Patented Aug.15, 1950

2,519,172

UNITED STATES PATENT OFFICE

2.519,172

CONTROL OF ELECTRON DISCHARGE DEVICE OF AREA SELECTION TYPE

George W. Brown, Cranbury, N. I., assignor to Radio Corporation of America, a corporation of Delaware

Application August 30, 1946, Serial No. 694~O41

8 Claims. (CL 250-27.5)

This invention relates to electron discharge devices of the area selection type which employ a plurality of angularly related grid wires which are adapted to be individually energized so as to open and close selected apertures to control the passage of electrons. A co-pending application of J. A. Rajchman, serial No.665,031, filed April 26, 1946, now Patent No. 2494,670, issued January 17, 1950, for improvements in Electron Discharge Devices, describes and claims a discharge device of this type which has the ability to select instantly any one of a very large number of apertures, and thus to control the particular area on a target electrode which is impinged by electrons.

The co-pending application of J. A. Rajchman referred to above describes various forms of and uses for the area selection tube. One of the more Important uses resides in its ability to store or remember information in connection with electronic computing devices. The primary purpose of the present invention is to provide an improved method of interconnecting the grid wires so as to control a very large number of apertures or "windows" with a minimum number of external leads from the tube and a minimum quantity of control circuits. Consequently, the specification and drawings of the Rajchman application are embodied herein by reference.

From an operational point- of view, there are two basic types of control which may be utilized in the area selection tube, alternatively, (a) deflection and (b) potential barrier. The former comprises a cathode of conventional construction and a grid mesh which consists of two grid networks, each comprising a plurality of spaced, parallel grid wires, the wires of both networks being substantially perpendicular to the path of the electrons while being mutually at an angle one with respect to the other so as to form windows through which electrons may pass to the target electrode. The target electrode may comprise .a dielectric surface and such other elements as are necessary to form a memory element, or a fluorescent screen may be utilized, or a combination of both. The grid wires of each network, which may, for example, be disposed horizontally and vertically, respectively, should be shaped and/or spaced so that the depth of the passageway between adjacent wires, measured along the electron axis, is at least twice the distance between the wires. In one form, the wires may be rectangular in shape to fulfill this requirement. It was shown that if a negative potential is applied to all grid wires, electrons will be repelled and none will pass through the grid. If one wire is made positive by 100 volts, say, electrons in the vicinity will be attracted to it, but none will pass through the grid. However, if two adjacent grid wires are made positive, then electrons will be accelerated towards and pass between those two wires. One adjacent, horizontal pair and one adjacent, vertical pair of wires can thus be considered as forming a window through which electrons will pass only when all four wires are positive.

The potential barrier type of construction utilizes a cathode, a first accelerating grid near the cathode, a second accelerating grid just ahead of the control grid, a control grid and a suitable target electrode. The second accelerating grid consists of a plurality of wires equal in number to and in register with the wires of the adjacent control grid network. Thus, If the control grid network nearest the cathode consists of a plurality of wires parallel to the axis of the cathode, or vertically arranged, then the accelerating grid wires would be parallel thereto and, of course, at right angles to the horizontal grid wires of the second control grid network. All of the wires of each accelerating grid are connected together and suitable positive potentials applied thereto, say 100 volts. As before, the wires of the control grid networks are adapted to be individually biased with either one of two voltages to open and close selected windows. In the present case, a window will be closed to the passage of electrons if any one of the four grid wires defining it is biased to a negative potential of, say, -100 volts. To open a window, all four wires must be at cathode potential.

The present invention is not concerned with the shape or arrangement of the tube and is utilizable with either the potential barrier or deflection types of control. Many modifications will be apparent, including those described in the co-pending application referred to above. For some purposes, the grid and target electrodes may lie in parallel planes, or perhaps in parallel segments of a cylinder. In other cases, a complete cylindrical form may be preferred in which the grid wires of one network are parallel to and equidistant from the central cathode and the other wires are circular, or where the networks are formed by wires which spiral in a right-handed and left-handed fashion, respectively, about the cathode. It will be appreciated, however, that in all cases, the number of windows available, and hence the definition of the grid, is equal to the product of the number of wires in one grid network multiplied by the number of wires in. the other grid network. When the particular requirement is satisfied by a relatively small number of windows, no particular problem is involved in connecting the grid wires individually to controlled sources of potential. However, when economy of design demands the largest possible number of windows, say a million, it would be entirely impractical to bring out from the tube two thousand lead wires, one thousand for each grid network. Such a large number of discrete control possibilities is entirely practical and provides, for example, nearly unlimited design of computers where the tube is used as a memory device, or where the fluorescent screen trace produced by the successive opening of different windows requires a high degree of definition.

