

May 3, 1966

TOSHIHIKO NAKAJO ET AL

3,249,802

ELECTRONIC GLOW-DISCHARGE INDICATOR

Filed March 31, 1961

FIG. 1

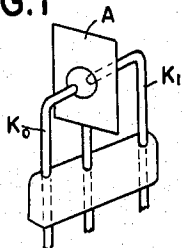


FIG. 2

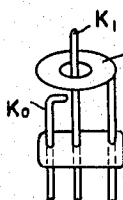


FIG. 3

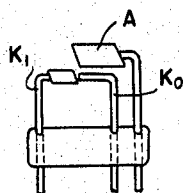


FIG. 4

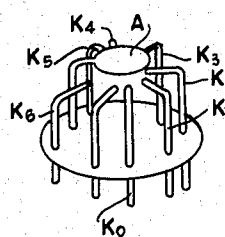
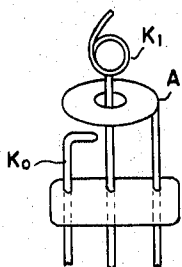


FIG. 6

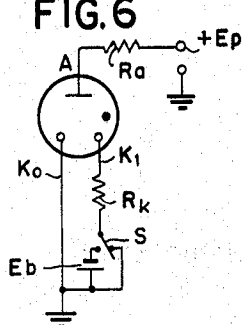


FIG. 7

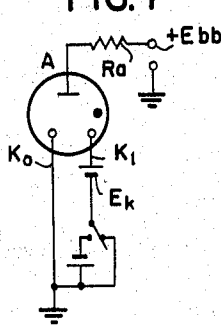


FIG. 8

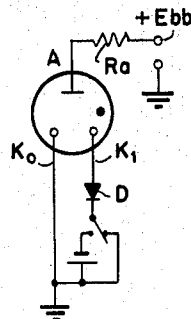


FIG. 5

FIG. 10

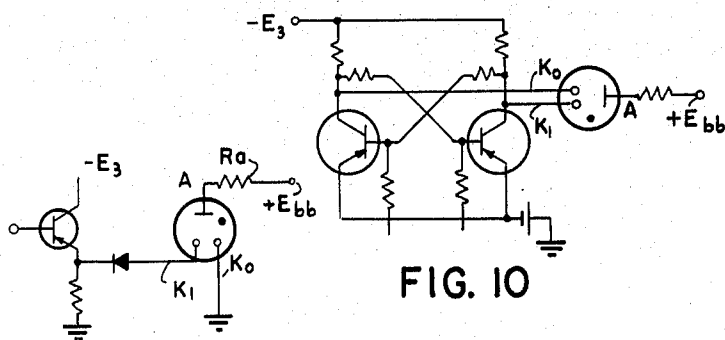


FIG. 11

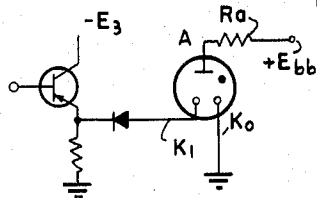


FIG. 9

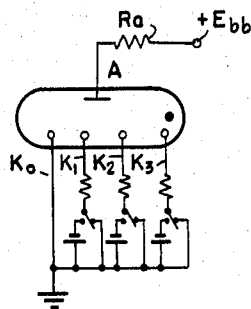


FIG. 12

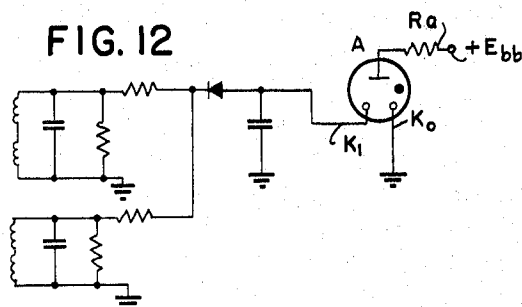
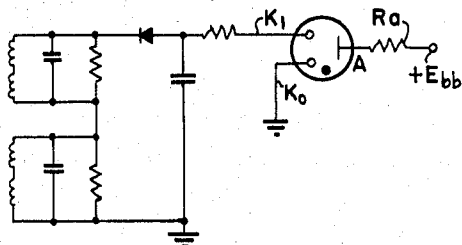


FIG. 13



1

3,249,802

ELECTRONIC GLOW-DISCHARGE INDICATOR

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8 Claims. (Cl. 315-167)

Our invention relates to electronic indicators whose indicating member proper is a cold-cathode glow-discharge tube.

