

Sept. 10, 1957

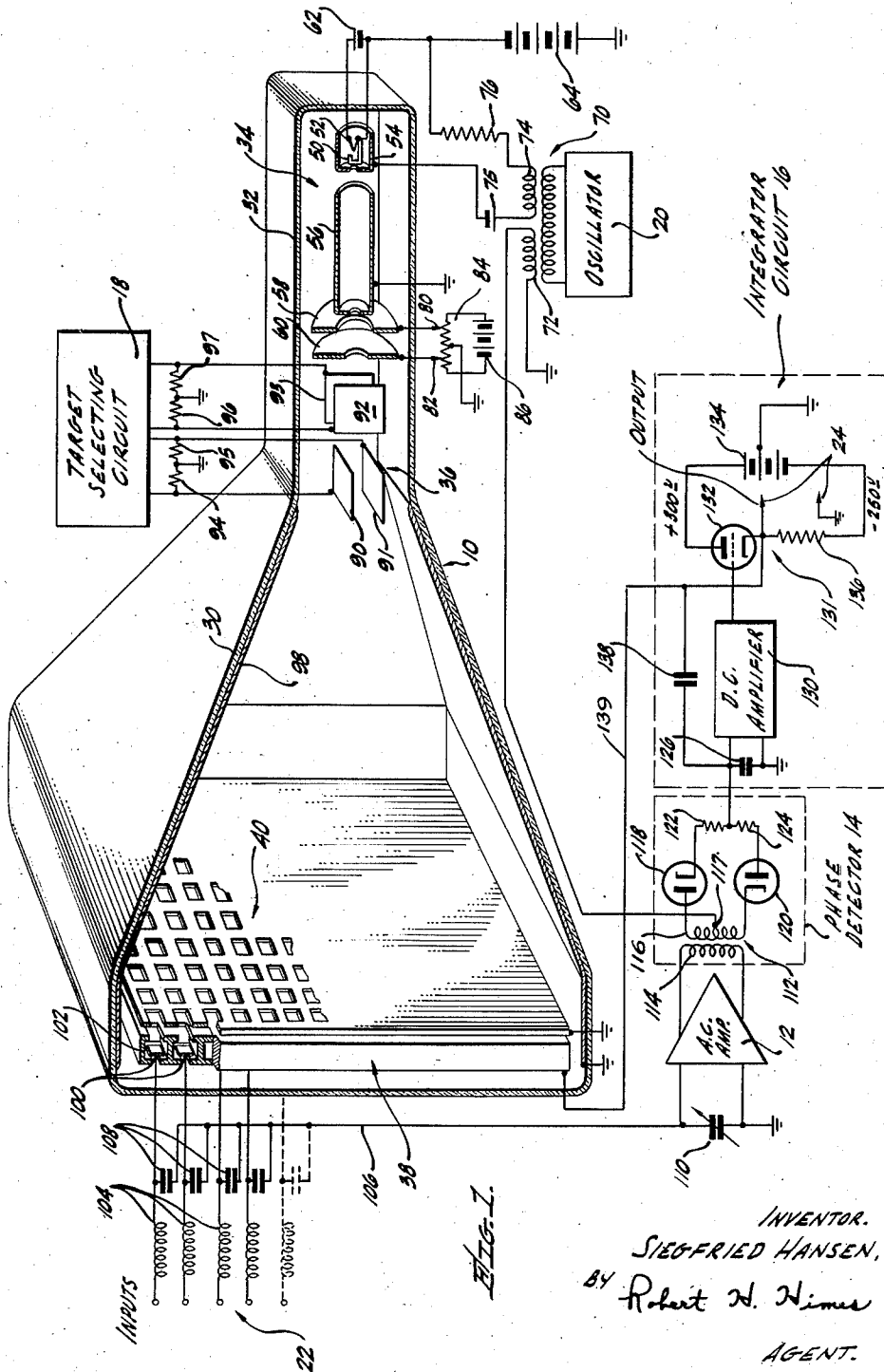
S. HANSEN

2,806,175

ELECTRONIC SELECTOR SWITCH

Filed May 10, 1954

2 Sheets-Sheet 1



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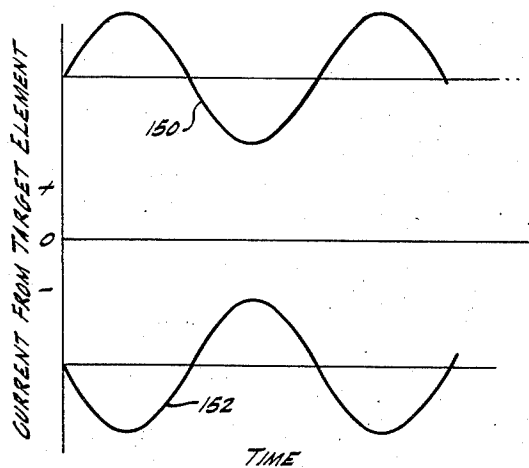
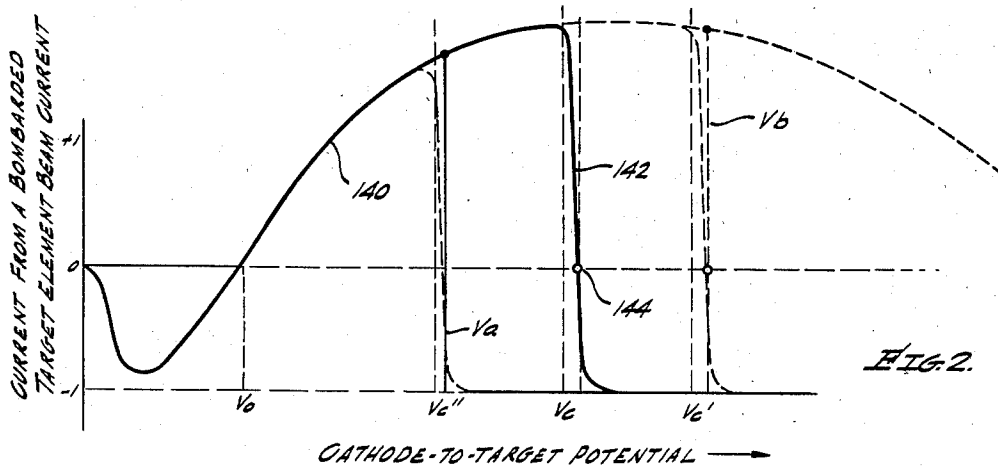


FIG. 3.

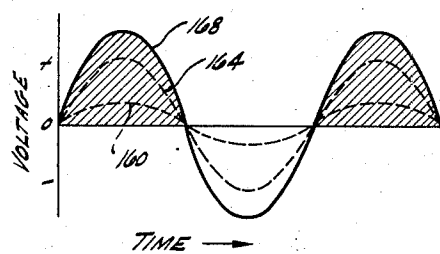


FIG. 4.

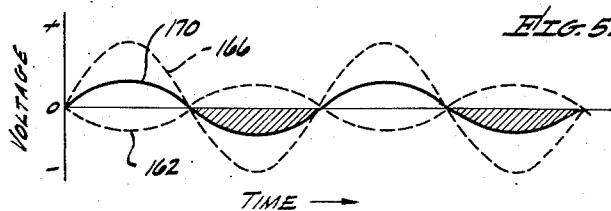


FIG. 5.

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ELECTRONIC SELECTOR SWITCH

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4 Claims. (Cl. 315—12)

This invention relates to an electronic switching device and more particularly to an electronic switching system incorporating a cathode ray device.

The employment of digital computers in control systems often requires that separate and successive readings be taken from a plurality of instruments. These readings are normally derived in the form of direct-current voltages, the magnitudes of which are proportional to indicated or measured instrumentally recorded quantities. In the operation of the system it is necessary that these voltages, called input voltages, be sampled according to a predetermined arrangement and repeatedly and successively read by selector switches which are connected to a common output terminal.

It has been the practice to employ mechanical commutator or rotary switches to perform computer switching functions. In some cases, mechanical switches are unsatisfactory because of their relatively short lives. In a great many cases, the maximum operating speed of these switches is so slow that they are made completely useless for some computer applications. In this event, electronic circuits are employed to replace the mechanical switches. These circuits normally include numerous conventional electron tubes. In view of the number of tubes required to perform a relatively few switching functions, the original cost, the maintenance costs, and the operating power loss, the cost of operating these circuits is unfavorably high. Frequently, the space necessarily occupied by this type of equipment is also an outstanding disadvantage.

Cathode ray type electron tubes are sometimes employed to perform various non-computer switching functions. These tubes normally comprise a conventional electron gun for producing an electron stream, stream deflector plates, sweep voltage sources for deflecting the stream, and a plurality of target electrodes, commonly called targets, from which separate output signals are taken. Currently, these cathode ray tubes are only employed as output devices having single inputs and multiple outputs connected to the targets. In particular, cathode ray devices are not presently employed as digital computer input switches because it is necessary to prevent loading the input sources which are connected to the targets.

