June 9, 1942. G. M. BROWN 2,285,895

AUTOMATIC AMPLIFICATION CONTROL

Filed June 13, 1939 2 Sheets-Sheet 1

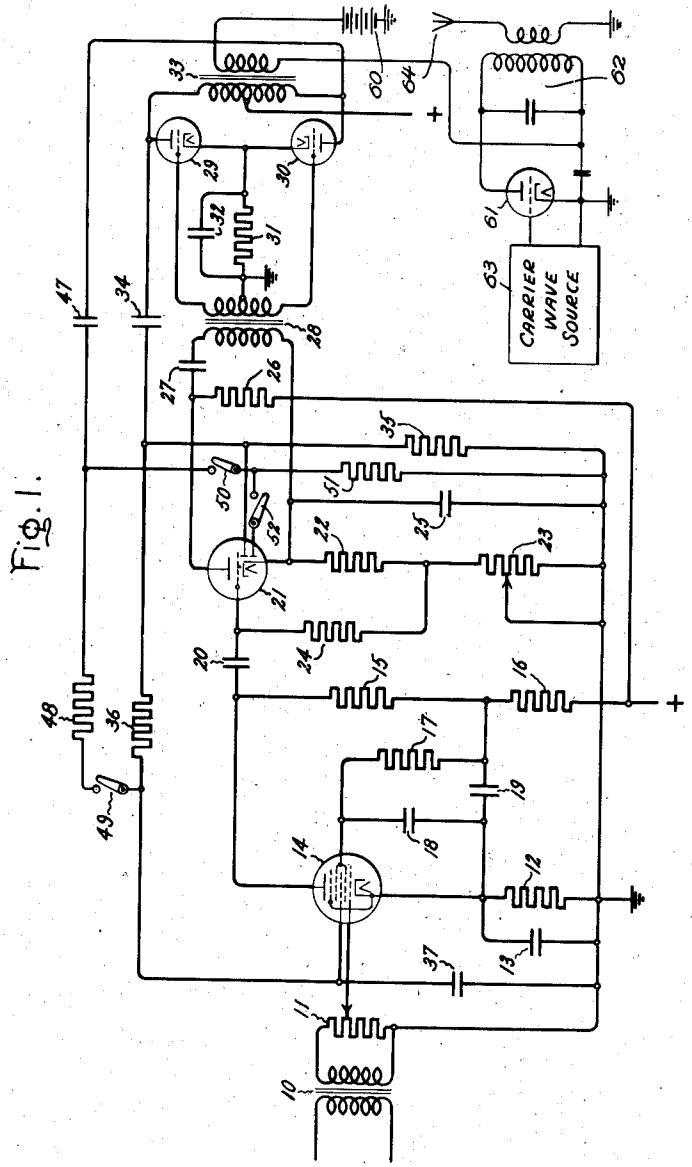


Fig. 1.

