

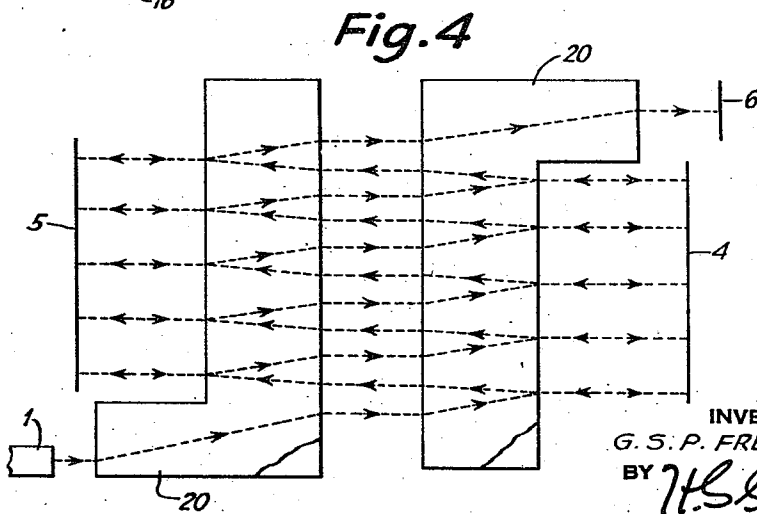
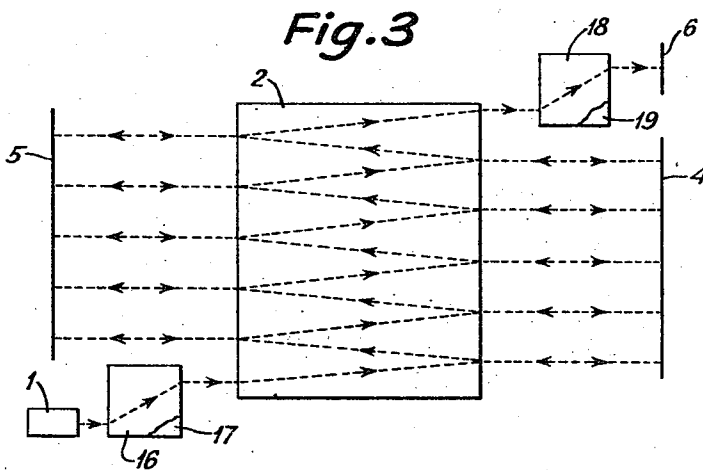
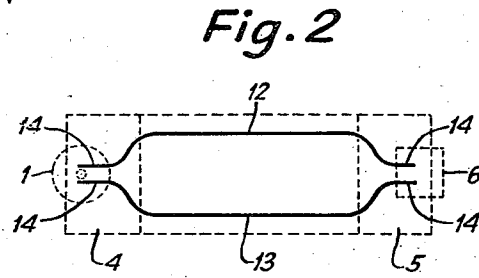
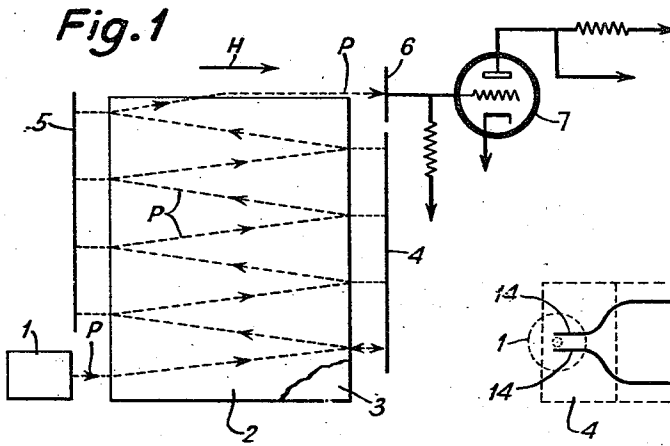
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2,312,033

ELECTRICAL TIME DELAY MEANS

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ELECTRICAL TIME DELAY MEANS

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The present invention relates to electron discharge devices, and electric circuit arrangements including such devices.

The object of the invention is to provide an arrangement operating with electron discharge in which the transit time of electrons in the discharge is large and readily controllable. Such arrangements may be employed, for example, to provide a time delay for signals.

The invention also provides novel electron discharge devices.

