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ELECTRONIC COMMUTATOR

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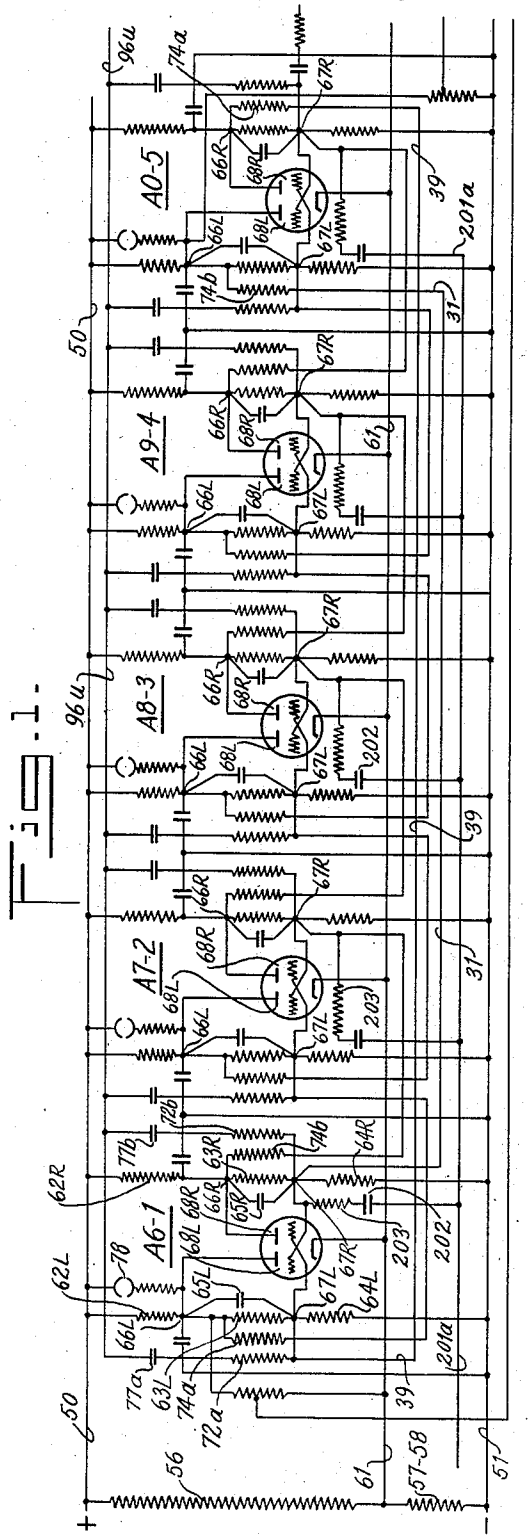


Fig. 1.

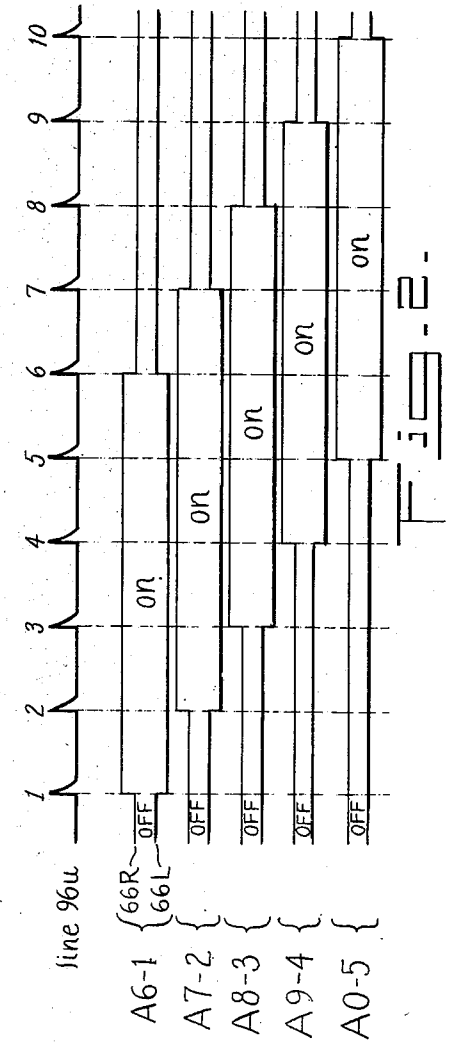


Fig. 2.

