Aug. 26, 1947. W. J. FIELD 2,426,497

AMPLIFYING SYSTEM

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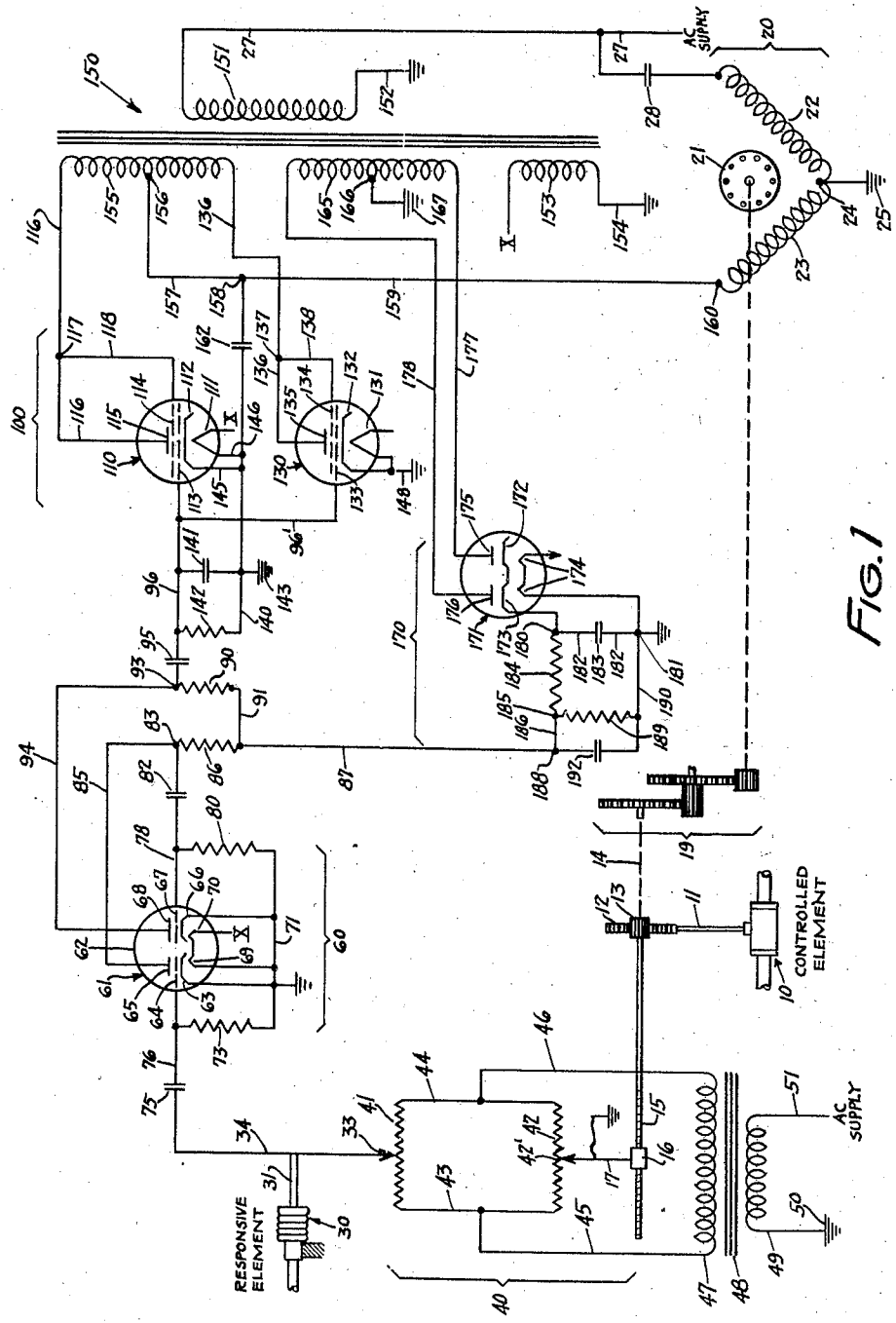


FIG. 1

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Fig. 2.

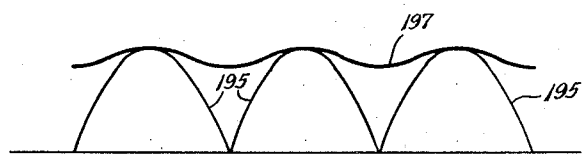
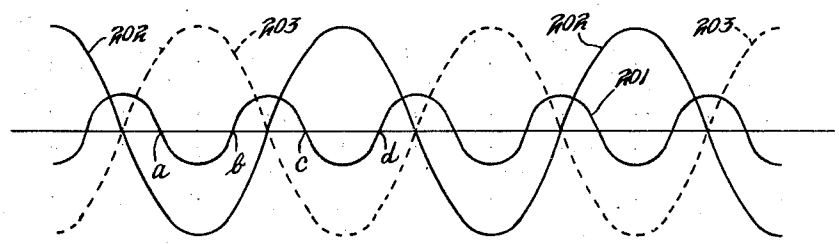


Fig. 3.