According to the present invention, an electric circuit arrangement for operation with electron discharge wherein, in operation, the discharge is produced within a strong magnetic field and takes place through an electrostatic deflecting field, is provided, said arrangement including electron reflecting means which cause electrons in said discharge to pass repeatedly through said deflecting field whereby the length of the path of said discharge and the transit time of said electrons is increased. In the case where an arrangement according to the invention is utilised as a time delay for signals, the arrangement may comprise means for modulating said discharge in accordance with signals to be delayed and an anode for receiving said discharge connected in an output circuit into which said signals are repeated with the desired delay. An arrangement according to the invention can also be employed for mixing signals with desired delays. In this case an arrangement is used in which, in operation, a plurality of similar discharges are produced, each discharge being modulated in accordance with one of the trains of signals to be mixed and the discharge currents being combined in a common output circuit to mix the signals by which said discharges are modulated, said signals being delayed with respect to each other in accordance with the electron transit times in said discharges.

In the preferred form of the invention a discharge device adapted to be operated to produce an electron discharge with large transit time is provided, including a cathode from which is derived, in operation, an electron stream, a pair of deflecting electrodes, reflecting electrodes arranged one at each end of said deflecting electrodes, and a collecting anode, the arrangement being such that in operation if a strong magnetic field is maintained about said electrodes and suitable potentials with respect to said cathode are applied to said deflecting electrodes, said reflecting electrodes and said

collecting anode, electrons proceed from said cathode under constraint by said magnetic field, pass between said deflecting electrodes towards one reflecting electrode and are deflected by the electrostatic deflecting field between said deflecting electrode, said electrons then being retarded by said reflecting electrode and returned through said deflecting field towards the other reflecting electrode, and again retarded and returned through said deflecting field, the electrons being caused to pass through said deflecting field repeatedly and finally emerging therefrom and being constrained by said magnetic field to impinge on said collecting anode.

In order that the said invention may be clearly understood and readily carried into effect, the same will now be more fully described with reference to the accompanying drawing, in which:

Figure 1 is a diagrammatic plan view of the arrangement of electrodes in one embodiment of the present invention by way of example, the evacuated envelope in which the electrodes are included not being represented in order to simplify the representation.

Figure 2 is a diagrammatic side view of a modified pair of electrodes in a device in accordance with the invention, and

Figures 3 and 4 are diagrammatic plan views of electrode arrangements in further embodiments of the invention. In each of the figures of the drawing like like parts are indicated by the same reference numerals.

Referring to Figure 1 of the drawing, it will be seen that the arrangement therein shown includes a cathode ray gun 1 adapted, in operation, to eject a beam of electrons axially and to permit the projected beam to be modulated in accordance with the signals to be delayed. This gun faces one side of one end of the space between two plane rectangular and parallel plate-shape deflecting electrodes 2, 3, and at the opposite end of the deflecting electrodes 2, 3, from the gun 1 is disposed a further plane plate-shape electrode 4, termed a reflecting electrode, which extends at right angles to the deflecting electrodes. A further reflecting electrode 5, similar to the electrode 4, is arranged at the same end of the deflecting plates 2, 3, as the gun 1 opposite the electrode 4, but slightly staggered therefrom or otherwise disposed or formed so as not to interfere with the emission of electrons from the gun 1 into the space between the deflecting electrodes 2, 3.

Substantially diagonally of the deflecting elec-

trodes 2, 3, from the gun 1 is a collecting anode 6 adapted to receive electrons. The collecting anode 6 may be included in a suitable signal repeating circuit, for example, including the electron-discharge valve 7 shown diagrammatically together with certain of its operating circuit elements.

In operation, the electrode system including the electron gun 1 and electrodes 2 to 6, inclusive, is immersed in a uniform magnetic field having a direction indicated by the arrow, H, this field being strong, that is to say, such as will cause electrons projected into it to proceed in a spiral path of small radius. The deflecting electrodes 2 and 3 are maintained at potentials such that a satisfactory deflecting field is set up between them and their mean value of the potentials is higher than that of the potential of the cathode of the gun 1 and is preferably equal to that of the final anode of the gun 1. The potential difference between the electrodes 2, 3, can be quite small, for example, such that the potential gradient between the plates is less than one volt per centimetre. The electrodes 4 and 5 are maintained at a potential equal to or slightly negative with respect to the potential of the cathode of gun 1. The anode 6 is maintained at a potential such that it will collect electrodes emitted from the gun 1 and may conveniently be connected through a suitable load to the final anode of the gun.

