

July 8, 1941.

W. VAN B. ROBERTS

2,248,785

AUTOMATIC VOLUME CONTROL CIRCUITS

Filed Sept. 17, 1938

2 Sheets-Sheet 1

Fig. 1

R₁ AND R₂ ARE RESISTORS WHOSE TEMPERATURE COEFFICIENTS ARE UNEQUAL

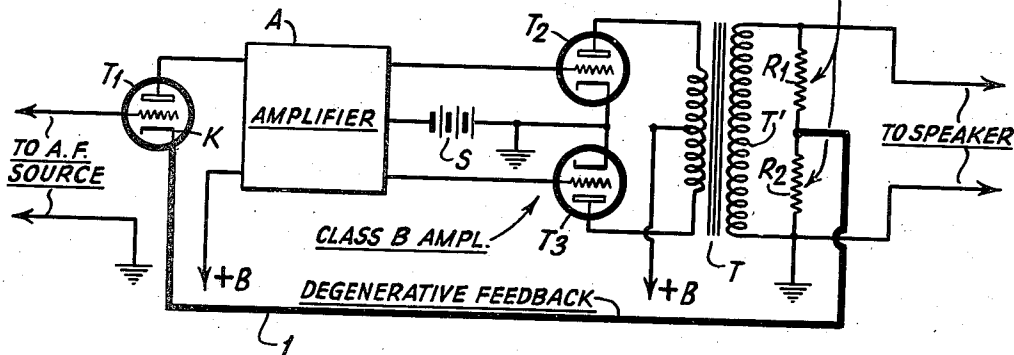


Fig. 2

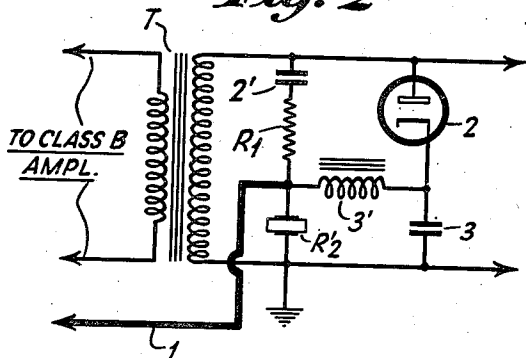


Fig. 3

CHARACTERISTIC OF R'₂

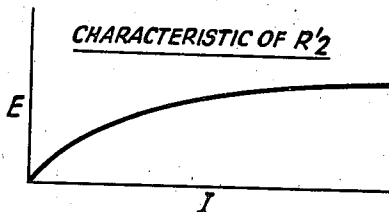
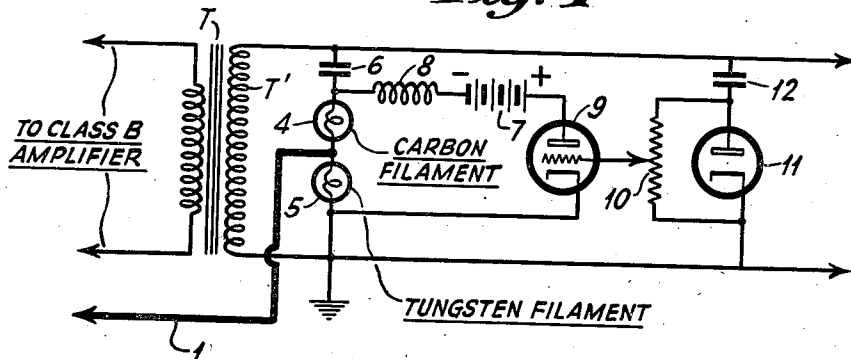


Fig. 4



BY

INVENTOR.
WALTER VAN B. ROBERTS

H.S. Sover
ATTORNEY.

July 8, 1941.

