Aug. 25, 1959 S. G. NEVIUS 2,901,663

ELECTRONIC DIGITIZING DEVICE

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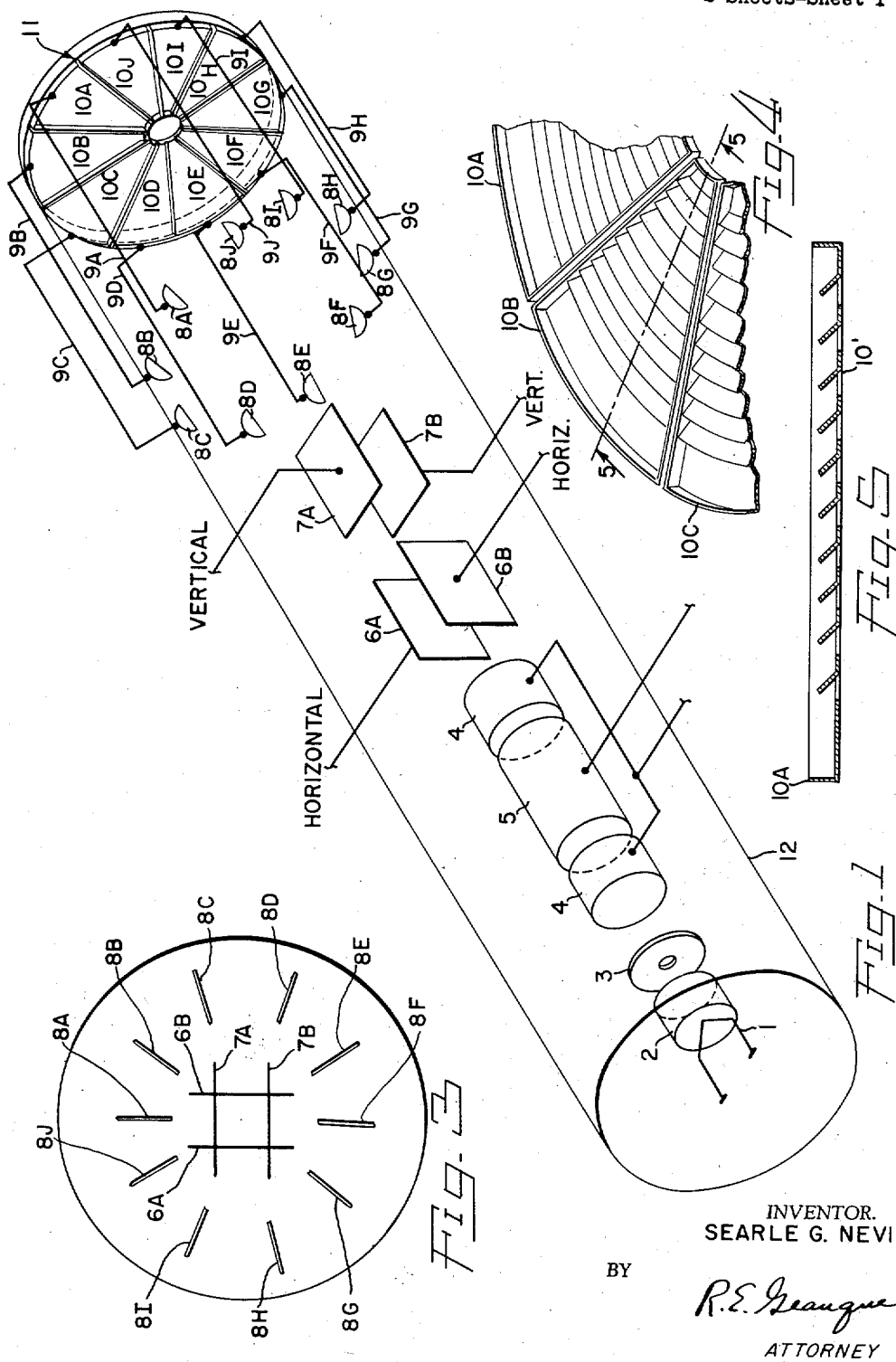


