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ELECTRON TUBE AMPLIFIER

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Fig. 1.

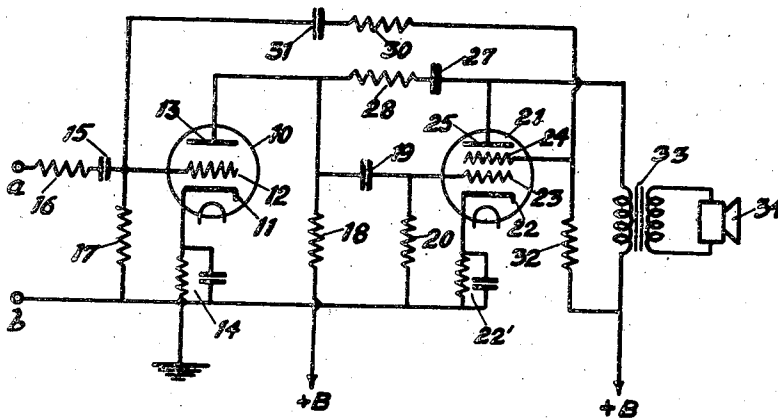
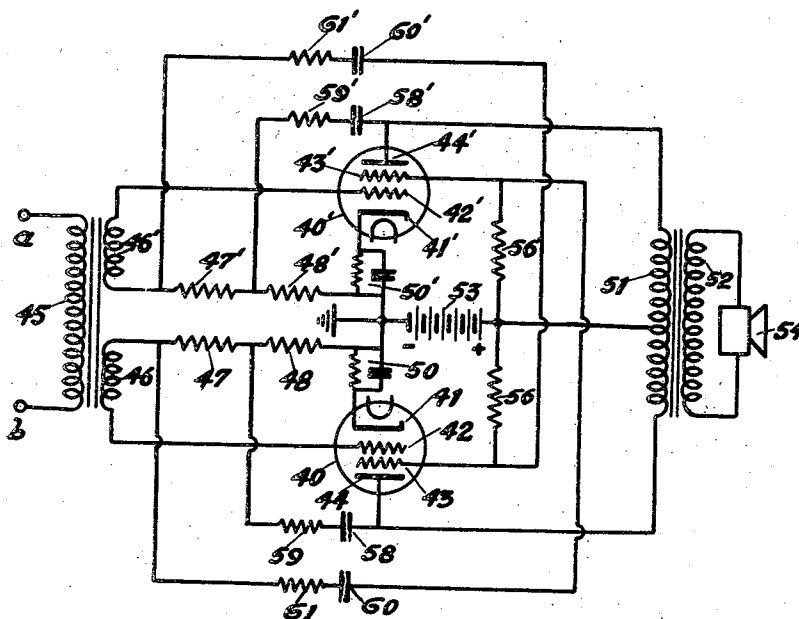


Fig. 2.



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ELECTRON TUBE AMPLIFIER

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The present invention relates to electron tube amplifiers, more particularly to amplifiers embodying feedback to improve the operating characteristics and performance thereof.

It has already become known to reduce or eliminate distortion produced in an electron tube amplifier by the employment of feedback having a predetermined non-linear frequency response. In order to eliminate or equalize distortion in this manner it is necessary that the operating characteristics of the tubes and the characteristics of the non-linear impedances or circuits used should be properly matched, a condition which may not be easily complied with in many instances.

It has furthermore been proposed to effect distortion equalization by the aid of differential feedback by the simultaneous use of positive and negative feedback in an amplifier by deriving positive or regenerative feedback potential or current from an impedance in the plate circuit and deriving negative or degenerative feedback potential or current from an impedance inserted in the common cathode return lead of an amplifying tube.

The object of the present invention is to provide an improved feedback amplifier of the above general type capable of efficient equalization of undesirable distortion by the employment of both positive and negative feedback substantially without sacrifice of amplification.

