Sept. 6, 1955 J. R. DESCH 2,717,334

ELECTRONIC COUNTERS

Filed April 21, 1953

FIG. 2

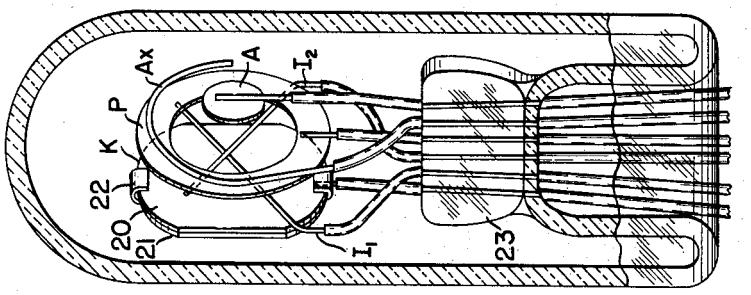


FIG. 1

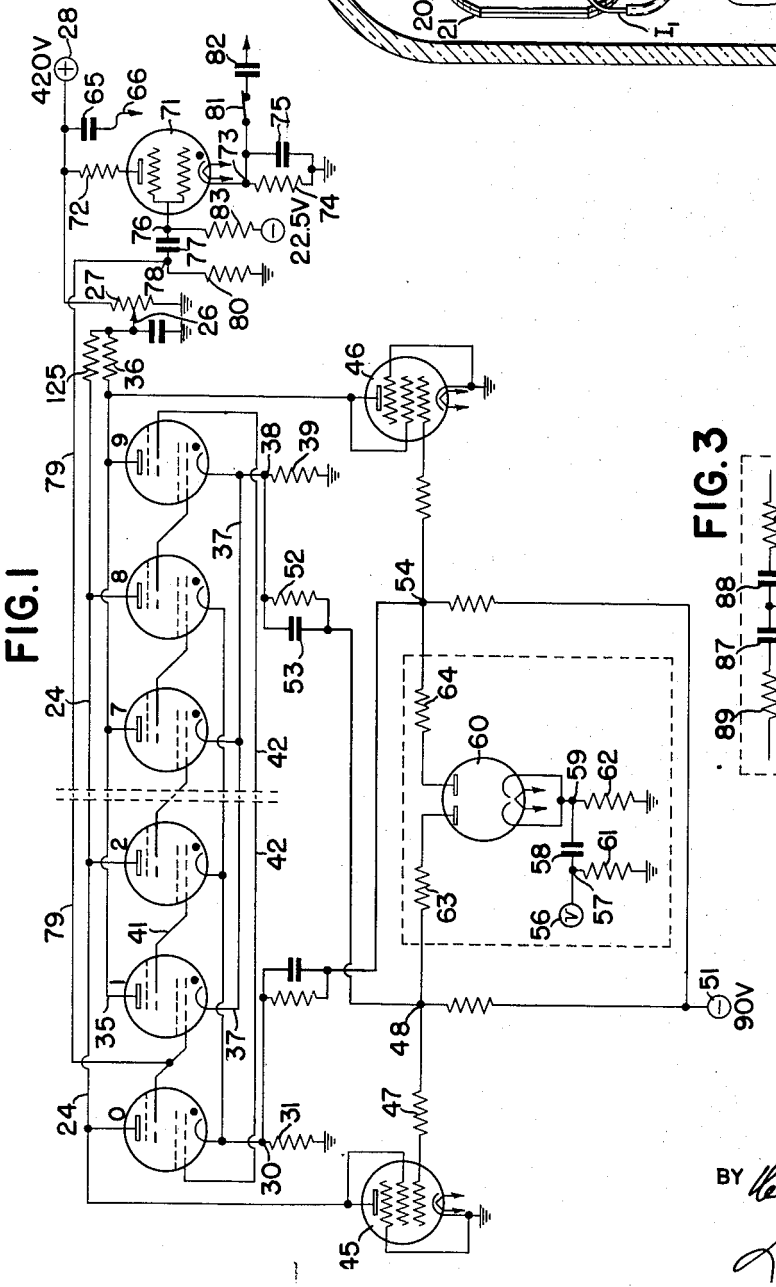
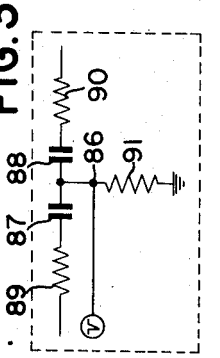


FIG. 3



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2,717,334

ELECTRONIC COUNTERS

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3 Claims. (Cl. 315—166)

This invention relates to a novel electron tube counting circuit and in particular relates to a circuit employing cold-cathode gas tubes connected in a ring or chain for operation one after another in sequence, and also employing a pair of control tubes which are trigger connected with the various tubes of the ring as counting progresses and which control the sequential operation of the tubes of the ring in response to input impulses.

