

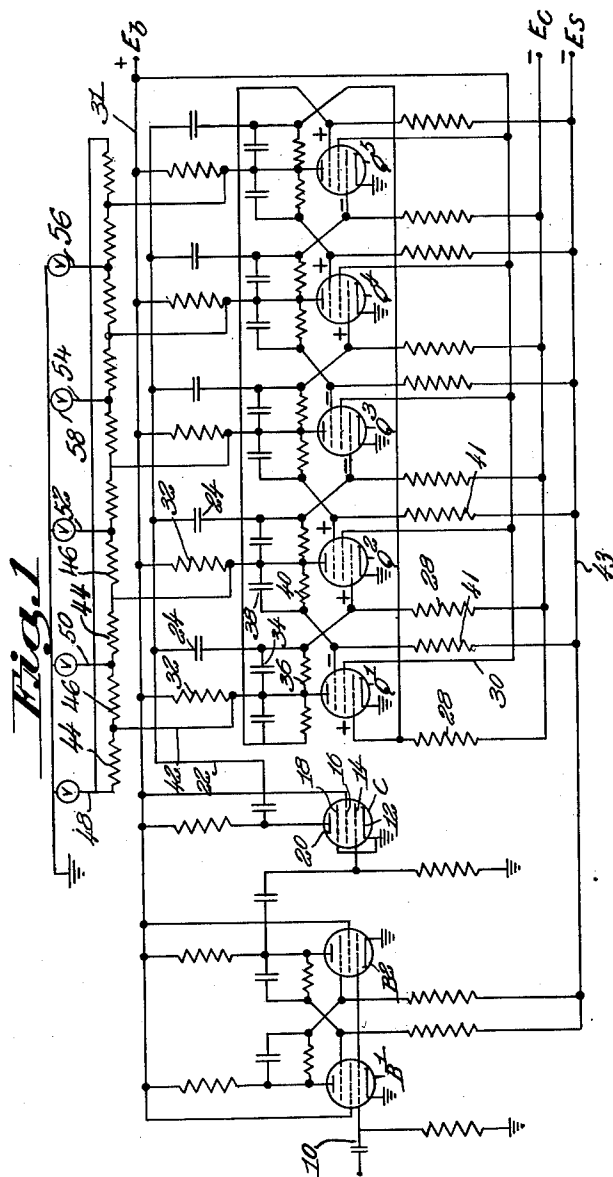
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W. P. OVERBECK
ELECTRONIC COUNTING SYSTEM

2,470,716

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2 Sheets-Sheet 1



Witness

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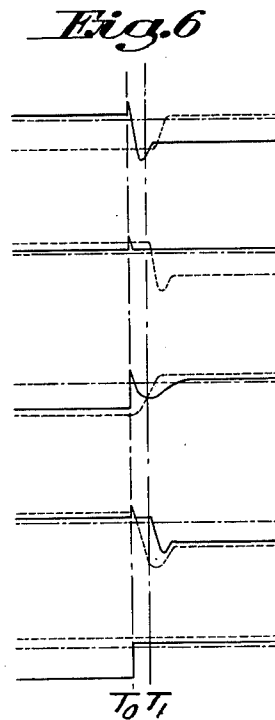
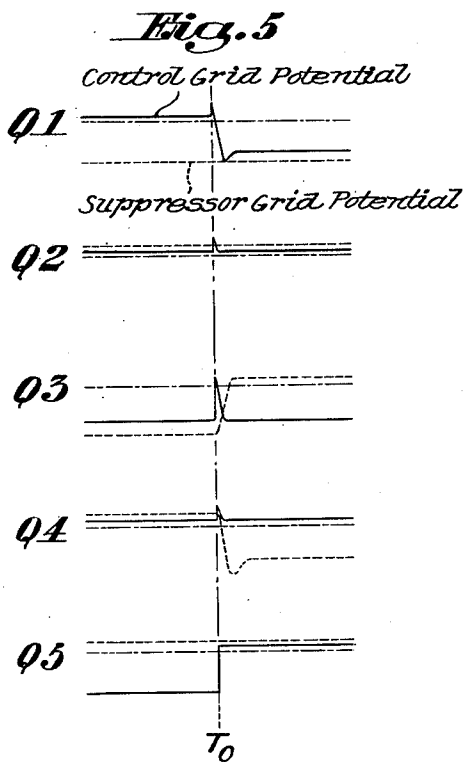
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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

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ELECTRONIC COUNTING SYSTEM

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10 Claims. (Cl. 235—92)

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The present invention relates to electronic counting systems, and more particularly to counting systems for operation at extremely high speeds.

