

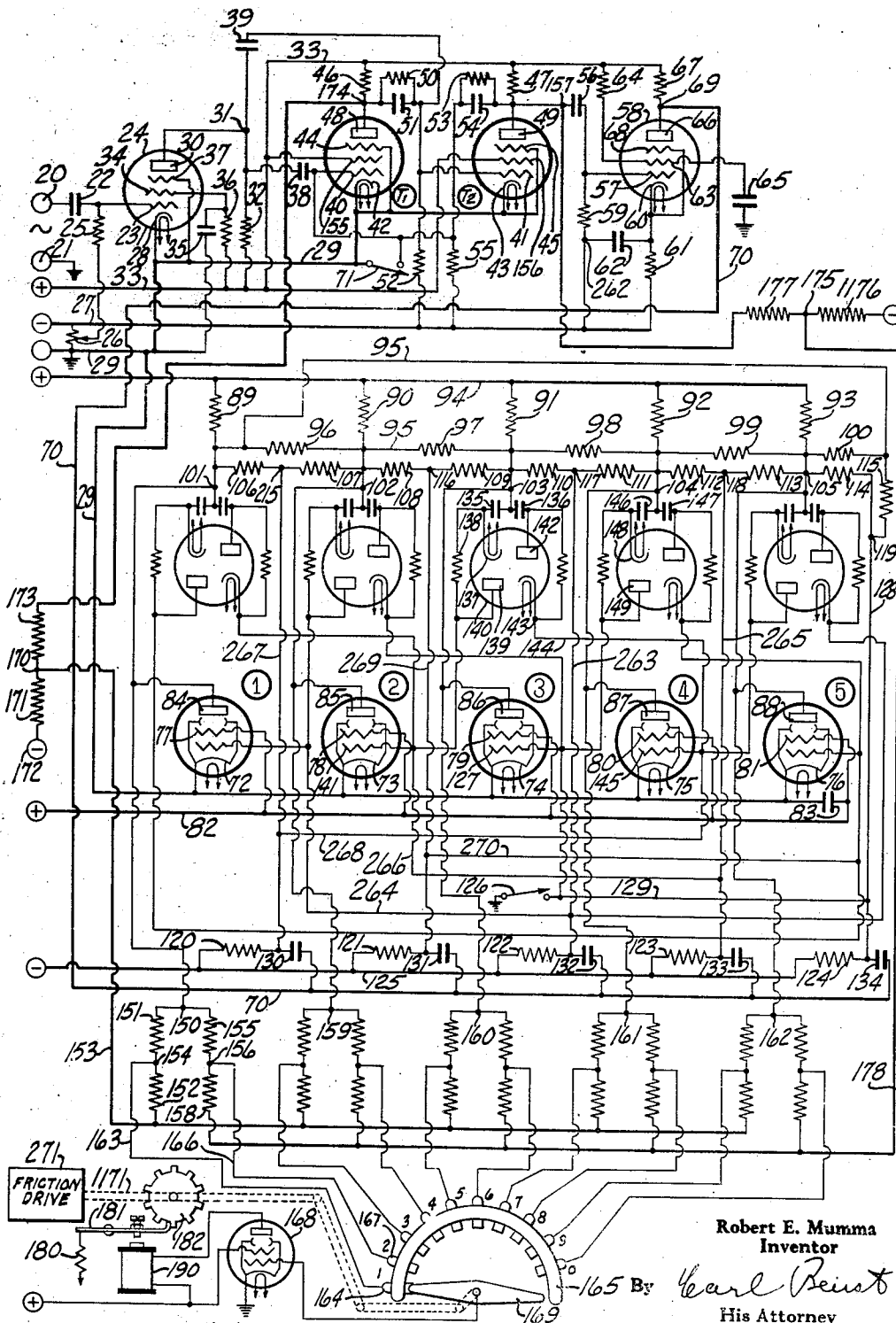
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ELECTRONIC ACCUMULATOR

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ELECTRONIC ACCUMULATOR

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This invention relates to a high-vacuum electron tube counting ring and more particularly pertains to a plurality of high-vacuum tubes which are operated sequentially in response to commonly-received electric potential impulses.

The principal object of the invention is to provide a plurality of more than two high-vacuum electron tubes connected in an endless operative chain whereby, because of circuit characteristics, but one tube of the ring may be conducting at any one time, and the tubes, when operated, are rendered conducting one at a time in endless chain sequence.

Another object of the invention is to provide means whereby a plurality of more than two high-vacuum electron tubes are rendered conducting in sequence one at a time in response to each of commonly-received electric potential impulses.

Another object of the invention is to provide an electron tube counting ring accumulator of data, utilizing more than two high-vacuum electron tubes as data-representing devices, the tubes being connected in an endless operative chain whereby they are caused to be rendered operative one at a time in endless chain sequence, all the parts being stationary except electrons moved by differences in potential.

Another object of the invention is to provide means whereby received electric impulses are divided by two and impressed upon the high-vacuum electron tube counting ring, one impulse for every two impulses received, and means is further provided for determining, from the state of the dividing means and the state of the ring of electron tubes, the total number of received impulses.

Another object of the invention is to provide two sensing points for each tube of the counting ring, each of said points being affected by the associated tube and by the dividing means to determine whether the conduction in a tube of the ring represents the first or the second impulse received by the dividing means affecting said tube.

