

July 13, 1943.

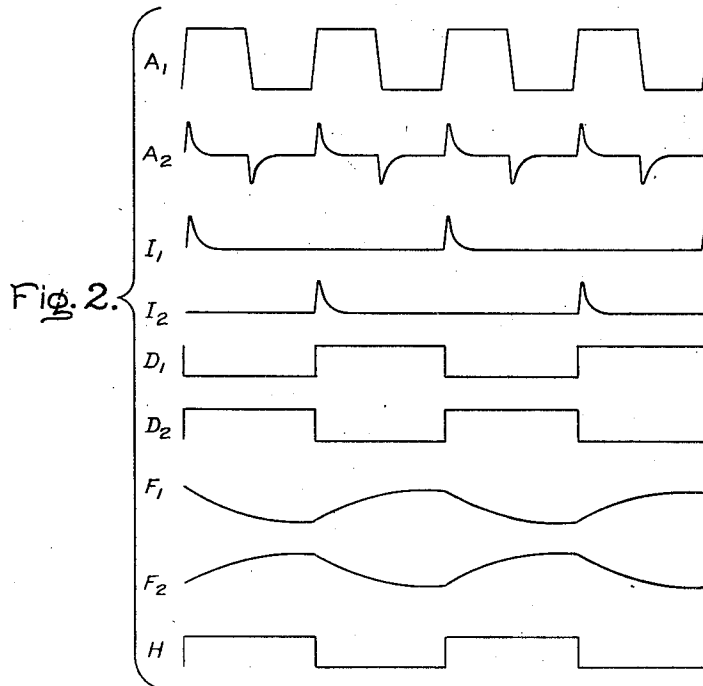
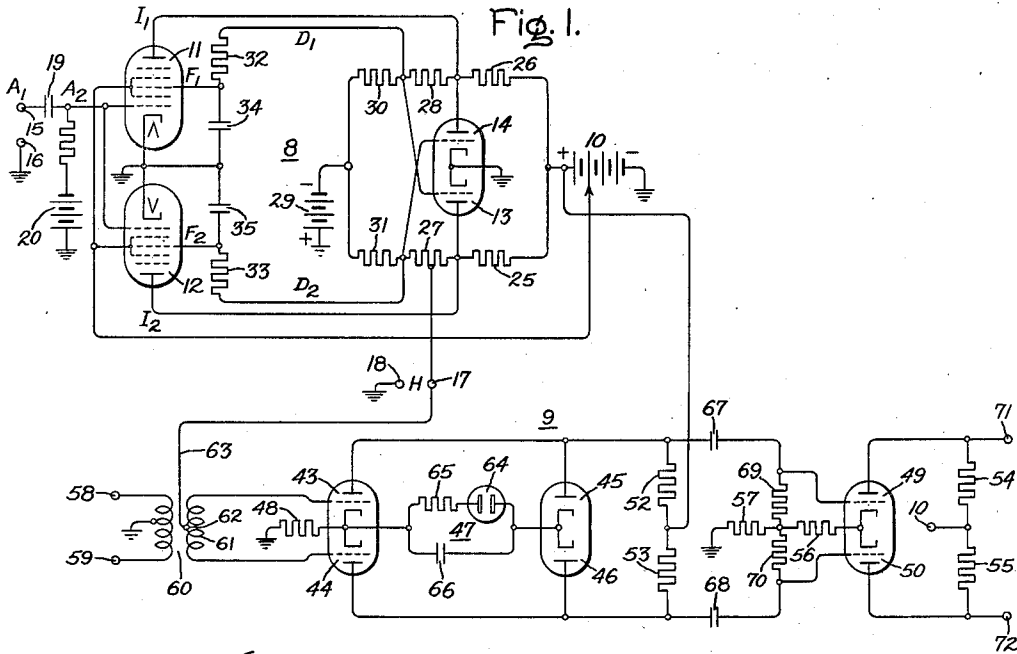
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2,324,314

ELECTRONIC SWITCH

Filed Nov. 13, 1941

2 Sheets-Sheet 1



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July 13, 1943.

