Jan. 23, 1951 | P. GLASS | 2,539,127

METHOD AND MEANS FOR BALANCING SENSITIVITY OF DUAL TUBES

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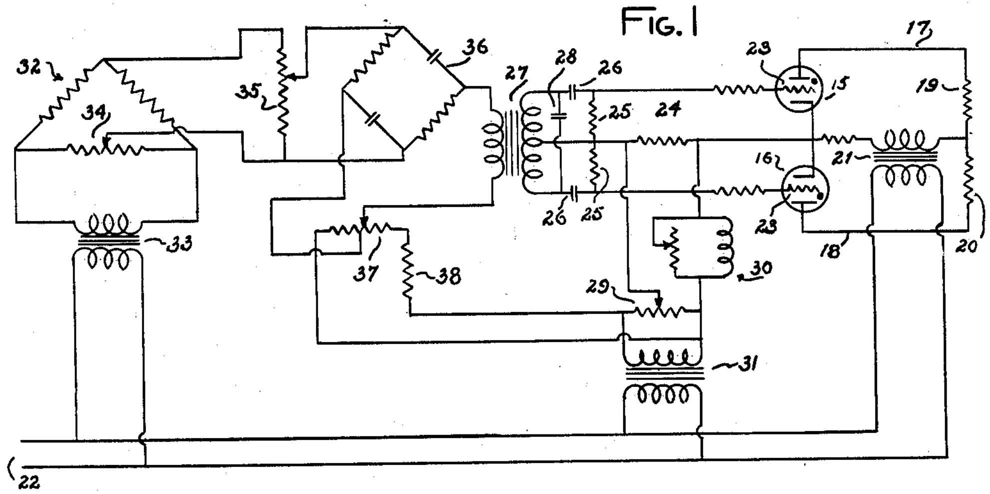
FIG. 1



