March 30, 1943. H. BOUCKE 2,315,043

ELECTRIC AMPLIFIER SYSTEMS

Filed March 29, 1940 2 Sheets-Sheet 1

Fig.1.

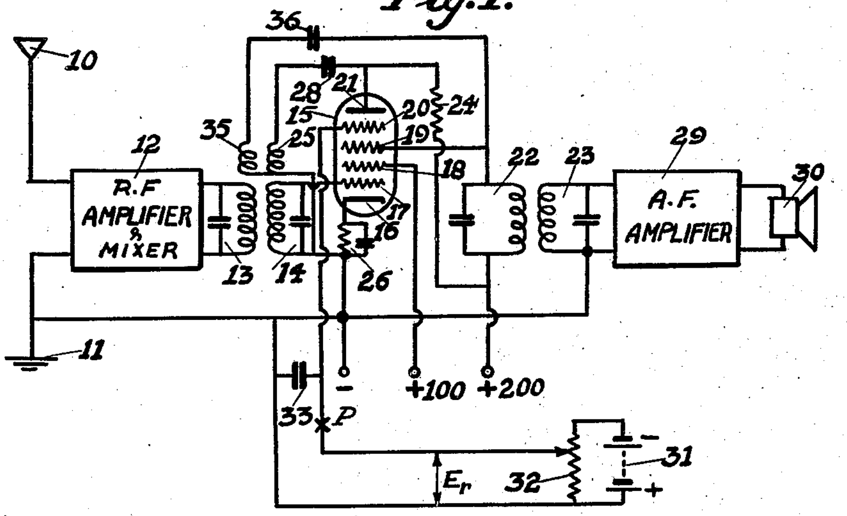

Fig.2.

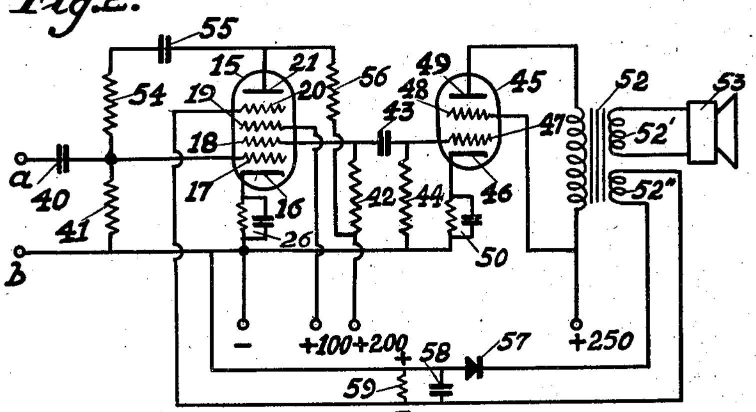

Fig.3.

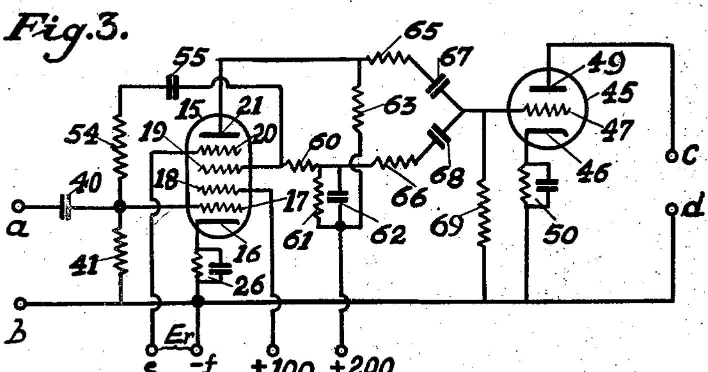

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Fig. 4.

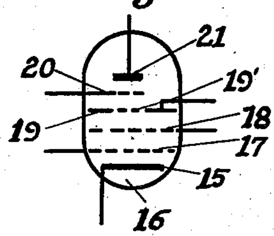


Fig. 5.

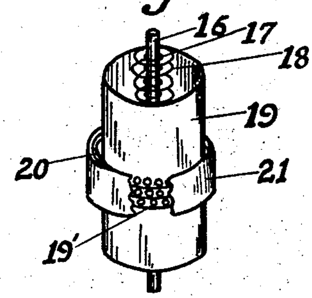


Fig. 6.

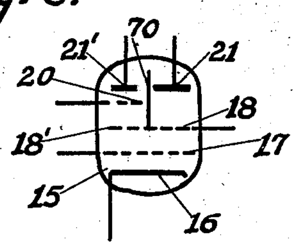


Fig. 7.

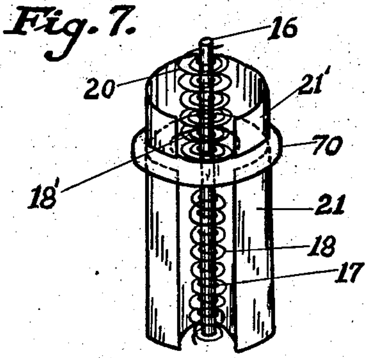
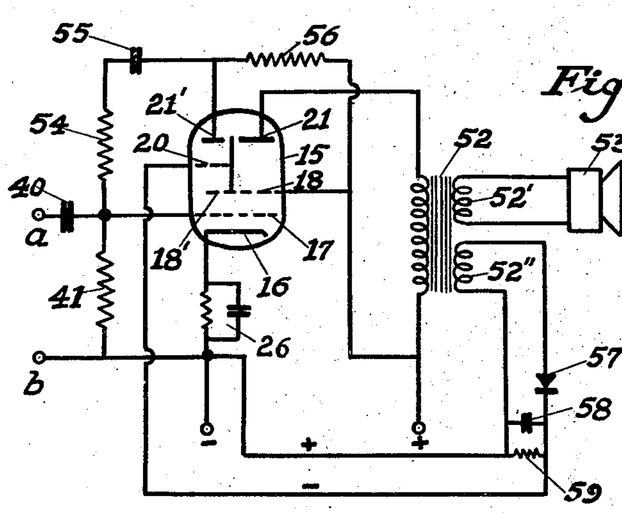


Fig. 8.



