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SEQUENTIAL ELECTRONIC COMMUTATOR
WITH SUPPLEMENTARY GRID CONTROL
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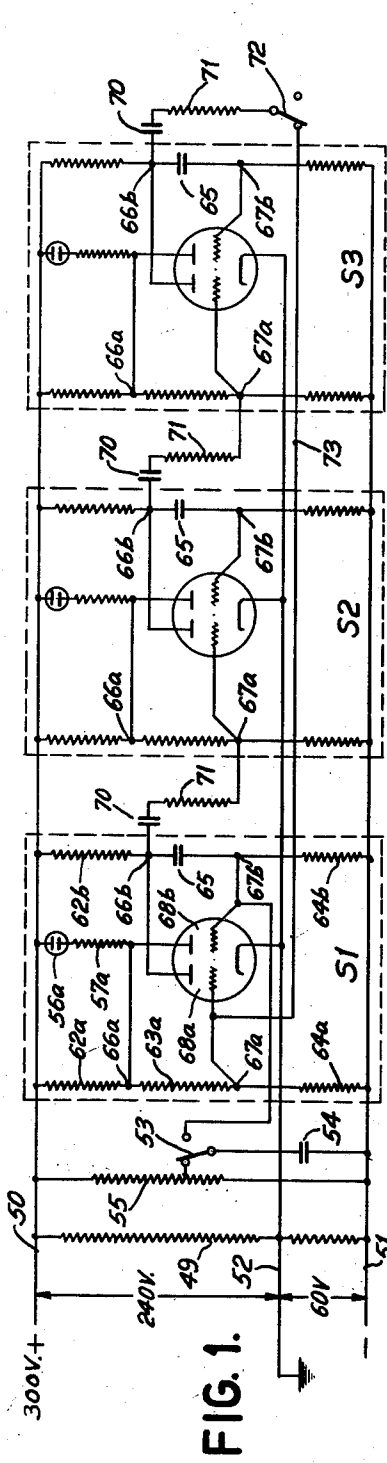


FIG. 1.

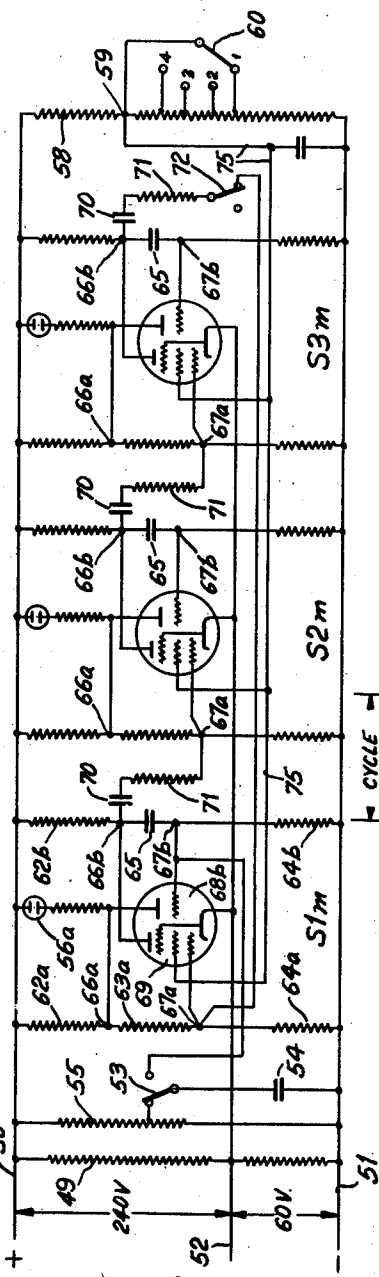


FIG. 2.

