Aug. 26, 1947. R. E. MUMMA ET AL 2,426,279

ELECTRONIC ACCUMULATOR

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FIG. 1

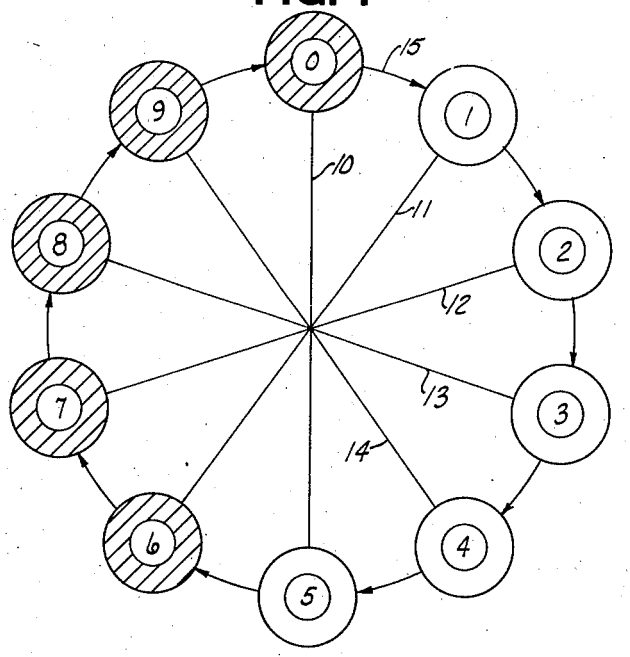
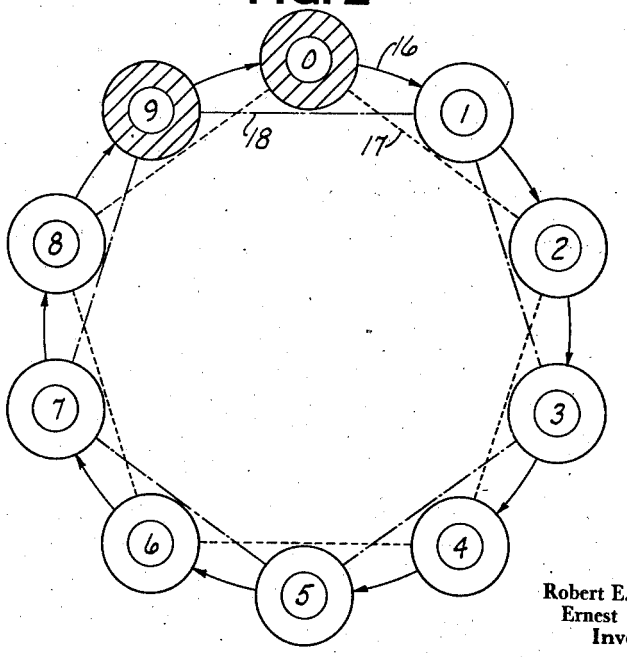


FIG. 2



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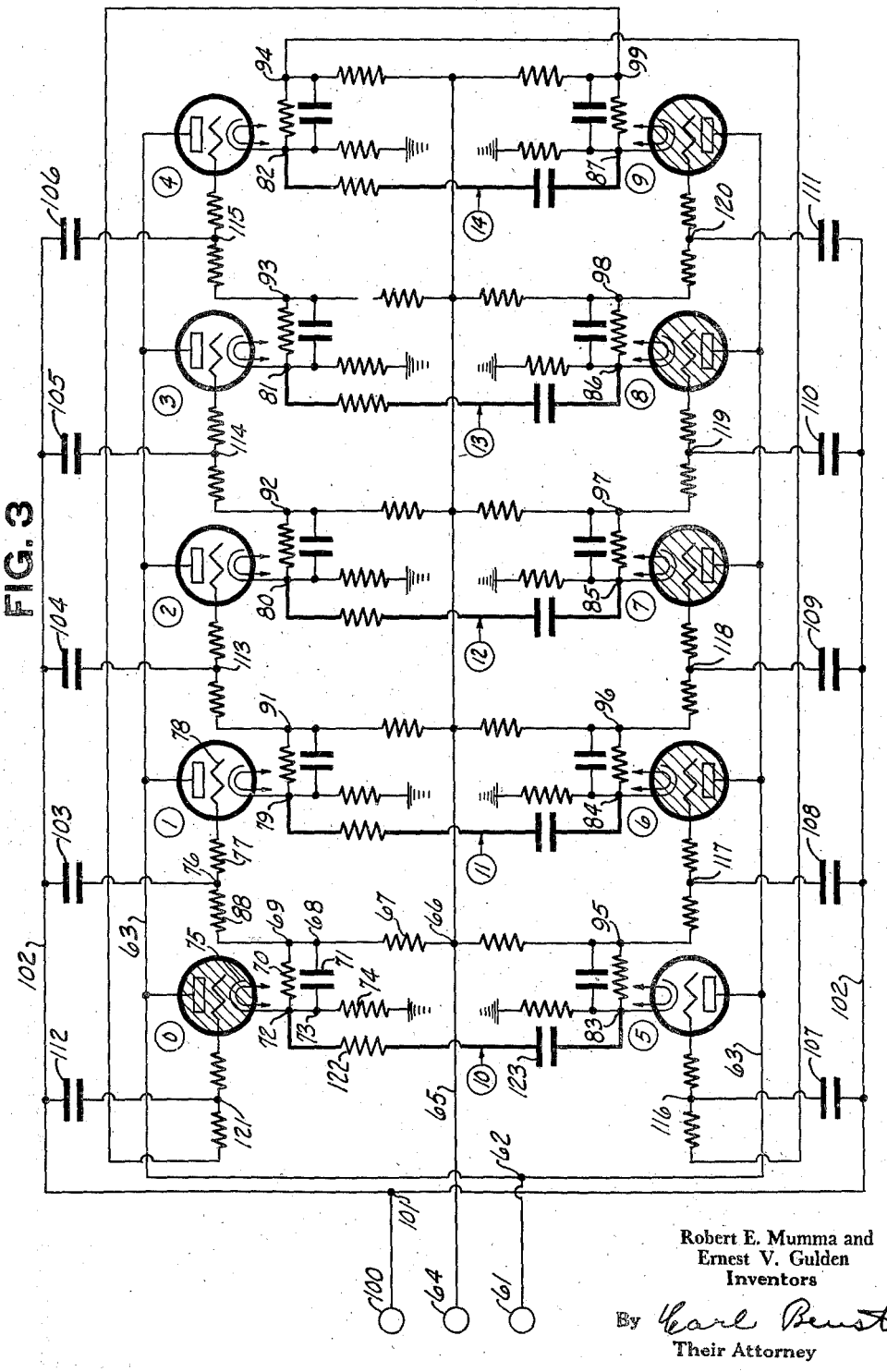
ELECTRONIC ACCUMULATOR