In known indicators of this type, a visible indication of a signal by means of a glow discharge is effected by changing the amount of plate current flowing from the cathode to the anode and causing the visible glow, the size of the glow being approximately proportional to this current under normal operating conditions. The change in current and hence in indicating glow is effected by changing either the potential difference between anode and cathode or the magnitude of the series resistance in the external cathode-anode circuit. In practice, since the series resistance has a relatively great value, the signal input voltage necessary for obtaining a satisfactory change in current intensity and glow is usually relatively large in comparison with the plate voltage, whereas no applicable change in indication is obtained with only slight signal input voltages.

It is an object of our invention to devise an electronic indicator of the cold-cathode glow-discharge type which affords a valuable rapid operation with a much smaller signal power than heretofore required.

To this end, and in accordance with a feature of the invention, we provide the cold-cathode glow discharge tube with one or more sets of electrodes, each set comprising two or more cathodes which have one anode in common to operate from a single plate-voltage supply. One of these cathodes is a keep-alive or holding electrode for continuously maintaining a glow discharge that ionizes the plasma, whereas at least one other cathode is an indicating electrode and becomes effective to produce an indicating visible glow in response to a switching signal. In each electrode set, or in each tube, the holding cathode and indicating cathode work together as one unit, and are arranged close to each other so that the total plate current can be distributed onto these cathodes. Hence each partial current magnitude can be controlled by an external cathode-coupling resistance and the change of relative cathode potential takes place without appreciable change in total anode current. By maintaining a constant discharge at the holding cathode and applying either a negative input signal voltage to the indicating cathode or a positive input signal voltage to the holding cathode, the visible glow can be made to shift from the holding cathode to the indicating cathode under control by a small signal and to return to the holding cathode upon termination of the signal.

The invention, its objects and advantages as well as the foregoing and other features, will be described in the following with reference to the embodiments of indicators according to the invention illustrated by way of example in the accompanying drawings, in which:

FIGS. 1 to 5 show, in schematic perspective, five different embodiments of indicator-tube electrode assemblies;

FIGS. 6 to 8 show three different examples of schematic circuit diagrams for indicator tubes according to any one of FIGS. 1 to 5;

FIG. 9 is another circuit diagram for use with tubes of the type shown in FIG. 4; and

FIGS. 10 to 13 are four further examples respectively of indicator circuit diagrams according to the invention.

The same reference characters are applied to function-

2

ally corresponding elements respectively in all illustrations. Denoted by A is the anode, by K_0 the holding cathode, and by K_1 an indicating cathode.

The invention will first be described in more detail with reference to the electrode set down in FIG. 1 and the circuit diagram of FIG. 6, the same principles being applicable to the other embodiments.

According to FIG. 1, the anode A is a perforated plate. The two cathodes K_0 and K_1 have their respective extremities closely spaced from each other substantially in the center axis of the anode perforation and are symmetrically located on opposite sides of the anode plate A. The cathodes consist of wires made of molybdenum, nickel or other metals.

According to FIG. 6, the anode A is connected to the positive terminal of a plate-voltage source E_p through a series resistance R_a whose magnitude substantially determines the total plate current drawn from the source E_p . The negative terminal of source E_a , shown grounded, is connected to both cathodes K_0 , K_1 . A coupling resistor R_k and a switching means S, shown schematically as a mechanical switch although electronic switching means are preferable, are connected serially between the indicating cathode K_1 and the negative plate-voltage terminal (ground). A source E_b bias voltage is actively inserted between holding cathode and resistor R_k when switch S is closed.