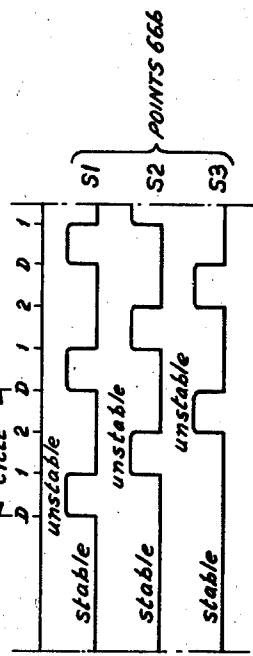


FIG. 3.

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SEQUENTIAL ELECTRONIC COMMUTATOR
WITH SUPPLEMENTARY GRID CONTROL

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1 Claim. (Cl. 250-27)

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This invention relates to electrical systems and particularly to impulse-driven and impulse generating systems capable of various uses; for example, as electrical commutators or the like.

Electronic commutators previously have been devised utilizing electronic trigger circuits of the type having alternate and opposite stable conditions. Such circuit was tripped from either stable condition to the other in response to one driving pulse and tripped back to its former stable condition by another driving pulse.

In contradistinction, the present invention has for an object the provision of a commutator using trigger circuits each of which is characterized by only one stable condition.

An object of the invention is to provide an electronic trigger circuit which has one stable condition and a reverse unstable condition and which must be driven from the stable to the unstable condition by an impressed impulse but which produces its own impulse for returning the circuit to the stable condition and wherein a multi-grid tube is provided in one branch of the circuit, such tube having a supplementary grid which is alterable in potential to control the duration of the unstable status.

In relation to the above object, the invention contemplates the provision of a common bias adjusting device for the supplemental grids of all the stages to adjust the self-timed periods of operation of the stages.

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

In the drawings:

Fig. 1 shows an illustrative circuit arrangement of the main embodiment of the invention.

Fig. 2 shows an illustrative arrangement of a modification.

Fig. 3 graphically illustrates the general form of waves of potential produced at pertinent points of the commutator.

General description of the commutators

The electronic commutator enables desired results to be obtained without mechanical inertia and at great speed. The commutator has a number of stages depending on the number of steps through which the commutator is to progress in a single sequence or cycle of the commutator. The electronic commutators are disclosed herein to exemplify the invention. As illustrative, each commutator has three stages.

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Each stage employs vacuum tubes and associated impedances and capacity, so interrelated as to form a novel trigger circuit. This trigger circuit has two alternate states, one of which is a normal or stable state in which it will remain until driven therefrom by electrical energy, such as an impulse, applied from an external source. The other or reverse state of the circuit is an off-normal or unstable state; i. e., one which is temporary and from which the circuit automatically switches back, after a time lapse, to the stable state. Initially, all the stages of the commutator are in their stable states. To initiate a cycle of the commutator, a driving impulse will be applied to the first stage to switch it to its unstable status. After a time determined by the electrical constants of the stage, which may be adjusted in one embodiment by an external agency, the first stage automatically switches back from its unstable to its stable status. In so doing, the first stage produces a driving impulse which is transmitted to the second stage to drive it to its unstable status. The second stage acts similarly to the first stage, and in returning to its stable status, initiates a reciprocation in status of the third stage. In the illustrative commutators, the third stage is the last, and if it is desired to effect only a single cycle of a commutator for each impulse applied to the first stage, then the last and first stages are not coupled to each other. Such commutator may be called a start-stop commutator. If it is desired to provide a continuously operating commutator, the last stage is coupled to the first stage to form a closed chain of circuits. Then, when the last stage switches back to its stable status, it produces an impulse for repeating the reciprocation in status of the first stage. Repetitive and sequential operation of the succeeding stages then occurs, and so on in continuous fashion until power is removed from the commutator or until the connection between two of the stages, as the last and the first, is opened. There are no time delay circuits supplementary to and intermediate the successive stages to prevent undesired, concurrent operation of the successive stages upon the application of a single driving impulse to one stage. Sequential operation of the stages is attained by the use of the novel, self-timing trigger circuits as the stages of the commutator.

