance with claim 4 wherein said energizing means comprises means connecting said strip electrodes into groups wherein no two adjacent strip electrodes are in the same group and said strip electrodes are arranged such that when a prescribed potential is applied to any two of said groups only one pair of adjacent strip electrodes is brought to said potential.

6. Electron discharge apparatus comprising a secondary electron emissive target, means for projecting an electron stream against one face of said target, a collector electrode opposite said face, means for deflecting said stream in one direction along said face, and means for resolving signals applied to said deflecting means into one of a number of potentials across said deflecting means, each of said potentials corresponding to a respective range of signals, each resolving means comprising electrode means adjacent said target and defining a row of windows arrayed in said direction, there being one window for each range of signals, means for selectively energizing said electrode means concomitantly with the application of each signal to said deflecting means to open only the window corresponding to the range in which the signal lies, thereby to permit passage of secondary electrons from said target to said collector electrode through the opened window, and a feedback coupling from said collector electrode to said deflecting means.

7. Electron discharge apparatus comprising a secondary electron emissive target, means for projecting an electron stream against one face of said target, a collector electrode opposite said face, a plurality of members adjacent said face and defining a row of windows for passage of secondary electrons from said target to said collector electrode, each window being bounded by a respective pair of adjacent members, means for deflecting said stream in the direction of said row, a feedback coupling between said collector electrode and said deflecting means, means for selectively biasing any pair of adjacent members at a potential relative to said target and collector electrode to permit passage of secondary electrons from said target to said collector electrode through the window bounded by the biased adjacent members, and means for controlling said stream to vary the focussing thereof, during the period of biasing of any pair of adjacent members, so that at the beginning of said period the stream passes through all of said windows and at the end of said period said stream is substantially focussed upon the window, bounded by the adjacent biased members.

8. Electron discharge apparatus comprising a secondary electron emissive target, means for projecting an electron stream against one face of said target, a collector electrode opposite said face, a plurality of members adjacent said face and defining a row of windows for passage of secondary electrons from said target to said collector electrode, each window being bounded by a respective pair of adjacent members, means for deflecting said stream in the direction of said row, a feedback coupling between said collector electrode and said deflecting means, means for controlling the focus of said stream, means connecting said members in interleaved groups such that upon application of potential pulses to any two groups only one pair of adjacent members will be energized, means for selectively applying to any two of said groups a potential such as to permit passage of secondary electrons from said target to said collector electrode through the window bounded by the two adjacent members energized, and means for energizing said focus controlling means so that initially said beam is spread over said target and is brought to a sharp focus upon said window concomitantly with the application of said potential.

9. Electron discharge apparatus in accordance with claim 8 wherein there are $k(2k+1)$ windows, k being a whole number, and said members are connected into $(2k+1)$ groups.

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