Jan. 27, 1959 J. R. DESCH 2,871,408

ELECTRONIC COUNTER

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FIG. 1

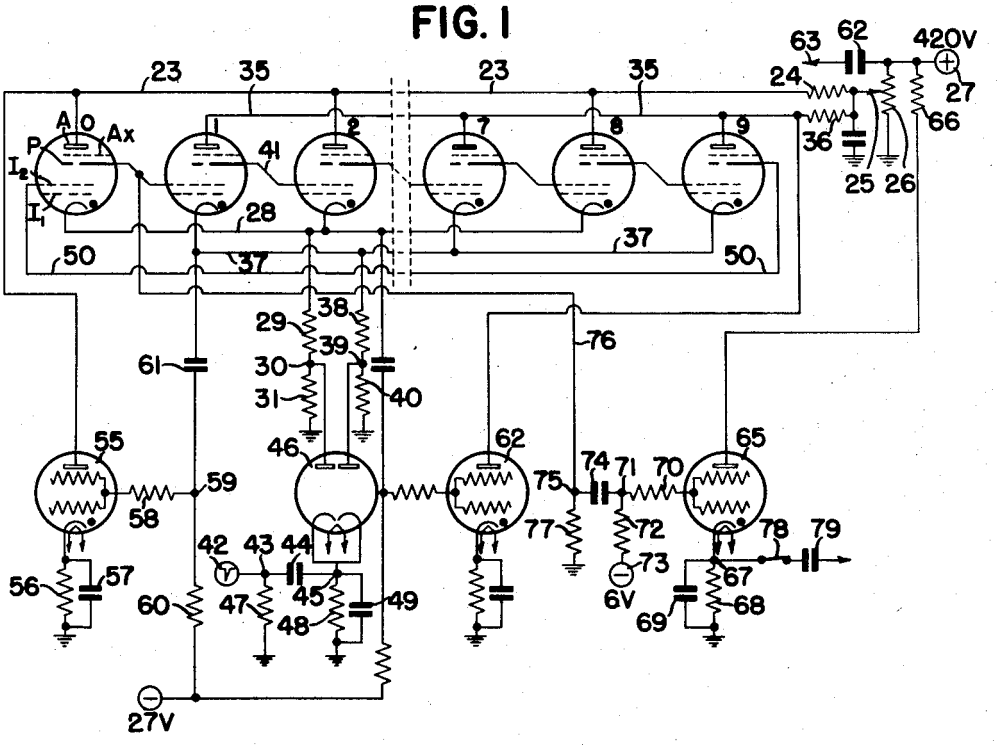

FIG. 2

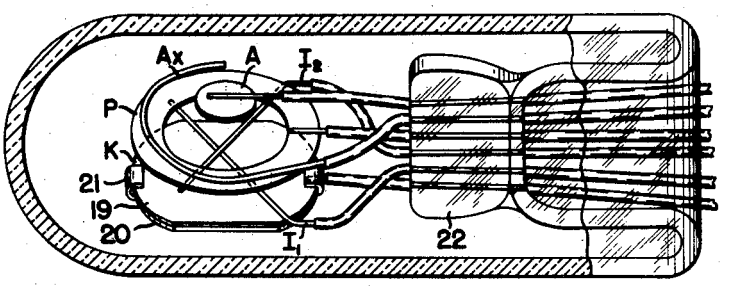

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FIG. 3

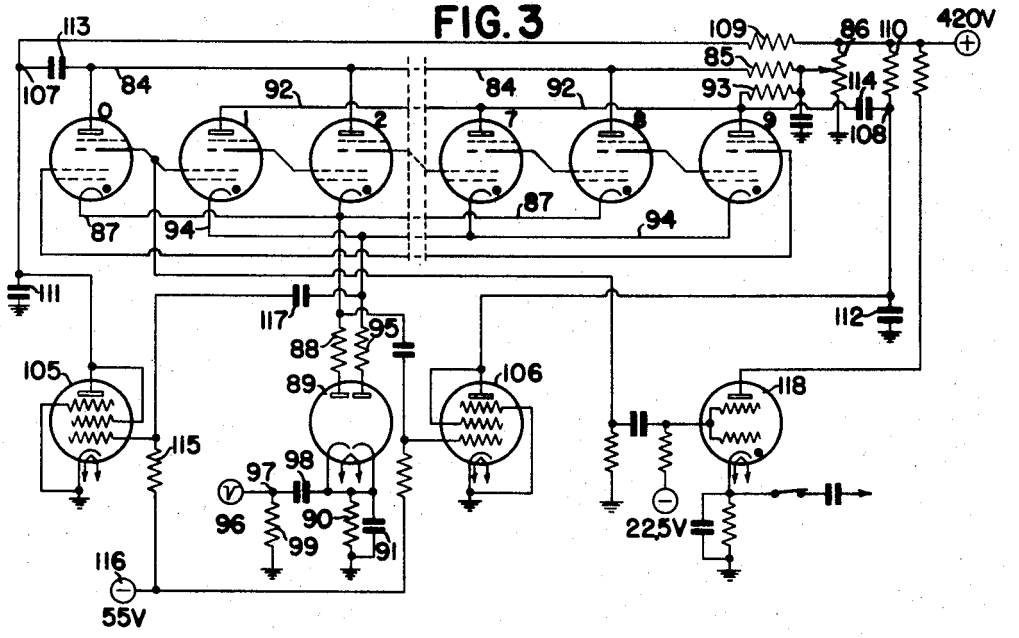
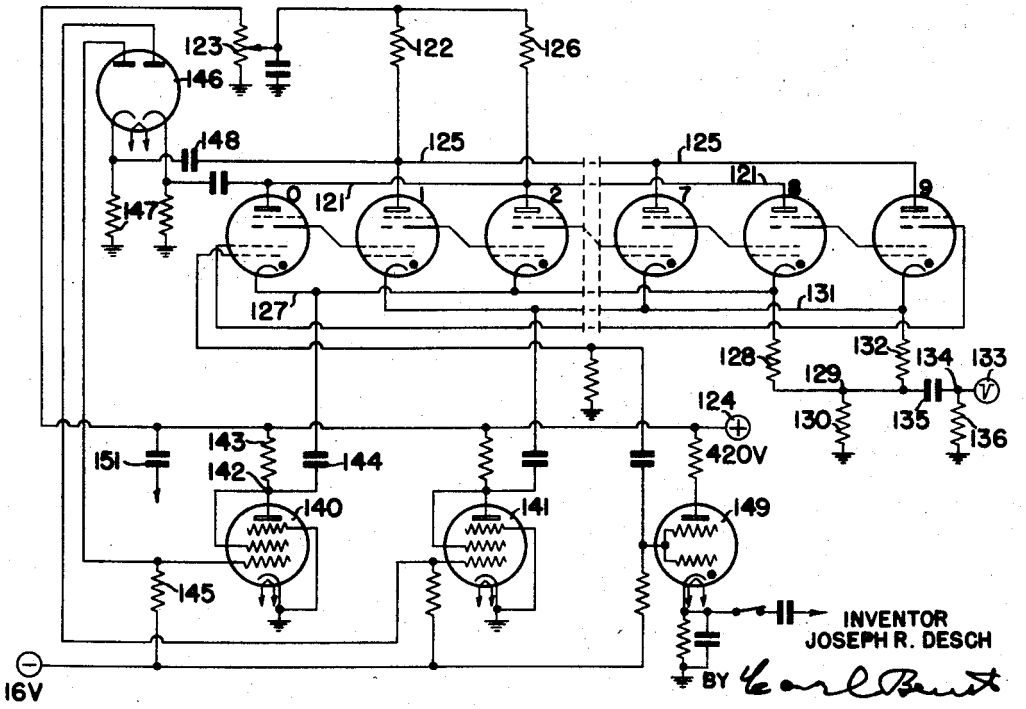