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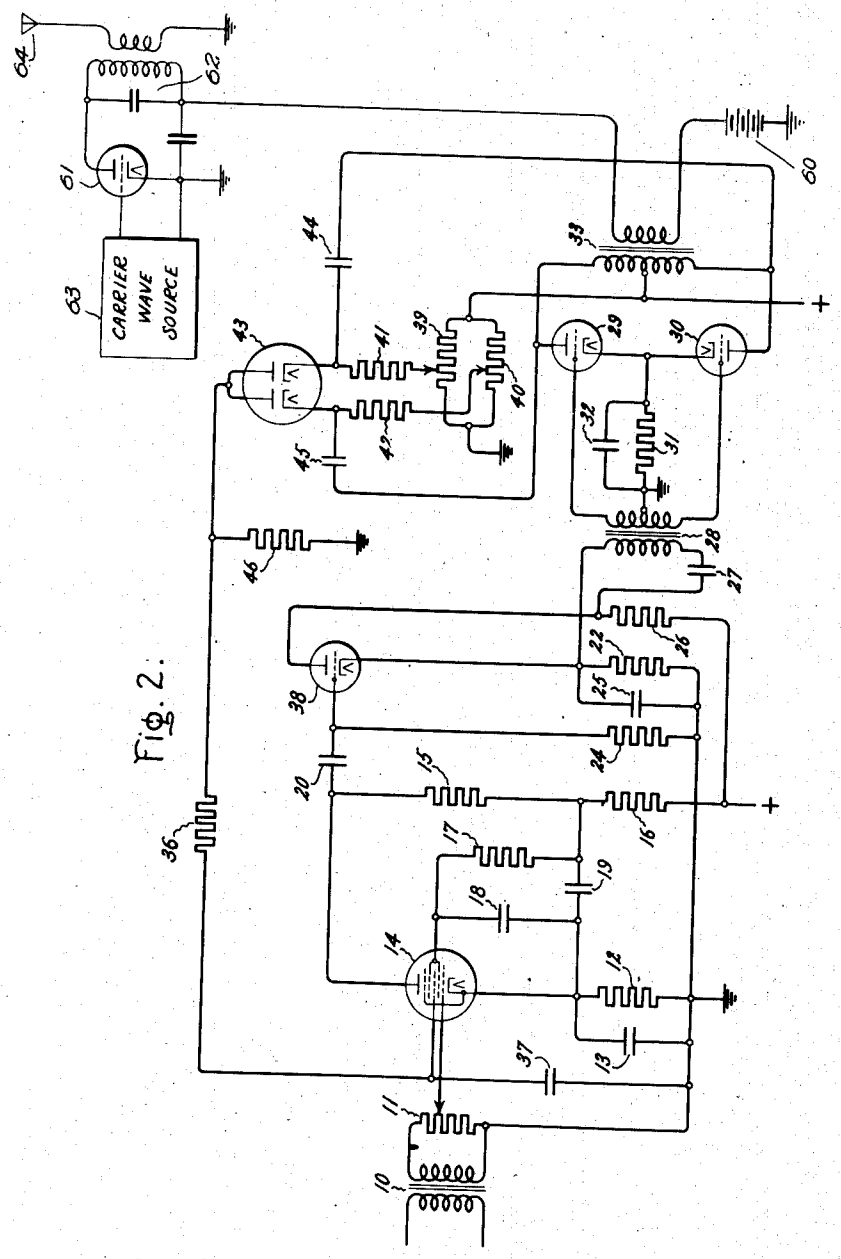


Fig. 2.

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AUTOMATIC AMPLIFICATION CONTROL

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6 Claims. (Cl. 179—171)

This invention relates to electron discharge amplifier circuits.

It has been a problem in the art of communication by modulated carrier waves to obtain a maximum amount of modulation at all times in order to use the carrier wave most efficiently. It is desirable to amplify signal waves with which a carrier is to be modulated in such a way that the average modulation depth approaches 100 per cent as nearly as possible while retaining the fidelity of the signal waves. The design of my amplifier is such that signal waves are amplified linearly up to some arbitrary amount which modulates the carrier wave at an arbitrary depth, such as 90 per cent, while for signal waves of greater level than this arbitrary value the amplification is reduced so that the output of my amplifier increases very slowly above this arbitrary value. It is accordingly an object of my invention to provide an improved and simplified audio amplifier of conventional construction which is adapted to supply amplified signal energy to any utilization circuit and at the same time controls the amount of amplification in response to the relation of the amplified wave to an arbitrary level.

In certain types of amplifiers, such as those used with transmitters of frequency modulated waves, or phonograph recording apparatus and the like, it is desirable to provide means responsive to peaks of the signal waves of either polarity to control the amplification of the amplifier. In the case of frequency modulated waves the available band width of the receiver is definitely limited and the frequency modulated waves transmitted must not exceed this band width in their frequency changes. In phonographic recording the available groove width must not be exceeded on either side. Many communication systems have similar limitations. It is therefor an additional object of my invention to provide improved amplifying apparatus continuously adjusted in amount of amplification in response to the level of peaks of alternating voltage of either polarity.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawings in which Fig. 1 is a circuit diagram illustrating schematically an audio amplifier embodying my invention; and Fig. 2 is a circuit diagram illustrating a modification of the circuit of Fig. 1.

