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ELECTRONIC SWITCHING APPARATUS

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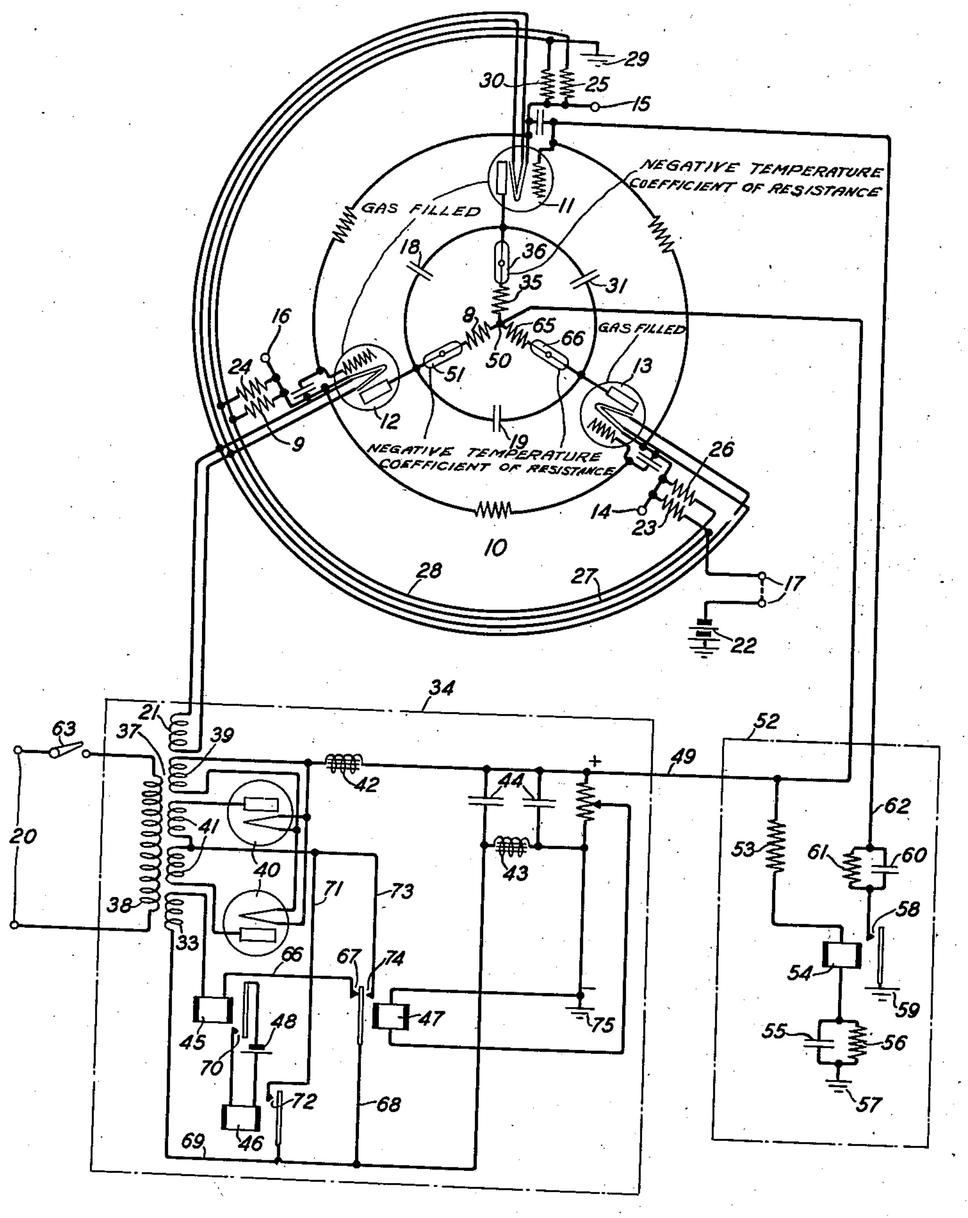

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ELECTRONIC SWITCHING APPARATUS

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This invention relates to electronic switching apparatus, and more particularly to an arrangement for controlling the time constant of individual electronic tubes embodied in such apparatus.

