

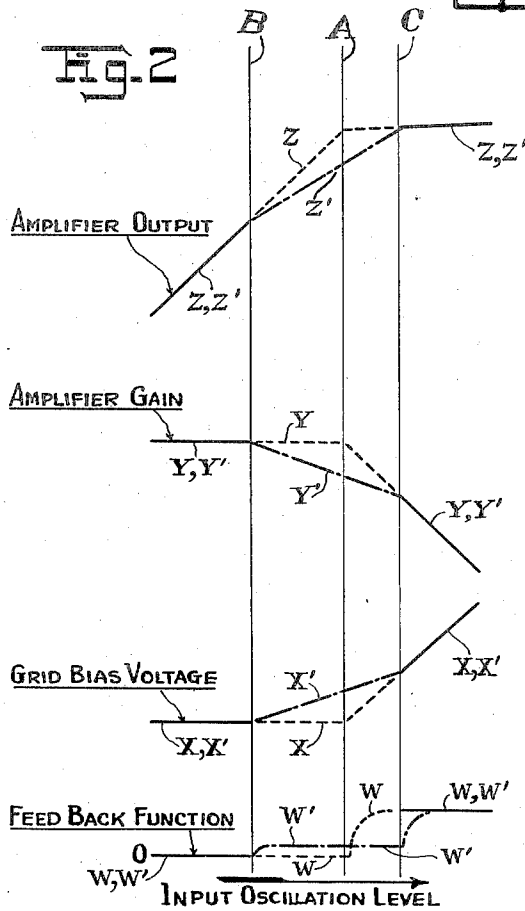
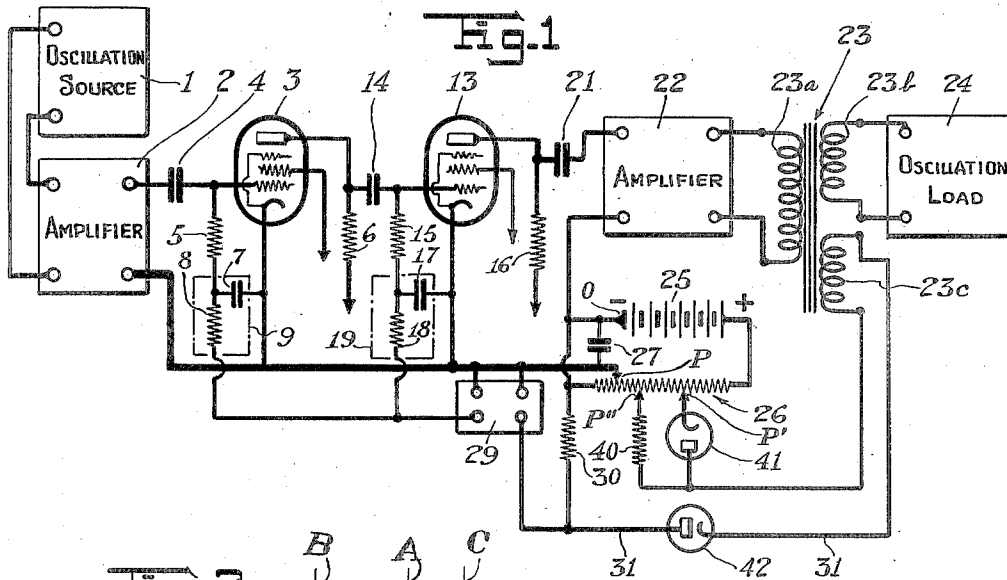
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ELECTRICAL CONTROL SYSTEM

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ELECTRICAL CONTROL SYSTEM

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This invention relates to electrical control systems, and more particularly to systems for the automatic control of the gain or output volume of an electrical amplifier. While no unnecessary limitation thereto is intended, the invention has particular utility, and has been illustrated and described, in connection with an amplifier for the amplification of audio frequency oscillations.

It is a broad object of my invention to provide an improved, and improvements for a system for automatic amplifier gain control.