Referring to Fig. 1, a suitable source of audio frequency waves is represented by an input transformer 10, across the secondary of which a voltage dividing resistance 11 is connected. The primary of the transformer 10 may be suitably supplied with audio frequency waves from a microphone or a phonograph pick-up, or the like. One end of the resistance 11 is connected to ground and is also connected through a cathode bias resistor 12 and a by-pass condenser 13 to the cathode of a pentagrid tube 14. The movable contact of the resistance 11 is connected to the first grid of tube 14, which serves to amplify voice waves applied through transformer 10. The anode of the tube 14 is connected through a resistor 15 and a resistor 16 to a suitable source of operating potential. The second and fourth grids of the tube 14 are screen grids and are connected through a resistor 17 to a point between resistors 15 and 16 in order to provide the screen grids with the proper biasing potential. These two screen grids are connected by a condenser 18 to the cathode of tube 14. Another condenser 19 connects the point between resistors 15 and 16 with the cathode of tube 14. The fifth grid of tube 14 is connected directly to the cathode and acts as a suppressor grid.

Voice waves applied to the first or control grid of the tube 14 through the transformer 10 produce corresponding variations in anode potential of the tube 14 due to the variations in voltage drop through resistor 15. These variations in voltage are coupled by a condenser 20 to the control grid of a duplex diode triode tube 21. The cathode of the tube 21 is connected to ground through cathode biasing resistors 22 and 23 in series. A grid resistor 24 is connected from the grid of tube 21 to a point between resistors 22 and 23 to provide proper bias potential for the grid. The resistor 23 has a sliding contact which is connected to ground and is adapted to vary the effective portion of the resistor 23 in the cathode circuit. Resistors 22 and 23 are shunted by a by-passing condenser 25. The anode of the tube 21 is connected through a resistor 26 to a suitable source of operating potential.

The grid of tube 21, which is supplied with voltage variations by condenser 20, causes voltage variations on the anode of tube 21 due to the voltage drop through the resistor 26. These anode voltage variations are coupled through a condenser 27 to the primary of a transformer

28. The other end of the transformer primary is connected to the cathode of tube 21. The ends of the secondary of transformer 28 are connected respectively to the grids of a pair of tubes 29 and 30 arranged in push-pull relation. The secondary of the transformer 28 has a center tap connection which is grounded and is also connected through a resistor 31 shunted by a bypass condenser 32 to the cathodes of the tubes 29 and 30. The anodes of the tubes 29 and 30 are connected respectively to the ends of the primary of a transformer 33. A center tap connection of the primary of transformer 33 is connected to a suitable source of anode potential. The secondary of the transformer 33 is adapted to supply amplified audio waves to any suitable device. This device may, for example, be the modulation stage in a radio transmitter, with which my invention is particularly useful.

A typical plate modulated transmitter, as illustrated, may include a source 60 of operating potential for a carrier wave power amplifier device 61. The negative terminal of the source 60 is grounded and the positive terminal is connected through the secondary of transformer 33 and through a tuned circuit 62 to the anode of the device 61, whose cathode is grounded. A carrier wave source 63 impresses a carrier wave upon the device 61 to be amplified therethrough by an amount governed by the operating potential supplied through transformer 33. The amplified carrier wave in the tuned circuit 62 is radiated from an antenna 64.

The anode of tube 29 is coupled through a condenser 34 to a conductive impedance 35, which is shown for convenience as a pure resistance. This resistance is grounded at its other end. Voltage variations of this anode therefore appear across the resistance 35. A diode anode of the tube 21 is connected to a point between condenser 34 and resistance 35.

The cathode of tube 21 remains at a substantially constant positive potential with respect to ground due to resistor 22 and the variable resistor 23. The diode anode of the tube 21 therefore allows current to pass only when its voltage rises to positive values greater than the substantially constant voltage existing across resistor 22 and variable resistor 23.

Whenever such high positive values of voltage are rectified through the diode anode, a continuous voltage is developed across resistor 35. The voltage across this resistor 35 is supplied through a conductive impedance 36, which is shown as a pure resistance, to the third grid of the tube 14. This third grid is connected through a condenser 37 to ground. This condenser is of sufficiently large value that voltage variations which occur at relatively high speed do not affect the third grid of the tube 14. The resistor 36 in conjunction with the condenser 37, in fact, forms a filter which has a time constant of the order of a fifth of a second. This time constant must be such as to prevent the automatic control embodied in my invention from taking effect so quickly as to smooth out variations of the speech wave. However, the filter circuit must respond with sufficient speed to bias the third grid of tube 14 on the occurrence of peaks in the voice wave.