Because the passage of electrons through a given grid network is controlled by the application of suitable voltages to two adjacent wires, certain combinatorial arrangements are possible. That is, if certain grid wires of a network are interconnected permanently within the tube so that when two adjacent grid wires are energized to allow electrons to pass the other grid wires connected to them do not lie adjacent to one another in any instance, then individual control can still be exercised and the number of leads can be greatly reduced. The so-called "Binary" system described and claimed by Rajchman accomplishes this result but it requires more than one grid mesh disposed for the successive selection of areas. For example, a tube having 4,096 windows requires three horizontal and three vertical grid networks each having 64 wires. Each network is to interconnected that any quarter of its area may be opened, the second network selecting a quarter of the first open area, and the third selecting a quarter of the remaining area which is the one desired window. The external leads are grouped in pairs and are energized in push pull. This system is ideally suited for use with the Binary counting system since all numbers as we ordinarily know them, are represented by combinations of two numbers, zero and one. "Zero" can then conveniently be represented by the condition in which the first wire of each pair is positive with respect to the second, and "one" by the opposite condition. However, not all uses of the tube utilize the Binary counting system and the requirement for more than two grid networks imposes a great difficulty of construction since all the is wires of each similar grid network must be accurately in register. It is therefore a further purpose of this invention to overcome the disadvantages of the earlier system and to provide combinatorial arrangements which do not require more than two grid networks, one horizontal and one vertical, or the equivalent.

It is a further object of this invention to provide an improved area selection tube.

A still further object of this invention is to provide means for and a method of interconnecting a plurality of grid wires so as to control the passage of electrons to a selected spot or area of a target

A further object of this Invention is to provide means for controlling individually the opening of one of a plurality of windows formed by the intersections of the grid wires of a pair of grid networks while utilizing a number of connected leads substantially less than the number of wires In each network

A still further object is to control the point of impact of electrons to selected areas of a target electrode while employing a number of control leads which is substantially less than the number of areas available for selection.

A still further object of this invention is to provide a system of applying a selected voltage to any adjacent two of a plurality of grid wires, utilizing a number of connecting leads less than the number of grid wires.

A still further object is to provide, in a discharge device having only two associated networks of grid wires, which control the passage of electrons therethrough, means for applying a selected voltage to any two selected adjacent Grid wires in each network but not at the some time to any other adjacent grid wires by means of lead wires less in number than the total number of wires in said networks.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects end advantages thereof, will best be understood from the following description of several embodiments thereof, when read in connection with the accompanying drawings, in which:

Figure 1 represents a grid mesh connected in accordance with the Group of One system;

Figure 2 represents a grid mesh connected in accordance with the Group of Two system; and

Figures 3 and 4 are sectional views of a preferred embodiment of this invention.

There are two related systems which may be employed in carrying out this invention. The first of these is herein called the "Group of One" system since for each grid network there is one group of leads, any two of which may be energized to open just one gate, where a gate is the passageway between adjacent wires of a single network. The second is called the "Group of Two," since the leads to a given network are divided into two groups having the same or different numbers of leads in each group. In this case, a single gate is opened by the application of suitable voltages to a lead in each group.

Group of One

Considering a typical Group Of One system first, reference is made to Fig 1 which illustrates diagrammatically an interconnected grid mesh within the dash line **1** comprising a first grid network **3** of 21 horizontal grid wires and a second grid network **5** of 21 vertical wires. Within the tube connections are made from the wires of networks **3** and **5** to a group of seven leads **1** and **9** which are brought through the glass envelope in any convenient manner.