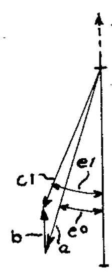


FIG. 2

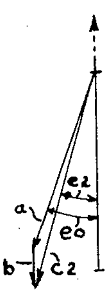


FIG. 3

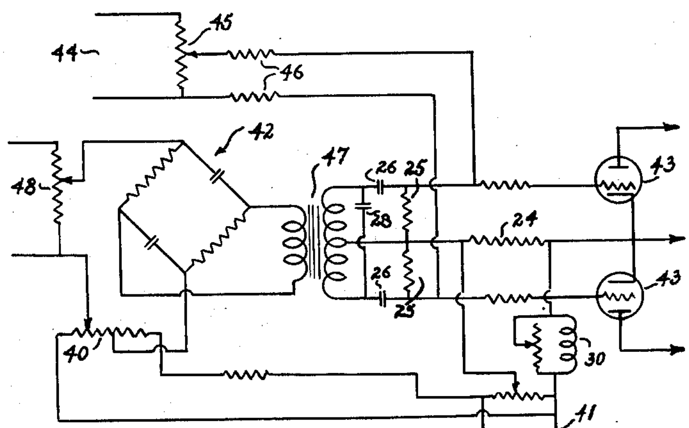


FIG. 4

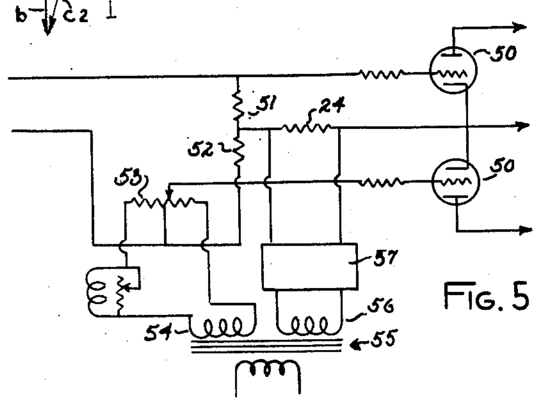


FIG. 5

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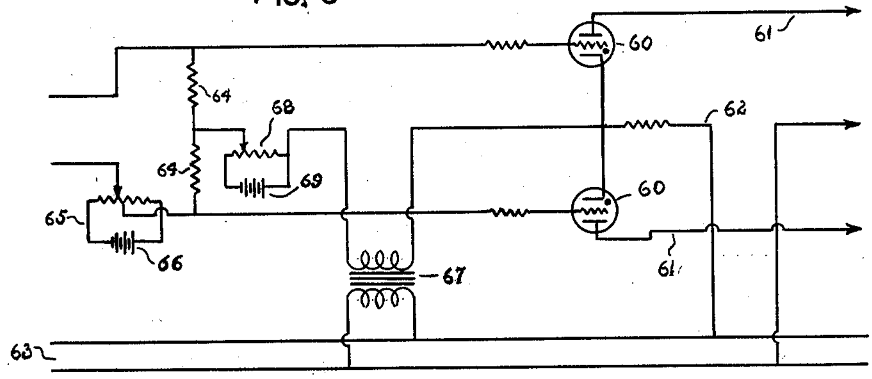
FIG. 6



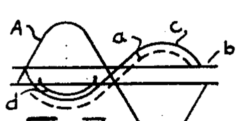


FIG. 7

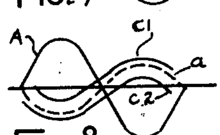
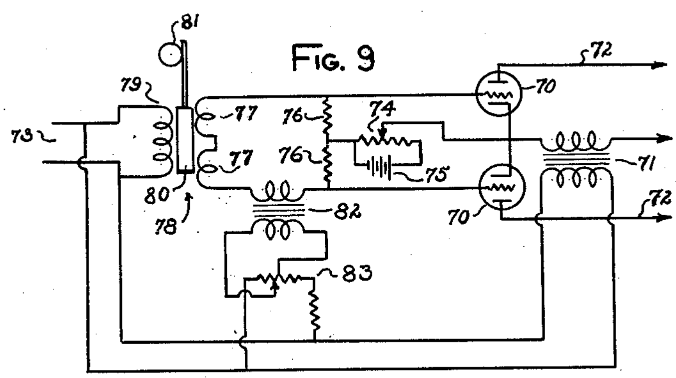


FIG. 8

FIG. 9



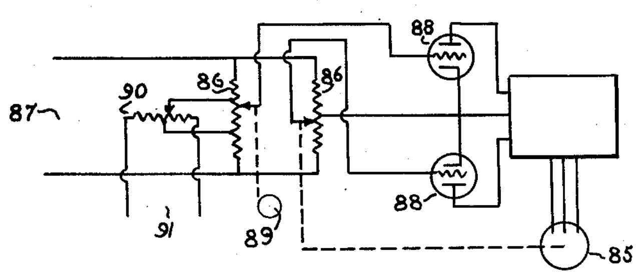


FIG. 10

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UNITED STATES PATENT OFFICE

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METHOD AND MEANS FOR BALANCING SENSITIVITY OF DUAL TUBES

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Application December 11, 1948, Serial No. 64,757

12 Claims. (Cl. 315—246)

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This application is continuation in part of my copending application for United States patent, Serial No. 489,207, filed May 31, 1943, now Patent No. 2,476,657, dated July 19, 1949. Whereas that application relates to a motor control circuit including dual tubes, selectively rendered conductive to select direction of operation of the controlled motor, the present invention relates to balancing sensitivity of dual tubes, several forms of the invention being disclosed in the noted copending patent application.

