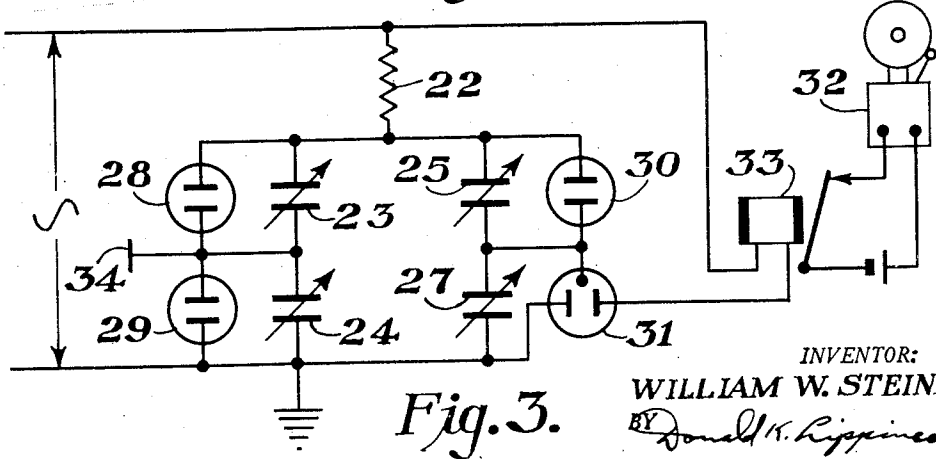
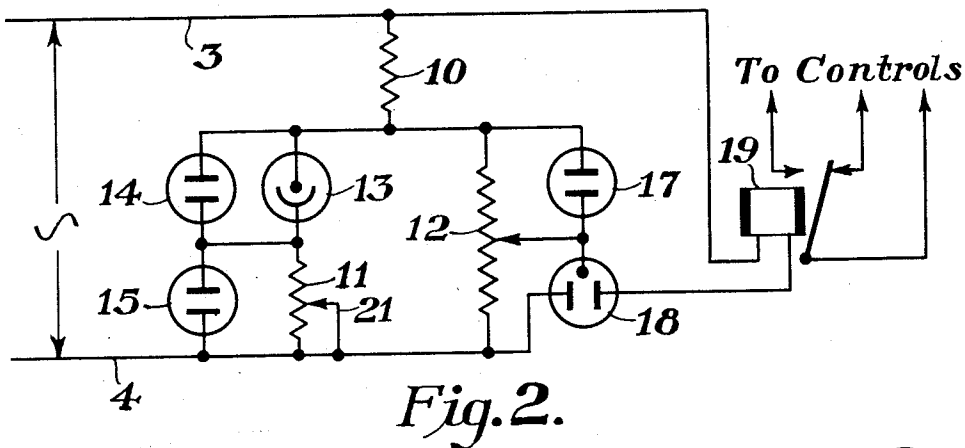
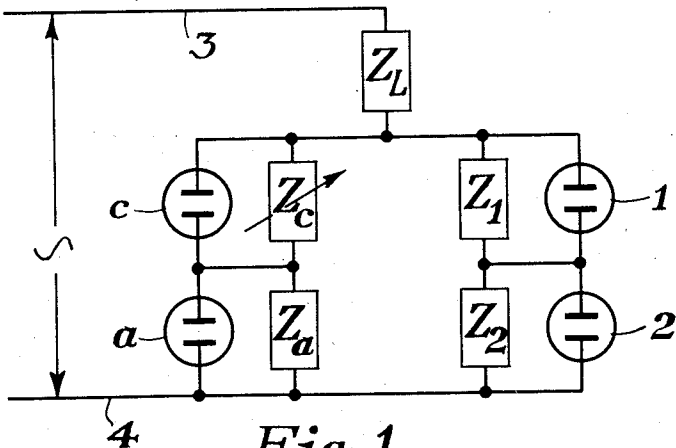


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SUPERVISORY CIRCUIT

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This invention relates to supervisory circuits, such circuits being broadly defined to include means for giving a mere indication as to the present or past value of some quantity which is to be supervised or of indicating that some event has occurred or is occurring, as well as means for holding such quantities to a fixed value or within a predetermined range.

Use for supervisory apparatus as thus defined occurs constantly and in many fields. Such use may be to show what a state of affairs was at the time of occurrence of some single event. It may be to give a warning when some event occurs, such as the extinguishment of a pilot light, the variation of some quantity, such as temperature, frequency or light intensity beyond some critical value, or it may be to control the quantity to be supervised.