For convenience of illustration, the two grid networks have been shown as lying in spaced parallel planes but it is to be understood that any of the physical arrangements described above or which conform to the functional requirement set forth may be employed. It is also to be understood that each grid wire is insulated from every other grid wire connections to the leads being indicated by a heavy dot on the intersection of the lines representing the respective elements. Since a preferred form of construction is a helical arrangement in which the first wire is adjacent the last wire and is paired with it to form one of the gates, the electrical equivalent of this has been indicated by the dotted grid wires **11** and **13** which are shown adjacent the last grid wire of each network but electrically connected to the first grid wire in each case. If a flat construction is illustrated as used, this wire would be physically included and connected as shown. It will be assumed, therefore, in the considerations below, which show the numerical relationships between the grid wires and leads, that the helical arrangement is used. If it is not, the equivalent shown will require one additional wire for each network.

Since the two networks and their connected leads are identical, it will suffice to limit the detailed description to one of the networks.

Remembering that the object of interconnecting the leads 9 with the wires 5 is to make certain that when an. opening voltage is applied to any two leads, there will be one and only one pair of adjacent wires connected to those leads, one of the many possible combinations is illustrated by the heavy dots on the Intersections of the lines. Reading from left to right for the network wires and down for the lead wires, it will be observed that these first seven wires are connected to the first seven leads; the eighth to eleventh wires connect to leads **1, 3, 5** and **7*;*** the twelfth to fourteenth wires connect to leads **2, 4** and **6**; the fifteenth to seventeenth wires connect to leads .1, 4 and ***1;*** the eighteenth and nineteenth wires connect to wires 3 and 5; and wires 20 and 2 connect to leads 2 and 0, all respectively. It may be observed that whatever two leads are selected, one and only one pair of adjacent grid wires can be found connected to them.

It will be observed also that in each network there are twenty-one gates controlled by seven leads. When ***n*** is the number. of leads, and when is odd, there are

$$\frac{n(n-1)}{2}$$

possible different pairs or combinations which may be made. Obviously, when $n=7$, there are twenty-one possible combinations, and, therefore, the arrangement. shown provides the most complete and efficient use of the grid. Thus, In the Group of One system, with any odd number of leads connected to a given grid network, the maximum number of gates or the selecting power of the grid is one out of

$$\frac{n(n-1)}{2}$$

The selecting power of the complete grid mesh is, of course, determined by the product of the gates in the cooperating grid networks, and in the present case is 1 out of 21^2 or 441. Therefore, with a total of 14 control leads, any one of 441 distinct incremental areas or points on the target may be selected, and this with only one grid mesh; as distinguished from the Binary system which, for example, with 16 leads would require four grid networks or two meshes and would only have a selective power of one out of 256.

To illustrate. the selective power of a single grid network fed by n lead wires, and complete grid meshes of two similar networks, consider the following table showing typical arrangements:

n	Selective Power of Network $\frac{n(n-1)}{2}$	Total Selective Power of Mesh (two networks)	Total Number of Grid Leads (2*n*)
5	10	100	10
7	21	441	14
11	55	3,025	22
15	105	11,015	30
21	210	44,100	42
25	300	90,000	50
35	595	354,025	70
45	990	980,100	90

From this chart it may be seen that two grid networks with 990 grid wires each connected to a total of only 90 grid leads can control the individual selection of nearly a million windows. When used in a memory area selection tube, 90 electronic or mechanical switches can thus control nearly a million memory-elements, so that by the selection of all possible combinations of pairs of horizontal and vertical leads, that number of memories may be successively actuated in a single tube, the information being stored and held until needed and then taken from the tube in the manner fully set forth in the. Rajchman application. The equivalent tube using the Binary control method would require less leads (40), it is true, but the tube construction would be complicated by the necessity of providing five horizontal and five vertical grid networks in register, each network having over 1024 grid wires.

It must be appreciated that the particular grid-to-lead connection scheme illustrated is but one of an innumerable number of ways of interconnecting these elements to insure selection with-out duplication. To insure that no possible combination is overlooked, and to make certain that there is no duplication, it is desirable to figure the connections in accordance with some definite plan. The plan used above, by way of illustration, applicable to any Group of One system when the number of leads ***n*** is odd, is as follows: Number the ***n*** leads in sequence, 1, 2, 3 ... ***n.*** Write these numbers in a circle. Thus, where n=7:

1
7 2
6 3
5 4

Number the grid wires in sequence,

$$1, 2, 3 \ldots \frac{n(n-1)}{2}$$

which in this case is 21. Connect the grid wires from 1 to 21 to the numbered leads obtained by

(a) Starting with 1, read around the circle in order, 1 to 7;

(b) Starting with 1, take alternate numbers until all numbers have appeared once; I. e., 1, 3, 5, 7, 2, 4, 6;

(c) Starting with 1, take every third number until all numbers have appeared once; i. e., 1, 4, 7, 3, 6, 2 and 5.

