

June 30, 1953

J. R. DESCH
ELECTRONIC COUNTER

2,644,112

Filed Dec. 4, 1951

2 Sheets-Sheet 1

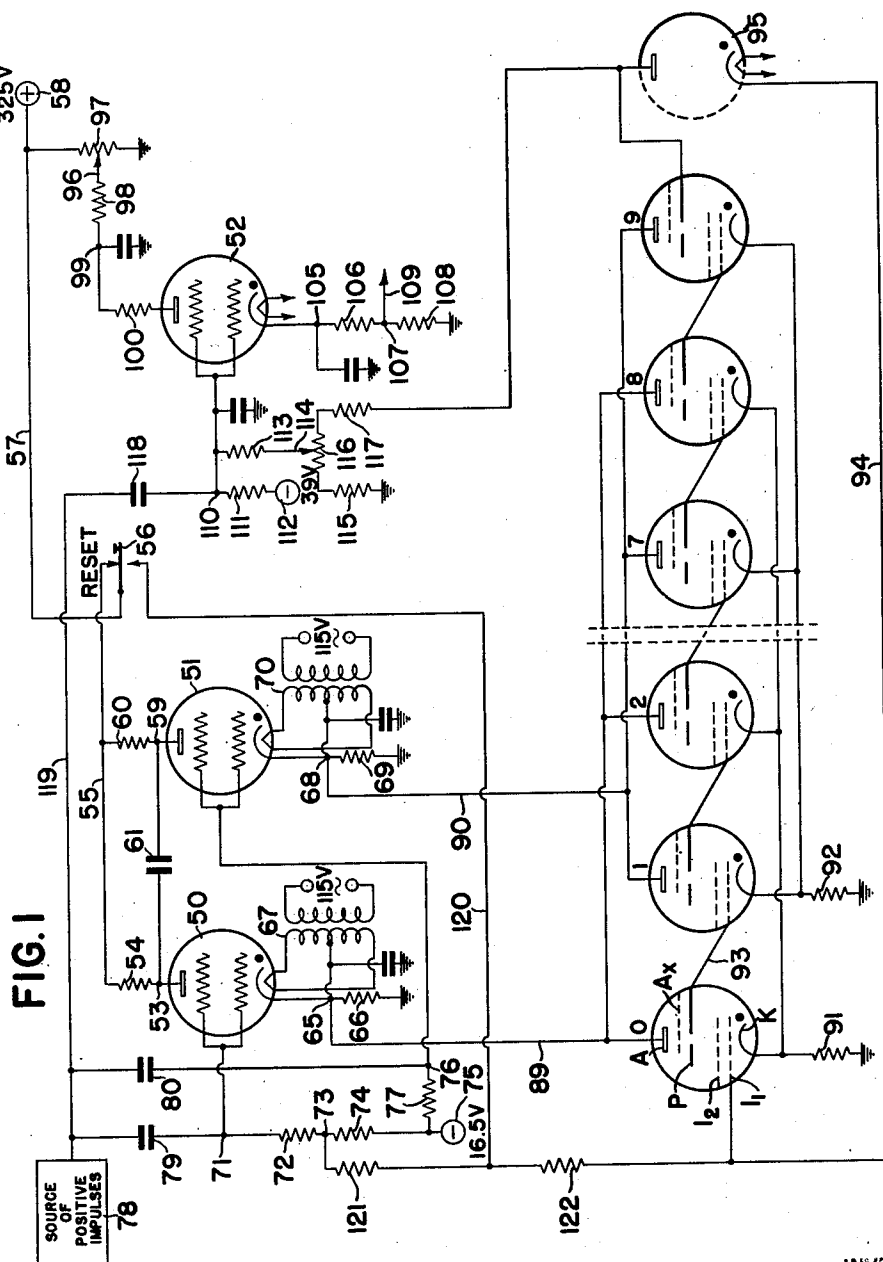


FIG. 1

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FIG. 2

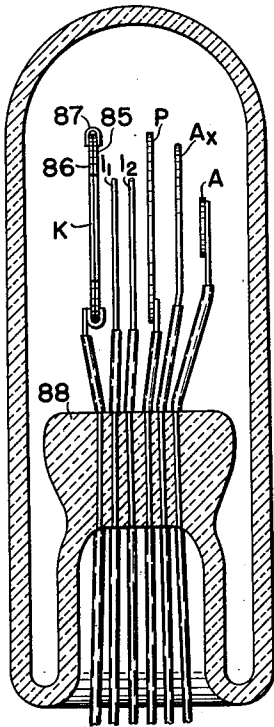
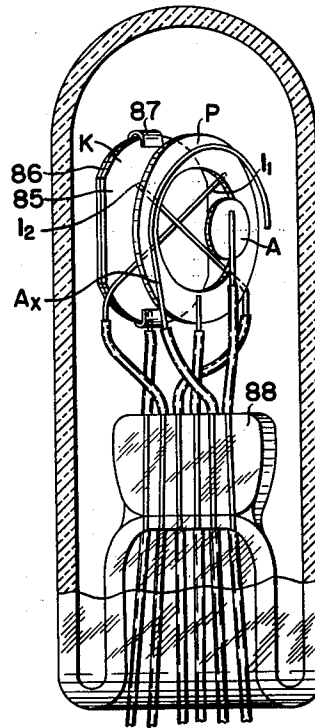


FIG. 3



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ELECTRONIC COUNTER

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

The principal advantage of the novel counting circuit lies in its simplicity, the input impulses being applied to an entry device which in turn controls the stepping of the ring. In the novel circuit, the ring or chain is of extremely simple construction, since it requires only two resistors apart from the tubes, and this is true whether there be four tubes or more than four tubes in the ring or chain.