Heretofore, electronic switching apparatus has been employed for collecting signals from geographically spaced antennas such that thermionic amplifiers associated with each antenna are rendered operative as electronic tubes individual to each antenna ionize seriatim. Signals of at least a predetermined magnitude received over the antenna connected to the operative amplifiers serve to arrest ionization of the electronic tubes. This condition obtains so long as the signals maintain the predetermined magnitude. Signals below such magnitude allow the electronic tubes to resume ionization which continues until another antenna and the operative amplifiers associated therewith supply signals of requisite magnitude to arrest ionization. Such apparatus is disclosed in the patent of A. P. King et al. No. 2,136,621, granted November 15, 1938.

The ionization period of the individual electronic tubes embodied in apparatus according to the above patent is controlled by a grid time constant R_tC_t. A residual charge on the capacity C_t may occasion inaccuracies in such time constant, particularly if there is a tendency to reduce it to a relatively small value. Accordingly, this invention contemplates an electronic switching arrangement in which the time constant of the individual gaseous discharge tubes is independent of the charge on the capacity C_t.

A general object of the invention is to control the time constant of the individual gaseous discharge tubes embodied in electronic switching apparatus.

Another object is to precondition the individual tubes before a flow of space current is effected therein.

A further object is to institute ionization in a certain tube in advance of others in such apparatus.

The invention will be more readily understood from the following description taken together with the accompanying drawing, the single figure of which illustrates the invention in its preferred embodiment.

As hereinbefore mentioned, a plurality of gaseous discharge tubes has been arranged such that a discrete voltage pulse is effected on the occasion of the institution of ionization in each thereof. This is caused to take place seriatim. Each ionization period depends upon the time constant R_tC_t of the individual tubes. Thus, ionization of one tube serves to charge a capacity C_t associated with a succeeding tube until such charge nullifies the grid biasing voltage normally applied to the latter tube whereupon ionization is instituted therein.

In a preferred embodiment, the invention comprises a resistance having a negative temperature coefficient of resistance, such as boron, pitchblende, etc., disposed in the anode circuit of each tube to control the time constant thereof. As each tube is ionized, the temperature of such resistance increases due to a flow of space current in the anode-cathode circuit thereof. This reduces the effective value of such anode resistance so that the flow of space current in the anode-cathode circuit of the ionized tube increases correspondingly. This causes the production of an increasing voltage which at a certain magnitude serves to render ineffective the normal grid biasing voltage applied to the next succeeding tube, thereby effecting ionization therein.

Another feature tending to extend the useful life of the individual gaseous discharge tubes embodies a network of electromagnetic relays to delay the application of the anode voltage to the tubes until the cathodes thereof have attained a certain temperature. Also, a further feature includes the starting of the switching apparatus such that ionization is instituted only in one tube at a given time. As the latter involves the presence of a grid biasing voltage, the application of the anode voltage serves to energize an electromagnetic relay which applies ground momentarily to the grid of a certain tube. As a consequence, this tube ionizes in advance of others.

Referring to the drawing, a multiple tube switching circuit **10**, comprising gas-filled electron discharge tubes **11**, **12** and **13**, is arranged so that the individual tubes ionize seriatim in a counter-clockwise direction in a manner that will be subsequently explained. The number of such devices is equal to the number of switching operations to be performed. For example, the switching circuit **10** may be utilized in a signal collecting system to render operative a pair of amplifiers and an antenna associated therewith, not shown, in the manner pointed out in the patent of A. P. King et al., supra. Accordingly, the discrete voltage pulses effected to accomplish such operation are available at terminals **14**, **15** and **16** relative to ground while a signal voltage to maintain any one of the tubes in the ionized condition is supplied across the terminals 17, 17. A more detailed description of this arrangement may be had by referring to the patent of A. P. King et al., supra.