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ELECTRONIC COMMUTATOR

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13 Claims. (Cl. 250—27)

1

This application is a division of my application Serial No. 515,719, filed December 27, 1943, for Electronic Accounting Apparatus.

The present invention involves a novel electronic commutator used in said electronic accounting apparatus and having general utility as a distributor of potential. This electronic commutator presents improvements over the electronic commutators of my prior application Serial No. 394,884, filed May 23, 1941, as well as over other electronic commutators in the prior art.

The electronic commutator comprises a plurality of interconnected electronic triggers. Each trigger is composed of a circuit which includes a trigger pair of electron units or tubes which are cross-tied, anode of each to a control electrode of the other, to produce either one relation of opposite conductive conditions of the trigger pair of tubes or a reverse such relation, whereby the trigger has two, alternative states determined by the two different relations in conductivity of the trigger pair of tubes. Tripping of the trigger from one of its states to the other is effected by changing the relative conductivity of the trigger pair of tubes.

The present invention is featured by a novel method and means for effecting the change in relative conductivity of the trigger pair of tubes.

According to the invention, the triggers in the commutator are coupled in a novel series chain fashion.

More specifically, the invention provides a novel pattern of connections, from trigger to trigger, which consists of separate connections from the anodes of both tubes of a trigger pair to control electrodes of the two tubes in another trigger pair. By means of this pattern of connections, each trigger pair of tubes depending on its relative condition of conductivity primes or influences a next trigger pair of tubes for either a change in one direction or in an opposite direction of the relative condition of conductivity of the influenced trigger pair.

One state of the trigger may be named, for convenience, an off state and the alternative state may then be called the on state. Using these terms, the invention provides such a pattern of priming connections from anodes of one trigger pair of tubes to control electrodes of a next trigger pair of tubes that when one trigger is in one state it primes the trigger pair of tubes of the next trigger, if this trigger is off, towards reversal of this next trigger to on state; but if the priming trigger is in its alternative state then it primes

2

the trigger pair of tubes in the next trigger, if this trigger is on, towards reversal of this next trigger to off state. This next trigger similarly primes the trigger pair of tubes in a following trigger, and so on.

According to the invention, a closed ring of such priming pattern of connections is provided by which a chosen last trigger of the commutator when in off state primes the cross-tied, trigger pair of tubes of the first trigger for reversal from off to on state, the first trigger thereupon similarly primes the second trigger for reversal from off to on state and so on till the last trigger is reversed to on state, the last trigger thereupon priming the trigger pair of tubes in the first trigger for reversal from on to off state, the first trigger then similarly priming the second tube for reversal to off state, and so on. In this manner, the triggers are sequentially primed and turned to on state and then sequentially primed and turned back to off state, in repetitive fashion. According to the invention, driving pulses for effecting the actual reversals of the triggers when primed are simultaneously applied to control electrodes of all the tubes tied into trigger pairs. Each such driving pulse is effective in conjunction with the priming potential applied to one trigger pair of tubes at a time, in the sequential priming pattern, for changing the relative condition of conductivity of the primed pair of tubes and thereby effecting the reversal in state of the trigger containing this primed pair of tubes.

Other objects of the invention will be pointed out in the following description and claims and illustrated in the accompanying drawings, which disclose, by way of example, the principle of the invention and the best mode, which has been contemplated of applying that principle.

In the drawings:

Fig. 1 shows the commutator circuit.

Fig. 2 is a chart of voltage conditions at anode points of the trigger pairs of tubes during a commutator cycle.