Dual tubes with a common grid circuit are well known and used in a tremendous number of different circuit arrangements, such as those wherein selection of one of two circuits for energization is accomplished by signals applied to the tubes, so that the tubes act as a switch or wherein degree of energization of two circuits depends on signals applied to the respective tubes, wherein the tubes act as variable resistances, or wherein two parallel connected tubes are to control simultaneous energization of two circuits in the manner of a switch, or to simultaneously vary degree of energization of the circuits that they respectively control, by application to the tubes of a common signal, or by application to the respective tubes of different signals. In any such situation, it is highly desirable that the paired tubes be of equal sensitivity, so that application of a common signal voltage, application of equal signal voltages to the respective tubes at different times, and so forth, will produce exactly similar operation of the two tubes. Commercially available tubes, however, vary in characteristics of sensitivity from tube to tube, and consequently operation of dual tube controlled circuits has been much more difficult in practice than in theory. Such expedients as careful matching of tubes for close sensitivity similarity, and independent adjustment of bias voltages have been resorted to. The former expedient requires a tedious and expensive matching procedure, the latter, while being fairly satisfactory so far as sensitivity equalizing per se is concerned, tends to upset the grid circuit conditions by changing the response of one or the other, or both tubes to a given value of signal.

One object of the present invention is to provide simple and effective method and means permitting sensitivity equalization of dual tubes, which does not involve adjustment of the tube-controlling bias, and which permits exact balance of response of the tubes to a given value of signal.

Another object is the provision of such method

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and means capable of use with a dual tube common grid circuit of practically any arrangement, and usable with various types of signal voltages, or variable amplitude direct or alternating current signal voltages.

The invention is based on the concept of simultaneously, equally and oppositely varying the sensitivity of two tubes having a common grid circuit, by applying between the control grids a sensitivity bias voltage, so that adjustment of such voltage increases bias on one tube and simultaneously decreases that of the other, in the manner of swinging the respective grid voltages in opposite directions about the main bias voltage that primarily selects response of the two tubes to a given signal.

In the accompanying drawings,

Figs. 1, 4 to 6, 9 and 10 are schematics showing various selected embodiments of the invention applied to different grid circuits of dual tubes, and illustrating the flexibility and great extent of possible applications of the invention.

Figs. 2 and 3 are vector diagrams of operation of the form of invention of Fig. 1.

Figs. 7 and 8 are voltage graphs indicating operation of the invention as applied in Fig. 6.

In the present application the term "dual tubes" is intended to apply to tubes having a common control grid circuit, and operating to control one or more output circuits. The term includes, but is not limited to such tubes as comprise dual sets of elements in a single envelope, and it applies equally to entirely separate tubes.

The drawings present only a few of the many fields of use and arrangements of the invention, and are to be considered as being purely for illustrative disclosure and example, and not as limiting the invention to the specific forms therein shown.

Figs. 1 to 6 represent grid circuits disclosed by the noted Patent No. 2,476,657, with elimination or simplification of parts of the circuits disclosed by such application that are not necessary to full understanding of the present invention.

Describing the drawings in detail, and first referring to Fig. 1, tubes 15 and 16 exemplify a pair of dual tubes, respectively controlling circuits 17 and 18 that may include loads, represented by resistances 19 and 20, it being assumed that such circuits are to be selectively energized or both deenergized. The anode circuits 17 and 18 of the tubes are supplied with alternating voltage in phase agreement through a transformer 21, the secondary of which is connected in the common anode return of the tubes, and the primary energized by an alternating current source 22. To prevent conduction of the tubes during positive half cycles of anode voltage, a suppressing bias of adjustable amplitude and phase is applied to the control grids 23 across a resistance 24 connected in the common return of the grid circuit. Signal potentials of opposite sense are applied to the control grids of the tubes across grid return resistances 25 by condensers 26 which connect corresponding terminals of such resistances, and the control grids to opposite ends of the secondary of a signal input transformer 27, a condenser 28 being shunted across such secondary.

The variable amplitude and phase suppressing voltage applied to the two control grids in phase agreement is supplied across the resistance 24 through a potentiometer 29 and a phase shifting network 30 from the secondary of a transformer 31, the primary of which is energized by the same alternating current source 22 that supplies the anode circuits of the tubes. The alternating suppressing voltage applied across the resistance 24 is, by means of potentiometer 29, adjusted to prevent conduction by either tube 23 in the absence of a signal voltage when such voltage is substantially in phase opposition to the anode voltage. The phase shifter 30 may be so adjusted that the suppressing voltage applied to the control grids of the two tubes leads the anode voltage by somewhat less than 180°, to overcome a dead zone of the tubes and render them sensitive to a very small signal.

