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COLD CATHODE TUBE CIRCUIT

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FIG. 1

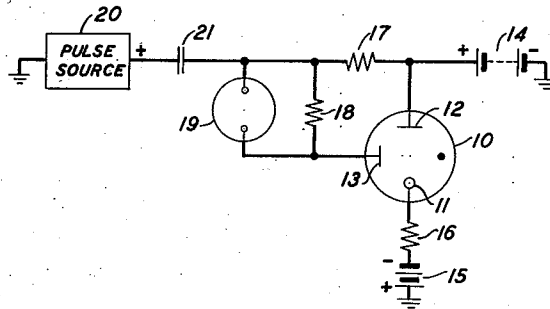


FIG. 2

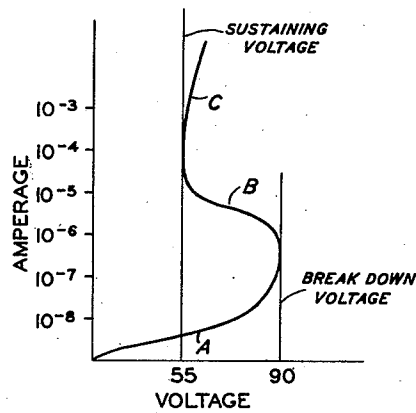
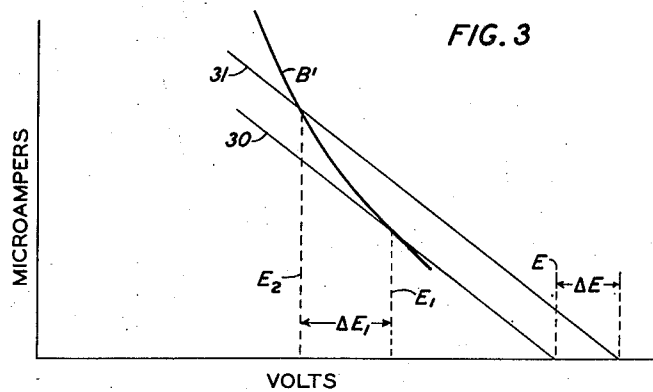


FIG. 3



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1

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COLD CATHODE TUBE CIRCUIT

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6 Claims. (Cl. 315—168)

This invention relates to electric discharge device circuits and more particularly to such circuits including cold cathode gaseous discharge devices.

In a variety of applications, for example, in control and switching systems, a gaseous discharge device is utilized to effect closure of a controlled or load circuit in response to application of a signal to an input or controlling circuit. The device comprises a gas filled tube having a main anode, a cathode defining a main gap therewith, and an auxiliary electrode defining a starter gap with the cathode. The main anode and cathode are relatively biased at below the breakdown voltage of the main gap but above the sustaining voltage thereof. Conduction across the main gap, which is in the circuit with a load or utilization circuit, is initiated by application of a signal voltage between the cathode and auxiliary electrode such as to establish a discharge across the starter gap. The current in the starter gap resulting from the discharge therein will increase the ionization in the tube to cause the main gap to break down and conduct. The starter gap current required to cause breakdown in the main gap is known as the transfer current and its value is determined by the main anode voltage, the external impedance in the starter gap circuit and the geometry of the tube.

Gaseous discharge device circuits of the general type above described and of configurations now known suffer from several limitations. One is the relatively large signal amplitude required for operation of the device. A second is the slowness of the starter gap breakdown which in turn results in a relatively long delay for the main gap breakdown after the application of the controlling signal voltage. It is well known that the use of radioactive materials such as radium in gaseous discharge devices of the general type described above will raise the level of initial ionization in the device and thereby secure increased speeds of operation. However, it has been found impractical to employ enough radium in such devices to secure operating time of a millisecond or less. It is well known also that by means of illumination, photoelectric emission of electrons from the electrodes of such devices will also raise the level of initial ionization in the devices and thereby secure increased speeds of operation. However, illumination is difficult to control and is not generally used. A third limitation of gaseous discharge device circuits, of the general type described above in which condenser coupled input circuits are employed, is the tendency for such circuits to cause uncontrolled breakdown of such gaseous discharge devices by the coupling condenser causing a relaxation oscillation of the circuit.