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 to a separate source of anode potential for each group.

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, and, if the ring is to control some other device to produce an output signal for each cycle of operation of the ring, this connection can include a rectifier to insure that the proper control will be obtained. 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 received.

The stepping of the conducting condition of

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the tubes of the ring or chain is obtained by varying the anode potentials supplied to the two groups of tubes between a high potential which will support conduction and a low potential which will not be capable of supporting conduction, the relation between the potentials being such that, when high potential is supplied to one group of tubes, low potential is supplied to the other group, with the high and low potential conditions being reversed each time it is desired to step the ring.

In the embodiment which is being described to explain the invention, the anode potentials for the two groups of tubes are derived from the entry device, which also serves as an anode potential control means to which the input impulses are applied and which can be operated alternately to one or the other of two stable operating conditions by the impulses. The anode potentials are derived from the entry device or anode potential control means in such a manner that they can vary with the different operating conditions of the means. When the control means is in one operating condition, the anode potential which is supplied to one of said groups of tubes will be high enough to cause conduction in a tube of that group; but, when the control means is in its other operating condition, the anode potential which is supplied to this one group of tubes will have been reduced to a value which will not support conduction in the tubes of the group. In a similar manner, the anode potential which is supplied to the other group of tubes will be high or low, depending on the operating condition of the potential control means. The relation between the anode potentials which are supplied to the two groups of tubes is such that, whenever the high anode potential is supplied to one group of tubes, the low potential will be supplied to the other group of tubes.

In the novel circuit, therefore, the combination of the grouping of the tubes and the variation of the anode potentials applied to the groups, together with the floating connections which connect the tubes in a chain or ring, enables an extremely simple circuit to be obtained and enables the tubes of the ring or chain to be operated one at a time in response to input impulses which are applied to the anode potential control means.

The novel circuit can be used to control or operate means to produce an output signal in each cycle of operation of the ring when a particular tube conducts. If the novel circuit is

used as one denomination of an accumulator, then the means which produces the output signal could be effective as a tens transfer means to enter a unit in a higher order each time the lower order makes a cycle of operation.

If desired, controls may be provided to cause a particular tube in the ring or chain to conduct to prepare the ring or chain for step-by-step operation.

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 in which the sequential operation of the tubes is effected by variations in operating potential supplied to the tubes.

A further object of the invention is to provide a step-by-step-operating cold-cathode tube ring in which conduction in the main gap of a tube causes ionization in the starter gap in the next tube in sequence in the ring and in which the stepping of the operation of the tubes is controlled by varying the anode-cathode operating potentials supplied to the tubes in response to input signals.

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

Of the drawings,

Fig. 1 is a circuit diagram of one of the novel counting circuits including a counting ring with means to preset the ring to a predetermined condition and including means to produce an output signal for each cycle of operation of the ring.

Fig. 2 is a section through one of the cold-cathode tubes used in the ring, showing the spacing of the electrodes.

Fig. 3 is a perspective view of the tube of Fig. 2, showing the shape and relative positioning of the electrodes.

Detailed description

In order that the invention may be more clearly explained, it will be described as embodied in a counting ring 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 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.

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.

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.

The circuit of Fig. 1 includes an entry device which is operated by input impulses and which is made up of a pair of thyratrons 50 and 51 and an associated resistance network from which are derived the high and low anode potentials; a ring of digit-representing tubes which are operable step by step in sequence; and an output signal tube 52, which may serve as a tens transfer tube to send an impulse to the next higher denomination each time the ring exceeds its capacity when the ring is used as one denomination of an accumulator.

In order to simplify the showing of the circuit, only the "0," "1," "2," "7," "8," and "9" digit-representing tubes of the ring 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.

The entry device has the input impulses applied thereto and operates to control the stepping of the operating condition of the ring by controlling the application of high and low anode potentials to the groups of tubes of the ring. The tubes 50 and 51 of the entry device are tetrode thyratrons, of the type sold under the designation 2050, which tubes are connected in a trigger circuit operable alternately to either of two stable states.

The anode of tube 50 has potential supplied thereto over point 53, resistor 54, of 10,000 ohms, conductor 55, normally-closed contact of reset switch 56, conductor 57, and terminal 58, to which +325 volts is applied. The anode of tube 51 is similarly supplied with potential by being connected over point 59 and resistor 60, of 10,000 ohms, to conductor 55.

Points 53 and 59 in the anode circuits are coupled by a blow-out capacitor 61, of .05 microfarad, which transmits the negative impulse, which is created as a tube begins to conduct, to the other tube, which is already conducting, to extinguish the previously-conducting tube. This connection insures that only one of the trigger tubes will be conducting at a time.

The cathode of tube 50 is connected to ground over point 65 and resistor 66, of 30,000 ohms. Point 65 is coupled to the center tap of the secondary of a filament transformer 67 and also to ground over a .01-microfarad capacitor. The potential of point 65 will vary from a low value when tube 50 is not conducting to a high value when it is conducting.

Similarly, the cathode of tube 51 is connected to ground over point 68 and resistor 69, of 30,000 ohms, point 68 being connected to the center tap of a separate filament transformer 70 for this tube and to ground over a .01-microfarad capacitor. The potential of point 68 will also vary between a high value and a low value, depending on the conducting status of tube 52.