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Patented Mar. 30, 1943

2,315,043

UNITED STATES PATENT OFFICE

2,315,043

ELECTRIC AMPLIFIER SYSTEM

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Application March 29, 1940, Serial No. 326,639
In Germany March 27, 1939

12 Claims. (Cl. 179—171)

This invention relates to electric amplifiers serving for strengthening weak signal variations of both low and high frequency for use in radio signaling, talking picture, public address and various other systems known in the art.

More particularly the invention is concerned with amplifiers of the type comprising means for controlling the amplification or a different characteristic of the output signals in dependence upon a condition or another characteristic of the signals being amplified.

Among numerous uses, the invention has special application in feedback amplifiers comprising an arrangement for varying the degree of feedback by controlling the amplification of a valve serving simultaneously for amplifying the useful (signal) variations.

In arrangements of the above type the change in feedback due to variation of the mutual conductance or amplification of the valve is accompanied by a substantial variation of the amplification of the useful signal variations. In radio frequency amplifiers having controlled feedback for band width or fidelity control the above drawback may be eliminated by employing a control potential varying according to the average amplitude of the radio signals (AVC potential) for controlling the feedback. In low (audio) frequency feedback amplifiers an arrangement of this type for controlling the feedback cannot be employed in most practical cases.

Accordingly, an object of the present invention is to provide a method of and means for varying the degree of feedback in an amplifying stage by varying the amplification of the feedback potential or current substantially without interfering with or affecting the amplification of the useful (signal) oscillations.

With this general object in view, the invention involves the use of an amplifying valve in a feedback amplifying stage comprising in addition to the cathode and the usual control grid at least two further positively biased or current conveying electrodes (anodes) the currents to which are controlled by an additional control or regulation grid or any other controlling element in a different sense or at least to a different degree. The circuit connected to one of the positive electrodes advantageously includes the coupling elements for translating the signal variations to a succeeding amplifying stage or translating device, while the circuit connected to the other positive electrode preferably serves to supply the feedback potential to be impressed upon the input grid circuit or upon another preceding circuit of the amplifier system.

Accordingly, a more specific object of the invention is to provide a single feedback amplifier stage for both positive and negative feedback and suited for both low (audio) frequency and high frequency amplification, said stage embodying means for controlling the amount or degree of feedback substantially without affecting the amplification of the useful signal variations.

Another object is the provision of an improved feedback amplifier embodying resonant coupling means in the input and output circuits thereof, wherein the phase of the feedback potential or current is substantially unaffected by variations of the signal frequency and the characteristics of said coupling means.

A further object is to provide means for and a method of effective band width or selectivity control in an amplifier for low frequency or modulated high frequency signal energy substantially without affecting the operating characteristics, in particular the amplification of the amplifier.

Another object is to effect automatic selectivity (background noise) control in an audio frequency amplifier without affecting the operating characteristics, in particular the amplification of the useful signals.

A further object is to provide a novel construction for an amplifier valve especially suited for the purposes of and adapted for embodiment in the circuits according to the invention.

The above and further objects of the invention will become more apparent from the following detailed description taken with reference to the accompanying drawings forming part of this specification and wherein;

Figure 1 is a circuit diagram for a high frequency amplifier embodied in a radio receiver with controlled feedback for effecting a variable band width or fidelity control utilizing the principle of the invention,

Figure 2 is a diagram for an audio frequency amplifier especially suited for use in connection with sound pick-up devices and embodying a controlled feedback system for effecting automatic background noise control in accordance with the invention,

Figure 3 shows a modification including features of improvement of an amplifier of the type according to Figure 2,

Figure 4 represents a schematic diagram of an amplifying valve structure suited for use in the crcuits shown in the previous figures,

Figure 5 is an isometric view with parts broken away showing a structural design for a valve according to Figure 4,

Figure 6 is a schematic view of a modification of a valve suited for the purposes of the invention,

Figure 7 is an isometric view with parts broken away of a structural embodiment of a valve according to Figure 6,

Figure 8 is a diagram for automatic fidelity control in an audio frequency amplifier similar to Figure 2 but embodying a valve of the type shown in Figures 6 and 7.

Like reference numerals identify like parts throughout the different views of the drawings.