Another object of the invention is to provide a high-vacuum electron tube counting device having a ring of more than two tubes, said device being responsive to electric impulses received at any intervals greater than one twenty-five-thousandth of a second.

Another object of the invention is to provide a novel method for accumulating and storing numerical data in a denominational system of numerical notation.

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Another object of the invention is to provide two electron tube counting rings of different denominational value and means to cause a step of operation in one ring on completion of a cycle of steps in the other ring.

It has been known how to connect two high-vacuum tubes in a trigger circuit for alternate operation in response to commonly-received electric impulses, thus forming a ring of two tubes, but such circuits are not adaptable for more than two tubes. This invention provides for joining more than two tubes in an endless operative chain, utilizing an entirely new type of circuit from what has hitherto been known.

In the disclosed embodiment of the invention, which embodiment is not to be deemed to limit the broad principles of the invention, each of the tubes of the novel ring is designated to stand for two possible items of data. The condition of conduction of a tube signifies the registration of data, and consideration must be given to the conducting tube and to the impulse-dividing means whereby to determine which of the two possible items of data is represented by the condition of the conduction of a particular tube. It will be obvious that the counting ring tubes may also be used to represent single items of data by eliminating the dividing means.

Five tubes have been provided in the disclosed ring, each of said tubes representing two adjacent digits in a denominational order of the decimal system of numbers. For instance, a tube may represent "8" and "9," or "9" and "0," or "0" and "1," or "1" and "2," depending on whether "0" or "1" is deemed the starting point of the ring. If one tube represents the digits "0" and "1," the next tube of the ring represents the digits "2" and "3." The condition of conduction in a tube indicates that either of the two digits it represents is registered. The condition of the dividing means, as to which one of two possible conditions is prevailing, determines which of the two digits is registered.

It is to be understood that the essential and underlying principle of the invention is to provide a circuit network for a plurality of more than two high-vacuum electron tubes wherein only one tube can be conducting at a given time and wherein the tubes may be made to be conducting one at a time in sequence in response to each of commonly-received electric potential impulses. The particular embodiment disclosing the invention pertains to counting or accumulating numerical data using the decimal system. It is apparent, however, that the principles of

the invention go beyond the number of the tubes used in this disclosure and the designation given to them, and go beyond the idea of using a tube of the ring for representing two digits, the invention being capable of use in many ways which will be apparent from the description which follows with reference to the drawing.

The drawing represents a typical circuit network, showing the impulse-dividing means, the five-tube counting ring, and an indicator means for translating the condition of the tubes into the decimal system of numerical notation.

General description

In the disclosure of the invention, a source of electric impulses to be counted must be specified, and, for the particular embodiment herein disclosed, a source of sine wave impulses is chosen, which wave source is indicated conventionally as being impressed on terminals 20 and 21. All potentials given are relative to ground potential. Cathode heaters are shown conventionally. Terminal 21 is grounded. Terminal 20 is coupled through capacitor 22 to the control grid 23 of vacuum amplifier tube 24, as, for instance, an "1852" type of pentode, having a grounded cathode 28. The grid is negatively biased far beyond cut-off by being connected through resistor 25 of 50,000 ohms to potential divider resistance 26 connected between ground and a conductor 27 given a negative potential of 180 volts. The anode 30 is connected through point 31 and resistor 32 of 25,000 ohms to conductor 33 given a potential of 120 volts positive. The screen grid 34 is coupled to ground through a capacitor 35 of 4 microfarads and connected through resistor 36 of 50,000 ohms to the 120-volt positive conductor 33. The suppressor grid 37 is grounded. Under these conditions, point 31, due to resistor 32, drops in potential for each sine wave of over 15 volts impressed on terminals 20 and 21, as tube 24 is rendered conductive during a portion of the positive half of the sine wave.

The negative potential impulses impressed on point 31, each of which represents a sine wave, are fed through capacitors 38 and 39, of 10 micro-microfarads each, to the control grids 40 and 41 of vacuum tubes T1 and T2 respectively, said tubes being pentode amplifiers which may be of the "1852" type mentioned, arranged in a trigger circuit by conductively coupling the anode of each tube to the control grid of the other tube of the pair. Upon receipt of a commonly-received negative potential impulse on the control grids 40 and 41, the tubes will stably assume a mode of operation in which one or the other of the tubes is conducting, awaiting the next commonly-received negative electric potential impulse on their grids. Said stable mode of operation follows the receipt of the impulse, which impulse causes the conduction in the conducting tube to cease, which cessation in turn causes conduction in the other tube to commence, it being impossible to have both tubes conducting at the same time because of the nature of the coupling circuit. The cathodes 42 and 43 of the tubes T1 and T2, respectively, are grounded by being connected to conductor 29, as are the suppressor grids 44 and 45. The anodes 48 and 49 of tubes T1 and T2, respectively, are connected through resistors 46 and 47, respectively, each of 5,000 ohms, to the 120-volt positive conductor 33. The screen grids 155 and 156 of tubes T1 and T2, respectively, are connected to the 120-volt positive conductor 33. The anode 48 of tube T1 is

