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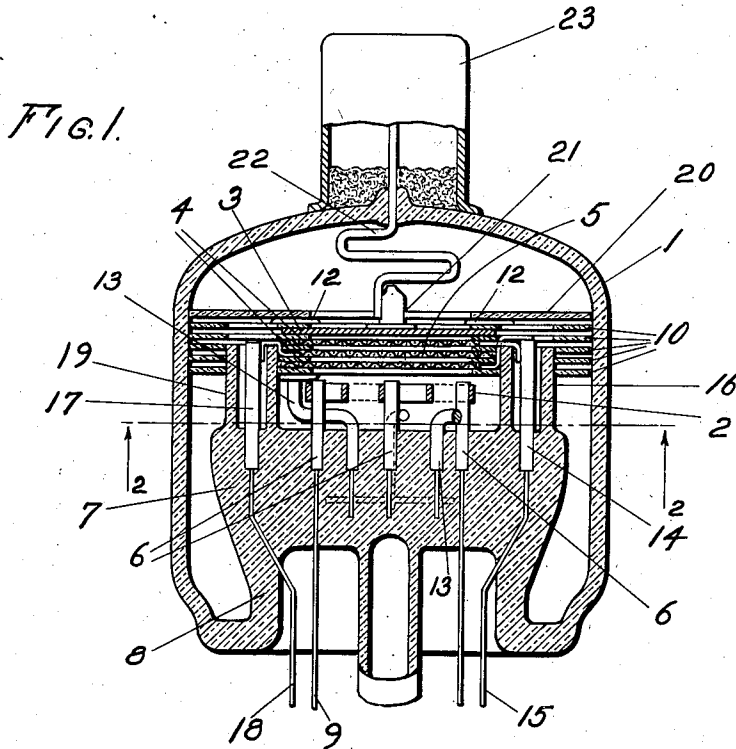
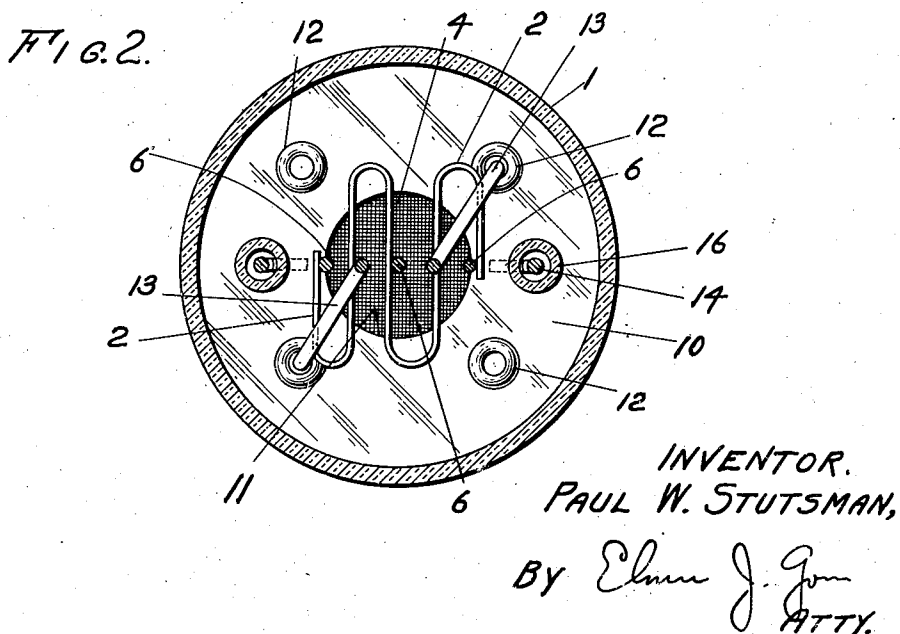
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2,436,835

