June 30, 1953 J. R. DESCH 2,644,110

ELECTRONIC COUNTER

Filed Feb. 20, 1952

FIG. 1

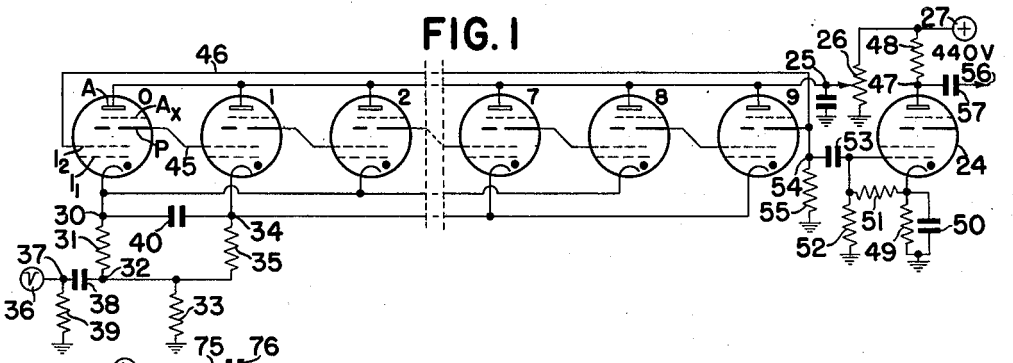


FIG. 2

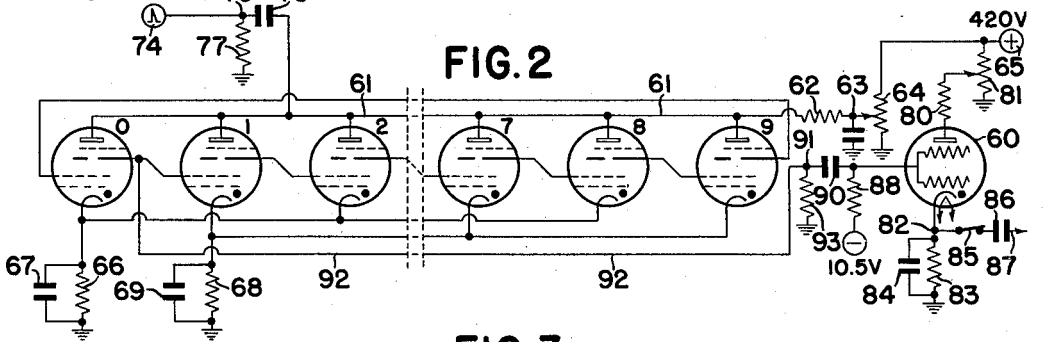


FIG. 3

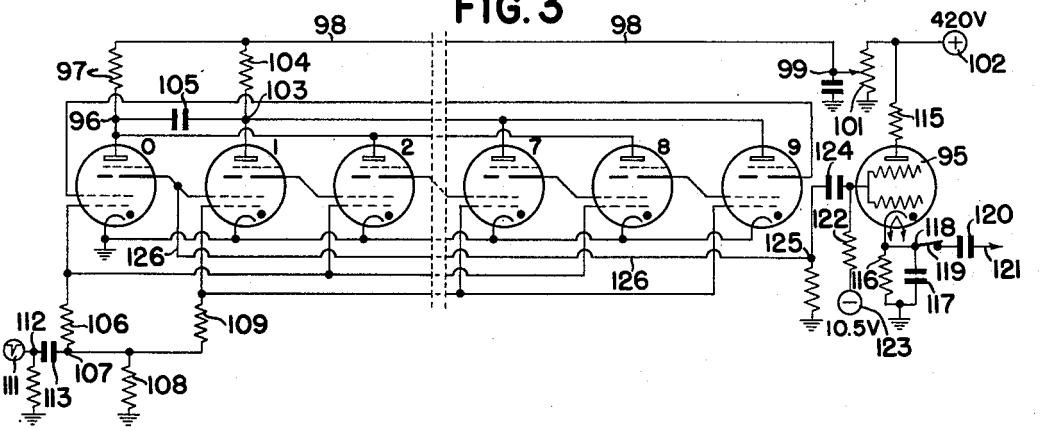
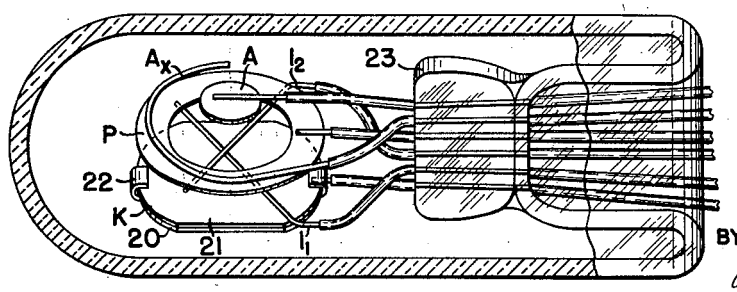


FIG. 4



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2,644,110

ELECTRONIC COUNTER

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20 Claims. (Cl. 315—166)

1

This invention relates to novel electron tube counting circuits and in particular to circuits employing cold-cathode gas tubes connected in a chain or ring for sequential operation one after another in response to input impulses.

The principal advantage of the novel counting circuits lies in their simplicity. These circuits require no more impedance elements for a ring of more than two tubes than would be required to operate two tubes as a binary counter. Consequently, a chain or ring of ten tubes for counting in the decimal notation requires only those resistors and capacitors which would be necessary for two tubes to operate as a binary counter.

Briefly, the novel ring or chain circuits utilize cold-cathode tubes of the type having at least an anode, a cathode, one or more igniter electrodes, an auxiliary anode, and a probe electrode. In these tubes, an igniter and a cathode or two igniters can be used to form a starter gap by which ionization can be induced in a tube, and the anode and the cathode can form a main gap to which ionization spreads when the tube is operating.

The tubes are connected into an operative chain or series by floating connections between the tubes, which connections extend from a probe of a tube of the chain to an igniter of the next tube in the chain. In the case of a ring, the probe of the last tube of the sequence is connected to the igniter of the first tube of the sequence. These floating connections are simple, direct connections which contain no impedance elements and have no additional connections to potential sources but derive potential only from conduction in the tubes which they connect. These connections control the sequential operation of the tubes of the chain or ring in the desired order by enabling the probe electrode in a conducting tube to so influence the igniter in the starter gap of the next tube of the sequence that the starter gap will be prepared so that said next tube will conduct when the next input impulse is impressed on all the tubes.