The trigger circuit (main form)

This trigger circuit is the basic unit of the commutator shown in Fig. 1. Three such units or stages S1, S2, and S3 are provided for the com-

mutator, as illustrative. Each trigger unit is similar and is shown in a dotted box.

Desired voltage, which may be 300 v. d. c. as indicated, is supplied from a suitable source to the plus line 50 and minus line 51. A voltage divider 49 across these lines is tapped by a line 52. Preferably, the potential thereby applied to line 52 is 60 volts positive with respect to minus line 50. Line 52 may be grounded, as shown.

Since all the trigger circuits in Fig. 1 are alike, a full set of reference characters is applied only to one of them; namely, S1.

Each of these trigger circuits has two impedance networks or branches. One includes resistors 62a, 63a and 64a in series across lines 50 and 51. This impedance network may be considered as including the vacuum tube unit 68b. The other impedance network includes resistor 62b, condenser 65, and resistor 64b in series between lines 50 and 51. The latter network may be considered as including vacuum tube unit 68a. Units 68a and 68b may be separate vacuum tubes or may be units of a duplex tube, as shown. The units 68a and 68b may be of the 6SC7 type. The common cathode of the tube is connected to line 52. The anode of triode 68b is connected to point 66a at the junction of resistances 62a and 63a, while the anode 68a is connected to point 66b which is between resistance 62b and condenser 65. The grid of 68a is connected to point 67a which is at the junction of resistors 63a and 64a; the grid of 68b is connected to point 67b which is between condenser 65 and resistor 64b. These connections provide cross-coupling between the two impedance networks; that is, each impedance network is coupled to the anode-cathode path of a tube unit which has its grid connected to the opposite impedance network.

Resistances 62a and 64a are equal in value, and each is approximately one-third the value of resistance 63a. The values of any one or more of resistances 62b and 64b and of condenser 65 may be varied in accordance with the desired duration of time for which the circuit is to maintain itself in unstable status. Different durations of unstable status were obtained by using different capacities of condenser 65; for example, a condenser 65 with a capacity in the order of .00025 microfarad produced an extremely short duration of unstable status, a condenser 65 with a capacity of substantially .02 microfarad produced a longer duration of unstable status, and a condenser 65 with a capacity of substantially .25 microfarad produced a still longer duration of unstable status. Resistance 62b may be in the order of .1 megohm and resistance 64b may have a value of substantially 1.1 megohms. Resistances 62a and 64a may each have a value of .1 megohm and resistance 63a may have a value of .3 megohm.

In stable status of the trigger circuit, the grid of triode 68b is substantially at the same potential as minus line 51 since it is connected thereto by resistance 64b. The normal grid bias of 68b is then negative as to maintain 68b at cut-off. Under this condition, 68b has an impedance relatively high in comparison to that of resistance 62a, and the point 66a, to which the anode of 68b is connected, has a potential which is high with respect to line 52. With resistances 62a, 63a, and 64a properly proportioned, the potential drop across 63a is such as to maintain point 67a substantially at the potential of cathode line 52. Hence, the grid of tube 68a is at zero bias. With the bias of 68a at zero, this tube is highly

conductive and has an impedance relatively low as compared to that of resistance 62b. Consequently, point 66b, to which the anode is connected, then has a potential which is not much greater than that of common cathode line 52. Such potential of point 66b has no effect upon the potential of point 67b, inasmuch as these points are bridged by condenser 65. The foregoing describes the stable status of the circuit, in which 68a has maximum current flow, and 68b is at cut-off, and in which point 66a is at a higher potential, with respect to lines 52 and 51, than is point 66b. Fig. 3 indicates the general form of the potentials produced at points 66b of the circuits S1, S2, and S3 and shows that points 66b of all the trigger circuits are initially at minimum potential; hence that all the circuits are initially in stable status. The manner of switching the trigger circuit to unstable status will be described in connection with trigger circuit S1. It is understood, then, that for the present, the trigger circuit elements referred to below are those of circuit S1.