The cathode heaters of the tubes 11, 12 and 13 are energized by secondary winding 21 of a transformer 37 whose primary winding is connected to commercial power input terminals 20, 20 which are applied across a suitable alternating current source, not shown. Steady grid biasing current flows in a circuit comprising grounded battery 22, across the terminals 17, 17 connected to lead 27, resistances 23 and 26 associated with the tube 13, lead 28 and ground 29. As the resistances 24 and 9 associated with the tube 12 bridge the leads 27 and 28 in series, the steady biasing current from the biasing source 22 also flows therethrough. Likewise, as the resistances 25 and 30 associated with the tube 11 shunt the leads 27 and 28 in series, the steady biasing current from the biasing source 22 flows therethrough.

Consequently, the voltages developed across the resistances 23, 24 and 25 serve to supply the necessary bias to the grids of the respective tubes 11, 13 and 12 to maintain the latter normally in a deionized condition. The negative biasing voltages developed across the resistances 30, 9 and 26 prevent ionization of the respective tubes 11, 12 and 13 except in a manner that will be presently explained. The anodes of tubes 11 and 12 are directly joined by a capacity 18; those of tubes 12 and 13 by a capacity 19; and those of tubes 13 and 11 by a capacity 31. In series with the anodes of the respective tubes 11, 12 and 13 are resistances 35, 8 and 65. A circuit organization of this general character has been utilized in an antenna switching system in the manner pointed out in the patent of A. P. King et al., supra.

In accordance with this invention, resistances 36, 51 and 66, connected in series with the anodes of the respective tubes 11, 12 and 13, comprise boron, pitchblende, or other material having a negative temperature coefficient of resistance. The thermal inertia of these resistances serves to control the time constants of the individual gaseous discharge tubes in a manner that will be hereinafter explained.

A power supply 34 includes the transformer 37 whose primary winding 38 is connected across the commercial power terminals 20, 20 and whose secondary winding 39 energizes the cathodes of a pair of rectifier tubes 40, 40. The anodes of the latter are energized by means of a pair of secondary windings 41, 41. Inductances 42 and 43, together with capacities 44, 44, constitute a low-pass filter for reducing ripple voltages. Secondary winding 33 is connected both to the filter and an electromagnetic relay 45 with which is associated an electromagnetic relay 46 and a source 48 of direct current. Relay 45 is preferably a slow-acting or thermal type. Disposed in the output of the filter is an electromagnetic relay 47 whose contacts are associated with the relays 45 and 46 and the secondary windings 41, 41 in a manner that will be presently described. A lead 49 connects the positive terminal of the filter to a terminal 50 which is common to the anodes of the tubes 11, 12 and 13.

An automatic starting circuit 52 serves to institute ionization in the tubes 11, 12 and 13, when starting, such that but one thereof is ionized at a time, thereby conditioning the switching circuit 10 for the operations that will be subsequently explained. This starting circuit comprises a resistance 53 having one terminal connected to the lead 49 and its opposite terminal connected through the winding of an electromagnetic relay 54 and a capacity 55 and resistance 56 in parallel to ground 57. A normally open contact 58 associated with the relay 54 and grounded at 59 may be applied through a capacity 60 and resistance 61 in parallel and a lead 62 to the grid of tube 11 as will be subsequently mentioned.

In operation, a switch 63, connected in series with one of the input terminals 20, is closed to apply an alternating current voltage simultaneously to the cathode heaters of tubes 11, 12 and 13 from secondary winding 21. At the same time, a voltage is also impressed by means of transformer 37 on the input of the power supply 34. After a predetermined interval, say, for example, of the order of one minute, the thermal relay 45 operates due to its operating circuit comprising the secondary winding 33, operating winding of relay 45, lead 66, normally closed front contact 67 of relay 47, lead 68 and lead 69 returning to the secondary winding 33.

This causes contact 70 associated with relay 45 to apply the direct current source 48 to the operating winding of the relay 46. The latter operates to complete the alternating current input circuit for the rectifiers 40, 40 as the mid-point of the secondary windings 41, 41 applied to the anodes thereof is now connected by lead 71, closed contact 72 of relay 46 and lead 69, returning to the input of the filter. Now, the direct current voltage available across the output of the filter is applied to relay 47 which operates to lock in the alternating current input circuit for the rectifiers 40, 40 by means of a circuit comprising the mid-point of the secondary windings 41, 41, lead 73, closed back contact 74 of relay 47, lead 68 and lead 69 returning to the input of the filter. As the front contact 67 of relay 47 is now opened, relay 45 is deenergized to open the operating circuit of relay 46 which also becomes deenergized. This interrupts the alternating current input circuit completed via lead 71 and closed contact 72 of relay 46 as hereinbefore mentioned.