Other objects and advantages of the invention will become more apparent from the following detailed description taken with reference to the accompanying drawing forming part of this specification and wherein

Figure 1 is a circuit diagram of a two-stage amplifier, and

Figure 2 is a diagram for a push-pull amplifier embodying the invention.

With the above and further objects in view as will appear hereinafter, the invention involves the provision of one or more amplifying stages each comprising an electron tube amplifier including one or more screen grid electrodes and means for deriving a positive or regenerative potential from at least one screen grid and means for deriving a negative or degenerative potential from the plate or anode of at least one of the amplifying stages, both feedback potentials being impressed upon the input of the same or a different preceding stage of the amplifier. The design and adjustment of the circuit is preferably such that for low signal amplitude or small input potential swing the positive and negative feed-

backs substantially neutralize each other, and that with increasing signal amplitude the positive feedback becomes increasingly predominant over the negative feedback in such a manner as to eliminate to a more or lesser degree distortion caused by the upper bend in the characteristic operating curve of an amplifying tube and manifesting itself primarily by the formation of a disturbing third harmonic component.

Arrangements of this type have the following advantages among others. In the first place, the distortion in a screen grid tube is reduced somewhat below the corresponding amount of distortion in a single grid tube or ordinary triode without substantially reducing the amplification. Furthermore, the employment of regeneration or positive feedback does not tend to cause any instability or production of oscillations, inasmuch as the positive feedback becomes effective only during excessive control periods or periods of excessive signal amplitude and to a comparatively small degree only. A further advantage of the inventive method of distortion equalization when used in a push-pull amplifier stage is the fact that in addition to the third harmonic, also the second harmonic distortion is substantially compensated, thus resulting in a practically distortion free amplifier.

Referring to Figure 1, input signal energy to be amplified and supplied by way of input terminals *a-b* is impressed upon the grid 12 and cathode 11 of an electron tube amplifier 10 through a grid coupling condenser 15 in series with an impedance 16 which may be an ohmic resistance and a grid coupling resistance 17. The tube 10 which may be of any known type and construction further comprises an anode or plate 13 and is provided with a biasing network 14 constituted by a resistance and by-pass condenser inserted in the cathode-to-ground lead to provide suitable grid operating bias in accordance with standard practice.

Amplified signal energy in the plate circuit of tube 10 is impressed upon the grid 23 and cathode 22 of a subsequent amplifying stage embodying amplifying tube 21 by way of a resistance coupling network in the plate circuit comprising a plate coupling resistance 18, grid coupling condenser 19 and grid leak resistance 20. The tube 21 further comprises a screen grid 24 and an anode or plate 25. Amplified signal energy in the plate circuit of tube 21 may be impressed upon a further subsequent stage of amplification or may serve to feed a suitable translating de-

vice such as a loud speaker 34 by way of a coupling transformer 33.

There is further shown in Figure 1 in accordance with the invention a negative feedback circuit comprising a condenser 27 in series with a resistance 28 and connecting the plate 25 of tube 21 to the input side of grid coupling condenser 19 to provide inverse feedback or degeneration for distortion elimination and improvement of the operational stability of the amplifier stage. In addition to the inverse feedback there is further provided positive feedback or regeneration through a feedback path comprising a resistance 30 and a condenser 31 in series and connecting the screen grid 24 of stage 21 to the input grid 12 of the preceding stage 10. In order to develop signal potential variations for the positive feedback at the screen grid 24, the latter is connected to the source of positive potential indicated by the plus sign through a suitable coupling impedance such as a choke coil or an ohmic resistance 32 provided in the example illustrated.

In the exemplification according to Figure 1, a two-stage amplifier is required to obtain positive feedback from the screen grid of the second stage to the input grid of the first stage due to the 180° phase reversal effected in a vacuum tube between the input (grid) and output (plate) potentials. Alternatively, the positive feedback or regeneration may be produced in the same stage by coupling the screen grid 24 to the input grid 23 of the same tube through a properly poled transformer acting as a phase reversing device in a manner well understood.