The broad purpose of my invention is to provide a circuit which is generally applicable to such purposes. More specifically, included in the objects of my invention are to provide a circuit which will give positive action in response to very small changes in the supervised quantity; to provide a circuit which will act to control relatively large power in response to such small changes; to provide a circuit which itself consumes little power, and is simple and inexpensive to construct and maintain, and to provide a circuit which will function accurately despite relatively large variations in supply voltage.

My invention has other objects and features of advantage, some of which will be indicated or will become apparent by reference to the ensuing description and to the appended drawings, wherein:

Fig. 1 is a generalized diagram disclosing the basic circuit of my invention;

Fig. 2 is a diagram of an embodiment wherein a relay is actuated by deviation of illumination from a prescribed range; and

Fig. 3 is a diagram of the application of the circuit to a burglar alarm.

The basic diagram of Fig. 1 shows a divided circuit, one branch of which includes a pair of glow discharge tubes *a* and *c* in series, the other a similar pair of tubes *1* and *2*. Bridged across each tube is an impedance element, *Z_a* and *Z_c*, respectively, across the tubes of the first mentioned pair, *Z₁* and *Z₂* across the second.

The tubes may be of almost any of the available types, but preferably should have breakdown or striking voltages and sustaining voltages which are respectively as nearly uniform as possible. One of the advantages of the circuit is that the

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very small and cheap neon tubes, used by radio technicians to indicate circuit excitation, are entirely satisfactory. Such tubes comprise a miniature glass envelope less than an inch long and perhaps $\frac{1}{4}$ inch in outside diameter, with two wire electrodes sealed therethrough, the envelopes being filled with neon under low pressure. Their striking or breakdown voltage is approximately 55-60 volts instantaneous, and the glow will sustain itself, after it is once established, at 10-15 volts less than this. They will carry safely 300-400 microamperes.

Such tubes, in common with all glow discharge devices, have a negative resistance characteristic, i. e., the voltage across them decreases as the current increases. For stable operation they therefore require a ballast or current limiting impedance in series. This is provided by the impedance element *Z_L*, connected in series with the branched circuit, and so chosen as to drop the voltage to the sustaining value of two of the tubes in series when a current flows through it within the safe carrying capacity of one tube. With the tubes just discussed it may be of the order of 250,000 ohms. The leads 3 and 4, through which the entire circuit is supplied, can then connect to a conventional 110-120 volt A. C. supply. Direct current supplies can be used, however, where a single indication is required, and interrupted or pulsating D. C. can be employed wherever A. C. can be, provided the peak voltage and limiting impedance values are so related as to give the conditions above mentioned.

The impedances bridging the glow tubes are of a higher order of magnitude than *Z_L*; with the given value of the latter they may be of from 1 to 40 megohms, with the preferred values in the midportion of this range, say from 10 to 20 megohms. The impedance *Z_c*, shown as variable, will be considered to be varied by the quantity to be supervised.

Assume now that each tube has the same value of striking voltage—60 volts, that *Z_c*, *Z_a* and *Z₂* are each 10 megohms, and that *Z₁* has a slightly higher value, say 1%. As long as no tubes are excited about $2\frac{1}{2}\%$ of any voltage applied across the circuit will appear across *Z_L*. Of the remaining $97\frac{1}{2}\%$ one-half or $48\frac{3}{4}\%$ of the total will appear across each of tubes *a* and *c*, but in the other branch of the circuit the voltage across tube *1* will exceed that across tube *2* by 1%, and in each half cycle, as the voltage rises from zero toward its peak value of approximately 155 volts

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(for 110 R. M. S.) the drop across tube 1 will exceed that across the others and it will reach its striking value first.

At the instant before this occurs each branch circuit will be carrying about 6 microamperes. When tube 1 strikes it will increase the current through Z_L , reducing the voltage across the branch circuits fractionally and delaying the striking of either of tubes a or c , but the voltage across tube 1 will be decreased by 10 or 15 volts, while a like increase will appear across tube 2, which accordingly will strike instantly. Thereafter, owing to the limiting of current by Z_L , the total voltage across tubes a and c will not exceed their sustaining voltage, and neither can strike. This condition obtains until toward the end of the half cycle, when the voltage drops below the sustaining value of about 45 volts per tube, and the tubes extinguish.