Anode voltage for the tubes 11, 12 and 13 is supplied thereto on the lead 49. In connection therewith the time delay provided by the thermal relay 45 serves to withhold the application of this voltage until the cathode heaters of the gas discharge tubes 11, 12 and 13 and of the rectifier tubes 40, 40 attain normal operating temperatures. This tends to extend the useful life of the respective tubes.

At the instant the direct current voltage becomes available at the output of the filter embodied in the power supply 34, a surge of current passes through the resistance 53 and operating winding of the relay 54 to charge the capacity 55. Relay 54 operates to close its contact 58. This applies ground to the grid of tube 11 through a circuit comprising ground 59, closed contact 58, capacity 60 and lead 62. Consequently, the normal biasing voltage developed across the resistance 23 and impressed on the grid of tube 11, as previously explained, is now grounded. In other words, a surge of current passing through the resistance 23 charges the capacity 60, thereby depriving the grid of tube 11 of its normal biasing voltage. This will cause the tube 11 to ionize in advance of the tubes 12 and 13, both of whose grids are supplied with normal biasing voltage.

The resistance 56 connected in parallel with the capacity 55 serves to discharge the condenser 55 during intervals of non-use of the starting circuit 52. For the constants, resistance 53=50,000 ohms, capacity 55=0.1 micromicrofarad and the winding of relay 54=1500 ohms, the surge of current through the latter closed the contact 58 for a period of the order of 1/100 second. In this illustration the resistance 56 is 500,000 ohms, thereby giving the capacity 55 in parallel therewith a time constant of substantially 0.05 second. Capacity 60 is approximately 75 micromicrofarad and the resistance 61 in parallel therewith may have any suitable value to discharge the capacity 60 during periods of non-use of the starting circuit 52.

The switching circuit 10 is so arranged that the tubes ionize in the counter-clockwise order of 11, 12, 13, 11, 12 . . . . As the tube 11 is now ionized in the manner above described, space current flows in its anode-cathode circuit which includes ground 75 embodied in the filter of the power supply 34, lead 49, common terminal 50, resistance 35, resistance 36 having negative temperature coefficient of resistance, anode-cathode circuit of tube 11, resistance 30 and ground 29. Prior to the ionization of tube 11, there was no flow of space current in the resistance 36 which in such condition manifests its maximum resistance. However, when the tube 11 was ionized, the flow of space current in the resistance 36 began to increase the temperature of the latter and thereby to reduce the effective resistance thereof.

As the temperature of the resistance 36 increases, the amount of the flow of space current in the anode-cathode circuit of tube 11 increases correspondingly. This means that there is a gradually increasing positive voltage being developed across the resistance 30 embodied in the anode-cathode circuit of tube 11 as hereinbefore mentioned. This positive voltage increases until it has attained an amount which is sufficient to render ineffective the negative biasing voltage produced across the resistance 25 and applied to the grid of the tube 12. This tends to render the grid of the tube 12 less negative until the value of the grid-trip voltage thereof is attained, whereupon the ionization of tube 12 is instituted to produce a flow of space current in its anode-cathode circuit.

Once ionization is instituted in the tube 11, it may be terminated only by removing the positive voltage from the anode thereof, which voltage in this illustration is substantially 150 volts. This is accomplished by means of the anode resistances 35 and 8 and the capacity 18, all of which are utilized as follows: The initial anode voltage of 150 volts applied to anodes of the tubes 11 and 12 was decreased, for example, by 110 volts, when ionization was instituted in each thereof, that is, to 40 volts. When tubes 11 and 12 were in the deionized condition, each side of the capacity 18 had a potential of 150 volts acting through the resistances 35 and 8. As tube 11 was the first to ionize, the potential on both sides of the capacity 18 was decreased, for the purpose of illustration, to 40 volts for an instant.