coupled through a resistor 50 of 50,000 ohms and a capacitor 51 of 50 micro-microfarads, in parallel, to the grid 41 of tube T2. The grid 41 is connected through resistor 52 of 50,000 ohms to the 180-volt negative conductor 27. In a like manner, the anode 49 of tube T2 is connected through resistor 53 of 50,000 ohms and capacitor 54 of 50 micro-microfarads, in parallel, to grid 40 of tube T1. Grid 40 is connected through resistor 55 of 50,000 ohms to the 180-volt negative conductor 27. Under these conditions, on each negative impulse commonly impressed on grids 40 and 41, the conducting tube, of tubes T1 and T2, will be rendered non-conducting, and the consequent rise in anode potential will be impressed on the grid of the other tube of the pair, causing it to conduct. Such trigger tube circuits are well known and comprise a two-tube vacuum electron tube counting ring. The negative potential impulse occurring at the anode of either tube T1 or T2 when commencing to conduct is impressed on the grid of the other of the pair, keeping it more negative than the critical point, which is 20 volts in the type of tube used, until the mode of operation of the tubes is changed.

From point 157, connected to anode 49 of tube T2, the change in potential caused by resistor 47 each time tube T2 stops conducting is impressed through capacitor 56 of 10 micro-microfarads onto the control grid 57 of pentode amplifier 58, which may be of the "6AG7" type, said grid being normally negatively biased beyond the critical point of 30 volts by being connected through resistor 59 of 50,000 ohms to the 180-volt negative conductor 27. Cathode 60 is connected through resistor 61 of 25,000 ohms to the 180-volt negative conductor 27 and is coupled to point 262 through capacitor 62 of 4 microfarads. Screen grid 63 is connected to the 120-volt positive conductor 33 through resistor 64 of 3,750 ohms and is grounded through capacitor 65 of 4 microfarads. Anode 66 is connected to the 120-volt positive conductor 33 through resistor 67 of 5,000 ohms. Suppressor grid 68 is connected to the cathode.

With the aforementioned connections, tube 58 acts as an overbiased amplifier responsive by conducting on each positive impulse impressed through capacitor 56, and hence responsive once for each two sine wave impulses impressed on terminals 21 and 22 as tube T2 ceases conducting, thus constituting a means to divide the input sine wave impulses by two. Due to the resistance 67 in the supply conductor for anode 66, there is a drop in potential at point 69 each time tube 58 commences to conduct. The drop in potential of point 69 causes a sharp negative impulse to be impressed on conductor 70 each time tube 58 starts conducting.

Tube T1 may be rendered conducting by grounding its grid 40 by temporarily closing switch 71 and then opening it. Hence, if tube T1 is thus rendered conducting, then, on the first sine wave input impulse impressed on terminals 20 and 21, tube T1 is rendered non-conducting, and conduction commences in tube T2. On the second sine wave input impulse impressed on terminals 20 and 21, tube T2 is rendered non-conducting, conduction commences in tube T1, and a sharp negative impulse is impressed on conductor 70.

Tubes "1," "2," "3," "4," and "5" are high-vacuum electron tubes of high mutual conductance each having an anode, a cathode, a control grid, a screen grid, and an electrode connected

to the cathode for directing the electron flow to the anode efficiently. The "6Y6G" type of tube is satisfactory for use in the particular embodiment of the invention herein disclosed, but it will be apparent that the particular characteristics of the tube are not a fundamental part of the invention and the invention is not limited in scope by the type of tube, by the screen grid, by the electron-directing cathodes, or by the particular values of resistance and capacitance used with the tubes, as the essential operation may be accomplished by a triode vacuum electron tube having an anode, a cathode, and a control grid.

The cathodes 72, 73, 74, 75, and 76 are connected to ground conductor 29, and screen grids 77, 78, 79, 80, and 81 are connected to conductor 82, which has a positive potential of 30 volts applied thereto.

A capacitor 83 of 4 microfarads couples ground conductor 29 and the screen grid supply conductor 82.

Each of the anodes 84, 85, 86, 87, and 88 is connected through a 25,000-ohm resistor, numbered 89, 90, 91, 92, and 93, respectively, to a 290-volt positive supply conductor 94. The anodes are connected with one another in an endless chain operative series by conductor 95, there being a 25,000-ohm resistor in the conductor 95 between each two adjacent anodes of the series. Thus, resistor 96 connects anode 84 of the "1" tube to anode 85 of the "2" tube; resistor 97 connects the anode 85 of the "2" tube to the anode 86 of the "3" tube; resistor 98 connects the anode 86 of the "3" tube to the anode 87 of the "4" tube; resistor 99 connects the anode 87 of the "4" tube to the anode 88 of the "5" tube; and resistor 100 connects the anode 88 of the "5" tube with the anode 84 of the "1" tube. Connecting each two adjacent anodes, and forming part of the resistance mesh, are a pair of resistances, each of the pair being of 100,000 ohms value, resistors 106 and 107 joining the anodes of tubes "1" and "2," resistors 108 and 109 joining the anodes of the tubes "2" and "3," resistors 110 and 111 joining the anodes of tubes "3" and "4," resistors 112 and 113 joining the anodes of tubes "4" and "5," and resistors 114 and 115 joining tubes "5" and "1." From the juncture of each of the last-named pairs of resistors—namely, points 215, 116, 117, 118, and 119—is a connection through a resistor of 100,000 ohms, like resistors 120, 121, 122, 123, and 124, to a negative potential supply conductor 125 of 320 volts. By connecting the anodes of the tubes "1," "2," "3," "4," and "5" in such an endless chain symmetrical resistance network formed of a ring of resistance loops, with the potentials given the supply conductor and with the tubes specified, a condition is set up whereby, if one of the tubes of the series "1," "2," "3," "4," and "5" is conducting, the network, at points symmetrical to the point of connection to the anode of the conducting tube, has certain corresponding potentials due to the current flow through the conducting tube. The resistance network being symmetrical and the anodes of the tubes "1," "2," "3," "4," and "5" being joined to the network at points 101, 102, 103, 104, and 105, respectively, in a symmetrical manner, the pattern of potential variations in the network ring is regular, but is stepped around the ring in sequence as the tubes become conducting in sequence in response to the received impulses, as will be explained.