Modifications of the above plan are possible without limit. For example, instead of numbering the grid wires in sequence, they may be numbered in any arbitrary order. Alternatively, or in addition, the lead wires may be numbered in any arbitrary sequence. Also, the numbers 1 to ***n*** may be arranged in the circle in any arbitrary sequence. A further modification is to start not at 1 but at any number. The essential requirement is, however, that considering any two lead wires, only one pair of adjacent grid wires can be found connected to them.

A plan which has constructional advantages, which result from the uniformity of the connection pattern, modifies the steps of sub-paragraphs (a) to (c) above to the following extent: Instead of completing all n numbers by taking first every number, then every second and then every third, change the sequence with each step. That is, starting with any number on the circle, 1, for example; advance one number, then two numbers, then three numbers, repeating 1, 2, 3, 1, 2, 3, until the cycle is completed. The step sequence may be 3, 2, 1, or 2, 1, 3, or any arbitrary sequence or the

$$\frac{n-1}{2}$$

numbers, as desired.

Where *n* is even, similar systems may he used. However, no particular advantage is gained and there will be certain unused pairs.

Group of Two

Like the Group of One, the Group of Two uses only one grid network for each direction, and the method or connection is the same for each network. The wires or each network are connected to leads divided into groups or families "a" and "b" as shown in Fig. 2. Thus, each network has "a"+"b" leads and the system a total of 2(a+b) leads. In operation, the opening or control voltage is always applied to one lead in each group. Since It is possible to choose one group "a" lead and one group "b" lead a X *b* times without duplication of pairing, it follows that each grid network will have a X *b* wires and there will be a X b gates and $(a \times b)^2$ windows controlled thereby. The greatest degree of control for a given number of grid wires will occur when a and b are equal. It is also clear that each grid wire connected to a lead of the "a" group must be adjacent a grid wire of the "b" group. For maximum efficiency of the use of leads, "a" and "b" should be even. While it is usually preferable, it Is not essential to have the two grid networks identical.

The grid wire connections to the leads illustrated in Fig. 2 is only one of many possible arrangements. Systems for assuring the variation of the lead sequence without repetition can be employed as in the case first described, and it is believed to be unnecessary to give further details.

For purposes of comparison, figures are given below showing a few representative combinations of design.

Leads in Group "a"	Leads in Group "B"	Number of Gates (a X b)	Number of Windows $(a \times b)^2$	Total Number of Leads (2(a X b))
4	4	16	256	16
2	8	16	256	20
4	8	32	1,024	24
8	8	64	4,096	82
4	16	64	4,096	40
10	10	100	10,000	40
8	16	128	16,384	48
16	10	256	65,536	64
32	32	1,024	1,048,576	128

From the above, it can be seen that two grid networks of 1024 wires each, connected to a total of 128 leads will control over a million windows or memory elements when the leads are connected in two groups of 32 wires each.

The Group of Two system Is particularly suitable for use with decimal system computers since with 40 leads (a multiple of 10) ten thousand elements (a power of 10) can be controlled.

Figs. 3 and 4 illustrate the essential features of a preferred embodiment of this invention employing two grid networks of 32 wires each, although for simplicity of illustration every other grid wire has been omitted, the missing wires being indicated by dotted lines where they terminate. A central cylindrical cathode **15** is provided which may be indirectly heated in conventional manner. The first grid network consists of 32 rectangular grid wires **17**, each wire being mounted at its extreme ends in mica supporters **19, 21** and spiraling concentrically about the cathode so as to be equidistant from the cathode. The pitch is such that each wire completes a half a turn about the cathode. The wires are uniformly spaced from each other, and bent so that the thin edge is always perpendicular to radial lines passing through the cathode. Looking down on the top view (Fig. 3) the wires of the first network spiral downward In a counter-clockwise direction. The second grid network lies just outside the inner network, and is concentric therewith. Each of its wires **23** spiral in a clockwise direction. Consequently, each wire of the first network intersects or crosses each wire of the second network when viewed from the cathode to form a complete grid mesh of 1024 windows. Enclosing the grid is a cylindrical target electrode **25** which may be of various forms to comprise a dielectric memory element, fluorescent screen or both, as previously discussed. The electrodes are all mounted within a suitable evacuated glass envelope **27**. At one end, the necessary leads are brought out through small glass to metal seals **29** as is well known. The number will be determined by the system used to interconnect the grid wires, plus those required for the cathode, heater and target electrodes. No attempt has been made to show the internal connections, since these have been fully explained above, the systems being illustrated in Fig. 1 or 2.