Accordingly, the voltages applied to the anodes of the tubes 11 and 12 were also lowered to 40 volts for the same instant. As tube 11 continues to ionize, the side of capacity 18 connected thereto will remain at a potential of 40 volts while the side connected to the deionized tube 12 will be returned to a potential of 150 volts. When ionization was instituted in tube 12, the potential applied to both sides of the capacity 18 was again lowered by 110 volts, for an instant. Hence, the potential applied to the anodes of the tubes 11 and 12 was also lowered by 110 volts, for the same instant.

As the potential on the side of capacity 18 connected to tube 11 was 40 volts, it is now decreased, for an instant, by 110 volts, that is, by the algebraic sum of (+) 40 and (—) 110, or to an instantaneous value of (—) 70 volts. For the same instant, the potential impressed on the anode of tube 11 was also (—) 70 volts. The side of condenser 18 connected to tube 12 was also lowered by 110 volts and now remains at a steady 40 volts. The change of the anode voltage of tube 11 from (+) 40 volts to an instantaneous (—) 70 volts serves to extinguish the ionization of tube 11, thereby terminating the flow of space current therein. Consequently, the initial 150 volts is again applied to the anode of tube 11 and to the side of capacity 18 connected thereto. At the same time, a potential of 40 volts is applied to the anode of tube 12 and to the side of capacity 18 connected thereto. For a more detailed explanation of the extinguishment of ionization in tube 11, reference is made to the patent of A. P. King et al., supra.

Similarly, as the tube 12 ionizes, space current flows in its anode-cathode circuit comprising ground 75 embodied in the filter of the power supply circuit 34, lead 49, common terminal 50, resistance 8, resistance 51 having a negative temperature coefficient of resistance, anode-cathode circuit of tube 12, resistance 9, lead 28 and ground 29. As the temperature of the resistance 51 increases and, therefore, as its effective resistance value decreases, the amount of the flow of space current in the anode-cathode circuit of tube 12 increases correspondingly. Consequently, there is an increasing positive voltage developed across the resistance 9. This positive voltage increases until it has attained an amount which is sufficient to render ineffective the negative biasing voltage produced across the resistance 24 and applied to the grid of tube 13, as hereinbefore explained. This tends to render the grid of tube 13 less negative until the value of the grid-trip voltage thereof is attained whereupon ionization of tube 13 is instituted to produce a flow of space current in its anode-cathode circuit. At the instant tube 13 was ionized, the side of the capacity 19 connected to tube 12 has its potential lowered to an instantaneous (—)70 volts, which voltage was applied to the anode of tube 12 for the same instant to extinguish ionization therein, and the side of the capacity 19 connected to tube 13 was lowered to (+)40 volts.

Likewise, as the tube 13 ionizes, space current flows in the anode-cathode circuit comprising ground 75 embodied in the filter of the power supply 34, lead 49, common terminal 50, resistance 65, resistance 66 having a negative temperature coefficient of resistance, anode-cathode circuit of tube 13, resistance 26, lead 28 and ground 29. As the temperature of resistance 66 increases and, therefore, as its effective resistance value decreases, the amount of the flow of space current in the anode-cathode circuit of tube 13 increases correspondingly. Accordingly, there is an increasing positive voltage produced across the resistance 26. This positive voltage increases until it has attained an amount which is adequate to counteract the negative biasing voltage produced across the resistance 23 and applied to the grid of tube 11. This tends to render the grid of tube 11 less negative until the value of the grid-trip voltage thereof is reached, whereupon the ionization of tube 11 is instituted to effect a flow of space current in the anode-cathode circuit thereof. At the instant tube 11 was ionized, the side of capacity 31 joined to tube 13 had its potential reduced to an instantaneous (−)70 volts, which voltage was applied to the anode of tube 13 for the same instant to extinguish ionization therein, and the side of the capacity 31 connected to tube 11 was lowered to (+)40 volts.

