

Sept. 30, 1952

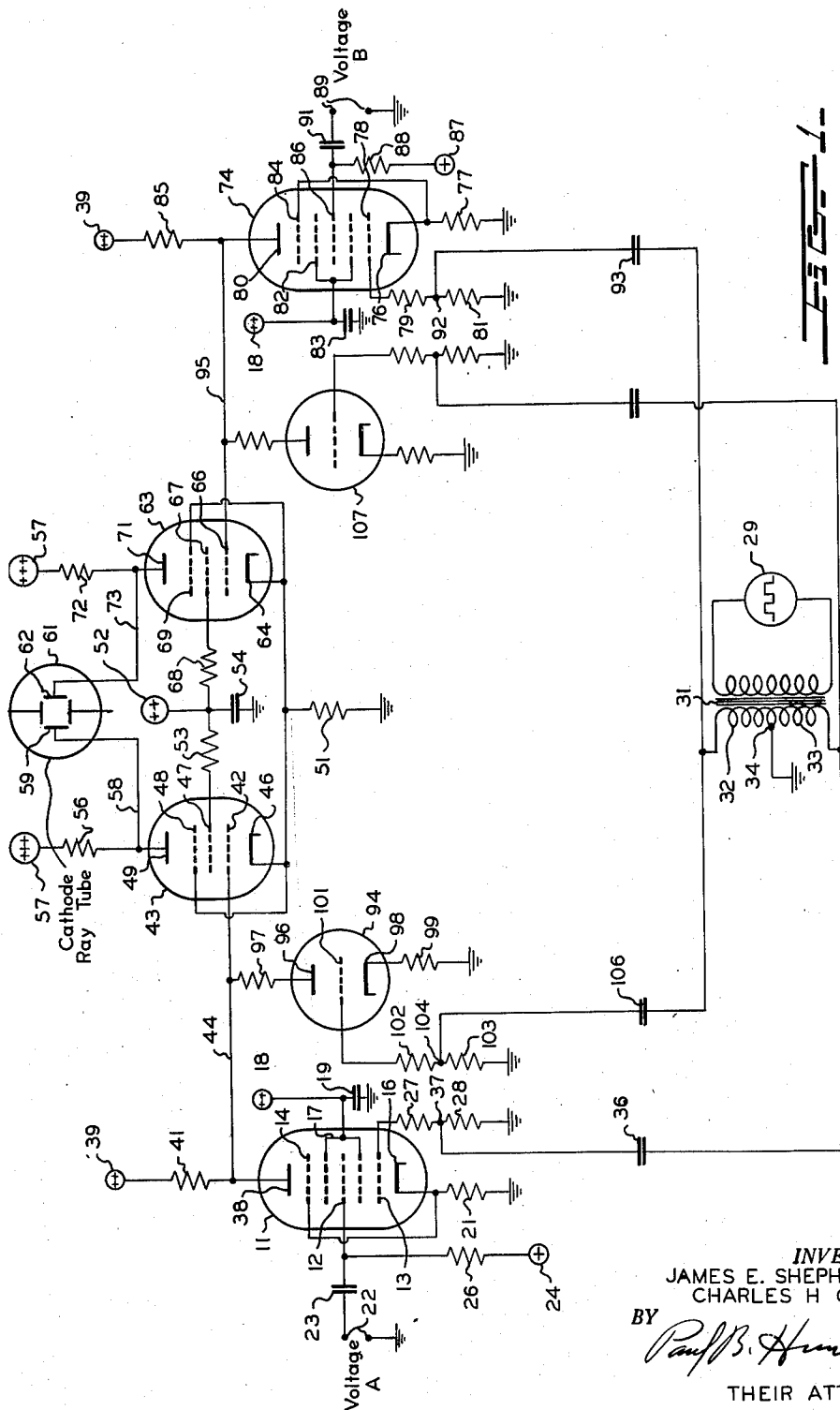
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2,612,621