A typical track P of electron emitted from the gun 1 is indicated in dotted lines. It will be seen from this that electrons emitted from the gun 1 are constrained to move parallel to the magnetic field H until they enter the electrostatic deflecting field between the deflecting electrodes 2 and 3. In the deflecting field the electrons are deflected at right angles to the deflecting field and to the magnetic field H parallel to the deflecting electrodes 2 and 3, so that the track P becomes inclined as shown in the drawing. After emerging from the deflecting field the electrons continue to move with a direction generally parallel to that of the field H towards the reflecting electrode 4, which electrode causes the electrons to be reflected back into the deflecting field to undergo a further deflection in the same direction as before. After re-passing through the deflecting field the electrons approach the reflecting electrode 5 in a direction parallel to the magnetic field H and are again reflected and re-enter the deflecting field. The electrons thus pass to-and-fro between the electrodes 4 and 5 undergoing deflection at each passage through the deflecting field until finally the electrons emerge on the collecting anode 6.

In this connection it must be borne in mind that the use of crossed magnetic and electrostatic fields brings about forces which cannot be combined linearly, but must be combined vectorially. As a result, as is well known from the fundamental behavior of electrons, the force acting on the electron must always be at right angles to both the magnetic field and the electrostatic field. That is to say, a moving electron subjected to mutually perpendicular electrostatic and electromagnetic fields is acted upon by a composite force which is mutually perpendicular to both of the fields. Consequently, where the fields are so adjusted that the magnetic field is relatively strong and the electrostatic field is relatively weak, the electrons follow a path as indicated in Figures 1, 3 and 4. The electrons in following such a path, as for example in Figure 1

along the line P, may actually rotate about the line P as an axis, since the presence of the electromagnetic field prevents radial dispersion of the electrons. This effect is well known in the art, and has been described in the literature, as for example in the paper entitled "The Orthicon—A television pick-up tube" by Rose and Iams, RCA Review, vol. 4, #2, October, 1939, pp. 186-199, where the action of the crossed fields on electrons is described in detail (see especially pages 193-195).

The time taken by the electrons to travel between the gun 1 and electrode 6 will be dependent mainly on the strength of the deflecting field between the electrodes 2, 3. This will be readily appreciated from the following discussion.

Thus, assuming that the potential of the region in which the electrons move between the deflecting electrodes 2 and 3 is the same as that of the final anode of the gun 1 and the collecting electrode 6, then the electrons will be projected from the gun 1 with a velocity v , say, and will move with this velocity through the deflecting field between electrodes 2, 3, to the right-hand end thereof. In this region the electrons will be subject to a retardation due to the field of the reflecting electrode 4 which will bring the electron velocity to zero, and subsequently the electrons will be caused to return into the deflecting field, regaining a velocity of magnitude v , but in a reverse sense from that with which the electrons were projected initially. If d is the separation between the final anode of the electron gun 1 and the left-hand end of electrodes 2, 3, and also between electrode 4 or 5 and the adjacent ends of electrodes 2 and 3, and l is the length of electrodes 2 and 3 in the direction of the magnetic field H, and the electrons are uniformly decelerated as they move between the deflecting electrodes and the reflecting electrodes, the electrons will move from the final anode of gun 1 to the electrode in a time given approximately:

$$\frac{d+l+2d}{v} = \frac{l+3d}{v}$$

Likewise, the time taken to travel between the two reflecting electrodes is given by:

$$\frac{2d+l+2d}{v} = \frac{l+4d}{v}$$

Also, if the collecting anode 6 is at the same potential as the final anode of gun 1 and is the same plane as electrode 4, as shown in Figure 1, the time taken for an electron to travel between reflecting electrodes 4, 5, and collecting anode 6 will be

$$\frac{l+3d}{v}$$

Thus, if an electron makes N traversals through the deflecting field, the time occupied will be approximately

$$\frac{l+3d}{v} + (N-2) \left(\frac{l+4d}{v} \right) + \frac{l+3d}{v} = \frac{N(l+4d) - 2d}{v}$$

However, N will be determined by the rate of deflection (θ) of the beam in the deflecting field. It can be shown that θ is proportional to E/H where E is the potential difference between electrodes 2 and 3. Thus, we may write:

$$\theta = K \frac{E}{H}$$

where K is a constant. The deflection which takes place during each traversal of an electron

through the field will be given by the product $\Theta \cdot l/v$ (rate of deflection multiplied by the time during which the deflecting force is operating).

Thus, if the width of the deflecting electrodes is D , the number of traversals possible between them will be

$$\begin{aligned} & \frac{D}{\Theta \frac{l}{v}} \\ &= \frac{vD}{\Theta l} \\ &= \frac{vD.H}{K.E} \end{aligned}$$

Putting this value for N , we have that the time occupied by an electron in passing from the gun 1 to the collecting electrode 6 will be

$$T = \frac{D.H}{K.E} (l + 4d) - \frac{2d}{v}$$

The quantity T will represent the time delay obtainable in the device.