In this form of circuit, the signal may take the form of a variable amplitude voltage applied in opposite phase to the two control grids, and in such phase relation to the anode and suppressing voltages variation in its amplitude serves to advance and retard phases of the resultant controlling voltages applied to the grids of the respective tubes depending on the phase of the signal voltage, so that one tube is rendered conductive while the other is maintained non-conductive. While a variety of signal circuits may be used for accomplishing such results, Fig. 1 shows a circuit disclosed by the noted copending application.

In Fig. 1, a bridge circuit 32 is energized by a transformer 33 having its primary energized from the source 22 so that phase of the signal voltage may properly be related to those of the tube-energizing circuits. The bridge 33 has a movable contact 34 by which a signal of reversible phase and variable amplitude may be generated. Such voltage is applied to the primary of the signal transformer 27 through a potentiometer 35 and a phase shifter 36. This phase shifter is arranged to displace the signal voltage by substantially 90° with reference to the anode voltage of the tubes. By this arrangement, variation of the output of bridge 32 by variation of contact 34 serves to advance and retard the respective grid voltages, identity being determined by the phase of such signal voltage, as indicated above, to render conductive the tube of which the grid voltage is advanced.

In order to equalize sensitivity of the two tubes so that they respectively become conductive at equal degrees of advancing phase shift of the respective controlling grid voltage, resulting from the respective shifting effect of signal voltages of equal but opposite phase, in spite of variance between the firing response of the respective tubes to magnitude of control grid voltage phase advance, means are provided for applying an auxiliary inter-grid bias for producing equal and opposite sensitivity variance compensating shifts in phase between the resultant grid voltages in the two grid circuits. In Fig. 1 this takes the form of a device for injecting in the two grid circuits supplemental alternating current bias voltages that are of opposite phase relative to each other, and displaced in phase a variable degree with respect to the suppressing voltage applied across the resistance 24.

Such means comprises a center tapped potentiometer 37 supplied from the source 22 by the secondary of the suppressing voltage supplying transformer 31, through a limiting resistance 38. Variation of the movable contact of the potentiometer 37 selects the relative directions of grid voltage phase shifts introduced by the supplemental phase-shifting bias voltages, and magnitude of such variations the degrees of such shifts. By such variations, adjustment may be made of the amplitudes of signal voltages introduced by the transformer 27, which renders the respective tubes conductive.

The operation of the equilizer arrangement may be explained by reference to the vector diagrams of Figs. 2 and 3. Vector A represents the line, or tube anode voltage, and a represents the suppressing bias voltage applied across resistance 24, which is common to the two grid circuits. The phase relation of vector a is fixed by phase shifter 30, and this voltage leads the anode voltage by $(180-e0)$, degrees. If it is supposed that the phase shift angles necessary to render tubes 23 just conductive are $e1$ and $e2$, respectively, then the pre-phase shift $e0$ would not be sufficient to fire one tube, but would be ample to fire the other. The supplemental equalizing voltage introduced from equalizer 37 is shown by the vectors b and b' in Figs. 2 and 3 respectively, and it will be noted that these vectors have opposite phase relation, b being in phase with the anode voltage, while b' is opposite in phase to the anode voltage. The resultant alternating biasing voltages for the two grid circuits are now represented by the vectors $c1$ for one tube and $c2$ for the other, and these vectors have the proper phase angle to adjust both tubes so that they become conductive at equal signal values.

In practice, the amount of equalizing voltage necessary to equalize the two tubes is small compared with the common suppressing voltage developed across the resistance 24. It is not necessary that the equalizing voltages be in phase and opposite to the phase of the anode voltages, but preferably they should be out of phase with the suppressing voltage across resistance 24.