FIG. 1

FIG. 4

FIG. 5

FIG. 3

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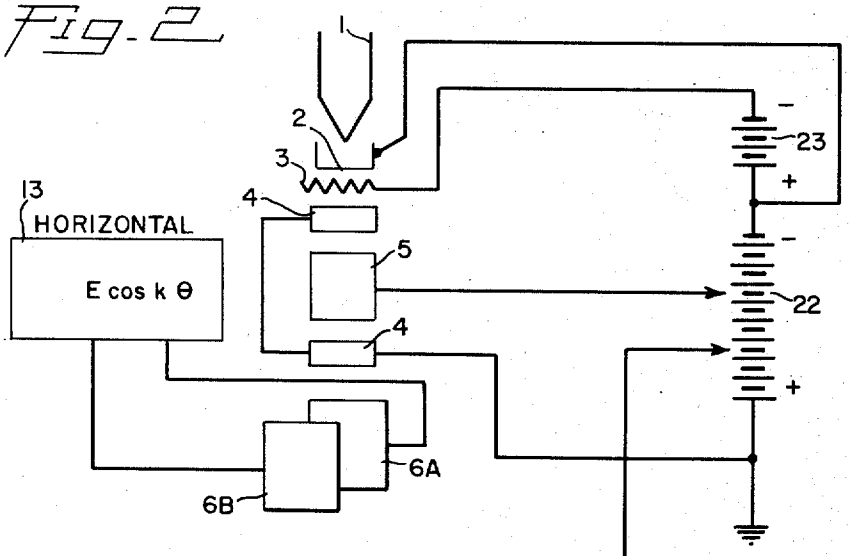
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Fig. 2



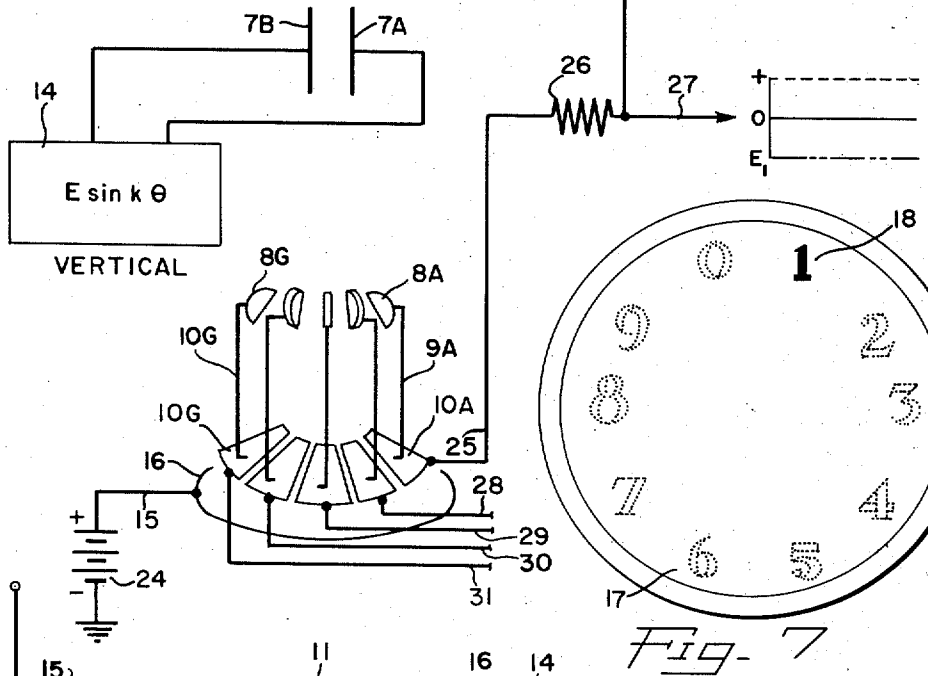


Fig. 7

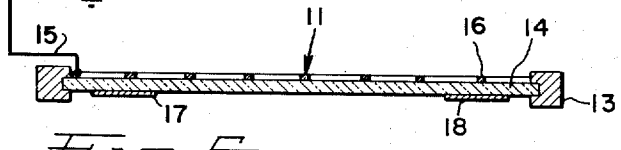


Fig. 6

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2,901,663

ELECTRONIC DIGITIZING DEVICE

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Application July 15, 1957, Serial No. 671,816

10 Claims. (Cl. 315—12)

This invention relates to electronic digitizing devices and more particularly to cathode-ray devices for analog-to-digital converters.