It should be noted that positive peaks of voltage on the anode of tube 29 may correspond either to maximum or minimum amplitudes of the carrier, or in other words, to either positive or negative modulation peaks. This is due to the fact that the secondary of transformer 33 may be poled in either direction.

It should also be noted that, when values of voltage appear on the diode anode of tube 21, sufficient to be rectified, that anode is prevented from rising to positive voltages corresponding to such values although it does follow the voltage wave as it swings in the negative direction. An effective negative biasing voltage is thus developed across resistor 35 and is applied through the resistor 36 to the third grid of the tube 14. This negative biasing voltage reduces the gain of tube 14 rapidly so that the output from transformer 33 rises only very slightly even with a great increase in the input to the transformer 10. The critical value at which this reduction in gain begins to occur may be adjusted by means of the sliding contact on the variable resistor 23. By movement of this contact the amount of resistance between the cathode of tube 21 and the ground is varied with the result that the positive voltage of the cathode of tube 21 with respect to ground may be adjusted. For any particular adjustment of the positive voltage of this cathode the reduction in gain of the tube 14 begins to occur when the level of the peaks of voltage on the diode anode is equal to the positive voltage of the cathode of tube 21.

The proper adjustment of my amplifier for use in a radio transmitter is such that the output of transformer 33 rises linearly in accordance with the input to transformer 10 up to a critical value at which the output from the transformer 33 is sufficient to modulate the carrier wave with a predetermined depth, such, for example, as 90 per cent. Any other suitable depth may be chosen as desired. The operation of my amplifier then prevents any great rise in output from transformer 33 above this value and accordingly reduces tremendously the possibility of over-modulation. With an amplifier of this type there can be no appreciable distortion of the modulated carrier wave with corresponding radiation at undesired frequencies, since over-modulation may be completely prevented except for momentary transients.

It has been found that some music and most speech, when translated into electric wave energy, has greater peak amplitudes of one polarity than of the other. Since the phenomenon called "over-modulation" with the accompanying radiation of spurious signals is due principally to flattening of the carrier envelope on the zero axis rather than by extension of the maximum carrier amplitude beyond the level at twice the amplitude of the carrier when unmodulated, it is desirable that such higher peaks of a signal wave produce the positive modulation peaks or maximum carrier amplitudes and that the smaller peaks of opposite polarity produce the negative modulation peaks of the carrier. The provision of such operation allows more energy to be radiated for a given signal wave, assuming maximum permissible modulation, with a corresponding increase in efficiency. It is desirable, therefore, to secure such operation, to pole the output from transformer 33 to insure that the peaks of higher polarity produce positive modulation peaks. It is, of course, first desirable to pole the input to transformer 10, from the microphone or the like, so that the reduction of amplification shall be initiated in response to the lower peaks of the signal waves.

Since there is an unavoidable direct coupling from one side of the push-pull circuit including

tubes 29 and 30 to the third grid of tube 14 through condenser 34 and resistor 36, there may be some feedback which should be minimized by condenser 37. This feedback may be further reduced by including additional low pass filters in cascade with the one formed by resistor 36 and the capacitor 37. In the design of this particular circuit, one should connect the condenser 34 to that anode of the push-pull stage which creates degeneration, in case there is any remaining feedback. This is desirable to obviate any possibility of oscillation.

A very convenient way of minimizing feedback is by the use of a bridge circuit in which audio voltages of opposite phase are fed from the respective tubes 29 and 30 to the third grid of tube 14. In Fig. 1 a condenser 47, a resistance 48, and a switch 49 are connected in series between the anode of tube 30 and the third grid of tube 14. The condenser 47 should be substantially identical with condenser 34 and resistance 48 with resistance 36. With the switch 49 open the operation of the circuit is as has been described. When the switch 49 is closed an audio voltage is supplied to the third grid of tube 14 in such phase that the audio voltage fed back through condenser 34 and resistance 36 from the anode of tube 29 is substantially canceled.

A switch 50 and a resistance 51 are connected in series between ground and a point between condenser 47 and resistance 48. The resistance 51 should be substantially identical with resistance 35. When the switch 50 is closed a more complete cancellation of the audio voltage feedback to the third grid of tube 14 is attained, since the bridge is more nearly perfectly balanced.