Adjustment of sensitivity of the two tubes readily can be accomplished by short circuiting the input terminals of the transformer 27, and adjustment of the equalizing potentiometer 37 until both tubes become conductive at the same instant upon advancement of the phase of the suppressing voltage by variation of phase shifter 30.

Fig. 4 shows a variation in the equalizer arrangement, and also illustrates an arrangement for controlling by a direct current signal a pair of dual tubes supplied with alternating anode and suppressing voltages in the manner of Fig. 1. The equalizer itself is the same as in Fig. 1, being a center tapped potentiometer 40, supplied by a transformer 41, and having its variable contact and center tap connected in series in the circuit. In Fig. 3 the equalizer is connected in the input to the phase shifter 42, rather than in the output. This arrangement has the advantage that the equalizing voltages are shifted in phase by the phase shifter 42, and have a phase angle displaced in phase by substantially 90° with reference to the equalizing voltages *b*, shown in Figs. 2 and 3. With this phase angle, smaller equalizing voltages are required to shift the resultant grid voltages from the vector *a* to the vector *c*, and the resulting vectors *c1* and *c2* in Figs. 2 and 3 are substantially equal in amplitude.

For control of tubes 43 by a direct current signal of reversible polarity and variable amplitude, such signals may be impressed from a source 44 across the grid circuits of such tubes through a potentiometer 45 and series resistances or inductances 46 which prevent the direct current signal source from influencing the alternating voltages applied to the grid circuits through the transformer 47.

By the arrangement of Fig. 4, a direct current signal of one polarity will cause conduction of the tube while a signal of opposite polarity will cause conduction of the other tube. The effective output current will vary in accordance with the amplitude of the direct current signal, and operation is not dependent upon presence of an alternating voltage applied through potentiometer 48, although the system will respond equally well to a variable amplitude alternating voltage of proper phase relation, as explained relative to Fig. 1, applied through the potentiometer 48.

While the previous circuits have been arranged to apply equalizing voltages to the grid circuits of both tubes, it is possible to accomplish equalization in a simple and satisfactory manner by applying an equalizing voltage between the grids by means of a voltage source connected in one grid circuit. An arrangement of this kind is shown by Fig. 5, the grid circuit arrangement therein, as in Fig. 4, being such that either a direct or an alternating voltage of variable amplitude may be used to control the dual tubes 50. Direct current signal voltages are applied across resistances 51, 52 in series, and an equalizing potentiometer 53 is connected in series with the grid circuit of one of the tubes 50, whereby an alternating current equalizing voltage of reversible phase and variable amplitude, both of which are selected by the position of the movable contact of the potentiometer relative to its center tap, may be applied to the grid circuit in which the potentiometer is connected. The potentiometer is shown as being supplied from a secondary winding 54, of a transformer 55, separated from the secondary winding 56 that supplies the suppressing voltage across the resistance 24, but may be supplied as in Figs. 1 and 4, or in other suitable manner. A phase shifter may be included in the supply circuit to potentiometer 53, as indicated at 57, so that the equalizing voltage can be made in phase quadrature with the suppressing voltage, or to have any other desired phase relation. In this arrangement, the equalizing voltage, which is effective to shift the resultant grid voltage of the tube in the grid circuit of which it is connected, makes such shift with respect not only to the suppressing voltage phase, but also to the phase of the voltage applied to the grid of the other tube, since the supplemental equalizing voltage is applied between the grids.

In Fig. 6 is shown a control circuit for selecting, by means of a direct current signal of reversible polarity and variable amplitude conductivity of two tubes 60, which respectively control output circuits 61 having a common return 62, and energized by direct connection with an alternating current source 63. The direct current signal is impressed across resistance 64 in series with the center tap and variable contact of the resistances of an equalizing potentiometer 65, to which direct current is supplied from a source represented by battery 66. It will be understood that the equalizer potentiometer 65 supplies equalizing potentials of opposite polarity to the grid circuits of the tubes 60, and that such potentials may be varied in amplitude and reversed in polarity by adjusting the contact of the potentiometer. The secondary winding of a suppressing bias transformer 67, energized by the source 63, is connected in series in the common grid lead for the two tubes, and supplies a suppressing voltage in 180° phase opposition to the anode voltage, and of sufficient amplitude to prevent conduction of the tubes in absence of a signal voltage.