The shield grid and the control grid of tube 50 are connected together, and a normal nega-

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tive blocking bias is applied over point 71, resistor 72, of 250,000 ohms, point 73, resistor 74, of 250,000 ohms, and terminal 75, which is supplied with a potential of -16.5 volts.

Terminal 75 also supplies blocking potential to the shield grid and the control grid of tube 51, which are tied together and are connected to the terminal over point 76 and resistor 77, of 470,000 ohms.

Input impulses from an input source shown generally at 78, which might be a source of digit-representing impulses, as disclosed in the *Mumma United States Patent No. 2,404,739*, or any source of positive impulses, are applied over coupling capacitors 79 and 80, each of 50 micro-microfarads, to points 71 and 76 and will cause tubes 50 and 51 to conduct alternately. This operation of the tubes will cause one of the points 65 or 68 to have a high potential and the other a low potential, which potentials will be reversed when a further impulse reverses the operation of the trigger pair. The potentials of the points 65 and 68 are applied as the anode potentials of the two groups of digit-representing tubes making up the ring of cold-cathode tubes, which are operable step by step as counting progresses.

It is to be understood that the entry device which is shown in Fig. 1 for causing the stepping of the operating condition of the ring is merely illustrative of one form of device for supplying anode potentials and varying these potentials to cause the stepping of the ring. Other forms of trigger pairs and other potential-varying means are within the purview of the invention so long as they can supply high enough potential to one group of tubes to cause conduction in one of the tubes of the group and at the same time supply a low potential to the other group of tubes to prevent conduction therein, and so long as they can reverse the high and low potential conditions to supply high potential to one and the other groups alternately.

As cold-cathode tubes having the desired electrode arrangements and operating characteristics were not available, a suitable tube was developed. Fig. 3 is an enlarged perspective view of the tube, while Fig. 2 is a side elevation which shows the side-spacing of the electrodes.

The tube is provided with a plurality of electrodes, including, in order, a cathode, K; two igniters, I₁ and I₂; 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 85 of magnesium and a sheet 86 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 87 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 I₁, 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 I₂ also extends across the cathode, parallel thereto, but runs approximately at right angles to igniter I₁ and is spaced about .075 of an inch from the cathode. The igniter I₂ can be used with either

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the cathode or the igniter I₁ 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 88 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 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 I₁ to cathode K of about 90 volts; from igniter I₂ 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 I₁ or I₂ 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" numbered digit-representing tubes have their anodes connected together and over conductor 89 to point 65 in the cathode circuit of tube 50, from which point they will be supplied with a potential which is high enough to cause conduction in any tube of the group when the tube 50 conducts, but which will be low enough so as not to support conduction in any tube of the group when tube 50 is non-conducting. Similarly, the anodes of the "odd" numbered tubes are connected together and over conductor 90 to point 68 in the cathode circuit of tube 51, from which point they will be supplied with a high potential when tube 51 conducts and a low potential when tube 51 is non-conducting. Since only one of the tubes 50 and 51 is conducting at a time, only one group of tubes will have high potential applied thereto, and, when one of the groups has high operating potential applied thereto, the other group will have low potential supplied thereto.

It is to be noted that, if it is desired to obtain greater potential variations for the anodes of the groups of tubes than are possible from the variations in the cathode potentials of the trigger pair, each group of tubes can be coupled to the trigger pair over a high-vacuum, phase-reversing amplifying tube. The anodes of the group of tubes are connected to the anode of the amplifying tube, which has high enough potential supplied to its anode over an impedance to provide the desired range of potential variation; has its

cathode connected to ground; and has its control electrode coupled to the point, as 65 or 68, in the cathode circuit of the trigger pair. Variations in the point in the cathode circuit of the trigger pair will control conduction in the amplifying tube to produce the required potential variations at the anodes of the tubes of the group.

The cathodes of the "even" numbered digit-representing tubes (Fig. 1) are connected together and to ground over a common resistor 91, of 22,000 ohms, and the cathodes of the "odd" numbered tubes are connected together and to ground over resistor 92, of 22,000 ohms.

Since the anodes of the "even" digit-representing tubes are connected together and to the same potential-supplying point and the cathodes of these tubes are connected together and to ground over a common resistor, it is seen that a common operating potential supply is provided for the group of tubes. Similarly, there is a common operating potential supply for the "odd" digit-representing tubes.

The chain connections between the tubes extend from the probe of one tube to the igniter I₁ of the next tube in the series; for example, from the probe of the "0" tube to the igniter I₁ of the "1" tube; from the probe of the "1" tube to the igniter I₁ of the "2" tube, etc. These connections, which are shown at 93, are direct wire connections which contain no impedance elements and are floating, since they have no direct connection with any potential source.

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 94 to the igniter I₁ of the "0" tube. If the ring is to control some other means to generate a signal each time the ring passes from a representation of "9" to a representation of "0" and the connection between the "9" tube and the "0" tube is used in the control of this means, then a rectifier 95, such as half a 6H6 type tube, can be included in the connection to enable the proper control to be obtained, as will be explained more fully hereinafter.

The grouping of the tubes with a separate operating potential supply for each group, and the floating chain connections between the tubes in the groups, enable the stepping of the conducting tube in the ring to be obtained by controlling the potential supplied to the groups.