Referring to Figure 1, there is shown a diagram for a superheterodyne radio receiver embodying an IF stage with controlled feedback for fidelity or band width control in accordance with the invention. The remaining portions of the receiver are shown schematically only being unnecessary for an understanding of the invention. An input circuit (not shown) connected between antenna 10 and ground 11 serves to receive input signals applied to an RF amplifier and first detector or mixer collectively shown by the rectangle 12 and well known to those skilled in the art. Intermediate frequency signals supplied by the first detector are impressed upon the grid-cathode path of the multiple grid, intermediate frequency amplifying valve 15 by way of a band-pass filter comprising the primary and secondary resonant circuits 13 and 14. The valve 15 forming the control stage according to the invention further comprises a cathode 16 followed in succession by a signal control grid 17, a screen grid 18 at zero alternating and positive direct potential relative to the cathode, a first grid shaped anode referred to as anode grid 19, a further control electrode referred to as current distribution control or regulation grid 20, and a second anode or plate 21. Amplified IF signals are derived from the first anode or grid 19 by way of a band-pass filter comprising resonant primary and secondary circuits 22 and 23, respectively, and impressed upon a succeeding IF stage or directly upon the second detector and audio frequency amplifier of standard design collectively shown by the rectangle 29. The amplified audio signals are applied to a suitable translating device such as a loud speaker 30. Item 26 represents a network comprising a resistance shunted by a condenser in the cathode return lead to provide proper operating bias for the grid 17 in accordance with standard practice. Suitable positive potential is applied to the grids 18, 19 and to the plate 21 in a well known manner such as by way of a tapped potential divider or the like indicated by the plus signs in a conventional manner.

Feedback signal potential is generated at the anode 21 by the action of a suitable coupling impedance such as ohmic resistance 24 connected between the anode and the source of positive potential supply. The feedback potential is impressed upon the grid input circuit 14 by way of a feedback circuit shunted across the anode-cathode path of the valve and comprising a condenser 28 and feedback coil 25 arranged in inductive coupling relation with the inductance of the input circuit 14. The ohmic resistance 24 may be replaced by an inductive impedance as is readily understood. Condenser 28 may be variable for adjusting the feedback or frequency discriminating characteristic of the feedback circuit.

In an arrangement of the aforedescribed type, if a regulating (bias) potential E_r applied to the grid 20 is varied towards negative values such as by the aid of a potential divider 32 shunted across a biasing potential source 31, the amount of feedback current conveyed to the anode 21 will be decreased. At the same time, the current conveyed to the circuit of the grid 19 and consequently the amplification in this circuit will be increased, thereby effecting a compensation for the increased damping of the input circuit 14 due to the decreased feedback or regeneration. By a proper choice of the working point upon the operating characteristic for the grid 20 and design of the circuit constants, the conditions for a practically constant amplification may be established.

A circuit of the type described may serve for remote control of the band width or selectivity by placing the potential divider at the distant control point. Shunting condenser 33 serves to eliminate disturbances and interfering potentials.

The effect of band width control may be improved by the employment of a negative or inverse feedback circuit in addition to and controlled in an opposite sense to the positive feedback. In the example shown there is provided for this purpose a further feedback path connected between the positive grid 19 and the cathode and comprising condenser 36 in series with feedback coil 35 arranged in inductive coupling relation with the input circuit 14 in such a manner as to counteract the direct feedback produced by coil 25. The simultaneous use of both positive and negative feedback controlled in an opposite sense by the regulating potential on the grid 20 on account of the opposite effect of the latter on the electrodes 19 and 21 makes it possible, provided a suitable (symmetrical) design of the feedback circuits, to render the degree of damping reduction of the input circuit substantially independent of ageing phenomena of the cathode (variation of the emission current) as well as of variations of the fluctuations of the operating potential especially of the anode supply voltage and other influences, inasmuch as the latter will affect both output circuits in a like manner and produce feedback effects cancelling each other in contrast to the feedback current variations due to the control by the grid 20. This is of special importance if a maximum and stabilized damping reduction is desired.

The circuit according to Figure 1, in addition to the independence of the amplification from the degree of feedback, has the further advantage that the feedback potential is not derived from an oscillatory or resonant circuit, thereby eliminating the danger of self-oscillation and tendency to instability inherent in the known feedback arrangements in high frequency systems.

If desirable, a further screen grid may be arranged between the regulation grid 20 and either of the adjacent positive electrodes (anodes) 19 and 21 in order to minimize or eliminate the influence of the feedback control potential upon either of the output circuits, especially the circuit coupled to the succeeding amplifying stage. An exemplification of an arrangement of this type is shown in Figure 2.

The latter represents a two-stage audio frequency amplifier embodying a frequency band width or pass range control in the first stage constructed in accordance with the invention. The input audio signals which may be supplied from any source such as the output of the detector stage in a radio receiver, a sound pick-up device or the like connected to input terminals a—b are impressed upon the grid-cathode path of multiple grid amplifier valve 15 by way of coupling condenser 40 and grid leak resistance 41. Valve 15 is of similar construction to that shown in Figure 1. Contrary to the circuit according to Figure 1, the amplified (audio) potentials are derived from the positively biased grid 18 adjacent to the input control grid 17 by the aid of a coupling resistance 42—which may be replaced by an inductance coil—connected between the grid 18 and the high potential supply source designated as +200 in the drawings. The signal potential variations set up at the grid 18 are applied by way of coupling condenser 43 and grid leak resistance 44 to the grid-cathode path of the succeeding amplifier valve 45 for further amplification before being impressed upon the loud speaker 53 or any other translating device. Valve 45 in the example shown is of the tetrode type comprising a cathode 46, input control grid 47, a screen grid 48 and plate or anode 49. Item 50 represents a biasing network in the cathode lead similar to network 26 for the valve 15. The amplified audio signals are applied to the loud speaker 53 by way of secondary winding 52′ of an audio transformer 52 having its primary winding inserted in the anode circuit of tube 45. The grid 19 of valve 15 is maintained at a positive direct potential (+100 in the example shown) and at zero alternating potential with respect to the cathode to prevent reaction between grid 20 and the circuit connected to the grid 18 in such a manner that the grid 20 will not affect the amplification of the main or useful signals in the output circuit of grid 18. Negative feedback potential set up at the anode 21 by means of load impedance 56 preferably an ohmic resistance as shown is impressed upon the input grid 17 by way of condenser 55 in series with resistance 54 connected between the anode 21 and the grid 17 whereby resistances 54 and 41 form a potential divider for introducing the negative feedback potential into the input circuit. Condenser 55 is so dimensioned that the negative feedback is predominantly effective for the higher audible frequencies.