By practicing the present invention, digital computer input switching may be accomplished by the use of a cathode ray device of the general type described wherein means are provided for sampling input signal amplitudes and for producing them at a single output terminal with no substantial loading of the input sources.

Multiple electronic switching is accomplished with the present invention by means of a cathode ray device including an electron gun for producing an electron stream, stream deflection means, a plurality of target electrodes, and a collector electrode. The targets, which are each responsive to an input signal to be sampled, are constituted of secondary electron emissive materials. The collector electrode has the form of a metallic multicellular structure which substantially encloses each separate target so as to isolate it from the others.

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In its operation, the particular target responsive to the input signal to be sampled is bombarded by the electron beam which is intensity modulated with an alternating-current voltage of a predetermined frequency. The bombardment by the electron beam causes a current to flow either to or from the target, depending on whether the potential of the target is greater or less than the potential of the collector electrode. In the case where the potential of the target is substantially the same as that of the collector electrode, no current flows. When a current does flow, however, the current flowing to and the current flowing from the target each contain alternating-current components that are opposite in phase and are of a magnitude proportional to the total current flowing. The alternating-current component in the current flowing to or from the target is amplified by an alternating-current amplifier and compared to the original alternating-current voltage of predetermined frequency by a phase detector to produce a direct current potential of an amplitude and polarity dependent on the amplitude and phase of the alternating-current component. This direct-current potential is integrated by means of a high-gain direct-current amplifier and the resulting output signal impressed on the collector grid in a manner to minimize the difference in its potential from that of the target element. Thus, the output signal developed at the output terminal of the high-gain direct-current amplifier by virtue of its connection to the collector electrode, is substantially an exact reproduction of the input signal impressed on the particular target being bombarded by the electron beam. It is thus seen that the target, collector electrode, alternating-current amplifier, phase detector, and high-gain direct-current amplifier form what may be designated as a high-gain "null-seeking" closed servo loop. Also, in order to switch to a particular input signal, it is only necessary to deflect the electron beam to the appropriate target.

It is therefore an advantage of the present invention in that it may be employed to accomplish input switching in a more rapid manner than heretofore practiced in taking data in digital computer applications. For example, sampling time may be easily reduced to 100 or 200 microseconds. The invention has a greater life span than high speed mechanical switches; however, unlike conventional electronic switching circuits, the original cost and maintenance of the present invention is very low compared to its relative utility. For example, one cathode ray tube with associated circuitry, constructed in accordance with the invention, may replace fifty to one hundred conventional tubes in electronic switching circuits presently employed.

It is an object of the invention to provide an improved cathode ray electronic switching device.

It is another object of the invention to provide a cathode ray electronic switching device for sampling the voltage of a selected complex wave source without substantially loading the source.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawing in which an embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only, and is not intended as a definition of the limits of the invention.

Fig. 1 is a schematic diagram of an embodiment of the tube and circuit of the present invention; and

Figs. 2-5 are waveforms explanatory of the operation of the device of Fig. 1.

Referring now to Fig. 1 there is illustrated an em-

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bodiment of the present invention comprising an electronic switching tube 10 which operates in conjunction with a feedback circuit including an alternating current amplifier 12, a phase detector 14 and an integrator circuit 16. The electronic switching tube 10 is also responsive to an oscillator 20 and a target selecting circuit 18 which effects the switching of any one of a plurality of input signals impressed upon its input terminals 22 to output terminals 24.

More particularly, electronic switching tube 10 comprises an evacuated envelope 30 having a neck portion 32 at its right extremity as viewed in the drawing. Within the neck portion 32 there is disposed an electron gun 34 for producing an electron stream and deflecting means 36 for directing the electron stream in a desired direction towards a target assembly 38 and shielding electrode 40 disposed in an enlarged portion of the evacuated envelope 30.

Electron gun 34 comprises a cathode 50 with a heating element 52, an intensity grid 54, an accelerating electrode 56 and focusing electrodes 58 and 60. Heating element 52 is connected across a potential source 62 which may be connected to one side of cathode 50 which is, in turn, connected to the negative terminal of a battery 64, the positive terminal of which is connected to ground. Battery 64 maintains cathode 50 at a potential of the order of 3000 volts negative with respect to ground.

