June 8, 1948. J. A. RAJCHMAN 2,442,985

METHOD OF AND MEANS FOR INDICATING CONDITION OF MEMORY ELEMENT AND SELECTRON

Filed Jan. 8, 1947

Fig. 1

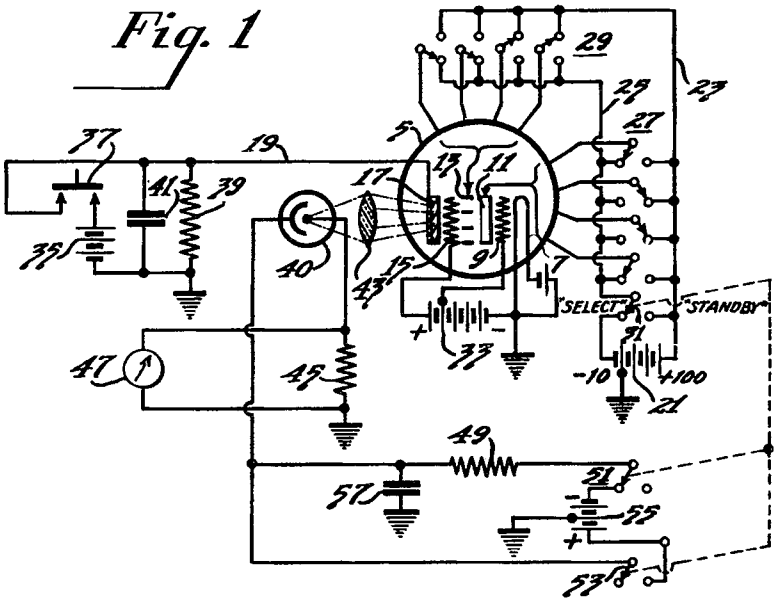


Fig. 2

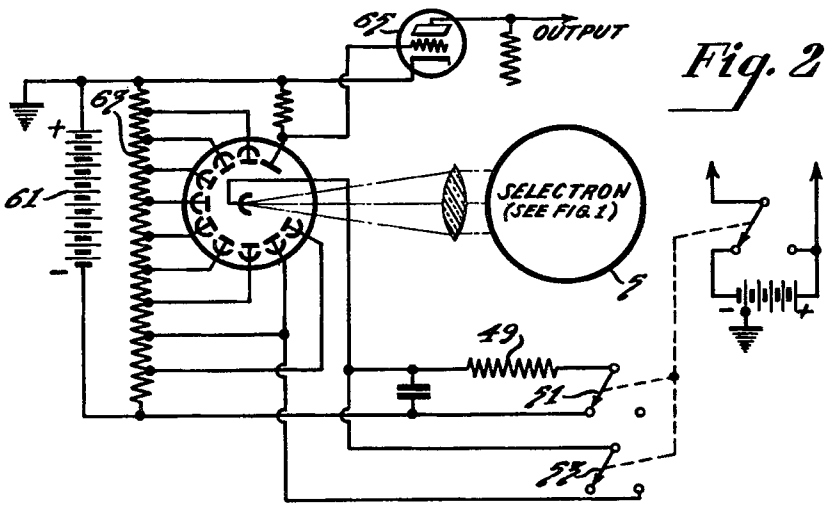
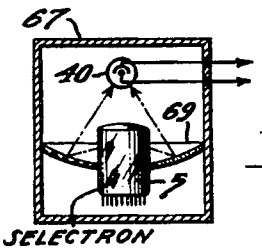


Fig. 3



Inventor

Jan A. Rajchman

By

Attorney

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METHOD OF AND MEANS FOR INDICATING CONDITION OF MEMORY ELEMENT AND SELECTRON

Jan A. Rajchman, Princeton, N. J., assignor to
Radio Corporation of America, a corporation of Delaware

Application January 8, 1947, serial No.720,876

Claims. (Cl. 250~41.5)

This invention relates to an electronic storage device and in particular to an improved method of and means for indicating the condition of a memory element.

In a copending application of J. A. Rajchman, Serial No.665,031, filed April 26, 1946, there has been described an electronic storage device which is capable of electronically selecting one of a very large number of electronic storage or memory elements, conditioning the selected element to one or the other of two stable conditions indicative of a condition to be "remembered," and subsequently producing a voltage or current which indicates to which one of the two possible conditions the element had previously been set.