From the above expression for the time delay, it will be seen that if the term $2d/v$ is small compared with the other term in the expression, the time delay T is proportional to H/E . If the electron stream traverses the deflecting field a few times the term $2d/v$ can in fact, usually be ignored. Thus, if as is normally the case, H is constant, the time delay which can be obtained with the device will be inversely proportional to the potential difference between the deflecting electrodes. It is thus possible to control the time delay obtained in the device merely by adjusting the aforesaid potential difference. Moreover, the time delay will be relatively great when the potential difference between the deflecting electrodes is small.

The magnetic field H is preferably adjusted so that the electrons enter and leave the deflecting field without, say, tendency to "spread." This phenomenon is discussed, for example, in the specification of United States Patent No. 2,213,175. If desired, the deflecting electrodes 4, 5, can be curved, or other expedients adopted as described in the aforesaid specification.

It may be desirable in some cases to separate the electron gun and the collecting electrode from the reflecting electrodes 4 and 5 more widely than is done in the arrangement shown in Figure 1. Thus, for example, in the pair of deflecting electrodes 12 and 13 shown in Figure 2, the gap existing between the electrodes is made less in the region of the gun 1 and the collecting electrode 6, the deflecting plates being bent so that their edge portions 14 are brought together while their middle portions remain relatively widely spaced. With this arrangement the deflection of the electron stream is effected at a greater rate at the regions where it enters the deflecting field than at other parts of the deflecting field so that the deflections occurring during the initial and final traversals are greater than those occurring during the intermediate traversals.

Alternative methods of obtaining a greater initial and final deflection are illustrated in Figures 3 and 4.

In Figure 3, the desired additional deflection is obtained by providing additional pairs of deflecting electrodes 16, 17, and 18, 19, between the gun 1 and the electrodes 2, 3, and between the electrodes 2, 3, and the collecting electrode 6 respectively. An advantage of this arrange-

ment is that the potential difference or differences between the additional deflecting electrodes can be made greater than that between the main deflecting electrodes without reducing the delay obtained with a given size for the main deflecting electrodes. Alternatively, the additional deflecting electrodes can be more closely spaced than the main deflecting electrodes.

It will also be observed that in Figure 3 the reflecting electrodes 4 and 5 are more widely spaced from the deflecting electrodes 2 and 3 than is the case in Figure 1. It will be appreciated from the discussion above in connection with Figure 1 that since the distance d is increased the effect of this arrangement is to increase greatly the delay obtainable in the device with a given potential difference between the deflecting electrodes.

Instead of providing additional deflecting means the main deflecting electrodes can be provided with extensions as indicated at 20 in Figure 4 of the drawing. In this case also two pairs of main deflecting electrodes 21, 22, and 23, 24, are provided, these electrodes, with their extensions 20, being in the form of L-shaped plates. This arrangement may be convenient in cases where very large delays are required.

By incorporating more than one source of electrons or by producing more than one modulated stream of electrons in a device according to the invention, for example, in the manner described in the specification of co-pending United States application Serial No. 366,639, with reference to Figure 3 thereof, it is possible to employ such a device for mixing similar or different signals with varying delays. Further, if desired, each stream of electrons may be passed through a separate deflecting field and impinge on the common collecting anode or a separate collecting anode, the separate collecting anodes, if such are used, being electrically connected together.

I claim:

1. The method of producing a time delayed train of electrical signals which comprises the steps of producing a beam of electrons, modulating the produced beam of electrons by the train of electrical signals to be delayed, directing the modulated beam of electrons along the lines of magnetic force of a substantially homogeneous electromagnetic field crossed at right angles by an electrostatic field, reflecting the electrons passing through the electrostatic field to re-pass them through the crossed fields, and collecting the re-passed electrons of the modulated beam of electrons.

2. The method of producing a time delayed train of electrical signals which comprises the steps of producing a beam of electrons, modulating the produced beam of electrons by the train of electrical signals to be delayed, directing the modulated beam of electrons along the lines of magnetic force of a substantially homogeneous electromagnetic field crossed at right angles by an electrostatic field, reflecting the electrons passing through the electrostatic field to re-pass them through the crossed fields, collecting the re-passed electrons of the modulated beam of electrons, and producing a voltage proportional to the collected electrons.