Electronic counting systems in general involve the use of electronic trigger circuits, each of which is capable of assuming either of two conditions of stability. In the usual system, one condition of stability is satisfied when current flows to the anode and the second condition of stability when no current flows to the anode, these two conditions being respectively designated as "on" and "off" conditions. Although the trigger circuit forms the basis of the counting system, there are a number of different ways in which triggering action may be availed of to produce a counting action.

Counting systems, as heretofore constructed, may in general be classified in either one of two types, namely, the ring or chain system, and the binary or scale-of-two system.

The ring or chain system has in each stage a number of trigger circuits (ten for the decimal system) in which only one tube is in conducting condition. The circuits are so arranged that when an initiating pulse is applied to all of them, it causes the next tube beyond the conducting tube to be itself converted to the conducting condition, the previously conducting tube being then extinguished. In some systems, the selective action occurs by virtue of a priming arrangement, the circuits being so arranged that only a primed tube will be converted by the action of the initiating pulse. In any case, the extinction of the previously conducting tube follows the conversion of the next tube to the conducting condition, for which purpose a transfer pulse or its equivalent is generated by the conversion of the new tube. In most instances the time required for extinction of the previously conducting tube must be greater than the length of the initiating pulse. A limitation is, therefore, placed upon the rapidity of the initiating pulses, and this places a limit on the counting speed of the system.

It will be understood that for counting numbers larger than the number of tubes in the chain, additional stages will be used with appropriate carry-over devices. Since the carry-over stages necessarily operate at lower speeds than the initial stage, the speed limitation is usually significant for the initial stage only.

In the binary or scale-of-two system, the first stage comprises a single circuit, usually involving two tubes, one of which is in the conducting and the other in the non-conducting condition. An initiating pulse immediately converts the conducting tube to the non-conducting condition, and the non-conducting tube to the conducting condition. The entire action occurs within the duration of the initiating pulse. Hence, the

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speed limitation is much less severe than in the case of the counting ring. Additional stages may be used to count up to any desired number. The principal disadvantage of the binary system is in its awkward counting scale, and ultimate conversion to the decimal scale is necessary for practical reasons.

The principal object of the present invention is to provide a counting system in which the speed of operation is not limited by the necessity for successive triggering actions, and which, therefore, has the speed advantages of the binary system, but which may be operated in other number scales.

With this object in view, the present invention contemplates the use of a counting system involving an odd number of tubes and with a peculiar progression of triggering action, whereby the counting steps may be accomplished in a time not substantially greater than the duration of the initiating pulse. Since, as will hereinafter appear, this system requires an odd number of tubes, the counting may be accomplished in the scale of 3, 5, 7, 9, or any other odd number, although the distinctive characteristics of the system are most apparent when the scale is 5 or greater. In order to make use of the system for practical counting purposes, it is preferable to use a quintary system (scale-of-five), which may be used in combination with a binary system to obtain results in the decimal number system.

In the accompanying drawings, Fig. 1 is a diagram of the preferred form of system, and Figs. 2, 3, 4, 5 and 6 are diagrams illustrating the sequence of operations.

The system shown in Fig. 1 comprises an input circuit 10 of conventional form, leading to a binary counting circuit having the tubes B¹ and B². The output of the binary circuit is fed through a coupling tube C to the quintary circuit involving five tubes designated Q¹ to Q⁵. Each tube is preferably a pentode, having a cathode 12, a control grid 14, a screen grid 16, a suppressor grid 18 and an anode 20. Although the "control grid" and the "suppressor grid" are herein designated by the terms usually applied in the tube art, both grids are used as conduction-controlling electrodes, as will hereinafter appear.

For the present, only the quintary circuit will be described, since this is capable of being operated by impulses from any input circuit. The input to the quintary system comprises a line 22 connected by independent condensers 24 to the control grids of the several pentodes. The several control grids are connected through independent resistors 28 to a source of negative bias potential E_c. The several screen grids are connected by direct connections 30 to a source of positive potential E_b. The potential E_b is also applied to the anodes of the several tubes through

a connection 31 and independent resistors 32. Each anode is connected through a parallel condenser 34 and resistor 36 with the control grid of the next succeeding tube and through a parallel condenser 38 and resistor 40 with the suppressor grid of the next preceding tube. The suppressor grids are connected through resistors 41 with a line 43 connected with a source of negative biasing potential E_s . It will be noted that the same connections are made between tubes Q^1 and Q^5 whereby a ring or closed chain of five tubes is formed.