During the operation of the electronic switching tube, it is necessary to modulate the current of the electron beam at a frequency which may be of the order of 30 megacycles. This modulation potential is provided by oscillator 20 which has an output transformer 70 having output windings 72 and 74. Intensity electrode 54 is both modulated and maintained at a quiescent negative potential with respect to that of cathode 52 by a connection therefrom through a battery 75, output coil 74 of oscillator 20, and a load resistor 76 to the cathode 50. The quiescent negative potential provided by battery 75 is of the order of from -10 to -50 volts.

Accelerating electrode 56 is maintained at a high positive potential with respect to that of cathode 50 by means of a direct connection to ground. Electrodes 58 and 60, which provide means for producing an electrostatic lens for focusing the electron beam on the target assembly 38, are maintained at potentials of the order of 200 volts negative with respect to ground and 200 volts positive with respect to ground, respectively. This is effected by connecting electrodes 58, 60 to taps 80 and 82, respectively, of a potentiometer 84 which has an intermediate point connected to ground and is, in turn, connected across a battery 86 so that both positive and negative potentials are provided.

The electron beam deflecting means 36, comprising vertical deflecting plates 90 and 91 and horizontal deflecting plates 92 and 93, is disposed about the path of the electron beam immediately after it passes through focusing electrodes 58 and 60. Suitable voltages for directing the electron beam in a desired direction toward target assembly 38 are provided by target selecting circuit 18. These voltages are impressed on vertical deflecting plates 90, 91 across resistors 94, 95 and on horizontal deflection plates 92, 93 across resistors 96 and 97. The junction between resistors 94 and 95 and between resistors 96 and 97 are each connected to ground so as to maintain the vertical and horizontal deflection plates at quiescent ground potential.

Intermediate the electron beam deflecting means 36 and target assembly 38 there is disposed a conductive coating 98 disposed about the inner surface of evacuated envelope 30 which provides an equipotential drift region in this space for the electron beam. Conductive coating 98 is maintained at ground potential by a suitable connection thereto.

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Target assembly 38 is disposed in the enlarged portion of evacuated envelope 30 in a manner to intercept the electron beam. Target assembly 38 comprises a plurality of target elements 100 and a collector electrode 102. This collector electrode is a multicellular structure having a cell for substantially enclosing each target element except for an aperture opening towards the electron gun 34. Shielding electrode 40 is disposed adjacent to target assembly 38 on the side exposed to the electron beam and has an aperture in register with each aperture of the multicellular collector electrode 102. The purpose of shielding electrode 40 and the multicellular structure of collector electrode 102 is to completely isolate a bombarded target element from the remaining target elements. Silver or magnesium are suitable materials for target elements 100 and stainless steel or nickel is suitable for making collector electrode 102 and shielding electrode 40.

The input signals are impressed on the target elements 100 by suitable connections from terminals 22 through inductors 104 to respective target elements. Each of the target elements are then coupled to a common bus 106 through capacitors 108. This common bus 106 is connected to a variable capacitor 100 which is, in turn, connected across the input terminals of alternating current amplifier 12.

The phase of the output of alternating current amplifier 12 is compared with the reference signal produced by oscillator 20 by phase detector 14. This phase detector 14 comprises an input transformer 112 having a primary winding 114 and a secondary winding 116 which has a center tap at a terminal 117, diodes 118 and 120, and resistors 122 and 124. The output of alternating current amplifier 12 is impressed across primary winding 114 and the reference signal provided by output winding 72 of oscillator 20 is connected from ground to the center tap 117 of secondary winding 116. The extremities of secondary winding 116 are connected to the plate of diode 118 and to the cathode of diode 120. The cathode of diode 118 is then connected through resistors 122 and 124 to the plate of diode 120 to form a closed unidirectionally conducting circuit. The common junction between resistors 122 and 124 provides the output from phase detector 14 which is smoothed by virtue of its being connected through a capacitor 126 to ground. The voltage appearing at this output will have a polarity that is dependent upon the phase of the input signal applied through primary winding 114 relative to that of the reference signal and an amplitude directly proportional to the amplitude of the input signal.