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2,426,497

AMPLIFYING SYSTEM

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Application October 15, 1943, Serial No. 506,313

10 Claims. (Cl. 250—27)

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This invention relates to electrical amplifying systems and more particularly to systems for thermionically amplifying signal impulses for the control of other apparatus.

Heretofore, in certain thermionic amplifying systems, it has been common practice to supply the plate potentials of the amplifier tubes from a rectifying system energized by an alternating current source. In the usual rectifying systems, there has been included a filter network for smoothing the rectified output thereby to reduce and substantially eliminate the alternating current component of the rectifier output voltage. To achieve this result, there has been required a relatively heavy and expensive filter network which has added to the weight and cost of such systems.

According to the present invention, there is provided an amplifying system in which the alternating current component of the rectified plate current supply is advantageously utilized for biasing purposes and as a result, a low weight, low cost, simplified amplifying system is provided, capable of excellent results in control service.

It is an object of the invention to provide such an amplifier, and more particularly, to provide an improved amplifying system for control service capable of being energized from an alternating current.

It is also an object of the invention to provide an amplifying system wherein the plate potential of the amplifier of one stage has an alternating current component which is utilized to produce a desired biasing effect in connection with a succeeding stage.

Other and further objects are those inherent in the invention illustrated, described and claimed.

The invention is illustrated with reference to the drawing in which

Figure 1 is a wiring diagram of the amplifier system; and

Figures 2 and 3 are wave diagrams illustrating the operation of the amplifier apparatus.

Throughout the illustration and description of the invention, the same numerals refer to corresponding parts.

In Figure 1, the amplifier system of the invention is illustrated as controlling an element, generally designated 10, which may be of any mechanism for example a valve, gate or damper, or a speed, direction, acceleration, volume, position or gas analysis control, requiring physical movement throughout a range of positions. The positioning movement of the controlled element 10 is desired to be made in accordance with the operation of a responsive element, generally designated 30, which is designed so as to be responsive to the condition being controlled and thus as required may be responsive to pressure, speed, direction, acceleration, volume, mere position, the analysis of gases or any other factor or derivative function, which in the end is responsive to the manipulation of the controlled element 10. The responsive element 30 is frequently and indeed usually a low energy instrument; hence the need for amplification in utilizing the output of such an element.

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In the illustrated environment of the present invention, the reversible movement for positioning the controlled element 10 is furnished to stem 11 of the element, by means of a rack and pinion, 12 and 13 respectively, or any other suitable mechanical gear. Pinion 13 is carried upon shaft 14 and may be driven through reduction gearing 19 from a motor, generally designated by the numeral 20.

Motor 20 includes relatively rotatable rotor and stator elements 21 and 22—23. The element 21 may be of the squirrel cage, wound, or other suitable type, depending upon the characteristics of the load of controlled element 10. Windings 22 and 23 are connected together at 24 and grounded at 25.

Winding 22 is connected so as to be constantly energized from an alternating current supply line 27 through a phase displacing capacitator 28. The response of the rotor of motor 20 depends upon the energization of winding 23 and the direction of the response upon whether the current through winding 23 in effect leads or lags the current through winding 22. The amplifier system of the present invention provides the energizing power supply for winding 23.

The rotation of shaft 14 produced by motor 20 effects the desired positioning of the controlled element 10 and also operates a rebalancing potentiometer of a resistance bridge generally designated by the numeral 40. Bridge 40 includes resistor elements 41 and 42 which are connected in parallel by leads 43 and 44 and energized through feeders 45 and 46 from a suitable transformer secondary winding 47. The responsive element 30 mechanically positions a variable tap 33 at selected positions along resistor 41, in accordance with the condition affecting the responsive element 30 and so selects the operating potential applied to line 34.

The screw threaded end of shaft 15 works in a threaded block 16 to which is secured a blade 17 in slidable engagement with resistance 42.

Hence, as shaft 14 rotates in one direction or the other, the blade 17 is moved along resistor 42, and so rebalances the bridge 40 as controlled element 10 is brought to its next position.

The amplifier system includes a thermionic amplifier tube or tubes and appurtenances, generally designated 60, a discriminator tube section 100, a transformer section 150 and a rectifier section, generally designated 170.