FIG. 4



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2,871,408

ELECTRONIC COUNTER

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Application April 21, 1953, Serial No. 350,133

10 Claims. (Cl. 315—84.5)

This invention relates to novel electron tube counting circuits and in particular relates to circuits employing cold-cathode gas tubes connected in a ring or chain for sequential operation one after another in response to input impulses and employing blow-out electron tube means external to the ring or chain for causing a previously conducting tube of the chain to be extinguished whenever another tube in the chain is rendered conducting.

The principal advantages of the novel counting circuits lie in their simplicity and in the reliability of their operation, the external extinguishing circuits insuring proper and rapid blow-out of the cold-cathode gas tubes of the ring or chain as counting progresses.

Briefly, the novel ring or chain circuit utilizes cold-cathode tubes of the type having at least an anode, a cathode, an igniter electrode, and a probe electrode. In these tubes, the igniter and the cathode form a starter gap by which ionization can be induced in a tube, and the anode and the cathode form the main gap, to which ionization spreads when the tube is operating. The tubes of the ring or chain are divided into two operational groups, with the cathodes of the tubes of each group being connected together and to ground over connections which include a resistor which is common to the group, and with the anodes each group connected together and over a resistor, which is common to the group, to a source of anode potential.

The tubes, which are positive-grid tubes, are connected into an operative chain by floating connections between the tubes, which connections extend from the probe of a tube of one group to the igniter of a tube of the other group. In case of a ring, the probe of the last tube, which is in one group, is connected to the igniter of the first tube, which is in the other group. These floating connections are simple direct connections, which contain no impedance elements and have no additional connections to potential sources. They cause the sequential operation of the tubes to take place in the desired order by enabling the probe electrode in a conducting tube to so influence the igniter in the starting gap of the next tube in the sequence that the starting gap will be primed to prepare the next tube so that it will conduct when the next input impulse is received on the cathodes.

The stepping of the conducting condition of the tubes of the ring or chain is obtained by applying negative potential input impulses to the cathodes of the tubes, that tube firing whose igniter is connected to the probe of a conducting tube of the chain and is primed by the conduction in that tube.

An additional extinguishing or blow-out tube is provided for each of the groups of the chain to cause a previously-conducting tube of the chain to be extinguished each time the next tube in the chain is rendered conducting. Each blow-out tube has its anode connected to the tubes of its related group and has its control grid connected to the tubes of the other group so that whenever a tube in one group begins to conduct, it will send an impulse to the blow-out tube related to the other group which causes that tube to operate and reduce the potential across the previously conducting tube of the other group thereby extinguishing the previously conducting tube. The two blow-out tubes, accordingly, serve to blow-out any of the tubes of the ring.

The use of separate blow-out tubes removes the blow out function from the tubes of the ring or chain so that no provision need be made in the ring circuits, per se, for causing other tubes to be extinguished. The separate blow-out tubes and their related circuits enable strong blow-out impulses to be obtained which can be made strong enough to insure that the cold-cathode tubes of the ring will be completely de-ionized as stepping progresses around the ring.

It is an object of the invention, therefore, to provide a simplified electron tube counting circuit with separate blow-out tube means for blowing out or extinguishing previously conducting tubes as new tubes become conducting.

A further object of the invention is to provide blow-out means external to the ring for producing strong blow-out impulses which will insure that any previously conducting tube of the ring will be extinguished as a new tube is rendered conducting.

With these and other incidental objects in view, the invention includes certain novel features of construction and arrangement of parts shown in the several embodiments which are hereinafter described with reference to the drawings which accompany and form a part of this specification.

Of the drawings:

Fig. 1 is a circuit diagram of one embodiment of the invention in which the blow-out tubes are thyratrons having their anodes connected directly to the anodes of their related groups of tubes of the ring.

Fig. 2 is a perspective view of one of the cold-cathode tubes which make up the ring of tubes, showing in particular the shape and relative position of the several electrodes in the tube.

Fig. 3 is a circuit diagram of another embodiment of the invention in which the blow-out tubes are high vacuum tubes having their anodes connected to a higher anode potential than the tubes of the groups and having their anodes also coupled to the anodes of the tubes of their related groups to impress negative blow-out impulses thereon.

Fig. 4 is a circuit diagram of another embodiment of the invention in which the blow out tubes are high vacuum tubes operated by impulses from the anodes of the tubes of the groups and supplying positive blow-out impulses to the cathodes of the tubes of the groups.

Detail description

In order that the invention may be more clearly explained, it will be described as embodied in various forms of counting circuits which are suitable for use as denominational orders of a decimal accumulator. It is to be understood that the invention is not limited to the use of the novel circuit as a counting ring or to the use of ten tubes in the ring, because it is susceptible of use wherever sequential operation of tubes is desired and with different numbers of tubes in the ring, the only limitation being that, when connected to operate as a ring, an even number of tubes must be provided. It will also become obvious from the following description that additional tubes can be included in the ring circuit without requiring any additional circuit elements of resistance or capacitance.