In certain cases, for example, in frequency modulation or in phonographic recording where it is desirable to limit amplification in response to signal peaks of either polarity, it may be convenient to bias the third grid of tube 14 with a bias voltage derived from signal peaks of either polarity which are greater than a fixed voltage. In such cases a switch 52 connecting the other diode anode of the duplex tube 21 to a point between the switch 50 and the resistance 51 may be closed. Such a connection, of course, retains the advantage of the bridge circuit described. This other diode anode develops a biasing voltage on the third grid of tube 14 in the same way as the first diode anode with its coupling condenser 34 and resistances 35 and 36. Separate diodes with separate sources of bias voltage may be substituted for the diodes in tube 21. This arrangement may be better understood by considering the principles of operation of the circuit illustrated by Fig. 2.

Referring to Fig. 2, certain parts of the circuit illustrated thereby are identical with those shown in Fig. 1, and like parts have been given like reference numerals. Primarily the difference in this circuit is that series diodes are used to minimize feedback and each diode may be separately adjusted to become conductive at a different peak value of signal voltage. Input signals are supplied to the amplifier by the input transformer 10 as in Fig. 1. The tube 14 has the same input and output connections as in Fig. 1. Instead of tube 21, a triode discharge device 38 has its grid coupled by condenser 20 to the anode of tube 14. The cathode biasing resistor 22 shunted by by-passing condenser 25 connects the cathode of tube 38 to ground. It should be noted that resistor 23 is omitted, and that the grid resistor 24 is connected directly to ground.

The grid of tube 38, which is supplied with voltage variations by condenser 20, causes similar voltage variations on the anode of tube 38 due to the voltage drop through resistor 26 which is conected between the anode of device 38 and a suitable source of operating potential. The voltage variations across resistor 26 are coupled as in Fig. 1 to a pair of tubes 29 and 30 arranged in push-pull relation. The anodes of these tubes are connected to the output transformer 33.

A pair of voltage dividing resistances 39 and 40 are connected across a suitable source of direct current. The sliding contact of the resistance 39 is connected through a conductive impedance 41, which is shown for convenience as a pure resistance, to the cathode of a diode element of a tube 43. Similarly the sliding contact of the resistance 40 is connected through a conductive impedance 42, also shown as a resistor, to the cathode of a second diode element of the tube 43. The cathode of the first diode is connected through a condenser 44 to the anode of tube 30. The cathode of the other diode is connected through a similar coupling condenser 45 to the anode of tube 29.

The anodes of these two diodes are connected together and to ground through a resistor 46. These anodes are also connected through resistor 36 to the third grid of tube 14, which is coupled by the condenser 37 to ground.

In operation, under the condition when no signal is being amplified, the cathodes of the tube 43 are maintained at positive potentials with respect to ground by amounts equal to the voltage from the sliding contact of the respective resistances 39 and 40 to ground. The anodes of tube 43 are maintained at ground potential by resistor 46.

When signals are amplified by the arrangement, the voltage variations of the anodes of tubes 29 and 30 are impressed on the cathodes of tube 43. These voltage variations due to signals make the cathodes of tube 43 less positive during certain portions of the signal wave. When these cathodes become negative due to a signal of greater level than that necessary to overcome the respective positive bias voltages produced by resistances 39 and 40, the tube 43 passes current and the anodes of tube 43 become negative with respect to ground. This produces a similar negative voltage on the third grid of tube 14 and reduces the amplification thereof in a manner like that of the circuit of Fig. 1.

It should be noted particularly that tube 29 amplifies signal voltage swings of one polarity and tube 30 those of the other. Hence, if the signal peaks of either polarity increase more than predetermined amounts, the tube 43 passes current in the corresponding diode element and the amplification of tube 14 is reduced. It should also be noted that the predetermined levels at which the two diode elements pass current may be separately adjusted by the sliding contacts of the two resistances 39 and 40. They are preferably adjusted in proportion to the magnitude of alternating voltage on the respective anodes of tubes 29 and 30 for the particular type of signal being amplified.