CONTROL CIRCUIT FOR GAS DISCHARGE TUBES

Filed May 6, 1944

3 Sheets-Sheet 1



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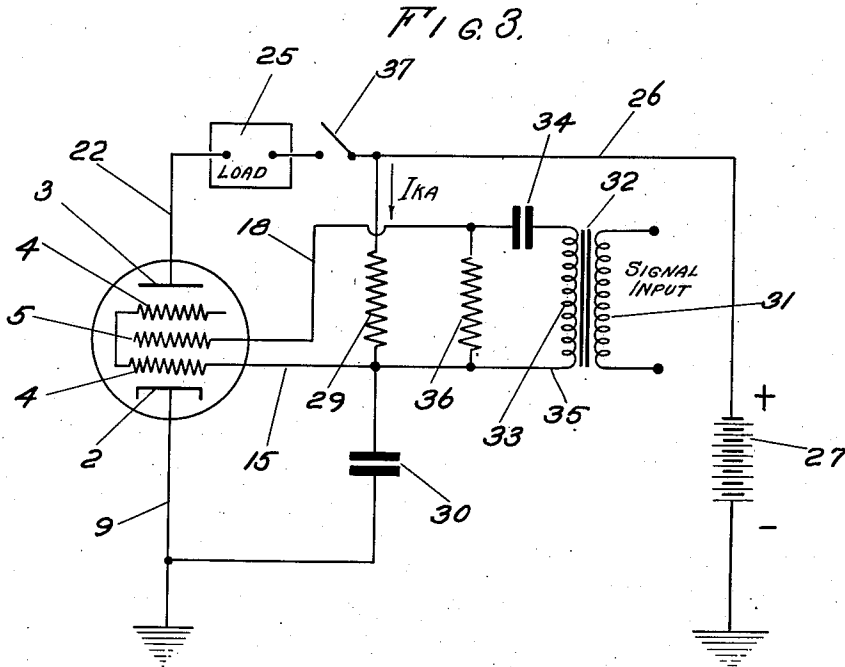
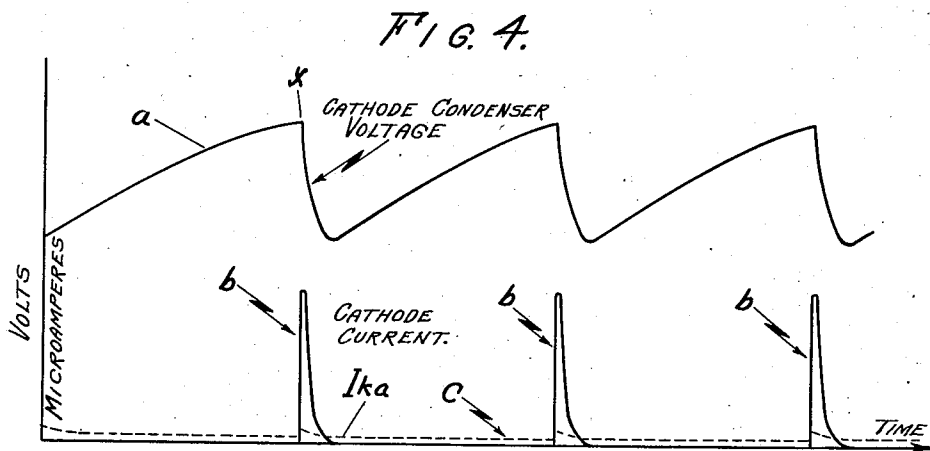
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CONTROL CIRCUIT FOR GAS DISCHARGE TUBES