Filed April 30, 1942 2 Sheets-Sheet 2

FIG. 3



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Patented Aug. 26, 1947

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UNITED STATES PATENT OFFICE

2,426,279

ELECTRONIC ACCUMULATOR

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Application April 30, 1942, Serial No. 441,102

16 Claims. (Cl. 315—230)

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This invention relates to an electronic device for representing data, and particularly to a device which is capable of high-speed operation in response to one or more electrical impulses.

The electronic device of the invention may be used to represent any desired kind of data which is transmitted thereto as electrical impulses. In the disclosed embodiment, the electronic device consists of a plurality of gaseous electron tubes, each tube representing a unit of data and being arranged in a ring. The tubes of this ring are coupled in an endless series to be operated sequentially in response to electrical impulses which may represent any desired kind of data to be transmitted thereto. The input impulses are impressed on all of the tubes of the ring simultaneously at a frequency the maximum of which is determined by the speed of operation of the ring, but are effective only on the tubes which have been "primed" or made ready for operation. The coupling of the tubes in the endless operative series is effective to provide the necessary priming of the tubes because, when one tube is conducting, the coupling will enable this tube to prime the next tube to be fired in the sequence and thus render that tube responsive to the next impulse.

Since the tubes making up the ring are gaseous electron tubes, they will continue to conduct once they are fired and are conducting, and, in order that the tubes of the ring may be operated step by step and over and over again in endless chain sequence, provision must be made to extinguish the tubes after they have been fired. Applicants have provided a novel control over the extinguishing of the tubes which will enable an extremely rapid operation of the device.

One of the known methods of extinguishing the tubes is to couple the cathodes of the tubes of the ring together in such a manner that the potential change of the cathode of one tube, as that tube is fired and becomes conductive, is impressed on the cathodes of all the other tubes and will momentarily raise the potential of the cathode of any previously conducting tube to a value which exceeds the anode potential and will cause that tube to cease conducting and become extinguished. After the momentary change in potential has been impressed on the cathodes of the tubes, these cathodes are allowed to "recover" or resume their normal potential, at which time the tubes are ready to have another input impulse impressed thereon. Thus, when all the cathodes of the tubes of a ring are affected by the firing of each tube, further input

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impulses may not be impressed on the ring until the cathodes recover from the potential change impressed thereon by the firing of any other tube in the ring, and this limits the speed of operation of the ring.

In applicants' novel arrangement, the tubes are not coupled so that the extinguishing action resulting from the firing of a tube is impressed on all the other tubes of the ring, but the tubes of the ring are connected in groups, and, when any tube of a group is fired, it will affect only the tubes of its group and cause any conducting tubes of the group to be extinguished. By including adjacent tubes in sequence in different groups of tubes, it is seen that a primed tube will not be affected by the extinguishing action of its preceding tube and will not have to recover from this extinguishing action before it is ready to have an input impulse impressed thereon.

Inasmuch as one tube in each group of tubes which are connected together will be conducting, it follows that, in the operation of the ring, the number of tubes that will be conducting at any time will be equal to the number of groups into which the tubes of the ring have been divided.

While applicants' novel control over the extinguishing action is shown in conjunction with the method of extinguishing the tubes by electrostatically connecting the cathodes so that the potential rise of the cathode of one tube as it is fired can cause a previously conducting tube to be extinguished, it is not limited to use with this method, but is also applicable with other methods that may be used. The method shown in the United States patent application of Robert E. Mumma, Serial No. 395,995, which was filed on May 31, 1941, and which issued on June 4, 1946, as Patent No. 2,401,657, may be used, in which method the cathodes are isolated and the extinguishing action is brought about by having a resistor in the anode circuit, which, when a tube is fired, causes the anode potential of a previously conducting tube to drop below the potential of its cathode, thus extinguishing the previously conducting tube, and, when this method is used, the tubes may be grouped for mutual extinguishing action by interconnecting the anodes of the tubes constituting each group and connecting each group of anodes over a separate resistor to a source of anode potential. This arrangement will also isolate the extinguishing action between the groups.

The novel arrangement will probably be more clear if a concrete example is considered.

In the disclosed embodiment, which is illustrative of one kind of data which the device can represent, there are shown ten tubes arranged in a counting ring, each of the tubes in the ring representing one of the values "0" to "9" in a denominational order in the decimal notation. The tubes of the ring are interconnected in an endless chain for causing the tubes to be selectively primed and to be operated sequentially one after another in response to electrical input impulses impressed on all the tubes simultaneously. In the disclosed embodiment of the ring, the tubes are connected in five groups of two tubes each, as follows: the cathodes of the "0" and the "5" tubes are connected together, as are the cathodes of the "1" and the "6" tubes, the cathodes of the "2" and the "7" tubes, the cathodes of the "3" and the "8" tubes, and the cathodes of the "4" and the "9" tubes, and in each of the groups the firing of either tube will be effective through the cathode connection to extinguish the other tube of that group. With this arrangement, half of the tubes of the ring will be conducting at any instant.

When the "0" tube is fired by an input impulse, it will cause the "5" tube to be extinguished, and, with the tubes connected in five groups as indicated above, the "5" tube can recover during the time that impulses are effective to fire the "1," "2," "3," and "4" tubes in succession. With this length of time to recover, the time between the firing of adjacent tubes is not limited by the recovery of any tube after the extinguishing operation, but is limited principally by the time constant of the grid input circuit for the tubes, and by the ionization time of the primed tube. The loss in the input circuit of the primed tube can be partially overcome by causing the priming potential to overshoot by means of a priming capacitor.