This output voltage is applied to a high-gain direct-current amplifier 130, the output of which is applied to the grid of a cathode follower stage 131 comprising a triode 132 which has its plate connected to the positive terminal of a battery 134 and its cathode connected through a load resistor 136 to the negative terminal of battery 134, an intermediate tap of which is connected to ground so as to maintain a potential of the order of +300 volts on the plate and a potential of the order of -250 volts on the load resistor 136 connected to the cathode. The output signal from this cathode follower stage is developed across resistor 136 and appears at terminals 24. The output voltage is degeneratively coupled back through a capacitor 138 to the input of direct-current amplifier 130 to cause the output voltage appearing at terminals 24 to represent the integral of the voltage impressed on the input terminals of the direct-current amplifier 130. Further, capacitor 138 has the additional effect of maintaining the junction between resistors 122 and 124 substantially at ground potential which is desirable from the standpoint of the operation of phase detector 14. The aforementioned output voltage is also impressed on the collector electrode 102 by means of a suitable connection 139 thereto, thereby com-

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pleting the closed servo feedback loop formed by the target 100, the alternating-current amplifier 12, the phase detector 14, and the integrator circuit 16 which includes high-gain direct-current amplifier 130.

In its operation the modulated electron beam is directed by target selecting circuit 18 to a target element of target assembly 38 that is responsive to the particular input signal that it is desired to switch to the output terminals 24. Bombardment of this one of the target elements 100 produces a secondary electron emission characteristic 140 as illustrated in Fig. 2. In this figure, the current from a bombarded target element per unit of beam current is plotted versus the cathode-to-target potential. As is apparent from this characteristic, the electrons of the beam initially strike the target at such a low potential that few true secondary electrons are produced. The target element intercepts the beam current, however, which results in a negative current thereto. As the electrons of the beam bombard the target element at higher and higher voltages an increasing number of secondary electrons are produced until a point is reached where the number of secondary electrons is equal to the number of primary electrons impinging on the element.

The voltage through which the electrons have been accelerated at this point is generally designated as the critical voltage, V_c , of the secondary electron emissive surface of the target element.

As the electrons of the beam strike the target element at increasingly higher velocities greater than this critical voltage, the number of secondary electrons becomes increasingly greater than the primary electrons incident on the target element. If the velocity of the incident primary electrons is increased still further, they penetrate deeper into the molecular matrix comprising the target element until the point is reached where increasingly greater numbers of the prospective secondary electrons cannot get free of the surface and hence result in a decrease in the number of secondary electrons. In the case that the secondary electrons are collected at a particular potential, V_e , the secondary electrons obviously cannot be collected at potentials substantially greater than this. Hence the current from a bombarded target element will decrease in the manner indicated by the line portion 142. An increase or decrease in the potential of the collector electrode 102 would obviously cause the bombarded target element to tend to charge towards this potential.

This phenomenon is employed in the present invention to reproduce an input signal on the output terminals. Thus, with an initial collector voltage V_e , and a target element at a potential V_a , as shown in Fig. 2, a positive current would flow from the bombarded target element. If the electron beam were modulated, this current flowing from the target element would obviously be greater for the larger values of beam current and smaller for the smaller values and, thus, would vary sinusoidally in the same manner and same phase as the reference signal. This is shown in Fig. 3 as voltage waveform 150. On the other hand, with the collector electrode potential still at V_e , if the target electrode were at a potential such as V_b as shown in Fig. 2, a negative current would flow from the bombarded target element. This negative current would also increase and decrease in magnitude with the beam current and thus vary sinusoidally in the same manner. This is shown as waveform 152 in Fig. 3. It is noted that in comparing waveforms 150 and 152 that the positive current is 180° different in phase than the negative current. Further, the amplitude of the alternating component of the current in each case is proportional to quiescent current from the target element bombarded by the electron beam. Thus if a target element is charged to the point where the same number of secondary electrons leave the target element as are incident thereon, no further change in potential will take place. This potential will normally be only a few volts higher than the collector electrode potential. As illustrated in Fig. 2,

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if the collector electrode 102 were at the potential V_e , the target element would charge to a potential corresponding to a point 144 on the secondary electron emission charge characteristic.

In the operation of the electronic switching circuit of the present invention, the electron beam, as previously mentioned, is caused to bombard a target element that is responsive to a particular signal that it is desired to switch to the output terminals 24. If the instantaneous voltage of this target element is below or above that of the collector electrode 102, a positive or a negative current, respectively, will flow from the target element due to secondary electron emission. Modulation of the electron beam will cause this current to vary sinusoidally in magnitude. Variable capacitor 110 is adjusted so that the alternating current component of the current from the bombarded target element has a maximum amplitude at the input terminals of alternating current amplifier 12. The magnitude of this current is indicative of the error between the potential of the collector electrode 102 and that of the target element 100.