One general object of this invention is to improve electric discharge device circuits. More specific objects of this invention are to reduce the signal amplitude requisite to effect the operation of cold cathode triodes and to decrease the time required for operating such triodes. A further specific object is to prevent false operation

2

of such triodes in circuits wherein condenser coupled inputs are employed.

In accordance with one feature of this invention, in an electric discharge device circuit of the general organization above described, a diode-resistor combination is provided in association with the starter gap of the discharge device. This combination is so constructed and arranged that in the absence of a control or input signal, a current flow obtains across the starter gap. This current flow is maintained at a value less than the transfer current value required to cause breakdown of the main gap and constitutes a keep-alive discharge or keep-alive current in the device. Upon application of a control or input signal, the diode breaks down or conducts so that the starter gap current increases abruptly to a value higher than the transfer current value thereby to cause breakdown of the main gap of the discharge device. Thus, the auxiliary electrode serves as both a keep-alive and starter electrode. The keep-alive current across the starter gap of the device raises the level of ionization in the device and substantially enhances the speed of breakdown of the main gap in response to the input or control signal.

In accordance with another feature of this invention, certain parameters of the diode-resistor combination and of the discharge device are correlated so that a voltage gain is obtained with respect to the input or control signal. More specifically, in accordance with a feature of this invention, the combination above noted includes a high resistance in series with the starter gap and the nominal bias across the starter gap is such that upon application of the control signal the gap operates upon a portion of its characteristic exhibiting negative resistance whereby a voltage is developed across the high resistance which is greater in magnitude than control signal voltage.

In accordance with a further feature of this invention, the control or input signal is applied by way of a condenser coupling in such manner as to prevent uncontrolled breakdown of the discharge device by relaxation oscillations.

The invention and the above noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing, in which:

Fig. 1 is a diagram depicting one electric discharge device circuit illustrative of this invention;

Fig. 2 is a graph representing the current-voltage characteristic of the starter gap of a gaseous discharge device of the type contemplated for utilization in circuits constructed in accordance with this invention; and

Fig. 3 is a graph portraying a portion of the characteristic shown in Fig. 2, on an enlarged scale.

Referring now to the drawing, the circuit illustrated in Fig. 1 comprises a gaseous discharge device 10, for example, of the argon type, having a main cathode 11, a main anode 12 and an auxiliary electrode or anode 13. The cathode 11 and anode 12 are relatively biased by sources such as batteries 14 and 15, poled as indicated, at a potential below the breakdown voltage of the main gap of the device but at least as great as the sustaining voltage for this gap. A load, for example, a relay or other utilization element, depicted by the resistor 16, is connected in series with the main gap.

The auxiliary electrode 13 is connected to the positive side of the source 14 through a pair of resistors 17 and 18, the former of which is of relatively low value, say of the order of 10,000 to 100,000 ohms, and the latter of which is of high value, say of the order of 10 megohms. A diode 19 is connected across the resistor 18. Diode 19 may be a gaseous diode or a semiconductor diode having Zener characteristics, connected across resistor 18

as shown in Fig. 1. Diode 19 may also be a high vacuum type diode or a germanium type diode biased a few volts below cutoff. Breakdown of the main gap is effected by application of a suitable potential or pulse from a source 20 through condenser 21 to the common point of resistors 17 and 18.

Normally, that is, in the absence of a pulse or signal from source 20 and when the potentials from sources 14 and 15 are first applied to the circuit, the main discharge gap of device 10 is substantially nonconducting. Condenser 21 will start to charge from source 14 through resistor 17 and will continue to charge until it attains a potential which is equal to or slightly greater than the breakdown voltage of the starter gap of the device 10. When this breakdown voltage is attained, the starter gap of device 10 breaks down and conducts a relatively small current between cathode 11 and auxiliary electrode 13. By selecting the sources and resistors of the circuit in ways known in the art, the current in the starter gap of discharge device 10, after the starter gap breaks down, may be limited in magnitude to a value below the transfer current value of device 10 and thus prevent a breakdown of the main gap. This current, although insufficient to effect breakdown of the main gap of device 10, will act as a keep-alive current in device 10 and will raise the level of ionization therein so that the time necessary for establishment of conduction in the main gap of device 10 is substantially decreased. The keep-alive current in the starter gap circuit of device 10 is limited in magnitude by resistor 18 so that it will develop a voltage drop across resistor 18 which is below the breakdown or cutoff voltage of diode 19 and diode 19 thus remains nonconducting.