It is common practise to effect such control by rectifying oscillations from the output of the amplifier, or some other high-oscillation-level point therein, and feeding the rectified voltage back as a control voltage to one or more lower level points, for example to vary appropriately the grid bias or some other controlling parameter of one or more repeater tubes of the amplifier. In such feeding-back it is necessary to filter the rectified voltage so that in the control voltage there is a proper suppression of oscillatory components—which components are of course capable of seriously impairing the amplifier performance and defeating its stability. Such filtering causes some time lag or delay, in the completion of any change of control voltage, behind the output oscillation amplitude change giving rise thereto—and in the control action a corresponding time lag which is frequently very objectionable. It is an object of my invention to reduce this time lag without impairing the amplifier performance or stability.

It is an allied object to provide an improved, and improvements for an, automatic gain control system wherein and whereby this time lag will be reduced.

Conversely, assuming a given time lag, it is an object of the invention to improve the amplifier performance and reduce tendencies toward instability.

It is an allied object to provide an improved and improvements for an, automatically controlled amplifier wherein and whereby tendencies toward instability will be reduced.

There is of course known the suitable biasing of the rectifying means to provide a threshold of oscillation level below which the automatic control will be inoperative. It is an object of the invention to provide improved and novel biasing systems for the rectifying means.

With many automatically controlled amplifiers—purely by way of example, with so-controlled audio frequency amplifiers employed in the electrical recording of sounds of such widely

varying volume as conferences and the like—it is necessary that the ultimate limitation of output volume be quite rigid (or, in other words, that the output at high input levels shall change quite negligibly with input level change), while at the same time it may be desirable that over a wide range of lower input levels there be some noticeable change of output with each input level change.

It is an object of the invention to extend this range, while maintaining a desired such ultimate output limitation.

It is an allied object to provide an improved, and improvements for an, automatically controlled amplifier wherein and whereby there is effected this range extension, but with this output limitation maintenance.

Other and allied objects will more fully appear from the following description and the appended claims.

In the description reference is had to the accompanying drawing, of which:

Figure 1 is a schematic diagram of an amplifier with which my invention has been incorporated; and

Figure 2 comprises a group of approximate curves illustrating various actions and effects of my invention, particularly in relation to those of a conventional system.

I may first describe, with reference to Figure 1, a typical amplifier and control system wherein the incorporation of my invention will thereafter be described. In this figure, 1 represents a source of electric oscillations to be amplified—purely by way of example, a microphone—and 2 represents an initial amplifier portion, which may if desired be simply a coupling portion for the proper transfer of oscillations from the oscillation source 1 to succeeding amplifier portions. Two tandemed stages of the amplifier are more fully illustrated; these may comprise the respective repeater tubes 3 and 13, preferably of the variable-mu variety, provided respectively with the input condenser 4 coupling the output of portion 2 to the grid of tube 3, and with the input condenser 14 coupling the plate of tube 3 to the grid of tube 13. The tubes are further respectively provided with the grid-leaks 5 and 15, and with the plate load resistances 6 and 16. A condenser 21 may couple the plate of tube 13 to an amplifier portion 22, which may typically include a power or output stage; and to the output of portion 22 may be connected the primary 23a of a transformer 23, having the secondary 23b connected to any oscillation load

24—purely by way of example, an electrical phonographic recorder. There may also be included on the output transformer 23 a tertiary winding 23c, whose function is to provide a point of origin for the automatic gain control system or feed-back circuit hereinafter described.