In the illustrated embodiment of the invention, the amplifier section 60 includes two stages of amplification, which may be accomplished in separate thermionic tubes or in a double tube, generally designated 61, as illustrated. Tube 61 consists of a single evacuated envelope 62, and contains two triodes. The first triode constituting the first amplification stage comprises an indirectly heated cathode 63, and its cooperating grid 64 and plate 65. The second triode which functions as the second amplification stage comprises the indirectly heated cathode 66 together with the latters cooperating grid 67 and plate 68. The cathodes are heated by two filaments 69 and 70 connected in series, one terminal of the series filament circuit being connected to grounded line 71 and the other terminal supplied by a filament feeder X, which is in turn supplied by a secondary 153 of transformer 150 as hereinafter explained.

The grid 64 is connected to ground wire 71 by means of a ballast resistor 73, the signal impulse being communicated to the grid by means of wire 34, which is connected through capacitor 75 to the grid lead 76. The grid element 67 of the second amplifying stage is fed by grid lead 78, the latter being connected to the ground line 71 by means of a resistor 80 and connected through capacitor 82 to junction 83 of the plate circuit 85 of the first amplifying stage. From junction 83, there extends a resistor 86, the lower terminal of which is connected by line 87 to the output terminal 188 of the rectifier section 170.

A second resistor 90 is connected by line 91 to the junction of resistor 86 and line 87, the upper terminal 93 of resistor 90 being connected by line 94 to the plate 68 of the second amplifier stage. Junction 83 of resistor 90 is the output terminal of the second amplifying stage and is connected through blocking capacitor 95 to the grid control line 96 and its branch 96'. The thermionic tubes, generally designated 110 and 130 constitute the discriminating tube section 100 of the amplifier, and each includes an indirectly heated cathode, a control grid, screen grid and plate. Thus, tube 110 includes a cathode 112 which is indirectly heated by filament 111, a control grid 113, screen grid 114 and plate 115. Similarly, tube 130 includes a cathode 132, which is indirectly heated by filament 131, a control grid 133, screen grid 134 and plate 135. The grid 113 of tube 110 and grid 133 of tube 130 are joined by connection 96' and are fed by the same grid lead 96. The grid lead 96 is connected to ground wire 140 by a capacitor 141 and a resistor 142. The wire 140 is grounded at 143. The indirectly heated cathode 112 and one terminal of the heated filament 111 are connected to the ground wire 140, and similarly, the indirectly heated cathode 132 and one terminal of its filament heater 131 are connected together and grounded at 148.

Transformer 150 energizes the system and includes a primary 151, one terminal of which is grounded at 152, the other terminal being fed through an alternating current supply line 27 from a suitable source. The transformer includes a filament heater secondary 153 having one terminal grounded at 154 and the other terminal feeding supply line X, which is in turn joined to the filament terminal X of each of the thermionic tubes, 61, 110, 130 and 171.

Another secondary 155 of the transformer has one terminal connected by line 116 to the plate 115 of discriminator tube 110, the screen grid 114 likewise being connected by means of line 118 to a junction 117 of the plate feeder 116. The opposite terminal of the winding 155 is connected by means of line 136 to the plate 135 of discriminator tube 130, screen grid 134 being likewise connected by means of line 138 to junction 137 on line 136. A center-tap 156 of the winding 155 is connected by means of line 157 to junction 158 and thence by means of line 159 to terminal 160 of the motor winding 23. Junction 158 is connected to cathode 145 through capacitator 162.

Another secondary winding 165 supplies power to the rectifier section, generally designated 170. The rectifier section includes a full-wave rectifier tube or tubes, generally designated 171, having cathodes 172—173, which are indirectly heated by filaments 174. Adjacent the cathodes are the anodes 175 and 176.

Anode 175 is connected by line 177 to one terminal of transformer secondary winding 165 and anode 176 is connected by line 178 to the opposite terminal of winding 165. The mid-point 166 of the winding 165, is grounded at 167. The cathodes 172—173 of the full wave rectifier tube 171 are connected to terminal 180, the latter being connected to ground 181 by capacitator 183. The junction 180 is also connected through resistor 184 to junction 185, which is in turn connected by line 186 to the output terminal 188 of the rectifier. Junction 185 is connected through resistor 189 to the ground line 190 and the output terminal 188 is similarly connected through a capacitator 192 to ground.

For clarity in the drawings, the transformer, composed of windings 47 and 49 and core 48, for supplying the rebalancing bridge 40, has been shown as separate from the transformer 150, but the two transformers may, and in most instances are, a unitary structure. Thus secondary winding 47 is merely added to the transformer 150 and is not separate.