As the tubes 11, 12 and 13 ionize in the order mentione dhereinbefore, the voltages developed across the respective resistances 30, 9 and 26 and available at the terminals 15, 16 and 14 serve to provide pulses which may render operative a pair of amplifiers and the antenna associated therewith in a signaling collecting system or perform other functions as pointed out in my patent, supra. Thus, the period of ionization of the individual tubes 11, 12 and 13 is controlled by the respective resistances 36, 51 and 66 whose individual value, when cold, may be of the order of 20,000 to 100,000 ohms and, when heated, may be reduced to 1000 ohms or less. The time required to effect such resistance change is a function of the thermal inertia of a particular resistance unit, which inertia is dependent upon the mass, heat capacity, heat radiation and loss of heat by conduction. These resistances are capable of effecting time constants of the order of a fraction of a second, and may be mounted in the envelope of the individual gas tubes when vacuum mounting is required.

What is claimed is:

1. An electronic switching apparatus comprising in combination a plurality of gaseous discharge tubes each of which embodies a grid, a cathode and an anode, circuit means embodying said tubes and arranged to institute ionization in each thereof seriatim to produce discrete voltage pulses, said circuit means comprising means including a resistance element individual to each tube to apply biasing voltage to the grid of a next succeeding tube to render all said tubes normally inoperative, and means to control the time constant of ionization of each tube including a pair of resistance elements connected in series in the anode-cathode circuit of each of said tubes, one of said pair of resistance elements providing a voltage to counteract the biasing voltage applied to said next succeeding tube and the other of said pair of resistance elements possessing a negative temperature coefficient of resistance; means to apply voltage to the anodes of said tubes, and electromagnetic means responsive to the initial operation of said anode voltage means to apply ground potential momentarily to the grid of a certain tube to effect ionization therein in advance of the other tubes so that the flow of space current in the anode-cathode circuit of said ionized certain tube increases as the effective resistance of said resistance element connected in the anode-cathode circuit of said ionized certain tube and possessing the negative temperature coefficient of resistance decreases in response to the increase in the temperature thereof due to the increase in the flow of space current to cause a corresponding increase in the counteracting voltage produced across said one resistance element of said pair of resistance elements individual to said ionized certain tube to render ineffective the grid biasing voltage applied to the grid of said next succeeding tube to institute ionization therein, each pair of resistance elements connected in the anode-cathode circuit of each tube and each grid biasing resistance element individual to each tube functioning in like manner to institute ionization in each next succeeding tube.

2. An electronic switching apparatus comprising in combination a plurality of gaseous discharge tubes each of which embodies a grid, a cathode and an anode, circuit means embodying said tubes and arranged to institute and extinguish ionization in each thereof seriatim to produce discrete voltage pulses, said circuit means comprising a plurality of capacities, circuit connections to connect the terminals of each of said capacities to the anodes of adjacent pairs of tubes, a source of grid biasing voltage, circuit connections to apply said grid biasing source to the grids of said tubes, a resistance element individual to each of said tubes and disposed in said grid biasing connections to apply biasing voltage to the next succeeding tube to normally render all said tubes inoperative, circuit connections to connect the cathodes of said tubes including a resistance element individual to the anode-cathode circuit of each tube to provide a voltage to counteract the grid biasing voltage applied to the next succeeding tube, and circuit connections including a common terminal and a resistance element in series therewith and individual to the anode-cathode circuit of each of said tubes, each of said last-mentioned resistance elements possessing a negative temperature coefficient of resistance; means to energize the cathodes of said tubes, means to supply voltage to said common terminal and thereby to the anodes of said tubes so that the same voltage is applied to both terminals of each of said anode capacities, and means responsive to said anode voltage to reduce the grid biasing voltage on a certain tube, when starting, to a value which is less by at least a predetermined amount than the grid biasing voltage applied to the other tubes so as to institute ionization in said certain tube in advance of the other tubes, said last-mentioned means comprising electromagnetic means operated in response to a surge of the anode voltage to apply momentarily ground potential to the grid of said certain tube, the flow of space current in the anode-cathode circuit of said certain tube increasing as the effective resistance of said resistance element connected therein with said common terminal decreases with increases in the temperature thereof to cause corresponding increases in the voltage produced across said counteracting voltage resistance element individual to the anode-cathode circuit of said certain tube until the biasing voltage impressed on the next succeeding tube is rendered sufficiently less negative to institute ionization therein, the ionization of said next succeeding tube serving to change from a positive to a negative value the voltage applied to the terminal of said capacity connected to the anode of said certain tube to extinguish ionization therein, said resistance elements and said capacity associated with each adjacent pair of said tubes functioning in like manner to institute ionization in the next succeeding tube and to extinguish ionization in the next preceding tube, each cycle of instituting ionization in one tube and extinguishing the same in the other tube effecting a discrete voltage pulse.