CONTROL CIRCUITS FOR CATHODE-RAY TUBES

Filed June 18, 1942

2 SHEETS—SHEET 1



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2 SHEETS—SHEET 2

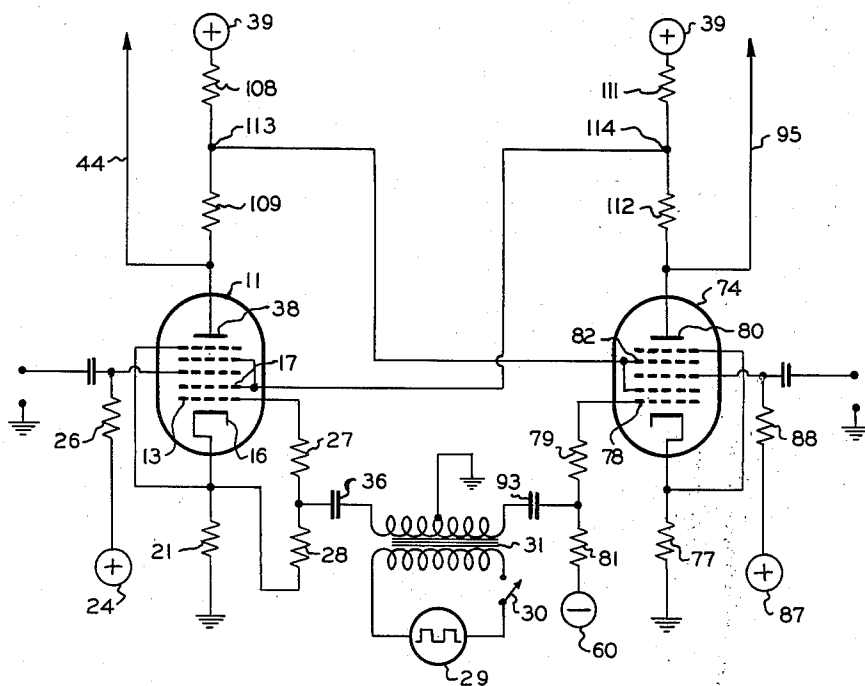


FIG. 2

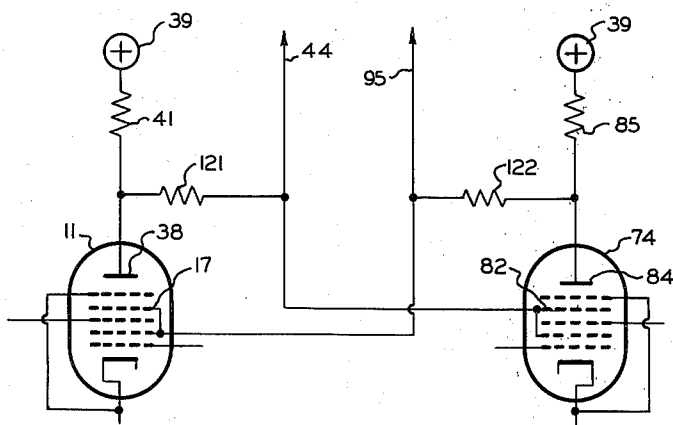


FIG. 3

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CONTROL CIRCUITS FOR CATHODE-RAY
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The present invention relates to the art including cathode ray tube control circuits.

For producing bright indications on a cathode ray screen, high accelerating voltages are required, resulting in low deflection sensitivity. Under these conditions, large deflecting voltages are required to completely move the trace from one side of the cathode ray tube screen to the other. These voltages may be of the order of 700 volts. Systems are known in which a single amplifier provides this deflecting voltage. However, a large voltage requirement of this sort generally exceeds the voltage rating of the power supply and of the tube itself for tubes ordinarily used in such devices. A further disadvantage of prior art devices resides in the fact that, with high accelerating voltages, serious de-focusing of the spot trace may result unless the average voltage of each pair of deflecting plates is kept approximately constant.

These disadvantages may be overcome by the use of push-pull amplifiers for supplying the deflecting potentials, whereby the maximum voltage of each deflecting plate is reduced to substantially half that required from a single amplifier, permitting the use of commercially available tubes and power supplies, and whereby, further, the average potential of each pair of plates is kept substantially fixed.

Where it is desired to control a cathode ray tube by two distinct inputs to alternately produce corresponding traces on the screen of the cathode ray tube at a rate sufficiently high to render these traces simultaneously visible, as in the present invention, further problems are encountered. In many prior systems, alternating current amplifiers for the input control voltages are used, upon whose output is superposed a uni-directional voltage for determining the average spot position. Where it is desired to superpose two or more indications, such a system suffers the disadvantage that the average or central positions of all the cathode ray patterns are controlled simultaneously and cannot be independently controlled.

In order to avoid this difficulty, the present invention uses a direct current amplifier for supplying the complete deflecting potentials required. This amplifier is of the push-pull type for the reasons discussed above and is controlled by an electronic switch having separate switching tubes which alternately provide respective control voltages to be applied to the deflecting plates of the cathode ray tube by this amplifier. Separate uni-directional pattern positioning voltages may be then supplied to each of the switching tubes so

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that the respective cathode ray patterns produced on the screen of the tube may be independently positioned by simple low voltage positioning controls, without being affected by the positioning control for any other pattern.

The present invention thus provides an efficient and desirable device whereby two or more rapidly varying voltages, which, for example, may comprise a high frequency test voltage and a sweep voltage, or a test voltage and a timing wave, may be simultaneously viewed on a cathode ray screen, and each pattern may be positioned independently on the screen.

In addition, it may be desirable in some cases to change the position of any or all patterns at some slow rate. This may be easily accomplished by the system of the invention by superimposing a low frequency alternating voltage on the pattern-positioning voltages already fed through the switching tube. Such a system is inherently capable of extremely fast switching action, and renders itself readily applicable to the simultaneous viewing of rapid recurrent transient phenomenon and other phenomena on the same screen without loss in brilliance of the transient pattern.

Thus, in previous slower acting systems, the transient pattern, for example, would be placed on the screen for half the total time and the other pattern for the remaining time. In the present system, however, the switching period may be made equal to the recurrence period of the transient phenomenon and synchronized with it. Thereby the transient phenomenon pattern may be switched on at each occurrence thereof, and, if it persists for an interval less than half the switching period, will be projected completely on the screen during each of its occurrences, without affecting the usefulness of the screen for showing the other phenomenon during the portions of the switching period when the transient phenomenon does not occur. In this manner, the brilliance of the transient pattern is the same as though the entire cathode ray tube were devoted solely to its presentation, as distinguished from prior systems in which the transient period can be only a fraction as bright because of its appearance on the screen for only a fraction of time.

Accordingly, it is an object of the present invention to provide improved control circuits for cathode ray tubes.

It is another object of the present invention to provide improved control circuits for cathode ray tubes controlled by a plurality of input voltages.

It is a further object of the present invention to provide improved control circuits for the de-

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deflecting plates of the cathode ray tubes controlled by a plurality of input voltages and providing independently positionable traces upon the screen of the cathode ray tube.

It is still another object of the present invention to provide improved control circuits for the deflecting plates of cathode ray tubes employing push-pull direct-coupled amplifiers.

It is a still further object of the present invention to provide improved control circuits for the deflecting plates of cathode ray tubes employing push-pull direct-coupled amplifiers having a pair of inputs independently and alternately controlled from an electronic switch comprising a pair of switching tubes.