A battery or other current source 25 may be employed to supply plate and screen potentials to the tubes 3 and 13; for the sake of simplicity the returns from screens and plate load resistances to suitable points of positive potential in the source 25 have not been shown in full, but simply schematically indicated by arrow-heads. The cathodes of the tubes may be joined together, and with the return from the portion 2, and connected to a point P of slight positive potential relative to the negative terminal of source 25, so that that negative terminal (designated as O) will become available to supply a normal grid bias potential for the tubes. The point P may be provided on a potentiometer or resistance system 26 shunting the source 25, if desired; and a condenser 27 may form an oscillation by-pass from P to the terminal O, to which latter, for example, the input return of amplifier portion 22 has been shown connected. The terminal O may be connected to the grid returns of the tubes 3 and 13—i. e., to the lower extremities of the grid-leads 5 and 15—through a load impedance 30 whose function is hereinafter especially considered, and through low-pass filter means; these means have been shown by way of example as comprising common filter 29, and individual filters 9 and 19 for the respective tubes. Each of these filters may typically comprise one or more sections of the series-resistance, shunt-capacity type, as has been indicated in the case of filters 9 and 19 by the series resistances 8 and 18 and the capacities 7 and 17 shunted from the output extremities of those respective resistances to the common cathode connection.

The load impedance 30—shown in the typical and preferred form of a resistance—forms a load element, and the several filters the filtering means, for an automatic gain control system or feed-back circuit connected from a high-level point in the amplifier—typically the tertiary winding 23c—back to the abovementioned grid returns. In addition to the mentioned elements this system may basically comprise, for example, a connection as by conductor 31 of one of the terminals of tertiary winding 23c to the filter-ward extremity of the load resistance or impedance 30; and, as a biased rectifying means, a rectifier 41 connected between the second tertiary winding terminal and a point P' of positive potential on the potentiometer or resistance system 26. The rectifier 41, preferably of the simple two-element type, is so poled as to block current flow through itself from the point P' to the tertiary winding. There are shown in Figure 1 two additional elements—resistance 40 and second rectifier 42—but the circuit action will first be considered with these additional elements omitted (i. e., resistance 40 open-circuited and rectifier 42 short-circuited).

Oscillations being impressed upon the amplifier as from source 1, they will be amplified thereby and will appear in amplified form across the oscillation load 24, at the same time producing a voltage across the tertiary winding 23c proportional to that across the load. It will be obvious that so long as the peak voltage across the tertiary winding does not exceed the bias of rectifier

41—i. e., the direct potential between P' and O—no current will flow in the tertiary circuit; no voltage drop, either direct, pulsating or alternating, will occur in load impedance 30; and the grid bias of tubes 3 and 13 will be of normal value—i. e., equal to the potential between P and O. As the peak voltage of the tertiary winding is caused to exceed the bias of rectifier 41, however, pulsating currents will flow in the tertiary circuit, and there will be developed across load impedance 30 a pulsating voltage drop of polarity to render the filter-ward (lower) extremity thereof more negative; this pulsating voltage is smoothed by the filter means and thereby applied to the grids of tubes 3 and 13 as a bias increase, reducing their effective amplification factors and the gain of the amplifier.

The magnitudes of such pulsating current, pulsating voltage drop, bias increase and gain reduction of course rise with voltage across the tertiary winding—i. e., with oscillation level. Accordingly it will be understood that at oscillation levels progressively higher than a predetermined one (whereat the bias of rectifier 41 is just exceeded) the amplifier gain will be progressively reduced; if the magnitude of the source of feedback voltage—e. g., of the tertiary winding—be made great enough, the amplifier output will at these higher levels be held very nearly constant in spite of progressive input increase. I have approximately illustrated these actions by the curves X, Y and Z in Figure 2. In all of these curves horizontal dimension may be taken as representing input oscillation level, increasing to the right for example approximately logarithmically; the vertical line A may denote the input oscillation level at which the bias of rectifier 41 is just noticeably exceeded. Curve X, vertically representing negative grid bias (for example, logarithmically) shows the maintenance of a steady normal bias at oscillation levels below A, with steady rise at higher levels. Curve Y, vertically representing amplifier gain (for example, in decibels) shows the resulting maintenance of normal amplifier gain at oscillation levels below A, with steady decrease at higher levels. Curve Z, vertically representing output voltage or power from the amplifier (for example, in decibels) shows a normal progressive rise at oscillation levels up to A, and substantial constancy of output at higher levels. It will be understood that in practise at least a slight softening of the angles of each curve at the line A may be expected, but that the basic nature of the actions is fairly approximated by these curves.