The ring operates in the following manner. If the ring is operating to represent a digit, as "1," then the "1" digit-representing tube will be conducting. At this time, the "odd" group of tubes will have high anode potential applied thereto, due to conduction in tube 51, and the "even" group will have low anode potential applied thereto, due to non-conduction in tube 50.

The probe of the "1" digit-representing tube is in the ionized medium of the conducting tube, and, due to conduction in the tube, will become effective to cause the starter gap of the "2" tube, between the igniter I₁ to which it is connected and the cathode, to become ionized and pass sufficient starter gap current to cause main gap breakdown of the "2" tube. The ionization in the starter gap of the "2" tube cannot spread to the main gap, and the "2" tube cannot become conducting at this time, because the low anode potential which is being supplied to the anodes of the even group of tubes will not support conduction in any of them.

It is to be noted that, while the other tubes of the "odd" group are being supplied with high

anode potential at this time, none will be rendered conducting, because the anode potential which is applied is not high enough to cause a breakdown in the main gap directly between the anode and the cathode of any of them unless there has been a previous breakdown at the starter gap. There will be no breakdown of the starter gap in these tubes, because the igniter I₁ in each of these tubes is connected to a probe in a non-conducting "even" tube, and the cathodes of these tubes, which are connected to the cathode of the conducting "1" tube, will be more positive, due to conduction in that tube. This will cause insufficient voltage across the starter gaps to bring about ionization therein.

There will be no breakdown of the starter gaps in the tubes of the "even" group other than the "2" tube, because the igniter I₁ in each of these tubes is connected to a probe in a non-conducting "odd" tube, and the potential across the gap will be insufficient to cause its breakdown.

With the ring in the "1" digit-representing condition, in which the "1" tube is conducting and the starter gap of the "2" tube is ionized, the next input impulses will be effective in the following manner to cause the "2" tube to conduct and the "1" tube to cease conducting. The positive input impulse from the source 78 will be impressed on the entry device and will cause tube 50 to be fired and rendered conducting. As tube 50 fires, it will cause the potential of point 65 and the anodes of the "even" tubes to become high and conduction to occur in the main gap of the "2" tube, in which the starter gap had been ionized. Also, as the tube 50 fires, it will send a negative impulse over the blow-out capacitor 61 to the tube 51 to extinguish this tube, which causes the anode potential of the "odd" tubes to drop to a value which will not support conduction, and the "1" digit-representing tube will cease conducting. The starter gap of the "1" tube also will not be ionized at this time, because the probe of the "0" tube, to which igniter I₁ of the "1" tube is connected, is no longer in the ionized medium of a conducting tube, since the "0" tube is not conducting.

Conduction in the "2" digit-representing tube will cause its probe to be effective to cause the starter gap of the "3" digit-representing tube to become ionized.

In a similar manner, the next input impulse will fire tube 51, which will apply high anode potential to the "odd" tubes to cause conduction in the main gap of the "3" tube. The firing of tube 51 will extinguish tube 50, which in turn lowers the anode potential of the "even" tubes and extinguishes the conducting "2" tube.

Subsequent impulses will cause further step-by-step operation of the digit-representing tubes, the probe-to-igniter connections selecting the tubes which are to be operated in the sequence.

It will be obvious from Fig. 1 that the addition of tubes to the ring will not require any additional circuit elements of resistance or capacitance in the ring circuit.

Each of the digit-representing tubes will be operated once during a cycle of operation of the ring, and a control may be taken from any desired digit-representing tube to produce an output signal for each cycle of operation of the ring. In the form shown in Fig. 1, the "9" digit-representing tube primes the output signal tube 52, so that the output signal tube will be operated by the same input impulse which causes the "0"

tube to operate following an operation of the "9" tube.

The output signal tube 52 is a tetrode thyratron of the 2050 type and is connected in a self-extinguishing circuit. The tube is provided with an anode potential of about +250 volts, derived from a tap 96 of a potentiometer 97, of 40,000 ohms, which is connected between terminal 58 and ground, the connection extending from the tap 96 over resistor 98, of 250,000 ohms, point 99, and resistor 100, of 1,000 ohms, to the anode, with point 99 connected to ground over a .005-microfarad capacitor.

The cathode of tube 52 is connected to ground over point 105, resistor 106, of 250,000 ohms, point 107, and resistor 108, of 250,000 ohms, with point 105 coupled to ground over a .005-microfarad capacitor and with an output signal conductor 109 connected to point 107 to receive a positive output impulse each time the tube conducts. The circuit constants in the anode and cathode circuits are such that the tube will be extinguished automatically shortly after it is fired.

The shield grid and the control grid of tube 52 are connected together and over point 110 and resistor 111, of 1 megohm, to terminal 112, which has -39 volts applied thereto. The grids are also connected to ground over a 500-micro-microfarad capacitor and are connected over a resistor 113, of 1 megohm, and a tap 114 to a resistance network which includes a resistor 115, of 2.2 megohms, a resistor 116, of 1 megohm, and a resistor 117, of 2.2 megohms connected in series between the probe of the "9" tube and ground, the tap 114 cooperating with resistor 116 to control the effect of the potential variations of the probe of the "9" tube on the grids of the output signal tube 52.