The principle by means of which the individual memory element is precisely and accurately selected is fully described in the aforementioned copending application. In brief, the system utilizes one or more grid networks, each of which comprises a plurality of parallel spaced wires adapted to be individually biased with suitable control potential. The networks are positioned so as to form a grid mesh. Electrons from a cathode

source are directed toward the grid mesh, and by the suitable application of control potentials to adjacent pairs of wires the electrons are permitted to pass through selected "windows" defined by the intersecting grid wires and to impinge on a target electrode. The target electrode consists of dielectric secondary-emissive material, such as mica, and the small area which the electrons strike on passing through the grid window constitutes a memory element which may be conditioned to one or the other of two predetermined stable conditions so as to retain or store information indicative of the condition to which it was previously set. A signal plate is provided which is capacitively coupled to all points in the dielectric surface and may be formed, for example, by depositing on the rear surface of the mica dielectric a thin, transparent coating of metal. Willemite or other fluorescent material may also be coated on the target so as to produce light when the memory element is struck by electrons. The details of construction and the nature of the operation of the memory element itself is described and claimed in a copending application of R. L. Snyder, Serial No. 516,425, filed December 31, 1943.

As discussed more fully in the first mentioned copending application, when a small area or memory element of the secondary-electron emissive dielectric surface is bombarded by electrons having sufficient energy to release more secondary electrons than the number of bombarded electrons, (that is, when the secondary emission ratio is greater than unity) and when there is a secondary-electron collector electrode adjacent the memory element, the surface of the dielectric will assume the potential of the collector. This will then be a stable condition, since if the surface potential tends to rise above that of the collector electrode the secondary emission will be suppressed. Since a greater number of negative electrons remain on the dielectric element, it will have a lower potential. On the other hand, if the dielectric element tends to go below collector potential, the secondary emission will tend to increase, due to the greater collecting field, and the loss of additional electrons will tend to raise its potential. Collector potential is, therefore, a stable condition.

If, however, the intensity of electron bombardment is reduced to a value such that the secondary emission ratio becomes less than unity, then the dielectric element will

immediately go to cathode potential. This is also a stable condition, since, if, for any reason the dielectric potential tends to rise above cathode potential the surface will immediately attract a large number of negative electrons which will drive the potential downward. The dielectric element cannot go below cathode potential as a result of electron bombardment, since the negative potential would prevent electrons from reaching its surface.

Because of the above described characteristic of the storage or memory element, the device has great utility in connection with computing equipment, where it is desired to record and retain for subsequent use voltages indicative of one or the other of the two digits of the binary system of counting or the two on-off signals coding any other system such as decimal. Thus the condition of stability when the dielectric is at collector potential may be used to represent the digit 1, while the condition when the dielectric element is at cathode potential may be used to represent the digit 0 in the binary system (or simply on-off conditions). It should also be noted that having once established the desired condition in a given memory element, the condition may be maintained indefinitely by continuously bombarding all of the memory element, since, as stated above, the two conditions are stable under electron bombardment.

The method of conditioning the selected memory elements to a desired one of the two possible stable potentials is described in the first mentioned copending application. In brief, the storage element is conditioned by applying a voltage pulse to the signal plate and controlling the electron bombardment of the selected element so as to bring the element to collector or cathode potential, as the case may be. Thereafter the electron current will hold the potential of the element at the desired value.

The earlier method for, deriving information from the storage device after it has been conditioned was somewhat complicated and required a circuit which was rather delicate in adjustment. It is therefore the primary object of this invention to provide an improved method of and means for deriving information from a memory or storage tube indicative of the condition of a selected memory element.

When the dielectric target is coated with fluorescent material, or alternatively where the fluorescent material is coated directly on a transparent metallic signal plate and itself

functions as the dielectric, light will be emitted from the element when it is bombarded by electrons of sufficiently high velocity. However, when the element is at cathode potential the electrons strike the element at such a low rate of speed and in such a small quantity that no light is produced. Consequently, the presence or absence of light is indicative of the condition of the memory element.

It Is a further object of this invention to provide a method of and means for deriving Information from a storage device of the character described which Is responsive to the light emitted from the selected element.