If, now, in succeeding half cycles the impedance Z_c increases due to change in the quantity controlling it, no change in action will occur until Z_c and Z_1 are equal. This is the critical point which will be indicated by the circuit; beyond it impedance Z_c will exceed impedance Z_1 , and tube c will strike first, tube a will follow immediately, and neither of the two tubes in the other branch will strike, the conditions as between the two branches of the circuit having reversed.

In practice it is unlikely that the striking voltages of the glow tubes will be identical, but the same results can be attained in spite of this, even though the tubes may be quite widely dissimilar. Tubes can always be selected where the difference between striking and sustaining voltages is greater than that between the respective striking voltages.

It will be seen that the two impedances in each branch circuit act as a voltage divider. The same total voltage is applied across each divider, and the criteria for operation are the ratios of the proportional voltages applied to the various tubes to their respective striking voltages. Whichever branch contains the higher ratio will strike first and take over the operation.

Thus,

$$\frac{Z_c}{Z_c + Z_a}$$

gives the proportion of the total voltage applied across the tube c and

$$\frac{Z_1}{Z_1 + Z_2}$$

the proportion of the same voltage applied across tube 1. Calling these ratios P_c and P_1 respectively, the respective striking voltages E_c and E_1 and using like symbols with respect to the other two tubes the branch circuit in which the highest P/E ratio occurs will strike first and take control, provided the phases of the "P" ratios are the same. If there is a phase difference between the two ratios the one relating to the lagging voltage must be multiplied by the cosine of the difference in the phase angle.

If all that is desired of the circuit is an indication of whether the quantity to be supervised is above or below a critical value, it is sufficient that the higher P/E ratios in the two branch circuits be equal at that value, the phase correction being made where necessary. For many applications this is sufficient, but the circuit will

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also operate to show deviations on either side of a desired range. This requires that

$$\frac{P_c}{E_c} = \frac{P_a}{E_a}$$

at some value within the desired range of the supervised quantity, and that the greater of

$$\frac{P_1}{E_1} \text{ or } \frac{P_2}{E_2}$$

be equal to one or the other of the two former ratios at the critical points. It will be obvious that as the value of the higher of the latter ratios approaches the values of the former at equality, the narrower the range between the critical points becomes, but that if

$$\frac{P_c}{E_c} = \frac{P_a}{E_a} = \frac{P_1}{E_1}$$

the range of operation becomes vanishingly small and the device ceases to function.

The basic circuit as thus described is useful per se since either tube a or tube c can be used as a tell-tale or warning light to indicate deviation from a desired range of operation. Fig. 2 indicates a practical application of the invention where relay operation is desired.

In this figure the impedance Z_L is represented by a pure resistance 10, the impedance Z_a by another resistance 11, and impedances Z_1 and Z_2 by a high resistance potentiometer 12. Impedance Z_c is replaced by a photocell 13.

Three of the glow discharge tubes, 14, 15 and 17, are of the type already described; the third tube 18 is shown as a "grid-glow" tube, such, for example, as an OA4G, with its grid cathode connections in the branch circuit and the anode circuit connected in series with the line 3-4 and the actuating coil of a relay 19.

It will be seen that this circuit embodies special features not found in the general case. The photocell 13 carries current unidirectionally, so that when the sensitive surface is positive its impedance approaches infinity and the entire voltage drop occurs across tube 14, which therefore always strikes first on this half of the cycle. On the other half cycle the current is approximately proportional to the voltage during the initial portion of the half cycle, until saturation is attained, and therefore is independent of voltage, and the effective impedance rises rapidly.

The tube 18 is also unidirectional in its characteristics, since when the grid is negative it tends to prevent the tube discharging even though tube 17 may have struck.

The supervisory action therefore depends on whether tubes 17 and 18 carry current during the alternate half cycles when this is possible. The striking voltage between cathode and starter anode is ordinarily a few volts higher than that of the other tubes, so the circuit is best adjusted so that tube 17 strikes first. The disparity is not enough to prevent the immediate striking of tube 18 when this occurs, however, and as soon as cathode-grid current rises to about 100 microamperes the discharge transfers to the plate circuit, which will pass 100 milliamperes safely, and so operate the relay 19 to actuate any desired mechanism.