It may be desirable only to limit the signal peaks of either polarity to the same value. In such case, the resistance 40 may be omitted and the resistor 42 connected to the sliding contact of resistor 39. It is, of course, obvious that one diode element may be omitted with its corresponding resistor, condenser and voltage divid-

ing resistance. Only peaks of the signal of one polarity are then limited to a predetermined level, as is desirable in normal amplitude modulation.

It is worthy of note that, since there is little capacity between the anode and cathode of a diode, degeneration is minimized by a series connected rectifier. However, in certain cases it is convenient to use the diode elements shown by Fig. 2 connected in shunt as in Fig. 1, to avoid the use of an extra tube.

While I have shown a particular embodiment of my invention, it will of course, be understood that I do not wish to be limited thereto, since different modifications may be made both in the circuit arrangement and instrumentalities employed, and I aim by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

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

1. In combination, an electron discharge amplifier having a control electrode and an output, means to rectify alternating potential from said output to produce a control potential, said control potential having a continuous component and an alternating component, means to impress said control potential on said control electrode, and means to supply alternating potential of opposite phase from said output to said control electrode to minimize the effect upon said control electrode of the alternating component of said control potential.

2. In combination, an electron discharge amplifier having a control electrode and including a push-pull stage, said amplifier being arranged to amplify alternating current, means to rectify alternate half cycles of alternating current from one side of said push-pull stage and to supply the rectified potential to said control electrode to control the amplification of said amplifier, and separate means for supplying alternating potential from the other side of said push-pull stage to said control electrode to oppose alternating potential supplied to said control electrode by said rectifying means.

3. An electron discharge, alternating potential amplifying device comprising a balanced output circuit and a control electrode, impedance means connecting one side of said balanced circuit with said control electrode to impress alternating voltage on said control electrode from said balanced circuit, rectifying means connected from said impedance means to a fixed potential point to produce a direct potential on said control electrode and to vary the amplification of said amplifier thereby, and impedance means connected from the other side of said balanced circuit to said control electrode to impress thereon alternating voltage of opposite phase to said above-mentioned alternating voltage and of such intensity as substantially to prevent the appearance of any alternating voltage from said balanced circuit on said control electrode.

4. In combination, an electron discharge amplifier having a control electrode and including a push-pull stage, said amplifier being arranged to amplify alternating potential, means to rectify alternate half cycles of alternating potential from one side of said push-pull stage and to supply the rectified potential to said control electrode to control the amplification of said amplifier, said means comprising an alternating current connection from said one side of said push-pull stage to said control electrode, said connection being effective to impress alternating potential of predetermined phase on said control electrode, and separate means comprising an alternating current connection from the other side of said push-pull stage to said control electrode for supplying alternating potential of opposite phase to said control electrode to oppose alternating potential supplied to said control electrode by said first conection.

5. An electron discharge amplifier comprising a balanced output circuit and a control electrode, means comprising an alternating current connection from one side of said balanced output circuit to said control electrode to impress alternating voltage of predetermined phase from said balanced circuit on said control electrode, rectifying means connected from said alternating current connection to a fixed potential point to produce a continuous potential on said control electrode and to vary the amplification of said amplifier thereby said rectifying means having a predetermined impedance, and means comprising a second alternating current connection from the other side of said balanced output circuit to said control electrode and means having an impedance comparable to the impedance of said rectifying means connected from said second alternating current connection to said fixed potential point to impress alternating voltage of opposite phase from said balanced output circuit on said control electrode, the intensity of said alternating voltage of opposite phase being such as substantially to prevent the appearance of any alternating voltage from said balanced output circuit on said control electrode.

6. An electron discharge amplifier comprising a balanced output circuit and a control electrode, means comprising an alternating current connection from one side of said balanced output circuit to said control electrode to impress alternating voltage of predetermined phase from said balanced circuit on said control electrode, rectifying means connected from said alternating current connection to a fixed potential point to produce a continuous potential on said control electrode and to vary the amplification of said amplifier thereby, means comprising a second alternating current connection from the other side of said balanced circuit to said control electrode to impress on said control electrode alternating voltage of opposite phase and of such intensity as substantially to prevent the appearance of any alternating voltage from said balanced circuit on said control electrode, and rectifying means connected from said second alternating current connection to said fixed potential point to cooperate with said first rectifying means in producing said continuous potential on said control electrode to vary the amplification of said amplifier.

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