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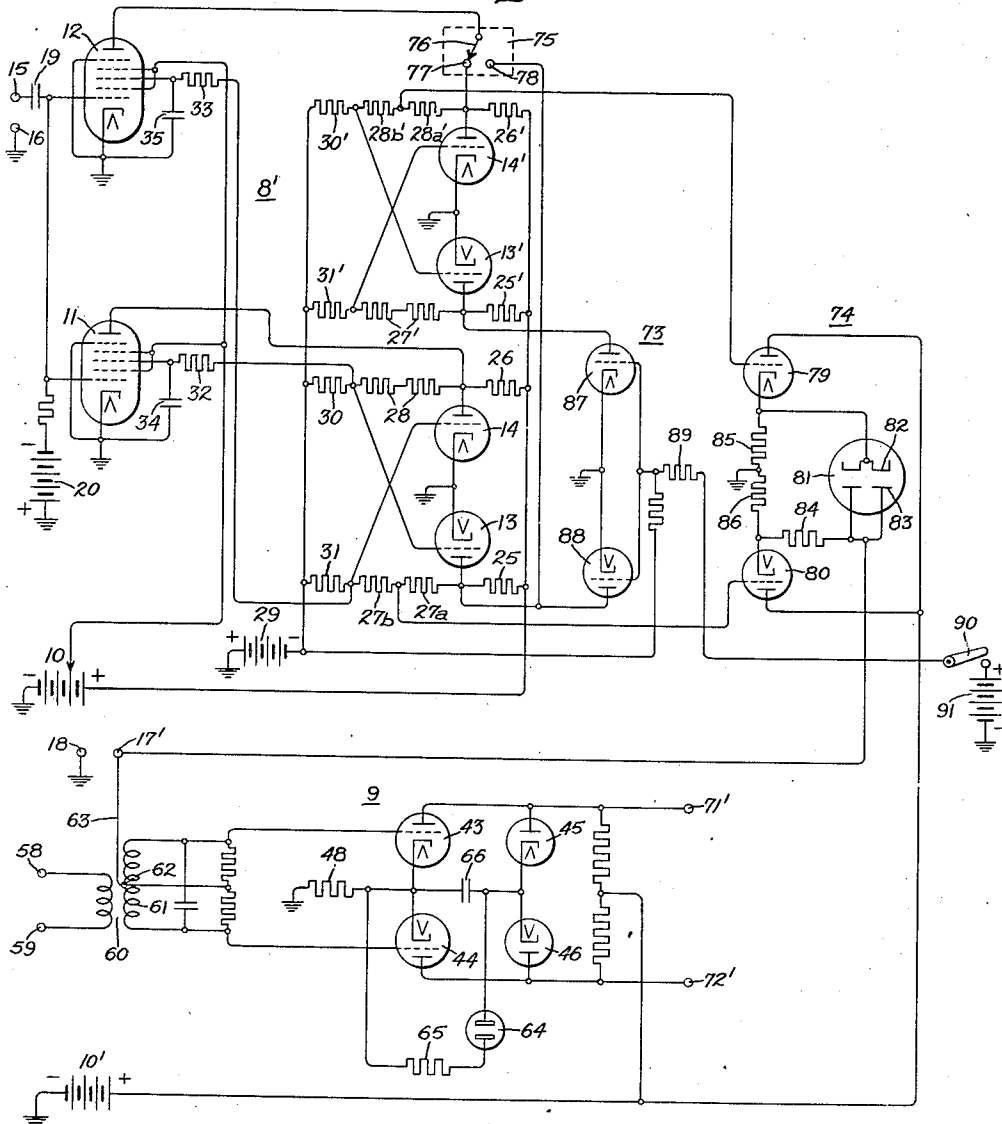
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2 Sheets-Sheet 2

Fig. 3.



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UNITED STATES PATENT OFFICE

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ELECTRONIC SWITCH

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Application November 13, 1941, Serial No. 419,035

11 Claims. (Cl. 250—27)

This application is a continuation in part of my copending application for a Counter circuit, Serial No. 419,034, filed November 13, 1941, assigned to the same assignee as the present application.

My invention relates to current controllers and concerns particularly electric discharge circuits which may be controlled in response to impulses.

It is an object of my invention to provide an improved electronic switch or an improved ionic switch avoiding switching transients in the output circuit.

Other and further objects will become apparent as the description proceeds.

In carrying out my invention in its preferred form I provide what may be called a scale of two counter circuit and an amplifier circuit. The amplifier circuit is controllable and serves as a switch to control the transmission of signal impulses between input and output terminals. The counter circuit serves as a relay responsive to control impulses for turning the amplifier on and off. The scale of two counter circuit is arranged to be shifted back and forth between two equilibrium conditions by successive control impulses actuating the counter circuit. The amplifier is arranged to be turned on and off by a bias control which is high or low according to the equilibrium condition of the scale of two counter circuit. The circuit which is to be controlled is connected to the input side of the amplifier and the output side of the amplifier either reproduces the current variations of the circuit to be controlled or not according to whether the amplifier is turned on or off.