With switch 53 in the position shown, it connects one side of condenser 54 to a point on the voltage divider 55, which is between lines 50 and 51. The opposite side of condenser 54 is connected to line 51. The potential of the aforementioned point, of voltage divider 55, to which the condenser is connected is such that the condenser 54 is charged to a potential which is higher than that of point 67a. When switch 53 is shifted to a reverse position from that shown, condenser 54 discharges through resistance 64b. Such discharge is in the form of a sharp positive pulse, and causes point 67b to rise in potential with respect to line 51. The voltage difference between line 52 and point 67b is the grid bias of tube 68b, and the aforementioned increase in potential of point 67b, due to a pulse application, decreases the grid bias of tube 68b sufficiently to cause 68b to start conducting. Current flow occurs from line 50 via resistance 62a and triode 68b to line 52, and causes point 66a to drop suddenly in potential. A related drop occurs at point 67a, increasing the negative grid bias of 68a. Accordingly, current flow through 68a and resistor 62b is decreased, causing point 66b to rise suddenly in potential, producing a positive pulse. This pulse feeds through condenser 65 to the grid of 68b, promoting the reduction in negative grid bias of 68b. Such action continues and point 67a is driven considerably below the cut-off potential for triode 68a. The potential of point 66a has now dropped, while that of point 66b has risen to upper value, and the triode 68b is now fully conductive while triode 68a is at cut-off. It is seen that the electrical conditions in the trigger circuit are now reversed with respect to the electrical conditions prevailing in the former status, which is the stable status, of the circuit. As has been described, the circuit was tripped to unstable status by impressing a positive pulse on point 67b of the circuit, as a result of which a negative pulse was produced at point 67a of the circuit. It is appreciated that a negative pulse may be impressed directly from an external source upon point 67a of the circuit with the same effect of tripping the circuit from its stable to its unstable status. Such negative pulse applied to point 67a will drive tube 68a to cut-off, whereby point 66b will rise abruptly to its upper value.

With the point 66b of the circuit at the upper value, the circuit is in unstable status, as is indicated in Fig. 3. The circuit will maintain itself

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in the unstable status for a chosen interval and will then automatically trip itself back to its stable status wherein it will remain until it receives another tripping pulse from an external source. The manner in which and the reasons why the circuit trips itself back from unstable to stable status will now be explained.

As previously described, upon the tripping of the trigger circuit from stable to unstable status, point 66b rose abruptly in potential, and the attendant positive pulse was fed through condenser 65 to point 67b and the grid of triode 68b, reducing its grid bias to zero. Stated differently, the rise in potential of point 66b produced a charging current which flowed through condenser 65 and resistor 64b and resulted in an increase in potential of the grid 68b. Depending upon the RC product of the condenser and resistors in the charging circuit, condenser 65 continues to charge for a predetermined period of time. The charging current declines in value as condenser 65 becomes more and more charged. Hence, the grid potential of triode 68b declines accordingly, whereby the conductivity of this triode gradually declines. Such action is reflected in a gradual increase in the potential of points 66a and 67a. Eventually, the point 67a rises in potential to such value that the difference in potential between point 67a and cathode line 52 is less than that required to maintain triode 68a at cutoff. Thereupon, triode 68a starts to conduct, and current flow occurs from line 50 through resistances 62b and 68a to line 52. Consequently, point 66b suddenly drops in potential, producing a negative pulse. This pulse is transferred by condenser 65 to the grid of triode 68b, promoting the change of its negative grid bias to the cut-off value, whereby point 66a rises substantially instantaneously to its high value. Since, as just described, the potential of point 66a has now risen and that of 66b has now dropped, the trigger circuit automatically has returned to stable status, in which tube 68b is at cut-off, while tube 68a passes a large amount of current. This stable status is maintained until another pulse is applied to point 67b. When the commutator is conditioned for single cycle operation, the switch 53 must be returned from reverse position to the shown position in order to charge condenser 54, before another pulse can be derived therefrom to start another cycle. But when the commutator is conditioned for repeat cyclic operation, repeat tripping of S1 will be under control of a pulse derived from S3.