In an arrangement of the aforementioned type, a decrease of the negative potential on the control grid 20 will result in an increased suppression of the higher audible frequencies. This effect is utilized to obtain a variable band width or pass range adjustment such as for control of the background noise or needle scratch suppression in an amplifier connected to a sound reproducing device in dependence upon the momentary strength of the sound signals. For this purpose a portion of the output energy derived in the example shown by way of tertiary winding 52″ of output transformer 52 energizes a rectifying circuit comprising a rectifier 57 in series with load resistance 59 shunted by a smoothing condenser 58. The rectified potential developed by the resistance 59 serves to control the bias of regulation grid 20, the rectifier 57 being connected in such a manner that the bias potential is negative with respect to the cathode as indicated in the drawings.

With the rectifier 57 connected in the manner shown, the operation of the system will be as follows; assuming the bias on the grid 20 which may have an additional fixed negative bias (not shown) applied to it, to result for medium average sound current intensity in a determined amount of inverse feedback current through the circuit 41, 54, 55 and a corresponding degree of noise reduction and linearity of the amplification characteristic. If the sound intensity increases beyond this value, the bias potential at the grid 20 will become more negative due to the increased potential drop across resistance 59, resulting in a proportionate blocking of the negative feedback current conveyed to the plate 21. As a result thereof, the effective frequency pass range of the amplifier will be widened due to the decreased negative feedback for the higher sound frequencies, resulting in greater fidelity and increased noise, the latter being no longer objectionable inasmuch as it will be drowned out or blanketed by the increased sound intensity. Conversely, if the sound intensity decreases below the above value, the negative bias on the grid 20 will become less, resulting in an opening up of the anode (negative feedback) path and a proportionately increased suppression of the higher sound (noise) frequencies by the negative feedback.

In known arrangements for inverse feedback, especially in audio frequency negative feedback amplifiers, great difficulties are experienced due to the inductive and/or capacitative load in the output circuit, whereby the feedback potential to be superimposed upon the input potential may have its phase rotated to a considerable extent. Since the phase rotation is dependent on frequency, the effects of the negative feedback such as distortion equalization, noise reduction, etc., largely depend upon the frequency or frequency characteristics of the input signal and the load or coupling circuits of the amplifier with the effect that the inverse feedback may be changed into a positive or direct feedback for certain frequencies or groups of frequencies, resulting in self-oscillation and impairment of the operational stability of the amplifier. This drawback is greatly minimized or eliminated by arrangements proposed by the invention wherein the negative feedback potential is derived from a separate auxiliary anode arranged in such a manner that it is subject to the influence of the main control grid 17 in the same manner as the main or output anode, but is substantially unaffected by the signal potential variations on the main anode. This auxiliary anode in general may be of small dimension compared with the main anode since it only serves to produce the feedback control without involving substantial energy expenditure, whereby it will collect only a small percentage of the total space current. Again in turn, only ohmic resistance may be provided in the circuit connected to this auxiliary anode to serve as a load impedance (resistance 24 or 56), avoiding thereby any objectionable phase rotation of the feedback potential. The anode potential and anode resistance for the auxiliary anode should be chosen in such a manner that the kind and degree of distortion of the alternating potential set up at the auxiliary anode corresponds substantially to the distortion characteristic of the main anode circuit. It has been found advantageous to shield the auxiliary anode from the main anode by means of a negatively or positively biased screen or a grid connected to a cathode. This screen may be structurally combined with an existing screen grid to form a single unit.

The control of the inverse or direct feedback may serve to effect indirectly a volume control, or to obtain simultaneous volume and fidelity control. For this purpose the feedback path in

Figure 2 should be designed in such a manner that the inverse feedback is effective for all frequencies especially the medium range of the audible frequencies. If in such a system the volume is decreased by increasing the amount of negative feedback, the low and high notes will be relatively strengthened. When using a control potential proportionately to the average intensity or amplitude of the signals being transmitted such as shown in Figure 2, a volume expansion or compression is obtained dependent on the polarity of the control potential applied to the grid **20**. If desired, the shielding effect of a screen grid arranged adjacent to the regulation grid **20** with respect to one of the output electrodes may be reduced by providing an ohmic resistance in the connection from the high potential source to the screen grid.

Again in turn, it is possible to effect a control of the amplification of the signals being translated in the same stage such as a volume control (AVC) in dependence upon the RF signal amplitude in the case of Figure 1 or for volume expansion and compression in an audio frequency amplifier of the type according to Figure 2. For this purpose the operating characteristic for the input grid **17** should be of the exponential (variable mu) type. The potential for controlling the amplification such as an AVC potential is impressed upon the signal grid **17** in a manner well known. In order to prevent this amplification control from reacting upon the feedback circuit it is necessary to apply an additional volume control potential to the regulation grid **20** in such a manner as to produce an effect upon the feedback potential opposite to that caused by the control potential applied to the input grid **17**. In this manner the degree of feedback remains constant and is subject only to the influence of the feedback control potential applied to the regulation grid **20**. Moreover, the simultaneous amplification control by the grid **20** for the output circuit **22**, Figure 1, entails an improvement of the AVC or fading compensation provided no screen grid is arranged between the grids **19** and **20**. In order to obtain automatic volume control, therefore, in Figure 1 the AVC voltage produced in the usual manner by rectification of a portion of the RF energy is applied with its negative pole to the control grid **17**. In addition, an additional AVC voltage is applied with its positive pole to the grid **20**. The additional AVC voltage is preferably produced in a separate rectifying circuit and inserted at a suitable point P in the grid circuit.