Operation

When alternating current is supplied to feeders 27 and 51, the system is energized and winding 22 of the motor 20 is constantly energized. The voltage across winding 22 is displaced in phase with respect to the voltage across primary 151 by about ninety degrees, due to the series condenser 28 in the line feeding the motor winding 22.

The rectifier 171 and the center tapped secondary 165 function in the usual manner of a full wave rectifier. Thus, during one half cycle, current tends to flow from the upper end of secondary 165 through conductor 178, anode 176, cathode 173, conductor 182, condenser 183, and ground connections 181 and 167 back to the center tap of the secondary winding 165. During the opposite half cycle, current tends to flow from the lower end of secondary 165 through conductor 177, anode 175, cathode 172, conductor 182, condenser 183, and ground connections 181 and 167 back to the center tap of the secondary. Thus, during each half cycle, there is a tendency for current to flow across condenser 183 in such a direction as to cause a voltage to

exist across condenser 183. The polarity of the voltage will be such that the upper terminal of condenser 183 will be positive with respect to the lower terminal. In other words, a positive voltage will exist between junctions 180 and 181. The condenser 183 and the condenser 192 cooperate with resistor 184 in the usual manner of the condensers and resistors in a filter system to filter out to a certain extent the alternating current component of the rectified current. Thus, referring to Figure 2, curve 195 represents the voltage across the output terminals of the rectifier before it enters the filter system. The line 197 represents the voltage existing across the output terminals of the filter system. In other words, the curve 197 represents the voltage existing across condenser 192. It will be noted that the voltage represented by line 197 is substantially unidirectional with a slight alternating component. Furthermore, the frequency of this alternating component is twice that of the supply voltage. The curve of the supply voltage would be represented by the curve which would result if the central peak of the three peaks shown in Figure 2 were inverted with respect to the base line. The function of the rectifier in producing the voltage represented by line 195 is simply to invert alternate peaks and to cut off any portion of a voltage curve below the base line. If the second peak of the voltage curve 195 is inverted to represent the original alternating voltage curve, it will be quite obvious that the curve 197 has twice as many alternations as the original alternating voltage curve.

The magnitude of this alternating component of the voltage represented by line 197 in Figure 2 will depend upon the degree of filtering. The greater the amount of filtering, the less pronounced will this alternating component be. In the ordinary amplifier circuit it is considered desirable to employ as many sections of filtering as is economically advisable so as to reduce as much as possible the alternating component of the output voltage of the filter system. In the circuit of the present invention, this filter system is so selected as to produce an alternating component of a magnitude just sufficient to give the desired biasing effect.

Referring now to the operation of the control portion of the apparatus, the various elements are shown in the position they assume when the controlled element 10 is in the position demanded by the control device 30. With the control elements in this position, the positions of sliders 33 and 17 correspond so that no voltage exists between them. Thus, no signal voltage is applied to grid 64. Let it be assumed now that the condition to which element 30 is responsive changes so as to cause a movement of slider 33 to the right. This will result in an alternating voltage existing between sliders 33 and 17 so as to cause an alternating voltage to be impressed upon grid 64 through blocking condenser 75. The result of this alternating voltage being applied to the grid 64 is that the current flow through the plate circuit of the first triode of tube 61 has an alternating component corresponding in magnitude and phase relation to the alternating signal voltage, this current flowing through the following plate circuit: from junction 188 through conductor 87, coupling resistance 86, junction 83, conductor 85, plate 65, cathode 63, through the ground connections back to terminal 181. The current flowing through coupling resistance 86 not only has an alternating component due to the signal

voltage but also has an alternating component equal in magnitude to the alternating component of the output of the filter system, as discussed above. The alternating component of the voltage across resistor 86 is applied to resistor 80 and hence to grid 67 through the blocking condenser 82, the blocking condenser functioning in the usual manner to block out any unidirectional component of the voltage.