The coupling resistance 32 in the screen grid circuit or the resistances 28 and 30 in the feedback circuits are advantageously made adjustable in such a manner as to enable a balance of the propagation constants of both feedback circuits whereby the positive and negative feedback substantially cancel each other in case of small signal amplitudes or will result in a slight residual negative feedback for relatively weak signal energies. As the signal amplitude increases, the positive feedback from the screen grid will become more and more predominant over the negative feedback resulting in efficient compensation or equalization of the distortion caused by the upper bend of the characteristic operating curve of the amplifier, that is, primarily elimination of the third harmonic distortion inherent in vacuum tube amplifiers.

This phenomenon is due to the fact that, with the proper design and choice of the circuit constants, the plate current will flatten out at high amplitude input signal, that is, whenever the input signal is such as to cause operation on the non-linear portion of the plate operating curve a sine wave will be changed into a square wave, while the screen current continues to increase substantially linearly even at high input signal amplitudes. Accordingly, for low volume of input signal where the plate current operates on the linear portion of the curve and the screen current likewise operates on the linear portion of its operating curve, the positive feedback derived from the screen and the negative feedback derived from the plate will increase and decrease in the same proportion as a function of the input signal amplitude. In accordance with the invention the circuit constants are chosen in such a manner that the positive and negative feedbacks are substantially balanced so as to cancel each other whereby distortion-free output

without loss in volume is obtained for relatively low signal amplitudes

If, now, the signal amplitude increases beyond the limit where non-linear distortion due to the curvature or upper bend of the plate current curve occurs, the peaks of the signals in the plate circuit will be flattened. However, the peaks of the signals developed in the screen grid circuit will not be flattened since the screen current is linear over a wider range than the plate current. Hence, the positive screen feedback output will exceed the negative plate feedback output, that is, the positive feedback will predominate over the negative feedback resulting in a correction of the distortion caused in the plate circuit.

Figure 2 illustrates a single push-pull stage embodying negative and positive feedback means according to the invention without requiring a transformer or other phase reversing device. There are provided for this purpose a pair of screen grid vacuum tubes 40, 40' having cathodes 41, 41', input grids 42, 42', screen grids 43, 43' and anodes or plates 44, 44', respectively. Signal energy to be amplified delivered by way of input terminals a—b is impressed upon the primary 45 of an input transformer having a pair of secondaries 46, 46', the former being coupled to the grid 42 and cathode 41 of tube 40 in series with voltage divider resistances 47 and 48 and the latter being coupled to the grid 42' and cathode 41' of tube 40' in series with voltage divider resistances 47' and 48', respectively. Items 50 and 50' are networks inserted in the cathode-to-ground leads of the tubes to provide suitable grid operating bias in accordance with standard practice. The plates 44 and 44' of the tubes are connected to the opposite ends of the output transformer primary 51 having a secondary 52 feeding in the example shown a loud speaker 54. The center point of the primary 51 is connected in a known manner to the positive pole of a suitable source of space current 53 having its negative pole connected to ground, or any other zero potential point of the system.

In order to avoid the use of transformers or other phase reversing devices, the positive feedback derived from the screen grid of one tube is impressed upon the input grid of the other tube this being enabled in view of the operation of the push-pull circuit in which the potentials at the respective points of the two circuits are in phase opposition to each other. The screen grid potentials are produced by suitable coupling impedances such as resistances 56 and 56' connecting the screen grids with the positive pole of the source 53. Positive feedback potential for the tube 40' is derived from the screen grid 43 of the tube 40 through a feedback circuit including a condenser 60' and resistance 61' and connecting the screen grid 43 with the cathode side of the secondary winding 46' of the input transformer 45. Similarly, positive feedback potential for the tube 40 is derived from the screen grid 43' of tube 40' through a feedback path comprising condenser 60 and resistance 61 and connecting the screen grid 43' with the cathode side of the secondary winding 46 of the input transformer 45.