There are various ways of adjusting this circuit to operate at desired critical points. One is to illuminate the photocell 13 to the desired minimum critical value and adjust the potentiom-

eter 12 until the relay 19 just operates, then give the photocell the maximum critical illumination and adjust variable contact 21 on resistor 11 until the relay again just operates. Two or three repetitions of this procedure are sufficient to get a very accurate setting.

This particular variant of my invention clearly illustrates the great sensitivity of the circuit. In one such setup, where the mean photocell current was 6 microamperes, it was found possible to get positive operation within as narrow a range as might be desired. Other methods would have required much greater complication, since the photocell current is much too small to actuate directly even so sensitive a device as the grid-glow tube.

Fig. 3 illustrates operation of the circuit as a burglar alarm. In this case the impedance Z_L is again a resistor 22, while the impedances in the branch circuits are capacitive, being represented by the condensers 23, 24, 25 and 27. Radio "trimmer condensers" are suitable. Tubes 28, 29 and 30 are simple glow discharge tubes; tube 31 is again of the grid-glow type connected to operate an alarm bell 32 through a relay 33. An electrode 34 is connected to the junction of condensers 23 and 24, and the other side of the latter is grounded.

Electrode 34 may be a wire around a window or door casing, a metal plate, or other capacitive element. The approach of a person to this plate will sufficiently change the capacity across tube 29 to cause tubes 28 and 29 to strike and operate the alarm.

It is obvious that almost any physical quantity can be supervised in the manner here set forth, and it is considered unnecessary to multiply examples. Temperature, pressure, weight, or any other quantity that can be used to change an effective impedance whether resistive, reactive or complex. If Z_c is made capacitive or inductive and the other impedances in the branch circuits are resistive the circuit becomes as sensitive to frequency variation as may be desired. I therefore do not wish to be limited to the embodiments of the invention shown herein, but to protect it as broadly as possible within the scope of the following claims.

I claim:

1. In a supervisory circuit, a pair of branch circuits connected in parallel, each branch comprising two glow discharge tubes in series, an impedance element connected across each of said glow tubes, one of said impedance elements varying in accordance with a quantity to which the circuit is to respond, and means for supplying current within the safe carrying capacity of one of said glow tubes to said branch circuits at a potential not less than the striking voltage of one of said glow tubes, plus the sustaining voltage of another.

2. Apparatus in accordance with claim 1 wherein

$$\frac{P}{E} = \frac{P_1}{E_1}$$

at a critical point in the operation of said circuit, where

$$\frac{P}{E}$$

is the higher of the ratios of the proportion of the voltage across one of said branch circuits applied

to one of the tubes therein to the striking voltage of said tube and

$$\frac{P_1}{E_1}$$

is the higher of the like ratios in the other branch circuit.

3. Apparatus in accordance with claim 1 wherein

$$\frac{P}{E} = \frac{P_1}{E_1}$$

at two critical points delimiting a predetermined range of values of the quantity to be supervised, where

$$\frac{P}{E}$$

is the higher of the ratios of the proportion of the voltage across one of said branch circuits applied to one of the tubes therein to the striking voltage of said tube and

$$\frac{P_1}{E_1}$$

is the higher of the like ratios in the other branch circuit.

4. Apparatus in accordance with claim 1 wherein one of said glow discharge tubes is of the grid-controlled type and the impedance associated therewith is connected in the grid circuit thereof, and including a work circuit connected for actuation by said grid-controlled tube.

5. A supervisory circuit for actuation by a source of electrical potential comprising a series impedance element for limiting the current from said source to the safe carrying capacity of a glow discharge tube, a pair of branch circuits fed by said series element, each of said circuits comprising a pair of such glow discharge tubes in series, and an impedance element of a higher order of magnitude than said series element connected across each of said tubes, one of said elements being variable in accordance with the value of a quantity to be supervised.

6. Apparatus in accordance with claim 5 wherein at a predetermined point of critical value of the quantity to be supervised

$$\frac{E_c}{Z_c} < \frac{E_a}{Z_a}, \frac{E_c}{Z_c} = \frac{E_1}{Z_1}$$

and

$$\frac{Z_c}{Z_c + Z_a} = \frac{Z_1}{Z_1 + Z_2}$$

where Z_c is the value of said variable impedance, Z_a the value of the other impedance in the same branch circuit, Z_1 and Z_2 the values of impedance in the other branch circuit, and E_c , E_a and E_1 the respective striking voltages of the glow tubes across which the impedances bearing the like subscripts are connected.

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