It is still another object of the present invention to provide an improved electronic commutating circuit adapted to sequentially and periodically transmit several input voltages to the output thereof.

It is still another object of the present invention to provide an improved electronic commutating system for alternately transmitting plural input voltages, wherein the average output potential of said commutating system for each of said input voltages may be independently adjusted.

It is yet another object of the present invention to provide an improved electronic switching circuit under the control of a switching voltage, in which the circuit is rendered substantially independent of fluctuations in magnitude of the switching voltage.

It is still a further object of the present invention to provide improved apparatus for rendering an electronic discharge tube alternately conductive and non-conductive while maintaining substantially constant the average output voltage thereof.

It is still another object of the present invention to provide improved apparatus for rendering a pair of electron discharge tubes alternately and oppositely conductive and non-conductive while maintaining substantially constant the average output potential of each of the tubes.

Other objects and advantages will become apparent from the specification, taken in connection with the accompanying drawings wherein the invention is embodied in concrete form.

In the drawings,

Fig. 1 shows a circuit diagram of one embodiment of the present invention.

Fig. 2 shows a modification of the invention of Fig. 1.

Fig. 3 shows a modification of the invention of Fig. 2.

Referring to Fig. 1, there is shown one type of electronic switch embodying the features of the present invention. There is provided a switching tube 11, preferably of the mixer type having two independent input electrodes, viz., control grid 12 and control grid 13. The usual suppressor grid 14 is connected to cathode 16 and a screen grid 17 is provided connected to a suitable source of positive potential indicated schematically at 18, and by-passed to ground for alternating currents by the usual by-pass condenser 19. Cathode 16 is connected to ground through a suitable cathode biasing resistor 21, which produces a desired bias voltage for the two control grids 13 and 12.

Control grid 12 is energized through a suitable coupling condenser 23 from one of the input voltages to be commutated, indicated as voltage A connected to terminals 22. Control

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grid 12 is also connected to a suitable source of positive biasing potential 24 through a grid input resistor 26. The potential of source 24 is preferably adjustable, and is suitably adjusted so as to maintain the average potential or bias on grid 12 at a value slightly negative with respect to cathode 16, and of such a value that tube 11 may act as a class A amplifier for voltage A connected to input terminals 22. As will appear later, the voltage of source 24 is made adjustable to adjust the position of the cathode ray pattern corresponding to voltage A.

Control grid 13 is connected to ground through series-connected grid-current-limiting resistor 27, which is preferably of a high value compared to the internal grid-to-cathode impedance of tube 11, and resistor 28, which serves as an input or coupling resistor for grid 13.

A source 29 of switching voltage is provided, which energizes a suitable transformer 31 having a center tapped secondary winding 32, 33, the center tap 34 being grounded, as shown. Any other phase inverting device for producing two oppositely phased voltages may be used in place of transformer 31. The switching voltage controlling the conductivity of tube 11 is derived from one section 33 of the secondary winding of transformer 31, and is connected by way of a coupling and blocking condenser 36 to the junction point 37 of resistors 27 and 28.

The anode 38 of switching tube 11 is connected to a suitable source of positive anode potential 39 through an output resistor 41. The output voltage of tube 11 is fed directly to the input grid 42 of an amplifying tube 43 by means of a direct connection 44 between anode 38 of tube 11 and control grid 42. Amplifying tube 43 is shown as comprising a conventional pentode amplifier having the usual cathode 46, screen grid 47, suppressor grid 48 and anode 49, but may be any conventional type of amplifying tube. Cathode 46 is connected to ground through suitable cathode biasing resistor 51 which provides the proper bias for control grid 42. Preferably, this resistor 51 is so chosen that the average potential of cathode 46, with respect to ground, is slightly higher than that of anode 38 and grid 42, whereby the proper bias is derived for grid 42 to permit undistorted amplification by tube 43. This is feasible, since source 57 supplying the anode of tube 43 may have a substantially higher positive potential with respect to ground than does source 39 supplying anode 38 of tube 11.

Screen grid 47 is connected to a suitable source of positive potential 52 through a voltage-dropping resistor 53 and is provided with a by-pass condenser 54. Suppressor grid 48 is connected to cathode 46 in the usual manner. Anode 49 is connected through an output resistor 56 to a suitable source of high positive potential 57. Anode 49 is also directly connected as by lead 58 to one of the deflecting plates 59 of the cathode ray tube 61.

For the energization of the other deflecting plate 62, a second amplifying tube 63 is provided whose cathode 64 is connected directly to cathode 46 of tube 43. In this manner, cathode biasing resistor 51 is common to both amplifier tubes 43 and 63. Control grid 66 of tube 63 is provided with grid bias in a manner which will be later described, this bias being substantially the same as the average or zero signal potential of anode 38 of tube 11, whereby the bias on

control grid 66 of tube 63 is the same as that on control grid 42 of tube 43 and is held constant while voltage A is operative to deflect the cathode ray beam.

Screen grid 67 of tube 63 is connected to a positive potential source, which may be the same as source 52, through resistor 68. Suppressor grid 69 of tube 63 is connected directly to its cathode 64 in the usual manner. Anode 71 of grid 63 is connected to a high positive potential source, which may be the same as source 57, through its output resistor 72. Anode 71 is also connected directly as by lead 73 to the second deflecting plate 62 of cathode ray tube 61.