In the following description, values of potential with reference to ground and values of resistance and capaci-

tance, as well as tube types, will be given. It is not intended that the invention be limited to these particular potentials or to the values of resistance specified herein, because the potentials used are merely selected as convenient potentials for the disclosure, and the values of the circuit elements of resistance and capacitance given correspond in relative value to the potentials chosen. It is also obvious that other types of tubes may be used and also that other potentials may be used, and, when this occurs, the values of the circuit elements can be adjusted accordingly to maintain the proper relationship between the various parts of the circuit.

Excellent results have been obtained from circuits constructed according to the invention, using values of resistance, capacitance, and potentials to be given. These circuits also show good tolerance to variations in the positive potential supply and in the size of input impulses which were supplied thereto.

In order to simplify the showing of the circuits, only the "0," "1," "2," "7," "8," and "9," digit-representing tubes of the rings have been shown, because the circuits and operation of the "3" to "6" digit-representing tubes are the same as those shown and will be clear from those circuits which are shown.

As shown in Fig. 1, the counting ring is made up of cold-cathode tubes. These tubes are of the type shown more fully in Fig. 2.

The tube is provided with a plurality of electrodes, including, in order, a cathode, K; two igniters, I_1 and I_2; two further electrodes, one of which may be considered as a probe, P, and the other may be considered as an auxiliary anode, A_x; and an anode, A.

The cathode K, which is a substantially round flat disc about .75 of an inch in diameter, is made of a sheet **19** of magnesium and a sheet **20** of nickel, which are mounted on a support with the magnesium sheet facing the anode. The two sheets are fastened together at the support but are merely clipped together by a clip **21** at a point remote from the support to allow relative movement and prevent buckling due to the different coefficients of expansion of the two metals.

Adjacent the cathode are the two igniter electrodes, which are made of .02 of an inch nickel wire. Igniter I_1, which extends across the cathode parallel thereto and is spaced about .032 of an inch therefrom, can cooperate with the cathode to form a starting gap. Igniter I_2 also extends across the cathode, parallel thereto, but runs approximately at right angles to igniter I_1 and is spaced about .075 of an inch from the cathode. The igniter I_2 can be used with either the cathode or the igniter I_1 to form a starting gap.

The probe P is a flat annular member made from sheet magnesium. Its outside diameter is substantially the same as that of the cathode, and it is mounted parallel to the cathode about .16 of an inch therefrom. This probe lies adjacent the anode-cathode discharge path and can be influenced greatly by a discharge in the tube.

The auxiliary anode A_x also is made of .02 of an inch nickel wire, is curved to generally follow the shape of the probe P, lies between the probe and the anode A, and also can be influenced by discharge in the tube.

The anode A is a disc of nickel about .25 of an inch in diameter. It is mounted on a suitable support parallel to the probe and about .16 of an inch therefrom.

The supports for the various electrodes are insulated and extend through a press **22** at the bottom of the tube.

This tube was activated by pulse bombardment of the cathode and the probe and is filled with argon gas at a pressure of 12 millimeters of mercury.

This type of tube has excellent operating characteristics and is very flexible in its use, since the several electrodes intermediate the anode and the cathode can be used in a variety of ways as igniters, as auxiliary cathodes, or as probes, as required in the circuit in which the tube is to be used.

A tube constructed as above will have a striking potential from igniter I_1 to cathode K of about 90 volts; from igniter I_2 to cathode K of about 140 volts; from probe P to cathode K of about 180 volts; and from anode A to cathode K of about 300 volts. With the tube conducting and passing 5 milliamperes, it has a drop of about 67 volts from the cathode to either igniter I_1 or I_2 and a drop of about 75 volts from the cathode K to the anode A, and the probe P will be about 60 volts more positive than the cathode.

As shown in Fig. 1, the "even" tubes of the ring are connected to form a group by having their anodes connected together over conductor **23** and thence over resistor **24** of 10,000 ohms to the tap **25** of a 10,000 ohm potentiometer **26** which is connected between the +420 volt terminal **27** and ground and by having their cathodes connected together over conductor **28** and to ground over resistor **29** of 22,000 ohms, point **30** and resistor **31** of 6800 ohms.

Similarly the "odd" tubes of the ring are connected to form a group by having their anodes connected together over a conductor **35** and thence over a resistor **36** of 10,000 ohms to the tap **25** of the potentiometer, and by having their cathodes connected together over conductor **37** and to ground over resistor **38** of 22,000 ohms, point **39** and resistor **40** of 6800 ohms.

The tap **25** which is coupled to ground over an 8 microfarad stabilizer capacitor is adjusted to provide the two groups of tubes with anode potential of about +150 to +175 volts.

The chain connections between the tubes extend from the probe of one tube to the igniter I_2 of the next tube in the series; for example, from the probe of the "0" tube to the igniter I_2 of the "1" tube; from the probe of the "1" tube to the igniter I_2 of the "2" tube, etc. These connections, which are shown at **41**, are direct wire connections which contain no impedance elements and are floating, since they have no direct connection with any potential source.

It is to be noted that the chain connections extend from the probe of a tube in one group to the igniter I_2 of a tube in the other group, that is, the probe of a tube in the "even" group is connected to the igniter I_2 of the next higher digit value tube in the "odd" group and the probe of a tube in the "odd" group is connected to the igniter I_2 of the next higher digit tube value in the "even" group. When the digit-representing tubes are connected to form a ring, as shown in Fig. 1, the probe of the "9" tube is connected over a conductor **50** to the igniter I_2 of the "0" tube.

These chain connections enable the tubes to be primed in succession so that they will operate one after another in response to negative input impulses applied to the cathodes of the tubes. For example, if the "0" tube is conducting, the probe of the "0" tube is in the ionized medium of the conducting tube and will make the igniter I_2 of the "1" tube more positive. Since the "0" tube is the only tube which is conducting in the ring, the igniter I_2 of the "1" tube will be more positive than the similar igniter of any of the other tubes and the "1" tube will fire when a negative input impulse is applied to the cathodes of all the tubes. Such a counter chain comprising a plurality of serially-connected digit-representing tubes is essentially the same as that disclosed in applicant's co-pending application Serial No. 259,857, now Patent No. 2,644,112, filed December 4, 1951, issued June 30, 1953, and assigned to the present assignee of the instant application; however, the above-referred-to application utilizes an entirely different concept and circuit for bringing about the sequential operation of the chain from that of the instant invention, as will be fully described hereinafter.