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3 Sheets-Sheet 2



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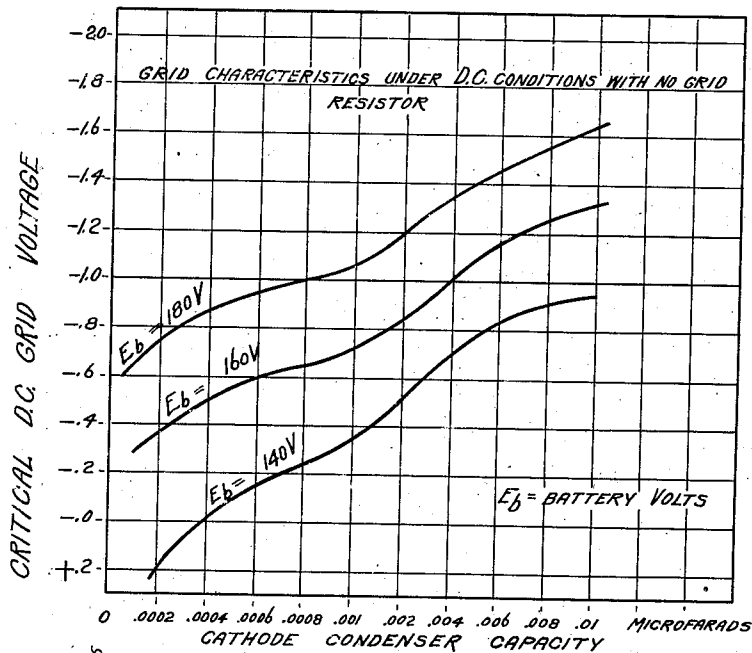
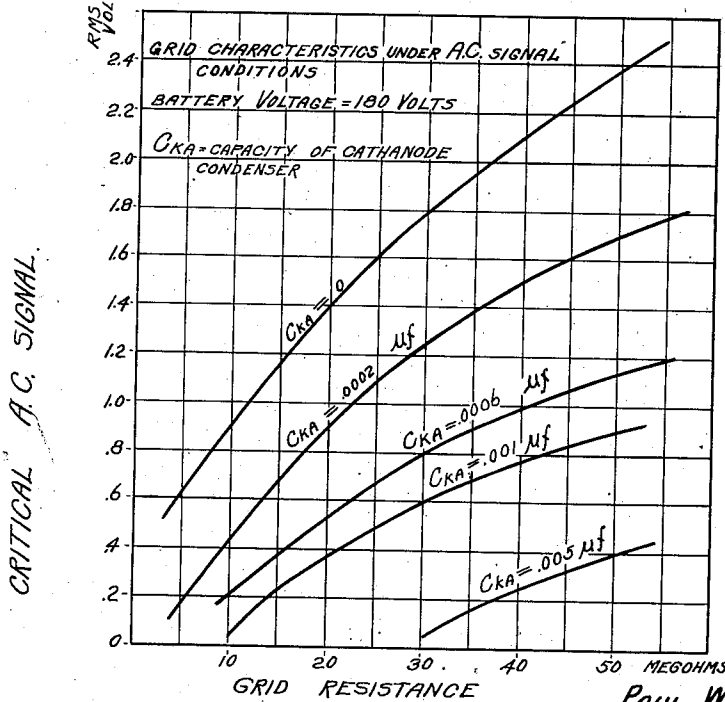
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CONTROL CIRCUIT FOR GAS DISCHARGE TUBES

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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CONTROL CIRCUIT FOR GAS DISCHARGE TUBES

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6 Claims. (Cl. 315—60)

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This invention relates to an electrical system utilizing a gaseous discharge relay tube which conducts current between a cathode and anode in response to a predetermined value of signal voltage applied to a control grid or electrode.

An object of this invention is to devise such a tube and system having a high grid impedance and which operates reliably with very low grid power.

Another object is to devise such a tube and system which operate consistently under variable anode voltages with a substantially uniform maximum required signal voltage of the order of about one volt.

A further object is to devise such a tube and system which operate from a source such as a battery with a very low standby current of the order of a few microamperes.

The foregoing and other objects of this invention will be best understood from the following description of an exemplification thereof, reference being had to the accompanying drawings wherein:

Fig. 1 is a vertical cross-section of one form of my novel tube for use in my novel system;

Fig. 2 is a cross-section taken along line 2—2 of Fig. 1;

Fig. 3 is a circuit diagram of one embodiment of my novel system;

Fig. 4 is a set of curves illustrating the standby conditions in the system of Fig. 3; and

Figs. 5 and 6 are characteristic curves of a tube built and operated in accordance with my invention.