Thus, any voltage impressed upon control grid 42 of amplifier 43 will be amplified and a corresponding potential will be impressed on deflecting plate 59. At the same time, the potential of cathode 46 will also vary in accordance with this input signal, since biasing resistor 51 is not by-passed. This variation of voltage across resistor 51 produces a varying voltage between cathode 64 and control grid 66 of amplifier 63, which will thereby amplify this varying voltage. Accordingly, it will be clear that the potential of lead 73 will vary similarly to that of lead 58. However, the variation in potential of these two leads 58, 73, and hence of deflecting plates 59, 62, will be exactly in opposite senses by virtue of the phase reversal produced by means of the common cathode biasing resistor 51. Therefore, push-pull potentials, substantially balanced with respect to ground, are impressed upon the deflecting plates 59 and 62 of the cathode ray tube 61, resulting in bilateral deflections of the cathode ray beam.

It is to be noted that by this method a larger variation of deflecting voltage can be produced than in the ordinary situation where one of the deflecting plates is grounded. In the latter situation the voltage applied to the ungrounded deflecting plate must be able to swing positive and negative by the full amount of the desired deflecting potential. In the present case, however, the equivalent deflecting potential can be produced by a change in the instantaneous potential output of one or the other of tubes 43, 63, of an amount approximately only half the required deflecting potential and hence only half the required deflecting potential and hence only half the amount of control voltage is needed. In addition, the necessity for producing negative as well as positive voltages is completely obviated by the present system.

It is to be noted that the control signal may be impressed upon either of the two control grids 42 and 66, and that in this respect the circuit is completely symmetrical. In effect, the circuit comprising tubes 43 and 63 forms an extremely efficient and useful phase inverter capable of producing a substantially balanced push-pull output from any type of single voltage input. This phase inverter, of course, is capable of wide use outside the circuit of the present system.

Control grid 66 of amplifier 63 is connected to the output of a second switching tube 74 similar in all respects to tube 11 already described. Thus, the cathode 76 of tube 74 is connected to ground through its biasing resistor 77. Control grid 78 is connected to ground through its current-limiting resistor 79 and input resistor 81. Screen grid 82 is connected to the source of positive potential 18 and is provided with a bypass condenser 83. Suppressor grid 84 is connected directly to cathode 76. Anode 80 is con-

nected through output resistor 85 to positive source 39, and by lead 95 to grid 66.

The second control grid 86 of tube 74 is provided with bias from an adjustable voltage source 87 (which may be the same as source 24 except when independent positioning of the cathode ray patterns is desired for the two input signals A and B) through input resistor 88, again of such value as to maintain tube 74 in a class A amplifying condition. The second input signal, indicated as voltage B, is connected to terminals 89 and is led to control grid 86 through a suitable coupling condenser 91.

The junction 92 of resistors 79 and 81 is led through a coupling and blocking condenser 93 to the second section 32 of the secondary winding of transformer 31, whereby a switching voltage equal to and opposite in phase to the voltage impressed at point 37 of the circuit of tube 11 is impressed at point 92.

In operation, the switching voltages derived from secondaries 32 and 33 act to alternately block and unblock switching tubes 11 and 74, thus causing first voltage A and then voltage B to be impressed on deflecting plates 59, 62 of cathode ray tube 61. Thus, during half cycles of the switching voltage of such a polarity that a positive potential is applied at point 37, it will be seen that grid 13 is rendered positive with respect to ground. The amplitude of switching voltage is preferably so chosen that grid 13 is also thereby rendered positive with respect to cathode 16, whereby grid current flows between grid 13 and cathode 16. This grid current also flows through the grid-current-limiting resistor 27, and the volt-drop therein produced reduces the potential of control grid 13 to a value only slightly above that of cathode 16.

When this is done, tube 11 is conditioned to act as a class A amplifier, and will then amplify its input voltage A, which is thereby impressed upon control grid 42 and serves to control the potentials applied to deflecting plates 59 and 62 of cathode ray tube 61 in the manner already indicated.

It is to be noted that the present system is rendered substantially independent of fluctuations in the amplitude of the switching wave above its average value so long as this amplitude is sufficient to draw definite grid current through grid 13, and at the same time to cut-off tube 74, as will later appear, since, no matter what the amplitude of the switching voltage may be, the potential of grid 13 is caused to remain substantially unchanged with respect to cathode 16.

During these same half cycles of this switching voltage in which tube 11 is conductive, a negative voltage will be applied to grid 78 of tube 74. The amplitude of the switching voltage is also selected or adjusted so that this negative voltage applied to grid 78 will be sufficient to bias tube 74 beyond cut off, whereby no electrons are permitted to flow from cathode 76 to anode 80 and hence the plate current of tube 74 is completely cut off.

During the half cycles of the switching voltage of reverse polarity, it will be clear that tubes 11 and 74 will interchange their conditions, that is, tube 11 will become blocked, and tube 74 will transmit its input voltage B to the deflecting plates 59, 62 in the manner described.

Considering tube 11 for the moment, it will be clear that since during its conductive periods it operates as a class A amplifier, in which a standby or zero signal current continuously flows, the average or zero-signal potential of anode 38 will

be less than that of source 39 by the amount of the stand-by volt-drop in output resistor 41. Accordingly, the average potential of control grid 42 will be less than the potential of cathode 46 which may be adjusted to be substantially equal to that of source 39, whereby tube 43 can act as a class A amplifier.

During the same half cycles of switching voltage, tube 74 is blocked and the bias potential of grid 66 will rise to equal that of source 39 and hence will have lower or even positive bias with respect to cathodes 46 and 64. This is undesirable since it creates an unbalanced condition between amplifiers 43 and 63 and may introduce distortion. It will be clear that an opposite unbalance occurs during the other half cycles of the switching voltage. These conditions produce undesired unbalance and distortion in the cathode ray tube deflecting voltages.