3. In combination, a gaseous discharge tube having a grid, means to apply a biasing voltage to the grid to maintain said tube normally in a non-ionized state, means to counteract the biasing voltage to institute ionization in said tube, means to extinguish ionization in said tube, and means having a negative temperature coefficient of resistance and responsive to a flow of space current due to ionization in said tube to actuate said counteracting means to determine the time interval of ionization of said tube.

4. In combination, a plurality of gaseous discharge tubes each having a grid, means to apply a biasing voltage to the grids to maintain said tubes normally in a non-ionized state, and means to render said biasing means ineffective with regard to individual tubes such that ionization is instituted in said tubes in sequence to produce a series of discrete voltage pulses, said rendering means including a resistance element having a negative temperature coefficient of resistance and individual to each tube to be responsive to a flow of space current occasioned by ionization therein to actuate said rendering means to control the time constant of each of said voltage pulses.

5. In combination, a plurality of gaseous discharge tubes each having a grid and anode, means to apply a negative biasing voltage to the grids to maintain said tubes normally in a non-ionized state, means to apply a voltage to the anodes of said tubes, electromagnetic means responsive to an initial operation of said anode voltage means to apply ground potential momentarily to the grid of a certain tube to effect ionization therein in advance of the other tubes, and means operated automatically to render the biasing voltage applied to the grid of each tube less negative by an amount which is sufficient to institute ionization in said tubes in sequence to produce a series of discrete voltage pulses, said automatic means including a plurality of resistance elements connected in said anode voltage means such that each resistance element is individual to one tube, each of said resistance elements possessing a negative temperature coefficient of resistance and responsive to a flow of space current in a respective ionized tube to control said automatic means such that each tube is ionized for a predetermined interval of time.

6. In combination, a plurality of gaseous discharge tubes each embodying a grid, a cathode and an anode, and circuit means embodying said tubes and arranged to institute and extinguish ionization in each tube seriatim to produce a series of discrete voltage pulses, said circuit means comprising means connecting the grids and cathodes of said tubes and including a resistance element individual to each tube to produce a voltage to bias the grid of the next succeeding tube to maintain said tubes in a non-ionized state, and means connecting the anode-cathode circuits of said tubes and including a resistance element individual to each anode-cathode circuit to produce a voltage to counteract the biasing voltage applied to the grid of the next succeeding tube to institute ionization therein, and a resistance element possessing a negative temperature coefficient of resistance and individual to each anode-cathode circuit to control the time constant of ionization of each tube, said last-mentioned resistance element, in response to a flow of space current in the anode-cathode circuit of a certain ionized tube, decreasing its effective resistance so that an increase in the space current causes a corresponding increase in the voltage produced by said counteracting voltage resistance element individual to the anode-cathode circuit of said certain ionized tube until the biasing voltage on the grid of said next succeeding tube is sufficiently counteracted to allow ionization therein.

7. In combination, a plurality of gaseous discharge tubes each embodying a grid, a cathode, and an anode, means connecting the grids and cathodes to apply biasing voltage to the grids to maintain said tubes normally in a non-ionized state, means to apply a voltage having one polarity to the anodes of said tubes, means connecting the cathodes of said tubes and responsive to a flow of space current due to ionization in a certain tube to control said grid biasing means such that the grid biasing voltage applied to the next succeeding tube is rendered sufficiently less negative to effect ionization in said latter tube, means embodied in said anode voltage means and responsive to the simultaneous ionization in both said certain tube and said next succeeding tube to control said anode voltage means to apply to the anode of said certain tube a substantially instantaneous voltage having a polarity opposite to the polarity of the voltage initially applied thereto to extinguish ionization in said certain tube, the institution of ionization in each tube producing a voltage pulse, and means having a negative temperature coefficient of resistance and embodied in said anode voltage means to be responsive to a flow of space current due to ionization in said certain tube to actuate said biasing voltage controlling means to fix the time interval of each of said voltage pulses.