Upon the application of an appropriate voltage pulse or signal from source 20 through condenser 21 to the common point of resistors 17 and 18 which comprise a voltage divider network, the potential drop across resistor 18 is raised above the breakdown or cutoff voltage of diode 19 and the latter becomes conducting and shunts resistor 18. Condenser 21 then immediately starts to discharge through diode 19 and the starter gap of device 10. The current flow in the starter gap is thereby increased abruptly to a value which is substantially above the transfer current value of the device 10. Because the current in the starter gap of the device 10 is now substantially above the transfer current value of the device, a discharge is rapidly established between the main anode 12 and cathode 11 and the circuit through load 16 is closed. Resistor 17 acts as a current-limiting resistor after diode 19 breaks down or conducts to limit the current flow in the starter gap circuit of device 10 caused by the bias potentials of sources 14 and 15 to prevent damage to the starter gap electrodes.

When the charge on condenser 21 which is discharging through diode 19 and the starter gap of device 10 drops in magnitude to a point where the voltage across the starter gap of device 10 is below the sustaining voltage thereof, the discharge through the starter gap is extinguished. The extinguishment of the discharge in the starter gap of device 10 will terminate the current in resistor 18 which in turn will cause the voltage applied to diode 19 to be reduced below the sustaining value or cutoff value thereof. The reduction of the voltage applied to diode 19 to a magnitude below the sustaining voltage or cutoff voltage thereof by the elimination of the voltage drop across resistor 18 will cause the discharge or conduction through diode 19 to terminate.

When the conduction through diode 19 is halted, condenser 21 once again starts charging from source 14 through resistor 17. When the charge on condenser 21 attains the breakdown voltage of the starter gap of device 10, the starter gap is again broken down and the keep-alive current is reestablished in device 10. Further action of the elements of the circuit halts and the circuit remains in this condition until the application of the next pulse. The above-described action takes place whether

or not the main gap discharge is extinguished. Therefore, when the load 16 has performed its function and the main gap of device 10 is extinguished by external means, the device 10 is in condition to respond to the next succeeding pulse from source 20.

It will be appreciated, thus, that the auxiliary electrode 13 serves both as a starter and a keep-alive electrode. The keep-alive current in the starter gap reduces the magnitude of the signal voltage or control pulse requisite to initiate conduction in the main gap of the device 10. Further, such keep-alive current substantially decreases the time necessary for establishment of conduction in the main gap of device 10 because the starter gap has previously broken down and is conducting keep-alive current and the delay usually encountered for the starter gap breakdown before the main gap breakdown is eliminated. For example, in typical circuits constructed in accordance with this invention, operation times of a millisecond or less may be obtained. It will be appreciated further that by suitable correlation of circuit parameters the keep-alive current can be set at a desired value whereby the amplitude of the pulse or signal from source 20 necessary to render the device 10 conducting can be set accurately at preassigned values.

By coupling the signal voltage or pulse from source 20 through condenser 21 to the common point of resistors 17 and 18 as shown in Fig. 1 and described above, the tendency of the starter gap to oscillate in a relaxation manner caused by the alternate charging and discharging of condenser 21 is eliminated. After the application of a voltage pulse from source 20 and after the circuits recover as described above and condenser 21 attains a new charge, condenser 21 cannot discharge through the starter gap because of the current-limiting action of resistor 18 and, therefore, there will be no alternate charging or discharging of condenser 21 except in response to a signal pulse from source 20. Unwanted or uncontrolled discharges of device 10 are thereby eliminated.

Concomitant with the enhanced speed of operation and reduction in the signal voltage amplitude required to effect breakdown discussed hereinabove, the invention enables realization of voltage gain. This will be understood most readily by reference to the graphs of Figs. 2 and 3. Fig. 2 depicts the current voltage characteristic of the starter gap 11, 13 in the device 10. In this figure, the scale for the abscissae is linear and that for the ordinates is logarithmic. Fig. 3, wherein both the ordinates are linear, portrays a portion of the characteristic of Fig. 2 to an enlarged scale.

Referring now to Fig. 2, it will be seen that over the portion A of the characteristic, which embraces low currents and extends up to the breakdown voltage, the resistance of the starter gap is positive. This region represented by A is followed by the portion B wherein the resistance of the starter gap is negative, this region extending to about the sustaining voltage for the gap. For the portion C of the characteristic, the discharge is self-sustaining and the resistance of the gap is positive.