In Figure 2 I also show a curve W of the feed-back function or propagation factor of the control system or feed-back circuit—i. e., of the capability of the circuit, the filtering means being neglected, of feeding back oscillation components as well as a steady control voltage. This curve, which vertically represents this function arithmetically, shows its maintenance at zero at oscillation levels below A—i. e., so long as the rectifier 41 bias is not exceeded—and shows its sharp rise at A to become asymptotic to a value of unity—corresponding to appearance across load 30 of substantially the full amplitude of alternate half-cycles of the oscillations from across the tertiary winding. From a joint consideration of this curve W and curve Y it will be appreciated that in the region just to the right of A there exists the greatest danger of instability of the amplifier or of other impairment of its performance—for this danger is dependent on the pro-

uct of amplifier gain by the feed-back function, and in this region each of these is almost at a maximum and their product therefore at its maximum. Accordingly it is this region which determines the attenuation for which it is necessary to design the filtering means—an increase of which attenuation will be understood in general to be achieved only at the expense of increased time lag in the control action.

According to my invention I provide, intermediate between the low-level range of zero function value and the high-level range of large or unity function value, a range of low but finite function value; purely by way of example, this intermediate range may embrace the upper portion of the usual low-level range and the lower portion of the usual high-level range. As oscillation level is increased throughout this intermediate range, the grid bias voltage will be progressively increased and the amplifier gain progressively reduced, but in each case at a lower rate than that of the eventual (high-level) increase or reduction; and the amplifier output will be caused to vary progressively, but at a lower rate than in proportion to oscillation level. These actions I have illustrated in Figure 2 by the respective curves W', X', Y' and Z', the intermediate range being taken as between the vertical lines B and C. It will immediately be apparent that the maximum product at any oscillation level of the gain and feed-back function (curves W' and Y') has been substantially reduced, permitting a lower degree of filtering and smaller attendant time lag.

In Figure 1 I have shown a typical arrangement for providing this intermediate range of low function value; this may comprise an impedance (typically and preferably a resistance) 40 shunted about the biased rectifier 41—i. e., from the junction of rectifier 41 and the tertiary winding to a point P'' on potentiometer 26 of smaller positive potential than point P'—and a second rectifier 42 in series in the tertiary circuit, for example interposed in conductor 31, and poled to pass current in the same direction as the rectifier 41. The impedance 40 will preferably be of several times the value of the load impedance 30. To cause the intermediate range to lie as represented in Figure 2, embracing portions of both low- and high-level ranges as first described, the point P' may be one of somewhat higher positive potential than assumed in the initial description.

The rectifier 42 will be seen to be biased (through impedance 40 as well as through the tertiary winding and load impedance 30) by the potential from P'' to O. When the peaks of oscillations from the tertiary appreciably exceed this potential (corresponding to an oscillation level of B, Figure 2) the rectifier 42 will become active and will pass a pulsating current, cause a pulsating voltage drop across 30, a bias increase and a gain reduction, as will be understood. Because much of the possible pulsating voltage is dropped in impedance 40, however, the feed-back function, though finite, is maintained low. The rectifier 41 is meanwhile inactive. But as the peaks from the tertiary winding appreciably exceed the higher biasing potential of tube 41 from P' to O (corresponding to an oscillation level of C, Figure 2) the rectifier 41 will become active to raise the feed-back function substantially to its originally described value. It is true that the circuit for tube 41 is now completed only through the rectifier 42; but this is not objectionable, as the latter is always obviously in operation under

conditions which render possible the operation of the former.

It is equally permissible to consider the circuit from the converse point of view of a rectifier (42), desirably moderately biased and having in series therewith both load (30) and voltage-consuming (40) impedances; and a further rectifier (41) biased (in this view, by the potential between P' and P'') to be inoperative during lower-level (left of C, Figure 2) operation of the first rectifier (42) but to effectively substantially short out the voltage-consuming impedance (40) at higher (right of C, Figure 2) levels. In either view, it is of course obvious that rectifier 41 provides a means for effecting gain reduction responsive at a predetermined rate to high oscillation levels; and rectifier 42 a means for effecting gain reduction responsive at a lower rate to lower oscillation levels, or levels below the minimum of rectifier 41 responsiveness.