Therefore, with applicants' novel arrangement, each tube is extinguished by the operation of the other tube of the same pair, and the extinguished tube is not primed for operation until one tube of each of the other pairs making up the ring has been operated. In the interval of time in which the extinguished tube can recover from the effects of its being extinguished and return to the condition to be fired by an impulse after it has been primed by the operation of a tube of the group of tubes next preceding it in sequence, other impulses can be impressed on the ring, and the speed of operation of the ring can be increased approximately five times that possible when each extinguishing action is impressed on all of the tubes of the ring.

The disclosed embodiment of the invention shows the tubes grouped for extinguishing action in such a way that half the tubes are conducting at any given instant when the ring is in use; however, it is obvious that other groupings of the tubes may be made, depending upon the number of tubes in the ring, the number of tubes that are to be conducting at any instant, and the speed at which the ring is to operate. For instance, the tubes may be connected for extinguishing action in two groups of five tubes each, and in this arrangement only two tubes of the ring will be conducting at any instant. Though this grouping would reduce the number of tubes that are conducting at any instant, it would slow down the operation of the ring, because each group of tubes would be affected by every other input impulse, and a second impulse could not be impressed on another tube of the group until all the tubes of that group had recovered. The use of two groups of five tubes each will enable impulses to be impressed on the ring approximately twice as fast as when all the tubes are affected by each extinguishing action.

It is an object of this invention, therefore, to provide a counting ring of electronic devices which can operate at a higher speed than speeds previously known in the operation of similar counting rings.

Another object of the invention is to provide a high-speed gaseous electron tube counting ring which will enable impulses to be impressed on the ring at a high frequency to cause the step-by-step operation of the tubes in the ring.

A further object of the invention is to provide a novel manner of connecting the tubes of a gaseous electron tube ring so that they may be selectively extinguished without the extinguishing action affecting all the tubes.

A further object of the invention is to provide a gaseous electron tube ring in which the tubes are connected in groups, so that the firing of a tube in any group will be operative to cause an extinguishing action on only the tubes of its group, and in which the tubes of different groups are coupled for sequential firing in response to impressed impulses, the pattern of the grouping of the tubes being such as to enable a maximum number of impulses to affect the ring without a recurrence of firing of the tubes in any of the groups, whereby a maximum number of impulses can be impressed on the ring in any given period of time to cause its operation at a high rate of speed.

With these and incidental objects in view, the invention includes certain novel features of construction and combinations of parts, the essential elements of which are set forth in appended claims and 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 said drawings:

Fig. 1 is a diagrammatic showing of the priming couplings between the tubes of a gaseous electron tube counting ring for representing the digits of a denominational order in the decimal notation and also a diagrammatic showing of the coupling of the tubes in pairs for mutual extinguishing action.

Fig. 2 is a diagrammatic showing of the priming couplings between the tubes of a gaseous electron tube counting ring for representing the digits of a denominational order in the decimal notation and also a diagrammatic showing of another arrangement for the coupling of the tubes in groups for mutual extinguishing action.

Fig. 3 is a circuit diagram for operatively connecting the ten gaseous electron tubes according to the arrangement shown in Fig. 1.

General description

In Fig. 1, which is a functional diagram of the operation of the ten gaseous electron tubes connected in a network, the circles represent the tubes, the numbers in the circles represent arbitrarily assigned digital values of the tubes in the decimal system, and the shading and non-shading of the circles indicate the conducting and non-conducting condition of the tubes, respectively.

In the arrangement disclosed in this figure, the tubes are divided for mutual extinguishing action into five groups of two tubes each. When the

ring is being operated, one or the other of the tubes of each group of tubes is in a conducting condition, which causes the other tube of the group to be in a non-conducting condition. As shown in this figure, the "6," "7," "8," "9," and "0" tubes are conducting. The conducting tube representing the sum of the accumulated data is to be considered for the purpose of this disclosure as the most clockwisely disposed tube of the tubes that are conducting, which in this case is the "0" tube. Though the most clockwisely positioned tube of the conducting tubes has been chosen as the one to represent the accumulated data in the example given, it is obvious that any identifiable position may be chosen to represent the accumulated data, as long as the chosen relation is adhered to throughout the reception of the particular data.

The tubes of the ring are paired for mutual extinguishing action by having their cathodes electrostatically connected, so that, when one tube of the pair is fired or becomes conducting, the potential change of its cathode will cause the other tube of its pair, which tube is already conducting, to be extinguished, and this extinguishing action is isolated within the pairs of tubes and does not extend to or affect the tubes of other pairs of tubes making up the ring. The connections between the cathodes of the pairs of tubes are shown schematically in Fig. 1 by the line 10, connecting the "0" and the "5" tubes; the line 11, connecting the "1" and the "6" tubes; the line 12, connecting the "2" and the "7" tubes; the line 13, connecting the "3" and the "8" tubes; and the line 14, connecting the "4" and the "9" tubes. The grids of the tubes normally are biased sufficiently to prevent the input impulses from causing the non-conducting tubes to become conducting, but a connection between the cathode of one tube and the grid of the next succeeding tube in the ring enables the cathode potential rise of one tube, when that tube is conducting, to reduce the bias of the grid of the next tube or "prime" that tube so that the next input impulse impressed on the tubes will be effective to fire the primed tube. The adjacent tubes of the ring are accordingly connected by priming couplings in an endless operative chain, so that, as the impulses are impressed on the ring, the tubes will be fired one after another in a step-by-step sequence. The priming couplings are schematically indicated in Fig. 1 by lines, as 15, which connect adjacent tubes, the arrows on the lines indicating the direction in which priming takes place.

As explained above, the condition of the counting ring as shown schematically in Fig. 1 represents the value zero, because the most clockwise tube, which is shown conducting, is the "0" tube. When this tube became conducting, it was effective, through the extinguishing connection 10, to cause the "5" tube to become extinguished and, through the priming connection, to prime the "1" tube for operation by the next input impulse. This condition of the ring will continue until the next impulse is received, at which time the primed "1" tube will be fired and become conducting and cause the "6" tube to be extinguished and the "2" tube to be primed for operation. The tubes of the ring now represent the digit "1." The following impulse will cause the "2" tube to fire and become conducting, which causes the "8" tube to be extinguished and the "3" tube to be primed for operation. The tubes of the ring are thus rendered conducting one after

the other in sequence by the input impulses, but it should be noted that, in the tubes paired for extinguishing action, there is no recurrence of the firing of the tubes in any pair until the fifth impulse is received and a tube of each of the other pairs has been fired. This enables the ring to be operated at a high rate of speed.