As will presently appear, the circuit will lock into any one of five stable conditions in which the anode circuits of two non-adjacent tubes are conducting and the anode circuits of the other three tubes are non-conducting. A tube is capable of anode conduction only when both its control and suppressor grids are at positive potential.

In Fig. 1 certain grid potentials are indicated, these being such as to show tubes Q^2 and Q^4 in conducting condition, and the remaining tubes in non-conducting condition. Tube Q^1 has its control grid positive and its suppressor grid negative, tube Q^3 has both grids negative, and tube Q^5 has its control grid negative and suppressor grid positive. The conducting tubes Q^2 and Q^4 have both control and suppressor grids positive. The flow of current to the anode of tube Q^2 through its anode resistor 32 holds its anode potential low and therefore maintains negative potentials on the suppressor grid of Q^1 and the control grid of Q^3 . Likewise, the suppressor grid of Q^3 and the control grid of Q^5 are held negative by anode conduction of tube Q^4 . Conversely, the control and suppressor grids of Q^2 and Q^4 are positive, because of the high anode potentials of tubes Q^1 , Q^3 and Q^5 , which are non-conducting.

The particular condition shown in Fig. 1 is diagrammatically illustrated in Fig. 2, wherein a dark circle represents an "off" or non-conducting tube and a light circle an "on" or conducting tube. Considering the tubes as existing in a ring or chain, it will be noted that between Q^2 and Q^4 there is a single "off" tube Q^3 , but between Q^4 and Q^2 there are two "off" tubes, Q^5 and Q^1 .

Thus Q^5 and Q^1 may be said to represent a double gap between two conducting tubes of the chain. This arrangement is entirely general, regardless of how many tubes there are in the chain, so long as the total number is odd. That is, the tubes will be alternately on and off with the exception of two adjacent off tubes at some point. The position of the two off tubes is determinative of the number of counted pulses.

With the tubes as shown in Fig. 2, assume that a positive pulse is applied over the input line 22. Two possible modes of operation may now be followed, depending on the values of the voltages applied to the several electrodes of the tubes. The simplest mode of operation, which will now be described, results in a peculiar stepping sequence, whereby the first tube of the "double gap" becomes conducting. Thus on the first pulse, Q^4 goes off and Q^5 goes on, so that the double gap is now at Q^3 and Q^1 , as shown in Fig. 3. The next pulse turns Q^2 off and Q^3 on (Fig. 4). This sequence continues until after five pulses, the original condition of Fig. 2 is restored. This sequence occurs when the normal potentials on the control and suppressor grids are fairly high.

The foregoing operations are illustrated by the graphs of Fig. 5, showing in solid lines the

control grid potentials and in dotted lines the suppressor grid potentials for each of the five tubes. These potentials are illustrated for the condition of Fig. 1 up to a time T_0 . At T_0 a positive initiating pulse is assumed to be applied to the tubes, leading to the condition illustrated at the right hand side of each graph. Prior to T_0 , in Q^1 the suppressor grid is at its full negative bias potential, but its control grid is slightly positive because the anode potential of Q^5 is high. (It will be understood that because of grid conduction, the positive potential on any grid never rises above a small value.) In Q^2 , both grids are slightly positive, because the tube on each side has a high anode potential. For Q^3 both grids are negative because the tube is included between two conducting tubes for which the anode potential is low. Q^4 is the same as Q^2 , and for Q^5 the control grid is negative but the suppressor grid is slightly positive. A pulse applied at time T_0 has no effect on Q^2 except momentarily to increase the potential on the control grid by a slight amount. The pulse, however, raises the potential on the control grid of Q^5 from a negative to a slightly positive value, thereby causing Q^5 to become conducting, with the immediate consequence of causing the control grid of Q^1 to become negative and the suppressor grid of Q^4 to become negative. For Q^3 the pulse causes the control grid to become momentarily positive, but since Q^2 is conducting, this positive potential for Q^3 cannot be maintained. The suppressor grid of Q^3 becomes positive by virtue of the extinction of Q^4 . In an extremely short time Q^4 assumes the condition previously held by Q^1 , Q^5 assumes the condition previously held by Q^2 . Each tube assumes the condition formerly assumed by the second tube to the right, the shift being indicated by the following diagram:

1→3
2→4
3→5
4→1
5→2

The visible result is simply that conduction has been transferred from Q^4 to Q^5 , so that the double gap now occurs at Q^3 and Q^1 , as illustrated in Fig. 3.