Fig. 3 represents a part B' of the negative resistance region B, Fig. 2, of the starter gap characteristic. Consider a voltage from a source of voltage E, greater than the breakdown voltage of the starter gap, applied through a high resistor, such as the sources 14 and 15 and resistor 18 in Fig. 1. The load line corresponding to this resistance is indicated by 30 and, it will be seen, intersects the characteristic B' at a point corresponding to a voltage E₁ and a low current. Now assume that a voltage increment ΔE is applied to voltage E, such an increment as would be obtained from source 20. The load line for the same resistance is as indicated by 31 on Fig. 3. This intersects the characteristic B' at a point corresponding to a voltage E₂, substantially smaller than E₁ and corresponding to a relatively high current. It is evident that by suitable fixing of the magnitude of

5

the high resistance, ΔE_1 can be made substantially greater than ΔE . Thus, by making the positive resistance of resistor 18 slightly greater than the negative resistance of the starter gap, a voltage change across the diode 19 and resistor 18 greater than the input signal or pulse from source 20 will be realized. Hence, the voltage sensitivity of the device 10 is enhanced or, viewed in another way, the amplitude of the signal or pulse requisite to render the device 10 conducting is decreased.

What is claimed is:

1. In combination, a gaseous discharge device having an anode, a cold cathode and an auxiliary electrode, means for establishing a potential across the anode-cathode gap below the breakdown voltage and above the sustaining voltage thereof, and means for effecting breakdown of said gap comprising a diode and resistor in parallel with each other and in series with the cathode-auxiliary electrode gap, means for maintaining a keep-alive current through said cathode-auxiliary electrode gap and resistor with the potential drop across said resistor below the breakdown voltage of said diode, and means for increasing said potential drop to the breakdown voltage of said diode.

2. The combination defined in claim 1 wherein said means for maintaining the keep-alive current comprises a source of potential of magnitude above the breakdown potential of said cathode-auxiliary electrode gap and said resistor is of value such that the keep-alive current is in the negative resistance range of the cathode-auxiliary electrode gap.

3. The combination defined in claim 1 wherein said means for increasing said drop comprises a pulse source, a second resistor connected in series with said resistor thereby forming a voltage divider network, and a condenser coupling said source to the terminal of said resistor remote from said auxiliary electrode and common to said second resistor.

4. In combination, a gaseous discharge device having a cold cathode and an anode defining a main gap and having also an auxiliary electrode defining a starter gap with said cathode, means biasing said anode relative to said cathode at a potential below the breakdown voltage but above the sustaining voltage of said main gap, and means for effecting breakdown of said main gap

6

comprising a gas diode in series with said starter gap, means in circuit with said starter gap for maintaining a keep-alive discharge in said starter gap and establishing a potential across said diode below the breakdown voltage thereof, and means for increasing the potential across said diode to above the breakdown voltage thereof.

5. In combination, a gaseous discharge device having a cathode and an anode defining a main gap and having also an auxiliary electrode defining a starter gap with said cathode, means biasing said anode relative to said cathode at a potential below the breakdown voltage but above the sustaining voltage of said main gap, a resistor in series with said starter gap, a pulse source connected to said resistor, means including said resistor and a source in series therewith and of potential greater than the breakdown voltage of said starter gap for establishing in said starter gap a current of amplitude within the negative resistance range of the starter gap current-voltage characteristic, and means responsive to a pulse from said pulse source for increasing the current in said starter gap to establish a self-sustaining discharge in said main gap.

6. In combination, a gaseous discharge device having an anode and a cathode defining a main gap and having also an auxiliary electrode defining a starter gap with said cathode, a low and a high resistance connected in series between said anode and auxiliary electrode, means for biasing said anode relative to said cathode at a potential below the breakdown voltage of said main gap but above the sustaining voltage thereof including a source of positive potential connected to said anode and a source of negative potential connected to said cathode, said means biasing said auxiliary electrode relative to said cathode to maintain a keep-alive current in said starter gap, a gaseous diode in shunt with said high resistance and having a breakdown voltage greater than the potential drop across said high resistance due to said keep-alive current, and means for causing breakdown of said gaseous diode.

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