According to a modified arrangement the succeeding stage may be connected to the anode **21** and the feedback potential derived from the grid **19**. In this case the additional AVC potential applied to the grid **20** should have the same polarity as the AVC potential on the grid **17** to eliminate the influence of the volume control upon the feedback. The above modifications are not limited to arrangements with additional volume control but apply in a like manner to other methods for controlling the amplification of the signal being translated such as for volume expansion and compression in audio amplifiers of the type according to Figure 2.

According to a further feature, the arrangements described may be combined with other control circuits such as for band width or fidelity control or many other uses. A combined arrangement for band width or fidelity control in an audio frequency amplifier is shown in Figure 3 wherein a supplementary fidelity control system is used as described in my copending application Serial No. 314,411 filed January 18, 1940, which matured into Patent No. 2,257,782 dated October 7, 1941. Input audio signal potentials to be amplified and derived from a suitable source are impressed by way of input terminals *a*—*b* upon the grid-cathode path of valve **15** through coupling condenser **40** and grid leak resistance **41** in substantially the same manner as shown in Figure 2. The grid **18** in this example constitutes a screen grid and is maintained at a fixed positive potential. If desired, this grid may be dispensed with. The output or anode grid **19** is connected to the high voltage source through a pair of resistances **60** and **61** in series. Resistance **61** serves as a load to produce amplified control potential at the junction between the resistances **60** and **61** to be impressed upon the grid **47** of the succeeding amplifier stage **45** by way of decoupling impedance such as an ohmic resistance **66**, blocking condenser **68** and grid leak resistance **69**. Additional potential is developed at the anode **21** by the action of anode load resistance **63** and applied simultaneously to the grid **47** of amplifier **45** by way of decoupling resistance **65** and blocking condenser **67**. Condensers **67** and **68** serve to isolate the grid **47** from the high potential at the plate **21** and grid **19** of valve **15**. Resistances **65** and **66** serve to prevent mutual interaction or coupling between the output circuits of grid **19** and plate **21** of valve **15** by way of the common grid input circuit of valve **45**. Resistance **61** in the output circuit of grid **19** is shunted by a condenser **62** designed so as to by-pass the high audible frequencies. Inverse feedback potential is applied from the grid **19** to the input grid **17** by way of a feedback circuit comprising condenser **55** and resistance **54**. Condenser **55** is designed to predominantly pass the high audible frequencies whereby these frequencies are suppressed on account of the inverse feedback action. The circuit for the anode **21** has a substantial linear frequency characteristic or may be designed for accentuation of the higher notes or audio frequencies. A further amplification stage or a translating device connected to output terminals *c*—*d* may be energized by the output of valve **45** as is understood.

In a system as described hereinbefore, if the control potential E_r applied to the regulation grid **20** by way of terminals *e*—*f* has a high negative value the anode path will be blocked in such a manner that only the grid **19** will supply control potential for the succeeding stage. The existing high degree of inverse feedback together with the action of condenser **62** will result in a considerable suppression of the higher sound frequencies. With small values of the control potential on the other hand the anode path will be opened resulting in a widening of the frequency pass range assisted by the decrease of the current to the anode **19** and consequent reduction of the higher frequencies due to the inverse feedback.

It is to be pointed out that the regulation grid need not of necessity be arranged between the positive electrodes or anodes **19** and **20**. The latter may both be arranged at one side of the control grid, it being only essential for the invention that the influence on both electrodes by the control grid is of an unequal nature. Thus, for instance, Figure 2 may be modified in the following manner: The connection of the anode **21** is interchanged with the connection of grid **19**. In a modified arrangement of this type, the inverse feedback potential derived from the grid 19 is subject to a more intense control by the auxiliary control grid 20 than the more remote electrode 18. In this case the polarity of the control potential should be reversed since a decrease of the negative potential at the grid 20 will no longer intensify but rather reduce the feedback potential. In order to secure the required operating range for the control potential it is necessary to provide a high constant grid bias which is more or less decreased by the controlling potential. In the aforementioned modified circuit, in order to protect the grid 18 from the influence by the control grid, a screen grid may be arranged between the grids 18 and 19. In arrangements of this type the anode is not absolutely necessary if sufficiently high potentials are applied to the grids 18 and 19. If the anode is omitted or left disconnected, the grid 20 no longer will have the function of a current distribution grid but will effect regulation in such a manner that the current to the grid 19 decreases the higher the negative bias on the grid 20. In order to obtain the same effect, the polarity of the control potential may be the same as shown in Figure 1.

According to a further modification, the positive electrode which should be substantially unaffected by the auxiliary control electrode may be disposed between the cathode and the input control grid.

In the foregoing there are described arrangements suitable for effecting a volume control being either dependent upon or independent of frequency by varying the degree of negative feedback in an amplifier. This control is produced by the aid of an auxiliary (regulation) grid arranged to influence the current to a pair of positive (anode) electrodes in a different sense or at least in a varying degree. The inverse feedback potential is supplied by the positive electrode which is subject to intense control by the regulation grid, while the potential serving for controlling the succeeding stage or for energizing a translating device is supplied by the positive electrode not or less subject to the control influence of the regulation grid, to obtain e. g. a band width or fidelity control without attendant volume changes or to effect volume control exclusively by varying the degree of negative feedback.

