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MEANS FOR INDICATING CONDITION OF MEMORY ELEMENT

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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.

The invention herein described is an improvement in the one described in Patent No. 2,442,985, issued June 8, 1948, for "Method of and Means for Indicating Condition of Memory Element and Selectron" to Jan A. Rajchman. In that patent, there is shown a system for reading the condition of an individual memory element in an electron discharge device having a storage target including a plurality of memory elements. Such an electron discharge device is described and claimed in Patent No. 2,494,670, issued January 17,1950, to Jan A. Rajchman. The electron discharge device referred to has a storage target having a large number of memory elements. Means are provided, within the tube, for selecting a single one of these memory elements and then placing it in one or the other of two stable conditions indicative of a condition to be remembered.

The principle by means of which the individual memory element is precisely and accurately selected is fully described in the aforementioned patent. 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 he 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 fear 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 Patent No. 2,464,420 of R. L. Snyder, issued March 15,1949, for "Plural Beam Cathode Ray Tubes."

As discussed more fully in Patent No. 2,442,985 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 either the potential of the collector or that of the cathodes, as fully explained in the above mentioned patent. 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 he 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.

By pulsing the capacity plate in a manner described in the above mentioned patent the dielectric element can be made to 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.

The method of conditioning the selected memory elements to a desired one of the two possible stable potentials is described in the first mentioned patent. In brief, the storage element is conditioned by applying a voltage 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.

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 he 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.

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 tube 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.

In Patent No. 2,442,985 there is described a system for using a light responsive indicator to indicate the condition of a single memory element. This system provides for desensitizing the light responsive indicator, after the general electron bombardment has been stopped for the period of time required for the light, produced by all the illuminated elements, to die down to a value substantially less than that of one element. The light responsive element would then be sensitized again to produce an output depending upon the condition of the element selected.

In order for this system to function properly however, great care must be taken to ascertain that the light from one element is sufficiently strong to be distinguishable from stray light and the light responsive device dark current. The time required for reading the element condition depends upon the phosphor decay time. This decay time is a variable and no positive indication is available to indicate when the light from the elements which have been switched off, has decayed to at least the value of the that from the selected element which has been left on.

It is an object of the present 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 the conditions, an improved method of and means for determining the condition of a selected one of the elements.

It is a further object of the present 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 the conditions, a more accurate method of and means for determining the condition of a selected one of the elements.

It is still a further object of the present 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 the conditions, a more rapid method of and means for determining the condition of a selected one of the elements.

These and other objects are achieved in the present invention by providing a reading system utilizing a pulse reading technique. In most phosphors the rise time of illumination is much shorter than the decay time. Such a phosphor is employed in the electron discharge device the condition of an element of which is desired to be read. The electron bombardment of all the elements in the electron discharge tube is terminated. After a period of time not necessarily the period required for the light from all the elements to decay to a value less than that of a single element the election bombardment to a selected element is turned on. If the element is at collector potential a light pulse with a steep front is superimposed upon the decaying light from the other elements. The resulting signal generated by an associated photoelectric multiplier is amplified and differentiated in a circuit connected to the output of the multiplier. Since this detecting circuit is an alternating current coupled device, any direct current components from the stray light and the dark current of the multiplier are eliminated. The differentiated pulse is applied to a gating tube which is pulsed to be responsive only during the time of occurrence of such pulse.

The novel features of the invention as well as the invention itself, both as to its organization and method of operation, will best be understood from the following description, when read in connection with the accompanying drawings, in which, :

Figure 1 is a graph showing curves of decaying phosphor illumination, as well as a superimposed increase in such illumination versus time.

Figure 2 is a schematic diagram of an embodiment of the invention and

Figure 3 is a representation of some of the waveshapes required and obtained in the operation of the embodiment of the invention shown.

Referring to Figure 1, the light from a number of illuminated elements, having an exponentially rising and decaying phosphor, decays along a curve T_d within a time t_r. Time t_r is assumed to be the minimum waiting time after which reading may start. When a single element, at the end of time t_r, is bombarded with electrons, its illumination rises sharply along the curve t_r. Let the total number of light-producing elements in a memory tube be N. Let the maximum light from each element be Φ. The condition for reliable indication, namely that the light from the decaying elements should be equal or less than the light from the selected element, is represented by the equation

This indicates that for the direct current system the minimum

$$\phi = N \cdot \phi \cdot e^{\left(-\frac{t_r}{T_d}\right)}$$

reading time, $t_r = T_d \log_e N$.