The condition of the trigger circuit may be determined by observation of glow discharge tube 56a, which is connected in series with current limiting resistor 57a between line 50 and point 66a. When the circuit is in stable state, point 66a is at a high potential with respect to line 52, and the difference in potential between this point and line 50 is insufficient to ignite tube 56a. When the circuit is in unstable state, the point 66a is at a low potential, and the difference in potential is great enough to cause tube 56a to fire. Accordingly, when tube 56a is dark, it indicates that the circuit is in stable state. When tube 56a is lighted, it indicates that the circuit is in its unstable condition.

The foregoing has described a stage of the electronic commutator shown in Fig. 1. It is seen that each such stage has a normal, stable condition and a reverse, unstable condition; that the stage is self-maintained for a predetermined, limited interval in the unstable condition; and that

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at the end of this interval, the stage self-triggers itself back to its stable condition. The length of the interval in which the unstable status is maintained may be varied by varying the electrical constants of the stage; for example, by varying the capacity of condenser 65.

The commutator (main form)

This commutator is shown in Fig. 1 and it includes trigger circuits of the kind just described. Since the commutator is to progress through three steps in a cycle, it has three stages, trigger circuits S1, S2, and S3. Stage S1 is coupled to stage S2 by a condenser 70 and resistor 71 extending from point 66b of S1 to point 67a of S2. Stage S2 is coupled by a similar condenser and resistor to stage S3. If the commutator, once started in operation, is to perform repeat cycles automatically, then a switch 72 is closed and a connection is provided from point 66b of the last stage, S3, via a condenser 70 and resistor 71, the switch 72, and a wire 73 to point 67a of the first stage S1. It is seen, then, that each stage is coupled to the next by a similar condenser-resistor circuit and that the last stage may be coupled to the first by a similar circuit which, however, includes a switch for enabling the first and last stages to be disconnected. When this switch, 72, is opened, the commutator will perform only a single cycle for each starting impulse applied to the first stage. The recovery time of the condenser and resistor coupling 70 and 71 between each stage and the next is very small in order that a change in potential at point 66a of one stage shall produce a substantially concurrent change in potential at point 67a of the next stage. Thus, the stages of the commutator are interconnected by coupling circuits which have no time delay circuits and which do not include electronic tubes.

All the stages are normally in their stable status. In this status of a stage, its tube 68a is fully conductive and point 67a is substantially at cathode potential, as previously explained. To initiate operation of the commutator, switch 53 is reversed, whereupon condenser 54 discharges a steep positive pulse upon resistor 64b of S1 which succeeds in raising the potential of point 67b of S1 above cut-off potential. As a result, S1 is tripped to its unstable status, as previously described. Point 66b of S1 rises abruptly in potential and the occurrence of this action marks the beginning, D (Fig. 3), of a cycle. It may be mentioned that the rise in potential of 66b (S1) is transmitted by the related condenser and resistor coupling to point 67a of S2. The attendant rise in potential of point 67a of S2 merely confirms S2 in its stable status.

S1 remains in its unstable status for a chosen time duration and then trips itself back to stable status, as explained previously. Point 66b of S1 drops abruptly in potential and, through the condenser and resistor coupling, a negative pulse is fed to point 67a of S2. This negative pulse is of sufficient amplitude to trip S2 from its stable to its unstable status, in the manner described before. The simultaneous occurrence of the return of S1 to stable status and its tripping of S2 to unstable status defines point "1" of the cycle (see Fig. 3). It is seen that a reciprocation in status of the controlling trigger circuit, S1, effects a single change in status of the controlled trigger circuit, S2.

S2, likewise, trips itself back to stable status after a chosen interval and in so doing trips S3

to unstable status. This action marks point "2" of the cycle.