In modern electronic data handling equipment, the need often arises for the conversion of information in the analog domain, such as might be generated by a resolver, to information in the digital domain wherein it might be easily operated upon by an electronic digital computer. The present invention provides arrangements enabling the use of an electronically detented circular sweep of a cathode-ray beam over a plurality of circularly disposed target areas. While the invention employs a cathode-ray tube having a conventional electron gun and horizontal and vertical deflection plates, certain improvements reside in novel auxiliary deflection electrodes, novel target elements, and novel indicating means.

The principal object of this invention is to provide a single cathode-ray tube which can digitize the dual electronic signal $E(\sin N_n\theta + \cos N_n\theta)$ where E equals voltage, N_n equals a constant, and θ equals a variable.

Another object of this invention is to quantitatively and visually display the trigonometric output from a resolver in discrete numerical form.

A further object of this invention is to provide a novel cathode-ray tube employing electrostatic deflection of the electron beam under the control of target elements having a secondary emissive property.

A still further object is to provide such a cathode-ray tube which provides an electronic detent function in which the electron beam has a finite number of discrete stable states.

A further object is to provide such a cathode-ray tube giving direct visual indication of its stable states on a fluorescent screen.

Another object is to provide such a cathode-ray tube having output control terminals corresponding to the number of stable states of the electron beam.

These and other objects of the invention, not specifically set forth above, will become readily apparent from the accompanying description and drawings in which:

Figure 1 is a schematic perspective view of the device of one form of the invention;

Figure 2 is a schematic illustration of the device of Figure 1 showing a circuit useful in explaining the principle of operation of the invention.

Figure 3 is a sectional view of Figure 1 showing the relationship of the horizontal and vertical deflection plates and the ten deflector electrodes;

Figure 4 is an enlarged fragmentary perspective view of the target elements of the device of Figure 1;

Figure 5 is a sectional view of a target element along line 5—5 of Figure 4 showing certain details of the louvered openings therein;

Figure 6 is a sectional view of the collector element useful in attracting secondary electrons emitted from certain areas of the target structure, and for suppressing a space charge.

Figure 7 is a front view of the device of Figure 1 showing the manner in which the digital output of the invention may be visually displayed by means of fluorescing phosphor numerals.

In the following description, similar reference characters are used throughout to indicate similar structures.

Referring to Figure 1, there is shown one form of the tube according to the present invention, comprising a heater 1, a cathode 2, a control grid 3, a pair of acceleration electrodes 4, and a focusing electrode 5. These comprise a well known type of electron gun which functions to produce a beam of electrons. It will be understood that any conventional or desired form of electron gun may be used.

While a particular embodiment of an electron tube construction of the present invention is shown in Figure 1, the envelope 12 typically may be of either all glass or metal construction. Various aspects of this construction are pictured more readily in cross section in the other figures and will be described later in the specification. The envelope and basing arrangement employed may be of any suitable form utilizing a suitable quantity of connecting pins. The electrode construction and the enclosing envelope, in general, is not of necessity drawn to scale and the element lead wires are shown as taken directly outside the walls of the tube envelope, whereas the correct location of the lead wires is to pin connections within the circle of the tube envelope at its base. In addition, the placement of the leads connecting the pins and the electrodes is in schematic form and the electrode supports and spacers are not shown.

Coaxially aligned with the electron gun 1–5 are a pair of horizontal deflection plates or electrodes 6A, 6B and a pair of vertical deflecting plates or electrodes 7A, 7B. The order of arrangement of these pairs of plates is immaterial; either may be adjacent the electron gun 1–5. In the beam path beyond these deflecting electrodes are ten deflector electrodes 8A to 8J hereinafter called flag electrodes, which are elliptically arranged about the beam path. Each of these flag electrodes is shaped somewhat like a half disc and each is connected by means of a wire 9A to 9J to a corresponding pie-shaped target sector electrode 10A to 10J. Each of these target electrodes is the same size and shape. Each of these target electrodes depends for its operation on the emission of secondary electrons from its surface. As will be made clear hereinbelow, the particular number of flag electrodes and target electrodes shown is merely by way of illustration, since any desired number may be used according to the digital number system desired.