Negative input impulses of any value between −250

and —400 volts are applied to the counting circuit at terminal 42 which is coupled to the cathodes of the two groups of tubes of the ring over the following circuit which extends from terminal 42 over point 43, capacitor 44 of .02 microfarad, and point 45 in the cathode circuit of a twin diode 46 of the 6H6 type. Point 43 in this circuit is coupled to ground over a resistor 47 of 220,000 ohms. The cathodes of the diode 46 are connected together and to ground over point 45 and resistor 48 of 220,000 ohms and capacitor 49 of .003 microfarad in parallel and the anodes of the diodes are coupled to points 30 and 39 in the cathode circuits of the two groups of tubes of the ring. The diode 46 in the input circuit decouples the two cathode circuits of the ring to enable them to be used more efficiently in controlling the blow-out tubes.

A separate blow-out tube is provided for each group of tubes of the ring. These blow-out tubes are thyratrons of the 2050 type and are connected in self-extinguishing circuits by which they will be extinguished automatically shortly after they have been fired. The circuits for tube 55 which is the blow-out tube associated with the "even" group of tubes are representative of the circuits for both blow-out tubes and are as follows. The blow-out tube 55 has its anode directly connected to the conductor 23 which connects the anodes of the "even" tubes together, has its cathode connected to ground over a resistor 56 of 330,000 ohms and capacitor 57 of .1 microfarad in parallel and has its control grid and shield grid connected together and connected over a resistor 58 of 22,000 ohms to point 59 which is connected to a —27 volt bias potential over a resistor 60 of 250,000 ohms and is coupled over a capacitor 61 of .0005 microfarad to the conductor 37 which connects the cathodes of the "odd" tubes together. Similarly, the blow-out tube 62 for the "odd" group has its anode connected to the conductor 35 which connects the anodes of the "odd" group of tubes together and has its shield and control grids coupled to the conductor 28 which connects the cathodes of the "even" tubes together.

The operation of the blow-out tubes can best be understood by considering the operation of the tube 55 in extinguishing one of the "even" group of tubes when an "odd" tube is fired. With an "even" tube, say the "0" tube conducting, its cathode, as well as the cathodes of all "even" tubes which are connected thereto will be more positive than the potential of the cathodes of the "odd" tubes. Conduction in the "0" tube will cause the igniter I_2 of the "1" tube to be more positive than the igniters of the other "odd" tubes so that when a negative impulse is impressed on all the cathodes, the "1" tube will fire. As the "1" tube fires its cathode potential will rise sharply and this rise will be impressed over capacitor 61, on the grids of blow-out tube 55 and will fire this tube. At the moment tube 55 is fired, its cathode potential will be held at ground while capacitor 57 is charging and during this time its anode potential will drop and will be positive by only the amount of the drop across the tube. Since the anode of the blow-out tube is directly connected to the anodes of the "even" group of tubes, the anodes of the tubes of this group will drop a similar extent and will be less positive than their cathodes which are at their higher potential due to conduction in the "0" tube and will cause conduction to cease in any tube of the group. As soon as the capacitor 57 has been charged, the anode potentials of the "even" tubes begin to rise and when the blow-out tube has been extinguished they will be back to operating values so that the next "even" tube, the "2" tube, can operate in response to the next input impulse. In a similar manner, the firing of the "2" tube will fire the blow-out tube 62 and cause its anode potential and that of the "odd" tubes to drop below cathode potential and extinguish the "1" tube.

The separate blow-out tube for each of the groups of tubes of the ring has the advantage that blow-out capacitors can be eliminated from the circuits of the various tubes of the ring and also has the further advantage that stronger blow-out impulses can be had to insure that the cold cathode tubes will be extinguished.

If the ring is to produce an output impulse each time a certain tube therein operates, as when the counting circuit forms one order of an accumulator, then the ring must cause the operation of an output tube. The output tube 65, which is a thyratron of the 2050 type, is connected in a circuit which will cause the tube to be extinguished automatically after it has been fired. The tube 65 has its anode connected over a resistor 66, of 250,000 ohms, to the +420-volt terminal 27; has its cathode connected to ground over point 67, resistor 68, of 470,000 ohms, and capacitor 69, of .01 microfarad, in parallel; and has its shield grid and control grid connected together and over resistor 70, of 100,000 ohms, to point 71, which is connected over resistor 72, of 220,000 ohms, to the —6-volt bias supply terminal 73, and is coupled over capacitor 74, of 50 micro-microfarads, point 75, and conductor 76 to the probe of the "0" tube, from which an impulse is received each time the "0" tube conducts. Point 75 in this circuit is connected to ground over a resistor 77, of 4.7 megohms. The impulse from the probe of the "0" tube will cause tube 65 to fire and conduct momentarily, which causes a positive output impulse to be sent out from point 67 in the cathode circuit for tube 65 over a switch 78 and a capacitor 79, of .003 microfarad. The switch 78 is provided to prevent output impulses from being sent from the tube 65, as when the counting circuit is initially preset to zero by causing the "0" tube to conduct.

The operation of the counting circuit is as follows. In order that the sequential operation of the tubes of the ring can take place, one of the tubes of the ring must be made conducting to provide the prime for the next tube to be operated. Any suitable means may be provided for this purpose, one such means being shown in Fig. 1 and consisting of a capacitor 62 of .0005 microfarad having one plate connected to the +420 volt terminal 27 and having the other plate connected to a conductor 63. After having discharged the capacitor by touching the conductor 63 to the terminal 27, the conductor is then momentarily connected to the igniter I_1 of the desired tube of the ring. This will cause the tube to conduct and prime the next tube of the chain for response to an input impulse. If the "0" tube is the one that is thus fired to prepare the ring for operation, the switch 77 in the output circuit can be opened to prevent a spurious output signal from being sent from the circuit.

Considering that the "0" tube has been fired to prepare the ring for operation, its cathode will have become more positive due to conduction in the tube, and since the other "even" cathodes are connected to the cathode of the "0" tube, they too will be more positive so that a negative input impulse applied to the cathodes of the "even" tubes will be ineffective to cause them to fire.

Of the "odd" tubes only the "1" tube will have its igniter I_2 connected to the probe of a conducting tube, the "0" tube. This will prime the "1" tube and make it more susceptible to fire when the negative impulse is applied to the "odd" cathodes.

When the "1" tube is fired, its cathode potential rise will fire the blow-out tube 55 which will cause the anode potential of the "even" tubes to drop to a value, relative to the potential of the cathodes, which will not support conduction in the "even" tubes and will thus extinguish the "0" tube.

The next impulse will fire the "2" tube which will cause the blow-out tube 62 to fire and extinguish the "1" tube.

Additional input impulses will cause the other tubes of the ring to become conducting one after another, the "9" tube priming the "0" tube to enable the sequential firing of the tubes to be continued.