A variation in the manner of connecting the tubes of the ring for mutual extinguishing action is shown in Fig. 2. The conventions noted in connection with the showing of the ring in Fig. 1 apply also to this ring. The shading of the "9" and the "0" tubes shows that, of all the tubes of the ring, only two—the "9" tube and the "0" tube—are conducting, and this is the zero-representing condition of the ring. The priming connections for coupling the adjacent tubes are shown schematically by the lines, as 16, with the arrows indicating the direction of the priming action. In the ring as shown in Fig. 2, the tubes are not connected in pairs for mutual extinguishing action, but are connected in two groups of five tubes each, with adjacent tubes in the ring being included in different groups. One of these groups is schematically shown connected by the dotted line 17 and includes the "0," "2," "4," "6," and "8" tubes. Through this connection, the firing of any tube in the group will cause any other conducting tube of the group to be extinguished. The other group of tubes is schematically shown connected by the dot-and-dash line 18 and includes "1," "3," "5," "7," and "9" tubes, which connection enables the firing of any tube of this group to cause any other tube of the group to be extinguished.

In the ring as shown in Fig. 2, the "9" tube and the "0" tubes are conducting, and, as explained above, this is a condition which represents a value of zero. When the "0" tube was fired and became conducting, it impressed an extinguishing action on the "2," "4," "6," and "8" tubes of this group and caused the "8" tube, which was the only tube of the group to be conducting, to be extinguished. The conducting "0" tube also primed the "1" tube to render the "1" tube receptive to be operated by the next impulse impressed on the tubes. This condition of the tubes will continue until the next impulse is impressed on the ring, at which time the primed "1" tube will be fired and will become conducting and cause the "9" tube to be extinguished and the "2" tube to be primed for operation. The following impulse will cause the "2" tube to fire and become conducting, which causes the "0" tube to be extinguished and the "3" tube to be primed. Similarly, the remaining tubes of the ring can be fired in sequence. With the arrangement of tubes shown in Fig. 2, there are but two tubes conducting at any given time, but there will be a recurrence of the extinguishing action in each group when every other tube of the ring is fired.

The step-by-step sequential operation of the pairs of tubes as functionally described with reference to Figs. 1 and 2 is not necessarily based on their physical adjacence, nor is this step-by-step operation to be deemed to limit the scope of the invention, as the number of tubes of the ring may be increased or decreased to suit a numerical notation desired or to suit any other form of data to be represented, and the grouping of the tubes may be varied with the different numbers of tubes used and the speed of operation desired.

The novelty of the invention resides not only in the particular circuit network as shown, but also in the broad idea of grouping the tubes for

mutual extinguishing action and in the isolation of the extinguishing action between groups of tubes forming a ring, which enable the ring of gaseous electron tubes to be operated at high speeds.

When the counting ring is used to represent a numerical denominational order, it may be used with other similar rings to form a plural denominational order accumulator for numerical data. The condition of completion of each sequential operation of all the tubes of one denominational ring can give rise to an electrical impulse, which can be used to cause one step of operation of the ring of another denominational order in any suitable way, one of which will be explained hereinafter.

The circuits

The circuits connecting the ten tubes according to the arrangement shown in Fig. 1 are shown in Fig. 3. In the explanation of these circuits, the values given for the various potentials, resistors, and capacitors are relative and are merely illustrative, so that any changes in the type of tubes or in the speed or stability of operation desired may require a variation in these values.

As in Fig. 1, the tubes in the circuit diagram make up a denominational order in the decimal notation, and the digit values "0" to "9" have been assigned to them. These tubes are thermionic gaseous electron tubes, contain an anode, a cathode, and a grid, and are grid-controlled. The grid is normally given a higher negative potential than the cathode and will prevent the tube from firing or becoming conducting until the negative potential of the grid is lowered to within 15 volts of the cathode potential. The heater elements for the cathodes of these tubes are shown conventionally in the diagram.

A terminal 61, which is the source of anode potential supply, is supplied with a potential of +75 volts and is connected through the point 62 and the conductor 63 to the anode of each of the tubes.

A terminal 64, supplied with a potential of −150 volts, furnishes the potential for the cathode and the negative biasing potential for the grid of each of the tubes. The terminal 64 is connected to the conductor 65, from which extend parallel circuits, one for each tube. Since the parallel circuits are identical, that for the "0" tube will serve as an example. From the conductor 65 at point 66, the circuit for the "0" tube extends over a resistor 67 of 150,000 ohms to points 68 and 69 over a resistor 70 of 100,000 ohms and a capacitor 71 of 150 micro-microfarads in parallel to points 72 and 73 and then over a resistor 74 of 15,000 ohms to ground. The cathode 75 of the "0" tube is connected in this circuit at the point 72 and has a potential of approximately −8.5 volts. From the point 69 in this circuit, a circuit extends over a resistor 88 of 500,000 ohms to point 76, then over a resistor 77 of 50,000 ohms to the grid 78 of the "1" tube, and supplies this grid normally with a potential of approximately −65 volts. In the other parallel circuits extending from the conductor 65, the cathodes of the "1," "2," "3," "4," "5," "6," "7," "8," and "9" tubes are connected to the points 79, 80, 81, 82, 83, 84, 85, 86, and 87, respectively, and the grids of the "2," "3," "4," "5," "6," "7," "8," "9," and "0" tubes are connected over the necessary resistors to the points 91, 92, 93, 94, 95, 96, 97, 98, and 99, respectively, through which connections the required negative potentials are supplied to the cathodes and grids of these tubes.

The electrical input impulses which cause the step-by-step operation of the ring are impressed on the terminal 100 at a frequency which is limited only by the speed of operation of the ring. The terminal 100 is connected at point 101 to the impulse conductor 102. Circuits extend from the impulse conductor 102 and electrostatically couple the grids of the tubes to the conductor, so that impulses may be impressed on the tubes to cause their operation. The circuit from the impulse conductor 102 to the grid 78 of the "1" tube is representative of these couplings and extends from the impulse conductor 102 through a capacitor 103 of 5 micro-microfarads to the point 76 in the circuit to the grid 78. Similar circuits extend from the impulse conductor 102 over the capacitors 104, 105, 106, 107, 108, 109, 110, 111, and 112 to points 113, 114, 115, 116, 117, 118, 119, 120, and 121, respectively, in the grid circuits for the "2," "3," "4," "5," "6," "7," "8," "9," and "0" tubes.