The illustrated device has five stages each comprising an electronic trigger circuit which may simply be called a trigger. The first stage or trigger is designated A6—1, the second A7—2, the third A8—3, the fourth A9—4, and the fifth A0—5. The triggers are across + line 50 and — line 51 which are supplied with suitable D. C. voltage. Across lines 50 and 51 is a voltage divider comprised of resistors 56 and 57—58, the junction of these resistors being tapped by the cathode voltage line 61.

Each trigger comprises two impedance networks which may be referred to as left and right hand sides, portions, or branches of the trigger. The branches are symmetrical and corresponding elements thereof will be given the same reference number; those of the left hand branch may be distinguished by appended letter L and those of the right hand branch by letter R. Each branch comprises resistors 62, 63, and 64, a vacuum tube 68, and a condenser 65 shunting resistor 63. The anode of each tube is connected to line 59 by the resistor 62 of the same branch. The grid of the tube in one branch is connected to the point 67 of the opposite branch. The two tubes 68L and 68R which are the trigger pair, are shown as a twin triode, and their common cathode connects to line 61. It is understood that, if desired, the tubes may be in separate envelopes, each tube with its own cathode to be connected to line 61. Each tube is so chosen as to be conductive when its grid is substantially at cathode voltage; that is when the grid bias is substantially zero. The values of the elements are so chosen that when one of the tubes is at cutoff, the grid bias of the opposite tube will be substantially zero and the latter tube will be conductive; i. e., at low impedance. An efficient value relationship is one in which resistors 62 and 64 are equal in value, resistors 63 are approximately three times this value, and condensers 65 have a capacity of the order of a few hundred micromicrofarads. A tube may be referred to as on when it is conducting current, and as off when it is at cut-off. Each branch may be referred to as on or off according to whether its tube is on or off. For convenience, the trigger circuit unit will be considered as on or off in accordance with the on or off status of the left hand branch.

In further explanation, assume tube 68L is on. Accordingly, its impedance is low and the potential at anode-connected point 66L is then only slightly above cathode potential. The accompanying potential drop across resistors 63L and 64L forces the potential at point 67L below that of cathode line 61. Since the grid of tube 68R is connected to point 67L, the grid will at this time be biased sufficiently negative to maintain tube 68R off. The tube 68R, being off, its impedance is high and the potential at anode-connected point 66R is also high. The accompanying potential drop across resistors 63R and 64L does not force the potential at point 67R below cathode potential. Since the grid of tube 68L is connected to point 67R, the potential then existing at this point is sufficient to hold the grid at zero bias, so that tube 68L will be maintained conductive. In this manner, tube 68L when on maintains the 68R off and, conversely, tube 68R in off status maintains tube 68L in on status. The tubes in this relative status establish one state of stability of the trigger circuit unit; namely, the on state. In the reverse state of stability; that is, in the off state of the circuit, tube 68R will be on and tube 68L will be off. Also, the voltage values at the corresponding points of the two branches will be reversed and the interconnections between the branches will maintain the circuit in off state.

The trigger may be reversed from off state, in which tube 68L is at cut-off and tube 68R is conductive, by impressing positive potential on point 67R of sufficient amplitude to raise the grid potential of tube 68L above cut-off value. Tube 68L starts to conduct current from line 59 through resistor 62L and the tube to line 61. The potential at point 66L drops rapidly, feeding a negative pulse through condenser 65L to point 67L. Thereupon, the potential at the point 67L and, hence, the grid potential of tube 68R decreases suddenly to cut-off value and current flow in 68R ceases substantially instantaneously. Point 66R has an accompanying rapid rise in potential, and the resulting positive pulse is fed by condenser 65R to point 67R, promoting the increase in grid potential of tube 68L which was initiated by the application of positive potential to point 67R. Tube 68L is now conducting and tube 68R is off, the reverse of the previous status of the tubes. In this manner, adequate positive potential applied to point 67R has tripped the trigger from off state to on state. To trip the trigger back from on to off state adequate positive potential may be applied to point 67L. The grid of tube 68R thereupon is increased in potential to start current flow through this tube. In a manner now clear, the shift in status will continue until tube 68R is again conductive and tube 68L is again off; i. e., the trigger has been switched back, by positive potential applied to point 67L from on to off state.