The plate circuit of the second triode of tube 61 may be traced as follows: from junction 188 through conductors 87 and 91, coupling resistor 90, junction 93, conductor 94, plate 68, cathode 66, through the ground connections back to terminal 181. The current flowing through resistor 90 will accordingly be a function of the signal voltage as amplified by the first and second triodes of tube 61 and a function of the unbalance voltage appearing across the output terminals of the filter network. The nature of this component due to the unbalance voltage will be discussed in more detail later. In any event, the alternating voltage appearing across resistor 90 is impressed through condenser 95 on to grids 113 and 133. This voltage will consist primarily of an alternating voltage representing the amplified unbalance voltage of the bridge 40. The magnitude of this voltage will depend upon the extent of displacement of slider 33 with respect to slider 17. The phase of the unbalance voltage will be dependent upon whether slider 33 has moved to the right or to the left of slider 17. Obviously, when slider 33 has moved to the right of slider 17, as in the case being considered, the unbalance voltage is 180° displaced in phase from that existing when the slider 33 assumes a position to the left of slider 17. As was noted in connection with the previously traced circuit connections between the center tapped secondary 155 and the two tubes 110 and 130, the plates 115 and 135 are so connected to the secondary 155 that the voltages applied to them are 180° displaced with respect to each other. In other words, during any given half cycle in which plate 115 is positive with respect to cathode 112, plate 135 will be negative with respect to cathode 132. The various circuit constants such as condenser 141 and resistor 142 are so selected in value that the amplified unbalance voltage of bridge 40 as it appears on grids 113 and 133 will be in phase either with the voltage applied to the anode 115 or that applied to anode 135. Depending upon which anode voltage it is in phase with, one or the other of the tubes 110 and 130 will become more conductive. Let it be assumed that under the conditions described in which the slider 33 has been moved to the right with respect to slider 17, the unbalance voltage as applied to grids 113 and 133 is in phase with the anode voltage applied to anode 115. Under these conditions, current will flow through winding 23 of the motor as follows: from the upper terminal of secondary 155 through conductor 116, plate 115, cathode 112, conductor 145, ground connections 143 and 25, junction 24, winding 23, junction 160, and conductors 159 and 157 to center tap 156. During the next half cycle, obviously no current flows through the tube 110 since plate 115 is negative with respect to cathode 112. During the same half cycle, anode 135 is positive with respect to cathode 132 but the voltage applied to grids 113 and 133 will be 180° displaced in phase. In other words, the grids 113 and 133 will be negative with respect to the cathode by reason of the signal voltage. Thus, under these conditions, no current will flow through tube

130 and current will flow through tube 110 only during the half cycles in which plate 115 is positive with respect to cathode 112. The result will be that a voltage is impressed across winding 23 corresponding to the voltage output of the half wave rectifier. Since it is desired to improve the wave form of the voltage flowing through winding 23 so that it more nearly corresponds to the wave form of an alternating current, the condenser 162 is connected in parallel with winding 23 through the following circuit: from one terminal of condenser 162 through conductor 140, ground connections 143 and 25, terminal 24, winding 23, terminal 160, and conductor 159 back to the other terminal of condenser 162. The condenser 162 by shunting out the higher harmonics tends to cause the curve of the voltage across winding 23 to be more nearly a sine curve.

The phase relationship of the voltage across winding 23 with respect to that appearing across winding 22 will obviously depend upon whether tube 110 or tube 130 is conductive since these tubes are conductive during opposite half cycles. In the case being considered, in which the tube 110 is conductive, the voltage across winding 23 will be 180° displaced from that when tube 130 is conductive. In one case, the current through winding 23 will lead by approximately 90° that through winding 22 while in the other case, the current will lag by approximately 90° that through winding 22. The motor 21 will rotate in one direction or the other depending upon whether the current through winding 23 lags or leads that through winding 22. In the case being considered, it will be assumed that the motor rotates in such a direction as to so move rod 15 to cause the threaded block 16 to be moved to the right. This same movement will cause the stem 11 of valve 10 to be moved upwardly so as to increase the opening of the valve. The movement of threaded block 16 causes slider 17 to be moved to the right. Such movement will continue until the slider 17 corresponds in position to slider 33, at which time, no voltage will exist between sliders 33 and 17. When this happens, the voltage impressed upon grids 113 and 133 will possess no component derived from bridge 40 and for reasons presently to be described, neither tube 110 nor tube 130 will be conductive. Thus winding 23 will be deenergized and motor 21 will stop. The apparatus is so designed that this will occur when the controlled element 10 has assumed a position corresponding to that demanded by the responsive element 30.

It will be obvious from the above that if slider 33 is moved to the left, the voltage between sliders 33 and 17 will be 180° displaced from that which existed in the case just considered. As a result, the voltage impressed upon grids 113 and 133 will be similarly 180° displaced in phase. As a result, the voltage applied to grids 113 and 133 will no longer be in phase with the anode voltage applied to plate 115, but, on the other hand, will be in phase with that applied to anode 135. As a result, only tube 130 will be conductive so that current will flow through winding 23 as follows: from the lower terminal of secondary 155 through conductor 136, plate 135, cathode 132, ground connections 148 and 25, terminal 24, field winding 23, terminal 160, and conductors 159 and 157 to the center tap of secondary 155. As a result of current flowing through this circuit, winding 23 will again be energized, but the current flowing therethrough will be 180° displaced in phase from that just considered when tube 110 was conductive. As a result, motor 21 will rotate in a direction opposite to that previously considered to move valve stem 11 downwardly and to move the threaded block 16 to the left. The movement of threaded block 16 to the left will correspondingly move slider 17 to the left. Such movement will occur until slider 17 corresponds to the position of slider 33.