A corresponding condition for the pulse reading system is, that the absolute value of the time derivatives of the decaying light and the superimposed light should be equal.

$$\left| \frac{d}{dt}\left(N \cdot \phi \cdot e^{-\frac{t}{T_c}}\right)_{t = t_r} \right| = \left| \frac{d}{dt}\left(\phi\left(1 - e^{-\frac{t - t_r}{T_r}}\right)\right)_{t = t_r} \right|$$

$$t_r = T_d \cdot \ln(N) + T_d \cdot \ln\left(\frac{T_r}{T_d}\right)$$

Since, as may be seen from the curves In Figure 1, $T_r << T_d$, the

actual reading time is shorter
for the pulse reading system, since the logarithm of a quantity smaller than one is negative. Therefore, the quantity

$$T_d \log_e \frac{T_r}{T_d}$$

is a negative quantity.

Referring to Figure 2, an electron storage device is shown schematically. This tube is preferably an electron discharge device of the type described in the aforementioned Patent No. 2,442,985 by 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 patent. 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. This material is selected to have a characteristic such that when bombarded by electrons it will become illuminated at a much greater rate than its rate of decrease of illumination upon termination of the electron bombardment. On the outer surface of the target is 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 pulse sources of potentials for "opening" and "closing" the selected windows. In the case illustrated the required pulse potentials are -10 v. and +100 v. which are produced by each of the pulse sources represented by rectangles. 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 pulse potentials will. be 0 and -100 V.

By means of two conductors **23** and **25**, the pulse potentials are applied to the respective contact points of the four vertical selecting switches **27** and the four horizontal selecting switches **29**. In the normal or standby condition both pulse sources apply an opening potential to both conductors. At this time selection of any one of the **16** memory elements may be made for reading by operating the vertical and horizontal switches, which are connected to the grid wires defining a window opposite a selected element, to be connected to the selected grid pulse source **30**. The remaining vertical and horizontal switches are operated to the non-selected grid pulse source **32** A key **36** and battery **34** are connected to both selected non-selected grid pulse sources and the dynode pulse source **38**. These are used for simultaneously keying the three pulse sources **30**, **32**, **38**; when a reading of an element is desired. 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 that any of the previously described systems of control may be employed for electrically selecting the desired one of a plurality of memory elements including those described in a copending application of J. A. Rajchman, Serial No. 702,775 filed October 11, 1946, now Patent No. 2,558,460.

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-multiplier tube **45**. A lens **43** serves to focus any light from the target electrode on to the cathode **53** of the photo multiplier tube **45**. Successively greater positive potentials are applied to the nine dynodes by means of a battery **47** and a voltage divider **49** in a conventional manner. In order to prevent the photo-multiplier tube from being overloaded during the quiescent period of the memory tube when every positively charged element is illuminated, the first dynode **51** is connected to the same potential as the cathode **53** and the gain of the multiplier tube is reduced to a low value. During the reading period a positive pulse is applied to this dynode **51** from the multiplier pulse source **38** which sensitizes the tube for the period of its use.

The output of the photo-multiplier tube is connected to an amplifier **55** which inverts and amplifies the output to it from the photo-multiplier tube **45**. The output of the amplifier stage is connected to a differentiating circuit. The time constants of the resistor **57** and condenser **59** of the differentiating circuit are selected in a manner well known to the art to provide discrimination between a fast-rising and a slow-declining signal. The differentiating circuit output is applied to a normally closed electron gate. This may consist of an electron discharge tube **61** having at least a control grid **63** and a screen grid **65** and being normally biased below cut off. The control grid **63** is connected to the differentiating circuit while the screen grid **65** is connected to a source of positive pulses or a gate pulse source **67.** This supplies a positive pulse at the proper time to allow the tube to provide an output in accordance with the signal applied to its control grid. Whether or not there is an output depends upon the condition of the memory element which has been selected.

After the switches have been set so that a desired memory element has been selected the key **36** is momentarily closed to apply a pulse simultaneously to both grid pulse sources **30**, **32** and the multiplier pulse source **38**. This keys both grid pulse sources to provide output pulses which bias the selecting grid to terminate the electron. bombardment of all the memory elements and extinguish their illumination. Referring now to Figure 3, from the non-selected grid pulse source **32**, a pulse having a long duration is applied to all the selecting grid wires except the ones defining a window opposite the desired element. Simultaneously a pulse is obtained from the selected grid pulse source **30** which has a shorter duration. This is equal to the time required for the rate of decay of the light from all the elements to be less than the rate of rate of the light due to illuminating the selected element. The time is less than the time required for the light from all the illuminated elements to decay below the light from one element. The multiplier pulse source **36** supplies a positive pulse to the first dynode **51** of the photo-multiplier tube to overcome the bias from the cathode **53** and to restore the gain of the tube **41** to its normal value The duration of this pulse to the photo multiplier tube may be made as long as the non selected grid pulse. At the application of this gate pulse the photo-multiplier tube output rises responsive to the light from all the memory elements. As this light slowly decays the tube output slowly decays until a sharp rise in its output occurs again when the selected memory element is illu-minated.