The tubes of the chain are connected into two operational groups, alternate tubes in the chain being included in different groups, and the two groups are interconnected for mutual extinguishing action, so that conduction beginning in a tube in one group will cause any conducting tube of the other group to be extinguished. Various types of extinguishing circuits may be used, depending upon the type of input impulses which are available.

If desired, the ring or chain can control a

2

suitable output signal means to produce an output signal each cycle of operation of the ring or when any particular tube of the chain conducts.

In the novel circuits, therefore, the combination of the connecting of the tubes for sequential operation by means of floating connections and the grouping of alternate tubes of the series for extinguishing action enable an extremely simple circuit to be obtained, in which circuit the sequential operation of the tubes is obtained in response to input impulses which are applied to all the tubes.

It is an object of the invention, therefore, to provide a simplified electron tube counting circuit.

A further object of the invention is to provide a step-by-step-operating electron tube counting circuit which requires a minimum of circuit impedance elements.

Another object of the invention is to provide a counting circuit of more than two tubes which are capable of operating step by step to accumulate amounts but which require no more circuit impedance elements than would be required for a binary counter involving only two tubes.

A further object of the invention is to provide a counting circuit which includes more than two tubes which are operable one at a time in sequence in response to input impulses applied to all the tubes, but which includes no more circuit elements of resistance or capacitance than would be necessary to operate two tubes as a binary counter.

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

Of the drawings:

Fig. 1 shows a circuit diagram of one embodiment of the counting circuit which is operable in response to negative input impulses applied to the cathodes of the tubes and has the cathodes of the tubes grouped and the groups coupled for extinguishing action.

Fig. 2 shows a circuit diagram of another embodiment of the counting circuit which is operable in response to positive impulses applied to the anodes of the tubes and has the cathodes grouped and provided with an extinguishing circuit for mutual extinguishing action between groups.

Fig. 3 shows a circuit diagram of a further embodiment of the counting circuit which is oper-

able in response to negative impulses applied to one of the igniters in the tubes which acts as an auxiliary cathode and in which the anodes are grouped and the groups are coupled for extinguishing action.

Fig. 4 is an enlarged perspective view of one of the cold-cathode tubes used in the rings of Figs. 1, 2, and 3 and shows the shape and relative position of the electrodes in the tube.

Detailed description

In order that the invention may be more clearly explained, it will be described as embodied in counting rings which are suitable for use as denominational orders of a decimal accumulator. It is to be understood that the invention is not limited to its use 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.

Values of potential with reference to ground and values of resistance and capacitance, as well as tube types, will be given in the following description. 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 potential 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 showed good tolerance to variations in the positive potential supply and in the size of input impulses which were supplied thereto.

While the circuits of Figs. 1, 2 and 3 show various embodiments of the invention, they all use the same general type of multi-electrode cold-cathode tube.

The construction of the cold-cathode tube which is used in the simplified counting circuits is shown in Fig. 4.

The tube is provided with a plurality of electrodes including, in order, a cathode K, two igniters I_1 and I_2, a probe P, an auxiliary anode A_x, and an anode A.

The cathode K, which is a substantially round flat disc-like electrode 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 **221** at a point remote from the support to allow relative movement and prevent buckling due to different coefficients of expansion of the two metals.

The igniters I_1 and I_2 are made of .02 of an inch nickel wire and extend across the cathode parallel thereto but are spaced apart and at right angles to each other. 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. This probe lies parallel to the cathode midway between the cathode and the anode in the discharge path therebetween. Conduction in the tube will greatly influence the probe and will enable the probe to be used to effect a control external to the tube.

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

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

The supports for the various electrodes are insulated and extend through a press **23** at the bottom of the tube.

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

Several types of tubes were made having this electrode arrangement but with different spacing between the electrodes. These several types had similar operating characteristics and differed only in the striking potentials and drops between the various electrodes, which would naturally follow from their different spacing.

One type, type I, had its electrodes spaced from the cathode the following distances: igniter I_1, .049 of an inch; igniter I_2, .119 of an inch; probe P, .315 of an inch; auxiliary anode A_x, .354 of an inch; and anode A, .630 of an inch. This type of tube will have a striking potential of about 105 volts from igniter I_1 to cathode; about 155 volts from igniter I_2 to cathode; about 260 volts from probe to cathode; and about 440 volts from anode to cathode. With the tube conducting and passing about 5 milliamperes, it has a drop of about 65 volts between the cathode and the igniters and a drop of about 80 volts between the cathode and the anode.

Another type, type II, had its electrodes spaced from the cathode the following distances: igniter I_1, .032 of an inch; igniter I_2, .075 of an inch; probe P, .160 of an inch; auxiliary anode A_x, about .200 of an inch; and anode A, .320 of an inch. This type of tube will have a striking potential from igniter I_1 to cathode of about 90 volts; from igniter I_2 to cathode of about 155 volts; from probe to cathode of about 180 volts; and from anode to cathode of about 300 volts. With the tube conducting and passing 5 milliamperes, it has a drop of about 67 volts between the cathode and either of the igniters I_1 or I_2; and a drop of about 75 volts between the cathode and the anode A.

In either type of tube, the probe P and the auxiliary anode A_x will acquire a positive potential due to conduction in the tube and will be able to control external circuits accordingly.

In Figs. 1, 2, and 3, the counting rings are arranged to count in the decimal notation and contain ten tubes; however, in order to simplify the showing, only the "0," "1," "2," "7," "8," and "9" digit-representing tubes are shown, because the operation of the circuits will be clear from a description of the tubes and circuits which are shown. The manner in which the

omitted tubes "3," "4," "5," and "6" would be connected in the circuits will be clear from the description of the respective circuits.

The circuits of Fig. 1 will now be described. The figure shows an output signal tube **24** in addition to the tubes of the ring, which tube **24** will fire and generate an output signal for each cycle of operation of the ring. This signal may be used to operate any desired mechanism; for instance, when the ring is one order of an accumulator, this signal can be used to cause a tens transfer entry to be made in a higher order directly or can be used to condition any conventional delayed-type transfer means for subsequent operation to enter the value in the higher order.

