Sept. 16, 1941. L. BRÜCK 2,256,072

TONE CONTROL CIRCUIT

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Fig. 1

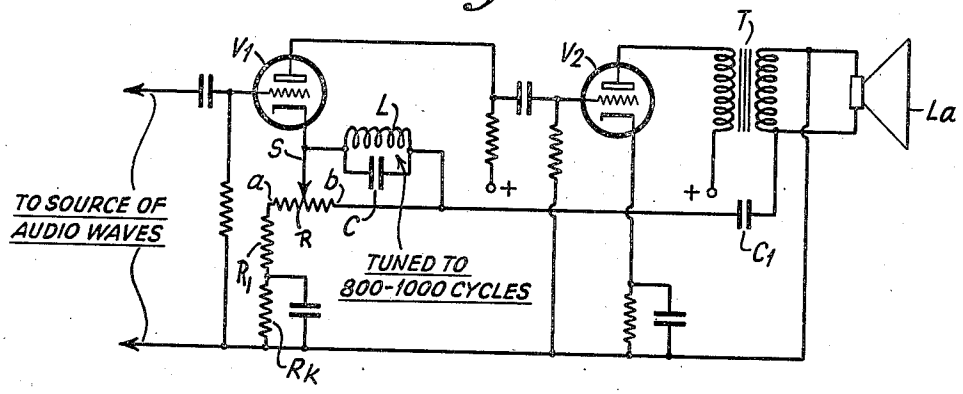


Fig. 2

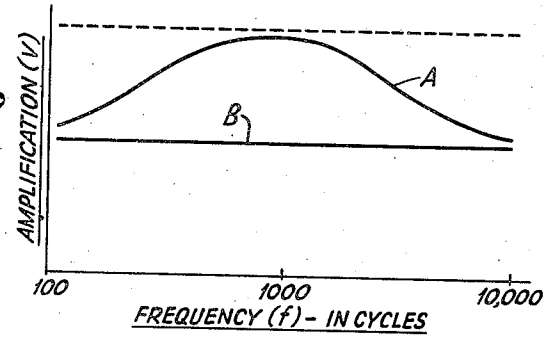


Fig. 3

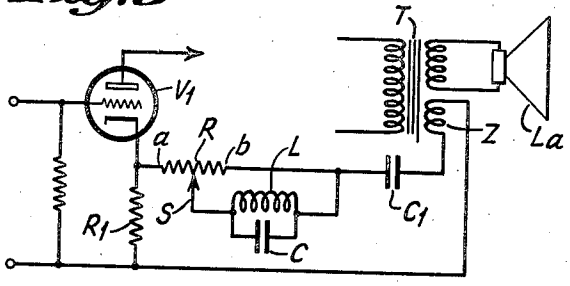


Fig. 4

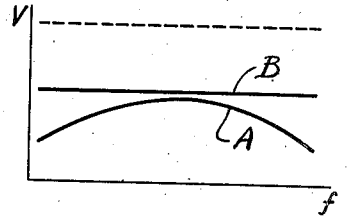


Fig. 5

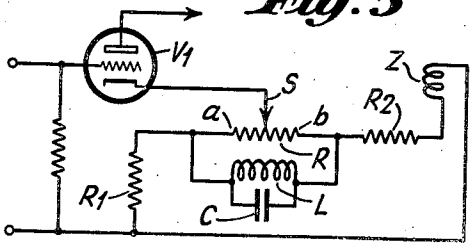
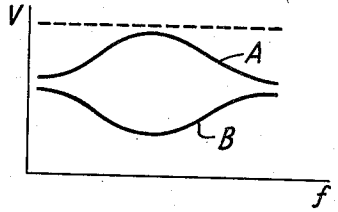