A variable direct current voltage is also introduced in the common grid lead for the two tubes by a potentiometer 68 supplied from a suitable source represented by the battery 69.

In Fig. 7, the curve A represents the potentials applied to the plates of tubes 60 in Fig. 6. The dotted curve *a* represents the common alternating suppressing voltage applied to the grid circuits of the two tubes from the secondary of transformer 67. The line *b* parallel to the zero line represents the positive potential applied to each grid from the potentiometer 68, and the solid curve *c* represents the resultant potential applied to each grid of tubes 60 from transformer 67 and potentiometer 68. It is clear that the resultant effect of the direct current bias from potentiometer 68 is to shift the alternating suppressing voltage curve *a* upwardly to the position *c*, and the direct current biasing voltage is adjusted until this curve just fails to touch the critical characteristic curve *d*. In this way, the so called "dead zone" of the tubes is reduced, and a very small signal voltage will serve to cause one tube to fire, depending on the polarity of the signal. If the two tubes have slightly different characteristics, adjustment of the contact on equalizer 65 will secure operation of the two tubes in response to equal signal voltages. The effect of the equalizer adjustment is illustrated in Fig. 8 where curves *c1* and *c2* represent the individual grid voltage curves which are required in order to just fail to touch the respective critical grid characteristics. These characteristic curves as well as the direct current bias line are omitted from Fig. 8 for the sake of clearness, and it will be understood that the separation between the curves *c1* and *c2* is greatly exaggerated.

An incoming signal which causes the grid of one tube 60 to go more positive will cause this tube to conduct to energize one circuit 61, while an incoming signal which causes the grid of the other tube to go more positive will energize the other circuit 61. In either case, the incoming signal causes the grid of the inoperative tube to become less positive and thereby insures against operation of both tubes.

Fig. 9 discloses a different type of signal circuit wherein phase of a signal voltage selects one of dual tubes 70 to be rendered conductive, and amplitude of such voltage determines amplitude of current output of the tube so selected. The anode voltages of the tube are supplied in phase agreement through a transformer 71, the secondary of which is connected in the common return of the two output circuits 72, and the primary of which is energized by an alternating current source 73. Bias to prevent conduction of the tubes in absence of a signal may be applied by a potentiometer 74 connected in the common grid lead and energized by a suitable source 75. An alternating signal voltage is applied across series connected resistances 76, connected between the grid circuits of the respective tubes from the series-opposed connected windings 77 of a differential transformer 78, the primary 79 of which is energized by the source 73. As is well known, output of the secondary of such a transformer depends on relative degrees of coupling of the two secondary windings 77 to the primary 79. Such relative coupling is varaible by a movable core 80 that may be actuated by a mechanical control device 81. Presence of an output secondary voltage depends on unequal coupling between the windings 77 and the primary 79, the identity of the closer coupled windings determining the phase of the output, which is of reversible but otherwise fixed phase, and the amplitude of the voltage depending on the degree of unbalance produced by the unequal coupling.

In Fig. 9, equalization of the sensitivity of the two tubes is accomplished by connecting in series in the output circuit of the transformer 78, the secondary of a transformer 82, the primary of which is energized from source 73 through a phase-reversing and amplitude selecting center tapped potentiometer 83. This arrangement permits application between the grids of the respective tubes 70 an alternating potential of reversible phase and variable amplitude by means of which may be equalized response of the tubes to signals of equal amplitude and opposite phase, generated by the transformer 78 and applied to the grids across the resistances 76.