To overcome this difficulty it is necessary to maintain the average potential of grids 42 and 66 substantially constant during both halves of the switching cycle. Referring to tube 11 for the moment, an auxiliary tube 94 is associated therewith for this purpose. The anode 96 of tube 94 is connected to anode 38 and control grid 42 through a resistor 97. Tube 94 is shown as being a triode but may be of any grid-controlled type. The cathode 98 of tube 94 is connected to ground through a suitable biasing resistor 99. The control grid 101 of tube 94 is connected to ground through series-connected resistors 102 and 103, resistor 102 serving as a grid-current-limiting resistor and resistor 103 as an input resistor for a switching voltage. The junction 104 of resistors 102 and 103 is connected through a suitable coupling and blocking condenser 106 to secondary winding 32 of switching voltage transformer 31, whereby grid 101 is supplied with switching voltage of phase opposite to that supplied to control grid 13.

Thus, during the periods when tube 11 is conductive, the bias on tube 94 is so selected or adjusted that the negative switching voltage applied thereto will be sufficient to bias this tube beyond cut off, whereby no current is drawn from source 39 through tube 94. During the half cycles of opposite polarity, in which tube 11 is blocked, the now positive switching voltage applied to grid 101 is selected of sufficient amplitude to raise the potential of grid 101 above that of cathode 98, whereby grid current flows and resistor 102 drops the potential of grid 101 to a value only slightly above that of cathode 98.

With this situation, resistor 97 is so chosen as to cause a current flow from source 39 through resistors 41 and 97 and tube 94 of a value substantially equal to the stand-by or quiescent current during periods when tube 11 is conductive. In this manner, the average potential or bias of grid 42 is maintained constant during both the conducting and blocked periods of tube 11.

A similar grid-potential-controlling tube 107 is supplied for tubes 74, and acts in a similar manner to maintain the average potential of grid 66 at a substantially constant value during the entire switching cycle, if desired. Here again it will be seen that the action of grid-potential-controlling tubes 94 and 107 is rendered substantially independent of the peak value of the switching voltage, thereby providing deflection controlling voltages for the deflecting plates 59 and 62 of cathode ray tube 61 which are substantially independent of the magnitude of the switching voltage.

It is to be noted that tubes 94 and 107 may be controlled to produce a different average potential for grids 42 and 66 during the blocked condition of switching tubes 11 and 74 from that during the unblocked condition of these tubes, if desired.

It is to be noted also that the use of a balanced circuit as in the present device also causes the deflecting voltages to be substantially independent of variations in the potential of sources 39 or 57, since such variations will produce equal variations in the same sense in the potentials of plates 59 and 62, whereby the potential difference applied between plates 59 and 62 is not changed.

Since the adjustable voltage sources 24 and 87 are relatively low in voltage compared with the potential difference to be applied to the cathode ray deflection plates 59 and 62, the arrangement described provides for independently positioning the respective cathode ray patterns by simple low voltage positioning controls. The application of such separate unidirectional pattern-positioning voltages to the switching tubes eliminates the necessity for handling the high voltages in the cathode ray deflection plate circuits. The adjustment of the potential of the adjustable voltage source 24, for example, by varying the bias on the grid 12 of the switching tube 11, provides for varying the average potential of bias of the grid 42 of the amplifier 43 and serves for positioning the cathode ray pattern of the cathode ray tube.

Fig. 2 shows a modification of the grid-bias-maintaining apparatus of Fig. 1. Thus in Fig. 2 tubes 94 and 107 have been eliminated and instead the current characteristics of the screen grids of tubes 11 and 74 have been employed to provide the constant bias potential for grids 42 and 66. Thus, in Fig. 2 output resistor 41 of tube 11 has been split into two portions 108 and 109. In a similar fashion, output resistor 85 of tube 74 has been split into two portions 111 and 112.

The potential of screen grid 82 of tube 74 is now derived from the junction 113 of resistors 108 and 109 to which it is directly connected. In a similar fashion, the potential of screen grid 17, tube 11, is derived from the junction 114 of resistors 111 and 112 to which it is directly connected.

Mixer tubes, such as 11 and 74, have been found to have a characteristic such that their screen grid currents are of higher value than their anode currents. Furthermore, the screen grid currents have been found to vary oppositely to the anode currents; that is, a change in input voltage such as to produce an increase in anode current will simultaneously produce a decrease in screen grid current. These characteristics are taken advantage of in the present circuit. Thus, during the periods when tube 11 is conductive and tube 74 is blocked, the potential of anode 38 of tube 11 is supplied from source 39 through resistors 108 and 109. Since tube 74 is blocked by means of the now negative switching voltage applied to its control grid 78, its screen grid 82 takes no current and hence the volt drop produced in resistors 108 and 109 is due entirely to the anode current of tube 11. If the average potential of cathode 46 is made the same as source 39, the average value of this volt-drop across 108, 109 supplies the grid bias for grid 42.

At the same time, the potential for screen grid 17 of tube 11 is provided from source 39 through resistor 111. Since the screen grid current is larger than the anode current, a value for re-

sistor 111 may be chosen so that the screen grid current of screen grid 17 flowing through resistor 111 will produce a volt-drop equal to that of the average anode current of tube 74 flowing through resistors 111 and 112 in series during the other half of the switching cycle. In this manner, during periods when tube 74 is blocked, the potential of point 114 may be made equal to the potential of anode 80 during the periods when tube 74 is conductive, whereby the average potential of lead 95 and grid 66 of amplifier 63 remains unchanged during the whole switching cycle. In the same way, the bias of grid 42 is also kept constant.