The photo-multiplier output is amplified and inverted by the first amplifier stage **55** and then applied to the differentiating circuit. The differentiated photo-multiplier tube output first shows a large amplitude differentiated signal rapidly falling to zero in view of the time constants selected for the circuit. Then a smaller amplitude differentiated signal occurs at the end of time t_r when the selected element is bombarded with electrons. This second signal occurs only provided the condition of the element is such as to allow it to be illuminated when bombarded by electrons.

The gate tube **65** is biased off until. at the end of time t_r when a positive pulse is applied to its screen grid **65**. Thus the only pulse which the gate tube amplifies is the one which occurs when and if, the memory element is Illuminated. The gate pulse source **67** may be keyed by the termination of the biasing off pulse from the selected grid pulse source **30**. The gate pulse is terminated before the multiplier and non-selected grid pulses to avoid transient indications. All the pulse sources represented by rectangles may be flip flop or slideback types of unistable state circuits which are well known to the art and which revert to their single stable state after a time determined by the time constant selected. The pulse sources may also be trigger circuits which are made responsive to trigger pulses from a central electronic pulse source.

It will be appreciated that in view of the differentiating circuit and gating'. stage and the method of operation of the memory tube no false readings of elements occur. The reading system is responsive only to the sharp rise time of the selected element which is in a condition to be illuminated. No output occurs if the selected element is not in such condition the non-selected grid pulse and multiplier gate pulse may be terminated at any time after the differentiated signal caused by illumination of the selected element occurs.

Although the description of the method and means for indicating the condition of a memory element has been described in connection with a memory tube wherein the element serves as both the indicator and the memory element, the method and means described herein are also applicable to tubes wherein the indicating and memory functions are performed by separate targets.

From the foregoing description it may be seen that the present invention provides an improved, more accurate and more rapid method arid means for determining the condition of a selected element 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 the conditions. Although a single embodiment has been shown and described, it should be apparent that many changes may be made in the particular embodiment herein disclosed, and that many other embodiments are possible, all within the spirit and scope of the present invention: It is therefore desired that the foregoing description shall be taken as illustrative and not as limiting,

What is claimed is:

1. The combination with a device having a plurality of conditionable elements adapted to be bombarded with electrons which emit light under bombardment when in one condition but not when in another condition, said device also having selecting means to control the flow of electrons to bombard said conditionable elements, and said device also having leads connecting from said selecting means external to said device selection of certain ones which permit selection of a conditional element to be bombarded, of means to apply a first pulse of a given duration to all but the ones of said leads which select a desired element to be bombarded to extinguish all elements but said desired one, means to apply a second pulse simultaneously with said

first pulse to the remaining ones of said leads to extinguish said desired element said second pulse having a shorter duration than said first pulse, light responsive means, and means coupled to said light responsive means responsive only to a pulse signal whereby said last-named means provides an output at the termination of said second pulse dependent upon the condition of said selected element.

2. The combination with a device having a plurality of conditionable elements adapted to be bombarded with electrons which emit light under bombardment when in one condition but not when in another condition, said device having means to selectively control the bombardment of all or a selected one of said elements by electrons and said device having a plurality of leads connecting said means external to said device to permit external biasing of said selective control means of switch means to select the leads connected to the part of said selective control means controlling the bombardment of the one of said elements whose condition it is desired to determine means to apply a first bias for a given duration to all but said selected leads to prevent bombardment by electrons of all but said one element, means to apply a second bias to said selected leads simultaneously with said first bias to prevent bombardment by electrons of said one element said second bias being applied for a shorter duration than said first bias, said shorter duration being determined by the time required for the rate of decay of the total light from said illuminated elements to be less than the rate of rise of the light from one element, light responsive means associated with said device, means to maintain said light responsive means insensitive until the application of said first bias, and means coupled to said light

responsive means responsive only to
a rapid increase in electrical output of said light responsive means.

3. The combination with a device having a plurality of conditionable elements adapted to be bombarded with electrons which emit light under bombardment when in one condition but not when in another condition, said device also having means to selectively control the bombardment of all or a selected one of said elements by electrons and said device having a plurality of leads connecting said means external to said device to permit external biasing of said selective control means, of switch means to select the leads connected to the part of said selective control means controlling the bombardment of the one of said elements whose condition it is desired to determine, means to apply a first bias for a given duration to all but said selected leads to prevent bombardment by electrons of all but said one element, means to apply a second bias to said selected leads simultaneously with said first bias to prevent bombardment by electrons of said one element, said second bias being applied for a shorter duration than said first bias, said shorter duration being determined by the time required for the rate of decay of the total light from all said elements to be less than the rate of rise of the light from one element, light responsive means associated with said device, means to maintain said light responsive means insensitive until the application of said first bias, a differentiating network coupled to said light responsive means output, a normally closed electron gate to which said differentiating network is coupled and means to open said normally closed electron gate at the termination of the application of said second bias to provide an output dependent upon the condition

of said selected element.

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