In Fig. 10 is shown application of the invention to a bridge type signal circuit forming the input of a position control circuit, by means of which direction of operation of a motor 85 may be selected, and degree of operation of the motor is made proportional to magnitude of a signal by a signal-balancing feedback arrangement operated by the motor.

The bridge circuit comprises a pair of potentiometer resistances 86 connected across a source of current 87 that may be either direct or alternating, and the voltages of the respective variable potentiometer contacts are applied to the control grids of the dual tubes 88. The variable contact of one potentiometer 86 may constitute a signal voltage regulator, and may be driven by a mechanical controller 89, while the variable contact of the other potentiometer is movable by the controlled motor 85 to balance the bridge upon completion by the motor of an operation proportional in degree to magnitude of a signal voltage produced by moving the signal contact to unbalance the bridge.

In applying the invention to this circuit, an equalizing potentiometer 90, energized by a suitable source 91, the character of which depends on that of source 87, has its center tap and variable constant connected in series across a part of one of the bridge potentiometer resistances 86, shown as the signal potentiometer. By adjustment of the movable contact of the potentiometer, opposite potentials, of reversible phase and variable magnitude are applied to the grids of the respective tubes 88, and consequently compensation may be made for differences in sensitivity characteristics of the tubes.

Several types of circuit that may be controlled by a dual tube stage, wherein the tubes are compensated in accordance with the present invention to balance their sensitivity, are disclosed by my above-identified copending application. In that application the tubes corresponding to the tubes of Fig. 1 are gas discharge tubes, controlling a motor and the grid circuit therein disclosed is provided with auxiliary pulse-creating means for providing an anti-hunt drive of the motor.

It will be understood that in any of the circuits herein disclosed, where the tubes are used to control variable voltage or current output circuits, and the system is so arranged that the tubes are operated to produce such variable outputs, the tubes may be either of gas discharge type, as indicated by the dots enclosed in the tube envelopes of Figs. 1 and 6, or, if the circuit is designed for such tubes they may be of high vacuum voltage-amplifying or current-controlling type. As set forth in the parent application, in the circuits relating to control of the dual tubes by phase shift of grid voltage through variation of amplitude of a signal voltage having a fixed phase relation to the suppressing bias, and wherein the dual tubes are of gas discharge type, the suppressing voltages are substantially in excess of those necessary to prevent firing of the tubes, this safety measure against unintended firing being permitted by the provision of means for combining with the suppressing voltage a variable amplitude signal voltage having a fixed phase relation to the suppressing bias, and therefore capable of a readily and accurately controllable phase shift of the resultant grid voltages by the simple expedient of varying its amplitude. This arrangement is very valuable, especially in the combination with adjustable auxiliary third biasing means for adjusting phase of the resultant grid voltages to reduce the "dead zone" of the tubes to minimum.

It will be appreciated from the foregoing that many variations of the invention not disclosed by the drawings and specification may be resorted to, and the invention may be applied to a great many circuits other than those described. While the disclosure of the invention is limited to application in the primary input circuit of a stage containing dual tubes, it is obvious that it can be applied equally well in intermediate amplifying, inverting or other stages, and also to power or output stages. Accordingly it is to be understood that the scope of the invention and that of the protection accorded to it is determined by the claims rather than by the disclosure.

I claim:

1. In a control circuit that includes a pair of gaseous discharge tubes, a source of alternating current for energizing the anode circuits of said tubes by voltages having the same phase relation, means for supplying to the grid circuits of said tubes alternating suppressing voltages of the same phase and amplitude to normally prevent firing of said tubes, and means for supplying to the grid circuits of said tubes signal voltages having opposite variable tube-firing characteristics controlling the firing of said tubes; an arrangement for compensating variance between the firing responses of such tubes to magnitudes of tube-firing characteristics of such signal voltages, comprising means for introducing in said respective grid circuits supplemental alternating

voltages for firing the respective tubes at equal magnitudes of tube-firing characteristics of such signal voltages, said means being arranged to supply such supplemental voltages in opposite phase and displaced in phase with respect to said suppressing voltages, and adjustable to permit selection of sense of such phase displacement and amplitude of such supplemental voltage.