The principal advantages of the novel counting circuit lie in its simplicity and in the reliability of its operation, the trigger connections between the control tubes and the tubes of the ring insuring that the next tube in the ring is fired before a previously conducting tube is extinguished.

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 a resistor which is common to the group, and with the anodes of 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 ionized to prepare the next tube so that it will conduct when the next input impulse is applied to the counting circuit.

Each control tube has its anode connected to the anodes of one group of tubes and has its control grid connected by trigger connections to the cathodes of the other group of tubes. Accordingly, if one of the tubes of one group is conducting, the control tube connected to its cathode will be conducting and will reduce the anode potential of the other group so that conduction cannot occur in any tube of that group. At the same time, the control tube, which is trigger connected to the other group in which no tube is conducting, will also be non-conducting and will allow the anode potential of the group which contains the conducting tube, to remain high enough to support conduction in the tube.

The stepping of the conducting condition of the tubes of the ring or chain is obtained by applying negative impulses to the control tubes. The negative impulse will not change the conducting status of the non-conducting control tube but will drive the conducting control tube to cut-off. The consequent rise in the anode potential of the control tube which is thus driven to cut-off, and that of the related group of tubes, will enable the next tube in the sequence, whose starter gap has been ionized, to fire and become conducting. As the new tube becomes conducting, its cathode potential rise is transmitted over the trigger connection to the other control tube and will render it conducting. Conduction in this control tube will reduce its anode potential and that of the group of tubes connected thereto to extinguish the previously-conducting tube of the ring.

The use of the two control tubes and their trigger connections with the two groups of tubes of the ring insures that the operations of firing a new tube and the extinguishing of a previously-conducting tube of the ring have been accomplished, because each operation is dependent upon the completion of the other.

It is an object of the invention, therefore, to provide a simplified electron tube counting circuit with separate control tubes interconnected by trigger circuits to tubes of a ring to control the stepping of the conducting condition of the tubes as input impulses are applied to the control tubes.

With this and incidental objects in view, the invention includes certain novel features of construction and combinations of parts, hereinafter described with reference to the drawing which accompanies and forms a part of this specification.

Of the drawing:

Fig. 1 is a circuit diagram showing the counting circuit embodying the invention.

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 a modified form of input to the control tubes.

Detailed description

In order that the invention may be more clearly explained, it will be described as embodied in a counting circuit which is suitable for use as a denominational order 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 capacitance, 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.

Excelent results have been obtained from circuits constructed according to the invention, using values of resistance, capacitance, and potentials to be given. These circuits also showed 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 **20** of magnesium and a sheet **21** 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 **22** 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 **23** 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 **24** and thence over resistor **25** of 20,000 ohms to the tap **26** of a 10,000 ohm potentiometer **27** which is connected between the +420 volt terminal **28** and ground by having their cathodes connected together over conductor **29** and to ground over point **30** and resistor **31** of 27,000 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 20,000 ohms to the tap **26** of the potentiometer, and having their cathodes connected together over conductor **37** and to ground over point **38** and resistor **39** of 27,000 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 +300 to +350 volts.

The chain connections between the tubes extend from the probe of one tube to the igniter I_1 of the next tube in the series; for example, from tthe probe of the "0" tube to the igniter I_1 of the "1" tube; from the probe of the "1" tube to the igniter I_1 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_1 of a tube in the other group, that is, the probe of a tube in the "even" group is connected to the igniter I_1 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_1 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 **42** to the igniter I_1 of the "0" tube.

These chain connections enable the tubes to be prepared so that they will operate one after another in succession in response to input impulses.

It is to be noted that the above connections to the tubes of the ring are extremely simple and require only one anode resistor and one cathode resistor for each group of tubes.

The two control tubes **45** and **46** are of the 6L6 type. Tube **45**, which is related to the "even" group, has its anode connected to conductor **24** which connects the anodes of the "even" tubes together and has its cathode grounded. The control grid of tube **45** is connected over a resistor **47** of 100,000 ohms to point **48** which is connected over a resistor **49** of 250,000 ohms to a −90 volt bias terminal **51** and is connected over a trigger connection, including a resistor **52** of 220,000 ohms and a capacitor **53** of .005 microfarad to point **38** in the cathode circuit of the "odd" group of tubes. If none of the "odd" tubes is conducting, the bias on tube **45** will be effective to block conduction therein and the anode potential of the "even" tubes will be high enough to support conduction in any of this group but if any "odd" tube is conducting, point **38** in its cathode circuit will become sufficiently positive to overcome the bias on tube **45** and it will conduct. Conduction in tube **45** will cause the potential of the anodes of the "even" tubes to drop to a value which will not support conduction in any of the "even" tubes.