W. VAN B. ROBERTS

2,248,785

AUTOMATIC VOLUME CONTROL CIRCUITS

Filed Sept. 17, 1938

2 Sheets-Sheet 2

Fig. 5

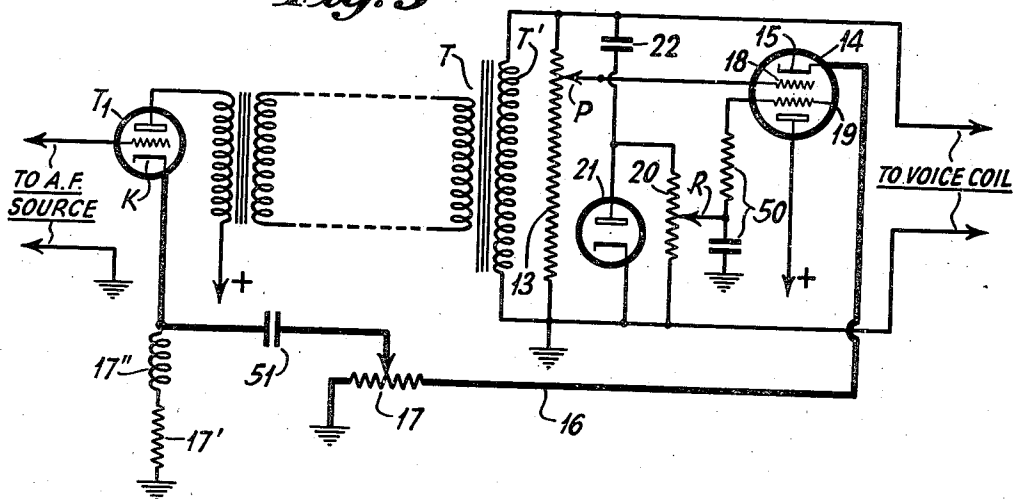
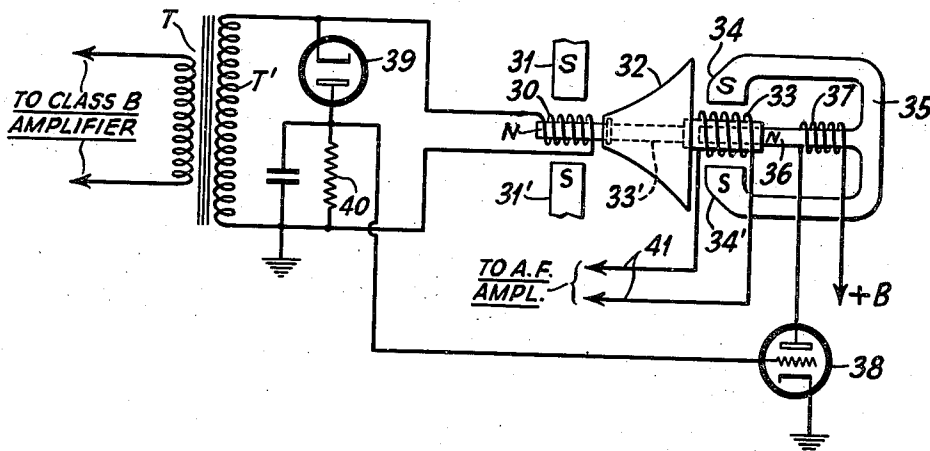


Fig. 6



INVENTOR.
WALTER VAN B. ROBERTS

BY

H.S. Swover
ATTORNEY.

UNITED STATES PATENT OFFICE

2,248,785

AUTOMATIC VOLUME CONTROL CIRCUITS

Walter van B. Roberts, Princeton, N. J., assignor
to Radio Corporation of America, a corporation
of Delaware

Application September 17, 1938, Serial No. 230,367

5 Claims. (Cl. 179—171)

My present invention relates generally to automatic control such as is employed to increase the dynamic range of speech and music, and more particularly the invention relates to a method of, and means for, expanding, or compressing, sound volume range by automatically varying the amount of inverse audio feedback in an audio amplifier system.

In the prior art it is known to expand, or compress, the dynamic range of music or speech by controlling the gain of an amplifier tube in accordance with the average level of sound; the control is effected by rectifying sound energy and applying the rectified voltage to a gain control electrode of an amplifier tube. This method, however, in the case of class B amplifiers is not very satisfactory, since the quality of reproduction at low signal levels is inherently inferior to that at high signal levels.

It may be stated, therefore, that one of the important objects of my present invention is to provide sound volume expansion by varying the amount of inverse feedback from the output of an audio amplifier to its input so that at low signal levels there is a large amount of feedback with the result that distortions, such as arise particularly in class B amplifiers, are minimized, while at high signal levels, where distortion in class B amplifiers is inherently relatively less, the amount of inverse feedback is reduced.