Since, in accordance with the present invention the condition of the memory element is indicated by means of a "light link," it will be appreciated that information may be derived from the selected element without disturbing or changing the condition of the element. This is a desirable feature, since it is frequently necessary to "read" or derive information from a storage device more than once.

It is a further object of this invention to derive information as to the condition of a memory element without altering its condition.

As previously stated, the condition of each memory element may be retained indefinitely at its assigned value by opening all the windows of the control grid so as to cause electrons to impinge simultaneously on all elements. This may be called the "standby" condition. In the operation of the device it is contemplated, therefore, that the tubes will be maintained in a standby condition at all times except when a single window is opened for the purpose of applying information to or deriving information from the selected memory element. A practical storage device may have 4000 or more individual memory elements. If a substantial number of these are at collector potential it will be appreciated that a large portion or perhaps the entire surface will emit a light during the standby condition. It is a characteristic of most fluorescent materials that the light is not extinguished instantaneously when the electron current is cut off, but dies down gradually In accordance with substantially exponential or hyperbolic curves. Compared to the amount of light produced by many elements, that emitted by a single selected element is extremely small. If the light responsive indicator is to respond accurately to the condition of the single selected element its response must be delayed after the

general electron bombardment has been terminated for the period of time required, under the given conditions, for the light produced by all the other elements to die down to a value substantially less than that of one element. In the case of a storage device having 4000 elements the total light emitted must therefore decrease to a value less than 1/4000 of its original value before an accurate indication can be made.

It is therefore a further object of this invention to provide in a device having a plurality of elements capable of being conditioned to either one of two conditions, and which emit light in one of said conditions, an improved method of and means for determining the condition of a selected one of the elements by producing an electrical current which is dependent upon the light emitted solely from the selected element when the measurement is made.

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

Figure 1 is a circuit diagram illustrating an embodiment of this invention;

Figure 2 Is a circuit diagram of an alternative embodiment employing an electron, multiplier and

Figure 3 is a view Illustrating an arrangement for collecting the light emitted from the entire surface of a cylindrical target electrode.

Referring to Figure 1, an electronic storage device **5** is shown schematically. This device is preferably a tube of the "Selectron" type described in the aforementioned copending application of J. A. Rajchman. For convenience the tube is shown schematically and for the purpose of illustrating the present invention it is assumed that a single rectangular target electrode is employed, although the tube may be made in accordance with all the structural modifications suggested in the earlier application. The tube contains a cathode **7**, an accelerating grid **9**, a "vertical" grid network **11**, only one wire of which is shown, a "horizontal" grid network **13**, a collecting electrode **15** and a target electrode **17.** The target electrode may comprise a thin dielectric mica sheet on

the inner surface of which is deposited a thin layer, of fluorescent material, and having on its outer surface a thin, transparent layer of conductive metal to which the lead **19** is connected.

For the sake of simplicity, the tube is, assumed to have only four horizontal and four vertical grid wires, although it is to be understood that these may be multiplied to provide the desired number of memory elements in accordance with the aforementioned earlier application. Furthermore, the tube may be constructed either as a "potential barrier" or "deflection" device and the construction and arrangement of the auxiliary electrodes may be modified accordingly. In order to illustrate the processes of grid control in its simplest form, a plurality of manually operated switches have been shown for connecting the individual wires of the control grid networks to suitable potentials for "opening" and "closing" the selected windows. In the case illustrated the required potentials are -10 v. and +100 V. which are produced by a battery **21**. This assumes that the tube is of the deflection type. If the potential barrier type of construction is employed, it will be understood that the control potentials will be 0 and -100V.

By means of two conductors **23** and **25**, the control potentials are applied to the respective contact points of the four vertical selecting switches **27** and the four horizontal selecting switches **29**. In addition, a switch **31** is provided which may be operated so as to connect conductor **25** directly to conductor **23** and thus to apply the "opening" potential to both conductors. This switch is employed during standby operation to open all the windows of the storage device so as to permit electron bombardment of all memory elements. In the position shown, switch **31** permits the selection of any one of the 16 variable memory elements by applying the opening potential to two adjacent pairs of horizontal and vertical grid wires. Since the method of grid selection is not a part of the present invention, it need not be described in greater detail. It is to be understood, however, that any of the previously described systems of control may be employed for electrically selecting the desired one of the plurality of memory elements, including those described in a copending application of J. A. Rajchman, Serial No.702,775, filed October 11, 1946.