Similarly the control tube **46** has its anode connected to the anodes of the "odd" group of tubes, has its cathode grounded, and has its control grid connected over point **54** to the bias supply terminal **51** and also to the point **30** in the cathode circuit of the "even" group of tubes over the trigger connection. Tube **46** will conduct whenever a tube of the "even" group is conducting, and, when conducting, tube **46** will prevent conduction in the "odd" group of tubes.

Control tubes 45 and 46 are further operable by input impulses to cause the step-by-step operation of the tubes of the ring. Negative input impulses of any value between —160 and —220 volts are applied to the counting circuit at terminal 56 which is coupled to the control grids of the control tubes 45 and 46 over the following circuit which extends from terminal 56 over point 57, capacitor 58 of .005 microfarad and point 59 in the cathode circuit of a twin diode 60 of the 6H6 type which is utilized to de-coupled the control grids of the control tubes 45 and 46. Point 57 in this circuit is connected to ground over a resistor 61 of 220,000 ohms. The diodes of tube 60 have their cathodes connected together and to ground over point 59 and a resistor 62 of 100,000 ohms and have their anodes connected over resistors 63 and 64 of 100,000 ohms to points 48 and 54 in the control grid circuits of the control tubes 45 and 46.

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 prepare 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 65 of .001 microfarad having one plate connected to the +420 volt terminal 28 and having the other plate connected to a conductor 66. After having discharged the capacitor by touching the conductor 66 to the terminal 28, 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 prepare the next tube of the chain for response to an input impulse.

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 and through the trigger connection to point 54 they will cause the control tube 46 to conduct. Conduction in tube 46 will cause the anode potential of the "odd" tubes to be reduced to a value which will not support conduction in any of the tubes of the group.

Of the "odd" tubes, only the "1" tube will have its igniter I_1 connected to the probe of a conducting tube and will have its starter gap ionized. The ionization will not spread to the main gap of the "1" tube at this time because its anode potential is reduced by conduction in the control tube 46.

Since none of the "odd" tubes is conducting and their cathodes are at their lower value of potential, control tube 45 will be at cut off, which allows the anode potential of the "even" group to be high enough to support conduction in the "0" tube.

The negative impulse on terminal 56 will be applied over the twin diode 60 to points 48 and 54 in control grid circuits of the control tubes 45 and 46. The impulse will not change the conducting status of tube 45 which is non-conducting but will cause the normally conducting tube 46 to be driven to cut off. As tube 46 is driven to cut-off, it will allow the anode potential of the "odd" tubes to rise and enable ionization to spread from the starter gap to the main gap of the "1" tube, causing the "1" tube to become conducting. Conduction in the "1" tube will cause its cathode potential to become more positive which, through the trigger connection, will cause the control tube 45 to conduct. Conduction in control tube 45 will reduce the anode potential of the "even" group of tubes to extinguish the "0" tube.

The negative input impulse therefore has caused the "1" tube to become conducting and the "0" tube to be extinguished. In bringing about this change the control tube 46 has been made non-conducting and the control tube 45 has become conducting.

Conduction in the "1" tube will ionize the starter gap in the "2" tube to prepare this tube for firing.

The next input impulse will be effective, through the control tubes, to cause the "2" tube to conduct and the "1" tube to be extinguished.

Similarly, further impulses will cause the conducting condition of the tubes to progress around the ring.

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 71 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 71 has its anode connected over a resistor 72 of 250,000 ohms to the +420 volt terminal 28, has its cathode connected to ground over point 73 and resistor 74 of 470,000 ohms and capacitor 75 of .01 microfarad in parallel, and has its shield grid and control grid connected together and over point 76 and resistor 83 of 220,000 ohms to the —22.5 volt bias supply terminal. Point 76 in this circuit is also coupled over capacitor 77 of 50 micro-microfarads point 78 and conductor 79 to the probe of the "0" tube from which an impulse is received each time the "0" tube conducts. Point 78 in this circuit is connected to ground over a resistor 80 of 4.7 megohms. The impulse from the probe of the "0" tube will cause tube 71 to fire and conduct momentarily which causes a positive output impulse to be sent out from point 73 in the cathode circuit for tube 71 over a switch 81 and capacitor 82 of .003 microfarad. The switch 81 is provided to prevent output impulses from being sent from the tube 71 as when the counting circuit is initially preset to zero by causing the "0" tube to conduct.