A better understanding of the invention will be afforded by the following detailed description considered in connection with the accompanying drawings in which Fig. 1 is a circuit diagram of one embodiment of my invention; Fig. 2 is a set of graphs illustrating the principle of operation of the type of scale of two counter circuit illustrated in the drawings, and Fig. 3 is a circuit diagram of a modification of the arrangement of Fig. 1, arranged to be responsive to only the first and second received impulses.

In the arrangement illustrated in Fig. 1 there is a scale of two counter circuit 8 arranged to control the bias of an amplifier circuit 9. The counter circuit 8 is energized by a source of anode voltage 10, which may be grounded on the negative side, and includes pairs of electric discharge devices 11 and 12, and 13 and 14. The devices 11 and 12 are responsive to input control impulses and the dis-

charge devices 13 and 14 are coupled to the first pair of discharge devices so as to be controlled thereby and to have the discharge current shifted back and forth between the discharge devices 13 and 14 in response to successive input control impulses as described more in detail in my original application.

The counter circuit 8 has a pair of input terminals 15 and 16, to which the control impulses are adapted to be applied, and has a pair of output terminals 17 and 18 connected to the control circuit of the amplifier 9 in a manner to be described more in detail hereinafter. If desired, the terminals 16 and 18 may be grounded, together with appropriate points in the circuits of the discharge devices. In the arrangement illustrated the discharge devices are vacuum tubes, the tubes 11 and 12 being shown as of the pentagrid type and the tubes 13 and 14 of the triode type. The latter may be combined to form a double triode if desired. The tubes 11 and 12 have primary control electrodes or #1 grids coupled to the input terminals 15 and 16 through a coupling condenser 19 and are negatively biased by a suitable source 20. As will be well understood by those skilled in the art the tubes 11 and 12, being of the pentagrid type, also contain suppressor grids or #5 grids which may be connected to cathodes. The #3 grids serve as auxiliary control electrodes. The #2 and #4 grids may be employed as shield grids for the #3 grids and may be connected to a point at an intermediate potential in the anode voltage source 10. The grids are, for convenience, designated by the numbers 1 to 5, the #1 grid being nearest the cathode.

In the arrangement illustrated the cathodes of the tubes are grounded and the anodes are connected to the positive terminal of the energizing source 10 through anode resistors 25 and 26. The anodes of the tubes 12 and 13 are connected to the source 10 through the resistor 25, and the anodes of the tubes 11 and 14 through the anode resistor 26. The control electrodes and anodes of the tubes 13 and 14 are cross coupled by means of resistors 27 and 28 and the control electrodes are negatively biased by connection to a source 29 through resistors 30 and 31. The #3 grids or auxiliary control electrodes of the tubes 11 and 12 are coupled to voltage varying points in the circuits of the tubes 13 and 14, for example, the control electrode thereof, by means of resistance condenser circuits. The coupling circuits may take the form of resistors 32 and 33 connecting the respective auxiliary control electrodes of the tubes 11 and 12 to the control electrodes of the tubes 13

and 14, and condensers 34 and 35 serving to ground the auxiliary control electrodes of the tubes 11 and 12 with respect to high frequency or steep transients.

The circuit constants are so chosen that at any given instant either the tube 13 or the tube 14 is conducting and whichever tube is conducting biases the other tube past cutoff. Likewise circuit conditions are such that the potentials to which the supplementary control electrodes of the tubes 11 and 12 are brought by the current conditions in the tubes 13 and 14 are such that one of the tubes 11 and 12 is responsive to impulses applied at the primary control electrode #1 grid and the other tube is non-responsive. The transmission of an impulse through the responsive tube to the tubes 13 and 14 however shifts the current from one of the latter tubes to the other and changes the relative potentials of the supplementary electrodes of the tubes 11 and 12 so that the other tube of that pair is responsive to the next impulse applied at the primary control electrodes or #1 grids. The output terminal 17 may be connected to a suitable point in the circuit of one of the tubes 13 and 14, for example, to a tap on the resistor 27.

With a wave shape of the input impulses as illustrated in the curve A₁ of Fig. 2, the potentials of the primary control electrodes of the tubes 11 and 12 will vary as represented by the curve A₂ of Fig. 2. Current impulses will accordingly be produced in the tubes 11 and 12 as represented by the curves I₁ and I₂ respectively of Fig. 2. The control electrode potentials of the tubes 13 and 14 will fluctuate in accordance with square wave shapes as represented by curves D₁ and D₂ respectively of Fig. 2. However, owing to the time delay produced by the condenser resistance coupling between the control electrodes of the tubes 13 and 14 and the supplementary control electrodes of the tubes 11 and 12, the potentials of the latter will follow the logarithmic curves F₁ and F₂ respectively of Fig. 2.