The impulses impressed on the input terminal 100 cause a potential rise of +100 volts to be impressed on the impulse conductor 102, which potential rise can affect the grids of all the tubes through the electrostatic couplings between the grids and the input conductor 102, but the grids normally have a sufficient negative bias that these impulses will not cause any tube to be fired unless that tube has been primed by having the negative bias of its grid reduced to such an extent that the positive potential rise derived from the input impulse will cause the negative potential of the grid to be lowered to within 15 volts of the cathode potential.

The priming of the tubes is accomplished by using the potential rise of the cathode of a tube, which occurs when the tube is conducting, to reduce the biasing potential of the grid of the next tube in the ring to be fired. The circuit, traced previously from the conductor 65 at point 66, over resistor 67, points 68 and 69, resistor 70 and capacitor 71 in parallel, points 72 and 73 and resistor 74 to ground, by which potential is normally supplied to the cathode 75 of "0" tube and the grid 78 of the "1" tube by their connections thereto at the points 72 and 69 respectively, is used to effect the priming of the "1" tube when the "0" tube is conducting. Before the "0" tube is fired and rendered conducting, the potential of its cathode 75 is −8.5 volts and is obtained principally from its connection to the potential supply conductor 66. When the "0" tube is conducting, the cathode 75 not only is connected to the potential supply conductor 65, but also is coupled electronically to the anode of the "0" tube, which anode has a potential of +75 volts applied thereto. Under these conditions, the potential of the cathode 75 will rise to about +60 volts, and this will cause the potential of the grid of the "1" tube, which is connected to the same circuit at point 69, to become less negative. The capacitor 71 in the priming circuit causes this potential rise to be applied quickly to the grid 78. This change in potential of the grid of the "1" tube reduces the controlling bias of the grid to such an extent that the next impulse impressed on the grids of all the tubes will be effective to reduce the potential of the grid 78 to less than 15 volts more negative than the potential of the cathode of the "1" tube, causing that tube to fire and become con-

ducting. Similar couplings between the successive tubes of the ring enable the tubes to be primed and fired one after another in an endless chain sequence in response to one or more impressed impulses.

As explained earlier herein, the gaseous electron tubes as used in this ring will continue to conduct once they have been fired. Accordingly, some form of extinguishing action is required to stop conduction within the tubes. This is accomplished, in the method shown in the circuit diagram, by electrostatic connection of the cathode of a conducting tube with the cathode of a tube that is to be fired and causing the potential rise of the cathode of the tube, as it is fired, to momentarily raise the cathode potential of the previously conducting tube to a value greater than the anode potential and cause conduction to stop in the tube, thus enabling the grid to resume control. After the tube has been extinguished, its cathode "recovers" or resumes the potential which it had before the tube became conducting and is then ready, if primed, for further operation when another impulse is impressed thereon.

Applicants have provided a novel arrangement for connecting the tubes of the ring for extinguishing action, and, because of this arrangement, the ring of tubes may be operated at very high speeds. The tubes are connected in groups, with adjacent tubes of the ring being included in different groups. The various groups of tubes are isolated, so that the firing of a tube of one group will cause any other conducting tube of that group to be extinguished, but will not affect any of the tubes of the other groups, and the tubes of the other groups may be primed and operated while the tubes of one group are recovering from the extinguishing action.

In the embodiment of the invention as disclosed in Figs. 1 and 3, the "0" tube and the "5" tube are grouped and connected for mutual extinguishing action, so that, when the "0" tube is fired and becomes conducting, it will extinguish the "5" tube, and, when the "5" tube becomes conducting, it will extinguish the "0" tube. Accordingly, one or the other of the tubes of this group is conducting whenever the ring is in operation.

The connection between the cathode **75** of the "0" tube and the cathode of the "5" tube, as shown by line **10** in Figs. 1 and 3, extends in Fig. 3 from the point **72** over a resistor **122** of 5,000 ohms and a capacitor of 500 micro-microfarads in series to the point **83**. Similar connections, referred to generally as **11**, **12**, **13**, and **14**, which extend between the points **79**, **80**, **81**, and **82** and the points **84**, **85**, **86**, and **87**, respectively, connect the cathodes of the "1," "2," "3," and "4" tubes with the "6," "7," "8," and "9" tubes to form the various groups of tubes. As in the case of the "0" and "5" tubes, one or the other of the tubes of each group will be conducting when the ring is in operation.

If the ring as shown in Figs. 1 and 3 is to be used as one denominational order of a multi-denominational order accumulator, any suitable means may be provided to enter a unit in another denominational order each time the tubes of the one denominational order have completed a cycle of operation. For instance, one method would be to connect the "0" tube and the "5" tube to control the operation of a well-known trigger pair of tubes, which would operate a self-extinguishing electron tube to send an impulse to the other denominational order each time the "0" tube was fired.

With the understanding of the circuits shown in Fig. 3 to illustrate the connections of the tubes according to the arrangement of Fig. 1, it is not believed necessary to show the circuits for obtaining the arrangement according to Fig. 2, as the potential supply for the tubes, the impulse circuits, and the priming circuits would be the same as shown in Fig. 3. The only change would be that the extinguishing connections, including the 5,000-ohm resistor and the 500-micro-microfarad capacitor in series between cathodes would be included between the cathodes of the "0," "2," "4," "6," and "8" tubes as one group and the "1," "3," "5," "7," and "9" tubes as the other group.

Operation

In order that applicant's novel counting ring as shown in Figs. 1 and 3 will operate properly, it is necessary that half the tubes of the ring, or one of the tubes of each group or pair of tubes, must be conducting, and, if the necessary tubes are not already conducting, they may be rendered conducting by any convenient method such as temporarily grounding the control grids of these tubes.