Fig. 6



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TONE CONTROL CIRCUIT

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Fig. 7

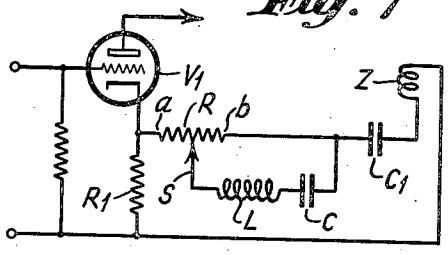


Fig. 8

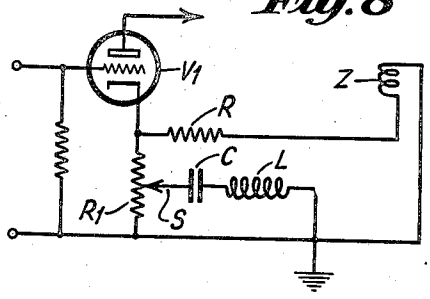


Fig. 9

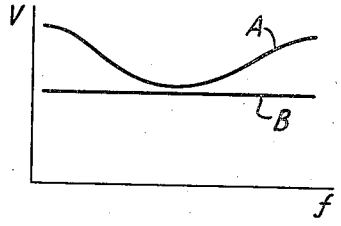


Fig. 10

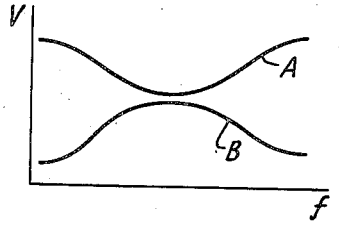


Fig. 11

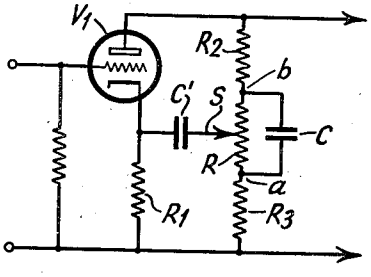
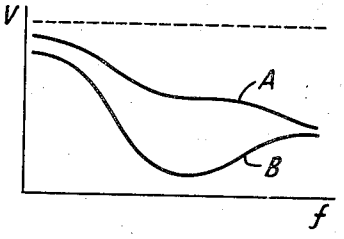


Fig. 12



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2,256,072

TONE CONTROL CIRCUIT

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Application July 29, 1939, Serial No. 287,275
In Germany August 1, 1938

6 Claims. (Cl. 179—171)

Tone control may be effected, as known in the art, in an audio amplifier by means of a variable negative, or reverse, feed-back which affects only the high pitches of the tonal range.

According to the present invention the relation of the reverse feedback for the medium tonal frequencies to the reverse feedback for the low and high tonal frequencies is made variable by making the reverse feedback of the medium frequencies, for at least a part of the regulation range, so great that the rattle, or blur, factor, that is the non-linear harmonic distortion, is essentially reduced.

The advantage of the invention is that either for the entire range of tone control, or at least for a substantial part thereof, an appreciable reduction practically of all non-linear distortions is brought about by the tone control, since the most important oscillations lie inside the median range of the frequency band. This advantage is unattainable in the arrangement known in the prior art, or at best is obtainable only to a limited extent, for the reason that the high tonal frequencies because of their small amplitudes are less important so far as the non-linear distortions are concerned. At the same time, in the arrangement of the invention, simultaneous regulation of the high and the low tonal frequencies with respect to the median frequencies ranges is obtained in the same sense with the result that the conditions as affecting the low frequency spectrum is essentially preserved.

In the drawings:

Fig. 1 shows a circuit diagram embodying the invention,

Fig. 2 shows graphically the functioning of the invention,

Fig. 3 shows a modification,

Fig. 4 graphically shows the operation of Fig. 3,

Fig. 5 shows another modification,

Fig. 6 shows the functioning of Fig. 5,

Figs. 7 and 8 show two other modifications,

Figs. 9 and 10, respectively show the operation of two different tone control arrangements,

Fig. 11 shows still another modification,

Fig. 12 shows graphically the operation of Fig. 11.

An embodiment of the invention is shown in Fig. 1, which shows the circuit of a two-stage resistance-coupled audio amplifier of a receiver apparatus. The audio oscillations to be amplified are fed to the control grid of tube V_1, and after amplification they are fed from the output end of the power amplifier tube V_2 by way of power transformer T to the loudspeaker L_a. The potential acting at the loudspeaker is impressed at the same time upon the series arrangement of a blocking condenser C_1 and three ohmic resistances R, R_1, and R_k. Resistance R is in the form of a variable voltage divider. The slider S of the latter is connected with the cathode of tube V_1. Since the lower end of resistance R_k is connected with the grounded return lead, it will be seen that the portion of the resistance R between the left-hand terminal *a* and the slider S, and the resistances R_1 and R_k are contained in the cathode lead of tube V_1. As a result reverse feedback of the output alternating potential to the cathode of the input tube is established, since only the resistance R_k, which substantially is proportioned for the production of the mean grid biasing voltage of tube V_1, is bridged capacitively.