The next pulse gives a similar stepping action, turning Q^2 off and Q^3 on, as shown in Fig. 4. A complete schedule of sequences, starting from the condition of Fig. 2, is as follows:

Number of pulses received	Tubes in conduction
0	2, 4
1	2, 5
2	3, 5
3	1, 3
4	1, 4
5	2, 4

In the second mode of operation, the negative bias potentials applied to the screen and suppressor grids are somewhat lower than the potentials that are applied in the first system described above. This results in a somewhat different sequence of operations, in that an incoming pulse results in both conducting tubes being turned off and the tubes adjacent thereto being turned on. Thus, from the condition of Fig. 2, an incoming pulse will turn off tubes Q^2

and Q^4 and ignite tubes Q^3 and Q^5 , leaving Q^1 unignited.

Fig. 6 is a grid potential diagram for this second mode of operation. The grid potentials prior to T_0 correspond to the condition shown in Fig. 2. A pulse is received at T_0 . A short time thereafter, at T_1 , the conditions are momentarily similar to those shown in the right-hand part of Fig. 5. In the tube Q^3 , however, the applied negative potential E_c is not sufficient to swing the control grid to the full negative potential illustrated by Fig. 5. Since the tube is obliged to assume a condition of stability, if the grid cannot go negative to the full extent, it must swing back to the positive condition, as illustrated by the diagram after the time T_1 . The tube Q^3 then becomes conducting and necessarily affects the operation of the two adjacent tubes Q^2 and Q^4 .

Ultimately, the system must reach a condition in which the potentials on the grids of the several tubes are compatible with maintenance of stability. This condition is as illustrated in the right-hand part of Fig. 6.

In Fig. 6, the operation of the tube Q^3 in swinging its control grid back to the positive potential produces a result exactly like the application of another pulse in Fig. 5. A single initiating pulse results in shifting from the condition of Fig. 2 to that of Fig. 4. A diagram illustrating the progression for a single pulse is as follows:

1→3→5
2→4→1
3→5→2
4→1→3
5→2→4

meaning that tube Q^1 momentarily assumes the condition formerly held by Q^3 and then assumes the stable condition formerly held by Q^5 .

It will be observed from Fig. 6 that the time required for operation in the second method is slightly greater than that required for the first method. Since the second method operates like two steps of the first method, its counting speed is in general reduced by about one-half. This reduction in counting speed is, however, balanced by the fact that the system, when set for operation under the conditions of Fig. 6, is somewhat more reliable, in that it will operate in the designated manner for wider variations of electrode potentials. The system indicated by Fig. 5, while somewhat more rapid, requires that the screen and suppressor grid potentials be held within fairly close limits.

A schedule of operations for the second method, starting with the condition of Fig. 2, is as follows:

Number of pulses received	Tubes in conduction
0	2, 4
1	3, 5
2	1, 4
3	2, 5
4	1, 3
5	2, 4

It will be noted that after five pulses the original condition is restored, but the intermediate steps are different from the method of operation illustrated by Fig. 5. As in the first method, there is always a "double gap" formed by two non-conducting tubes. The visible result of applying a

pulse is simply to advance the double gap by one step.

Although a quintary system has been shown, it will be understood that it may be applied to any odd number of tubes. It is not applicable to an even number of tubes, since such a system would not provide a double gap; alternate tubes would be off and on, and the same results would be obtained as in a conventional binary system.

The use of five tubes (quintary operation) is preferred, because it permits combination with a binary system to count in the scale of ten. The binary system represented by tubes B^1 and B^2 and their accompanying connections is entirely conventional. In one stable condition, B^1 is on and B^2 is off. The action of a pulse applied at the input 10 is to turn B^1 off and B^2 on. When B^2 goes on, as it will for every alternate pulse, it transmits a negative pulse to the control grid of the coupling tube C, thus turning C off and transmitting a positive pulse to the input circuit 20 leading to the control grids of the tubes of the quintary circuit. The next pulse at 10 turns B^1 on and B^2 off. When B^2 is turned off, a positive pulse is fed to the control grid of C but, since that grid is at cathode potential and C is already fully conducting, no appreciable effect is observed at the anode of C and no pulse is transmitted to the quintary section. Thus, each incoming pulse applied to the circuit 10 operates the binary system in the usual manner, and every second pulse causes the transmission of an activating pulse to the quintary circuit. The number of pulses may be counted by observing the conducting tubes in both the binary and quintary circuits.