The operation as described so far, with the exception of the presence of the alternating component due to the filtering system, is substantially like that of the motor control system disclosed in the copending application of Albert P. Upton, Serial No. 437,561, filed April 3, 1942. That portion of the operation which is concerned with the novel features of the present application will now be described.

It will be noted that in the circuit traced through the first triode of tube 61, reference was made to an alternating component of the voltage due to the alternating component of the voltage across the output terminals of the filter system. As previously explained, this alternating component will have a frequency twice that of the frequency of the supply voltage. Since this alternating voltage appears across resistor 86, it is applied to grid 67 and will be amplified by the second triode of tube 61. Consequently, it will appear in considerably amplified form across resistor 90. Since the plate circuit of the second triode is also supplied by the power supply system 170, there likewise will be introduced an alternating component in the voltage across resistor 90 due to this alternating component in the voltage applied to anode 68. In other words, the alternating component of the output of the power supply 170 will appear in the voltage across resistor 90 in two different forms. One of these is due to the application of this alternating component to the anode 68. The second is due to the application of this alternating component to plate 65 and consequently to grid 67 of the second triode. This second component will be 180° displaced in phase with respect to the first and will be very much greater than the first due to the amplifying effect of this second triode. In fact, due to the voltage gain of the second triode, the portion of the voltage component due to the presence of this alternating component in the voltage applied to plate 68 can be disregarded. Due to the fact that both grids 64 and 67 are connected to cathodes 63 and 66, current will flow in the first and second triodes at all times so that this alternating voltage will be present at all times. This alternating voltage will in turn be applied through blocking condenser 95 to grids 113 and 133. By reason of the phase reversing action between the first and second stages of amplification and by reason of the phase shifting action of condensers 95 and 141 and resistor 142, this voltage will be so related to the voltages applied to anodes 115 and 135 that it tends to drive grids 113 and 133 negative during those portions of the anode voltage cycles in which the anode is most positive with respect to the cathode. In other words, referring to Figure 3, the voltage due to the amplified alternating voltage existing across the output terminals of the filter system is represented in considerably exaggerated form by the curve 201. The voltage applied to plate 115 is represented by the curve 202 and that applied to plate 135 by the curve 203. It will be noted that at the point *a*, the curve 201 crosses the cathode voltage line so that the effect of this voltage from point *a* to point *b* while

anode 135 is positive, is to drive the grids 113 and 133 negatively. Similarly, the voltage curve 201 is below the cathode voltage line between points c and d so that when anode 115 is positive the effect of this voltage is likewise to bias the grid negative with respect to the cathode. Due to the fact that the voltage is of twice the frequency of the voltage applied to the anodes 115 and 135, it is thus possible to have an alternating voltage function so as to bias the grids negative with respect to the cathodes during both half cycles. Quite obviously, if the grid voltage were of the same frequency as the anode voltage, it could be effective to bias the grid negatively only during one of each two half cycles. With the present arrangement, however, it so functions during both half cycles. It is true that between points b and c, for example, the effect of this voltage is to drive the grid positive with respect to the cathode. During this portion of the anode voltage cycle, however, the anode voltage is relatively low so that there is very little tendency for the tube to pass current even though the grid may be at a higher potential than the cathode. Furthermore, due to the tendency of the anodes and screen grids to emit when hot and thus cause current to flow through condenser 141 during the half cycles in which the anodes are negative, there is a considerable tendency for a charge to be built up on condenser 141 of such polarity as to cause the grids to be biased negatively. Because of this, any current flow that takes place through tubes 110 and 130 in the absence of a signal from the bridge 40 is negligible.

It will be thus seen that I have devised an arrangement in which it is possible to reduce the amount of filtering that is necessary in the D. C. power supply and to utilize the resulting ripple in an advantageous manner to bias the grids of the final output tubes. The constants of the filtered network are so selected that the unfiltered alternating ripple is of such a value and phase as to give the correct amount of bias. Obviously, if it is too great, it will tend to counteract the effect of a small unbalance voltage from bridge 41. By properly selecting the constants of the filter circuit, however, it is possible to obtain the exact amount of bias that is necessary and at the same time to reduce the cost of the filter circuit.