In order to preclude the chance of an unduly great variation of the grid biasing potential, the resistance R may be made substantially smaller than the sum of R_1 and R_k. If it is impossible to choose the value thereof as stated, for reasons of an insufficient control range, then even for small resistances R_1 and R_k an additional current, say from the screen grid voltage divider of the preceding or input tube, may be passed through R_k whereby the drop of potential across the same is raised, so that the grid biasing voltage will be affected less markedly by the regulation of R.

The slider S and the righthand end of resistance R, are associated with each other by a parallel circuit L—C which is tuned to around 800 to 1000 cycles; in other words to the median frequencies of the signal band. The said parallel circuit substantially transmits the very low frequencies, say from zero to around 200 cycles, and the very high frequencies, say from 2000 up to 10,000 cycles (compared with the resistance R), whereas for the median frequencies, say from around 200 up to 2000 cycles, it constitutes a comparatively high impedance. If the slider S is positioned at *b*, the filter circuit is ineffective and the reverse feedback has its maximum value, that is uniformly for all frequencies. Hence, there results a gain curve which corresponds to graph B in Fig. 2, where the amplification (V) is plotted against the frequency (*f*) in cycles. But if the slider is located at point *a*, the result is a characteristic like graph A, Fig. 2. In the case of this curve the amplification for the very high and the very low frequencies has increased but slightly since almost the entire alternating output potential prevails across the ohmic resistance in-

cluded in the cathode lead. But the median frequencies suffer an appreciable drop of potential across the parallel arrangement R—C—L, with the result that for these frequency ranges the reverse feedback is substantially smaller so that the gain turns out essentially higher. In other words, the amplification comes pretty close to what would be obtained in the absence of the reverse feedback, as represented in Fig. 2 by the dash-line.

The circuit shown in Fig. 1 which produces the characteristics as shown in Fig. 2 is particularly adapted to receiver sets which are not equipped with a completely acting automatic volume control, and in which the tone control is to be used at the same time for the volume control actuated manually so as to compensate and balance the differences in signal strength of the various transmitter stations. In this arrangement a local station is received and heard with comparatively little amplification, little distortion, and uniform gain for all frequencies, whereas a distant transmitter station is heard with greater amplification, while the high and the low tonal frequencies are slighted. The attenuation, or slighting, of the high tonal frequencies means a reduction in the atmospheric interference. So far as the important range of the median frequencies is concerned, the highest possible amplification of the amplifier is utilized, though some of the chances of appreciably reducing the non-linear distortions are lost.

A modified form of construction of the invention is shown in Fig. 3. The alternating potential used for the negative feedback in this scheme is derived from a distinct winding Z of the output transformer T, and impressed upon the series path comprising the blocking condenser C_1, the voltage divider resistance R and the resistance R_1. The filament of tube V_1 is fixedly connected with the junction of resistance R_1 and resistance R, while between the slider S and the righthand terminal of resistance R is connected the parallel circuit L—C. What is obtained in such cases are amplification curves as a function of the position of the slider S, as shown in Fig. 4 for the two limiting or end positions. In this circuit the reverse feedback so far as the median ranges of frequency are concerned, is high at all events; as a result a marked reduction of the non-linear distortions is brought about throughout the entire range. It is only in one of the end positions (*b*) where the negative feedback is the same for the high and the low notes as for the middle notes, while in the opposite end position (*a*) the reverse feedback for the high and the low pitches is higher than for the median range. Indeed, for the latter the reverse feedback increases but slightly. The circuit here disclosed is particularly recommended for receiver apparatus with complete automatic volume control, or audio amplifiers for phonograph record reproduction or the like for which the mean input alternating potential is substantially the same, and where invariably the same average sound volume is desired to be obtained. In fact, the effect in this instance is that of tone control pure and simple.