A glow lamp 78 is connected, in series with a current limiting resistor, between line 59 and point 66L. When the trigger is off, point 66L is at high potential, and the difference of potential across the lamp is insufficient to ignite the lamp. When the trigger is on, point 66L is at low potential and there is enough difference in potential across the lamp to ignite it, thereby visually indicating the on status of the trigger.

Instead of reversing the trigger by applying positive potential to the grid of its non-conducting tube, the same effect can be obtained by applying negative potential to the grid of the conducting tube. When positive potential of sufficient amplitude is applied to the grid of the non-conducting tube, a regenerative action in the trigger is initiated for cutting off the conducting tube. When negative potential of sufficient amplitude is applied to the conducting tube of a trigger, a regenerative action is initiated for raising the grid potential of the non-conducting tube above cut-off. In the present embodiment, positive potential of adequate amplitude will be applied sequentially to the successive triggers in the commutator for effecting sequential reversals of the triggers. For effecting a concurrent reversal of the triggers to off or reset status, a negative pulse of adequate potential will be applied simultaneously to the grids of all the tubes 68L of the triggers.

According to the invention, the application of positive tripping potential to a grid of a tube in each trigger will take place in two steps. The first step is to produce a preparatory or priming rise in grid potential of the non-conducting tube of a trigger pair. This priming rise will be produced by a preceding trigger in the ring of triggers forming the commutator. The priming rise of itself will be inadequate to increase the grid potential above cut-off and the trigger will be unreversed. The second step is to apply a positive pulse to the grid. Of itself, the positive pulse will have insufficient amplitude to raise the grid potential of a non-conducting tube above cut-off. Only when the pulse is applied on top of the priming rise will the grid be driven above cut-off. In other words, the priming rise on the grid of a non-conducting tube combined with or supplemented by the additive effect of the positive

pulse on this grid will provide adequate positive potential to drive the grid above cut-off, causing the tube to conduct and the trigger to reverse.

The positive pulses are applied to a common input line 96*u* of the commutator. As will be brought out, each pulse is fed simultaneously to the grids of all the tubes of the trigger pairs. The pattern of priming connections is such that priming potential will be applied to the grid of only one non-conducting tube at a time of all the triggers in the commutator. Hence, each pulse although fed simultaneously to the grids of all the tubes will be effective to raise only the primed grid above cut-off potential, causing its tube to conduct and the trigger containing this tube to reverse. By this means, the triggers may be sequentially primed and reversed even though input pulses are each simultaneously applied to the grids of all the tubes in all the triggers.

The commutator circuit will now be described in detail.

The pattern of priming connections includes a resistive connection 74*a* between point 66L of the first trigger A6—1 and point 67L of the second trigger A7—2. Since point 66L is connected to the anode of tube 68L and point 67L is connected to the grid of tube 68R, the resistive connection 74*a* is between the anode of tube 68L of the first trigger and the grid of tube 68R of the second trigger. A similar connection is provided from the anode of 68L of the second trigger to the grid of 68R of the third trigger A8—3, between the anode of 66L of the third trigger and the grid of 68R of the fourth trigger A9—4, and between the anode of 68L of the fourth trigger and the grid of 68R of the fifth or last trigger A0—5. The point 66L and, hence, the anode of tube 68L, of the last trigger is connected by a resistor 74*b* and wire 31 to the point 67R and, hence, the control grid of tube 68L, of the first trigger A6—1. In short, the successive triggers are connected, anode of each left hand tube 68L to grid of each right hand tube 68R, but the anode of the left hand tube 68L of the last trigger in the series is connected to the grid of the left hand tube 68L in the first trigger.