Current is shifted back and forth between the two-equilibrium-mode tubes 13 and 14 by successive impulses actuating the commutating tubes 11 and 12. The voltage between the output terminals 17 and 18 will follow a square wave formed as represented by the curve H of Fig. 2, having half the frequency of the input control wave A₁.

The amplifier circuit 9 comprises a pair of electric discharge devices 43 and 44 connected in push-pull relation, each having an anode, a cathode and a control electrode, a pair of rectifying devices 45 and 46 and a suitable constant-voltage device such as a floating voltage source or a regulated voltage impedance unit 47. A degenerative cathode resistor 48 is connected in the common cathode lead of the tubes 43 and 44 and the regulated voltage impedance 47 is shunted across the anode-cathode circuits of the tubes 43 and 44 through the rectifying devices 45 and 46, respectively, for the purpose of limiting the fall in potential of the cathodes of the tubes 43 and 44 when biased to non-conducting position. If desired one or more stages of push-pull amplification may be provided consisting of pairs of discharge devices such as the discharge devices 49 and 50.

The pairs of discharge devices 43 and 44 and 49 and 50 may take the form of single or double triode vacuum tubes and the rectifying devices 45 and 46 may take the form of diode vacuum tubes or a double diode tube if desired. The

tubes may be energized from the common anode voltage source 10 with the anodes of the triodes connected to the positive terminal of the source 10 through anode resistors 52, 53, 54 and 55, the cathodes of the triodes 43 and 44 connected to the negative or grounded terminal of the anode voltage source 10 through the degenerative cathode resistor 48, and the cathodes of the triode 49 and 50 connected to ground through a common degenerative resistor consisting of two parts 56 and 57 in series.

The amplifier 9 has input terminals 58, 59 which may be coupled in any suitable manner to the control electrodes or grids of the tubes 43 and 44 in such a way as to apply potentials of opposite polarities to the latter. The coupling may take the form of a transformer 60, for example, having a secondary winding 61, and having a center tap 62 connected to the positive output terminal 17 of the counter circuit 8 for biasing the tubes 43 and 44 in accordance with the condition of the counter circuit 8.

The voltage regulated impedance 47 may take the form of a voltage regulator tube 64, such as a neon tube, for example, of a type in which the interelectrode space breaks down when the voltage exceeds a predetermined value, in series with a resistor 65 with a condenser 66 shunting the series unit consisting of the tube 64 and the resistor 65.

The amplifier tubes 49 and 50 may be resistance capacity coupled to the anodes of the tubes 43 and 44 by means of suitable coupling condensers 67 and 68 and grid-leak resistors 69 and 70, respectively. The resistors 69 and 70 are shown as connected between the control electrodes of the tubes 49 and 50, respectively, and the junction terminal of the degenerative cathode resistors 56 and 57.

As already explained, the application of successive control impulses at the terminals 15 and 16 of the counter circuit 8 causes the voltage at the bias voltage terminals 17 and 18 to rise or fall according to the square wave H of Fig. 2. The circuit constants are so chosen that the maximum output voltage of the circuit 8 is above the "on" threshold of the amplifier 9, and the minimum voltage is below the "off" threshold of the amplifier 9.

My invention is not limited to the use of particular circuit values. However, when triodes of the 6F6G type are employed for the tubes 43, 44, 49 and 50 and the maximum and minimum voltages of the wave H are 150 and 100 volts, respectively, satisfactory results may be obtained by utilizing the following circuit constants:

Resistance of resistor 48	ohms	20,000
Resistance of resistor 65	do	1,000
Resistance of resistors 52 and 53	do	500
Resistance of resistor 57	do	20,000
Resistance of resistors 69 and 70	megohm	1/2
Resistance of resistor 56	ohms	250
Resistance of resistors 54 and 55	do	2,000
Capacity of condenser 66	microfarad	1
Capacity of condensers 67 and 68	do	1/10
Anode voltage from source 10	volts	300
Type of diodes 45 and 46		6H6
Type of voltage regulator tube 64		VR 150

If desired the regulated voltage source 47 may take the form of a battery of dry cells insulated from ground, in case the "on" period of the amplifier is expected to exceed the period over which the voltage regulator tube 64 will remain ignited.