According to a further feature of the invention, the arrangements described may serve for improved volume control in such a manner that the indirect volume control by varying the degree of negative feedback is supplemented by the direct amplification control effected simultaneously by the same regulation electrode in the output circuit for the useful signal variations. For this purpose it is necessary that the regulation electrode is disposed between the positive electrodes and that these electrodes are arranged in such a manner that contrary to the previous arrangements both the auxiliary (feedback) electrode and the main output electrode are subject to efficient control by the regulation grid.

An exemplification of a system of this type is obtained by interchanging the connections of the grids 18 and 19 in Figure 2 and by designing the condenser 55 in the negative feedback circuit in such a manner as to pass all audible frequency freely. In this case the control by the grid 20 will be such that an increase of the inverse feedback potential is accompanied by a decrease of the amplification in the circuit of the grid 19; that is, the output circuit for the signal variations. Both effects of the regulation potential will produce a multiple total effect on the overall amplification by the stage. Thus, if the variation due to the negative feedback has a range of 1–20 and the direct regulation in the signal output a range of 1–5 or 1–10, then the actual total regulating range will be from 1–100 to 1–200, respectively.

In order to effect volume control in a high frequency amplifier in which case an efficient and intensive regulation is desirable, the circuit according to Figure 1 may be modified by changing the polarity of the coil 25 so as to produce an inverse or negative feedback and to connect the coil 35 so as to produce a direct feedback or in other words by interchanging the positive and negative feedback circuits. In such a circuit, due to the opposite effect of the separate feedbacks in combination with the direct control of the amplification in the output circuit of electrode 19, a very high sensitivity and increased range for the regulation are obtained.

An advantage of the proposed new regulating arrangement resides in the fact that improved regulating action is obtained without requiring a curved grid (variable mu) operating characteristic as in the case of the known regulating valves. It is therefore advisable to employ a tube with linear characteristic for volume or gain control in circuit arrangements of the type according to the invention.

In arrangements wherein the two output electrodes (anodes) are disposed directly at opposite sides of the auxiliary regulation grid, it has been discovered that space charge effects may occur, whereby with increasing negative control potential the inverse feedback potential at the anode will at first become zero, then reverse its phase and increase again, or in other words, that the inverse feedback becomes weaker and is finally converted into positive feedback. In order to obviate this drawback, the following three procedures may be followed: (1) The negative feedback potential is derived from the grid 19 located at the side of the cathode which is not subject to the phase reversal. In this case the control potential should not become excessive so as to cause phase reversal of the anode potential which in this case serves to supply the output for the succeeding stage; (2) limitation of the space charge near the grid 19 by suitable construction of the electrodes and choice of the operating potentials; (3) selection of the operating conditions in circuits according to Figures 1 and 2 so that the regulation takes place within the space charge region, whereby beginning with a certain regulating value the inverse feedback potential decreases and is changed into positive feedback. The sense of regulation does not change in this case and a more intensive volume control is obtained especially in high frequency stages.

In carrying out the invention as described hereinbefore, double control amplifying valves of the type known as hexode valves in the art may be employed to obtain the results desired. These valves, however, have been constructed with different considerations and for different purposes and therefore in most cases will not yield the most favorable results to be obtained by the invention. Most of the known hexode valves such as pentagrid converters are constructed on the basis that the amplified output potential is exclusively or predominantly supplied by the anode, whereas for the new application it is desirable to employ one or more positive electrodes disposed between control and regulating grids for supplying the amplified output (signal) potential. Most of the new circuits of the invention call for a supply of the output signal potential or energy from a positive electrode which is only little or not at all affected by the controlling action of the regulation grid or other controlling element.

Accordingly, the special tube constructions proposed by the invention and suited primarily for the purpose of the invention are characterized by the provision of at least two anodes having like or different load or current conveying capacity, the current to which is controlled by at least one controlling grid in an opposite sense or to a varying degree; that is, in the case of anodes of different load capacity in such a manner that the anode of higher load capacity is not at all or only to a slight extent subjected to the controlling action when compared with the anode of lower load capacity.

According to one embodiment, the above object is accomplished by arranging one of the anode electrodes in front of the regulation grid at the side of the cathode, while the other anode of like or preferably lower load capacity is disposed at the other side of the regulation grid. A schematic arrangement for an electrode structure of this type is shown in Figure 4, wherein like reference numerals are employed as in the preceding figure. The anode of high load capacity has an outer solid portion 19 and a central foraminous portion 19', while the anode of lower load capacity 21 (feedback anode, etc.) is substantially equal to in area and disposed opposite the foraminous portion 19' of the electrode 19. In this manner, the effect of the controlling grid 20 on the electrode 19 is greatly minimized or suppressed for practical purposes.

A practical electrode structure of this type comprising cylindrical electrode elements is shown in Figure 5, the details of which are self-evident from the foregoing.

According to a modification, the output electrodes or anodes may be arranged in juxtaposition as shown schematically in Figure 6. In the latter two anodes 21 and 21', the former being designed for high load capacity and the latter for low load capacity, are arranged side by side and screened from each other to prevent interaction by means of a screen element 70. The latter may be connected to the cathode 16 to serve as a suppressor grid or it may be maintained at a high positive potential and for this purpose structurally combined with an existing screen grid such as the grid 18 in the example shown.