Another embodiment is shown in Fig. 5. The output alternating potential serving for the reverse feedback acts upon the series path of resistances R_2, R, and R_1. The sliding contact S is connected with the filament of tube V_1, whereas resistance R is bridged by the parallel branch L—C. Fig. 6 shows the control curves to be obtained. The reverse feedback, and thus the amplification, for the high and the low notes remains essentially unaltered in the control or regular action, while the reverse feedback and thus the amplification for the median tones is variable within wide limits. In one of the end positions (*b*) the high and the low pitches are favored with respect to the median frequencies, while in the other end position (*a*) they are slighted. In the case of a receiver set with incomplete volume control, one of the end positions, that is (*b*) is suited for the reception of local stations, and the other end position is suited for distant station reception, if the same mean volume is desired. In the presence of stable and constant mean input alternating potential, the regulation results in orthophonic sound volume control, that is faithful reproduction.

Symmetric form of the graphs A and B as shown is obtainable, according to a closer examination and consideration, only if the resistances R_1 and R_2 are of like size. The range of variation for the median tonal frequencies in this instance is given by the ratio of $R:R+R_1$. If, on the contrary, R_2 is low in contrast to R_1, then the form of the curves comes closer to that shown in Fig. 2. If resistance R_2 is high in comparison with R_1, then the shape of the curves will come to resemble more closely that of the curves in Fig. 4.

In the circuit shown in Fig. 5, just as in the arrangement of Fig. 1, the grid biasing potential of tube V_1 is altered by the regulation here concerned. This effect is obtainable by choosing suitable dimensions for the resistances and, optionally, also by connecting in series with R_1 a capacitively shunted resistance R_k in line with the circuit shown in Fig. 1.

In the arrangement shown in Fig. 7 the reverse feedback potential acts upon the series path of condenser C_1, resistance R and resistance R_1. The last-named resistance is permanently in the cathode lead of tube V_1. The righthand terminal, or end point, *b* of resistance R by way of the series circuit L—C, tuned to median frequencies, is connected with the slider S.

In the circuit of Fig. 8 it is the cathode resistance R_1, rather than the resistance R, which is included in the lead that is provided with a slider S. The latter by way of the series circuit L—C is connected with the grounded return lead. In this circuit regulator curves as shown in Fig. 2 are obtainable.

If in the circuit shown in Fig. 1 the parallel circuit is replaced by a series circuit tuned to the median frequencies, as for example in Fig. 7, there result regulation curves of the kind shown in Fig. 9. In other words, in this arrangement the reverse feedback, and thus also the amplification, for the mean tonal frequencies stays practically unaltered, while the reverse feedback for the high and the low tonal frequencies can be made as low as may be desired with a resultant emphasis upon these frequencies.

If in the arrangement of Fig. 5 the parallel circuit is replaced by a series circuit, there result control curves as shown in Fig. 10. In this case the high and the low tonal frequencies can at will be attenuated or favored and raised in comparison with the median tonal frequencies substantially subject to constant reverse feedback. Circuits with control curves as shown in Figs. 9 and 10 are suitably used in instances where it is possible to figure with a constant mean input alternating potential, where a constant average

output volume is desired, and where tone control pure and simple is intended. The circuits comprising parallel circuits frequently will be preferred for the reason that the self-capacitance of the coil enters into capacity C. In the case of the series circuit, the self-capacitance of the coil L must be minimized to such an extent that for the frequency band which is concerned the capacitive reactance of the coil may still be sufficiently high.

Regulator or control characteristics of a similar form may be obtained also only with condensers. A circuit of this kind is illustrated, for instance, in Fig. 11 as incorporated in a single-stage amplifier. Between the plate and the grounded return of the tube is a series path of resistances R_2, R, and R_3. The resistance R is capacitively bypassed for the high frequencies by the condenser C. The sliding contact S by way of the condenser C' is connected with the filament of the tube which, in turn, is associated with the grounded return lead by way of the resistance R_1 which is not shunted capacitively. Condenser C' must be of such value that across it an appreciable fall of potential will be caused for the low tonal ranges, but not for the median tonal frequencies, the said voltage drop diminishing the negative feed-back for the low tonal frequencies. The resulting control curves are shown in Fig. 12. In one end position (*b*) the amplification for the low notes is essentially lower than for the high ones, and so much more so for the low tonal frequencies. In the other position, the amplification for the median tonal frequencies is essentially raised with the result that it is now greater than for the high tonal ranges, for which the amplification has been raised but little. The amplification factor for the low tonal frequencies has been increased somewhat, with the result that it has nearly reached the value of the amplification in the absence of reverse feedback (dash-line). The circuit as shown is suited for receiver apparatus with incomplete volume control for which, say for reasons of the fact that no high-grade loudspeaker is available, it is at all events desirable to insure an emphasis on the low tonal frequencies.