S3 similarly, trips itself back to stable status after a chosen interval and this marks the end of one cycle. If switch 72 is open, then a second cycle may be initiated by another initiating pulse received from condenser 54 or any other suitable source outside the commutator. If switch 72 is closed, then the return of S3 to its stable status acts through the coupling circuit to impress a negative pulse upon point 67a of S1 thereby tripping it to unstable status. The simultaneous occurrence of the return of S3 to stable status and its tripping of S1 to unstable status marks the beginning of a repeat cycle. Sequential operations will continue until either potential is removed from lines 50 and 51 or until switch 72 is opened.

It is seen that the commutator functions sequentially without the use of time delay coupling means between the stages but by the use of stages, comprising trigger circuits, which have self-timing characteristics.

The modification

The modification of the commutator is shown in Fig. 2. It is based on a modified form of the trigger circuit and is supplemented by means for adjusting the time duration of the unstable periods of the trigger circuits. Elements of the modification which correspond to elements of the main embodiment are given the same reference characters.

The modified trigger circuit differs from the main form in replacing the triode 68a by a multi-grid vacuum tube 69 which, in this instance, is preferably a pentode. In the main form, the duration of time in which the trigger circuit maintains itself in unstable status depends on the values of one or more of the resistors 62b and 64b and of condenser 65. In other words, the unstable period of the main form of the trigger circuit depends on the chosen constants of the circuit itself. In the modified form, shown in Fig. 2, the unstable period depends not only on the chosen constants of the trigger circuit itself but also on the adjustment of supplementary means which determines the potential of one of the control electrodes of the multi-grid tube 69. Specifically, the supplemental adjusting means includes a voltage divider 58 between lines 50 and 51 and varying portions of which may be short-circuited by an adjustable switch 60. The point 59 of the voltage divider is connected to a wire 75 from which connections are made to the screen grids of the tubes 69 of the trigger circuits S1m, S2m, and S3m of the three-step commutator shown in Fig. 2. It is seen that the screen potential of a tube 69 may be varied by adjustment of the switch 60. Thus, with the switch 60 at the spot 1, a large portion of voltage divider 58 is short-circuited and the screen potential will be at its lowest value. Adjustment of the switch to spot 2 will reduce the short-circuited portion of the voltage divider, and the screen potential will be increased. Further increases in screen potential may be had by adjusting switch 60 to spots 3 and 4.

The impedance of the pentode is a function of the potentials of the screen and control grids with respect to cathode potential. A rise in screen potential tends to reduce the impedance of the tube. Likewise, a rise in potential of the control grid tends to reduce the impedance of the tube. Thus, if the tube is at maximum imped-

ance or cut-off when the screen and control grid potentials are at certain values, it may be maintained at cut-off by suitably reducing the screen potential and raising the control grid potential or by reducing the control grid potential and raising the screen potential. Conversely, the higher the screen potential, then the less is the rise required in control grid potential to unblock the tube or to drive it to conductivity, while a reduction in screen potential will require a greater increase in control grid potential in order to unblock the tube. Thus, by adjustment of switch 60 to raise the screen grid potential, the rise in the control grid potential required to drive the tube to conductivity is lessened to a related degree. Specifically, the rise in potential required at point 67a, of a trigger circuit in the modified commutator, in order to unblock the pentode 69 is directly related to the screen potential of the pentode.

As in the main embodiment, a trigger circuit of the modified form is in stable status when its tube 68b is at cut-off and its points 66a and 67a are at their higher potentials. With point 67a at its higher potential, the control grid potential of tube 69, for any of the possible values of screen potential, is such as to maintain the tube at maximum conductivity. Upon application of an adequate positive pulse to point 67b of the circuit or of an adequate negative pulse to point 67a of the circuit, the circuit will be reversed to its unstable status. For instance, a positive pulse may be received by point 67b of circuit S1m from the condenser 54 when switch 53 is reversed. This pulse will unblock tube 68b and, in consequence, point 66a will drop abruptly in potential. A related drop in potential occurs at point 67a, increasing the negative control grid bias of tube 69. Accordingly, the impedance of tube 69 increases and point 66b rises suddenly in potential, producing a positive pulse. This pulse feeds through condenser 65 to the grid of 68b, promoting the reduction in impedance of 68b. The ultimate result is that point 67a is driven considerably below the potential at which it may maintain tube 69 conductive while point 67b is driven to substantially cathode potential. Now, with the tube 68b fully conductive and tube 69 at cut-off, the circuit S1m is in its unstable status.