The digit-representing tubes of the ring and the output signal tube **24** in this circuit are cold-cathode tubes having the electrode arrangement of Fig. 4, with the type I spacing.

The tubes of the ring have their anodes connected together and over point **25** to a tap on a 50,000-ohm potentiometer **26**, which is connected between ground and terminal **27**, to which +440 volts is applied. The tap is adjusted to supply the anodes with a potential of about +190 volts. Point **25** is connected to ground over a stabilizing capacitor of .25 of a microfarad.

As shown in Fig. 1, the "even" numbered digit-representing tubes have their cathodes connected together to form these tubes into one operational group, and the "odd" numbered digit-representing tubes have their cathodes connected together to form these tubes into another operational group. The "even" group of cathodes is connected to ground over point **30**, resistor **31**, of 10,000 ohms, point **32**, and resistor **33**, of 10,000 ohms, and the "odd" group of cathodes is connected to ground over point **34**, resistor **35**, of 10,000 ohms, and the resistor **33**, which is common to both groups of cathodes.

Negative input impulses of from about —270 to —470 volts on input terminal **36** are impressed on the cathodes of all the tubes of the ring over point **37**, capacitor **38**, of .1 microfarad, point **32**, and resistors **31** and **35** and will cause the stepping operation of the ring. Point **37** in this circuit is connected to ground over a resistor **39**, of 68,000 ohms, to allow the charge on capacitor **38** to leak off between impulses.

The two groups of cathodes are coupled by an extinguishing circuit from point **30** over a capacitor **40**, of .05 of a microfarad, to point **34**, which enables conduction beginning in a tube of either group to cause any previously-conducting tube of the other group to be extinguished.

The chain connections between the tubes for connecting them into an operational series extend from the probe of one tube to the igniter I_2 of the next tube in the series and enable conduction in said one tube to prepare said next tube for operation in response to the next input impulse. These connections, for example, extend 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., so that the tubes will be prepared and fired one after another in sequence. These connections, one of which is indicated at **45**, are direct-wire connections which contain no impedance elements and are floating, since they have no direct connection with any potential source and acquire potential only as a result of conduction in either of the tubes which they connect.

When the digit-representing tubes are connected in a ring, the probe of the "9" tube is connected to the igniter I_2 of the "0" tube over conductor **46**. If the tubes are to operate as a trigger pair or as a binary counter, only the "0" and the "1" tubes would be used, with the probe of the "0" tube connected to the igniter I_2 of the "1" tube and the probe of the "1" tube connected to the igniter I_2 of the "0" tube.

With the ring as shown, the connection **46** between the probe of the "9" tube and the igniter I_2 of the "0" tube is used to control the output signal tube **24** to cause an operation of tube **24** each time the "0" tube is fired and becomes conducting. Tube **24** is connected in a self-extinguishing circuit and will conduct momentarily each time the "0" tube is fired. The anode of tube **24** is connected over point **47** and resistor **48**, of 470,000 ohms, to terminal **27**, which has +440 volts applied thereto. The cathode of this tube is connected to ground over resistor **49**, of 270,000 ohms, and capacitor **50**, of .05 of a microfarad, in parallel. The igniter I_1 is connected to the cathode over a resistor **51**, of 220,000 ohms, and to ground over a resistor **52**, of 220,000 ohms.

The igniter I_1 of tube **24** is coupled over capacitor **53**, of .03 of a microfarad, and point **54** to the connection **46**, which extends between the probe of the "9" tube and the igniter I_2 of the "0" tube. This igniter of tube **24** will have a positive impulse impressed thereon when the "9" tube fires and also when the "0" tube fires, but the pulse which it receives when the "9" tube fires will be insufficient to fire the tube, and only the pulse which it receives when the "0" tube conducts will be effective to cause tube **24** to fire. Point **54** in the above circuit is also connected to ground over a 3-megohm resistor **55**.

An output signal conductor **56** is coupled over a capacitor **57**, of .1 of a microfarad, to point **47** in the anode circuit of tube **24** and will have a negative impulse impressed thereon each time tube **24** is fired.

The ring may be preset to any starting position by any conventional means, such as by momentarily removing anode potential to extinguish any previously-conducting tube and then, after anode potential has been restored to the tubes, by applying a positive potential to the igniter of the tube with which counting is to begin. This will cause the selected tube to conduct and prepare the next tube in the sequence for response to an input impulse.

It is clear that, since the chain connections contain no impedance elements and since the cathodes are connected into two groups for extinguishing action and require only three resistors, **31**, **33**, and **35**, and one capacitor, **40**, which would normally be required to operate the "0" and the "1" tubes as a binary counter or as a trigger pair, an extremely simple decimal counting ring is provided.

The operation of the ring is as follows:

With any one of the tubes conducting—for example, the "7" tube—the ring is in condition to operate in response to input impulses.

Conduction in the "7" tube will cause its cathode potential and that of point **34** to be about +100 volts and its igniter electrodes and probe to become more positive. Since the cathodes of the other "odd" tubes are also connected to point **34**, they likewise will have a potential of about +100 volts, but their igniters and probes will not become more positive, since there is no conduction in these tubes.

At this time, point 30 and the cathodes of the "even" tubes will be at a potential of about +50 volts due to the drop across resistor 33, but this will have no effect on the potential of the probes or igniters of these tubes, since there is no conduction in any of the "even" tubes at this time.

The chain connection from the probe of the "7" tube to the igniter I_2 of the "8" tube will enable the positive potential which is acquired by the probe to be applied to the starting gap of the "8" tube. This application of positive potential will not cause sufficient ionization between the igniter I_2 and the cathode of the "8" tube to cause the tube to be fired; accordingly, the "7" tube merely prepares the starting gap of the "8" tube so that the "8" tube can be fired by the next negative impulse applied to all the cathodes.

The negative impulse of from 270 to 470 volts on terminal 36 is applied over capacitor 38, point 32, and resistors 31 and 35 to the cathodes of the tubes.

The negative impulse on the cathode of the "8" tube will be effective to cause the starter gap of the "8" tube to be ionized sufficiently to cause a breakdown in the main gap of the "8" tube and the tube to conduct. Since the "8" tube is the only tube of the ring which is prepared by having its igniter I_2 connected to a probe in a conducting tube, it will be the only tube which will become conducting in response to the impulse.