The accelerating and collecting electrodes are connected to suitable sources of

positive potential provided by a battery **33**. The signal plate, which is a part of the target electrode, is connected by conductor **19** to the positive terminal of a battery **35** through a switch **37**, the negative terminal of the battery being connected to ground. The lead **19** is also connected to ground through a resistor **39** and a capacitor **41**. The purpose of switch **37** is to apply a pulse to the signal plate to set the potential of the selected memory element at the desired value. The purpose of the capacitor and resistor is to prevent the voltage pulse from reducing in amplitude too rapidly when switch **37** is opened.

Associated with the target electrode is a photo-tube **40**, It may be desirable to focus the target electrode on the photo-tube by means of a lens **43.** The photo anode is connected to ground through an output resistor **45** across which may be connected any suitable indicator such as a meter **47***.* The photo cathode is connected through a resistor **49** to the movable arm of a switch **51** operable between two positions. The photo cathode is also connected directly to the movable arm of an associated switch **53** also having two positions. One contact point of switch **51** is connected to a source of negative potential produced by battery **55**, while the opposite contact of the other switch **53** is connected to a suitable source of positive potential. The movable contact arms of switches **51** and **53** are operatively connected together for concurrent operation and also are similarly connected to the contact arm of switch **31**. The photo cathode of tube **40** is also connected to ground through a capacitor **57**.

In describing the operation of the device illustrated in Figure 1, it will be assumed that it is desired to indicate the condition of a given one of the memory elements which has previously been conditioned to represent the "Number 1" of the binary system of charging the dielectric surface to collector potential. Switches **27** and **29** are first placed in the position required to select the element which is to be read. Switch **31** is then moved from the "standby position" to the "select position," switches **51** and **53** being simultaneously moved to the positions illustrated. This stops the electron bombardment of an of the memory elements except the one selected, extinguishing the light previously produced by all those demerits some or all of which may have previously been conditioned to collector potential.

It should be noted that the previous position of switch **53**, during standby, desensitized the phototube since a positive potential was applied to the photo cathode of the tube, which potential also charged capacitor **51** to the same value. The operation of the combined switches to the "select" position then disconnects the positive potential and causes a negative potential to be applied to the photo cathode through resistor **49**. In a time determined by the time constant of the R.-C. network, the photo cathode potential will reduce to the value necessary to sensitize the photo tube for normal operation. It is well known that a phototube will not function when its cathode is positive with respect to its anode and that a negative cathode potential is required before the tube will operate.

The time constant of the R.-C. network, comprising resistor **49** and capacitor **57**, is selected so as to provide a time delay after the operation of switches **31**, **51** and **53** sufficient to hold the phototube in a desensitized condition until after the luminescence of the fluorescent material has decreased to a value less than that produced by the one selected element. When this time period has elapsed the tube is sensitized and will respond to the light emitted from the selected element.

If the selected element is at collector potential it will be bombarded by electrons and will produce luminescence. This will cause a current to flow through resistor **45** which will be indicated by meter **47.** On the other hand, if the selected element is at cathode potential, no luminescence will be produced, and this condition will be indicated by the absence of a deflection of meter **47**. While the indicator has been illustrated as a meter, it is to be understood that the output potential, or the absence of an output potential, as the ease may be, may be employed to actuate other devices which may be used in connection with computing apparatus, and that therefore the term "indication" is not to be limited to a visual indication, but is to include the production of any condition indicative of or responsive to the condition of the memory element.

In order to prevent a spurious indication or a spurious operation of the control device, when the control switches are returned to the "standby" position, switch **53** has been provided for the purpose of applying a positive biasing potential to the photo cathode so as to desensitize the tube instantly. Since this potential is not applied to the cathode through the time delay network, the phototube is cut off immediately and will not re-

spond to the light produced by the other elements when the electron bombardment is resumed.