There has thus been described an improved area selection tube characterized by its high selective power, with a minimum number of external leads and a single grid,

I claim as my invention:

1. In an electron discharge device having a plurality of grid wires for controlling the passage of electrons between a selected pair of adjacent wires by the application of the same predetermined potential to said adjacent wires, a plurality of leads affording external connection to said grid wires, each lead being connected to more than one grid wire, there being ***n*** leads and

$$\frac{n(n-1)}{2}$$

grid wires controlled thereby.

2. An electron discharge device having a cathode, a target and a control grid positioned between said first named elements, said control grid comprising two grid networks which cooperate to define windows through which electrons may pass to strike

a selected area of said target only when two adjacent grid wires of each network are energized with the same predetermined potential, a plurality of leads for each network, said leads being substantially less In number than the number of grid wires in the associated network, and connections between each of said leads and selected ones of said grid wires whereby the application of said predetermined potential to a given pair or leads for each network causes said potential to be applied to one and only one adjacent pair of wires in each network.

3 A device of the character described in claim 2 In which *n* leads control the unique application of potentials to

$$\frac{n(n-1)}{2}$$

grid wires in each network.

4. An electron discharge device, comprising a source of electrons, a target, grid means inter mediate said source and said target for control selectively the flow of electrons from said source to distinct incremental areas of said target through electron windows formed by an adjacent pair of grid wires in a first network and an adjacent pair of grid wires in a second network at an angle thereto, a plurality of leads for each network for applying controlling potentials to said pairs of grid wires so as to open and close said windows individually and thereby control the flow of electrons, said leads and said grid wires being interconnected so that the application of control potentials to a selected pair of leads for each network permits

$$\frac{n(n-1)}{2}$$

windows to be individually controlled, where *n* is the number of leads for each network.

5. A device of the character described in claim 4 In which the wires of one network form a right hand spiral on the surface of a cylinder concentric with said source of electrons and the wires of the other network form a left hand spiral on the surface of a cylinder of different diameter concentric with said source of electrons, each wire of one network intersecting each wire of the other network.

6. A device of the character described in claim 4 in which the leads for each of said networks are divided into two groups, control being effected by the selection of one lead from each group.

7. An electron discharge device comprising a cathode, a target electrode and a grid intermediate said cathode and said target, said grid comprising two grid networks each having a plurality of grid wires which cooperate to define windows through which electrons may pass to strike a selected incremental area of said target only when two adjacent grid wires of each network are energized with a predetermined potential, a plurality of lead wires for each network; the number of lead Wires being substantially less than the number of grid wires, and connections between said lead wires and one or more of said grid wires, said connections providing that in each network each pair of lead wires is connected to one and only one adjacent pair of grid wires.

8. An electron discharge device comprising a cathode, a target electrode and a grid intermediate said cathode and said target, said grid comprising two grid networks each having a plurality of grid wires which cooperate to define windows through which electrons may pass to strike a selected incremental area of said target only when two adjacent grid wires of each network are energized with a predetermined potential, a plurality of lead wires for each network, said lead wires for each network being divided in two groups, the number of lead wires for each network being substantially less than the number of grid wires in that network, connections between said lead wires and one or more grid wires of the associated network. said connections providing that in each network, each pair of lead wires comprising one lead from each group, is connected to one and only one adjacent pair of grid wires;

GEORGE W. BROWN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,946,223	Mason	Feb. 6, 1934
2,000,379	Deisch	May 7, 1935
2,122,102	Lundell	June 28, 1938
2,155,471	Cawley	Apr.25, 1939
2,172,859	Toulon	Sept.12, 1939
2,182,152	Hullegard	Dec. 5, 19S9