A feature of importance is that the pulses for operating the quintary circuit result only from the binary circuit and the coupling tube and do not depend in any way on the initiating impulses applied to the input circuit 10. Therefore, the operations in the quintary circuit may continue beyond the duration of the pulses applied to the binary circuit. This is important in considering the second mode of operation of the quintary circuit which, as heretofore stated, is somewhat slower than the first method. Since the quintary circuit is actuated only on every alternate pulse, and since the initiating pulses do not get through to the quintary circuit, this reduction in speed imposes no significant speed limitation on the inherent high speed operation of the binary circuit.

Suitable indicating means may be used to indicate the number of pulses. A simple form of indicating circuit is shown in Fig. 1. A connection 42 is run from the lower end of each anode resistor 32 to the junction point of two resistors 44, 46. There are two such resistors bridged between each two adjacent anodes. All ten of the resistors are connected in series in a closed ring. Indicator leads 48, 50, 52, 54 and 56 are taken off at the left-hand ends of the resistors 44.

As previously described, there are two adjacent "off" tubes in the quintary chain, for example, Q^5 and Q^1 in Fig. 1. The potential of lead 48 is therefore the full anode potential E_b . The other three tubes Q^2 , Q^3 and Q^4 are alternately on and off, so that their anodes are alternately at low and high potentials. Consequently, leads 50, 52, 54 and 56 are at the average of the high and low potentials. In any case, the lead which is at high potential indicates the position of the "double gap." Any suitable means may be used to give a visible indication of the single lead that is at the high potential, here illustrated as in-

dividual voltmeters 58. If desired, neon lamps may be used which, because of the fact that they become conducting only under potentials greater than the ignition potential, will indicate only the high potential lead.

The indicating circuits above described are applied only to the quintary system. For the complete binary-quintary system, high potential on the n th lead shows that $2n$ or $2n+1$ pulses have been counted, the exact number being determined by reference to the condition of the binary tubes. A suitable carry-over device leading to a subsequent circuit may be operated upon the raising of the fifth indicating lead to the high potential.

In summarizing the foregoing description, it will be observed that the quintary section, which forms the principal feature of the invention, is composed of five elemental trigger circuits, each of which is capable of assuming either of two conditions of stability. The condition assumed by any of the elemental circuits, however, is not independent of the other circuits in the system, but is dictated by the potential relations existing in the system as a whole. Upon the application of an initiating pulse the potential relations are upset simultaneously in the entire system. Thus the entire quintary section may be viewed as a single trigger circuit having five conditions of stability (or more generally, as many conditions of stability as there are elemental tube circuits). It is this fact which makes for exceptionally high-speed operation, since all elements of the system are converted immediately to the new conditions upon reception of a pulse, without the necessity of depending on a progressive action through the several tubes.

It will be understood that the particular embodiment herein shown is illustrative only and may be varied within the purview of the invention, as defined in the appended claims.

Having thus described my invention, I claim:

1. A counting system comprising an odd number, five or more, of trigger circuits each capable of assuming a conducting and a non-conducting condition of stability, conduction-controlling means for each circuit, connections between each circuit and the conduction-controlling means of adjacent circuits to establish different conditions of stability for alternate trigger circuits except for two adjacent circuits which are in the same condition of stability, and means responsive to an initiating pulse to affect the position of said adjacent circuits in relation to the other trigger circuits in the system.

2. A counting system comprising an odd number, five or more, of electronic trigger circuits, each capable of assuming a conducting and a non-conducting condition of stability, conduction-controlling means for each circuit, connections between each circuit and the conduction-controlling means of adjacent circuits to establish alternate conducting and non-conducting conditions in the several circuits except for two adjacent circuits which are in the non-conducting condition, and means responsive to an initiating pulse to shift the relation of adjacent non-conducting trigger circuits in the system.

3. A counting system comprising an odd number, five or more, of electronic trigger circuits, each having an anode and capable of stable operation at high or low anode potential, conduction-controlling means for each trigger circuit, connections between the anode of each circuit and the conduction-controlling means of adjacent circuits to establish the high-anode-potential

condition in any circuit adjacent to a circuit in which the condition of low anode potential exists, whereby two adjacent anodes in the system are at high potential, means for applying an input pulse to the several trigger circuits, and means responsive to said pulse to shift the condition of adjacent high anode potentials to other anodes in the system.