A structural embodiment of a tube of this type is shown in Figure 7, comprising cylindrical electrode elements the details of which will be self-evident from the foregoing. Instead of arranging the main anode 21 and auxiliary anode 21' at the same distance from the cathode both electrodes may be staggered to secure desired operating characteristics. The control grid 20 in this case mainly affects the auxiliary anode 21' in a manner similar as in the case of the construction according to Figures 4 and 5. Additional electrodes such as screen grids may be provided between the several electrodes as will be obvious from the above.

Referring to Figure 8, there is shown a low (audio) frequency amplifier with controlled inverse feedback to obtain automatic volume control. This circuit corresponds substantially to the circuit of Figure 2 with the exception of the employment of an amplifying valve of the type described and shown by Figures 6 and 7. The main output (signal) potential is supplied by the anode 21 and applied directly to the loud speaker 53 by way of audio transformer 52. The negative feedback potential is set up at the auxiliary anode 21' by the action of load resistor 56 and is applied to the input circuit in the manner described hereinbefore. The amount of negative feedback is controlled by the regulation grid 20 substantially independently of the amplification of the main or useful signals in the output circuit of anode 21 by means of a controlling potential obtained by averaging a portion of the output energy in a rectifying and smoothing system similar as shown in the preceding examplifications. In the example shown, with the grid 20 connected to the negative end of load resistance 59, a volume expansion for the output signals is obtained. If, on the other hand, such as in sound recording, a volume compression is desirable, a fixed negative potential should be applied to the grid 20 upon which the potential supplied by resistance 59 is superimposed with its polarity reversed compared with the arrangement shown in Figure 8.

According to a further feature, it is possible to render the volume control dependent on frequency by a corresponding design of the coupling path. Such an arrangement according to Figure 8 has the advantage that volume expansion may be effected by means of a control potential in a power amplifier which is not possible with power amplifiers of the present known type without entailing additional distortion. Such a regulation is especially desirable if the final stage is directly connected to the detector of a radio receiver without a previous audio (driver) stage. A further advantage is due to the fact that the A. C. hum of a stage when adjusted to low amplification is reduced to a considerable extent.

As is understood, the circuits for positive or negative feedback may be employed with a constant or fixed degree of feedback or regeneration in which case the auxiliary regulation grid 20 and associated control circuits may be omitted. Arrangements of this type have the advantage described above over the existing inverse feedback systems that the feedback potential is derived from a separate output or anode electrode by the aid of a non-reactive coupling element such as an ohmic resistance 56 thereby substantially avoiding frequency discrimination and eliminating the danger of phase rotation and consequent tendency to oscillate and instability of the amplifier.

Amplifying valves constructed according to the invention may also be employed in reflex stages for simultaneous amplification for high frequency and low frequency signals. In this case, the high frequency and low frequency potentials are impressed upon the same input grid (grid 17) but are derived from separate anodes. Thus, if the high frequency is derived from the anode 21' (Figure 8), volume control for the high frequency potential for fading elimination, etc., may be employed without affecting the low frequency amplification.

When using valves the anodes of which are designed for equal or substantially equal load capacity for fidelity control the anode predominantly subjected to the action of the regulation grid preferably serves to supply a circuit designed to admit the high audible frequencies, while the low and medium frequencies are derived from the circuit of the other anode. In such an arrangement, especially when provided in a power amplifier it is advantageous to energize a high frequency loud speaker from the first anode (21' according to Figure 8) while a low frequency speaker is energized from the other anode. By controlling the current conveyed to the first anode there is obtained in this manner a desired ratio between the high and low audible frequenies.

A low frequency power stage embodying a valve of the type described may also be employed for improving the volume control or fading elimination by impressing an AVC voltage with its positive side to the control grid 20 to effect a volume control by varying inverse feedback. If in such an arrangement the negative side of the AVC voltage is at the cathode it is necessary to produce the control potential for the inverse feedback by the aid of an additional rectifier circuit energized by a portion of the high frequency energy, or to reverse the sense of variation of the control potential by a phase reversing circuit.

It will be evident from the above that the invention is not limited to the specific details of construction and arrangement of parts shown and disclosed herein for illustration but that the underlying idea and principle of the invention are susceptible of nume· ›us variations and modifications coming within the broad scope and spirit of the invention as defined in the appended claims. The specification and drawings are accordingly to be regarded in an illustrative rather than a limiting sense.

I claim:

1. In an amplifier, an amplifying valve comprising cathode, signal control, main anode, auxiliary anode, and regulation electrodes, space current supply means for said anodes, said electrodes being relatively arranged so that said signal control electrode is effective in controlling the space current to both said anodes and said regulation electrode is effective in controlling the space current to said auxiliary anode only, signal input and output circuits operatively connected to said signal control electrode and said main anode, respectively, and feedback circuit means between the auxiliary anode and said input circuit.

2. In an amplifier, an amplifying valve comprising cathode, signal control, main anode, auxiliary anode and regulation electrodes, space current supply means for said anodes, said electrodes being relatively arranged so that said signal control electrode is effective in controlling the space current to both said anodes and said regulation electrode is effective in controlling the space current to said auxiliary anode only, signal input and output circuits operatively connected to said signal control electrode and said main anode, respectively, inverse feedback circuit means between said auxiliary anode and said input circuit, and means for applying variable bias potential to said regulation electrode.

3. In an amplifier, an amplifying valve comprising cathode, signal control, main anode, auxiliary anode and regulation electrodes, space current supply means for said anodes, said electrodes being relatively arranged so that said signal control electrode is effective in controlling the space currents to both said anodes and said regulation grid is effective in controlling the space current to said auxiliary anode only, signal input and output circuits operatively connected to said signal control electrode and said main anode, respectively, substantially non-reactive load impedance means connected to said auxiliary anode, inverse feedback means between said auxiliary anode and said input circuit, and means for impressing a variable bias potential upon said regulation electrode.