Fig. 3 shows a modified form of input circuit in which the de-coupling diode is eliminated and a capacitor input arrangement is substituted in its place. This input arrangement is not so tolerant of variation of anode potential and input impulse potential as the one shown in Fig. 1 but can operate accurately within its range. With anode potential of +280 volts on the ring, input impulses of between —300 and —400 volts applied to the input terminal 85 will cause proper step-by-step operation of the ring. These impulses are impressed over point 86, capacitors 87 and 88 of .001 microfarad and resistors 89 and 90 of 100,000 ohms to points 48 and 54 in the control grid circuits of the control tubes 45 and 46 and will cause them to operate and control the stepping of the ring in the same manner as when the input circuit of Fig. 1 is used. Point 86 in this circuit is connected to ground over a resistor 91 of 100,000 ohms.

The novel counting circuits in which the control tubes are trigger connected with the two groups of tubes and are paired with different tubes of the groups, require relatively few circuit components and at the same time are extremely stable in their operation.

While the forms of the invention shown and described herein are admirably adapted to fulfill the object 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 discharge devices; a first circuit connecting half of the devices into an operational group; a second circuit connecting the other half of the devices into another operational group; means connecting the devices in 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 conduction in a device in one group to prepare a device in the other group for firing in response to an input impulse; a pair of control tubes, one related to each group of devices; means connecting each control tube to its related group of devices to con-

trol conduction in the devices of its related group; trigger connections between each group of devices and the control tube of the other group to enable conduction in each group of devices to control the conduction in the control tube related to the other group, whereby one control tube will be conducting and the other non-conducting according to which of the devices of the series is conducting; means to apply input impulses to the control tubes, each impulse reversing the conducting status of one of the control tubes, which in turn causes a change in the conducting status of a device in its related group, which change in the conducting status of the device in the group is effective through the trigger connection to reverse the conducting status of the other control tube and thereby change the conducting status of a device in its related group which enables the other trigger connection to maintain the control tube, whose conducting status was reversed by the input impulse, in that status.

2. In a device of the class described, the combination of a first plurality of gaseous electron tubes; a second plurality of gaseous electron tubes; a first operating potential supply connected to the first plurality of tubes and forming them into a first operational group; a second operating potential supply connected to the second plurality of tubes and forming them into a second operational group; means connecting the tubes into an operational series in which the conducting condition of the tubes is advanced step-by-step, each series connection extending from a tube in one group to a tube in the other group and enabling conduction in a tube in one group to prepare a tube in the other group for operation; a pair of control tubes, one related to each group of tubes; means connecting each control tube to the operating potential supply of its related group; each control tube, when conducting, reducing the potential across the tubes of its group to prevent conduction in the tubes of the group; trigger connections between each group of tubes and the control tube of the other group to enable conduction in each group of tubes to control conduction in the control tube related to the other group, conduction in a tube in one group causing the control tube related to the other group to conduct and extinguish any conducting tube of said other group; whereby for any operating condition of the chain one control tube will be conducting and the other will be non-conducting; and means to apply negative potential input impulses to the control tubes, each impulse causing the then-conducting control tube to cease conducting and restore operating potential across its group of tubes to enable the prepared tube to fire, the firing of the prepared tube causing the other control tube to become conducting and thereby extinguishing the previously-conducting tube of its related group, and the extinguishing of the previously-conducting tube of its related group causing the tube that was rendered non-conducting by the impulse to be non-conducting until the next input impulse causes a further operation of a tube in the chain.

3. 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 an operational group; an anode-cathode potential supply circuit common to the tubes of the second plurality of tubes and connecting them into a second operational 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 ionize the starter gap of the next tube of the series for firing in response to an input impulse; a pair of control tubes, one related to each group of tubes; means connecting each control tube to the anode-cathode potential supply of its related group; each control tube, when conducting, reducing the potential across the main gaps of the tubes of its related group to prevent conduction in the tubes of the group; trigger connections between the cathodes of each group of tubes and the control tube of the other group to enable conduction in each group of tubes to control conduction in the control tube related to the other group, conduction in a tube in one group causing the control tube related to the other group to conduct and extinguish any conducting tube of said other group, whereby for any operating condition of the chain one control tube will be conducting and the other will be non-conducting; and means to apply negative potential input impulses to the control tubes, each impulse causing the then-conducting control tube to cease conducting and restore operating potential across the main gaps of its group of tubes to enable the ionization from the starter gap of the prepared tube to spread to the main gap, the ionization of the main gap of the prepared tube producing a cathode potential rise which is transmitted over the trigger connection to cause the other control tube to become conducting to reduce the potential across the main gaps of its related group to extinguish any previously-conducting tube therein, and the extinguishing of the previously-conducting tube of its related group causing the control tube which was rendered non-conducting by the impulse to be non-conducting until the next input impulse causes a further operation of a tube in the chain.

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