After dissipation of the operating pulse, the maintenance of point 67b at the potential necessary to maintain tube 68b conductive is temporary since it is receiving such potential by reason of the charging circuit through condenser 65. As the condenser becomes more and more charged, the charging current declines gradually in value and this is reflected in a gradual decrease in potential of point 67b. As point 67b declines in potential, the negative grid bias of tube 68b increases and the current flow through the tube decreases. Hence, points 66a and 67a of the trigger circuit rise in potential. Eventually the point 67a and, therefore, the control grid potential of tube 69 is raised sufficiently to cause the tube to start conducting. The potential which point 67a must attain to effect this action depends on the chosen screen potential. If the screen potential is high, then the potential which point 67a must attain to drive the tube 69 to conductivity is smaller than when the screen potential is low. Hence, the higher the screen potential, the smaller is the necessary rise in control grid potential and, therefore, the less time it takes for the control grid to attain the required potential. The rise in potential of the control grid is

directly related to the time required to charge the condenser 65. Thus, these two factors; one, the adjusted screen potential, and two, the charging circuit constants, determine the length of time elapsing between the tripping of the circuit to unstable status and the driving of tube 69 to a conductive status. When tube 69 reaches conductive status, point 65b drops abruptly in potential and the unstable status of the trigger circuit is terminated, the circuit resuming its stable status in the same manner as explained for the main embodiment.

The trigger circuits S1m, S2m, and S3m are interconnected in exactly the same way as the circuits S1, S2, and S3 of the main embodiment. Operation of the modified commutator, therefore, will be similar to that of the main embodiment and as indicated in Fig. 3. It is understood that although the unstable period of each of the stages of either commutator is indicated in Fig. 3 as substantially of equal duration, that the period of each stage may be adjusted to a different duration than that of any other stage. The rate of commutator operation may be adjusted by varying the constants of the charging circuit of condensers 65 and, in the Fig. 2 form of commutator, may also and more readily be adjusted by changing the setting of switch 60.

The sequential operation of either of the disclosed commutators renders available impulses which may be fed to and utilized by controlled circuits for suitable purposes.

While there have been shown and described and pointed out the fundamental novel features of the invention as applied to two embodiments, it will be understood that various omissions and substitutions and changes in the form and details of the devices illustrated and in their 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 claim.

What is claimed is:

An electronic commutator or the like, comprising a plurality of electronic trigger circuits, each including a pair of electronic tubes, a first one of which includes an anode, cathode, and current

controlling electrode and the second of which includes an anode, cathode, current controlling electrode and a supplemental electrode, means coupling the anode of the first tube of each pair to the current controlling electrode of the second tube of the pair so that with the first tube non-conductive it maintains the second tube conductive to establish a stable state of the trigger circuit, self-dissipating reactance means coupling the anode of the second tube to the current controlling electrode of the first tube so that with the second tube non-conductive the first tube is conductive to define an unstable state of the trigger circuit from which it returns to the stable state after a chosen time interval, means coupling the output of one of the trigger circuits to the input of the next trigger circuit so that upon return of the former trigger circuit from unstable to stable state it applies a tripping pulse to the next trigger circuit to reverse it from stable to unstable state for a chosen time interval, a common source of biasing potential for the supplemental electrodes of the plurality of trigger circuits, and adjustable means common to the plurality of trigger circuits for transmitting a variable proportion of the biasing potential to said supplemental electrodes so as to regulate the durations of the unstable intervals of said trigger circuits.

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