The tube as illustrated in Figs. 1 and 2 comprises a sealed glass envelope 1 containing a glow discharge cathode 2, an anode 3, and a pair of cathanode grids 4, 4 disposed on opposite sides of a control grid 5. The envelope 1 is filled with a suitable ionizable gas at a substantial pressure. For example, a mixture of krypton and xenon at about 10 mm. of mercury may be utilized.

The cathode 2 is supported by a plurality of conducting support rods 6 sealed in the upper end of a press 7 formed on the reentrant stem 8 of the envelope 1. The cathode 2 may be made of a ribbon of a nickel alloy and coated with barium carbonate fused onto said ribbon in air at a pressure of about 5 mm. of mercury. One of the conducting rods 6 may be provided with a lead-in conductor 9 extending through the press 7 and affording an external electrical connection to the cathode.

The grids 4 and 5 are preferably made of a rel-

atively fine mesh of nickel wire. The anode 3 may also be made of a disc of nickel. If relatively small voltages are used between the cathode and anode, the electrodes 3, 4 and 5 may be made of bright nickel. Under these conditions, voltages of about the order of 145 volts or less may be used. However, where higher voltages are present, it is desirable that the surface of the electrodes 3, 4 and 5 be coated with a poor electron-emissive material. Thus these electrodes are preferably carbonized by being coated with a layer of finely divided carbon. The electrodes 3, 4 and 5 are each in the form of a flat disc supported between a pair of insulating washers 10. Each of these insulating washers is provided with a central opening 11 so as to create an electron discharge passage between the cathode 2 and the anode 3. The insulating washers 10 are clamped together by a plurality of hollow rivets 12 which thus bind the assembly of the electrodes 3, 4 and 5 together into a compact unit. This unit is supported on the reentrant stem 8 by means of a pair of wire standards 13 sealed in the press 7. The upper ends of the standards 13 may be welded to two of the rivets 12. Each of the cathanode grids 4 has welded thereto a conducting tab which in turn is welded to a conducting rod 14 likewise sealed in the press 7 and provided with an external lead-in conductor 15. The rod 14, as it projects above the press 7, is surrounded by a glass sleeve 16 so as to protect said rod 14 against undesirable discharges. The glass sleeve 16 fits snugly into corresponding openings in the insulating washers 10. The control grid 5 likewise has welded thereto a conducting tab which in turn is welded to a conducting rod 17 likewise sealed in the press 7 and provided with an external lead-in conductor 18. The rod 17 is also surrounded by a glass sleeve 19 fitting snugly into corresponding openings in the washers 10. The purpose of the sleeve 19 is similar to that described in connection with the sleeve 16. In order to cut off all discharge paths between the electrodes, except through the discharge openings 11 in the washers 10, an additional insulating washer 20 is placed over the top of the electrode assembly and is provided with a single central opening for the purpose of enabling an electrical connection to be made to the anode 3. However, the washer 20 covers the openings in the washers 10 through which the sleeves 16 and 19 project and also covers the upper ends of the rivets 12. The washers 10 and also the washer 20 fit snugly within the side walls of the envelope 1, the washer 20 being retained in place

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by coming into contact with the lower portion of the upper curved section of the inner walls of said envelope. The anode 3 has welded to its upper surface a conducting stub 21 to which is welded a flexible lead-in conductor 22. This lead-in conductor is sealed through the top of the envelope 1 and is connected to an external connector cap 23 cemented to the top of said envelope.

As is well known, if two electrodes in an ionizable gas are brought closer together, the voltage at which the gas breaks down and at which a discharge is initiated between said electrodes falls until a predetermined distance is reached at which said breakdown voltage is a minimum. This distance is known as the minimum breakdown distance. If the separation between the electrodes is decreased still further, the voltage at which breakdown occurs is increased. In the present arrangement the cathode 2 is preferably spaced from the lower cathanode grid 4 by substantially the minimum breakdown distance. Since the cathode 2 is made of a ribbon having a substantial width, it will be seen that if any substantial part of the active surface of the cathode 2 is at the minimum breakdown distance from the lower cathanode grid 4, breakdown at the minimum voltage value will occur between said electrodes. The anode 3 is spaced from the upper cathanode electrode 4 by a distance substantially less than the minimum breakdown distance. The spacing between the electrode 5 and each of the adjacent grids 4 is preferably substantially the same as that of the spacing of the anode 3 from the upper grid 4. In a practical case with the above-mentioned krypton-xenon mixture at 10 mm., the cathode was spaced about .040" from the lower grid 4, while the spacings between the electrodes 3, 4 and 5 were each about .015".