Quasi D.C. voltages, whose magnitudes are a function of the sine and cosine of an angle θ when applied to the horizontal and vertical deflection plates 6A, 6B, 7A, 7B, cause the electron beam to assume positions on a circular locus at the end of the tube where θ is measured on the locus from a suitable reference point. This circular pattern is in a plane containing the ten target elements 10A through 10J at the end of the tube.

Referring to the beam spot position on a given target, there are three electrostatic fields affecting this position, two of these, the horizontal and vertical deflection plates position the beam spot on a circle as previously explained. Between the last pair of deflection electrodes 7A and 7B and the ten target elements 10A through 10J are aligned the ten radially disposed flag electrodes 8A through 8J. These flag electrodes influence the trajectory of the beam prior to its impinging upon the target electrodes.

As previously described, each of these flag electrodes is connected to a corresponding target electrode by means of wires 9A through 9J. The target electrodes have the property of emitting secondary electrons due to the impact of the beam. The beam impinging on a given

target electrode will cause the charge of that target electrode to become positive by reason of the secondary emission from the target. The closed circuit to the corresponding flag electrode will develop a positive charge on the flag electrode and will attract the beam and cause it to be bent toward the flag electrode. The beam will continue to strike the given target electrode up to the point at which the beam path, under the influence of the horizontal and vertical deflection plates, moves directly opposite the adjacent flag electrode.

When the magnitudes of the input voltages to the horizontal and vertical deflection plates **6A** and **6B**, **7A** and **7B** overcome the deflection force of the positively charged flag electrode and are such as to move the beam from one target segment to the next, a detent action will result since the beam will have been bent to a location directly opposite the adjacent flag electrode. The detent action or step function acts the same way, regardless of the direction of progress of the circular scan of the electronic beam.

A collector **11** comprises a grid or screen **16** which is located behind the ten target electrodes and which serves to collect the secondary electrons emitted by the target electrodes. Supporting this screen is a mica disc **14** as shown in Figure 6 upon which has been deposited or printed, numerals 0 through 9, in a phosphor which, when excited by the secondary electrons, serve to visually display the corresponding numeral and identify the position of the electron beam and the associated target electrode under beam bombardment. Thus, the output of the device is both visual, as displayed by the phosphor on the mica disc, and electronic, as indicated by one and only one target electrode and its associated output connection, later to be described, being positive with respect to all of the other target elements. It is pointed out that the electrical connections to the various elements within the evacuated container shown in Figure 1 are brought out to socket pin connections in a well-known manner. For purposes of clarity, the wiring connections and physical structural elements used to support the tube electrons are omitted from the schematic illustration of Figure 1.

In Figure 2, there is shown a simplified circuit such as is required to illustrate the principle of operation. While the various elements of Figure 2 are diagrammatically illustrated to some extent, it should be understood that these various elements, with the exception of the batteries, the resistor and the blocks representing the input sources, are enclosed within an evacuated container in a conventional manner. Power for operation of the device is derived from a suitable source, such as batteries **22**, **23**, and **24**, and suitable distribution of voltages from these sources to the various elements is effected by means of suitable taps to these batteries. The voltages required at these various taps is dependent upon the character of the electron gun. A beam of electrons from the cathode **2** is focused and projected in a conventional manner and is caused to pass between the deflection plates **6A** and **6B** and travel toward the opposite end of the tube. Similar deflection plates **7A** and **7B** control the vertical position of the beam. The phase quadrature input signals to the pairs of deflection plates is derived from an electronic source represented by block **13** labeled $E \cos k\theta$ and block **14** labeled $E \sin k\theta$.

The input signals comprise $E \cos k\theta$ and $E \sin k\theta$. Each digit covers slightly more than $360°/N$ and are thereby overlapped to prevent normal noise levels from causing oscillation between digits. These phase quadrature input signals are such that the beam circularly scans the ten target electrodes. The output from the tube comprises a static signal on any one of N lines, of which **25**, **28**, **29**, **30**, and **31** are typical, where N is the total number of digits for which the tube is designed. This static signal at each line is developed across a separate load resistor **26** and is externally available on an individual line **27**. In the embodiment described, 360° of rotation is divided into ten parts ($10N=360°$). This design also provides for a step function change from one digit to another in either direction.