The negative feedback is produced in the manner similar to that according to Figure 1 by the provision of feedback paths including condenser-resistance series network 58—59 and condenser-resistance series network 58'—59' and connecting the plates 44 and 44' to the junction points

between the voltage divider resistances 47, 48 and 47', 48', respectively. Like in Figure 1, it is advantageous in a system of this type to provide one or more adjustable impedances such as the screen grid resistances 56 and 56' or the feedback resistances 59, 59' and 61, 61', or alternatively, the feedback condensers 58, 58' or 60, 60' for properly balancing the positive and negative feedback in the manner described. The circuits, both according to Figure 1 and Figure 2, are preferably designed in such a manner that the screen grid resistors 56 and 56' have as small a range as will be compatible with the function and efficient operation of the system.

If a reduction of the amplification is not objectionable the negative feedback may be adjusted to substantially exceed the positive feedback in which case both the second and third harmonic distortion will be substantially eliminated resulting in a substantially distortion free amplifier.

It will be furthermore evident that the coupling circuits may be designed to have a desired frequency response and/or may be of any suitable type known in order to ensure a constant phase especially with regard to the negative feedback potential for substantially all the frequency components of the wave energy being translated or amplified.

From the foregoing it will be evident that the invention is not limited to the specific details and design of circuits shown and disclosed herein for illustration but that the underlying idea and principle of the invention will be susceptible of numerous variations and modifications coming within its broader scope and spirit as defined in the appended claims. The specification and drawing are accordingly to be regarded in an illustrative rather than a limiting sense.

I claim:

1. An electron tube amplifier comprising an input and an output and at least one screen grid amplifying tube, means for regeneratively feeding back screen grid signal potential from a higher to a lower energy level of said amplifier, further means for degeneratively feeding back plate signal potential from a higher to a lower energy level of said amplifier, and means whereby the regenerative and degenerative feedbacks cancel each other for a predetermined signal amplitude and the regenerative feedback exceeds the degenerative feedback in proportion to an increase in signal amplitude beyond said predetermined amplitude.

2. A resistance coupled electron tube amplifier comprising an input and an output and at least two stages in cascade the second of which embodies a screen grid amplifying tube, means for feeding back regenerative potential from the screen grid of the second stage to the input of the first stage, further means for feeding back degenerative potential from the output to the input of one of said stages, and means whereby the regenerative and degenerative feedbacks cancel each other for a predetermined signal amplitude and the regenerative feedback exceeds the degenerative feedback in proportion to an increase of signal amplitude beyond said predetermined amplitude.

3. A resistance coupled electron tube amplifier comprising an input and an output and at least two stages in cascade the second of which embodies a screen grid amplifying tube, means for feeding back regenerative signal potential from the screen grid of the second stage to the input

of the first stage, further means for feeding back degenerative signal potential from the plate to the grid of the second stage, and means whereby the regenerative and degenerative feedbacks cancel each other for a predetermined signal amplitude and the regenerative feedback exceeds the degenerative feedback in proportion to an increase in signal amplitude beyond said predetermined amplitude.

4. A resistance coupled amplifier comprising an input and an output and at least two amplifying stages in cascade, a coupling impedance in the screen grid circuit of the second stage, a first regenerative feedback path connecting the screen grid of the second stage to the input of the first stage, a second degenerative feedback circuit connecting the plate and grid of the second stage, and means whereby said regenerative and degenerative feedbacks cancel each other for a predetermined signal amplitude and the regenerative feedback exceeds the degenerative feedback in proportion to an increase in signal amplitude beyond said predetermined amplitude.

5. A resistance coupled amplifier comprising an input and an output and at least two stages in cascade the second of which embodies a screen grid amplifying tube, coupling impedance means in the screen grid circuit for the second stage, a first regenerative feedback circuit including a condenser and resistance in series connecting the screen grid of the second stage to the input of the first stage, a second degenerative feedback circuit including a condenser and resistance in series connecting the plate and grid of at least one of said stages, and means whereby the regenerative and degenerative feedbacks cancel each other for a predetermined signal amplitude and the regenerative feedback exceeds the degenerative feedback in proportion to an increase in signal amplitude beyond said predetermined amplitude.