The tube described above may be utilized in a circuit such as that illustrated in Fig. 3, wherein the same reference numerals are applied where the elements are identical with those of Figs. 1 and 2. In this circuit the cathode 2 is connected by its conductor 9 to ground. The anode 3 is connected through a suitable load 25, a conductor 26, and a source of potential 27, such as a battery, to ground. The battery 27 is polarized so as to make the anode 3 positive with respect to its cathode. The battery 27 is also connected through the conductor 26, a cathanode resistance 29, and a cathanode condenser 30 to the ground conductor 9. The cathanode 4 is connected by means of its conductor 15 to a point intermediate the resistance 29 and the condenser 30. A signal input voltage may be supplied to the primary winding 31 of a signal transformer 32 having a secondary winding 33. One end of said secondary winding is connected through a condenser 34 to the conductor 18 leading to the control grid 5. The other end of said secondary winding 33 is connected by a conductor 35 to the conductor 15 connected to the cathanode 4. A leakage grid resistance 36 is connected between the conductors 18 and 15.

During the standby condition, in which no signal voltage is supplied to the primary winding 31, the operation of the system illustrated in Fig. 3 is illustrated by the curves of Fig. 4. Under these conditions, relaxation oscillations will be generated between the cathode 2 and the cathanode 4. These said relaxation oscillations are the result of the periodic charging and discharging of the condenser 30. The curve *a* in Fig. 4

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represents the manner in which the voltage on condenser 30 varies during such charging and discharging. This voltage rises along said curve *a* until a point *x* is reached when the voltage between the cathode 2 and the cathanode 4 is at its breakdown value. Thereupon an ionizing discharge is initiated between said electrodes and the condenser 30 is discharged by the resulting flow of current between said electrodes. Thus, when the discharge is initiated at the point *x*, a current impulse *b* will flow between the cathode 2 and the cathanode 4. Due to the flow of the current impulse *b*, the voltage on the condenser 30 falls as indicated by the curve *a* beyond the point *x*. When this voltage falls to a value less than that which it is sufficient to maintain the discharge, the current *b* decreases to substantially zero and the discharge between the cathode 2 and the cathanode 4 is extinguished. Thereupon condenser 30 is recharged and the cycle is repeated. The cathanode resistance 29 is sufficiently large so that the charging current to the condenser 30 remains at a substantially uniform value. This charging current I_{ka} is represented by the curve *c* in Fig. 4. The current I_{ka} is the standby drain which the battery 27 is called upon to deliver. In a practical case this standby current has been about 25 microamperes. This value is so small that the drain on the battery is negligible and its shelf life is in nowise decreased thereby.

With the present device only a very small bias on the grid 5 is required to prevent a discharge from being propagated to the anode 3. A typical characteristic curve of the grid 5 is shown in Fig. 5 in which the value of D. C. grid bias voltage required to prevent a discharge to the anode 3 is shown with various values of voltage of the battery 27 and various values of capacity of the cathanode condenser 30. Values of grid voltage more positive than those indicated will cause a discharge to be propagated to the anode 3.

In the circuit Fig. 3, the grid 5, due to the presence of the high leakage grid resistance 36, will assume a negative bias sufficient to hold off the anode discharge under conditions of zero signal voltage. The electron flow to the grid 5 to maintain said negative bias is only about .2 microamperes in a practical case.