Referring now to Figure 3, there is shown the horizontal deflection plates **6A** and **6B** and the vertical deflection plates **7A** and **7B** and the ten flag electrodes **8A** through **8J**. As can be seen in this figure, the flag electrodes are arranged circumferentially about the axis of the electron beam in an elliptical arrangement. This elliptical arrangement is used to obviate the unwanted effects of beam astigmatism which result from the spatial displacement of the vertical plates with reference to the horizontal plates. Since the beam has a radial component as well as a circumferential component, it is also necessary that the flag electrodes be canted or tilted to produce a conical array as is more clearly shown in Figure 2.

Referring now to Figure 4, there is shown a fragmentary perspective view of the target electrodes **10A** through **10J**. The target electrodes are constructed to have a secondary electron emission coefficient greater than unity. For example, they may be of an alloy of silver and magnesium or the upper surface, as viewed in Figure 4, may be coated with a material having a high secondary electron emission coefficient. Each of the target elements is supported by an insulator. Since conventional methods of supporting, connecting, and spacing of the target electrons are used, details of their construction are not shown. In Figure 5, there is shown a sectional view taken along line **5—5** of Figure 4 which illustrates the louvered openings **10'** in each of the target electrodes. The configuration of these openings is such that the electron beam will always strike the surface of the target element and cannot pass directly through the openings. However, secondary electrons ejected from the emissive surface may be attracted by a positive charge in the region beyond the target element and may pass through the louvered openings.

Referring now to Figure 6, there is shown a cross section of the collector electrode **11** which comprises an insulating frame **13**, the mica disc **14**, the metallic screen **16**, a lead wire **15**, and phosphor numerals **17—18**. A high positive potential is applied to screen **16** via lead wire **15** from battery **24**. Secondary electrons are emitted from the surface of each target element when bombarded by the electron beam. Electrons emitted from the surface of target element **10A** are attracted by the positive charge on the screen **16** through the louvered openings **10'** and are, in part, collected on the surface of the screen **16**. Those electrons not collected upon the screen continue on through the interstices of the screen. The high velocity of electrons passing through the collector screen impinge on the phosphor numeral **18** and will cause number 1 to fluoresce and thereby indicate the presence of the beam. In a similar manner, each number will fluoresce when its corresponding target element is bombarded by the electron beam. It should be understood that although ten numbers are shown, only one number at a time may be caused to fluoresce since the beam is held on but one target electrode at a time. There is shown in Figure 7, an end view of the tube representing the arrangement of the phosphor numerals. The number 1, designated as **18**, has been shaded to indicate a fluorescing condition as if the electron beam were impinging on the first target electrode **10A** and the remaining numbers designated as **17**, are unshaded to indicate a non-fluorescing condition.

A separate load circuit **26** and **27**, associated with each line (such as **25**, **28–31**) of a target electrode, produces a voltage output when the electron beam is impinging upon that particular electrode and thereby provides an output signal that is in a digital or noncontinuous form even though the input is a continuous trigonometric function. As the beam passes over a given target, the output

voltage will swing from some negative potential E, through 0 to some positive potential. The output may be used to energize conventional visual display circuits, such as a bank of neon bulbs, an electric typewriter, a tape perforator, or line printer. An example of a read-out circuit that may be fed by load circuits and energize such equipment is described in Serial No. 271,825, filed February 15, 1952, now Patent No. 2,811,310, in the name of W. D. Caldwell and assigned to the assignee of the present invention.

It is thus apparent that the digitizer produces a number N_n of discrete indications equal to the radix of the number system used. Since it is customary to use a counting system based on the radix 10, it is convenient to design the digitizer tube to produce an output consisting of ten distinct indications for the 360° of mechanical rotation. It should be understood, however, that as few as two stable states or more than ten stable states may be obtained by suitably modifying the invention.