The point 66R and, hence, the anode of 68R, of the first trigger is connected by a resistor 74*b* to the point 67R and, hence the grid of 68L, of the second trigger. A similar connection is provided between points 66R and 67R of the second and third triggers, third and fourth triggers, and fourth and last triggers. The point 66R of the last trigger, however, is connected by a resistor 74*a* and line 39 to the point 67L of the first trigger. Thus, the anode of the right hand tube of each trigger except the last is connected to the grid of left hand tube of the next trigger, but the anode of the right hand tube of the last trigger is connected to the grid of the right hand tube of the first trigger.

The point 66L or 66R of a trigger is at high potential depending on whether the trigger is off or on, respectively. By reason of the described pattern of connections between triggers, the high potential at a point 66L or 66R of each trigger will be transmitted to a grid of a tube in the next trigger in the ring of triggers and will provide the priming potential for this grid. If the grid is in a non-conducting tube, then the applied priming potential added to the effect of an input pulse received by the grid from wire 96*u* will render the tube conductive, but if the grid is in an already conducting tube, it will experience no change from the combined effect of the priming and pulse potentials applied to the grid.

The input pulses on line 96*u* are each simultaneously applied to points 67L and 67R via parallel condenser-resistor connections 77*a*—72*a* and 77*b*—72*b*.

Assume all the triggers are off, so that all the points 67L are at high potential. Accordingly, each of the triggers, except the last trigger A0—5, is applying priming potential to the grid of the already conducting tube in the next trigger, but the last trigger A0—5 is priming the grid of the non-conducting tube 68L in the first trigger A6—1. Hence, the first following pulse, although simultaneously applied to all the grids, takes effect only on the primed grid of tube 68L in the first trigger A6—1, causing this primed grid to rise above cut-off potential, whereupon tube 68L becomes conductive and trigger A6—1 reverses from off to on state (see Fig. 2). The first pulse has thus turned on only A6—1. When A6—1 is in on state, its point 66R is at increased potential and its point 66L at reduced potential. Hence, priming potential is removed from point 67L of A7—2 and is applied now to point 67R of A7—2. The second pulse on wire 96*u* therefore will turn on A7—2. The pulse will have no effect on the other units. For instance, unit A6—1 is still primed at point 67R so that the pulse can be effective only to turn on this unit, a status which it already has. Units A6—1 and A7—2 are now on and the remaining units off. It will be clear now that a third pulse will turn on A8—3, a fourth pulse will turn on A9—4, and a fifth pulse will turn on A0—5. With A0—5 on, its point 66R is at increased potential and applying priming potential to point 67L of A6—1. Hence, the sixth pulse will turn off A6—1. With A6—1 off, it is priming point 67L of A7—2. Accordingly, the seventh pulse will turn off A7—2. Similarly, the eighth and ninth pulses will turn off A8—3 and A9—4 successively. The tenth pulse will turn off A0—5. This completes a commutator cycle, all the triggers having returned to their initial off state.

While each pulse is impressed on the grids of all the triggers simultaneously, each pulse can reverse only a single trigger. Thus with A6—1 primed at its point 67R, the first pulse initiates the tripping of this trigger to on status. Point 66R of A6—1 rises in potential exponentially, with an attendant exponential rise in potential of point 67R of A7—2. As the potential on point 67R of A7—2 is rising, the first pulse is receding. By the time point 67R of A7—2 has attained effective priming potential, the first pulse has declined in power and has ceased to exist, for practical purposes. Thus, this pulse will be unable to turn on A7—2. Similarly, each of the successive pulses will turn on only one trigger and will become powerless before the trigger being turned effectively primes the next trigger. Hence, each pulse may trip only one trigger, i. e., the trigger which was primed just before the pulse appeared.