When an input impulse is applied which raises the control bias of the amplifier 9 above the critical value turning the amplifier on, any impulses applied between the input terminals 58 and 59 are transferred to the output terminals 71 and 72. Owing to the push-pull connection of the triodes the input signal at the terminals 58 and 59 may be amplified appreciably, whereas any transients are only imperceptibly amplified and any line to ground noise is attenuated for the reason that the input signal impulses are in series on the control electrodes of the pairs of triodes being unaffected by the cathode resistors while the transient effects and line to ground noise or strays are applied to the control electrodes in parallel, causing degeneration or attenuating action of the cathode resistors. When the next control impulse is applied at the terminals 15 and 16 lowering the control bias voltage below the critical value and turning off the amplifier, input signals at the terminals 58 and 59 are no longer transferred to the output terminals 71 and 72. There is no perceptible transient produced in the output circuit for the reason that even when the amplifier is in the "off" condition the anode resistors 52 and 53 are carrying current and there is relatively little change in potential of the anodes of the tubes 43 and 44 whether the amplifier is turned on or off. The potential of the regulated voltage impedance 47 is so chosen in relation to the ignition voltage of the diodes 45 and 46 that when the control electrodes of the tubes 43 and 44 are biased "off," the potential of the cathodes of the tubes 43 and 44 will remain just above a value preventing conduction or amplification by the tubes 43 and 44. When the tubes 43 and 44 are biased "on" by the control voltage from the conductor 63 the potential of the cathodes of the tubes 43 and 44 is lower in relation to the average control electrode potential. Thus, when the amplifier is "on" current flows through the anode resistors 52 and 53 through the tubes 43 and 44 but when the amplifier is "off" current flows through the anode resistors 52 and 53 through the diodes 45 and 46. Consequently, there is relatively little change in the direct current component of current flowing through the resistors 52 and 53, whether the amplifier is "on" or "off." Therefore, relatively little switching transient is produced and as already explained the push-pull connection of the amplifier tubes 49 and 50 serves to attenuate any switching transient which may remain while amplifying the desired signal.

In the apparatus thus far described the amplifier 9 is turned "on" and "off" in response to alternate received control impulses. However, my invention is not limited to the specific arrangement described. As indicated in my aforesaid parent application separate sources of control impulses may be connected to the #1 grids of the tubes 11 and 12 so that the impulses from one control source can be effective only to turn the amplifier "on" and the impulses from the other control source can be effective only to turn the amplifier "off." In this case, if impulses are received alternately from the two control impulse sources the amplifier will also be turned on and off indefinitely. However, the apparatus may also be so arranged as to produce a single on and off operation, or vice versa.

If response to only first and second received control impulses is desired a combination of the scale-of-two input commutator section (tubes 11 and 12) with two separate two-equilibrium-

mode sections may be employed to provide "lock-out" action of the scale-of-two so that the amplifier is turned on and off (or off and on) but once until reset of the two equilibrium mode sections. Their reset is effected by lowering the plate or grid potential of the appropriate two-equilibrium-mode triode, either by momentarily grounding it through a resistor as already explained, or by permanently connecting it to the plate or anode of an auxiliary "reset" triode having a grid potential which is normally below cutoff and is momentarily raised for resetting.

In Fig. 3 is illustrated a modification of the arrangement of Fig. 1 which may be employed when only one "on" and "off" operation of the amplifier 9 is desired. In Fig. 3 a modified counter circuit 8' is employed which is like the counter circuit 8 of Fig. 1 in having a pair of commutating tubes 11 and 12 and having two-equilibrium-mode tubes 13 and 14. In the arrangement of Fig. 3 a second pair of two-equilibrium-mode tubes 13' and 14' is employed. The equilibrium-mode tubes 13 and 14 and 13' and 14' are so connected that when the commutating tube 11 has been actuated to shift current from the tube 13 to the tube 14 no further action takes place in this part of the circuit. Likewise when the commutating tube 12 has been actuated in response to the second impulse to shift current from the tube 13' to 14' no further action takes place. However, a suitable reset circuit 73 may be provided for restoring the tubes 13, 14, and 13', 14' to their original condition in a manner which will be described hereinafter.

Inasmuch as the apparatus of Fig. 3 includes two pairs of two-equilibrium-mode tubes instead of only one pair, the scale of two output terminals 17 and 18 of Fig. 1 are replaced by a corresponding pair of output terminals 17' and 18 which are indirectly connected to the output circuits of the tubes 13 and 14' through a discharge tube circuit 74, the action of which will be described more in detail hereinafter. In order that the apparatus of Fig. 3 may be operated either in the normal manner so as to produce only one "on" and "off" operation, or the operation may be repeated as in the case of Fig. 1, a suitable change-over switch 75 is provided which may take the form of a single pole double-throw switch having a movable contact 76 and a pair of stationary contacts 77 and 78. For normal or single operation, contacts 76 and 77 are brought together and for repeat operation contacts 76 and 78 are brought together. The movable contact 76 is connected to the anode of the commutating tube 12 and the stationary contact 78 is connected to the anode of the two-equilibrium-mode tube 13, so that when the switch 75 is in the repeat position with the circuit closed between the contacts 76 and 78, the tubes 13 and 14 only are effective and they are connected to the tubes 12 and 11 to produce the same action as in Fig. 1. However, when the switch 75 is in the normal position with the circuit closed between the contacts 76 and 77, the commutating tube 12 has its anode connected to the anode of the tube 14' instead of the tube 14 and therefore serves to commutate the tube 14' instead of the tube 14.