While I have shown a specific embodiment of my invention, it is to be understood that this is for purposes of illustration only and that my invention is to be limited only by the scope of the appended claims.

I claim as my invention:

1. An electronic discriminator circuit comprising a plurality of electronic discharge devices each comprising an anode, a cathode, and a control element, means for applying alternating voltages of the same predetermined frequency but of opposite phase relationship to the anodes of said devices, means for so applying signal voltages to the control elements of both devices that one or the other of said devices becomes conductive, the device that is conductive depending upon the characteristics of the signal voltages, and further means for applying to the control elements of both devices an alternating biasing voltage of twice the predetermined frequency, of a magnitude independent of the anode current, and of such phase relationship with respect to the alternating voltages applied to the anodes of said devices that said biasing voltage is effective over the intermediate portions of the positive half cycles of the anode voltages applied to both anodes to bias the control elements negatively with respect to the cathodes.

2. An electronic phase discriminator comprising a plurality of electronic discharge devices each comprising an anode, a cathode, and a control element, means for applying alternating voltages of the same predetermined frequency but of opposite phase relationship to the anodes of said devices, means for applying signal voltages of the same frequency and the same phase relationship to the control elements of both devices so that one or the other of said devices becomes conductive depending upon the phase relation of the signal voltage to the anode voltage of that device, and further means for applying to the control elements of both devices an alternating biasing voltage of twice the predetermined frequency, of a magnitude independent of the anode current, and of such phase relationship with respect to the alternating voltages applied to the anodes of said devices that said biasing voltage is effective over the intermediate portions of the positive half cycles of the anode voltages applied to both anodes to bias the control elements negatively with respect to the cathodes.

3. An electronic discriminator comprising a plurality of electronic discharge devices each comprising an anode, a cathode, and a control element, means including a source of alternating voltage for applying alternating voltages of the same predetermined frequency but of opposite phase relationship to the anodes of said devices, means for so applying signal voltages to the control elements of both devices that one or the other of said devices becomes conductive, the device that is conductive depending upon the characteristics of the signal voltages, and further means including a full wave rectifier energized by said source of alternating voltage for applying to the control elements of both devices an alternating biasing voltage of twice the predetermined frequency and of such phase relationship with respect to the alternating voltages applied to the anodes of said devices that said biasing voltage is effective over the intermediate portions of the positive half cycles of the anode voltages applied to both anodes to bias the control elements negatively with respect to the cathodes.

4. In a multi-stage amplifier, first and second electronic discharge devices, each having an anode, a cathode, and a control element, a source of alternating voltage, means comprising a rectifier and a filter system operatively connected to said source for obtaining therefrom a unidirectional voltage having a small component of alternating voltage, means for applying a signal voltage to the control element of said first electronic discharge device, means for connecting said rectifier and filter system to the anode of said first discharge device so as to form an anode circuit, means for applying voltage derived from said last named anode circuit to the control element of said second electronic discharge device, whereby the voltage applied to said control element of said second electronic discharge device has a component due to the signal voltage and an alternating component derived from said rectifier and filter system, means for applying an alternating potential derived from said alternating source of power to the anode of said second electronic discharge device, and means for maintaining a phase relationship between the alternating component of the voltage applied to the control element of said second discharge device and derived from the

rectifier and filter network and the alternating potential applied to the anode such that said alternating component is effective to apply sufficient biasing voltage to said control element of said second device that in the absence of a signal voltage said second discharge device is substantially non-conductive during the entire cycle.

5. In a multi-stage amplifier, first and second electronic discharge devices, each having an anode, a cathode, and a control element, a source of alternating voltage, means comprising a full wave rectifier and a partial filter system operatively connected to said source for obtaining therefrom a unidirectional voltage having a small component of alternating voltage of twice the frequency of said source, means for applying a signal voltage to the control element of said first electronic discharge device, means for connecting said rectifier and filter system to the anode of said first triode so as to form an anode circuit, means for applying voltage derived from said previously named anode circuit to the control element of said second electronic discharge device, whereby the voltage applied to said control element of said second electronic discharge device has a component due to the signal voltage and an alternating component derived from said rectifier and filter system, means for applying an alternating potential derived from said alternating source of power to the anode of said second electronic discharge device, and means for maintaining a phase relationship between the alternating component of the voltage applied to the control element of said second discharge device and derived from the rectifier and filter network and the alternating potential applied to the anode such that the alternating voltage applied to the control element of said second discharge device is effective to bias the grid negatively during that portion of the conductive half cycle in which the anode potential is greatest.