The foregoing has described the step by step operation of a commutator by successive pulses. The stepping operation always begins with the trigger following the one last turned. The number of steps of operation equals the number of applied pulses. A series of ten pulses returns the series of five triggers to the status which they had before the first of the series of ten pulses were applied. This is the case whether the triggers initially are all in off status or in

any other of the described relative states within the commutator sequence. With regard to the branches of the triggers, they will be turned successively to the same status, each as it turns to this state bringing about an accompanying change in its companion branch to the opposite state. Thus, if the triggers are all off initially, the pulses thereafter applied turn on the left hand branches of the triggers successively and then turn on the right hand branches successively. Of the ten branches, a group of only five is in the same state at any one time. Successive steps of operation advance this state from one group of branches to another such group. Stated otherwise, the branches are so interrelated and operated that a group of corresponding states progresses along the chain of branches from one position to a next position upon successive steps of operation of the network of branches.

In a manner described in detail in my parent application Ser. No. 515,719, when it is desired to reset the commutator; i. e., to return all the triggers to off states, a negative pulse of adequate amplitude is applied to a wire **201***a*. Condensers **202** and resistors **203** couple wire **201***a* to the points **67**R of triggers A6—1 to A0—5. By this circuit arrangement, the negative pulse appearing on wire **201***a* is simultaneously applied to the right sides of all the triggers. Thus, any of said triggers which are on are now tripped off concurrently.

While there have been shown and described and pointed out the fundamental novel features of the invention as applied to a preferred embodiment, it will be understood that various omissions and substitutions and changes in the form and details of the device illustrated and in its operation may be made by those skilled in the art, without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. In combination, a plurality of electronic devices each of which devices includes an anode, a cathode, and a control electrode; means connecting the devices, anode to control electrode, to form trigger pairs; and means connecting the devices of different trigger pairs together in an endless chain operative series, said chain connections being from the anodes of both devices in a pair to the control electrodes of both devices in another pair.

2. In combination, a plurality of vacuum tubes, each having at least an anode, a cathode, and a control grid; means connecting the tubes in trigger pairs, with the anode of each tube of a pair connected to the control grid of the other tube of the pair; and means connecting the different pairs together in an endless chain operative sequence in which the anodes of the tubes of a trigger pair are connected to the control grids of the tubes of another trigger pair and can control the effect of the control grids to select the pairs for sequential operation.

3. In combination, a plurality of pairs of electronic devices, each device having an anode, a cathode, and means to control conduction between the anode and the cathode; means connecting the devices for sequential operation, including anode-to-control-means trigger connections between the devices of each pair and priming connections between the anodes of the devices of a pair and the control means of a different pair, the priming and trigger connections cooperating to provide a blocking bias for the control means of the devices of all pairs except the one pair next to be operated and providing the control means of this one pair with a control which allows it to be operated quickly in response to an input impulse, and the pattern of the priming connections being such that the pairs are rendered operable one after another to respond to input impulses; and means common to all the devices to impress input pulses on the control means of all the devices to cause the primed pairs to operate.

4. In combination, a plurality of electronic devices, each device including an anode, a cathode, and means to control conduction between the anode and the cathode; means connecting the devices in pairs, anode to control means, to form trigger pairs in which one of the devices is conducting and the other device is non-conducting and in which the conducting and non-conducting condition of the devices of a pair can be reversed when the pair responds to an input impulse; means for applying input impulses to the control means of all the devices of the pairs, which impulses are ineffective to cause a reversal of the conducting condition of the pairs; and means to connect the anodes of a pair to the control means of another pair to control the effectiveness of the control means and thereby selectively prime the trigger pairs one after another to enable the input impulses to be effective thereon to cause them to operate and reverse the conducting and non-conducting condition of their constituent devices.

5. In combination, a plurality of electronic devices, each device having an anode, a control grid, and means to control conduction between the anode and the cathode; means for supplying operating potentials for the anodes, cathodes, and control means of the devices; means connecting the devices to form an operative ring and to control their conduction, including anode-to-control-means trigger connections for connecting devices to form trigger pairs, in each of which pairs one of the devices is conducting and the other device is non-conducting, which condition of the devices can be reversed upon an operation of the pair, and resistance network connections between the anodes of the devices of a pair and the control means of the devices of another pair for connecting the devices in a serial pattern, the trigger connections and resistance network connections controlling the controlling means of the devices to render the pairs of devices responsive to input impulses one after another in sequence and to provide an overbias on the remaining pairs at each stage of operation of the ring to prevent them from responding to input impulses impressed on the control means and render the devices stable against misoperation; and means to impress input impulses on the control means of the devices, each of which impulses is impressed on the control means of all the devices and causes the pair which is responsive to operate.