In the network ring of resistors, with no tube conducting, points like points 101, 102, 103, 104,

and 105 will have a positive potential of about 247 volts. Such a possibility is non-existent, except momentarily, in the circuit shown, as one tube will always be conducting due to the particular relative potentials used, one of the tubes becoming conducting accordingly as it has a tendency toward conductivity because of its varying in that manner from absolute perfection more than the other tubes. On application of potentials to the supply conductors, and as one of the tubes becomes conducting before the others, there will be caused, by reason of the current flowing through the tube, a readjustment of potentials of points 101, 102, 103, 104, and 105. Assuming that the "3" tube is conducting, which may be assured by temporarily closing switch 126, thus grounding grid 127, with the particular operating potentials applied to the supply conductors, the potential of point 103 and the anode 86 of the "3" tube will be about 7 volts positive with relation to the grounded cathode 74, as the internal potential drop of a "6Y6G" tube is about 7 volts.

The potential of points 102 and 104, representative of the anodes 85 and 87 of the tubes "2" and "4" respectively, will become about 122 volts positive, and the potential of points 101 and 105, representative of the anodes 84 and 88 of the tubes "1" and "5" respectively, will become about 160 volts positive. Under these conditions, point 119, connected to grid 127 of the "3" tube by means of conductors 128 and 129, assumes the potential of ground, rendering tube "3" highly conducting. At the same time, the potential of the control grid of tube "1" is the same as point 117, being connected thereto by conductors 263 and 264, which point is 60 volts negative with respect to ground; the grid of tube "2" is of the same potential as point 118, being connected thereto by conductors 265 and 266, which point 118 is 14 volts negative with respect to ground; the grid of tube "4" is of the same potential as point 215, being connected thereto by conductors 267 and 268, which point 215 is 14 volts negative with respect to ground; and the grid of tube "5" is of the same potential as point 116, being connected thereto by conductors 269 and 270, which point 116 is 60 volts negative. Thus, the two tubes adjacent in both directions in the sequence to the conducting tube have their grids nearer the critical point, which point is about 10 volts negative, than the grids of the tubes farther away in the sequence.

The input conductor 70, as explained, carries a negative potential impulse each time tube 53 is conducting, which impulse is impressed through capacitors 130, 131, 132, 133, and 134, each of 50 micro-microfarads capacity, onto the grids of all of the tubes "1," "2," "3," "4," and "5" simultaneously. The attenuated input negative impulses impressed on the control grids are of about 20 volts. A negative impulse impressed on conductor 70 as the "3" tube is conducting will render the "3" tube non-conducting, and the consequent positive potential surge at point 103 will be impressed on capacitors 135 and 136, each of 50 micro-microfarads capacity. The positive potential surge cannot cause conduction between anode 139 and cathode 137 of double diode rectifier tube 140, which may be of the "6H6" type, because it is of the wrong polarity, and the surge is attenuated as it passes through resistor 138 of 1 megohm, so it does not cause enough of a positive potential impulse on the grid 141 of the "2" tube, to which resistor 139

is connected, to cause tube "2" to conduct. The positive potential surge through capacitor 136 is impressed on anode 142, causing a positive potential surge at point 143 of 40 volts, due to resistor 120, which surge makes the grid 145 of the "4" tube more positive than the critical point, thus causing the "4" tube to become conducting. As tube "4" becomes conducting, point 164 has a potential surge toward the negative from 122 volts positive to 7 volts positive. This negative surge is impressed on capacitors 146 and 147, causing conduction to occur between cathode 148 and anode 149, causing a strong negative potential impulse to be impressed on grid 127 of tube "3," preventing it from again conducting due to the change in potential of point 162 from 122 volts positive to 160 volts positive which is impressed on grid 127 by way of the associated rectifier tube. Thus, the potential surges in the anodes of the tubes "1," "2," "3," "4," and "5" are utilized in conjunction with the rectifiers to cause the sequential operation to be in one direction only.

On the next negative potential impulse received commonly by the tubes "1," "2," "3," "4," and "5," the "4" tube will be rendered non-conducting, and the "5" tube will be rendered conducting. After the "5" tube, the "1" tube will be rendered conducting. This will occur in endless chain sequence, the endless chain of tubes being receptive and accurately responsive to more than 12,500 steps of operation per second with the values of resistors and capacitors, the type of tubes, and the potentials disclosed. This means that 25,000 potential impulses per second may be fed into terminals 20 and 21, and the state of the tubes T1 and T2 in conjunction with the state of the tubes "1," "2," "3," "4," and "5" may be sensed to accurately count up to ten the number of potential impulses received at a frequency of 25,000 per second.