6. In a multi-stage amplifier, first, second, and third electronic discharge devices, each having an anode, a cathode, and a control element, a source of alternating voltage, means comprising a full wave rectifier and a partial filter system operatively connected to said source for obtaining therefrom a unidirectional voltage having a small component of alternating voltage of twice the frequency of said source, means for applying a signal voltage to the control element of said first electronic discharge device, means for connecting said rectifier and filter system to the anode of said first and second triodes so as to form anode circuits therefor, means for applying a voltage derived from the anode circuit of said first device to the control element of said second electronic discharge device whereby the voltage applied to said control element of said second electronic discharge device has a component due to the signal voltage and an alternating component derived from said rectifier and filter system, means for applying a voltage derived from the output circuit of said second discharge device to the control element of said third discharge device, means for applying an alternating potential derived from said alternating source of power to the anode of said third electronic discharge device, and means for maintaining a phase relationship between the alternating component of the voltage applied to the control element of said third discharge device and derived from the rectifier and filter network and the alternating voltage applied to the anode such that the alternating voltage applied to the control element is effective to bias the control element negatively with respect to the cathode.

7. In a multistage electronic amplifier, a source of alternating voltage, a final stage comprising two electronic discharge devices each comprising an anode, a cathode, and a control element, said anodes being oppositely connected to said source of alternating voltage, said control elements of said discharge devices being connected together into a common input circuit, means including a voltage amplification stage for applying a control voltage to said common input circuit and for causing one or the other of said electronic units to be rendered conductive depending upon a characteristic of said control voltage, means including a source of pulsating unidirectional voltage for energizing said voltage amplification stage, said last named means being effective to introduce into said control voltage an alternating component due to the pulsations in said unidirectional voltage, and means for maintaining a phase relationship between said alternating component and said source of alternating voltage such that said alternating component is effective to bias the control elements of said electronic discharge devices negatively with respect to their cathodes during the intermediate portions of both half cycles of the anode voltage.

8. In a multistage electronic amplifier, a source of alternating voltage, a final stage comprising two electronic discharge devices each comprising an anode, a cathode, and a control element, said anodes being oppositely connected to said source of alternating voltage, said control elements of said discharge devices being connected together into a common input circuit, means including a voltage amplification stage for applying a control voltage to said common input circuit and for causing one or the other of said electronic units to be rendered conductive depending upon a characteristic of said control voltage, means including a full wave rectifier and a partial filter system connected to said source of alternating voltage for energizing said voltage amplification stage, said last named means being effective to introduce into said control voltage an alternating component due to the ripple in the output of said partial filter system, and means for maintaining a phase relationship between said alternating component and said source of alternating voltage such that said alternating component is effective to bias the control elements of said electronic discharge devices negatively with respect to their cathodes during the intermediate portions of both half cycles of the anode voltage.

9. In a multistage electronic amplifier, a source of alternating voltage, a final stage comprising two electronic discharge devices each comprising an anode, a cathode, and a control element, said anodes being oppositely connected to said source of alternating voltage, said control elements of said discharge devices being connected together into a common input circuit, means including a voltage amplification stage for applying a control voltage to said common input circuit and for causing one or the other of said electronic units to be rendered conductive depending upon a characteristic of said control voltage, means including a full wave rectifier and a partial filter system connected to said source of alternating voltage for energizing said voltage amplification stage, said last named means being effective to introduce into said control voltage an alternating component due to the ripple in the output of said

partial filter system, and means for maintaining a phase relationship between said alternating component and said source of alternating voltage such that said alternating component is effective to bias the control elements of said electronic discharge devices negatively with respect to their cathodes during the intermediate portions of both half cycles of the anode voltage, the filter system being so designed that said ripple is of such magnitude as to produce the desired amount of bias.

10. In a multistage electronic amplifier, a source of alternating voltage, a final stage comprising two electronic discharge devices each comprising an anode, a cathode, and a control element, said anodes being oppositely connected to said source of alternating voltage, said control elements of said discharge devices being connected together into a common input circuit, means including a voltage amplification stage for applying an alternating control voltage to said common input circuit, said control voltage being reversible in phase for causing one or the other of said electronic units to be rendered conductive depending upon the phase of said control voltage, means including a full wave rectifier and a partial filter system connected to said source of alternating voltage for energizing said voltage amplification stage, said last named means being effective to introduce into said control voltage an alternating component due to the ripple in the output of said partial filter system, and means for maintaining a phase relationship between said alternating component and said source of alternating voltage such that said alternating component is effective to bias the control elements of said electronic discharge devices negatively with respect to their cathodes during the intermediate portions of both half cycles of the anode voltage.

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