6. In combination, a plurality of electronic devices, each device containing at least an anode, a cathode, and control means; means normally supplying anode-cathode potential and biasing potential for the control means of said devices; means connecting the devices for controlling conducting therein, including connections connecting the devices anode to control means, in trigger pairs, and also including priming network connections between the anodes of the devices of

the pairs and the control means of the devices of other pairs for modifying the control of the control means to enable the trigger pairs to be responsive and change their mode of operation one after another in succession in response to impulses impressed on the control means of all the devices; and means to impress impulses on the control means of the devices to cause their operation, each impulse being impressed on the control means of all the devices and causing the trigger pair, which is primed at that time, to operate.

7. In combination, a plurality of electronic devices, each device including at least an anode, a cathode, and a control means; means connecting the devices to form trigger pairs by conductively coupling the anode of each device of the pair to the control means of the other device of the pair so that, at any instant, but one device of a pair will be conducting and so that, when primed, a pair can respond to an input impulse and can change its mode of operation; means also conductively coupling the control means of a device on one pair to anode of a device of another pair to form an endless operating chain of the devices and to enable the pairs of devices to be primed, the pattern of the priming connections being displaced from the pattern of trigger connections in such a manner that, at any stage of operation of the pairs of devices, the conducting device of only one pair will have its control means connected to the anode of a conducting device of another pair and the non-conducting device of said one pair will be the only non-conducting device having its control means connected to the anode of a non-conducting device of another pair, which condition causes said one pair to be primed to respond to an input impulse and to change its mode of operation, said one pair when operated being effective to cause a further pair to be primed; and means common to all the devices to impress input impulses on the control means thereof to cause the sequential change in the mode of operation of the pairs.

8. In combination, a plurality of vacuum tubes including at least an anode, a cathode, and a control grid; means for supplying operating potentials for the tubes and including an individual resistance for the anode of each tube whereby the potential of the anode of a tube will vary with its conductivity; means connecting the tubes anode to control grid to form trigger pairs in which, at any stage of operation of a pair, one or the other of the tubes is conducting and the other is non-conducting; and priming connections between the trigger pairs to connect the tubes in an operative ring and render the pairs selectively operable to change their mode of operation one after another, said priming connections extending from the anodes of the tubes of one pair to the control grids of the tubes of another pair and being of such a pattern that, at any stage of operation of the ring, only the primed trigger pair will have the control grid of its conducting tube connected to the anode of a conducting tube of another pair to make the potential of the control grid of the conducting tube of the primed pair less positive than the control grids of the other conducting tubes, and only the primed trigger pair will have the control grid of its non-conducting tube connected to the anode of a non-conducting tube of another pair to make the potential of the control grid of the non-conducting tube of the primed pair less negative than the control grids of the other non-conducting tubes, whereby the primed pair can respond to an input impulse and can change its mode of operation.

9. In combination, a plurality of electronic devices, each device including an anode, a cathode, and a control means; means connecting the devices to form trigger pairs in which, at any stage of operation of a pair, one or the other of the devices is conducting and the remaining device is non-conducting; priming network connections including conductive couplings between the anodes of the devices of a pair and the control means of the devices of another pair for connecting the pairs in a ring and for rendering the pairs selectively operable one after another in response to input impulses, said priming network connections being of such a pattern that they are effective at any stage of operation of the ring to cause the control means of the devices of all the pairs except the primed pair to have potentials applied thereto which prevent these pairs from responding to input impulses and changing their mode of operation; and means coupled to the control means of all the devices to apply input impulses to all the devices, each impulse being impressed on the control means of all the devices and causing the devices of the primed pair to operate and change their mode of operation.