There is obvious from curve Z' the increase of the total range over which some output change will attend input level change; this extends in the case of curve Z' up to the level C, whereas in the case of the curve Z it extended only up to A. This increase—which amounts to the replacement of a range (A to C) of substantially pure limitation by a larger range (B to C) of simple compression—is frequently of considerable value in the better preservation of the naturalness of multi-level sounds passed through an amplifier, upon which sounds there is still imposed the quite strict ultimate volume limitation. It will be understood, of course, that this comparison is made on the basis of cases wherein approximately the same level of ultimate limitation is observed.

While the choice above mentioned of the two rectifier biases above and below the bias which would be used for a single rectifier, with the resulting embracement by the intermediate range of a portion each of the former low- and high-level ranges, makes for a ready comparison of the two cases, it will be understood that it has been referred to herein only by way of illustration and in no sense as limitative. Obviously the biases may be adjusted, the ratios of impedance values of 40 and 30 chosen, and other parameters varied, within wide limits for the production of those quantitative effects desired in any particular case. Likewise, while a series arrangement of rectifying means and load means have been specifically shown herein by way of example, my invention and features thereof may be employed with any known mutual arrangement of these and other components. In these and other respects I do not intend that my invention be taken as limited by the details of the system chosen for illustrative and explanatory treatment, but rather that its scope be gauged by the appended claims, wherein that scope is intended to be expressed as broadly as the state of the art will permit.

I claim:

1. The combination, with an amplifier of electric oscillations including in a low-level portion thereof an amplifying tube having an electrode the direct potential of which controls the gain of said tube, of a gain control system, connected back to said electrode from a high-level portion of said amplifier for regulating the direct potential of said electrode, including a plurality of rectifiers and responsive at progressively increasing rates to oscillation level changes in progressively higher oscillation level ranges.