Each time the "0" tube is fired and conducts, the potential rise of its probe will be impressed as an impulse on

the output tube 65 which operates and generates an output impulse.

The embodiment of the invention shown in Fig. 3 is similar to the one shown in Fig. 1, differing therefrom in the particular blow-out tube circuits and input circuits which are used.

The "even" tubes of the ring have their anodes connected together by conductor 84 and over a resistor 85 of 22,000 ohms to the tap of a 10,000 ohm potentiometer 86 which is connected between a +420 volt terminal and ground and are supplied with a potential of about +150 volts therefrom. The cathodes of the "even" tubes are connected together by conductor 87 thence over a resistor 88 of 15,000 ohms to one of the anodes of a twin diode 89 of the 6H6 type whose cathodes are connected together and to ground over a resistor 90 of 6800 ohms and a capacitor 91 of .001 microfarad in parallel.

Similarly the anodes of the "odd" tubes of the ring are connected together by conductor 92 and are connected over a resistor 93 of 22,000 ohms to the tap on the potentiometer 86, and the cathodes of the "odd" tubes are connected together by conductor 94 which is connected over a resistor 95 of 15,000 ohms to the other anode of the twin diode 89.

The tubes of the two groups are connected in a ring, probe to igniter I_2, as in Fig. 1 to enable their sequential operation in response to input impulses.

Negative input impulses of from 250 to 500 volts can be applied to the cathodes of the diodes from input terminal 96 over point 97 and capacitor 98 of .02 microfarad, point 97 being connected to ground over a resistor 99 of 220,000 ohms.

As in the counting circuit of Fig. 1, the stepping of the ring of Fig. 3 will take place as negative impulses are impressed on the cathodes of the tubes, via their respective halves of the diode 89.

In Fig. 3 the blow-out tubes 105 and 106 are high vacuum pentodes of the 6L6 type having their anodes connected over points 107 and 108 and resistors 109 and 110 of 150,000 ohms respectively to the +420 volt terminal and also connected to ground over .005 microfarad capacitors 111 and 112, and having their cathodes grounded. Point 107 in the anode circuit for tube 105 is coupled over a .03 microfarad capacitor 113 to the conductor 84 which connects the anodes of the "even" tubes together; and point 108 is similarly coupled over a capacitor 114 to the conductor 92 which connects the anodes of "odd" tubes together.

Tube 105 has its control grid connected over resistor 115, of 250,000 ohms, to the −55-volt bias supply terminal 116, and coupled over a capacitor 117, of .005 microfarad, to the conductor 94, which connects the "odd" cathodes together. Similarly, the control grid of the blow-out tube 106 is connected to the bias supply terminal 116 and is coupled to the conductor 87, which connects the cathodes of the "even" tubes together. Due to the bias supplied to the control grids, tubes 105 and 106 are normally non-conducting.

The operation of the counting ring of Fig. 3 is similar to that of Fig. 1. The ring may be preset with any tube conducting by using a capacitor, as 61 in Fig. 1, discharging the capacitor, and then touching the free lead to the igniter I_2 of any tube to cause that tube to conduct and prime the next tube in the ring for response to input impulses.

Each negative input impulse will cause the primed tube of the ring to conduct, and the act of conduction in the tube will cause its cathode potential to rise to a positive value which will be applied as a positive impulse to the control grid of the related blow-out tube to cause it to conduct. Since the blow-out tubes have +420 volts applied to their anodes and have their cathodes grounded, conduction in one of these tubes will cause a large negative excursion of the anode potential, which is applied through capacitors 113 and 114, as the case may be, as a negative impulse to the anodes of the tubes of the group which contained the previously-conducting tube and will drive the anode potential of this group below the potential of their cathodes and cause the previously conducting tube to be extinguished.

The particular advantage of this blow-out tube arrangement lies in the fact that by using much higher anode potential for the blow-out tubes than that used for the tubes of the ring, much larger blow-out impulses can be obtained to insure that any previously conducting tube of the ring will be extinguished.

An output tube 118 similar to the one used with the circuit of Fig. 1 is provided and is controlled from the probe of the "0" tube to produce an output impulse each time the "0" tube is fired. The circuit constants of the output circuit are the same as those for the output circuit of Fig. 1 except that a bias of −22.5 volts is supplied to the control grid.

A further embodiment of the invention is shown in Fig. 4. In this embodiment, each blow-out tube is controlled from the anodes of the tubes of one of the groups and applies positive blow-out impulses to the cathodes of the tubes of the other group.

As in the other embodiments, the "even" tubes of the ring have their anodes connected together by conductor 121 and over a resistor 122 of 10,000 ohms to the tap of a 10,000 ohm potentiometer 123 which is connected between the +420 volt terminal 124 and ground; and the "odd" tubes of the ring have their anodes connected together by conductor 125 and over resistor 126 of 10,000 ohms to the tap on potentiometer 123. The anodes of both sets are supplied with a potential of about +150 volts over their respective circuits from the tap on the potentiometer.

The cathodes of the "even" tubes are connected together by a conductor 127 and to ground over resistor 128 of 22,000 ohms, point 129 and resistor 130 of 10,000 ohms and the cathodes of the "odd" tubes are connected together by a conductor 131 and to ground over resistor 132 of 22,000 ohms, point 129 and the resistor 130 which is common to the two groups of cathodes.

As in the counting circuits of Figs. 1 and 3, the tubes of the ring are connected, probe-to-igniter I_2, in series, which series connections enable conduction in a tube of the ring to prime the next tube for response to the next input impulse.

Negative potential input impulses are applied to the cathodes of the ring from terminal 133 over point 134 and capacitor 135 of .05 microfarad to common point 129 in the cathode resistor network, point 134 being connected to ground over a resistor 136 of 220,000 ohms. The input impulses will cause the primed tubes of the ring to fire and become conducting one after another, thereby producing step-by-step operation of the tubes of the ring.

Blow-out tubes 140 and 141, which are high vacuum tubes of the 6L6 type, are utilized to supply blow-out impulses to the ring. Tube 140 has its anode and screen grid connected over point 142 and resistor 143 to the +420 volt terminal 124 and has its suppressor grid and cathode directly connected to ground. Point 142 in the anode circuit of tube 140 is coupled over a capacitor 144 of .03 microfarad to the conductor 127 which connects the cathodes of the "even" tubes together.