10. In combination, a plurality of electronic devices, each device having at least an anode, a cathode, and a control electrode; means connecting the devices to form trigger pairs in which one device of a pair is conducting and the other device of the same pair is non-conducting and in which the conducting and non-conducting conditions of the devices of a pair will be reversed each time it operates in response to an input impulse; priming network connections including connections between the anodes of the devices of a pair and the control electrodes of the devices of another pair for connecting the pairs in a ring and for selectively rendering the pairs responsive one after another to input impulses, said network connections causing the control electrodes of all the pairs except the primed pair to be over-biased and stable against operation to allow only the primed pair to respond quickly to an input impulse and the pattern of the network connections causing the primed pair, when operated, to be given an over-bias and one of the previously over-biased pairs to be primed and made responsive to an input impulse whereby the ring is controlled for step-by-step operation of the pairs; and means to impress input impulses on the control electrodes of all the devices.

11. In combination, a plurality of electronic devices, each device having at least an anode, a cathode, and a control electrode; means to provide operating potentials for the devices; means to connect the devices, anode to control electrode, to form trigger pairs in which, at any stage of operation of a pair, one device of the pair is conducting and the other device is non-conducting and in which the conducting and non-conducting condition of the devices of a pair will be reversed each time it operates in response to an input impulse; priming network connections between the anodes of the devices of a pair and the control electrodes of the devices of another pair for connecting the pairs to form a ring and to render the pairs responsive one after another in endless sequence in response to input impulses, said priming connections causing at

least one control electrode in all pairs except the primed pair to have a potential which will prevent these pairs from operating in response to input impulses and causing the control electrodes of the primed pair to have potentials which will allow the primed pair to respond quickly to an input impulse, and said priming network conections having a pattern by which the pairs are primed for operation one after another; and means common to all the devices for supplying the control electrodes of the devices with input impulses which can cause an operation of the primed pair but which are not sufficient to overcome the blocking potential in the unprimed pairs.

12. In combination, a plurality of vacuum tubes, each tube having at least an anode, a cathode, and a control grid; means connecting the tubes to form trigger pairs in which one tube of a pair is conducting and the other tube of the same pair is non-conducting and in which the conducting and non-conducting conditions of the tubes of a pair will be reversed each time it operates in response to an input impulse; priming network connections, including connections between the anodes of the tubes of a pair and the control grids of the tubes of another pair, for connecting the pairs in a ring and for selectively rendering the pairs responsive one after another to input impulses, said network connections causing the control grids of all the pairs except primed pair to be over-biased and stable against operation to allow only the primed pair to respond quickly to an input impulse, and the pattern of the network connections causing the primed pair, when operated, to be given an over-bias and one of the previously over-biased pairs to be primed and made responsive to an input impulse whereby the ring is controlled for step-by-step operation of the pairs; and means to impress input impulses on the control grids of all the tubes.

13. In a battery operated vacuum tube ring, the combination of a plurality of battery operated vacuum tubes, each tube having an anode, a cathode, and means to control conduction between the anode and the cathode; means for supplying operating potentials for the anodes, cathodes, and control means of the tubes; means connecting the tubes to form an operative ring and to control their conduction, including anode-to-control-means trigger connections for connecting tubes to form trigger pairs, in each of which pairs one of the tubes is conducting and the other tube is non-conducting, which condition of the tubes can be reversed upon an operation of the pair, and resistance network connections between the anodes of the tubes of a trigger pair and the control means of the tubes of another trigger pair for connecting the tubes in a serial pattern in a ring, the trigger connections and resistance network connections controlling the controlling means of the tubes to render the pairs of tubes responsive to input impulses one after another in sequence and to provide an over-bias on the remaining pairs of tubes at each stage of operation of the ring to prevent them from responding to input impulses impressed on the control means and render the trigger pairs stable against misoperation; and means to impress input impulses on the control means of the tubes, each of which impulses is impressed on the control means of all the tubes and causes the pair which is responsive to operate.

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