The electric discharge device circuit 74 in the form illustrated consists of a pair of discharge devices 79 and 80 and a rectifying device 81. These devices may take the form of vacuum

tubes, the tubes 79 and 80 being shown as triodes with anodes, cathodes and control electrodes or grids represented by the customary symbols, and the rectifying tubes 81 taking the form of a diode rectifier. The cathode 82 is connected with the cathode of the triode 79 and the anode 83 is connected in series with a resistor 84 to the cathode of the triode 80. The anodes of the tubes 79 and 80 are connected to a source of anode voltage 10' which is common to the tubes 45 and 46 of the amplifier 9, and the cathodes of the tubes 79 and 80 are connected to the negative side of the source 10' by grounding them through cathode resistors 85 and 86, respectively. The control electrode of the tube 80 is connected to the junction terminal of resistors 27a and 27b which are interposed between the anode of the tube 13 and the control electrode of the tube 14. The control electrode of the tube 79 is connected to the junction terminal of resistors 28a' and 28b' which are interposed between the anode of the tube 14' and the control electrode of the tube 13'. The output terminal 17' for applying control bias to the amplifier 9 is connected to the anode 83 of the diode rectifier 81.

The reset circuit 73 consists of a pair of electric discharge devices which may take the form of triode vacuum tubes 87 and 88, having anodes, cathodes and control electrodes represented by the customary symbols. The anode of the tube 87 is connected to the anode of the tube 13' and the anode of the tube 88 is connected to the anode of the tube 13. The cathodes of the tubes 87 and 88 are grounded. The control electrodes of the tubes 87 and 88 are negatively biased to cutoff by connection to the source 29 through a suitable resistor and are connected in series with a resistor 89 and a normally open switch 90 to a suitable source of positive potential such as a point on the source 10' or a separate battery 91 grounded on the negative side.

When the change-over switch 75 is in the repeat position the vacuum tube circuit 74 acts merely as a coupling and the action is the same as explained in connection with Fig. 1. When the change-over switch 75 is in the normal position with the contacts 76 and 77 together, only one "on" and "off" action of the amplifier 9 is produced. It is assumed that the two-equilibrium-mode tubes 13 and 13' are initially conducting and that the tubes 14 and 14' are in non-conducting condition or are in the condition of carrying minimum current. As explained in connection with Fig. 1 the commutating tube 11 then has its auxiliary control electrode or #3 grid at an elevated potential so that it is in a condition to be responsive to impulses applied at the terminal 15. At the same time the commutating tube 12 is not in condition to respond to such impulses. When the first control impulse is received at the terminals 15 and 16 the commutating tube 11 becomes conducting momentarily and commutates the tube 14 to shift the current flow from the tube 13 to the tube 14. This lowers the potential of the #3 grid of the commutating tube 11 and renders it unresponsive to any further impulses applied to the #1 grid from the input terminal 15. The potential of the #3 grid of the tube 12 is simultaneously raised so that when the next impulse is received the commutating tube 12 will be responsive thereto.

The effect of the shift in current from the tube 13 to 14 is to raise the potential of the control electrode of the tube 80 therefore rendering

the latter conducting, passing current through the cathode resistor 86 and raising the potential of the anode 83 of the diode rectifier 81 to cause current to pass through it. Consequently, current flows also through the resistor 85 and the potential of the output terminal 17' is raised to the value represented by the potential drop in the resistor 85 plus the interelectrode drop in the diode 81. Accordingly, the grid potentials of the amplifier 9 are raised above the threshold value and the amplifier 9 is turned on.

When the next control impulse is applied to the input terminals 15 and 16 of the counter circuit 8' the tube 12 is, as already explained, in condition to be responsive and transfers the impulse to the anode of the tube 14' causing the latter tube to become conducting. Thus current is shifted from the tube 13' to the tube 14', and the potential of the control electrode of the tube 79 is lowered. Accordingly the flow of current in the tube 79 is diminished or cut off lowering the potential of the cathode of the tube 79 and correspondingly lowering the potential of the output terminal 17'. The circuit constants are such that this lowering of potential lowers the grid bias of the amplifier 9 below the "off" threshold and turns the amplifier 9 off. Any further impulses applied to the input terminals 15 and 16 will have no effect on the counter circuit 8' since current has already been shifted from the tube 13 to the tube 14 and from the tube 13' to the tube 14', and these pairs of tubes are in their equilibrium condition so that the current does not shift back.