The shading of the tubes in Fig. 3 shows that the "6," "7," "8," "9," and "0" tubes are conducting, which is the condition when the ring represents zero. The "0" tube, being conducting, is effective through the coupling between its cathode **75** and the grid **78** of the "1" tube to reduce the bias of the grid of the "1" tube almost to its firing point. When the next impulse is impressed on conductor **102**, it will be effective, by means of the connection through the capacitor **103**, to cause the potential of the grid **78** to be reduced below its critical biasing point and cause the "1" tube to fire. As the "1" tube fires and becomes conducting, the potential of its cathode will rise and, through the extinguishing coupling with the cathode of the conducting "6" tube, will cause the potential of the cathode of the "6" tube to rise above its anode potential and cause the "6" tube to be extinguished, after which the cathode of the "6" tube "recovers" or resumes its normal negative potential and is ready for further operation. The conducting "1" tube primes the "2" tube, and, when the next impulse is impressed on the conductor **102**, it will be effective, through the connection including capacitor **104**, to cause the "2" tube to fire and become conducting. The "2" tube will cause the "7" tube to be extinguished and the "3" tube to be primed for operation. Successive impulses will cause the tubes of the ring to be fired in sequence, with the "9" tube priming the "0" tube to enable the repeated operation of the tubes of the ring.

With the arrangement shown in Fig. 3, it is seen that the "5" tube, which is extinguished by the firing of the "0" tube, is not primed for operation until after the "1," "2," "3," and "4" tubes have been fired and is not affected in any way by the extinguishing actions involving the "1," "2," "3," and "4" tubes. Since a tube should not have an input impulse impressed thereon until after it has recovered from an extinguishing action, it follows that, with the above arrangement, the "5" tube can recover while the "1," "2," "3," and "4" tubes are being fired, so that the principal factors which would limit the rate at which impulses are impressed on the

ring are the time constant of the grid input circuit and the ionization time of the tubes. The arrangement shown enables an extremely high-speed operation of the gaseous electron tube ring.

The operation of the gaseous electron tube ring schematically shown in Fig. 2 is substantially the same as given above, except that only two tubes will be conducting at any instant and its speed will be reduced because every second impulse will cause a recurrence of an extinguishing action in the tubes of the groups. For example, if the "0" tube is fired, it extinguishes the "8" tube but also impresses the extinguishing action on the "2" tube, which must recover before it can have an impulse impressed thereon, and this means that only the "1" tube can be fired until the "2" tube has recovered.

While the form of mechanism herein shown and described 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 herein disclosed, for it is susceptible of embodiment in various forms all coming within the scope of the claims which follow.

What is claimed is:

1. In combination, a plurality of gaseous electron discharge devices, each device including at least two electrodes and means to control conduction in the device; means to couple the devices in an endless chain series for sequential firing in response to impressed impulses, the coupling between successive devices of the series including a connection between one of the electrodes of a device and the control means of the next device of the series and enabling the conduction in one device to cause the next device in the series, if non-conducting, to be prepared to be fired in response to an impulse impressed thereon; means to impress impulses on the control means of the devices; and means for connecting the devices into groups for mutual extinguishing action within each group, the connections between corresponding electrodes of the devices of any group enabling the act of conduction beginning in any device of that group to cause any previously conducting device of that group to be extinguished without affecting any of the devices of other groups, thus isolating the extinguishing action to the devices of that group, the means coupling the devices for sequential firing and the means for connecting the devices into groups being so coordinated that adjacent devices in the series are included in different groups and a device of each of the other groups will be fired before a recurrence of firing takes place within the devices of a group.

2. In combination, a plurality of gaseous electron discharge devices, each of said devices including at least a pair of electrodes and means to control conduction within the device; means dividing the devices into groups for mutual extinguishing action within each group, including connections between similar electrodes of the devices of a group to enable the firing of any device of the group to cause any conducting device of that group to be extinguished without affecting the devices of any other group, after which the non-conducting devices of that group recover from the extinguishing action and are ready to be fired; means to connect the devices in an endless chain series for sequential firing in response to input impulses, the connection between successive devices of the series extending between an electrode of a device and the control means of the next device of the series and enabling the conduction in one device to render the next device in the series, if non-conducting, responsive to be fired by an input impulse impressed thereon; and means to impress input impulses on the control means of the devices; the grouping of the devices being so chosen that successive devices in the series are included in different groups and a device in each of the other groups will be fired before a recurrence of firing occurs in any particular group, thereby enabling impulses to be impressed on the devices at a frequency sufficiently high to cause a device in each of the other groups to be fired and rendered conducting while the devices in one group are recovering.

3. In combination, a plurality of gaseous electron discharge devices, each device including at least a pair of electrodes and means to control conduction in the device; means to couple the devices for operation in an endless chain sequence, the couplings including a connection between an electrode of one device and the control means of the next device in the sequence to enable the conduction in a device to cause the next device in the chain sequence, if non-conducting, to be rendered responsive to an impulse impressed thereon, thereby preparing the devices selectively and sequentially for conduction in response to impulses; means to impress impulses on the control means of the devices; and a plurality of independent circuit networks for connecting the devices in groups for mutual extinguishing action within each group, each circuit network connecting together similar electrodes of the devices of the group to enable the act of conduction beginning in any device of a group to provide a potential change which is impressed on the other devices of the group and cause any previously conducting device to be extinguished and become non-conducting, after which the non-conducting devices of the group can recover from the extinguishing action and become ready to have further impulses impressed thereon, the chain connections and independent circuit networks being so coordinated that adjacent devices in the chain are included in different groups so that a device which causes an extinguishing action in one group will prepare a device in another group for conduction in response to an impulse.

4. In combination, a plurality of gaseous electron discharge devices for representing data, each device including at least two electrodes and means to control conduction in the device; means for connecting the devices to form a ring, said connections including a connection between one of the electrodes of a device and the control means of the next device of the ring and enabling the conducting condition of a device to prepare the adjacent non-conducting device of the ring to be responsive to a data-representing impulse so that the devices of the ring can be fired and rendered conducting sequentially in an endless operative series in response to data-representing impulses; means to supply each data-representing impulse to the control means of all of said devices; and circuits for connecting the devices into groups for mutual extinguishing action within each group, said circuits extending between similar electrodes of the devices of the group and enabling the firing of any device of any group to cause any previously conducting device in only that particular group to be extinguished, thus isolating the extinguishing action within the group, and the coordination of the

means for connecting the devices in a ring and the circuits connecting the devices in groups being such that a device of each of the other groups is fired before a recurrence of firing occurs within any group of devices.