In the usual type of operation, screen grids 17 and 82 would be by-passed completely to ground with respect to alternating currents, whereby their potentials would remain substantially unchanged. However, if these screen grids are not completely by-passed to ground, then, by virtue of the tube characteristic just described, in which anode and screen grid currents vary equally and oppositely, it will be seen that, for example, during the periods when tube 11 is conductive and tube 74 non-conductive, a variation in anode current in one sense producing a variation in the input potential of control grid 42 in the same sense will be accompanied by a proportional variation in screen current of opposite sense, which will produce a corresponding variation in the potential applied to grid 66 of tube 63 in this opposite sense, and, accordingly, the push-pull action of the common biasing resistor 51 may be assisted by the action of the screen grid currents when not by-passed to ground. In this manner, in the arrangement of Fig. 2 as in the arrangement of Fig. 1, the same control voltage from the switching source 29 causes one electronic switch to be loaded when it is rendered non-conducting, and causes the other electronic switch to be unloaded when it is rendered conducting, and vice versa, in order to maintain the average output potentials of the switching tubes substantially constant.

In Fig. 2, the switching voltage input resistor 28 for grid 13 of tube 11 is connected directly to cathode 16, and corresponding resistor 81 of tube 74 is connected to a source 60 of negative biasing potential. In this manner, when switch 30 is opened, so that the switching voltage from source 29 is no longer impressed on tubes 11 and 74, tube 11 is rendered conductive and tube 74 non-conductive, so that switching action is interrupted and only voltage A is continuously applied to the cathode ray tube. If desired, of course, this same arrangement could be used in Fig. 1.

If it is desired to superpose both voltages A and B upon the deflecting plates 59, 62, this may be done by rendering both switching tubes 11 and 74 conductive simultaneously, as by removing the switching voltage and by proper adjustment of bias sources 24, 87. In this case, interaction between the two input voltages A and B would be substantially absent.

Referring once more to Fig. 1, it will be clear that if desired tubes 74 and 11 may have their anodes connected directly together, utilizing a common output resistor. If this is done, the necessity for the use of tubes 94 and 107 would be removed, since the average or stand-by current will be drawn through the common output resistor by one or the other of these two tubes, depending upon which is conducting at the moment in question. In this case, input potentials would be applied to only one or the other of grids 42 and 66, the other of these grids being

energized by means of the common cathode resistor 51 and provided with bias by connection to a suitable fixed bias voltage source or to two other similar switching tubes, already described.

If it is desired to impress two potentials simultaneously upon deflecting plates 56 and 62 without mutual reaction of these potentials one upon the other, this may be done by connecting each to a respective control grid 42 or 66 whereby the two potentials will be superposed in their effect upon deflecting plates 56 and 62 but will not react upon one another since they are coupled only by the very high grid-to-cathode impedance of these class A amplifiers.

It is also possible to superpose two input voltages by impressing one upon the control grid, such as control grid 42, and a second upon the screen grid, such as screen grid 47, of one of the amplifier tubes, either tube 43 or 63. In this case, of course, no commutation or switching of these input voltages will be produced but they will be superposed directly and continuously upon the deflecting plates 59 and 62 substantially without interaction.

Also, if desired, four separate input voltages could be switched in pairs and alternately impressed in pairs upon deflecting plates 56 and 62 by the use of two pairs of switching tubes of the type of tube 11 or 74, one pair having anodes connected together and to control grid 42, for example, and the second pair having anodes also connected together and to control grid 66, the two tubes of each pair being alternately switched in the manner described with respect to tubes 11 and 74. In this case, as described above, tubes 94 and 107 and their associated circuits would no longer be required.

Alternatively, four or any other number of waves may be switched in turn by appropriate switching waves applied to respective switching tubes whereby only one such tube is rendered conductive at a time.

As described above the circuit of Fig. 2 is useful where the screen grid currents of the vacuum tubes 11 and 74 used as switching tubes exceed their anode currents. However, under certain conditions and for certain tubes, it is possible for the anode current to exceed the screen grid current. For such tubes it is clear that the circuit of Fig. 2 could not operate to maintain the bias on grids 42 and 66 at the same level during both halves of the switching cycle.

Under these conditions recourse may be had to the circuit of Fig. 3, wherein are shown the anode and screen grid circuits of the tubes 11 and 74 under the assumed condition that the screen grid current is less than the anode current. The circuits of the remaining elements of tubes 11 and 74 are not shown in Fig. 3, but may be the same as in Fig. 2 or in Fig. 1.

In this figure, the screen grid 17 is connected to the anode 84 of tube 74 through a resistor 122 and the screen grid 82 of tube 74 is connected to the anode 38 of tube 11 through a resistor 121. Screen grids 17 and 82 are also connected directly to the amplifier tube grids 66 and 42 by means of the leads 95 and 44, respectively.

Considering now the half cycle of the switching period in which tube 11 is conductive and tube 74 is non-conductive, it will be clear that the variations in potential of the anode 38 of tube 11 will be conducted directly to grid 42 of amplifier 43 and that resistor 121 will have no effect, since no current is drawn therethrough either by control grid 42 or by screen grid 82 of tube 74, the latter

tube being now in a blocked condition. The current for screen grid 17 of tube 11 is drawn from source 39 through the output resistor 85 of tube 74 and resistor 122. By proper choice of resistor 122, the volt drop thus produced across resistors 85 and 122 by the current of screen grid 17 may be made equal to the quiescent volt drop across resistor 85 when tube 74 is conductive. By so doing, the average potential of lead 95 and hence of grid 66 will be the same during the non-conductive periods of tube 74 as during the conductive periods thereof, as is to be desired.

Similarly, the average potential of lead 44 and hence the bias on control grid 42 will be the same during both the conductive and non-conductive periods of switching tube 11, and accordingly the same result is produced as in Fig. 2 even though the tubes 11 and 74 be of the type in which the screen grid current is less than the anode current.