Amplifier 12 amplifies this alternating current error component and impresses it across the primary winding 114 of transformer 112 of the phase detector 14. A corresponding current is induced in the secondary winding 116 of transformer 112 which impresses potentials of opposite phase relation on the plate of diode 118 and on the cathode of diode 120. Figs. 4 and 5 illustrate, respectively, the voltages appearing across diodes 118 and 120. Waveform 160 in Fig. 4 and waveform 162 in Fig. 5 show the manner in which the error voltage appears across diodes 118 and 120, respectively. The reference signal, on the other hand, is applied to the center tap 117 of secondary winding 116 so that it appears in phase on both diodes. This is shown as waveform 164, Fig. 4, and waveform 166, Fig. 5, for the respective diodes. In the case of diode 118 the two voltages will add numerically, thus providing a signal represented as waveform 168, Fig. 4 which has an amplitude that is larger than the reference signal alone. In the case of diode 120, however, the error and reference voltages are of opposite phase and hence will subtract whereby the resulting voltage, shown as waveform 170, Fig. 5, is of a smaller amplitude than the reference signal. The two resultant signals 168, 170 are rectified and tend to charge capacitor 126 through resistors 122 and 124, respectively. The shaded areas beneath the waveforms 168, 170 indicate the periods and the relative conduction of the diodes 118, 120, respectively. From examination of these areas, it is apparent that a resultant charge is produced on capacitor 126 only when there is a difference in amplitude of the two signals. This resultant voltage is designated as a direct-current error signal voltage.

This direct-current error signal voltage is integrated by the circuit 16 in such a manner that the voltage appearing at output terminals 24, which is connected to the collector electrode 102, is changed in a direction toward the point of zero charging current from the target element. For example, referring to Fig. 2, if the initial potential of the target element were V_a , the error signal thus produced would be integrated in such a manner so as to decrease the potential of the collector electrode 102 until it were equal to V_e . If the initial potential of the target element were V_b , the error signal would be of opposite phase and hence would increase in the opposite direction and increase the potential of the collector electrode 102 until it were equal to V_e . Thus, as is evident from this diagram, the potential of the output circuit is always substantially equal to the input signal impressed upon the particular target element being bombarded by the electron beam.

From the above, it is evident that a high-gain null-seeking servo loop is formed by the alternating-current

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amplifier 12 coupled to the target elements 100, the phase detector 14 responsive to the output from amplifier 12 and the voltage of predetermined frequency used to modulate the electron beam to produce a direct-current error signal, and the integrator circuit 16 for integrating the error signal to produce a potential which is impressed on the collector electrode 102 and which, in addition, serves as an output signal.

What is claimed is:

1. An electronic switching device for selectively reproducing any one of a plurality of input signals, said device comprising a plurality of secondary electron emissive target elements, each of said target elements being responsive to one of said input signals, means for producing an electron stream, a source capable of providing a reference signal of predetermined frequency, means for modulating said electron stream with said reference signal, means for directing said modulated electron stream towards a selected target element responsive to an input signal desired to be reproduced, whence secondary electrons are emitted from said target element, a collector electrode for collecting said secondary electrons whereby an error current flows from said selected target element, and means coupled to said reference signal source and said target element and having an output connected to said collector electrode for generating an output voltage on said collector electrode capable of decreasing said error current to zero whereby said output voltage is substantially equal to said input signal desired to be reproduced.

2. The electronic switching device as defined in claim 1 wherein said means coupled to said reference signal source and said target element comprises a phase detector responsive to the phase of said reference signal and the phase and amplitude of said error current to produce a direct-current potential having polarity and magnitude dependent upon the phase and amplitude, respectively, of said error current, and means coupled to said phase detector and responsive to said direct-current potential for generating said output voltage.

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3. The electronic switching device as defined in claim 2 wherein said means coupled to said phase detector and responsive to said direct-current potential is an integrator circuit.

4. In an electronic switching device having a tube including a plurality of secondary electron emissive target elements, each of said target elements being responsive to an input signal, a collector electrode for collecting secondary electrons from said target elements, an electron gun capable of producing an electron stream, means for directing said electron stream towards a selected target element responsive to an input signal desired to be reproduced, and apparatus for producing an output voltage representative of said input signal desired to be reproduced, said apparatus comprising: a source providing a reference signal of predetermined frequency coupled to said electron gun for modulating said electron stream, whereby an error signal current of a frequency equal to said predetermined frequency flows from said selected target element, said error signal having a magnitude and phase dependent on the difference in potential between said selected target element and said collector electrode, and means coupled to said reference signal source and said target element and having an output connected to said collector electrode for changing the magnitude of said difference in potential in a manner to decrease said error current to zero whereby the voltage available at said output is representative of said input signal desired to be reproduced.

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