The control grid of tube 140 is connected to a −16 volt terminal over a resistor 145 of 250,000 ohms and is supplied with −12.5 volts therefrom and is also connected to the anode of a diode which is half of a tube 146 of the 6H6 type. The related cathode of the diode is connected to ground over a resistor 147 of 470,000 ohms and is coupled over a capacitor 148 of .005 microfarad to the conductor 125 which connects the anodes of the "odd" tubes together.

Tube 140 normally is conducting but when an "odd" tube is fired, its anode potential drop is impressed across

the diode, on the control grid of tube **140** to decrease conduction therein. The anode potential rise, due to decreased conduction in tube **140** is impressed, as a positive blow-out impulse on the cathodes of the "even" tubes to force the cathode potential of any conducting tube of this group above its anode potential and thereby cause the previously conducting "even" tube to be extinguished.

Similarly the other blow-out tube **141** has its control grid coupled over the other diode of the tube **146** to the conductor **121** which couples the anodes of the "even" tubes together and has its anode coupled over a capacitor to the conductor **131** which couples the cathodes of the "odd" tubes together. Conduction beginning in any of the "even" tubes will cause blow-out tube **141** to cease conducting and send a positive blow-out impulse to the cathodes of the "odd" tubes to cause any previously conducting tube of the "odd" group to be extinguished.

It is to be noted that as in the case of the embodiment in Fig. 3, the anodes of the blow-out tubes **140** and **141** of Fig. 4 are supplied with +420 volt anode potential and strong positive blow-out impulses are obtained which will insure that a previously conducting tube of one group will be extinguished when a tube of the other group is fired.

An output tube **149** similar to those used with the circuits of Figs. 1 and 3 is provided to produce an output impulse each time the "0" tube is fired. In this embodiment the output tube is connected to the igniter I_1 of the "0" tube to receive a positive firing impulse therefrom each time the "0" tube is fired and becomes conducting.

A presetting means which includes a capacitor **151**, similar to the capacitor **62** of Fig. 1, is provided to preset the counting ring by causing any desired tube to become conducting.

The operation of the counting circuit of Fig. 4 is substantially the same as the operation of the circuits of Figs. 1 and 3, negative input impulses causing the step-by-step firing of the tubes of the ring and the firing of a tube in one group of tubes of the ring causing an operation of the blow-out tube means to extinguish the previously conducting tube in the other group of tubes of the ring.

In all three embodiments of the invention, the blow-out tubes, which are external to the tubes of the ring, enable strong blow-out impulses to be applied to the ring to insure that a previously conducting tube of the ring will be extinguished each time a new tube is fired and becomes conducting. The external blow-out tubes enable very reliable operation of the ring to be obtained.

While the forms of the invention shown and described herein are admirably adapted to fulfill the objects primarily stated, it is to be understood that it is not intended to confine the invention to the embodiments disclosed herein for it is susceptible of embodiment in various other forms.

What is claimed is:

1. In a device of the class described, the combination of a plurality of gaseous electron tubes, each tube having at least a pair of electrodes forming a main gap, an igniter cooperating with one of said main gap electrodes to form a starter gap, and a probe located in the ionizable medium of the main gap and capable of exerting a control when conduction occurs in the main gap; a first main gap electrode potential supply connected to the main gap electrodes of half the tubes and forming them into a first group; a second main gap electrode potential supply connected to the main gap electrode of the other half of the tubes and forming them into a second group; means connecting the tubes for operation in a series, using tubes of the first and second groups alternately, the connection between adjacent tubes of the series extending from the probe electrode in a tube of one group to the igniter in the starter gap of the tube of the other group, and enabling conduction in the tube in which the probe is located to prepare the starter gap of the next tube of the series for firing in response to an input impulse; means to impress input impulses on said one of the main gap electrodes in each of the tubes in both groups; a blow-out tube having a pair of main electrodes and means for controlling conduction therebetween; an operating potential supply circuit for said blow-out tube, including an impedance for producing a potential change at one of said main electrodes of the blow-out tube whenever the conducting status of the blow-out tube changes; means connecting the control means of the blow-out tube to one of the main gap electrodes of each of the tubes of the first group of tubes to change the conducting status of the blow-out tube each time one of the tubes of the group is fired; means connecting said one of the main electrodes of the blow-out tube to the other of the main gap electrodes of each of the tubes of the second group of tubes to enable the potential change at said one main electrode of the blow-out tube to produce a strong potential surge in the potential supply of the second group of tubes to extinguish any previously-conducting tube therein; a second blow-out tube having a pair of main electrodes and means for controlling conduction therebetween; an operating potential supply circuit for said second blow-out tube, including an impedance for producing a potential change at one of said main electrodes of the second blow-out tube whenever the conducting status of the second blow-out tube changes; means connecting the control means of the second blow-out tube to those main gap electrodes of the tubes of the second group of tubes to which the blow-out impulse was not applied, to change the conducting condition of the second blow-out tube each time one of the tubes of the second group is fired; and means connecting said one of the main electrodes of the second blow-out tube to the main gap electrode of each of the tubes of the first group which was not used to control the first blow-out tube, to enable the potential change of said one main electrode of the second blow-out tube to produce a strong potential surge in the potential supply of the first group to extinguish any previously-conducting tube therein.

2. A device as claimed in claim 1 in which the electrodes forming the main gaps in the gaseous electron tubes of the groups are anodes and cathodes; in which the connections from the groups of tubes to the control means of the blow-out tubes extend from the cathodes of the tubes of the groups; and in which the connections from the said one main electrodes of the blow-out tubes extend to the anodes of the tubes of the groups.

3. A device as claimed in claim 1 in which the electrodes forming the main gaps in the gaseous electron tubes of the groups are anodes and cathodes; in which the connections from the control means of the blow-out tubes extend to the anodes of the tubes of the groups; and in which the connections from the said one main electrodes of the blow-out tubes extend to the cathodes of the tubes of the groups.