As the negative impulse is applied to the tubes and conduction commences in the "8" tube, its cathode potential will rise sharply, from the value which it acquired due to the negative input impulse, to the higher positive value due to conduction in the tube. This cathode potential rise will be transferred over capacitor 40 to the cathode of the "7" tube, which is already conducting, and will cause the potential of this cathode to rise to such an extent that the potential across the tube will be less than the sustaining potential, causing cessation of conduction in the "7" tube. As soon as the "7" tube becomes nonconducting and the impulse has passed, the potential of the cathodes of the "odd" group of tubes will return to that of point 32, and this group of tubes is ready to respond to a further impulse.

Conduction in the "8" tube will prepare the starter gap in the "9" tube, and, when the next impulse is impressed on the cathodes, conduction will begin in the "9" tube. Similarly, conduction in the "9" tube will, over connection 46, prepare the "0" tube to be fired by the next impulse.

The connection 46 is also effective to cause the output signal tube 24 to be fired when the "0" tube is fired and becomes conducting. When the "9" tube is rendered conducting and its probe becomes more positive, the impulse created thereby over capacitor 53 will not be great enough to ionize the starter gap of tube 24 sufficiently to cause a breakdown of its main gap; but, when the "0" tube also is fired, it will, through its igniter, cause conductor 46 to become sufficiently more positive to cause a larger impulse to be sent to the igniter I_1 of tube 24 to cause the starter gap to break down sufficiently to ionize the main gap. The constants of the circuit in which tube 24 is connected are such that this tube will automatically be extinguished each time it conducts and will enable a strong negative impulse to be generated and sent over the output conductor 56.

The circuit of Fig. 2 will now be considered. This circuit differs from the circuit of Fig. 1 principally by using positive input impulses to cause the stepping of the tubes of the ring and by using a different circuit arrangement for causing the extinguishing action between the groups of tubes.

The tubes forming the ring are cold-cathode tubes of the type II noted above, and the output signal tube 60 is a tetrode thyratron of the 2050 type.

The anodes of the tubes of the ring are connected to a common anode conductor 61 and over a common anode resistor 62, of 10,000 ohms, and point 63 to a tap on a 10,000-ohm potentiometer 64, which is connected between ground and terminal 65, to which +420 volts is supplied. The tap is adjusted to supply the anodes with about +180 volts. Point 63 in the above circuit is coupled to ground over an 8-microfarad capacitor.

The "even" numbered digit-representing tubes have their cathodes connected together to form these tubes into one operational group, and the "odd" numbered digit-representing tubes have their cathodes connected together to form these tubes into another operational group. The "even" group of cathodes is connected to ground over resistor 66, of 10,000 ohms, and capacitor 67, of .05 of a microfarad, in parallel. Similarly, the "odd" group of cathodes is connected to ground over resistor 68, of 10,000 ohms, and capacitor 69, of .05 of a microfarad. It is to be particularly noted that but one resistor and one capacitor are required for each group of cathodes.

The common anode resistor 62 and the resistor-capacitor arrangements 66—67 and 68—69 in the cathode circuits of the two groups of tubes enable conduction beginning in a tube of either group to cause any previously conducting tube of the other group to be extinguished.

As is the case with the ring of Fig. 1, the tubes of the ring of Fig. 2 are connected into an operational series by direct-wire floating connections from a probe in a tube to the igniter I_2 of the next tube of the series, which connections enable conduction in a tube of the series to prepare the next tube in the series for response to an input impulse. When the tubes are to operate as a ring, the probe of the "9" tube is connected to the igniter I_2 of the "0" tube. If the tubes are to operate as a trigger pair or as a binary counter, only the "0" and the "1" tubes would be used, with the probe of the "0" tube connected to the igniter I_2 of the "1" tube and with the probe of the "1" tube connected to the igniter of the "0" tube.

Positive potential input impulses of from 140 to 220 volts on terminal 74 are impressed on the common anode conductor 61 over point 75 and capacitor 76, of .05 microfarad, point 75 being connected to ground over a resistor 77, of 220,000 ohms, to allow the charge on the capacitor 76 to leak off between impulses. Each positive impulse which is impressed on the anodes will be effective to cause the starting gap of the prepared tube to become ionized sufficiently to cause a breakdown of the main gap.

If desired, the positive input impulses can be applied to the auxiliary anodes A_x of the tubes instead of to the anodes. When the impulses are to be applied to the auxiliary anodes, the circuit is as shown in Fig. 2, except that the auxiliary anodes are connected together and the input means are connected to the interconnected auxiliary anodes. The input impulses applied to the auxiliary anodes will cause the ring to be stepped

in the same manner as when applied to the anodes.

The ring of Fig. 2 can control the output signal generating tube 60 to produce an output signal each time the "0" tube fires and becomes conducting. Tube 60 is connected in a self-extinguishing circuit and has its anode connected over resistor 80, of 250,000 ohms, to the tap of a 40,000-ohm potentiometer 81, which is connected between terminal 65 and ground. The tap is adjusted so that the anode of this tube is supplied with a normal operating potential of about +250 volts.

The cathode of tube 60 is connected to ground over point 82 and resistor 83, of 470,000 ohms, and capacitor 84, of .01 microfarad, in parallel. Point 82 in this circuit will have a sharp positive potential rise each time the tube conducts momentarily, and this rise can be sent over the normally-closed switch 85 and capacitor 86, of .003 of a microfarad, to an output conductor 87. The switch 85 can be opened to prevent spurious output signals when the ring is initially preset to zero and the "0" tube is fired.

The heater element for this tube is shown conventionally.

The shield grid and the control grid of tube 60 are connected together and over a 1-megohm resistor 88 to terminal 89, to which a potential of —10.5 volts is supplied, to normally bias the tube to cut-off. These grids are also coupled over capacitor 90, of 10 microfarads, point 91, and conductor 92 to the probe of the "0" tube, which coupling enables the positive potential of the probe, as the "0" tube conducts, to fire the output signal tube. Point 91 in this circuit is connected to ground over a 4.7-megohm resistor 93.

The output signal tube also can be fired from the igniter I_1 electrode of the "0" tube, if desired, merely by connecting conductor 92 to the igniter instead of to the probe.