The grids of the output signal tube are also coupled from point 110 over a capacitor 118, of 50 micro-microfarads, and conductor 119 to the source of impulses 78, so that each of the input impulses will be impressed on the grids. The normal bias which is supplied to the grids will normally prevent the input impulses from firing tube 52, but this bias is reduced and the tube is primed to respond to the input impulses when the "9" tube conducts. The probe of the "9" tube will become positive when the "9" tube conducts and will impress a positive potential on one end of the resistance network containing resistors 115, 116, and 117. The tap 114 is adjusted on the resistor 116 to enable the positive potential on the probe to be reflected on the grids in such a manner that the tube 52 will be primed and can respond to input impulses only when the "9" tube conducts.

The rectifier 95 prevents the potential rise of the igniter I₁ of the "0" tube, when that tube is conducting, from priming the output signal tube.

With these controls, the output signal tube 52 will be primed when the "9" tube conducts and will be fired by the same input impulse which causes the "0" tube to conduct and the "9" tube to be extinguished, thereby to produce an output signal for each cycle of operation of the ring.

If the counting ring forms one denominational order of an accumulator, the output signal can be used to control a tens transfer means of the delayed-action type or can be impressed on the entry device of the next higher order if no delay in the tens transfer entry is desired.

It is to be understood that the output signal means and the controls therefor shown in Fig. 1

are merely illustrative and are not the only form of such means or controls that may be used. Another control of the output signal tube 52 of Fig. 1 could be derived from the auxiliary anode A_x of the "9" digit-representing tube. Since the auxiliary anode A_x will also have a positive potential when the "9" tube conducts, it can be used with the circuit of Fig. 1 instead of the probe to prime the output signal tube. When this control is used, the priming is divorced from the probe-to-igniter connection between the "9" and "0" tubes, and the rectifier 95 can be eliminated.

Also, if it is desired to fire the output signal tube directly instead of priming it, either the auxiliary anode A_x or the igniter I₂ of the "0" tube can be used, since each of these electrodes becomes more positive when the "0" tube conducts, which positive potential rise can be used to fire the output signal tube directly each time the "0" tube conducts.

If the ring with the output control from the "0" tube is one order of an accumulator, then the entry device of the next higher order can be operated directly from the auxiliary anode A_x of the "0" tube, if desired, to effect tens transfer entries therein.

While the ring of Fig. 1 is arranged to cause a single output signal to be generated for each cycle of operation, the novel circuit is not limited to this use, since any desired one or more of the tubes of the ring can cause an output signal to be generated.

The electrodes which become more positive when conduction takes place in a tube, such as the auxiliary anode A_x or the igniter I₂, which are not used in the ring connections, can be sensed to control a means to indicate which tube is conducting, if desired.

Means have been provided to preset the circuit to zero condition. The anode potential supply for the trigger pair, and therefrom the tubes of the ring, extends over a normally-closed contact of the reset switch 56, which is operated momentarily in a resetting operation. The switch 56 also includes a normally open contact, the relation of the contacts being such that, in the operation of the switch, the normally-open contact will be closed before the normally-closed contact opens, and, in the return to normal condition, the normally-closed contact will reclose before the normally-open contacts open.

The normally-open contact is connected to conductor 120, thence over resistor 121, of 3 megohms, to point 73 in the circuit to the grids of tube 50 and resistor 122, of 680,000 ohms, to igniter I₁ of the "0" tube of the ring and, when closed, will apply anode potential to the grid and to the igniter.

In the resetting operation, therefore, positive potential will be applied to the grids of the tube 50 and to the igniter I₁ of the "0" tube, and then anode potential will be removed from all the tubes to extinguish any conducting tube. In the return movement of the switch, anode potential will be re-established before the normally-open switch is opened, and tubes 50 and "0" will conduct. When the switch has returned to normal position, the positive potential which was supplied to the grids of tubes 50 and to the igniter I₁ of the "0" tube will have been removed from these electrodes, and the circuit can function in the normal manner.

While the resetting potential is shown as being applied to the igniter I₁ of the "0" tube, it is not intended to limit the invention to this ar-

rangement, because the potential could also be applied to the igniter I₂ to cause the "0" tube to be fired in the resetting operation.

While the form of the invention shown and described herein is admirably adapted to fulfill the objects primarily stated, it is to be understood that it is not intended to confine the invention to the one form or embodiment 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 first plurality of electron discharge paths; a second plurality of electron discharge paths; a first operating potential supply connected to the first plurality of discharge paths and forming them into a first operational group; a second operating potential supply connected to the second plurality of discharge paths and forming them into a second operational group; means connecting the discharge paths into an operational series, for sequential step-by-step operation, each series connection extending from a discharge path in one group to a discharge path in the other group and enabling the discharge in the path in one group to prepare the next path in the series, which is in the other group, for discharge therein; control means operable alternately to one and the other of two conditions and in one condition being effective to control the first and second operating potential supplies to provide a potential to one group to cause conduction in a discharge path in that group and at the same time to provide potential to the other group which will not support conduction in any discharge path in that group and in the other condition reversing the potentials supplied to the two groups, each reversal of the potentials supplied to the groups causing a step of advance in the operating discharge path of the series.