It is apparent that another ring of tubes like tubes "1," "2," "3," "4," and "5" may be actuated in conjunction with another impulse divider like tubes T1 and T2 where they are made to operate a step in sequence each time the ring shown in the drawing completes one sequential cycle. As the input to tubes of a trigger circuit like tubes T1 and T2 requires a negative electric potential impulse for a step of operation, a conductor connected to point 191 will have impressed thereon a negative impulse each time tube "1" begins to conduct, and such negative impulse may be utilized for actuating another ring by one step by being connected to a point corresponding to point 31. Other rings may be connected to the proposed second ring in order to obtain a plural denominational system of any number. As many rings may be used in series as are required for the particular purpose for which the system is to be adapted.

The means for sensing the condition of the divider tubes T1 and T2 and the counting ring tubes "1," "2," "3," "4," and "5" comprises a resistance network for each counting ring tube, one part of each of the resistance networks being connected to the anode of tube T1 and the other part of each of the resistance networks being connected to the anode potential of tube T2, and the mid-part of each of the resistance networks being affected by the anode potential of the associated counting ring tube. Point 158, having the potential of anode 84 of tube "1," is connected through resistor 151 of 1,500,000

ohms, point 154, and resistor 152 of 500,000 ohms to conductor 153, which is connected to the point 179. Point 150 is also connected through resistor 155 of 1,500,000 ohms, point 156, and resistor 158 of 500,000 ohms to conductor 178, which is connected to the point 175. Each of the points 159, 160, 161, and 162 is connected to conductors 153 and 178 in the same manner as has been explained for point 159. From point 154 a conductor 163 extends to a "1" contact 164 on a commutator 165, and from point 156 a conductor 166 extends to a "2" contact 176 on commutator 165. Point 170 is connected through resistor 171 of 850,000 ohms to a 400-volt negative terminal 172 and is connected through resistor 173 of 500,000 ohms to point 174, which has the same potential as anode 48 of the tube T1, and conductor 178 is connected to point 175, which point is connected through resistor 176 of 850,000 ohms to a terminal of 400 volts negative potential and is connected through resistor 177 of 500,000 ohms to point 157, which has the potential of the anode 49 of the tube T2.

If the "1" tube is conducting, its anode 84 will be at 7 volts positive potential, and, if it is not conducting, it will be at 122 volts or 160 volts positive potential. If, while the "1" tube is conducting, tube T1 is conducting, anode 84 therefore being about 7 volts positive potential, then point 154 and contact 164 will be about 17 volts negative potential. If tube T1 is not conducting, then its anode is about 90 volts positive, and point 154 will be at 2 volts positive potential, whereas point 156 will be at 17 volts negative potential because tube T2 is conducting and its anode is at 23 volts positive. If point 150 were at 122 or 160 volts positive potential, as would be the case if tube "1" were not conducting and T1 were conducting, then points 154 and 156 would be 12 volts positive and 21 volts positive potential respectively. Consequently, the most negative contact 1 or 2 on commutator 165 represents the registered number. The same changes in potential toward the negative will occur on the other contacts of the commutator if the associated tube of the ring is conducting.

Vacuum tube 168 having a grounded cathode is of the same type as tube "1" having a critical grid potential of 10 volts negative, and consequently, when sensing arm 169 is caused to move over commutator 165 by means of friction drive 271, which moves axle 1171 (indicated by the dotted lines), if a contact is sensed having such critical potential or a potential more negative than the critical potential, conduction will stop in the tube 168, deenergizing solenoid 190 normally energized by conduction through tube 168, which allows the spring 180 to move the pawl 181 so as to stop the sensing arm 169, the wheel indicator 182, and the axle 1171, to which the wheel and the sensing arm are secured, against the action of friction drive 271, thus positioning the indicator wheel 182 corresponding to the position of the sensing arm 169, and consequently not only indicating which of the tubes "1," "2," "3," "4," and "5" is conducting, but also indicating which of the tubes T1 and T2 is then conducting. The change of potential of the commutator contacts, such as contact 164, when they are no longer sufficiently negative causes conduction to commence in tube 168, which retracts pawl 181, causing arm 169 to hunt another contact of the proper negative potential, and no

contact has the proper potential unless the two tubes associated therewith are conducting.

It is thus possible, by the impression of sine waves upon the terminals 20 and 21 in any number up to ten, to differentially actuate the tubes "1," "2," "3," "4," and "5" in conjunction with the tubes T1 and T2 so as to count and indicate the exact number of sine waves received. The waves may be impressed upon the terminals 20 and 21 at regular or irregular intervals and at frequencies as great as 25,000 per second. It has also been described how to construct a plural denominational high-vacuum tube counting device for accommodating larger accumulations of data.