5. In combination, a plurality of gaseous electron discharge devices, each device including at least a pair of electrodes and means to control conduction in the device; means for coupling the devices for sequential priming of the devices, said couplings including a connection between one of the electrodes of a device and the control means of the next device of the sequence to enable the conduction in a device to prime the next device in the sequence, if non-conducting, so that the devices may be fired and rendered conducting one after another in an endless operative series in response to data-representing impulses; means to supply data-representing impulses to the control means of the devices; and a plurality of independent circuits for connecting the devices in pairs for mutual extinguishing action which is isolated within each pair, said circuits extending between similar electrodes of the pair of devices enabling either device of the pair, when it is fired, to cause the other device of the pair, which is conducting, to be extinguished, after which the extinguished device recovers from the extinguishing action and is ready to be fired by data-representing impulses impressed thereon, the pattern of the connections connecting the devices in pairs and its relation to the couplings between devices being such that, while a device of a pair is recovering, a device in each of the other pairs of devices can be fired in response to data-representing impulses.

6. In combination, a plurality of gaseous electron discharge devices, each device representing a unit of data and including at least a pair of electrodes and means to control conduction in the device; means for connecting the devices in an endless chain series for sequential operation, the connection between successive devices of the series extending from one of the pair of electrodes of one device to the control means of the next device and enabling the conduction in one device to cause the next device of the series, if non-conducting, to be primed to be fired by the next data-representing impulse impressed on the devices of the series; means to impress data-representing impulses on the control means of all the devices; and a plurality of independent extinguishing circuits for connecting the devices in pairs for mutual extinguishing action which is isolated within each pair, said circuits connecting similar electrodes in the devices and enabling the firing of either device of the pair to provide a potential impulse which is impressed on the other device of the pair and causes said other device, which is conducting, to be extinguished, the priming connections and the pairing connections between the various devices being so coordinated that successive devices of the series are included in different pairs and a device of each of the other pairs is fired before a recurrence of firing within any pair takes place.

7. In combination, a plurality of gaseous electron devices each having an anode as one element thereof, a cathode as another element thereof, and a control grid to control conduction in the device; priming couplings between the devices to enable the devices to be fired and rendered conducting in an endless chain sequence one after another in response to input impulses impressed on all the devices, said couplings constituting a connection between the cathode element of one device and the control grid of the next device to be operated in the sequence, whereby the conducting condition of one device renders the control grid of the other device effective to cause the other device to be fired and rendered conducting in response to the next input impulse; means to impress impulses on all the devices; and means connecting the devices in groups for mutual extinguishing action within each group and including connections between similar elements of the devices comprised in the group whereby the firing of any device of the group will cause any other conducting device of the group to be extinguished, after which the non-conducting devices of the group recover for further operation, the grouping of the devices being so chosen that adjacent devices in the sequential operation are included in different groups, and the number of groups is such that a maximum number of impulses can be impressed on the devices before a recurrence of the firing of a device takes place within the devices of a group.

8. In combination, a plurality of gaseous electron tubes, each tube having an anode as one element, a cathode as another element, and a control means; means dividing the tubes in groups for mutual extinguishing action within each group, said dividing means including circuits connecting together similar elements in each of the tubes of the group so that a potential change on the element in a tube when it is fired can be transmitted to the other elements of the group and cause any conducting tube of the group to be extinguished; means to connect the tubes for sequential firing in an endless chain series in response to impressed impulses, the connection between successive tubes of the series enabling conduction in one tube to modify the control by the control means of the next tube in the series, if not conducting, and cause said next tube to be primed for firing in response to an impressed impulse; and means to impress impulses on the control means of the tubes to cause their sequential firing; the circuits of the means dividing the tubes into groups and the connections in the means for connecting the tubes for sequential firing being so coordinated that successively fired tubes in the chain series are included in different groups, thus enabling the firing of a tube to extinguish any conducting tube of its group and the conduction in the fired tube to cause a tube in another group to be primed for firing, whereby the primed tube is not affected by the extinguishing action.

9. In combination, a plurality of gaseous electron discharge devices, each device having an anode as one element, a cathode as another element, and a control means; means dividing the devices in groups for mutual extinguishing action within each group, said dividing means including circuits connecting together similar elements in each of the devices of a group and isolating the extinguishing action within the group so that a potential change on the element in a device when it is fired can be transmitted only to the other elements of the group and cause any conducting device of the group to be extinguished, after which the non-conducting devices recover from the extinguishing action and are ready to be fired; means to connect the devices for sequential firing in an endless chain series in response to impressed impulses, said connecting means including a connection between the cathode ele-

ments and the control means of successive devices of the series whereby the potential of the cathode element when its device is conducting can modify the control by the control means of the next device in the series, if that device is non-conducting, and render that device responsive to an input impulse; and means to impress impulses on the control means of the devices; the circuits of the dividing means and the means to connect the devices for sequential firing being so coordinated that a device in each of the other groups will be fired before a recurrence of firing occurs in any particular group, thus enabling impulses to be impressed on the devices at a frequency which will cause a device in each of the other groups to be fired and rendered conducting while the devices in one group are recovering.

10. In combination, a plurality of gaseous electron tubes, each tube having an anode as one element, a cathode as another element, and a control grid; means dividing the tubes in groups for mutual extinguishing action within each group, said dividing means comprising circuits connecting together similar elements in each of the tubes of any group so that a potential change on the element in a tube when it is fired can be transmitted to the other elements of the group and cause any conducting tube of the group to be extinguished, after which the elements of the non-conducting tubes of the group recover from the impressed potential change and are capable of being fired and rendered conducting; means to connect the tubes for firing sequentially in an endless chain series in response to impressed impulses; and means to impress impulse on the tubes to cause their sequential firing; the tubes of the groups being so selected that successive tubes in the sequential operation are included in different groups whereby a tube in one group, which has recovered from an extinguishing action, can be fired while the tubes in the other groups are recovering from an extinguishing action, thus enabling impulses to be impressed on the tubes at a high rate of speed.