2. A control circuit comprising, in combination, a pair of gaseous discharge tubes, a source of alternating current for energizing the anode circuits of said tubes by voltages having the same phase relation, means for supplying to the grid circuits of said tubes alternating suppressing voltages having suitable phase and amplitude values normally to prevent firing of said tubes, and adjustable means arranged for equally and oppositely varying the phase relation between such respective suppressing voltages.

3. A control circuit according to claim 2 wherein said phase adjusting means comprises means for advancing the phase of one grid suppressing voltage and for simultaneously retarding the phase of the other grid suppressing voltage, and vice versa.

4. A control circuit comprising, in combination, a pair of gaseous discharge tubes, a source of alternating current for energizing the anode circuits of said tubes by voltages having the same phase relation, means for supplying to the grid circuits of said tubes alternating suppressing voltages of the same phase and amplitude to normally prevent firing of said tubes, means for supplying to the grid circuits of said tubes signal voltages for selectively controlling the firing one or the other of said tubes, and means for introducing into the grid circuit of at least one of said tubes a supplemental alternating voltage of the same frequency as the suppressing voltage, said means being so arranged that such supplemental voltage is reversible in phase and variable in amplitude whereby said tubes may be conditioned for firing at the same signal values.

5. The combination with interconnected control grid circuits for controlling operation of dual tubes, and means for impressing on the control grids of such tubes signal voltages to control tube operation, of means for compensating variance between sensitivities of the respective tubes comprising means for applying between the grids of said tube a potential of selective sense and having oppositely effective tube-firing characteristic-altering effects that respectively aid and oppose signal voltages applied to the respective grids according to sense of such potential.

6. The combination with control grid circuits for controlling operation of dual tubes, said circuits being interconnected by a grid-cathode lead including grid bias means, of means for compensating variance between the response characteristics of the respective tubes comprising a circuit connected between said control grid circuits independently of the grid-cathode lead, and arranged to apply between said grid circuits a potential having characteristics respectively to aid and oppose tube-firing effects of signal voltages applied to the grids of the respective tubes by said control grid circuits according to sense of such potential.

7. A method of balancing sensitivity of dual electron tubes that comprises applying between the grids of said tubes of a potential that aids and opposes signal voltages applied to the grids of the respective tubes.

8. A method of balancing sensitivity of biased dual electron tubes that comprises applying between the control grids of such tubes an auxiliary bias voltage that aids and opposes signal voltages applied to the respective tubes.

9. The combination of claim 5 wherein the means for applying the potential between the control grids is arranged to permit selection of the magnitude and reversal of the sense of such potential.

10. The combination of claim 6 wherein the means for applying the potential between the control grids is arranged to permit selection of the magnitude and reversal of the sense of such potential.

11. In a dual tube-controlling grid circuit for applying signals of opposite character to the control grids of a pair of electron tubes, means for compensating for variance between the sensitivity characteristics of response of such tubes to variations in magnitude of signal values of voltages applied to their respective control grids by said circuit, comprising a source of variable voltage coupled effectively in series between said grids and arranged to apply between them a voltage having a biasing characteristic for equally and oppositely varying the response characteristics of such tubes, and single control means for simultaneously, equally and oppositely varying the biasing characteristic of such voltage effective on the control grids of such tube and for selecting the sense of such voltage.

12. In a dual tube-controlling grid circuit for applying signals of opposite character to the control grids of a pair of electron tubes, means in accordance with claim 11, wherein said source of variable voltage comprises an impedance coupled effectively in series between the control grids of said tube, means for applying voltage across said impedance, and adjustable control means arranged for selecting sense and magnitude of voltage applied between such grids.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,150,265	Conover	Mar. 14, 1939
2,221,517	Holters	Nov. 12, 1940