An alternative arrangement is shown in Figure 2, in which the storage device or Selectron 5 has not been shown in detail, but is assumed to be as illustrated in the preceding figure. The only difference between the two figures is that the sensitivity of the light responsive device has been increased by utilizing a conventional photo multiplier tube **59** which may be of the type commonly known as 931-A or 1P21. Successively greater positive potentials are applied to the nine dynodes by means of a battery **61** and a voltage divider **63** in the conventional manner. The photo cathode is connected to switch **51** through resistor **49** as before. The "select" contact of switch **51** is connected to the negative terminal of battery **61** and, since the first dynode is at a more positive potential, the operating bias is thus supplied. The cathode is also connected through switch **53** to a potential obtained from voltage divider **63** which is more positive than that of the first dynode. Thus it will be seen that the operation of the biasing control system under the control of switch **51** and **53** is the same as that previously described. Output is taken from the anode and may be applied to the grid of output tube **65**.

In accordance with one arrangement described in the copending application Serial No. 665,031, the storage device is provided with a cylindrical target electrode. In order to focus the light from all portions of such cylindrical electrode the arrangement illustrated in Figure 3 can be employed. The storage device or selectron 5 is suitably maintained within a light-tight container **97** so that the base section thereof extends through the center of a parabolic mirror **69**. At the focal point of mirror **69** there is located the light responsive device such as phototube **40**. In this manner the light produced by the memory elements over the entire cylindrical surface of the target electrode may be focused on the light responsive device. The circuit arrangements may be as shown in the preceding figures.

There has thus been described a method of and means for indicating the condition of a memory element by means of a light link which does not affect the state of the memory elements and which permits its condition to be determined independently of the

condition of all the other elements.

What I claim is:

1. In a device having a plurality of elements adapted to emit light as an indication of one condition and to emit no light as an indication of another condition, the method of determining the condition of a predetermined one of said elements which comprises extinguishing all elements other than the one to be indicated, producing an electrical current which is dependent upon the light emitted from said element, and producing a condition responsive to said current.

2. In a device having a plurality of elements capable of being conditioned to either one of two conditions and which emit light in one of said two conditions, the method of determining the condition of one of said elements which comprises extinguishing all elements other than the one to be indicated, producing an electrical current which is dependent upon light emitted from said element, and producing a condition responsive to said current.

3. In a device having a plurality of elements adapted to be bombarded selectively with electrons, which are capable of being conditioned to either one of two conditions, and which emit light under bombardment in only one of said conditions; the method of determining the existing condition of one of said elements which comprises discontinuing electron bombardment of all of said elements except the one to be indicated, producing an electrical current responsive to the light emitted from said one element, and producing a condition responsive to said current.

4. In a device having a plurality of elements adapted to be bombarded selectively or simultaneously with electrons, which are capable of being conditioned to either one of two conditions, and which emit light under bombardment in only one of said conditions, the method of determining the existing condition of one of said elements which comprises discontinuing electron bombardment of all of said elements except the one to be indicated, producing at a fixed time after said discontinuance sufficient to insure that the light from any of said elements except said one element has been extinguished an electrical current responsive to the light emitted from said one element, and producing a condition responsive to said current.

5. In a device having a plurality of conditionable elements adapted to be bombarded with electrons and which emit light under bombardment when in one condition but not when in another condition, the combination of first switching means for causing the selective bombardment of only one of said elements, light responsive means adapted to be energized by light emitted from said selected element and means controlled by said light responsive means for indicating the condition of said element.

6. In a device having a plurality of conditionable elements adapted to emit light when in one condition and to emit no light when in another condition, the combination of switching means for extinguishing all of said elements except a selected one; light responsive means associated with said device; means for normally desensitizing said light responsive means, and means for sensitizing said light responsive means during periods when only said selected element is emitting light.

7. In a device having a plurality of conditionable elements adapted to be bombarded with electrons and which emit light under bombardment when in one condition but not when in another condition, the combination of first switching means for causing the selective bombardment of only one of said elements, light responsive means associated with said device; second switching means operable in one condition to desensitize said light responsive means and in the other condition to sensitize said light responsive means, and means operatively coupling said first and second switching means whereby said light responsive means is sensitized only when said one of said elements is bombarded.

8. A device of the character described in claim 7 which includes, in addition, delay means for delaying the sensitizing of said light responsive means for a predetermined interval after the operation of said first switching means.

9. A device of the character described in claim 7 which includes, in addition, time delay means, operative upon conditioning said first switch to cause the selective bombardment of only one of said elements, for delaying the sensitizing of said light responsive device by a time sufficient to insure that the light emitted by all of said elements, except said selected element, has been extinguished.

JAN A. RAJCHMAN.