Another important object of this invention is to provide a method of providing volume expansion in an audio amplifier of the class B type, wherein the quality of reproduction is greatly improved on low signal levels by feeding back degeneratively a greater amount of audio signal energy during low volume reproduction than at high volume, such method of expansion in no way reducing the gain and high output capabilities of a class B amplifier at high signal levels.

Another important object of this invention is to provide a novel sound volume expansion system for an audio amplifier, wherein a pair of resistors are connected in series across the amplifier output terminals, the resistors having temperature coefficients which are unequal, and means being utilized for impressing an audio voltage drop across one of the resistors between the input terminals of the audio amplifier.

Another object of my invention may be stated to reside in the provision of a sound expansion system for an audio amplifier, wherein a voltage proportional to a vector of different physical nature from the amplified output, but derived therefrom, is developed and fed back to the amplifier

input circuit; electrical energy from the amplifier being rectified and utilized to control the factor of the aforesaid proportionality.

Still other objects of my invention may be stated to involve a general improvement in the simplicity of audio volume expansion circuits, and more especially to provide such arrangements in a reliable and efficient manner, and in a form such that they may be economically manufactured and assembled.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawings in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:

Fig. 1 schematically illustrates an audio amplifier network embodying one form of the invention,

Fig. 2 is a modification of the control arrangement shown in Fig. 1,

Fig. 3 graphically illustrates the characteristic of the resistor R_2 ,

Fig. 4 shows still another modification of the control circuit,

Fig. 5 illustrates a further modification of the invention,

Fig. 6 schematically shows still another modification.

Referring now to the accompanying drawings, wherein like reference characters in the different figures illustrate similar circuit elements, the audio amplifier network shown in Fig. 1 comprises generally an input amplifier tube T_1 whose input electrodes may be coupled to any desired source of audio frequency energy. For example, such an audio source may be the usual detector output circuit of a radio receiver; the microphone of a public address system; the electrical pick-up of a sound record reproducing system; or even the audio input of a talking picture system. Regardless of the nature of the audio input, whether it be speech or music, the amplifier T_1 amplifies the audio energy and impresses the amplified energy upon an amplifier A. The amplifier A may be omitted if desired, and, on the other hand, it may comprise one or more stages utilized to drive the final output amplifier stage. The output stage comprises a pair of tubes T_2 and T_3 arranged in push-pull relation, and having its con-

stants chosen so that it operates as a class B stage. Since those skilled in the art are fully acquainted with the nature of class B push-pull operation, it is only believed necessary to point out that the biasing source S will have a magnitude such as to bias each of the tubes substantially to plate current cut-off in the absence of signal input.

The output transformer T couples the common output circuit of the push-pull amplifier to any desired type of load circuit, such as a loudspeaker. In other words, it is to be understood that the secondary T' of output transformer T is connected to the voice coil of the loudspeaker, assuming the latter to be of the electrodynamic type. In shunt with the secondary winding T' are arranged a pair of series-related resistors R₁ and R₂. The cathode of tube T₁ is connected by lead 1 to the junction of resistors R₁ and R₂, it being noted that the low potential end of winding T' is grounded.

The polarity of the connections to secondary winding T' is so chosen that the audio voltage feedback from the secondary of transformer T to the cathode K is in opposition, in the grid circuit of T₁, to the signal voltage impressed on the latter. In other words an inverse, or degenerative, audio feedback path is provided between the junction of the shunt resistors and the cathode of the first amplifier tube. In accordance with the present invention the resistors R₁ and R₂ are composed of materials whose temperature coefficients, from a generic viewpoint, can be said to be unequal. More specifically, these resistors are composed of materials having different temperature coefficients so that of the entire secondary voltage of transformer T the fraction which is fed back to cathode K varies with the average temperature of these resistors, and hence with the average voltage applied to the load.