What is claimed is:

1. In a wave transmission network of the type comprising at least one tube provided with input and output circuits, said input circuit being adapted to have wave energy of a wide band of frequencies applied thereto, said tube being provided with at least a control grid, cathode and output electrode, said output circuit being coupled to said output electrode; the improvement which includes a degenerative wave voltage feedback path coupled between said output circuit and a point of relatively fixed alternating potential, means connecting said cathode to a second point on the path which is at a higher alternating potential than said first point, means connecting said grid to said fixed point, and a resonant circuit tuned to a narrow median frequency band of said wide band, operatively associated with said feedback path to diminish the feedback over said narrow median band.

2. In a wave transmission network of the type comprising at least one tube provided with input and output circuits, said input circuit being adapted to have wave energy of a wide band of audio frequencies applied thereto, said tube being provided with at least a control grid, cathode and output electrode, said output circuit being coupled to said output electrode; the improvement which includes a degenerative wave voltage feedback path coupled between said output circuit and a point of relatively fixed alternating potential, means connecting said cathode to a second point on the path which is at a higher alternating potential than said first point, means connecting said grid to said fixed point, and a resonant circuit tuned to a narrow median frequency band of said wide band and of the order of 800 to 2000 cycles, operatively associated with said feedback path to diminish the feedback over said narrow median band.

3. In a wave transmission network of the type comprising at least one tube provided with input and output circuits, said input circuit being adapted to have wave energy of a wide band of frequencies applied thereto, said tube being provided with at least a control grid, cathode and output electrode, said output circuit being coupled to said output electrode; the improvement which includes a degenerative wave voltage feedback path coupled between said output circuit and a point of relatively fixed alternating potential, means connecting said cathode to a second point on the path which is at a higher alternating potential than said first point, means connecting said grid to said fixed point, and a resonant circuit tuned to a narrow median frequency band of said wide band, operatively associated with said feedback path to diminish the feedback over said narrow median band, said tuned circuit being connected in parallel with a portion of said feedback path between said second point and a third point of the path of higher potential than the second point.

4. In a wave transmission network of the type comprising at least one tube provided with input and output circuits, said input circuit being adapted to have wave energy of a wide band of frequencies applied thereto, said tube being provided with at least a control grid, cathode and output electrode, said output circuit being coupled to said output electrode; the improvement which includes a degenerative wave voltage feedback path coupled between said output circuit and a point of relatively fixed alternating potential, means connecting said cathode to a second point on the path which is at a higher alternating potential than said first point, means connecting said grid to said fixed point, and a resonant circuit tuned to a narrow median frequency band of said wide band, operatively associated with said feedback path to diminish the feedback over said narrow median band, said tuned circuit being connected in parallel with a portion of said feedback path between said second point and a third point of the path of higher potential than the second point, and means for varying the potential difference between said second point and third point.

5. In an audio amplifier of the type provided with a tube having input and output electrodes, means impressing audio signals on the input electrodes, a resistive element in space current path of the tube which is common to the input and output electrodes, an output circuit coupled to the output electrodes, a degenerative audio voltage feedback path coupled between said output circuit and said resistive element, said path including a second resistive element in series with the first resistive element, and a resonant circuit in shunt with at least a portion of the second resistive element, said resonant circuit being tuned to a median band of audio frequencies.

6. In an audio amplifier of the type provided with a tube having input and output electrodes, means impressing audio signals on the input electrodes, a resistive element in space current path of the tube which is common to the input and output electrodes, an output circuit coupled to the output electrodes, a degenerative audio voltage feedback path coupled between said output circuit and said resistive element, said path including a second resistive element in series with the first resistive element, and a resonant circuit in shunt with at least a portion of the second resistive element, said resonant circuit being tuned to a median band of audio frequencies, and means for varying the magnitude of the second resistive element portion in shunt with said resonant circuit.

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