If a signal voltage is applied to primary winding 31, this signal voltage will be transferred through the transformer 32 and the condenser 34 and the grid 5. When the signal voltage swings in a positive direction so as to move the potential of the grid 5 more positive than the critical grid voltage, as shown for example in Fig. 5, electrons of sufficiently high speed projected into the space between the cathanode grids 4, 4 will be caused to pass in sufficient numbers to the anode 3 to initiate a self-sustaining discharge between the anode 3 and its cathode 2. As will be explained below, such projection of electrons occurs primarily at the beginning of each of the cathanode current impulses *b* as shown in Fig. 4. When the flow of current is initiated to the anode 3, the self-sustaining discharge which takes place is propagated throughout the entire discharge path between the cathode 2 and the anode 3. This causes the voltage drop between the cathanode 4 and the cathode 2 to fall to substantially the normal glow discharge value and thereafter the voltage drop persists at this value. Under these conditions, the relaxation oscillations will be suppressed and the device continues to operate with a substan-

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tially steady discharge, for example, of the order of five milliamperes between the cathode 2 and the anode 3. In order to restore the circuit to its standby condition, it would be necessary to interrupt the flow of current in this circuit at least momentarily as by opening a switch 37 at the circuit leading from the battery 21. A typical operating characteristic curve of the grid 5 is shown in Fig. 6 in which the critical R. M. S. value of signal voltage necessary to fire the tube is shown with various values for the capacity of the cathanode condenser 30 and for various values of the grid resistance 36.

The effectiveness and reliability of the tube and the system as described above are due, I believe at least in part, to the stabilizing of the tube conditions by the relaxation oscillations. The breakdown of the discharge space between the cathode 2 and the cathanode 4 tends to occur always at the same voltage, which voltage is dependent upon the gas, its pressure, the conditions of the surface of the cathode 2 and the spacing between the cathode 2 and the cathanode 4. Thus, the actual voltage of the battery 21 may vary over wide limits and still the voltage on the cathanode will rise along the curve *a* (Fig. 4), and the cathanode space will break down at substantially the same peak value *x*. It also appears that the speed at which the electrons from the cathanode space are projected into the space between the cathanode grids 4, 4 is a primary controlling condition in so far as the control exerted by the control grid 5 and the initiation of conduction to the anode 3 are concerned. During the non-conducting portion of the relaxation oscillation cycle, substantially no electrons are projected into the space between the cathanode grids 4, 4 and any electrons which do enter this space are of relatively low speed. When, however, the gap between the cathode 2 and the cathanode 4 breaks down, the discharge is rapidly propagated between said electrodes, and substantially at that instant electrons are projected through the lower cathanode grid 4 at substantially the maximum voltage attained by the cathanode 4 with respect to the anode 3. Thereafter the speed of the projected electrons falls off substantially as indicated by the falling portion of the curve *a* beyond the point *x* in Fig. 4. As already indicated the value of the cathanode voltage at the point *x* is fixed by the tube constants, and thus it will be seen that the critical control voltage is fixed largely by said tube constants and varies over a relatively small range with additional circuit variations. The most important variation in circuit conditions which is met with in practice is the variation of the battery voltage due, for example, to the aging of the battery. The extent to which the critical grid voltage is independent of such battery voltages is typically illustrated in Fig. 5. In this figure it will be seen that with various capacities for the cathanode condenser 30, the battery voltage may vary from 140 to 180 volts and yet the critical grid voltage remains below about one volt.

From the foregoing it will be seen that a tube and system, constructed and operated in accordance with my invention, satisfy the objects of this invention to a remarkable degree.

Of course it is to be understood that this invention is not limited to the particular details as described above as many equivalents will suggest themselves to those skilled in the art. For example, instead of using a source of direct current to energize the system and interrupting the anode

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discharge by a switch 37, the tube could be made to periodically discharge a condenser, or the anode voltage could be a pulsating or alternating voltage and in this way the anode discharge would be automatically interrupted in a periodic manner. Certain principles of this invention might likewise be utilized in a system in which the glow discharge cathode is replaced by a thermionic type of cathode. Various other equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. An electrical system comprising an electrical discharge tube containing an ionizable gas at a substantial pressure, a cathode, an anode for maintaining a discharge to said cathode, an auxiliary electrode for maintaining an auxiliary intermittent discharge to said cathode, and a control electrode interposed in the discharge path between said cathode and anode and adapted to control the initiation of said discharge between said anode and cathode, a circuit for applying a voltage between said cathode and anode tending to cause a discharge between them, a circuit interconnecting said cathode and auxiliary electrode for causing said intermittent discharge, and means for applying a signal voltage to said control electrode to cause said discharge between said anode and cathode to be initiated during an impulse of said intermittent discharge.