3. The method of producing a time delayed train of electrical signals which comprises the steps of producing a beam of electrons, modulating the produced beam of electrons by the train of electrical signals to be delayed, directing the modulated beam of electrons along the lines

of magnetic force of a substantially homogeneous electromagnetic field crossed at right angles by an electrostatic field, repassing the beam of electrons through the crossed fields a plurality of times, subsequently collecting the repassed electrons of the modulated beam of electrons and regulating the number of passages by controlling the intensity of the electrostatic field.

4. Apparatus for producing a time delayed train of electrical signals which comprises means for producing a beam of electrons, means for modulating the produced beam of electrons by the train of electrical signals to be delayed, means for directing the modulated beam of electrons along the lines of magnetic force of a substantially homogeneous electromagnetic field crossed at right angles by an electrostatic field, means for reflecting the modulated beam of electrons passing through the electrostatic field to repass them through the crossed fields, and means for collecting the repassed electrons of the modulated beam of electrons.

5. Apparatus for producing a time delayed train of electrical signals which comprises means for producing a beam of electrons, means for modulating the produced beam of electrons by the train of electrical signals to be delayed, means for directing the modulated beam of electrons along the lines of magnetic force of a substantially homogeneous electromagnetic field crossed at right angles by an electrostatic field, means for repassing the modulated beam of electrons through the crossed fields a plurality of times, means for subsequently collecting the repassed electrons of the modulated beam and means for regulating the number of passages by controlling the intensity of the electrostatic field.

6. Apparatus for producing a time delayed train of electrical signals comprising a pair of parallelly opposed reflecting electrodes, means to produce a substantially homogeneous electromagnetic field perpendicular to and intermediate said reflecting electrodes, electrode means intermediate said reflecting electrodes and perpendicular thereof for producing an electrostatic field perpendicular to said electromagnetic field, means adjacent one of said reflecting electrodes to project a signal modulated beam of electrons along lines of magnetic force into said electromagnetic and electrostatic fields, means adjacent the other of said reflecting electrodes to collect electrons from said beam and means to produce a train of electrical signals proportional to the collected electrons.

7. Apparatus for producing a time delayed train of electrical signals comprising a pair of parallelly opposed reflecting electrodes, means to produce a substantially homogeneous electromagnetic field perpendicular to and intermediate said reflecting electrodes, electrode means intermediate said reflecting electrodes and perpendicular thereof for producing an electrostatic field perpendicular to said electromagnetic field, means adjacent one of said reflecting electrodes to pro-

ject a signal modulated beam of electrons along lines of magnetic force into said electromagnetic and electrostatic fields, means adjacent the other of said reflecting electrodes to collect electrons from said beam, means to produce a train of electrical signals proportional to the collected electrons, and means intermediate said projecting means and said electrostatic means and between said electrostatic electrode means and said collecting means to produce deflections of the signal modulated beam.

8. Apparatus for producing a time delayed train of electrical signals comprising a pair of parallelly opposed reflecting electrodes, means to produce a substantially homogeneous electromagnetic field perpendicular to and intermediate said reflecting electrodes, L-shaped electrode means intermediate said reflecting electrodes and perpendicular thereof for producing an electrostatic field perpendicular to said electromagnetic field, means adjacent one of said reflecting electrodes to project a signal modulated beam of electrons along lines of magnetic force into said electromagnetic and electrostatic fields, means adjacent the other of said reflecting electrodes to collect electrons from said beam and means to produce a train of electrical signals proportional to the collected electrons.

9. Apparatus for producing a time delayed train of electrical signals comprising a pair of parallelly opposed reflecting electrodes, means to produce a substantially homogeneous electromagnetic field perpendicular to and intermediate said reflecting electrodes, a plurality of pairs of L-shaped electrode means intermediate said reflecting electrodes and perpendicular thereof for producing an electrostatic field perpendicular to said electromagnetic field, means adjacent one of said reflecting electrodes to project a signal modulated beam of electrons along lines of magnetic force into said electromagnetic and electrostatic fields, means adjacent the other of said reflecting electrodes to collect electrons from said beam and means to produce a train of electrical signals proportional to the collected electrons.

10. Apparatus for producing a time delayed train of electrical signals comprising a pair of parallelly opposed reflecting electrodes, means to produce a substantially homogeneous electromagnetic field perpendicular to and intermediate said reflecting electrodes, electrode means intermediate said reflecting electrodes and perpendicular thereof for producing a non-uniform electrostatic field perpendicular to said electromagnetic field, means adjacent one of said reflecting electrodes to project a signal modulated beam of electrons along lines of magnetic force into said electromagnetic and electrostatic fields, means adjacent the other of said reflecting electrodes to collect electrons from said beam and means to produce a train of electrical signals proportional to the collected electrons.

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