Although the circuit is shown for operation by an input of sine waves, it is perfectly apparent that any means of actuating tube 24 or impressing the proper potential impulses on point 157 or on conductor 70 is within the scope of the invention, and it is to be further noted that the kind of tubes used, the particular values of potentials and values of circuit elements employed, or the impulse dividing means shown are not limiting factors as to the high-vacuum tube counting ring, but merely show one practical embodiment of the invention. This and other embodiments of more or fewer tubes in the ring are within the scope of the invention as set forth in the claims which follow.

What is claimed is:

1. In combination, a plurality of more than two anode-cathode electrode pairs each in a vacuum; means supplying operating energy to the electrode pairs, said means including a ring of resistors, means connecting the anodes to symmetrical points in the ring, and resistance connections from said points to a common source of electric potential; and a control means for each of the electrode pairs each joined to the ring of resistors at a point diametrically opposite to the associated anode connection.

2. In combination, a plurality of more than two high-vacuum electron tubes each having an anode, cathode, and a control grid; a ring of resistors; means connecting the anodes to symmetrical points in the ring in sequence; resistance connections from said points to a common source of electric potential, the act of conduction in a tube causing a symmetrical variation of potential in the ring of resistors; means for initiating conduction in a tube; means connecting each control grid to a place in the ring of resistors whereby if conduction in any tube occurs the grids of the other tubes will be so strongly potentially biased that no conduction can occur therein and whereby one and only one tube will always be conducting; means for causing conduction to cease in any conducting tube, the change in potentials around the ring of resistors causing the next adjacent tube in the series to become conducting; and means furnishing a potential impulse to the control grid of the tube next in the sequence to the tube rendered non-conducting to aid its commencement of conduction.

3. In combination, a plurality of more than two high-vacuum electron tubes each having an anode, a cathode, and a control grid; means for supplying cathode energy to the tubes; common electric network means comprising a symmetrical network of resistors arranged in a ring for supplying anode energy to the tubes, said anodes being connected to the ring serially in symmetry, the condition of conduction in a certain tube

causing a corresponding symmetrical set of potentials at the anode connection points in the ring; means for initiating conduction in a tube; means connecting each control grid to a place in the ring whereby if conduction in any tube occurs the grids of the other tubes will be so strongly potentially biased that no conduction can occur therein and whereby one and only one tube will always be conducting; means for causing conduction to cease in any of the tubes, the change in potentials of the ring of resistors causing the next adjacent tube in the series to become conducting; and means electrostatically coupling the anode of a tube and the control grid of the tube next in series thus aiding the sequential operation of the tubes.

4. In combination, a plurality of high-vacuum electron tubes each having an anode, a cathode, and a control grid; means to supply cathode potential to the tubes; common means including a symmetrical mesh of resistors for supplying anode potential to the tubes, said anodes being connected symmetrically therethrough to the source of potential, means for biasing the grids of the tubes with a potential normally preventing conduction through the tubes, said biasing means including connections of the grids to symmetrical points in the mesh of resistors so that if a tube is conducting the grids of the other tubes will be given a potential more negative than normal but those two tubes immediately adjacent to the conducting tube as regards their anode connections to the resistor mesh being given less additional negative potential than the grids of the other non-conducting tubes; and means coupling the anode of each tube to the grid of each of the adjacent two tubes so that when conduction commences in a tube it causes a sharp negative potential impulse to be impressed on the grid of one of the adjacent tubes and when conduction ceases in a tube it causes a sharp positive potential impulse on the grid of the other of the adjacent tubes.

5. In combination, a plurality of high-vacuum electron tubes each having an anode, a cathode, and a control grid; means to supply cathode potential to the tubes; common means including a symmetrical mesh of resistors for supplying anode potential to the tubes, said anodes being connected symmetrically therethrough to the source of potential; means for biasing the grids of the tubes with a potential of a value normally preventing conduction through the tubes if another tube is conducting, said biasing means including connections of the grids to symmetrical points in the mesh of resistors so that if a tube is conducting the grids of the other tubes will be given a potential more negative than normal but those two tubes immediately adjacent to the conducting tube as regards their anode connections to the resistor mesh being given less additional negative potential than the grids of the other non-conducting tubes; means connecting the anode of each tube to the grid of each of the adjacent two tubes so that when conduction commences in a tube it causes a sharp negative potential impulse to be impressed on the grid of one of the adjacent tubes and when conduction ceases in a tube it causes a sharp positive potential impulse on the grid of the other of the adjacent tubes; and means to impress a negative potential impulse on the grids of all the tubes sufficient to stop conduction in any conducting tube thereby causing the adjacent tube whose grid receives the positive potential impulse to

commence conduction and in turn cause a negative potential impulse on the grid of the tube that stopped conduction.

6. In combination, a plurality of more than two high-vacuum electron tubes each having an anode, a cathode, and a control element; a common electric energy supply means for the anodes of said tubes including a network of resistors arranged in a ring to which the anodes are symmetrically connected forming an endless operative chain; means connecting each anode through a resistance to a common anode potential source; and means electrostatically coupling each anode to the control elements of the tubes immediately adjacent in the sequence, said means including a rectifier and capacitor in series in each coupling so that positive potential surges in an anode are conveyed to the control element in the tube next in the operative sequence and so that negative potential surges of an anode are conveyed to the control element of the tube preceding in the operative sequence.