8. An electronic system for producing voltage pulses comprising a plurality of gaseous discharge tubes each embodying a grid, a cathode and an anode, means including a plurality of resistance elements connecting the grid and cathode of each tube to the grid and cathode of the next succeeding tube such that a voltage developed across a resistance element individual to each tube serves to bias the grid of the next succeeding tube to maintain said tubes in a non-ionized state, means to apply a voltage having one sign to the anodes of said tubes, means including a plurality of resistance elements connecting the anode-cathode circuits of said tubes such that a voltage developed across a resistance element individual to the anode-cathode circuit of a certain tube in an ionized state serves to counteract the biasing voltage applied to the grid of said next succeeding tube to institute ionization in said latter tube, means embodied in said anode voltage means and responsive to simultaneous ionization in both said certain tube and said next succeeding tube to apply a voltage having another sign to the anode of said certain tube to extinguish ionization therein, each cycle of instituting ionization in one tube and extinguishing ionization in another tube being accomplished in sequence to produce a series of discrete voltage pulses, and means comprising a resistance element having a negative temperature coefficient of resistance and individual to the anode-cathode circuit of each tube to be responsive to a flow of space current due to ionization in said certain tube to control the voltage developed across said counteracting voltage resistance element individual to the anode-cathode circuit of said certain tube and there-

by to control the time constant of each pulse of the series of discrete voltage pulses.

9. An electronic apparatus for producing voltage pulses comprising a plurality of gaseous discharge tubes each embodying a grid and an anode, means to apply biasing voltage to the grids to maintain said tubes normally in a non-ionized state, means to apply a voltage having one polarity to the anodes of said tubes, means including an electromagnetic relay and responsive to an initial operation of said anode voltage means to apply ground potential momentarily to the grid of a certain tube to institute ionization therein in advance of the other tubes, means responsive to ionization in said certain tube to counteract the biasing voltage on the grid of a next succeeding tube to institute ionization in said latter tube, means embodied in said anode voltage means and responsive to simultaneous ionization in both said certain tube and said next succeeding tube to apply to the anode of said certain tube a voltage having a polarity opposite to that of the voltage initially applied thereto to extinguish ionization in said certain tube, each cycle of instituting ionization in one tube and extinguishing ionization in another tube being accomplished seriatim to effect a series of discrete voltage pulses, and means having a negative temperature coefficient of resistance and individual to the anode of each tube to be responsive to a flow of space current due to ionization in said certain tube to control said counteracting means to determine the time constant of ionization of each tube.

10. An electronic switching apparatus comprising in combination a plurality of gaseous discharge tubes each including a grid and an anode, and circuit means embodying said tubes and arranged to institute and extinguish ionization in each thereof seriatim to effect a series of discrete voltage pulses, said circuit means comprising means to apply biasing voltage to said grids to maintain said tubes normally in a non-ionized state, means to apply voltage having one polarity to the anodes of said tubes, means responsive to ionization in a certain tube to produce a voltage which counteracts the biasing voltage applied to the grid of a next succeeding tube to effect ionization in said latter tube, and means embodied in said anode voltage means and responsive to simultaneous ionization in both said certain tube and said next succeeding tube to apply a voltage of another polarity to the anode of said certain tube to extinguish ionization therein, and means comprising a resistance element having a negative temperature coefficient of resistance and individual to each tube to be responsive to a flow of space current in each tube to decrease its effective resistance as its temperature increases to cause a corresponding increase in the counteracting voltage produced by said counteracting voltage means until the biasing voltage applied to the grid of the next succeeding tube is sufficiently counteracted to allow ionization therein, the rate of development of the counteracting voltage determining the time constant of ionization of each tube.

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