4. In an amplifier, an amplifying valve comprising cathode, signal control grid, main anode, auxiliary anode and regulation electrodes, space current supply means for said anodes, said electrodes being relatively arranged so that said signal control electrode is effective in controlling the space currents to both said anodes and said regulation grid is effective in controlling the space current to said auxiliary anode only, signal input and output circuits operatively connected to said signal control electrode and said main anode, respectively, an ohmic load impedance connected to said auxiliary anode, inverse feedback means between said auxiliary and said input circuit, and means for impressing a variable bias potential upon said regulation electrode.

5. In a high frequency amplifier, an amplifying valve comprising cathode, signal control, main anode, auxiliary anode and regulation electrodes, space current supplymeans for said anodes, said electrodes being relatively arranged so that said signal control electrode is effective in controlling the space current to both said anodes and said regulation electrode is effective in controlling the space current to said auxiliary anode only, tuned high-frequency signal input and output circuits connected to said signal control electrode and said main anode, respectively, a periodic load impedance means connected to said auxiliary anode, feedback circuit means between said auxiliary anode and said input circuit, and means for impressing a variable bias potential upon said regulation electrode.

6. In an audio frequency amplifier, an amplifying valve comprising a cathode, a signal control grid, a main anode, an auxiliary anode and a regulation grid, space current supply means for said anodes, means whereby said signal control grid is effective in controlling the space current conveyed to both said anodes and whereby said regulation grid controls substantially the space current to said auxiliary anode only, signal input and output circuits operatively connected to the signal control grid and to the main anode, respectively, an inverse feedback circuit designed to predominantly pass the high audible frequencies connected between said auxiliary anode and said input circuit, and means for impressing a variable bias potential upon said regulation grid.

7. In an audio frequency amplifier, an amplifying valve comprising a cathode, a signal control grid, a main anode, an auxiliary anode and a regulation grid, space current supply means for said anodes, means whereby said signal control grid is effective in controlling the space current conveyed to both said anodes and whereby said regulation grid controls substantially the space current to said auxiliary anode only, signal input and output circuits operatively connected to the signal control grid and the main anode, respectively, substantially non-reactive load impedance means connected to said auxiliary anode, an inverse feedback circuit designed to predominantly pass the high audible frequencies connected between said auxiliary anode and said input circuit, means for producing a direct

potential varying in proportion to the average amplitude of the signal energy being amplified, and further means for impressing said direct potential upon said regulation grid.

8. In an electric amplifier, an amplifying valve comprising a cathode, a first anode, a signal control grid near said cathode, a regulation grid near said anode, a second foraminous anode located between said signal control grid and said regulation grid, a screen grid located between said regulation grid and said second anode, space current supply means for said anodes, signal input and output circuits operatively associated with said input grid and said second anode, respectively, feedback circuit means between said first anode and said input circuit, and means for applying a variable bias potential to said regulation grid.

9. In an audio frequency amplifier, an amplifying valve comprising a cathode, a first anode, a signal control grid near the cathode, a regulation grid near the anode and a second foraminous anode between said signal control grid and said regulation grid, space current supply means for said anodes, signal input and output circuits operatively connected to said input grid and to said second anode, respectively, substantially non-reactive load impedance means connected to said first anode, an inverse feedback circuit designed to predominantly pass the higher audible frequencies connected between the first anode and said input circuit, and means for impressing a variable bias potential upon said regulation grid.

10. In an audio frequency amplifier, an amplifying valve comprising a cathode, a first anode, a signal control grid near the cathode, a regulation grid near said anode, a second foraminous anode between said signal control grid and said regulation grid, a screen grid located between said regulation grid and said second anode, space current supply means for said anodes, signal input and output circuits operatively connected to said input grid and to said second anode, respectively, substantially non-reactive load impedance means in the output of the first anode, an inverse feedback circuit shunted across said cathode and said first anode and including an impedance having a tap thereon connected to said input grid, and means for impressing a variable bias potential upon said regulation grid.

11. In an audio frequency amplifier, an amplifying valve comprising a cathode, a first anode, a signal control grid near the cathode, a regulation grid near the anode, and a second foraminous anode between said signal control grid and said regulation grid, space current supply means for said anodes, signal input and output circuits operatively connected to said input grid and said second anode, respectively, substantially non-reactive load impedance means connected to said first anode, an inverse feedback circuit comprising a condenser in series with a resistive impedance shunted across the first anode and cathode, a connection from a point of said impedance to said input grid, said condenser being designed to predominantly pass the high audible frequencies, means for producing a direct potential varying in proportion to the average amplitude of the audio signals being amplified, and further means for impressing said direct potential upon said regulation grid to produce high inverse feedback for low signal intensity and low inverse feedback for strong signal intensity, respectively.

12. In an amplifier, an amplifying valve comprising cathode, signal control, main anode, auxiliary anode and regulation electrode, means whereby said signal control electrode is effective in controlling the space current to both said anodes and said regulation electrode is effective in controlling the space current to said auxiliary anode only, signal input and output circuits connected to said signal control electrode and said main anode, respectively, substantially non-reactive load impedance means connected to said auxiliary anode, feedback circuit means between said auxiliary anode and said input circuit, and means for impressing a variable bias potential upon said regulation electrode.

HEINZ BOUCKE.