2. In a device of the class described, the combination of a first plurality of electron discharge paths; a second plurality of electron discharge paths; a first operating potential supply connected to the first plurality of discharge paths and forming them into a first operational group; a second operating potential supply connected to the second plurality of discharge paths and forming them into a second operational group; means connecting the discharge paths into an operational series, for sequential step-by-step operation, using discharge paths from the first and second groups alternately, each series connection between discharge paths extending from a discharge path in one group to a discharge path of the other group and enabling the discharge in the path in one group to prepare the next path in the series, to which it is connected, for conduction therein; control means operable alternately to one and the other of two conditions and in one condition being effective to control the first and second operating potential supplies to provide a high operating potential to one group to cause conduction in a discharge path in that group and at the same time to provide low operating potential to the other group to prevent conduction in any discharge path in that group and in the other condition reversing the high and low operating potentials supplied to the two groups, each change in the operating condition of the control means from one condition to the other causing a step of advance in the operating discharge path of the series.

3. The device as claimed in claim 2 in which the first operating potential supply contains only a single impedance element which is common to the discharge paths of the group; in which the second operating potential supply contains only a single impedance element which is common to the discharge paths of the group; and in which the connections for connecting the discharge paths for operation in step-by-step sequence include no impedance element.

4. The device as claimed in claim 2 in which the control means includes a pair of tubes interconnected to operate as a trigger pair alternately to one and the other of two stable states in response to input impulses to provide the two operating conditions of the control means and to control the supplying of the high and low potentials to the groups of discharge paths.

5. The device as claimed in claim 2 in which an additional electrode is provided in each discharge path, which electrode will acquire a distinctive potential when conduction occurs in the path and can be sensed to determine in which path conduction is occurring.

6. In a device of the class described, the combination of a first plurality of gaseous electron discharge devices; a second plurality of gaseous discharge devices; a first operating potential supply connected to the first plurality of discharge devices and forming them into a first operational group; a second operating potential supply connected to the second plurality of discharge devices and forming them into a second operational group; means connecting the discharge devices into an operational series in which the conducting condition of the devices is advanced step by step, each series connection extending from a device in one group to a device in the other group and enabling the conduction in a device in one group to prepare a device in the other group for operation; control means operable alternately to one and to the other of two conditions and in one condition being effective to control the first and second operating potential supplies to provide a high operating potential for one group to cause conduction in a prepared discharge device in that group and at the same time to provide low operating potential for the other group to prevent conduction in any discharge device in that group and in the other condition reversing the high and low operating potentials supplied to the two groups; and means operable, at will, to operate the control means to reverse the operating condition thereof, each change in the operating condition of the control means from one condition to the other causing an advance in the discharge device which is in conducting condition.

7. The device as claimed in claim 6 in which the series connections between discharge devices are simply conductors and contain no circuit impedance elements.

8. The device as claimed in claim 7 in which the operating potential supply for each group of devices includes a single resistor which is common to the devices of the group and in which the series connections are simply conductors and include no circuit impedance elements.

9. In a device of the class described, the combination of a first plurality of electron tubes; a second plurality of 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

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ply connected to the second plurality of tubes and forming them into a second operational group; means connecting the tubes into an operational series, using tubes from the first and second groups alternately; control means operable alternately to one and the other of two conditions in response to input impulses and in one condition being effective to control the first and second operating potential supplies to provide a high operating potential to one group to cause conduction in a tube in that group and at the same time to provide low operating potential to the other group to prevent conduction in any tube in that group and in the other condition reversing the high and low operating potentials supplied to the two groups; and means for supplying input impulses to the control means, each impulse reversing the operating condition of the control means; the supplying of operating potentials in two groups and the varying of the operating potentials between high and low values, together with the series connections between the tubes, causing the tubes to be operated one at a time in sequence.

10. In a device of the class described, the combination of a first plurality of electron tubes; a second plurality of 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 for operation one after another in step-by-step sequence, using tubes from the first and second groups alternately, said connections being floating connections extending directly between tubes of different groups and enabling conduction in a tube in one group to prepare a tube in the other group for operation; control means including a pair of tubes interconnected to operate as a trigger pair which is operable alternately to one and the other of two conditions in response to impulses, and in one condition is effective to control the first and second operating potential supplies to provide a high operating potential to one group to cause conduction in a prepared tube in that group and at the same time to provide low operating potential to the other group to prevent conduction in any tube in that group and in the other condition is effective to reverse the high and low operating potentials supplied to the two groups; means to supply impulses to the control means to cause the trigger pair to operate to said one and said other conditions; the supplying of operating potentials to the two groups and the varying of the operating potentials between high and low values, together with the series connections between the tubes, enabling each change in the operating condition of the control means from one condition to the other to cause an advance in the tube in which conduction takes place.

11. In a device of the class described, the combination of a plurality of gaseous electron 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 ionizable medium of the main gap and capable of exerting a control when conduction occurs in the main gap; a first common anode-cathode potential supply connected to half the tubes and forming them into a first operational group; a second common anode-cathode potential supply connected to the other half of the tubes and forming them into a second operational group; means to control said first and sec-

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ond anode-cathode potential supplies to provide a high anode potential to one group to cause conduction in the main gap of a tube in that group which has its starter gap ionized and at the same time to provide a low anode potential to the other group to prevent conduction in any tube of that group, said control means being operable to reverse the high and low condition of the anode potential supplied to the groups; means connecting the tubes for connection in a series, using tubes of the first and second groups alternately, the connection between adjacent tubes of the series extending from the probe electrode in a tube of one group to the igniter in the starter gap of the tube of the other group, and enabling conduction in the tube in which the probe is located to ionize the starter gap of the next tube of the series; and means to operate the control means at will to reverse the high and low condition of the anode potential supplied to the groups thereby to cause a stepping of the operating condition of the tubes.