11. In combination, a plurality of gaseous electron tubes, each tube having an anode as one element, a cathode as another element, and a control means to control conduction therein; means for segregating the tubes into the maximum number of groups having equal numbers of tubes that may be obtained from the plurality of tubes, said segregating means including circuits connecting together similar elements in each of the tubes of the group so that a potential change on the element in a tube when it is fired can be transmitted only to the other elements of the group and cause any conducting tube of the group to be extinguished without affecting the tubes of the other groups; means to connect the tubes for sequential firing in an endless chain series in response to impressed impulses, said sequential connections including circuits between adjacent tubes in the series to enable the conduction in one tube to modify the control by the control means of the next tube in the series, if said next tube is not conducting, and thereby render said next tube responsive to be fired by an impulse impressed thereon; and means to impress impulses on the control means of the tubes to cause the sequential firing of the tubes; the relation between the segregating circuits and the sequential connections between the tubes being such that a tube in each of the other groups is fired before a recurrence of firing in any group occurs, thus enabling a maximum number of impulses to be impressed on the devices before a recurrence of firing in a group takes place.

12. In combination, a plurality of gaseous electron tubes, each tube having an anode as one element, a cathode as another element, and a control grid; means connecting the tubes in isolated groups for mutual extinguishing action within each group, said connecting means comprising circuits connecting together similar elements in each of the tubes of any group so that a potential change on the element in a tube when it is fired can be transmitted only to the other elements of the group and cause any conducting tube of the group to be extinguished without affecting the tubes of the other groups, after which extinguishing action the elements of the non-conducting tubes of the group recover from the impressed potential change and are capable of being fired and rendered conducting; means comprising a cathode element-control grid circuit between successive tubes of a series to selectively prime the tubes for sequential firing in an endless chain series in response to impressed impulses; and means to impress impulses on the tubes to cause their sequential firing; the tubes of the groups being so selected that successive tubes in the sequential operation of the tubes are included in different groups whereby a tube in one group which has recovered from an extinguishing action can be fired while the tubes in the other groups are recovering from extinguishing actions.

13. In combination, a plurality of gaseous electron tubes, each tube having an anode as one element, a cathode as another element, and a control grid; a plurality of independent networks for segregating the tubes in groups, each group having the same number of tubes, and each of said networks comprising circuits connecting together similar elements in each of the tubes of the group so that a potential change on the element in a tube when it is fired can be transmitted only to the other elements of the group to cause any conducting tube of the group to be extinguished without affecting the tubes of the other groups; means to connect the tubes in an endless chain series, said connecting means comprising a cathode element-control grid circuit between successive tubes of a series whereby conduction in one tube primes the next tube in the series for firing in response to an impressed impulse; and means to impress impulses on the tubes; the relation between the networks and the priming connections being such that a tube, which is fired and causes an extinguishing action in one group, will prime a tube in another group.

14. In combination, a plurality of gaseous electron tubes, each tube having an anode as one element, a cathode as another element, and a control grid; means for segregating the tubes into the maximum number of groups having equal numbers of tubes that may be obtained from the plurality of tubes, said segregating means isolating the groups and comprising circuits connecting together similar elements in each of the tubes of the group so that a potential change on the element in a tube when it is fired can be transmitted only to the other elements of the groups and cause any conducting tube of the group to be extinguished without affecting the tubes of the other groups, after which extinguishing action the elements of the non-conducting tubes of the group recover from the potential change and are capable of being fired and rendered conducting; means to connect the tubes

in a ring for sequential firing in an endless chain series in response to impressed impulses; and means to impress impulses on the tubes to cause their sequential firing; the relation between the segregating circuits and the connections for sequential firing being such that a tube in each group is fired before a recurrence of firing in any group takes place, thus enabling a maximum number of impulses to be impressed on the ring while the tubes of any group are recovering from an extinguishing action.

15. In combination, a plurality of gaseous electron tubes, each tube representing a unit of data and including an anode, a cathode and a control grid; a plurality of independent extinguishing circuits for connecting the tubes in isolated pairs, said circuits electrostatically coupling the cathodes of the tubes so that a potential rise of a cathode of a tube, as that tube is fired, will be impressed on the cathode of the other tube of the pair and will cause that tube, which is conducting, to be extinguished, after which the cathode of the extinguished tube recovers from the impressed potential rise and is ready to be fired; priming circuits for connecting the tubes in an endless operative series for sequential firing in response to impressed data-representing impulses, said priming circuits connecting the cathode of one tube with the control grid of the next tube in the series, thereby connecting the different pairs of tubes so that a tube in each pair will be fired before a recurrence of firing takes place in any pair; and means to impress data-representing impulses on the tubes at a frequency to cause a tube in each of the other pairs to be fired and rendered conducing while an extinguished tube in one of the pairs is recovering.

16. In combination, a plurality of gaseous electron tubes, each tube representing a unit of data and including an anode, a cathode, and a control grid; a plurality of independent extinguishing circuits for connecting the tubes in isolated pairs, said circuits electrostatically coupling the cathodes of the tubes so that a potential rise of a cathode of a tube, as that tube is fired, will be

impressed on the cathode of the other tube of the pair and will cause that tube, which is conducting, to be extinguished, after which the cathode of the extinguished tube recovers from the impressed potential rise and is ready to be fired; priming circuits for connecting the tubes in an endless operative series for sequential firing in response to impressed data-representing impulses, said priming circuits connecting the cathode of one tube with the control grid of the next tube in the series, thereby connecting the different pairs of tubes so that a tube in each pair will be fired before a recurrence of firing takes place in any pair; the relation between the extinguishing circuits and the priming circuits being such that a tube, which is fired and becomes conducting causes the extinguishing of the other tube of its pair and the priming of the non-conducting tube of the next pair in the sequence; and means to impress data-representing impulses on the tubes at a frequency to cause a tube in each of the other pairs to be fired and rendered conducting while an extinguished tube in one of the pairs is recovering.

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Certificate of Correction

Patent No. 2,426,279. August 26, 1947.

ROBERT E. MUMMA ET AL.

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Column 6, line 32, after the syllable "cludes" insert *the*; line 37, for "tubes" read *tube*; column 15, line 35, claim 10, for "impulse" read *impulses*; column 17, line 36, claim 15, for "conducing" read *conducting*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of October, A. D. 1947.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.