Also, in the same manner as in Fig. 2, the instantaneous variations of the screen grid current flowing through resistors 85 and 122 in the illustration used will produce corresponding variations in the potential of grid 66 and will thereby assist in the push-pull action of amplifiers 43 and 63 so that the effects of the screen grids in Fig. 3 are the same as in Fig. 2 with regard both to maintaining bias and to assisting push-pull action. Accordingly, all remarks directed to Fig. 2 apply also to Fig. 3.

It will be apparent that by the above description there has been shown an electronic commutating cable system capable of wide use apart from the system of the present invention, and embodying the many advantageous features previously discussed.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A control circuit for a cathode ray tube having a pair of deflecting plates, comprising two amplifiers direct-coupled to respective ones of said deflecting plates and having a common un-bypassed cathode resistor, a pair of switching tubes having outputs including respective load resistors respectively connected to the inputs of said two amplifiers, means for applying respective control voltages to the respective inputs of said two switching tubes, means for alternately rendering said switching tubes blocked and conductive, means for maintaining the average potential of each of said switching tube outputs constant for both its blocked and conductive periods, and means for individually adjusting the bias on each of said switching tubes, whereby the average potentials applied to said deflecting plates during said alternate periods may be individually adjusted.

2. A control circuit for a cathode ray tube having a pair of deflecting plates, comprising two amplifiers direct-coupled to respective ones of said deflecting plates and having a common un-bypassed cathode resistor, a pair of switching tubes having outputs respectively connected to the inputs of said two amplifiers, means for applying respective control voltages to the respective inputs of said switching tubes, means for alternately and oppositely rendering said

switching tubes blocked and conductive whereby said deflecting plates are alternately controlled in push-pull fashion by said control voltages, and means for individually adjusting the average values of the respective potentials applied to said deflecting plates under the control of said respective switching tubes.

3. A control circuit for a cathode ray tube having a pair of deflecting plates, comprising two amplifiers direct-coupled to respective ones of said deflecting plates and having a common un-bypassed cathode resistor, means for periodically impressing a control voltage on the input of one of said amplifiers, means for impressing a second control voltage alternately with respect to said first voltage on the input of the other of said amplifiers, whereby each of said voltages controls the potential of both of said plates in push-pull fashion during its respective impressed period, and means for individually adjusting the average values of the respective potentials applied to said deflecting plates under the control of said respective control voltages.

4. A control circuit for a cathode ray tube having a pair of deflecting plates, comprising two amplifiers direct-coupled to respective ones of said deflecting plates and having a common un-bypassed cathode resistor, a pair of screen-grid control tubes having outputs including respective load resistors respectively connected to the inputs of said two amplifiers, means for applying respective control voltages to said two control tubes, means for alternately and oppositely blocking and unblocking said control tubes, and means for maintaining the average potential of each of said control tube outputs constant for both its blocked and unblocked periods, comprising means for passing the screen-grid current of each of said control tubes through at least a portion of the load resistor of the other of said control tubes to maintain the average output potential of said other tube at substantially the same value during both said blocked and unblocked periods.

5. A control circuit for a cathode ray tube having a pair of deflecting plates, comprising two amplifiers direct-coupled to respective ones of said deflecting plates and having a common bypassed cathode resistor, a pair of switching tubes having outputs including respective load resistors respectively connected to the inputs of said two amplifiers, means for applying respective control voltages to the inputs of said two switching tubes, means for periodically rendering said switching tubes blocked and conductive, a control tube connected in parallel with each of said switching tubes, means for periodically rendering each of said control tubes blocked and conductive in synchronism with but oppositely to its respective switching tube, and means for adjusting the current drawn through said load resistors by said control tubes to maintain the average potential of each of said switching tube outputs constant for both its blocked and conductive periods.

6. A control circuit for a cathode ray tube having a pair of deflecting plates, comprising two amplifiers direct-coupled to respective ones of said deflecting plates and having a common un-bypassed cathode resistor, a pair of switching tubes having outputs including respective load resistors respectively connected to the inputs of said two amplifiers, means for applying respective control voltages to said two switching tubes, means for alternately blocking and unblocking said switching tubes, and means for maintaining

the average potential of said switching tube outputs constant for both blocked and unblocked periods.

7. A control circuit for a cathode ray tube having a pair of deflecting plates, comprising two amplifiers direct-coupled to respective ones of said deflecting plates and having a common unbypassed cathode resistor, means for periodically impressing a control voltage on the input of one of said amplifiers, means for impressing a second control voltage alternately with respect to said first voltage on the input of the other of said amplifiers, whereby each of said voltages controls the potential of both of said plates in push-pull fashion during its respective impressed period, and means for maintaining the average potential of each of said inputs substantially constant during both impressed and non-impressed periods of said control voltages.

8. A control circuit for a cathode ray tube having a pair of deflecting plates, comprising two amplifiers direct-coupled to respective ones of said deflecting plates and having a common unbypassed cathode resistor, a pair of switching tubes having outputs respectively connected to the inputs of said two amplifiers, means for applying respective control voltages to the respective inputs of said switching tubes, and means for alternately blocking and unblocking said switching tubes, whereby said deflecting plates are alternately controlled in push-pull fashion by said control voltages.

9. A control circuit for a cathode ray tube having a pair of deflecting plates, comprising two amplifiers direct-coupled to respective ones of said deflecting plates and having a common unbypassed cathode resistor, means for periodically impressing a control voltage on the input of one of said amplifiers, and means for periodically impressing a second control voltage on the input of the other of said amplifiers, and means for alternately rendering said voltage-impressing means effective, whereby each of said voltages controls the potential of both of said plates in push-pull fashion during its respective impressed period.