The ring also can be stepped by negative impulses applied from a source of impulses over separate capacitors to the two groups of cathodes. A bleeder resistor to ground can be provided to allow the charge on these capacitors to bleed off much in the same manner as is done by resistor 39 of Fig. 1 or 77 of Fig. 2. In this arrangement, the igniter of the "0" tube which is not used in the chain connections can be used to operate the output signal tube.

The potential changes on the probes of the tubes as the tubes operate can be used to operate other types of output signal generating means beside the one shown in Fig. 2. For instance, the potential rise of the probe of the "0" tube can be applied to one tube of a trigger pair to operate the pair from normal condition, and the potential rise of a probe of a subsequent tube of the ring can be applied to the other tube of the trigger pair to restore it to normal condition. The trigger pair, when operated, can generate an output signal impulse which can be used to operate some other apparatus as desired.

The ring of Fig. 2 can be preset to any starting condition in the same manner as the ring of Fig. 1.

The operation of the ring of Fig. 2 is as follows:

With any of the tubes conducting—for example, the "0" tube—the ring is in condition to operate in response to positive input impulses applied to the tubes.

Conduction in the "0" tube will cause its cathode, as well as the cathodes of all "even" tubes, to become more positive due to the drop across resistor 66. Conduction in the "0" tube causes its probe to become more positive and, over the chain connection, prepare the "1" tube for response to the next input impulse.

The input impulse which is applied to the anodes of all the tubes will cause the starter gap of the "1" tube to ionize sufficiently to cause a breakdown of the main gap and render the "1" tube conducting.

When the "1" tube begins to conduct, its cathode will be held from rising momentarily by the capacitor 69, and this will cause its anode potential, as well as the anode potential of all the other tubes, to drop sharply.

At this time, the cathode of the "0" tube will be at its most positive value, and the drop of its anode potential will cause the potential across the tube to be less than the sustaining potential, with the consequent extinguishing of conduction in the "0" tube.

After a momentary delay, which is sufficient for the "0" tube to be extinguished, the cathode of the "1" tube will become more positive, and the anode potential of all the tubes will rise. Conduction in the "1" tube will, over the chain connection, prepare the "2" tube for response to the next input impulse.

A further input impulse applied to the anodes will cause the prepared "2" tube to conduct and extinguished the "1" tube. In a similar manner, input impulses will cause the conduction in the tubes to be stepped around the ring.

The potential rise of the probe of the "0" tube, when that tube conducts, is transmitted over conductor 92 and capacitor 90 to the output signal tube 60 and will cause this tube to conduct momentarily and produce a positive output impulse on the output conductor 87.

The circuit of Fig. 3 will now be described. This circuit differs from the circuits of Figs. 1 and 2 in the manner in which input impulses are applied to the ring and in the form of the extinguishing circuit used between the two groups of tubes.

In this circuit, the ring is made up of cold-cathode tubes of type II, noted above, and the output signal tube 95 is a tetrode thyratron of the 2050 type.

In the circuit of Fig. 3, the anodes of the "odd" and "even" tubes are grouped instead of the cathodes, the cathodes being all connected together and directly to ground.

The anodes of the "even" tubes are connected together and over point 96 and resistor 97, of 39,000 ohms, to an anode potential supply conductor 98, which is connected over point 99 to the tap on a 10,000-ohm potentiometer 101, connected between ground and a terminal 102, to which +420 volts is applied. The tap is adjusted to supply conductor 98 with a potential of between +150 and +250 volts. Point 99 is coupled to ground over an 8-microfarad stabilizing capacitor.

The anodes of the "odd" tubes are likewise connected together and over point 103 and resistor 104, of 39,000 ohms, to the anode potential supply conductor 98.

The two groups of anodes are coupled by an extinguishing circuit from point 96 over a capacitor 105, of .05 microfarad, to point 103, which enables conduction beginning in any tube of either group to cause any previously-conducting tube of the other group to be extinguished.

The chain connections for connecting the

tubes in a ring are the same as shown in Figs. 1 and 2, each chain connection being a floating direct-wire connection from the probe of a tube to the igniter I_2 of the next tube in the chain and enabling conduction in a tube to prepare the next tube in the chain for conduction in response to an input impulse.

The means for applying input impulses to the tubes of the ring is different in the circuit of Fig. 3 from the means shown in the circuits of Figs. 1 and 2. The igniters I_1 of the tubes are used as auxiliary cathodes, to which input impulses are applied, and with the igniters I_2 form starter gaps for initiating conduction in the main gaps in sequence.

The igniters I_1 of the "even" group of tubes are connected together and to ground over resistor 106, of 100,000 ohms, point 107, and resistor 108, of 250,000 ohms, in series. Similarly, the igniters I_1 of the "odd" group of tubes are connected together and to ground over resistor 109, of 100,000 ohms, in series with resistor 108, which is common to the two groups.

Negative impulses of between 120 and 140 volts are applied from any convenient source 111 over point 112 and capacitor 113, of .01 microfarad, to point 107 and thence over resistors 106 and 109 to the igniters I_1. The negative impulses on the igniters I_1 will cause the starter gap of any tube whose igniter I_2 is connected to a probe in a conducting tube to be ionized sufficiently to start conduction between the anode and the cathode. Point 112 in the above input circuit is connected to ground over a resistor of 220,000 ohms.

When a tube conducts, its anode and the anodes of all the tubes of its related group will have a lower potential, due to the drop across its related resistor, 97 or 104. Then, when the next tube in the series is fired, which tube is in the other group, its anode potential will also drop, and this drop is impressed over the capacitor 105 on the anodes of the group containing the previously-conducting tube to drive the anode potential of this group below sustaining potential, thereby causing the previously-conducting tube to be extinguished. Thus, conduction beginning in a tube in one group will extinguish any previously-conducting tube of the other group.

The ring may be preset to any starting condition in the same manner as fully described in connection with the circuit of Fig. 1.

It is clear that in this ring of Fig. 3 only those elements of resistance and capacitance are required which would be in use in a binary counter or trigger pair and that the addition of tubes to make the ring capable of counting in a decimal notation does not require any additional resistors or capacitors.