4. In a device of the class described, the combination of a first plurality of gaseous electron discharge tubes; a second plurality of gaseous electron discharge tubes; each tube of the first and second pluralities of tubes having at least an anode and a cathode forming a main gap, an igniter cooperating with the cathode to form a starter gap, and a probe located in the ionizable medium of the main gap and capable of exerting a control when conduction occurs in the main gap; an anode-cathode potential supply circuit common to the tubes of the first plurality of tubes and connecting them into a first group; an anode-cathode potential supply circuit common to the tubes of the second plurality of tubes and connecting them into a second group; said anode-cathode potential

supply circuits including impedances which cause the potentials of the anodes and cathodes of a group to change whenever a tube in the group conducts; means connecting the tubes for operation in a series, using tubes of the first and second groups alternately, the connection between adjacent tubes of the series extending from the probe electrode in a tube of one group to the igniter in the starter gap of a tube of the other group, and enabling conduction in the tube in which the probe is located to prepare the starter gap of the next tube of the series for firing in response to an input impulse; means to impress negative potential input impulses on the cathodes of both groups of tubes to cause the firing of the prepared tube; a pair of normally non-conducting blow-out tubes, one for each of said groups of gaseous electron tubes, each blow-out tube having at least an anode, a cathode, and means to control conduction therebetween; a circuit connecting the anode of each blow-out tube to the anodes of the tubes of its related group; and a circuit connecting the control means of each blow-out tube to the cathodes of the other group of tubes and enabling the firing of a tube in one group to cause conduction in the blow-out tube of the other group, which conduction in a blow-out tube causes the potential of the anodes of its related group to drop and extinguish any conducting tube in its related group.

5. In a device of the class described, the combination of a first plurality of gaseous electron discharge tubes; a second plurality of electron discharge tubes; each tube of the first and second pluralities of tubes having at least an anode and a cathode forming a main gap, an igniter cooperating with the cathode to form a starter gap, and a probe located in the ionizable medium of the main gap and capable of exerting a control when conduction occurs in the main gap; an anode-cathode potential supply circuit common to the tubes of the first plurality of tubes and connecting them into a first group; an anode-cathode potential supply circuit common to the tubes of the second plurality of tubes and connecting them into a second group; said anode-cathode potential supply circuits including impedances which cause the potentials of the anodes and cathodes of a group to change whenever a tube in the group conducts; means connecting the tubes for operation in a series, using tubes of the first and second groups alternately, the connection between adjacent tubes of the series extending from the probe electrode in a tube of one group to the igniter in the starter gap of a tube of the other group, and enabling conduction in the tube in which the probe is located to prepare the starter gap of the next tube of the series for firing in response to an input impulse; means to impress negative potential input impulses on the cathodes of both groups of tubes to cause the firing of the prepared tube; a pair of normally non-conducting blow-out impulse-generating tubes, one for each of said groups of gaseous electron tubes, each blow-out impulse-generating tube having at least an anode, a cathode, and means to control conduction therebetween; an operating potential supply for each of the blow-out impulse-generating tubes, each supply providing a higher anode potential than that applied to the groups of tubes to enable a strong negative impulse to be generated when the impulse-generating tube conducts; circuits coupling the anode of each blow-out impulse-generating tube to the anodes of the related group of tubes to impress the negative impulses thereon to extinguish any conducting tube of the group; and connections between the control means of each impulse-generating tube and the cathodes of the tubes of the other group of tubes and enabling the firing of a tube in one group to cause conduction in the impulse-generating tube related to the other group, whereby the firing of a tube in one group will cause a negative impulse to be impressed on the anodes of the tubes of the other group to cause any conducting tube of the other group to be extinguished.

6. In a device of the class described, the combination of a first plurality of gaseous electron discharge tubes; a second plurality of electron discharge tubes; each tube of the first and second pluralities of tubes having at least an anode and a cathode forming a main gap, an igniter cooperating with the cathode to form a starter gap, and a probe located in the ionizable medium of the main gap and capable of exerting a control when conduction occurs in the main gap; an anode-cathode potential supply circuit common to the tubes of the first plurality of tubes and connecting them into a first group; an anode-cathode potential supply circuit common to the tubes of the second plurality of tubes and connecting them into a second group; said anode-cathode potential supply circuits including impedances which cause the potentials of the anodes and cathodes of a group to change whenever a tube in the group conducts; means connecting the tubes for operation in a series, using tubes of the first and second groups alternately, the connection between adjacent tubes of the series extending from the probe electrode in a tube of one group to the igniter in the starter gap of a tube of the other group, and enabling conduction in the tube in which the probe is located to prepare the starter gap of the next tube of the series for firing in response to an input impulse; means to impress negative potential input impulses on the cathodes of both groups of tubes to cause the firing of the prepared tube; a pair of normally conducting blow-out impulse-generating tubes, one for each of said groups of gaseous electron tubes, each blow-out impulse-generating tube having at least an anode, a cathode, and means to control conduction therebetween; an operating potential supply for each of the blow-out impulse-generating tubes, each supply providing a higher anode potential than that supplied to the groups of tubes to enable a strong positive impulse to be generated when the impulse-generating tube ceases conducting; circuits coupling the anode of each blow-out impulse-generating tube to the cathodes of the related group of tubes to impress the positive impulses thereon to extinguish any conducting tube of the group; and connections between the control means of each impulse-generating tube and the anodes of the tubes of the other group of tubes and enabling the firing of a tube in one group to cause conduction to cease in the impulse-generating tube related to the other group whereby the firing of a tube in one group will cause a positive impulse to be impressed on the cathodes of the tubes of the other group to cause any conducting tube of the other group to be extinguished.

7. In a device of the class described, the combination of a first plurality of electron-discharge devices; a second plurality of electron-discharge devices, each of said devices of said first and second plurality including at least two main electrodes and control means for controlling conduction therebetween; a first operating potential supply connected across said main electrodes of each of said discharge devices of said first plurality and forming them into a first group; a second operating potential supply connected across said main electrodes of each of said discharge devices of said second plurality and forming them into a second group; means connecting said discharge devices together for selective operation in a step-by-step sequence, using discharge devices of said first and second groups alternately, each connection between adjacent discharge devices in the sequence extending from a discharge device in one group to a discharge device in the other group and enabling the discharge in the device in one group to prepare the next device in the sequence, which is in the other group, for discharge therein; means for supplying input pulses to the devices of both groups to cause any prepared discharge device to be rendered conductive; a blow-out impulse-generating device having at least a pair of electrodes and control means for controlling

conduction therebetween, said control means of said blow-out device coupled to one of said main electrodes of each of said discharge devices of said first group and one of said electrodes of said blow-out device coupled to the operating potential supply of said second group of discharge devices to apply an extinguishing potential surge thereto each time a discharge commences in a discharge device of said first group, whereby any conducting device of said second group is extinguished upon initial conduction in a device of said first group; and a second blow-out impulse-generating device having at least a pair of electrodes and control means for controlling conduction therebetween, said control means of said second blow-out device coupled to one of said main electrodes of each of said discharge devices of said second group and one of said electrodes of said second blow-out device coupled to the operating potential supply of said first group of discharge devices to apply an extinguishing potential surge thereto each time a discharge commences in a discharge device of said second group, the grouping of the discharge devices into two groups and the connection of the devices for sequential operation, using devices of said two groups alternately, and the provision of blow-out impulse-generating devices external of and for causing extinguishing action in the respective groups, insuring that the discharge in any conducting device is properly extinguished when a discharge commences in a succeeding device and that conduction takes place in only one device at a time.