4. A counting system comprising an odd number, five or more, of electronic trigger circuits, each having a tube with an anode and conduction-controlling means, each circuit being capable of assuming either a stable conducting condition or a stable non-conducting condition, connections between the anode of each tube and the conduction-controlling means of adjacent tubes to establish the conducting condition only in each of those trigger circuits which are included between two circuits in the non-conducting condition, whereby the system at any time has two adjacent tubes in the non-conducting condition and the remaining tubes alternately in conducting and non-conducting condition, means for applying an input pulse to the several trigger circuits, and means responsive to said pulse for shifting the condition of adjacent non-conducting tubes in the system.

5. A counting system comprising an odd number, five or more, of electronic trigger circuits, each having an anode, a control grid and a suppressor grid, each circuit being capable of stable operation at high or low anode potential, connections from the anode of each circuit to the control grid of one adjacent circuit and to the suppressor grid of the other adjacent circuit, said connections establishing the condition of high anode potential in two circuits adjacent to circuits at low anode potential, the remaining circuits being alternately at high and low anode potential, means for applying an input pulse to the several circuits, and means responsive to said pulse for shifting the relation of stability conditions in the circuits in the system.

6. A counting system comprising an odd number, five or more, of electronic trigger circuits, each having an anode, a control grid and a suppressor grid, each circuit being capable of stable operation at high or low anode potential, connections from the anode of each circuit to the control grid of one adjacent circuit and to the suppressor grid of the other adjacent circuit, an anode being capable of assuming the low-potential condition only when its control grid and suppressor grid are both at positive potentials, whereby the circuits are alternately at high and low anode potential except for two adjacent circuits which are at high anode potential, means for applying an input pulse to the several circuits, and means responsive to said pulse for shifting the stability conditions in the circuits of the system.

7. An electronic counting system comprising an odd number, five or more, of elemental circuits, each including an anode and two conduction-controlling electrodes, each circuit being capable of assuming two conditions of stability, namely, a condition in which the anode is conducting when both of its conduction-controlling electrodes are positive, and a condition in which the anode is non-conducting when either of its conduction-controlling electrodes is negative, connections from each anode to one conduction-controlling electrode of one adjacent circuit and to the other conduction-controlling electrode of the other adjacent circuit, a source of positive

potential for the anodes, sources of negative potential for the conduction-controlling electrodes, whereby the anodes are alternately conducting and non-conducting, except for two adjacent anodes which are non-conducting, and resistor means between said potential sources and the corresponding electrodes, an input circuit connected with corresponding conduction-controlling electrodes of the several circuits.

8. An electronic counting system comprising an odd number of elemental circuits in a closed chain, each including an anode and two conduction-controlling electrodes, each circuit being capable of assuming two conditions of stability, namely, a condition in which the anode is conducting and at low potential when both of its conduction-controlling electrodes are positive, and a condition in which the anode is non-conducting and at high potential when either of its conduction-controlling electrodes is negative, connections from each anode to one conduction-controlling electrode of one adjacent circuit and to the other conduction-controlling electrode of the other adjacent circuit to establish the high-anode-potential condition in any circuit adjacent to a circuit in which the condition of low-anode-potential exists, whereby two adjacent anodes in the system are at high potential, a source of positive potential for the anodes, sources of negative potential for the conduction-controlling electrodes, resistor means between said potential sources and the corresponding electrodes, an input circuit connected with corresponding conduction-controlling electrodes of the several circuits, a bridge connection between each two adjacent anodes, and indicator means connected at an intermediate point of each bridge circuit to indicate the position of the two adjacent anodes which are in the high-potential condition.

9. An electronic counting system comprising an odd number of electronic tubes ($n+1$, where n is an even number greater than two), each of said tubes having an anode, a cathode, and two control electrodes, connections from each of said anodes to control electrodes of two other tubes of the group, said connections providing the sys-

tem with $n+1$ stable conditions, in each of which

$$\frac{n}{2}$$

tubes are conducting and

$$\frac{n}{2}+1$$

tubes are non-conducting, and input means for applying pulses to said control electrodes to cause the system to shift from one of said stable conditions to another.

10. A counting system comprising an odd number, five or more, of electronic trigger circuits, each having an anode and capable of stable operation at high or low anode potential, conduction-controlling means for each trigger circuit, connections between the anode of each circuit and the conduction-controlling means of adjacent circuits to establish the low-anode-potential condition only in each of those circuits which are included between two circuits in high-anode-potential condition, whereby two adjacent anodes in the system are at high potential, means for applying an input pulse to the several trigger circuits, and means responsive to said pulse to shift the condition of adjacent high anode potentials to other anodes in the system.

WILCOX P. OVERBECK.

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