2. The combination, with an amplifier of electric oscillations including in a low-level portion thereof an amplifying tube having an electrode the direct potential of which controls the gain of said tube, of a gain control system, connected back to said electrode from a high-level portion of said amplifier for regulating the direct potential of said electrode comprising means for effecting a reduction of the gain of said tube responsive at a predetermined rate to oscillation level increase at high oscillation levels, and means for effecting a reduction of the gain of said tube responsive at a lower rate to oscillation level increase at lower oscillation levels.
3. The combination, with an amplifier of electric oscillations including in a low-level portion thereof an amplifying tube having an electrode the direct potential of which controls the gain of said tube, of a gain control system, connected back to said electrode from a high-level portion of said amplifier for regulating the direct potential of said electrode comprising means including a biased rectifier for effecting reductions of the gain of said tube in one oscillation level range, and means including a differently biased rectifier for effecting reductions of the gain of said tube in an oscillation level range in which said first-mentioned means is ineffective.
4. The combination, with an amplifier of electric oscillations including in a low-level portion thereof an amplifying tube having an electrode the direct potential of which controls the gain of said tube, of a gain control system, connected back to said electrode from a high-level portion of said amplifier for regulating the direct potential of said electrode comprising means for reducing the gain of said tube responsive only to high oscillation levels, and means for reducing the gain of said tube responsive to oscillation levels below the minimum level of said first-mentioned responsiveness.
5. The combination, with an amplifier of electric oscillations, of a gain control system therefor comprising a feed-back circuit connected from a high-level point to a low-level point in said amplifier, and means responsive to oscillation level for varying the propagation factor of feed-back to said low-level point by said circuit to two finite progressive values in two respective progressive oscillation level ranges, each of said values being essentially constant substantially throughout its respective said range.
6. The combination, with an amplifier of electric oscillations, of a gain control system therefor comprising a feed-back circuit connected from a high-level point to a low-level point in said amplifier, and biased rectifier means for varying the propagation factor of feed-back to said low-level point by said circuit to two finite progressive values in two respective progressive oscillation level ranges, each of said values being essentially constant substantially throughout its respective said range.
7. The combination, with an amplifier of electric oscillations having a normal gain, of a gain control system therefor comprising a feed-back circuit connected from a high-level point to a low-level point in said amplifier and including a biased rectifier and characterized by a propagation factor of feed-back to said low-level point which is of predetermined value substantially throughout the range of operation of said rectifier, and means included in said circuit for reducing the maximum product of amplifier gain and feed-back propagation factor substantially below the product of said normal gain and said predetermined factor value.
8. The combination, with an amplifier of electric oscillations, of a gain control system therefor comprising a rectifier for oscillations from said amplifier, impedances in series with said rectifier, means responsive to oscillation levels in excess of a predetermined level for reducing the effective value of one of said impedances as to currents passed by said rectifier, and means for applying control voltage from the other of said impedances to said amplifier.
9. The combination, with an amplifier of electric oscillations, of a gain control system therefor comprising a rectifier for oscillations from said amplifier, impedances in series with said rectifier, biased rectifier means for reducing the effective value of one of said impedances at oscillation levels in excess of a predetermined level, and means for applying control voltage from the other of said impedances to said amplifier.
10. The combination, with an amplifier of electric oscillations, of a gain control system therefor comprising a rectifier for oscillations from said amplifier, mutually distinct load and voltage-consuming impedances both in series with said rectifier, means shunted about said voltage-consuming impedance for effectively substantially shorting the same at oscillation levels in excess of a predetermined level, and means for applying control voltage from said load impedance to said amplifier.
11. The combination, with an amplifier of electric oscillations, of a gain control system therefor comprising a biased rectifier, an impedance shunting said rectifier, a circuit serially including said shunted rectifier and a second rectifier, means for impressing oscillations from the amplifier across said circuit, and means rendering the gain of the amplifier responsive to currents passed by said circuit.
12. The combination, with an amplifier of electric oscillations, of a gain control system therefor comprising a biased rectifier, an impedance shunting said rectifier, a circuit serially including said shunted rectifier and a second and less strongly biased rectifier, means for impressing oscillations from the amplifier across said circuit, and means rendering the gain of the amplifier responsive to currents passed by said circuit.
13. The combination, with an amplifier of electric oscillations, of a gain control system therefor comprising a biased rectifier, an impedance shunting said rectifier, a circuit serially including said shunted rectifier and a load impedance and a second rectifier, means for impressing oscillations from the amplifier across said circuit, and means rendering the gain of the amplifier responsive to voltage across said load impedance.
14. The combination, with an amplifier of electric oscillations, of a gain control system therefor comprising a biased rectifier, an impedance shunting said rectifier, a circuit serially including said shunted rectifier and a load impedance and a second rectifier, means for impressing oscillations from the amplifier across said circuit, and filtering means connecting said load impedance with said amplifier.
15. The combination, with an amplifier of electric oscillations, of a gain-controlling system therefor, connected in feed-back relation from a high-level portion to a low-level portion of said amplifier, characterized by an oscillation feed-back propagation factor which with decreasing oscillation level decreases in a progressive manner.

ner whereby to enhance the margin of stability of the combination, and comprising two rectifiers respectively responsive to oscillations from said high-level amplifier portion exceeding two different predetermined levels, a common load for said rectifiers traversed by current whenever either rectifier is conductive, and means for applying a control voltage from said load to said low-level amplifier portion.

16. The combination, with an amplifier of electric oscillations including in a low-level portion thereof an amplifying tube having an electrode the direct potential of which controls the gain of

said tube, of a gain-controlling system therefor, connected back to said electrode from a high-level portion of said amplifier for feeding to said electrode a pulsating voltage whose direct and oscillatory voltage components are derived from said high-level amplifier portion, and characterized by a direct voltage output and an oscillatory voltage propagation factor each of which with decreasing oscillation level decreases in a progressive manner, whereby to enhance the margin of stability of the combination.

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