12. The device as claimed in claim 11 in which the anode-cathode potential supply for each group of tubes contains but one circuit impedance element, a cathode resistor, which is common to the tubes of the group; and in which the probe-to-igniter connections between tubes are simply conductors and contain no impedance elements whereby a minimum of impedance elements are provided in the circuits of the two groups of tubes.

13. The device as claimed in claim 11 in which the probe-to-igniter connections are floating connections and have no connection with outside potential sources but acquire potential only from conduction in the tubes in which the probe and the igniter are located.

14. The device as claimed in claim 11 in which the tubes are connected in a closed series or ring and which includes an output signal means, and means connecting the output signal means to a probe in one of said tubes to be controlled thereby to generate an output signal upon each cycle of operation of the ring.

15. In a device of the class described, the combination of a plurality of gaseous electron 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 ionizable medium of the main gap and capable of exerting a control when conduction occurs in the main gap; a first common anode-cathode potential supply connected to half the tubes and forming them into a first operational group; a second common anode-cathode potential supply connected to the other half of the tubes and forming them into a second operational group; means to control said first and second anode-cathode potential supplies to provide a high anode potential to one group to cause conduction in the main gap of a tube in that group which has its starter gap ionized and at the same time to provide a low anode potential to the other group to prevent conduction in any tube of that group, said control means being operable to reverse the high and low condition of the anode potential supplied to the groups; means connecting the tubes for operation in a series, using tubes of the first and second groups alternately, the connection between adjacent tubes of the series extending from the probe electrode in a tube of one group to the igniter in the starter gap of the tube of the other group, and enabling conduction in the tube in which the probe is lo-

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cated to ionize the starter gap of the next tube of the series; means to operate the control means at will to reverse the high and low condition of the anode potential supplied to the groups thereby to cause a stepping of the operating condition of the tubes; and a further electrode in each tube in the ionizable medium thereof, which electrode will acquire a positive potential when its tube conducts and which electrode can be sensed to indicate if the tube is conducting.

16. In a device of the class described, the combination of a first plurality of electron tubes; a second plurality of electron tubes, each tube having at least an anode, a cathode, a probe electrode, and an igniter cooperating with the cathode to form a starter gap; a first common anode-cathode potential supply connected to the first plurality of tubes and forming them into a first operational group; a second common anode-cathode potential supply connected to the second plurality of tubes and forming them into a second operational group; means including a pair of electron tubes interconnected to operate as a trigger pair to either of two stable states in response to input impulses to control said first and second potential supplies to provide a high anode potential to one group to cause conduction in a tube of that group which has its starter gap ionized and at the same time to provide a low anode potential to the other group to prevent conduction in a tube of that group, said control means when in the other of said states being operable to reverse the high and low anode potentials supplied to the groups; means connecting all the tubes into an operational ring, using tubes from the first and second groups alternately, each connection extending directly from the probe electrode of a tube in one group to the igniter of a tube in the other group and enabling the effect of conduction in a conducting tube on the probe thereof to ionize the starter gap of the tube in the other group to condition that tube for operation; and input means for causing input impulses to operate the trigger pair of the potential supply control means to cause a reversal of the high and low anode potentials supplied to the groups; the supplying of anode-cathode potentials in two groups and the varying of their anode potentials in response to impulses, together with the serial probe-to-conduction control-electrode connections between tubes, causing the tubes to be operated one at a time in sequence.

17. In a device of the class described, the combination of a first plurality of electron tubes; a second plurality of electron tubes, each tube being a cold-cathode tube having at least an anode, a cathode, a probe electrode, and an igniter electrode cooperating with the cathode to form a starter gap; a first common anode-cathode potential supply connected to the first plurality of tubes and forming them into a first operational group; a second common anode-cathode potential supply connected to the second plurality of tubes and forming them into a second operational group; means to control said first and second potential supplies to provide a high anode potential to one group to cause conduction in a tube of that group which has its starter gap ionized and at the same time a low anode potential to the other group to prevent conduction in a tube of that group, said control means being operable to reverse the high and low condition of the anode potential supplied to the groups each time an impulse is received; means connecting all the tubes into an operational series,

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using tubes from the first and second groups alternately, each connection extending directly from the probe electrode of a tube in one group to the igniter electrode of a tube in the other group to enable conduction in the tube of the one group to ionize the starter gap of the tube in the other group to condition this tube for operation; and input means for causing an operation of the potential supply control means to reverse the high and low conditions of the anode potential supplied to the groups; the supplying of anode-cathode potentials in two groups and the varying of their anode potentials in response to impulses, together with the serial probe-to-igniter electrode connections between tubes, causing the tubes to be operated one at a time in sequence.

18. In a device of the class described, the combination of a plurality of gaseous electron 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 main gap between the anode and the cathode and capable of exerting an external control when conduction occurs in the main gap; a circuit connecting the cathodes of half of the tubes together and over a common impedance to a cathode potential supply to form a first group of tubes; a circuit connecting the cathodes of the other half of the tubes together and over a common impedance to a cathode potential supply to form a second group of tubes; a circuit connecting the anodes of the first group of tubes together and to a first source of anode potential; a circuit connecting the anodes of the second group of tubes together and to a second source of anode potential; means to control said first and second sources of anode potential to provide a high anode potential to one group to cause conduction in the main gap of a tube in that group which has its starter gap ionized and at the same time to provide a low anode potential to the other group to prevent conduction in any tube of that group, said control means being operable to reverse the high and low condition of the anode potential supplied to the groups; 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 being a floating connection extending from the probe electrode in a tube of one group directly to the igniter in the starter gap of the tube of the other group and to no other source of potential, and enabling conduction in the tube in which the probe is located to cause the starter gap of the next tube of the series to be ionized; and means to operate the control means at will to reverse the high and low condition of the anode potential supplied to the groups thereby to cause a stepping of the operating condition of the tubes.