7. In combination, any plurality of more than two anode-cathode pairs; a control means for each pair; means to supply cathode energy to the pairs; means to supply anode and control energy to the pairs, said means including a ring of resistors to which the anodes and the associated control members are symmetrically electrically connected, an anode and its control member being diametrically connected to the ring; and a resistance connection between each anode and a common source of anode potential.

8. In combination, a series of resistors connected in a ring; resistance means connecting symmetrical points in the ring to a common anode potential supply conductor, there being two resistors between each two adjacent anodes; a plurality of high-vacuum electron tubes connected by their anodes to said points and connected by their cathodes to a source of cathode potential; means connecting the jointure of each two inter-anode resistors to a source of negative potential; a control element for each tube connected to the jointure between the two resistors farthest away in the ring from the point to which the associated anode is connected; and a common input conductor coupled to each control member.

9. In combination, a plurality of electron tubes; circuits connecting the tubes so that they are operated one at a time in sequence in response to each of a plurality of electric impulses commonly impressed on said tubes at regular or irregular intervals; means to divide the number of introduced impulses by two, said dividing means producing an output impulse for every two introduced impulses; means to impress the output of said impulse divider on said tubes so as to cause a step of sequential operation for each two produced impulses; two sensing stations for each tube and means to couple the tubes, the sensing stations, and the dividing means whereby it may be determined which one of the introduced impulses is represented by the state of conduction of any tube of the plurality, said means including a resistance network affected by the state of conduction in the tubes of the sequence and by the state of the dividing means which determines the electric potential at various points in said resistance network.

10. In combination, two high-vacuum electron tubes arranged in a trigger circuit so that but one tube of the two may be conductive at any one time and whose mode of operation may be changed by each of negative potential impulses

impressed thereon; a high-vacuum electron tube relay caused to conduct each time the tubes of the trigger circuit changes to a particular mode of operation, the act of conduction of said last-named tube causing a negative electrical potential impulse, each of said last-named impulses representing two of the impulses impressed on the trigger pair; a plurality of electron tubes arranged in a circuit for operation in endless chain sequence one at a time, which tubes are caused to operate step by step in response to each of received negative electric potential impulses; means to impress the trigger pair produced negative impulses on said tubes whereby each step of operation of the endless chain represents two of the impulses impressed on the trigger pair; and means coupling the tubes of the endless chain of tubes and the two trigger connected tubes in a resistance network so that the state of conduction of one tube of the endless chain and of one or the other of the trigger tubes causes a sensible change in potential at one or the other of associated points in the resistance network.

11. In combination, means for converting introduced sine wave electric potential impulses into negative electric potential impulses; two high-vacuum electron tubes arranged in a trigger circuit so that but one tube of the two may be conductive at any one time and whose mode of operation may be changed by each of the negative impulses produced by the converting means; a high-vacuum electron tube relay caused to conduct each time the tubes of the trigger circuit changes to a particular mode of operation, the act of conduction of said last-named tube causing a negative electrical potential impulse in an output circuit, each of said last-named impulses representing two of the impulses from the sine wave source; a plurality of vacuum electron tubes arranged in a circuit for operation in endless chain sequence one at a time, and caused to operate step by step in response to each of received negative electric potential impulses; means to impress the relay produced negative impulses on said tubes whereby each step of operation of the endless chain represents two of the introduced sine wave impulses; and means to couple the tubes of the endless chain of tubes and the two trigger connected tubes in a resistance network whereby the state of conduction of one tube of the endless chain and of one or the other of the trigger tubes cause a sensible change in potential in one or the other of two associated points in the network.

12. In combination, a plurality of high-vacuum electron tubes connected in an endless operative chain wherein they are rendered conductive one at a time in sequence in response to each of commonly-received electric impulses; an electric impulse dividing means including two electron tubes which are rendered conductive in alternate succession and either of which electron tubes may be conductive at the same time any one of the high-vacuum electron tubes is conductive; two electric terminals associated with each of the high-vacuum tubes, one of said terminals being associated with a high-vacuum tube and one of the foregoing two electron tubes and the other terminal being associated with the high-vacuum tube and the other of said two electron tubes; means connecting said terminals to said associated tubes, said means including resistances in said connections so that the potential of a terminal will change when the associated tubes change their state of conduction; and means automatically exploring the terminals for one whose potential is

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determined by the conducting condition of the two tubes associated therewith.

13. In combination, a plurality of high-vacuum electron tubes connected in an endless operative chain wherein they are rendered conductive one at a time in sequence in response to commonly-received electric impulses; an electric impulse dividing means including two electron tubes which are rendered conductive in alternate succession by received electric impulses and either of which electron tubes may be conductive at the same time any one of the high-vacuum electron tubes is conductive; two electric terminals associated with each of the high-vacuum tubes, one of said terminals being associated with a high-vacuum tube and one of the aforesaid two electron tubes and the other terminal being associated with the high-vacuum tube and the other of said two electron tubes; means connecting said terminals to their associated tubes so that the potential of a terminal will indicate whether both the associated tubes are conducting or not; means automatically exploring the terminals for one potentially affected by conduction in both its associated tubes; and means to stop the exploring when the terminal is sensed that has a potential indicating the condition of conduction of both the associated tubes.