With switch S in the condition shown, the resistance R_k is so chosen or adjusted that no glow, or only a slight glow appears between the indicating cathode K_1 and the anode A, the glow discharge being then substantially limited to the holding cathode K_0 on the other side of anode A. Under these conditions, as long as no signal is applied to cathode K_1 , most of the anode current passes through the holding cathode K_0 because of the presence of resistance R_k . However, when a signal is applied by closing of switch S, the bias voltage from source E_b makes the potential of the indicating cathode K_1 more negative than the potential of the holding cathode K_0 . Hence now more current flows through cathode K_1 than through cathode K_0 , and the indicating glow jumps from the holding cathode to the indicating cathode to become visible from the other side of the anode plate A. The glow returns to the holding cathode as soon as the signal is terminated.

This performance will be explained presently.

In general, when a discharge is maintained in one of two closely spaced discharge gaps within the same gaseous atmosphere, electrons and ions emitted by the discharge will diffuse into the other discharge gap. The resulting space charge in the second gap considerably reduces the discharge starting voltage in the second gap and eventually drops to a value nearly equal to the discharge-maintaining voltage. Hence the second gap has the inherent tendency to also assume the state of a normal glow discharge. This phenomenon is known as ionization coupling.

Now, if in these two gaps one anode is used in common for both gaps, and the cathode of the gap which has not been in discharge is connected directly or through a resistance with the cathode actually in discharge, these two cathodes undergo ionization coupling as mentioned above. If the resistance between the cathodes is small or if the cathodes are directly connected with each other, the current flows partially through both cathodes in an appropriate ratio. In this state, a glow discharge will be observed substantially equally at both cathodes.

With increased value of the inter-cathode resistance, one partial current is increased while the other is decreased without giving rise to any appreciable change to the total current. The glow of the cathode in which the current is decreasing is gradually reduced and eventually

nearly no glow is observed and an only weak ionic current will flow. This is because the potential of this particular cathode is raised by the current flowing in the resistance and the potential difference between the same cathode and the anode is decreased so that nearly the total anode current is caused to flow through the other cathode.

The phenomenon can be brought about by directly changing the potential difference between the two cathodes instead of varying the coupling resistance. In other words, whenever one cathode is made more positive than the other, the partial current flowing is decreased, whereas if the potential is made more negative, the partial current is increased. The invention thus affords obtaining and controlling the indication by a small input signal voltage, thus changing or shifting the glow displayed from a nearly unperceptible state to a clearly perceivable state by combining the effect of the coupling resistance between the two cathodes with the change of their potential difference.

The reasons why a very small change in voltage suffices to control the indication are the following.

Since as explained the two cathodes are intercoupled by ionization through the plasma, the proportion of anode current flowing through either cathode can be changed without changing the total anode current. Therefore, the series resistance in the plate circuit has no effect upon the control or signal voltage. Moreover, the impedance of the plasma is extremely small. It has been confirmed by experiment that the value of the coupling resistance can also be kept small in the practically usable range. All of these things contribute to make a comparatively small input voltage sufficient for the control of the partial current through each cathode.

The invention can be embodied in a variety of tube designs and circuits. Thus, in the example shown in FIG. 2, the holding cathode K_0 and the indicating cathode K_1 are asymmetrically arranged. The cathode K_1 protrudes upwardly through and beyond the perforation of the anode plate A, and the anode plate A is arranged to mask the holding cathode. Seen from above, the glow becomes visible or conspicuous only when it jumps from behind the anode to the front. FIG. 3 shows a device in which the indicator cathode K_1 consists of a plate in order to make the indicating area large, and anode A has no perforation and serves as a mask for cathode K_0 . FIG. 4 shows a tube in which six indicating cathodes K_1 to K_6 are arranged independently from one another around the common holding cathode K_0 as center, and each one of K_1 to K_6 performs an indication under control by an independent signal. According to FIG. 5 the cathode K_1 has the shape of a letter or number. Such devices facilitate reading the intended indication.