19. In a device of the class described, the combination of a first plurality of electron tubes; a second plurality of electron tubes, each tube having at least an anode, a cathode, a probe electrode which is capable of exerting an external control when the tube conducts, and an igniter cooperating with the cathode to form a starter gap; a first common anode-cathode potential supply connected to the first plurality of tubes and forming them into a first operational group; a second common anode-cathode potential supply connected to the second plurality of tubes and forming them into a second operational group; means connecting all the tubes into an opera-

tional ring, using tubes from the first and second groups alternately, each connection extending directly from the probe electrode of a tube in one group to the igniter of a tube in the other group and enabling the probe of a conducting tube to exert its control and ionize the starter gap in the tube of the other group to condition that tube for operation; means including a pair of electron tubes interconnected to operate as a trigger pair to either of two stable states in response to input impulses and effective in one of said states to control said first and second potential supplies to provide a high anode potential to one group to cause conduction in a tube of that group which has its starter gap ionized and at the same time a low anode potential to the other group to prevent conduction in a tube of that group, said trigger pair when in the other of said states being operable to reverse the high and low condition of the anode potential supplied to the groups; input means for causing input impulses to operate the trigger pair of the potential supply control means to cause a reversal of the high and low anode potentials supplied to the groups to cause the tubes of the ring to be operated one at a time in sequence; output signal means for generating an output signal for each cycle of operation of the ring; and means coupling a probe of a particular tube of the ring to the signal means to enable the positive potential on the probe as its tube conducts to control the output means to produce a signal.

20. In a device of the class described, the combination of a plurality of digit-representing electron tubes, each tube being a cold-cathode gaseous electron discharge tube having at least an anode and cathode forming a main gap, an igniter cooperating with the cathode to form a starter gap, and a probe located in the main gap between the anode and the cathode and capable of exerting an external control when conduction occurs in the main gap; a circuit connecting the cathodes of the "even" digit-representing tubes together and over a common resistor to ground to form a first group of tubes; a circuit connecting the cathodes of the "odd" digit-representing tubes together and over a common resistor to ground to form a second group of tubes; a circuit connecting the anodes of the first group of tubes together and to a first source of anode potential; a circuit connecting the anodes of the second group of tubes together and to a second source of anode potential; means connecting the tubes for step-by-step operation in a ring in a digital series, using tubes of the first and second groups alternately, the connection between adjacent tubes of the ring extending directly from the probe electrode in a tube of one group to the igniter in the starter gap of the tube of the other group, and enabling the probe, due to conduction in the tube in which the probe is located, to cause the ionization of the starter gap of the next tube of the ring; means to control said first and second anode potential supplies to provide a high anode potential to one group to cause conduction in the main gap of a tube in that group which has its starter gap ionized and at the same time to provide a low anode potential to the other group to prevent conduction in any tube of that group, said control means being operable to reverse the high and low condition of

the anode potential supplied to the groups, each reversal enabling conduction to occur in the main gap in the tube having its starter gap ionized and causing conduction to cease in the tube which was previously conducting whereby to cause the stepping of the operating condition of the tubes; and means to operate the control means at will to reverse the high and low condition of the anode potential supplied to the groups.

21. In a device of the class described, the combination of a plurality of digit-representing electron 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 main gap between the anode and the cathode and capable of exerting an external control when conduction occurs in the main gap; a circuit connecting the cathodes of the "even" digit-representing tubes together and over a common resistor to ground to form a first group of tubes; a circuit connecting the cathodes of the "odd" digit-representing tubes together and over a common resistor to ground to form a second group of tubes; a circuit connecting the anodes of the first group of tubes together and to a first source of anode potential; a circuit connecting the anodes of the second group of tubes together and to a second source of anode potential; means connecting the tubes for step-by-step operation in a ring in a digital series, using tubes of the first and second groups alternately, the connection between adjacent tubes of the ring including no impedance elements and extending directly from the probe electrode in a tube of one group to the igniter in the starter gap of the tube of the other group, and enabling the control exerted by a probe, due to conduction in the tube in which the probe is located, to cause ionization of the starter gap of the next tube of the ring; means to control said first and second anode potential supplies, said means including a pair of tubes connected to operate as a trigger pair alternately to one and the other of two stable states in response to positive potential impulses, and in one of said states providing a high anode potential to one group to cause conduction in the main gap of a tube in that group which has its starter gap ionized and at the same time to provide a low anode potential to the other group to prevent conduction in any tube of that group, said trigger pair when in said other state being operable to reverse the high and low condition of the anode potential supplied to the groups, each change in operating state of the trigger pair enabling conduction to occur in the main gap in the tube having its starter gap ionized and causing conduction to cease in the tube which was previously conducting whereby to cause the stepping of the operating condition of the tubes; and means to supply positive input impulses to the trigger pair to reverse its operating state to operate the control means at will to reverse the high and low condition of the anode potential supplied to the groups and cause the conducting condition on the tubes to be stepped around the ring.

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No references cited.