10. A control circuit for a cathode ray tube having a pair of deflecting plates for controlling the deflection of the cathode ray beam thereof, comprising an amplifier, means direct-coupling the output of said amplifier to one of said plates, means for energizing the input of said amplifier by a control voltage, a second amplifier, means direct-coupling the output of said second amplifier to the other of said plates, a common unbypassed cathode resistor for said two amplifiers, whereby said second amplifier is energized in opposite phase from said first amplifier to produce push-pull deflection of said cathode ray beam, means for energizing the input of said second amplifier by a second control voltage, whereby both said control voltages control said beam deflection, and means for individually adjusting the average bias on said inputs, whereby the average potential of said deflecting plates due to each of said control voltages may be individually adjusted.

11. A control circuit for a cathode ray tube having a pair of deflecting plates for controlling the deflection of the cathode ray beam thereof, comprising an amplifier, means connecting the output of said amplifier to one of said plates, means for energizing the input of said amplifier by a control voltage, a second amplifier, means for connecting the output of said second amplifier

to said other plate, a common unbypassed cathode resistor for said two amplifiers, whereby said second amplifier is energized in opposite phase from first amplifier to produce push-pull deflection of said cathode ray beam, means for energizing the input of said second amplifier by a second control voltage, and means for blocking one or the other of said energized means.

12. A control circuit for a cathode ray tube having a pair of deflecting plates, comprising a pair of substantially identical amplifying tubes, each comprising a cathode, a control grid and an anode, means for connecting said anodes through respective output resistors to a source of positive potential, means for connecting said anodes directly to said plates, means for biasing said grids to substantially the same potential, means for applying a control potential to one of said grids, means connecting said cathodes together and to a common grounded and unbypassed cathode resistor, whereby push-pull potentials are applied to said deflecting plates and the voltage across said plates is rendered substantially independent of fluctuations in the voltage of said source, and means for applying a second control potential to the other of said grids.

13. A control circuit for a cathode ray tube having a pair of deflecting plates for deflecting the cathode ray beam thereof, comprising an amplifier, means connecting the output of said amplifier to one of said plates, means for energizing the input of said amplifier by a control voltage, a second amplifier, means for connecting the output of said second amplifier to said other plate, a common unbypassed cathode resistor for said two amplifiers, whereby said second amplifier is energized in opposite phase from said first amplifier to produce push-pull deflection of said cathode ray beam, and means for balancing the amplifiers.

14. In an electronic switch, a pair of electron discharge tubes each having an anode and a screen grid, an output resistor connected to each of said anodes, means for alternately and oppositely rendering said tubes conductive and non-conductive, and means for maintaining the average potential of each of said anodes at substantially the same value during both said conducting and non-conducting periods, said last means comprising a connection between the screen grid of each of said tubes to a tap of the output resistor of the other of said tubes.

15. In an electronic switch, an electron discharge tube having a load resistor, means for periodically and alternately rendering said tube conductive and non-conductive, a control tube connected in parallel with said discharge tube and adapted when conductive to draw a current equal to the average current of said discharge tube through said load resistor during conductivity of said discharge tube, and means for periodically and alternately rendering said control tube conductive and non-conductive oppositely to the conduction and non-conduction of said discharge tube, whereby the average output potential of said discharge tube is maintained at substantially the same value during both said conducting and non-conducting periods of said discharge tube.

16. In an electronic switch, an electron discharge tube, means for periodically and alternately rendering said tube conductive and non-conductive, and means, including a control tube

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connected in parallel with said discharge tube and means for periodically and alternately rendering said control tube conductive and non-conductive oppositely to the conduction and non-conduction of said discharge tube, for maintaining the average output potential of said discharge tube at substantially the same value during both said conducting and non-conducting periods of said discharge tube.

17. In an electronic switch, an electron discharge tube, means for periodically and alternately rendering said tube conductive and non-conductive, and means for loading said tube when it is rendered nonconductive and unloading it when it is rendered conductive, so as to maintain the average output potential of said tube at substantially the same value during both said conducting and non-conducting periods.

18. An electronic switch for controlling the transmission of a signal voltage comprising an electron discharge tube having two input grids, means for applying said signal to one of said grids to be amplified during conductive periods of said tube, a source of alternating switching voltage having amplitude at least one-half the cut-off bias of said second grid, means for applying said switching voltage to said second grid, means for biasing said cathode to a value whereby said tube is driven beyond cut off during negative half cycles of said switching voltage and during positive half cycles said second grid is positive with respect to said cathode, and a current limiting resistor in series with said second grid, whereby said tube is rendered substantially independent of fluctuations in said switching voltage.

19. An electronic switch comprising an electron discharge tube having a control grid, a source of alternating switching voltage connected to said grid having amplitude at least half the cut off voltage of said tube, means for biasing said tube to a value such that during positive half cycles of said switching voltage said grid is positive with respect to said cathode and during negative half

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cycles said tube is biased beyond cut off, and a grid-voltage dropping resistor connected in series with said grid, whereby the operation of said tube is rendered substantially independent of variations in the magnitude of said switching voltage.

20. An electronic switch comprising an electron discharge tube, a source of periodically varying switching voltage, means for blocking said tube during half cycles of said voltage of predetermined polarity and for conditioning said tube to be conductive during opposite half cycles, and means for rendering said conditioning independent of the amplitude of said switching voltage.

21. In an electronic switch, a pair of electron discharge tubes each having an anode and a screen grid, an output resistor connected to each of said anodes, means for alternately and oppositely rendering said tubes conductive and non-conductive, and means for maintaining the average potential of each of said anodes at substantially the same value during both said conducting and non-conducting periods, said last means comprising a resistive connection between the screen grid of each of said tubes to the anode of the other of said tubes.

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