The ring can also control the output signal generating tube 95 to produce an output signal for each cycle of operation of the ring. In this particular embodiment, the tube 95 will be fired each time the "0" tube becomes conducting. Tube 95 is connected in a self-extinguishing circuit and has its anode connected over a resistor 115, of 250,000 ohms, to terminal 102 and has its cathode connected to ground over a resistor 116, of 470,000 ohms, and capacitor 117, of .01 microfarad, in parallel. The circuit constants of this circuit are such that the tube will be extinguished automatically each time it is rendered conducting.

Upon each momentary conduction, the potential of point 118 in the cathode circuit will have a sharp potential rise, and this rise can be sent as a positive impulse over the normally-closed switch 119 and capacitor 120, of .003 microfarad, to an output conductor 121. This output impulse can control or cause the operation of any desired mechanism. Switch 119 can be opened to prevent spurious output signals when the ring is initially preset to zero and the "0" tube is fired.

The heater element for tube 95 is shown conventionally.

The shield grid and the control grid of tube 95 are connected over resistor 122, of 250,000 ohms, to terminal 123, to which −10.5 volts is supplied to normally bias the tube to cut-off. The grids are also coupled over capacitor 124, of .001 microfarad, point 125, and conductor 126 to the probe of the "0" tube, which coupling enables the positive potential of the probe, when the "0" tube conducts, to fire the output signal generating tube. Point 125 is connected to ground over a 4.7-megohm resistor.

It is to be noted that the arrangement for applying impulses to auxiliary cathodes as shown in Fig. 3 could be used to operate the circuit of Fig. 2 instead of using the anode input shown therein. When the igniters I_1 of Fig. 2 are to be used as auxiliary cathodes, the igniters of "odd" and "even" tubes are grouped and connected to ground over a resistor network, as shown in Fig. 3. Negative input impulses on the network will cause a stepping of the conducting condition of the tubes of the ring.

The operation of the circuit of Fig. 3 is as follows:

With any of the tubes conducting—for example, the "1" tube—the ring is in condition to operate in response to negative input impulses applied to the igniters I_1, which function as auxiliary cathodes.

Conduction in the "1" tube will cause a drop in its anode potential and will also cause its probe to be effective on the igniter I_2 of the "2" tube over the chain connection to prepare the starter gap between the igniter I_2 and the igniter I_1 of the "2" tube, so that this tube will respond to the next input impulse.

The negative input impulse which is applied to the auxiliary cathode of all the tubes will cause the starter gap of the "2" tube, which is the only tube having its igniter I_2 connected to a probe in a conducting tube, to be ionized sufficiently to cause a breakdown of the main gap between the cathode and anode which renders the "2" tube conducting.

When the "2" tube begins to conduct, its anode potential will drop, and this drop is impressed on the anode of the "1" tube over capacitor 105, forcing the anode potential of the "1" tube, which was already low, due to conduction in the "1" tube, down momentarily to a point below the sustaining potential and causing the "1" tube to be extinguished. After the "1" tube has been extinguished, its anode potential will rise, as will that of the other "odd" tubes.

Conduction in the "2" tube will prepare the "3" tube to respond to the next impulse. The next impulse will cause the "3" tube to conduct, and conduction in the "3" tube will extinguish the "2" tube and prepare the "4" tube for response to the next impulse. In a similar manner, further input impulses will cause the conducting condition in the tubes to be stepped around the ring.

The potential rise of the probe of the "0" tube, when that tube conducts, is transmitted over

conductor 126 and capacitor 124 to the output signal tube 95 and will cause that tube to conduct momentarily and produce a positive output impulse on conductor 121.

It is clear from the above that the combination of the connection of the tubes for sequential operation by means of floating connections and grouping of alternate tubes in the sequence for extinguishing action enables extremely simple step-by-step operating circuits to be obtained, in which circuits a chain or ring of more than two tubes can be had without any more elements of resistance or capacitance than are necessary for a two-tube binary counter.

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 particular forms or 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, a plurality of electrodes forming a plurality of electron discharge paths in a gaseous medium; means connecting the discharge paths into an operational sequence, each connection being a floating connection extending from a discharge path to the next discharge path in the sequence and enabling the discharge in one path to prepare the next discharge path in the sequence for discharge in response to an input impulse; an operating potential supply for the discharge paths; circuits connecting the electrodes which form the discharge paths to the operating potential supply and into two groups for mutual extinguishing action between groups whereby conduction beginning in a discharge path of one group will extinguish conduction in a conducting discharge path of the other group, each of said groups containing alternate discharge paths of said sequence and the circuit of each group containing impedance which is common to the paths of the group and from which the extinguishing action is derived; and means to apply input impulses to the discharge paths to cause conduction in the prepared paths one after another in sequence.

2. In a device of the class described, a plurality of electrodes forming a plurality of electron discharge paths in a gaseous medium; means connecting the discharge paths into an operational sequence, each connection being a direct-wire floating connection extending from a discharge path to the next discharge path in the sequence and deriving potential solely from conduction in the paths to enable the discharge in one path to prepare the next discharge path in the sequence for discharge in response to an input impulse; an operating potential supply for the discharge paths; circuits connecting the electrodes which form the discharge paths to the operating potential supply and into two groups for mutual extinguishing action between groups whereby conduction beginning in a discharge path of one group will extinguish conduction in any conducting discharge path of the other group, each of said groups containing alternate discharge paths of said sequence and the circuit of each group containing impedance which is common to the paths of the group and from which the extinguishing action is derived, the direct-wire connections and common impedance for each group of paths enabling an extremely simple circuit to be obtained; and means to apply input impulses to the discharge paths to cause conduction in the prepared paths one after another in sequence.

3. In a device of the class described, a plurality of electrodes forming a plurality of electron discharge paths in a gaseous medium; means connecting the discharge paths into an operational sequence for step-by-step operation in response to input impulses, each connection being a direct connection containing no impedance elements and extending from a discharge path to the next discharge path in the sequence and being a floating connection deriving potential solely from conduction in the paths to enable the discharge in one path to prepare the next discharge path in the sequence for discharge in response to the next input impulse; an operating potential supply for the discharge paths; circuits connecting the electrodes which form the discharge paths to the operating potential supply and into two groups for mutual extinguishing action between groups whereby conduction beginning in a discharge path of either group will reduce the potential across the discharge paths of the other group to below sustaining potential to cause conduction to cease in a conducting discharge path of the other group, each of said groups being made up of alternate discharge paths of said sequence and the circuit of each group containing a load impedance which is common to the paths of the group and from which the extinguishing action is derived; and means to apply input impulses to one of the electrodes related to each of the paths to cause conduction in the prepared paths one after another in sequence.