If it is desired to reset the counter circuit 8' to its original condition so that it will perform another "on" and "off" operation the reset switch 90 is closed momentarily which thus raises the control electrode potential of the tubes 87 and 88 causing them to act as short circuits across the anode-cathode circuits of the tubes 13' and 13. This action commutates the tubes 13' and 13 and shifts the current back to them from the tubes 14' and 14.

I have herein shown and particularly described certain embodiments of my invention and certain methods of operation embraced therein for the purpose of explaining its application, but it will be obvious to those skilled in the art that many modifications and variations are possible, and I aim therefore to cover all such modifications and variations as fall within the scope of my invention which are defined in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. An electronic switch with negligible switching transients comprising a pair of electric discharge devices each having an anode, a cathode and a control electrode connected in push-pull relationship, a cathode degenerative resistor, a regulated voltage impedance, a pair of rectifying devices, load circuit connections for energizing the anode-cathode circuits of the discharge devices and connections for applying a variable control bias to the control electrodes of the discharge devices and for applying input signal voltage to the control electrodes with opposite polarities, the regulated voltage impedance being connected in series with one of the rectifying devices between the anode and cathode of one of the electric discharge devices and being connected in series with the other of said rectifying devices between the anode and cathode of the other of said electric discharge devices, the regulated

voltage impedance being selected to have such a voltage in combination with the voltage drop of the rectifying devices as to hold the potential of the cathodes of the discharge devices up to a point just above that required for non-conduction in the discharge devices with the control bias maintained at its lowermost potential value.

2. An electronic switch with negligible switching transients comprising a pair of electric discharge devices each having an anode, a cathode and a control electrode connected in push-pull relationship, a regulated voltage impedance, a pair of rectifying devices, connections for energizing the anode-cathode circuit, a cathode degenerative resistor connected in series with the cathode and an anode resistor connected in series with the anode through the energizing connections, connections for applying a control bias variable between predetermined limits in the control electrode cathode circuit, the regulated voltage impedance and a rectifying device being connected in series between the anode and the cathode of each electric discharge device, the regulated voltage impedance being selected to have a potential difference of such a value as to limit the potential difference between the anodes and cathodes to a predetermined value just below that sufficient to render the electric discharge devices amplifying when the control bias is at the minimum for turning the amplification off.

3. In combination, an electronic discharge device having an anode, a cathode and a control electrode, connections for applying a control bias variable between predetermined limits in the control electrode circuit for rendering the discharge device amplifying or non-amplifying, load-circuit connections for energizing the anode-cathode circuit, a cathode degenerative resistor connected in series with the cathode and anode through the energizing connections, a rectifying device and a constant voltage device, said rectifying device and said constant voltage device being connected in series between the anode and cathode of the said electric discharge device, the constant voltage device being selected to have a potential difference of such a value as to limit the potential difference between the anode and cathode to a predetermined value just below that sufficient to render the electric discharge amplifying when the control bias is at a minimum for turning the amplification off.

4. Apparatus of the character set forth in claim 3 including a resistor connected in series with the constant voltage device and a condenser connected across the last-mentioned resistor and the constant voltage device.

5. In combination, a current-controlling device having a voltage responsive control circuit and having an anode and a cathode, connections for energizing the anode-cathode circuit, connections for applying a control bias variable between predetermined limits in the control electrode circuit for rendering the current controlling device relatively conducting or non-conducting, and a voltage regulated impedance connected in circuit between the anode and the cathode of said current-controlling device, the regulated voltage impedance being selected to have a potential difference of such a value as to limit the difference between the anode and cathode to a predetermined value just below that sufficient to render the current controlling device relatively conducting when the control bias is

at the minimum for rendering the current controlling device relatively non-conducting.