Of many possible information input sources to be digitized, N_n may be associated with the construction of a position resolver and θ may be associated with the position of the resolver. Such a resolver performs trigonometric operations involving the resolution of input voltages into sine and cosine components in accordance with a varying position or shaft rotation representing the input to the resolver. A suitable resolver for supplying voltages having the required phase relationships is described in U.S. Patent No. 2,765,459 granted to A. J. Winter on October 2, 1956. By this means a phase shift may be produced which varies linearly with shaft rotation. The present invention acts as a direct coupled follower of the resolver and as such is bi-directional. The maximum digitizing rate is limited only by the transit time of the electron beam plus the time constants of the target electrode circuits. Various modifications are contemplated by those skilled in the art without departing from the spirit and scope of the invention as hereinafter defined by the appended claims.

What is claimed is:

1. An electronic digitizing device for converting simultaneous sine and cosine voltages into discrete step-function signals comprising means for projecting a beam of electrons, means responsive to variable phase quadrature signals for deflecting said electron beam, means for holding said beam and detecting the presence of said beam at discrete increments over its path, and means for varying said phase quadrature signals in response to information to be digitized, said beam being solely under the influence of said deflecting means and said holding means.

2. In an electronic digitizing device, a plurality of targets arranged in a circle, means for projecting an electron beam towards said targets, first deflection means for rotating said beam to produce a substantially circular trace over said targets, input signal means connected with said first deflection means for applying thereto quadrature voltages necessary to produce said circular trace, and a secondary deflection means for holding said beam on any given target until the deflecting force of said second deflection means is less than the deflecting force of said first deflection means, said first and second deflection means being correlated so that said beam passes from each target to the next succeeding target with detent action.

3. An electronic digitizing device for converting simultaneous sine and cosine voltages into discrete step-function signals comprising a plurality of substantially circularly disposed target electrodes, means for projecting an electron beam towards said target electrodes, means comprising space quadrature electrodes capable of deflecting said beam over a substantially circular trace passing over all of said target electrodes, a separate secondary electrode associated with each of said target electrodes for developing a holding force on said beam in response to beam impact on the associated target electrode, said beam being solely under the influence of said space quadrature electrodes and said secondary electrodes input signal means connected with said space quadrature electrodes to move said beam in response to an input signal, said input signal means comprising means for developing simultaneous sine and cosine voltages representing the input signal and capable of developing sufficient force on the beam to overcome the holding force of said secondary electrodes, the holding force of each of said secondary electrodes serving to hold said beam and maintain said beam on its associated target electrode until the force produced by the input signal on said space quadrature electrodes overcomes the holding force of the secondary electrode and causes said beam to detent onto the next adjacent target electrode.

4. An electronic digitizing device as defined in claim 3 wherein the connection of said input signal to said space quadrature electrodes comprises means for applying said sine voltage to one of said space quadrature electrodes and for applying said cosine voltage to the other of said space quadrature electrodes.

5. An electronic digitizing device as defined in claim 3 comprising means for connecting each target electrode with its associated secondary electrode, said target electrodes having secondary emissive properties for developing a positive potential upon a secondary electrode when said beam impinges upon the associated target electrode.

6. An electronic digitizing device as defined in claim 5 wherein each of said target electrodes comprise plates having louvered openings to permit passage through the target electrode of the secondary electrons, and collection means positioned on the opposite side of said target electrode from said projecting means for collecting said secondary electrons.

7. An electronic digitizing device as defined in claim 6 wherein said collecting means comprises a conducting grid having non-conducting openings to permit passage of secondary electrons through the grid, and means located beyond the grid and responsive to electron flow through the grid for indicating which target electrode is under bombardment by said electrode beam.

8. An electronic digitizing device as defined in claim 7 wherein said indicating means comprises a plurality of fluorescent indicia, one of said indicia being located behind each of said target electrodes.

9. An electronic digitizing device as defined in claim 5 having conductor means connected with each of said target electrodes for detecting the emission current on each of the target electrodes.

10. An electronic digitizing device as defined in claim 6 having conductor means connected with each of said target electrodes for detecting the emission current on each of said target electrodes.

References Cited in the file of this patent

UNITED STATES PATENTS

2,540,835	Anderson	Feb. 6, 1951
2,719,248	Josephson	Sept. 27, 1955