14. In combination, a plurality of high-vacuum electron tubes each having an anode, a cathode, and a control grid; means to supply cathode potential to the tubes; means including a symmetrical mesh of resistors for supplying anode potential to the tubes, said anodes being connected symmetrically therethrough to the source of potential forming an endless operative sequence; means for biasing the grids of the tubes with a potential tending to prevent conduction through said tubes, said biasing means including connections of the grids to symmetrical points in the mesh of resistors so that if a tube of the plurality is conducting the grids of the other tubes will be given a negative potential that prevents conduction in the associated tube, those two tubes immediately adjacent to the conducting tube as regards their anode connections to the resistor mesh being given less negative potential than the grids of the other non-conducting tubes; means coupling the anode of each tube to the grid of each of the adjacent two tubes of the sequence so that when conduction commences in a tube it causes a sharp negative potential impulse to be impressed upon the grid of one of the adjacent tubes and when conduction ceases in a tube it causes a sharp positive potential impulse on the grid of the other adjacent tube; and means to impress a negative potential impulse on the grids of all the tubes sufficient to stop conduction in any conducting tube thereby causing the adjacent tube whose grid receives the positive potential impulse to commence conduction and in turn by its commencing to conduct causing a negative potential impulse to be impressed on the grid of the tube that stopped conduction.

15. In combination, a plurality of high-vacuum electron tubes each having an anode, a cathode, and a control grid; means to supply cathode potential to the tubes; means including a symmetrical mesh of resistors for supplying anode potential to the tubes, said anodes being connected symmetrically therethrough to the source of potential, forming an endless operative chain of tubes; means for biasing the grids of the tubes with a potential tending to prevent conduction through said tubes, said biasing means including

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connections of the grids to symmetrical points in the mesh of resistors so that if a tube is conducting, the grids of the other tubes will be given a negative potential that prevents conduction in the associated tube, those two tubes immediately adjacent to the conducting tube as regards their anode connections to the resistor mesh being given less negative potential than the grids of the other non-conducting tubes; means coupling the anode of each tube to the grid of each of the adjacent two tubes of the sequence so that when conduction commences in a tube it causes a sharp negative potential impulse to be impressed upon the grid of one of the adjacent tubes and when conduction ceases in a tube it causes a sharp positive potential impulse to be impressed on the grid of the other adjacent tube; and means to impress a negative potential impulse on the grids of all the tubes sufficient to stop conduction in any conducting tube thereby causing the adjacent tube whose grid receives the positive potential impulse to commence conduction and in turn cause a negative potential impulse on the grid of the tube that stopped conduction; a high-vacuum electron amplifier tube having a resistance in its anode, which tube is caused to conduct at intervals; and means connecting the anode of the amplifier tube to the impressing means.

16. In combination, five high-vacuum electron tubes each having an anode, a cathode, and a control grid; means to supply cathode potential to the tubes; means connecting said five tubes in an endless operative chain series, said means including a symmetrical mesh of resistors for supplying anode potential to the tubes, said anodes being connected symmetrically therethrough to the source of potential and said means also including means for biasing the grids of the tubes with a potential tending to prevent conduction through the tubes by connection of the grids to symmetrically located points of the mesh of resistors and to a source of negative potential so that if a tube is conducting, the grids of the other tubes will be given a potential more negative than normal and those two tubes immediately adjacent in the chain to the conducting tubes as regards their anode connections to the resistor mesh will be given less additional negative potential than the grids of the other non-conducting tubes of the chain; means including couplings between the anode of each tube and the grids of each of the adjacent two tubes in the chain so that when conduction commences in a tube it causes a sharp negative potential impulse to be impressed on the grid of one of the adjacent tubes and when conduction ceases in a tube it causes a sharp positive potential impulse on the grid of the other of the adjacent tubes; means coupling the grids of all the tubes electrostatically to a common conductor; input terminals; means for causing a single negative potential impulse for each sine wave received on said terminals; two high-vacuum electron tubes arranged in a trigger circuit; means for impressing the negative impulses on the trigger circuit tubes so that each negative impulse received changes the mode of operation of the trigger circuit tubes; an amplifier electron tube having a control grid; means to overbias the control grid to normally prevent conduction in the amplifier tube; means connected with one of the trigger tubes so that when said trigger tube ceases conducting a sharp positive potential impulse is impressed on the grid of the overbiased amplifier tube, causing it to conduct temporarily; a resistance in the anode circuit of the anode conductor

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of the overbiased amplifier; and means connecting the anode of the overbiased amplifier to the electrostatic coupling means whereby the series of the five tubes is caused to take a step in the sequential operation on each two received sine wave impulses.

17. In combination, a plurality of electron tubes; circuits connecting the tubes so that they are operated one at a time in sequence in response to each of a plurality of potential impulses impressed thereon; means having two modes of operation to divide the number of introduced impulses by two, said means changing its mode of operation on each of introduced potential impulses; means to impress an impulse on said tubes when the divider assumes a certain one of its

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modes of operation so as to cause a step of sequential operation for each two impulses introduced into the divider; a plurality of sensing stations; and means including a resistance network coupling each of the tubes and the dividing means to an associated two of the sensing stations so that a particular one of the two sensing stations represents and has an electric potential determined by the conduction in a tube and one of the modes of operation of the dividing means and the other of the sensing stations represents and has an electric potential determined by the conduction in the said tube and the other mode of operation of the dividing means.

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