6. An electronic switch comprising a pair of commutating discharge devices each having an anode, a cathode, a primary control electrode, and an auxiliary control electrode, a pair of two-equilibrium-mode discharge devices each comprising an anode, a cathode and a control electrode with anodes and control electrodes cross coupled and couplings between their respective circuits and the auxiliary control electrodes of the first-mentioned pair of tubes respectively, a second pair of two-equilibrium-mode discharge devices each having an anode, a cathode and a control electrode with cross-couplings between the anodes and control electrodes, commutating connections between one of the commutating discharge devices and one of the devices of the first pair of two-equilibrium-mode discharge devices, commutating connections between the other commutating discharge device and a different one of the devices of the two-equilibrium-mode discharge devices, an amplifier adapted to be turned on and off in response to biasing potentials above and below predetermined values having a bias voltage terminal and a coupling circuit interposed between the bias terminal of the amplifier and the circuits of the first device of the second pair of discharge devices and the second device of the third pair of discharge devices for successively raising and lowering the amplifier bias voltage in response to current shifts in the second and third pairs of discharge devices, the first device of each of said second and third pairs of discharge devices being initially in conducting condition whereby a control input impulse applied to the primary control electrodes of the first pair of discharge devices is transmitted through the first of such devices to the second pair of discharge devices to shift the current, and a second impulse applied to the primary control electrodes of the first pair of discharge devices is transmitted through the second of said devices to the third pair of discharge devices for shifting the current therein.

7. An electronic switch comprising an amplifier having input bias terminals adapted to have bias potentials applied thereto for turning an amplifier on or off according to the magnitude of the potential, a scale of two counter circuit with control impulse input terminals adapted to have control impulses applied thereto and output terminals connected to the bias terminals of the amplifier for controlling the amplifier, said counter circuit comprising a pair of sections each providing alternate current paths with output connections from said sections to the output terminals of the scale of two counter, and current controlling devices successively responsive for transmitting control impulses first to one of said alternative current path sections and then to the other from said control input terminals for successively shifting the current paths in said sections and thus raising and lowering the potentials at the output terminals for turning the amplifier on and off.

8. A current controlling device with a pair of terminals and a voltage responsive control element adapted to have the potential thereof with respect to one of said terminals raised or lowered for rendering the device relatively conducting or non-conducting, and a voltage limiting unit connected between the terminals of the device for limiting the voltage therebetween to a value below that at which the device can become relatively

conducting with minimum control potential applied to the control element whereby relatively little change in voltage between the terminals of the device takes place when it is rendered relatively conducting or non-conducting and switching transients are thereby minimized.

9. Apparatus adapted to be rendered effective or ineffective to transmit electrical effects referred to as signal impulses in response to the successive application of electrical effects referred to as control impulses and unresponsive to the reception of more than two controlling impulses, said apparatus comprising a principal current controlling device for transmitting the said signal impulses having an electroresponsive control for rendering the device relatively conducting or non-conducting, a double-throw impulse transmitting apparatus having two alternative positions responsive to variation in control potential, a pair of alternative current path devices each having control means for rendering one or the other of two alternative current paths therein relatively more conducting than the other in response to electrical impulses and including electrical impedance in the alternative current paths for raising or lowering potentials at points therein in response to variations in current flow produced by relative variations in conductivity, and coupling means for transmitting oppositely effective control impulses from said alternative current path devices to the electroresponsive element of the main current controlling device in response to successive current shifts in the first and second alternative current path devices, the variable potential points of said alternative path devices being connected to the said double-throw impulse transmitting apparatus for making it effective successively to transmit control impulses first to one alternative current path device and then to the other whereby the first received control impulse is transmitted to the first of the alternative current path devices to shift current therein and transmit a control effect to the electroresponsive element of the main current controlling device for changing its condition, the

second received control impulse is transmitted to the second of said alternative current path devices for shifting current therein and transmitting a reversely effective control impulse to the electroresponsive element of the main current controlling device for restoring it to its original condition.

10. In combination, a single-pole double-throw switching apparatus having a normal setting and an alternative setting, a pair of electric discharge devices each having an anode, a cathode and a control electrode with cross-couplings between the anodes and control electrodes to maintain one or the other of the discharge devices in conducting condition while it biases the other to cut-off, couplings between the switching apparatus and the discharge devices for transferring impulses transmitted through the switching apparatus to one or the other of the discharge devices according to the setting of the switching apparatus, voltage responsive control for the switching apparatus with couplings to the discharge devices for transferring the switching apparatus from one setting to the other according to which of the discharge devices is in conducting condition, whereby the application of impulses successively through the switching apparatus transfers conduction back and forth between the discharge devices, and resetting mechanism comprising a current-controlling device adapted to have its conductivity increased, said latter device being connected across that one of said discharge devices which is conducting with normal setting of the apparatus for lowering the anode potential of said last-mentioned discharge device, transferring conduction to it, and restoring the apparatus to its normal setting, if in the alternative setting.

11. Apparatus of the character set forth in claim 10 in which the current-controlling device is an electric discharge device having a control electrode adapted to be energized for resetting the apparatus.

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