8. In a device of the class described, the combination of a first plurality of gaseous electron-discharge devices; a second plurality of gaseous electron-discharge devices, each of said devices of said first and second plurality including at least two main electrodes and control means for controlling conduction therebetween; a first operating potential supply connected across said main electrodes of each of said discharge devices of said first plurality, said potential supply connecting said devices of said first plurality in parallel with respect to one another and forming them into a first group; a second operating potential supply connected across said main electrodes of each of said discharge devices of said second plurality, said second potential supply connecting said devices of said second plurality in parallel with respect to one another and forming them into a second group; means interconnecting said discharge devices of said two groups alternately into an operational series in which the conducting condition of said devices is advanced step by step, each series connection extending from a discharge device in one group to a discharge device in the other group and enabling the conduction in a discharge device in one group to prepare a discharge device in the other group for firing in response to an input impulse; means to supply input impulses to the discharge devices of both groups to cause any prepared discharge device to be fired and rendered conductive; a blow-out impulse-generating device having at least a pair of electrodes and control means for controlling conduction therebetween, said control means of said blow-out device coupled to one of said main electrodes of each of said electron-discharge devices of said first plurality to be controlled thereby, to change its conducting status each time one of said discharge devices of said first plurality is fired, and one of said electrodes of said blow-out device connected to the operating potential supply of said discharge devices of said second plurality to produce a strong potential surge therein to cause any conducting discharge device of said second plurality to be immediately extinguished; and a second blow-out impulse-generating device having at least a pair of electrodes and control means for controlling conduction therebetween, said control means of said second blow-out device connected to one of said main electrodes of each of said electron-discharge devices of said second plurality to be controlled thereby to change its conducting status each time one of said electron-discharge devices of said second plurality is fired, and one of said main electrodes of said second blow-out device connected to the operating potential supply for said discharge devices of said first plurality to produce a strong potential surge therein to cause any conducting discharge device of said first plurality of discharge devices to be immediately extinguished, whereby the firing of a discharge device in either group causes the operation of its related blow-out device to extinguish the conducting discharge device of the other group.

9. In a device of the class described, the combination of a first plurality of gaseous electron-discharge devices; a second plurality of gaseous electron-discharge devices, each of said devices of said first and second plurality including at least two main electrodes and control means for controlling conduction therebetween; a first operating potential supply connected across said main electrodes of each of said discharge devices of said first plurality and forming them into a first group; a second operating potential supply connected across said main electrodes of each of said discharge devices of said second plurality and forming them into a second group; means connecting the discharge devices into an operational series in which the conducting condition of the devices is advanced step by step, using discharge devices of the two groups alternately, each series connection extending from a discharge device in one group to a discharge device in the other group and enabling the conduction in a device in one group to prepare the device in the other group for firing in response to an input impulse; means to supply input impulses to the devices of both groups to cause any prepared discharge device to be fired and rendered conductive; a blow-out tube having at least a pair of electrodes and control means for controlling conduction therebetween, said control means of said blow-out tube connected to one of said main electrodes of each of said electron-discharge devices of said first plurality to be controlled thereby, to change its conducting status to produce a strong blow-out impulse each time one of said discharge devices of said first plurality is fired, and one of said main electrodes of said blow-out tube connected to one of said main electrodes of each of said discharge devices of said second plurality to apply the blow-out impulse thereto to cause any conducting discharge device of said second plurality to be extinguished; and a second blow-out tube having at least a pair of electrodes and control means for controlling conduction therebetween, said control means of said second blow-out tube connected to the other of said main electrodes of each of said electron discharge devices of said second plurality to be controlled thereby to change its conducting status and produce a strong blow-out impulse each time one of said electron-discharge devices of said second plurality is fired, and one of said electrodes of said second blow-out tube connected to the other main electrode of each of said discharge devices of said first plurality to apply the blow-out impulse thereto to cause any conducting discharge device of said first plurality to be extinguished; the blow-out tubes operating alternately as the discharge devices of the series are fired in response to input impulses and insuring that a previously conducting device of the series is extinguished each time another device in the series is fired.

10. In a device of the class described, the combination of a first plurality of gaseous electron-discharge devices; a second plurality of gaseous electron-discharge devices, each of said devices of said first and second plurality including at least two main electrodes and control means for controlling conduction therebetween; a first operating potential supply connected across said main electrodes of each of said discharge devices of said first plurality and forming them into a first group; a second operating potential supply connected across said main electrodes of each of said discharge devices of said second plurality and forming them into a second group; means connecting the discharge devices into an operational series in which the conducting condition of the devices is advanced step

by step, each series connection extending from a discharge device in one group to a discharge device in the other group and enabling the conduction in a device in one group to prepare a device in the other group for firing in response to an input impulse; means to supply input impulses to the devices of both groups to cause any prepared device to be fired and rendered conductive; a blow-out impulse amplifier tube for each of said plurality of gaseous discharge devices, each having at least a pair of electrodes and control means for controlling conduction therebetween; an operating potential supply connected across said electrodes of said blow-out tubes for providing said tubes with a higher potential than that supplied to the plurality of discharge devices to enable relatively large amplitude blow-out impulses to be produced upon a change in the conducting status of each of said blow-out tubes; means connecting said control means of one of said blow-out tubes to one of said main electrodes of said electron-discharge devices of said first plurality to be controlled thereby, to change its conducting status and produce a strong blow-out impulse each time one of said discharge devices of said first plurality is fired; means connecting one of said electrodes of said blow-out tube to one of said main electrodes of each of said discharge devices of said second plurality to apply the blow-out impulse thereto to cause any conducting discharge device of said second plurality to be extinguished; means connecting said control means of the other of said blow-out tubes to the other of said main electrodes of each of said electron-discharge devices of said second plurality to be controlled thereby to change its conducting status and produce a strong blow-out impulse each time one of said electron-discharge devices of said second plurality is fired; and means connecting one of said electrodes of the other of said blow-out tubes to the other main electrode of each of said discharge devices of said first plurality to apply the blow-out impulse thereto to cause any conducting discharge device of said first plurality to be extinguished, the blow-out tubes operating alternately as the discharge devices of the sequence are fired in response to input impulses and producing large-amplitude blow-out impulses to insure that a previously conducting device of the series is extinguished each time another device in the series is fired.

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