6. The combination with a push-pull amplifier comprising a pair of electron tubes each having a cathode, an input grid, a screen grid and a plate and input and output circuits operatively connected therewith, of a pair of regenerative feedback circuits coupling the screen grids of each of said tubes with the input of the other tube, and a pair of degenerative feedback circuits coupling the plate of each tube with the input of the same tube.

7. The combination with a push-pull amplifier comprising a pair of electron tubes each having a cathode, an input grid, a screen grid and a plate and input and output circuits operatively connected therewith, of load impedance means in the screen grid circuits of said tubes, regenerative feedback circuits coupling the screen grid of each tube with the input of the other tube, and degenerative feedback circuits coupling the plate of each tube with the input of the same tube.

8. The combination with a push-pull amplifier comprising a pair of electron tubes each having a cathode, an input grid, a screen grid and a plate and input and output circuits operatively connected therewith, of load impedance means in the screen grid circuits of each tube, a potential divider in the input circuit of each tube, a pair of regenerative feedback circuits connecting the screen grids of each tube to a point on the potential divider in the input circuit of the other tube, and a pair of degenerative feedback circuits connecting the plates of each tube to

another point on the potential divider in the input circuit of the same tube.

9. The combination with a push-pull amplifier comprising a pair of electron tubes each having a cathode, an input grid, a screen grid and a plate and input and output circuits operatively connected therewith, of a potential divider in the input circuit of each tube, load impedance means in the screen grid circuit of each tube, a pair of regenerative feedback circuits comprising a condenser and resistance in series and connecting the screen grid of each tube to a point on the potential divider in the input circuit of the other tube, and a pair of degenerative feedback circuits comprising a resistance and a condenser in series and connecting the plate of each tube to another point on the potential divider in the input circuit of the same tube.

10. The combination with an alternating current electron tube amplifier, of a positive feedback circuit connected between points of higher and lower energy level of said amplifier, a negative feedback circuit connected between points of higher and lower energy level of said amplifier, the positive feedback balancing the negative feedback below a predetermined amplitude limit of input energy applied to said amplifier above which non-linear distortion occurs due to saturation of said tube, and means whereby the positive feedback increases with respect to the negative feedback as the amplitude of the input energy exceeds said predetermined amplitude to compensate for said non-linear distortion.

11. The combination with an alternating current electron tube amplifier including at least one screen grid stage, of a positive feedback circuit connected between the screen of said stage and a point of lower energy level of the amplifier, a

further negative feedback circuit connected between the plate of a stage and a point of lower energy level of the amplifier, the operating constants of said tube and said feedback circuits being so adjusted that the positive feedback balances the negative feedback up to a predetermined amplitude of input energy applied to said amplifier beyond which nonlinear distortion occurs due to saturation of said tube, and that the positive feedback increases with respect to the negative feedback as the amplitude of the input energy exceeds said predetermined amplitude to compensate for said non-linear distortion.

12. The combination with an alternating current electron tube amplifier, of a positive feedback circuit connected between points of higher and lower energy level of said amplifier, and means to normally render said feedback ineffective for input signal amplitudes below a predetermined limit beyond which non-linear distortion of the amplifier occurs due to saturation of said tube and to increase said feedback as the signal amplitude exceeds said predetermined amplitude to compensate for said non-linear distortion.

13. An electron tube amplifier comprising an input and an output and at least one screen grid amplifying stage, means for regeneratively feeding back screen grid signal potential to a point of lower energy level of the amplifier and further means for degeneratively feeding back plate signal potential from a point of higher to a point of lower energy level of said amplifier, the regenerative and degenerative feedbacks being balanced for input signal amplitudes below a predetermined limit amplitude.

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