Various other electrode designs and arrangements are analogously applicable, and a number of electrode sets can be sealed jointly in a single tube envelope. For further example, the anode A can be made of a wire. Cathodes K_0 and K_1 can be exchanged, particularly as long as their extremities are sufficiently close to each other. It is often of advantage to mask the part of K_0 by painting the tube envelope or preparing a case, or by placing a screen in the tube in order to facilitate recognizing the presence of the indication.

FIG. 7 shows an example in which the resistance R_k of FIG. 6 is replaced by a source of positive bias voltage E_k ; the system can also be put into operation by the required input voltage if the resistance and the bias are suitably matched. According to FIG. 8 the resistance R_k is replaced by a diode D or other non-linear conductor. FIG. 9 illustrates an example of a circuit used for a tube of the kind shown in FIG. 4. In this case the current of cathode K_0 is larger than when only one indicator cathode is used. However, by properly selecting the current intensity, the tube will operate to make one

cathode serve for indication while the others are out of operation.

In the foregoing examples, a positive voltage may be applied to K_0 as the input, and a negative voltage may be applied to K_0 as the bias. FIGS. 10 to 13 show examples of applicable circuits. FIG. 10 is an example of a driving circuit constituted by a flip-flop network of transistors. FIG. 11 shows an example of the invention applied to a transistor amplifier circuit. FIGS. 12 and 13 show examples of the invention applied with a parametron circuit.

The following advantages of the invention are of interest in comparison with other electronic indicators of conventional types.

In the first place, the signal-responsive indication effected according to the invention is reversible so that the original state of the indicator is instantaneously reestablished upon termination of the input signal. This is of advantage over such other discharge indicating tubes as conventional neon lamps and the like. The motion of the glow depends upon the movement of ions in an electric field and the time of completion of ionization, as a rule, is less than 100 microseconds. In consequence, a device according to the invention has a considerably higher speed of response in comparison with miniature tungsten lamps and other incandescent indicators. Since the cathode in a discharge tube according to the invention can be made of pure metals such as molybdenum, nickel, etc., it has a substantially longer life and better stability than a neon lamp, miniature tungsten lamp, magic eye and the like devices. While it is difficult to recognize the light of the magic-eye tube in a bright place because of diffused reflection at the surface of the opaque fluorescent material, the glow discharge of a tube according to the invention is so bright and of such a color that it can be recognized just as easily, even in a bright place, as the lighting of a neon lamp. The availability of a small input is the most important characteristic of the present invention. While several tens or hundreds of volts are required by the neon lamp, the device of the present invention is satisfactorily operated at several volts, for example 3 to 5 volts. Although it is necessary to maintain the current constantly at an optimum amount, i.e. at more than 100 microamps in the holding cathode, this current, below several hundred microamps, does not involve a larger power loss than incurred in the heater circuit of the magic-eye tube or other hot-cathode devices.

We claim:

1. An electronic-indicator, comprising a cold-cathode glow discharge tube having a plurality of cathodes and a substantially flat anode common to said cathodes of which one is a discharge holding cathode and at least another one is an indicating cathode, said anode and said cathodes having plate-voltage supply means in common, said holding cathode and said indicating cathode being closely juxtaposed to each other and to said anode so that the total plate current is distributed onto said latter cathodes and said cathodes are ionization coupled with each other, resistive means connected to said indicating cathode, a signal circuit connecting said holding cathode with said indicating cathode through said resistive means and being electrically interposed between said cathodes and said plate-voltage supply means, said signal circuit having signal-responsive voltage control means for shifting the potential of said indicating cathode relative to that of said holding cathode so as to increase the flow discharge of said indicating cathode during the application of a signal and for returning the glow discharge to its initial condition upon the removal of said signal.