4. In a device of the class described, the combination of a plurality of cold-cathode gas tubes, each tube having a plurality of electrodes, two of said electrodes forming a main gap, two of said electrodes forming a starter gap, and a further one of said electrodes located in the discharge of the main gap and capable of exerting an external control when conduction occurs in the main gap; means connecting the tubes for operation one after another in sequence in response to input impulses, the connection between adjacent tubes of the sequence being a direct floating conductive coupling from said further electrode of a tube to one of the starter gap electrodes of the next tube of the sequence which enables conduction in a tube to prepare the next tube for operation; operating potential supply for the tubes; circuits connecting the main gap electrodes of the tubes of the sequence to the potential supply and connecting the tubes into two groups for mutual extinguishing action between groups, whereby conduction beginning in any tube in one group will extinguish any previously-conducting tube in the other group, the circuit for each group of tubes connecting alternate tubes of the sequence together and containing impedance common to all the tubes of the group and from which the extinguishing action is derived; and means for supplying input impulses to all the tubes to cause their sequential operation.

5. In a device of the class described, the combination of a plurality of cold-cathode gas tubes, each tube having at least a pair of electrodes forming a main gap, an igniter cooperating with one of the electrodes to form a starter gap, and a probe located in the discharge of the main gap and capable of exerting a control when conduction occurs in the main gap; means connecting the tubes for operation in sequence in response to input impulses, the connection between adjacent tubes of the sequence being a direct, float-

ing, conductive coupling from the probe of a tube to the igniter of the next tube of the sequence which enables conduction in a tube to prepare the next tube for operation; an operating potential supply for the tubes; circuits connecting tubes of the sequence to the potential supply and into two groups for mutual extinguishing action between groups, whereby conduction beginning in any tube in one group will extinguish any previously-conducting tube in the other group, each group containing alternate tubes of the sequence and the circuit for each group including impedance common to all the tubes of the group and from which the extinguishing action is derived; and means for supplying input impulses to a similar electrode of all the tubes to cause their sequential operation.

6. In a device of the class described, the combination of a plurality of cold-cathode gas tubes, each tube 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 discharge of the main gap and capable of exerting a control when conduction occurs in the main gap; means connecting the tubes for operation in sequence in response to input impulses, the connection between adjacent tubes of the sequence being a direct floating conductive coupling from the probe of a tube to the igniter of the next tube of the sequence which enables conduction in a tube to prepare the next tube for operation; anode potential supply for the tubes; cathode potential supply for the tubes; circuits connecting tubes of the sequence to the potential supplies and into two groups for mutual extinguishing action between groups, whereby conduction beginning in any tube in one group will extinguish any previously-conducting tube in the other group, each group being made up of alternate tubes of the sequence and the circuit for each group containing impedance common to all the tubes of the group and from which the extinguishing action is derived; and means for supplying input impulses to all the tubes to cause their sequential operation.

7. In a device of the class described, the combination of a plurality of more than two cold-cathode gas tubes, each tube 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 discharge of the main gap and capable of exerting a control when conduction occurs in the main gap; means connecting the tubes in a ring for operation in sequence in response to input impulses, the connection between adjacent tubes of the sequence being a direct floating conductive coupling from the probe of a tube to the igniter of the next tube of the sequence containing no impedance elements and deriving potential solely from conduction in said adjacent tubes, each of which connections enables conduction in a tube to prepare the next tube for operation; anode potential supply for the tubes; cathode potential supply for the tubes; circuits connecting tubes of the sequence to the potential supplies and into two groups for mutual extinguishing action between groups, whereby conduction beginning in any tube in one group will extinguish any previously-conducting tube in the other group, each group being made up of alternate tubes of the sequence and the circuit for each group containing impedance common to all the tubes of the group and from which the extinguishing action is derived; the use of no impedance elements in the sequence connections and the grouping of the tubes into two groups for mutual extinguishing action, with common impedance for the tubes of each group, enabling a ring of more than two tubes to be produced, which requires no more impedance elements than would be required to connect two tubes to operate as a binary counter; and means for supplying input impulses to all the tubes to cause their sequential operation.

8. In a device of the class described, the combination of a plurality of digit-representing tubes, each tube being a cold-cathode gaseous electron discharge tube 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 discharge of the main gap and capable of exerting an external control when conduction occurs in the main gap; means connecting the tubes for step-by-step operation in a digital series in response to input impulses, each connection being a direct conductive connection extending from the probe of a tube to the igniter of the tube which is next in the series and enabling conduction in a tube in the series to prepare the next tube in the series for response to the next input impulse; a common anode potential supply to which the anodes of all the tubes of the series are connected; a circuit connecting the cathodes of the "even" digit value tubes together and over a first and a second resistor in series to a source of cathode potential; a circuit connecting the cathodes of the "odd" digit value tubes together and over a third resistor and said second resistor to said source of cathode potential; a blow-out capacitor connecting said "odd" and "even" groups of cathodes to enable an impulse which is generated at the cathode of a tube of either group as it conducts to extinguish any previously-conducting tube of the other group; and means to apply input impulses to all the tubes to cause any prepared tube to be fired.

9. The device as claimed in claim 8 in which the direct conductive connections between tubes contain no impedance elements and acquire potential solely from conduction in the tubes which they connect.

10. The device as claimed in claim 8 in which the means to apply input impulses to the tubes includes means to supply negative potential impulses to the juncture of the first, second, and third resistors and over the first and third resistors to the cathodes of the tubes.