2. An electrical system comprising an electrical discharge tube containing an ionizable gas at a substantial pressure, a glow discharge cathode, an anode for maintaining a discharge to said cathode, an auxiliary electrode for maintaining an auxiliary intermittent discharge to said cathode, and a control electrode interposed in the discharge path between said cathode and anode and adapted to control the initiation of said discharge between said anode and cathode, a circuit for applying a voltage between said cathode and anode tending to cause a discharge between them, a circuit interconnecting said cathode and auxiliary electrode for causing said intermittent discharge, and means for applying a signal voltage to said control electrode to cause said discharge between said anode and cathode to be initiated during an impulse of said intermittent discharge.

3. An electrical system comprising an electrical discharge tube containing an ionizable gas at a substantial pressure, a cathode, an anode for maintaining a discharge to said cathode, an auxiliary electrode for maintaining an auxiliary intermittent discharge to said cathode, and a control electrode interposed in the discharge path between said cathode and anode and adapted to control the initiation of said discharge between said anode and cathode, a circuit for applying a voltage between said cathode and anode tending to cause a discharge between them, an oscillatory circuit interconnecting said cathode and auxiliary electrode for causing said intermittent discharge, and means for applying a signal voltage to said control electrode to cause said discharge between said anode and cathode to be initiated during an impulse of said intermittent discharge.

4. An electrical system comprising an electrical discharge tube containing an ionizable gas at a substantial pressure, a cathode, an anode for maintaining a discharge to said cathode, an auxiliary electrode for maintaining an auxiliary intermittent discharge to said cathode, and a con-

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control electrode interposed in the discharge path between said cathode and anode and adapted to control the initiation of said discharge between said anode and cathode, a circuit for applying a voltage between said cathode and anode tending to cause a discharge between them, a relaxation oscillation circuit interconnecting said cathode and auxiliary electrode for causing said intermittent discharge, and means for applying a signal voltage to said control electrode to cause said discharge between said anode and cathode to be initiated during an impulse of said intermittent discharge.

5. An electrical system comprising an electrical discharge tube containing an ionizable gas at a substantial pressure, a cathode, an anode for maintaining a discharge to said cathode, an auxiliary electrode for maintaining an auxiliary intermittent discharge to said cathode, and a control electrode interposed in the discharge path between said cathode and anode and adapted to control the initiation of said discharge between said anode and cathode, a circuit for applying a voltage between said cathode and anode tending to cause a discharge between them, a condenser connected between said cathode and auxiliary electrode, a high resistance connected between said control electrode and said auxiliary electrode, and means for applying a signal voltage to said control electrode to cause said discharge between said anode and cathode to be initiated during an impulse of said intermittent discharge.

6. An electrical system comprising an electrical discharge tube containing an ionizable gas as

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a substantial pressure, a cathode, an anode for maintaining a discharge to said cathode, an auxiliary electrode for maintaining an auxiliary intermittent discharge to said cathode, and a control electrode interposed in the discharge path between said cathode and anode and adapted to control the initiation of said discharge between said anode and cathode, a circuit for applying a voltage between said cathode and anode tending to cause a discharge between them, a condenser connected between said cathode and auxiliary electrode, a source of potential connected in series with a high impedance across said condenser for producing relaxation oscillations causing said intermittent discharge, a high resistance connected between said control electrode and said auxiliary electrode, and means for applying a signal voltage through a condenser to said control electrode to cause said discharge between said anode and cathode to be initiated during an impulse of said intermittent discharge.

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