2. In an electronic indicator according to claim 1, said signal circuit comprising a bias source of low voltage connected with the plate-voltage and positively poled relative to said holding cathode, and said voltage control means comprising switching means for serially connecting and disconnecting said bias source between said

5

plate-voltage supply means and one of said holding and indicating cathodes so as to thereby change the relative potential of said indicating cathode from a value more positive to a value more negative than that of said holding cathode.

3. In an electronic indicator according to claim 1, said anode being a plate member, said holding cathode and indicating cathode being located at opposite sides of said plate member so that the glow discharge is substantially masked by said plate member when located at a given one of said two cathodes.

4. An electronic indicator according to claim 1, comprising a multiplicity of mutually insulated indicator cathodes having a single holding cathode in common, each of said indicator cathodes having its own signal circuit.

5. An electronic-indicator, comprising a cold-cathode glow discharge tube having a plurality of cathodes and a substantially flat anode common to said cathodes of which one is a discharge holding cathode and at least another one is an indicating cathode, said anode and said cathodes having plate-voltage supply means in common, said holding cathode and said indicating cathode being closely juxtaposed to each other and to said anode so that the total plate current is distributed onto said latter cathodes and said cathodes are ionization coupled with each other, resistive means connected to said indicating cathode, a signal circuit connecting said holding cathode with said indicating cathode through said resistive means and being electrically interposed between said cathodes and said plate-voltage supply means, said signal circuit having bias voltage means and signal-responsive voltage control means for changing the relative potential of said indicating cathode from a value more positive to a value more negative than that of said holding cathode, whereby application of a signal changes the current distribution between holding cathode and indicating cathode without appreciable change in total plate current and shifts the relationship intensity of the visible glow discharge from holding cathode to indicating cathode during the application of a signal and returns the glow discharge to its initial condition upon the removal of said signal

6. In an electronic indicator according to claim 5, said bias voltage means of said signal circuit comprising two opposingly poled bias sources, and said control means comprising switch means connected with said two sources and normally connecting a positive bias potential to said indicating cathode while switching it to negative bias potential when said switching means is actuated.

7. An electronic-indicator, comprising a cold-cathode glow discharge tube having a plurality of cathodes and a substantially flat anode common to said cathodes of which one is a discharge holding cathode and at least another one is an indicating cathode, said anode and said cathodes having plate-voltage supply means in common, said holding cathode and said indicating cathode being closely juxtaposed to each other and to said anode so that the

6

total plate current is distributed onto said latter cathodes and said cathodes are ionization coupled with each other, resistive means connected to said indicating cathode, a signal circuit connecting said holding cathode through said resistive means with said indicating cathode and being electrically interposed between said cathodes and said plate-voltage supply means, said signal circuit having a normally inactive source of bias voltage and having coupling resistance means connected in series between said signal cathode and said plate-voltage supply means, and said signal circuit having switching means for inserting said bias source between said resistance means and said supply means with negative poling of said bias source relative to said indicating cathode, whereby actuation of said switching means makes said indicating cathode more negative than said holding cathode to shift the relative intensity of the visible glow discharge from said holding cathode to said indicating cathode during the application of a signal and to return the glow discharge to its initial condition upon the removal of said signal.

8. An electronic-indicator, comprising a cold-cathode glow discharge tube having a plurality of cathodes and a substantially flat anode common to said cathodes of which one is a discharge holding cathode and at least another one is an indicating cathode, said anode and said cathodes having plate-voltage supply means in common, said holding cathode and said indicating cathode being closely juxtaposed to each other and to said anode so that the total plate current is distributed onto said latter cathodes and said cathodes are ionization coupled with each other, said anode forming a masking structure normally covering the glow discharge of said holding cathode, resistive means connected to said indicating cathode whereby application to said indicating cathode through said resistive means of a negative bias potential relative to said holding electrode causes the glow discharge to appear more intensely at said indicating cathode during the application of said negative bias potential and returns the flow discharge to its initial condition upon the removal of said negative bias potential.

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