11. In a device of the class described, the combination of a plurality of digit-representing tubes, each tube being a cold-cathode gaseous electron discharge tube 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 discharge of the main gap and capable of exerting an external control when conduction occurs in the main gap; means connecting the tubes for step-by-step operation in a digital series in response to input impulses, each connection being a direct conductive connection extending from the probe of a tube to the igniter of the tube which is next in the series and enabling conduction in a tube in the series to prepare the next tube in the series for response to the next input impulse; a common anode potential supply to which the anodes of all the tubes of the series are connected over a common impedance; a circuit connecting the cathodes of the "even" digit

value tubes together and over a cathode impedance, including a resistor and capacitor in parallel, to a source of cathode potential; a circuit connecting the cathodes of the "odd" digit value tubes together and over a cathode impedance, including resistor and capacitor in parallel, to a source of cathode potential; said anode and cathode impedances cooperating to enable a tube of either group as it conducts to extinguish any previously-conducting tube of the other group; and means to apply input impulses to all the tubes to cause any prepared tube to be fired.

12. The device as claimed in claim 11 in which the direct conductive connections between tubes contain no impedance elements and acquire potential solely from conduction in the tubes which they connect.

13. The device as claimed in claim 11 in which the means to apply input impulses to the tubes includes means to supply positive potential impulses directly to the anodes of the tubes.

14. In a device of the class described, the combination of a plurality of digit-representing tubes, each tube being a cold-cathode gaseous electron discharge tube having at least an anode and a cathode forming a main gap, an igniter and auxiliary cathode forming a starter gap, and a probe located in the discharge of the main gap and capable of exerting an external control when conduction occurs in the main gap; means connecting the tubes for step-by-step operation in digital series in response to input impulses, each connection being a direct conductive connection extending from the probe of a tube to the igniter of the tube which is next in the series and enabling conduction in a tube of the series to prepare the next tube in the series for response to the next input impulse; a circuit connecting the anodes of the "even" digit value tubes together and over an impedance to a source of anode potential; a circuit connecting the anodes of the "odd" digit value tubes together and over an impedance to the source of anode potential; a blow-out capacitor coupling the "odd" and "even" groups of the anodes to enable an impulse, which is generated at the anode of a tube of either group as the tube begins to conduct, to extinguish any previously-conducting tube of the other group; a circuit connecting the cathodes of all the tubes together and directly to a source of cathode potential; and means to apply input impulses to all the tubes.

15. The device as claimed in claim 14 in which the series connections contain no impedance elements and have no connection to a potential source but acquire potential solely from conduction in the tubes which they connect.

16. The device as claimed in claim 14 in which the means to apply input impulses to the tubes includes a circuit connecting the auxiliary cathodes of the "even" digit value tubes together and over a common impedance to a source of negative potential input impulses, and includes a circuit connecting the auxiliary cathodes of the "odd" digit value tubes together and over a common impedance to the source of negative potential input impulses.

17. In a device of the class described, the combination of a pair of cold-cathode tubes each having a plurality of electrodes, two of said electrodes forming a main gap, two of said electrodes forming a starter gap, and a further one of said electrodes located in the discharge of the main gap and capable of exerting an external control when conduction occurs in the main gap; direct floating connections between the probe of each tube and one of the electrodes of the starter gap of the other tube to enable conduction in a tube to prepare the other tube for response to an input impulse, each of said connections containing no impedance elements and having no connection to a source of potential but deriving its potentials from the discharge within the tubes; means connecting similar main gap electrodes together and to a source of potential; circuits connecting the other main gap electrodes over separate impedances to a source of potential; a blow-out capacitor coupling said other main gap electrodes to enable conduction beginning in either tube to extinguish conduction in the other tube; and means to apply input impulses to the tubes to cause the prepared tube to operate.

18. In a device of the class described, the combination of a pair of cold-cathode gaseous electron discharge tubes, each tube 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 discharge of the main gap and capable of exerting an external control when conduction occurs in the main gap; connections from the probe of each tube to the igniter of the other tube to enable conduction in either tube to prepare the other tube for response to input impulses, each of said connections being a direct conductive connection containing no impedance elements and being a floating connection having no connection to a potential source but deriving potential solely from the gaseous discharges in the tubes which it connects; a common anode potential supply to which the anodes of both tubes are directly connected; a circuit from the cathode of one of said tubes over a first and a second resistor in series to a source of cathode potential; a circuit from the cathode of the other of said tubes over a third resistor and said second resistor in series to said source of cathode potential; a blow-out capacitor coupling the two cathodes for mutual extinguishing action to enable an impulse generated at a cathode, as a tube begins to conduct, to be impressed on the cathode of the other tube which is already conducting to thereby cause said other tube to be extinguished; and means to apply input impulses to the tube to operate the prepared tube.

19. In a device of the class described, the combination of a pair of cold-cathode gaseous electron discharge tubes, each tube 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 discharge of the main gap and capable of exerting an external control when conduction occurs in the main gap; connections from the probe of each tube to the igniter of the other tube to enable conduction in either tube to prepare the other tube for response to input impulses, each of said connections being a direct conductive connection containing no impedance elements and being a floating connection having no connection to a potential source but deriving potential solely from the gaseous discharges in the tubes which it connects; a circuit connecting the anodes together and over a common resistor to a source of anode potential; a circuit from the cathode of one of said tubes over a resistor and capacitor in parallel to a source of cathode potential; a circuit from the cathode of the other

of said tubes over a resistor and capacitor in parallel to the source of cathode potential; the impedance in the anode and cathode circuits enabling conduction in either tube to extinguish the other tube; and means to apply input impulses to the tubes to operate the prepared tube.

20. In a device of the class described, the combination of a pair of cold-cathode gaseous electron discharge tubes, each tube having a pair of main electrodes which cooperate to form a main gap, a pair of starter electrodes forming a starter gap, and a probe located in the discharge of the main gap and capable of exerting an external control when conduction occurs in the main gap; connections from the probe of each tube to one of the starter electrodes of the other tube to enable conduction in either tube to prepare the other tube for response to input impulses, each of said connections being a direct conductive connection containing no impedance elements and being a floating connection having no connection to a potential source but deriving potential solely from the gaseous discharges in the tubes which it connects; a circuit connecting the anode of one of the tubes over a resistor to an anode potential supply; a circuit connecting the anode of the other of the tubes over a resistor to the anode potential supply; a common cathode potential supply to which the cathodes are directly connected; a blow-out capacitor coupling the two anodes for mutual extinguishing action to enable a negative potential impulse which is generated at the anode, as a tube begins to conduct, to be impressed on the anode of the other tube which is conducting and cause this other tube to be extinguished; and means to apply input impulses to the tubes to operate the prepared tube.

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