For example, resistor R₁ may comprise a tungsten filament incandescent lamp of low wattage. Since the resistance of a tungsten filament increases several fold from normal room temperature to its usual operating temperature, it will be seen that if resistor R₂ is chosen in resistance value to be somewhat greater than the cold resistance of R₁, then cathode K will be effectively connected to a point on the secondary winding T' whose potential is more than half the total potential developed in this winding, and a relatively large inverse feedback results which makes the overall gain of the entire audio system small.

In the presence of strong signals, however, the resistance of R₁ increases so as to become larger in value than the resistance of R₂. As a result the effective connection of cathode K is to a point having less than half of the total potential of the winding T'. This reduces the amount of inverse feedback, and increases the overall gain of the amplifier network. Since the overall gain is small for weak signals and large for strong signals it will be seen that the dynamic range is expanded. If the positions of R₁ and R₂ are interchanged, on the other hand, the dynamic range will be compressed. The compression control is sometimes useful in dealing with voice signals which tend to vary undesirably in accordance with the position of a speaker with respect to the microphone or the like. In choosing resistors R₁—R₂ the total resistance of the two in series will preferably be chosen to be at all times large compared with the impedance of the load in order not to absorb an appreciable portion of the power available for the load.

Furthermore, the thermal inertia of the heat-controlled resistance should be chosen sufficiently low so that the resistance will respond quickly to changes in output level, but not so low that its resistance will tend to follow individual waves of speech or music since in such a case wave-form distortion would be the result. In order to produce a still more pronounced expansion, or contraction, of the dynamic range, resistors R₁ and R₂ may be composed of materials having temperature coefficients of opposite sign. For example, R₁ may be the tungsten filament lamp, while R₂ may be a carbonized filament lamp whose resistance decreases with temperature increase. Generally speaking, while it is only necessary that R₁ and R₂ have different temperature coefficients, it is preferable to make the difference between the two as large as possible by making the signs of their coefficients opposite.

The operating level at which it is desired that amplification be maximum is an important consideration in the choice of R₁ and R₂. The latter should be so chosen that they develop a relatively large change in ratio at the maximum desired output level, but not to become hot enough to burn out. If it is desired to operate at some lower level, the resistor units may be replaced by another pair of units appropriate to the new level. In case it is desired to operate at a higher level, the upper end of R₁ may be connected to an intermediate point on the winding T', or ordinary resistor units may be connected in series with the heat-varied units to reduce the temperature of the latter.

In Fig. 2 there is shown a modification wherein for R₂ there is employed a material whose E—I characteristic is shown in Fig. 3. Any material having the characteristic shown in Fig. 3 may be used. Such a material is, for example, silicon carbide known under the trade-name "Thyrite." The element R'₂ is connected in series with the space current path of diode 2 through a choke coil 3'; the latter is in shunt across R₁. The condenser 3 is connected in shunt with R'₂. When the audio input is weak, no direct current flows through R'₂ and its resistance is high so that there exists a maximum of inverse feedback over lead 1. Upon an increase in the audio amplitude, the space current flow through diode 2 increases and the A. C. resistance of R'₂ is lowered. This greatly reduces the reversed feedback with consequent expansion of audio volume. Condenser 2' is a blocking condenser. If R₁ were given an increasing temperature coefficient, while R'₂ decreases, the action would be accentuated.

In Fig. 4 there is shown a modification of the volume control arrangement wherein the shunt resistor elements are a carbonized filament lamp 4 and a tungsten filament lamp 5. One terminal of the filament of lamp 4 is connected by condenser 6 to the high potential end of winding T'. Instead of using the heating effect of the audio impulses and thereby wasting audio frequency power, a local heating source is employed. Thus, current source 7 has its negative terminal connected to the junction of condenser 6 and the carbon filament through choke 8. The positive terminal of the current source 7 is connected to the plate of a triode 9, say of the 2A3 type. The cathode of the latter is connected to the grounded end of the tungsten filament. The internal resistance of tube 9 is varied by connecting the grid of the tube to any desired point on resistor 10; the latter being in shunt to the diode 11. The anode of diode 11 is connected by condenser

12 to one of the audio output terminals, while the diode cathode is connected to the other output terminal.

This arrangement functions in the following manner. With weak signals, very little rectified voltage appears at 10, and tube 9 passes sufficient plate current to heat 4 and 5 so that the resistance of 4 is low while that of 5 is high thus feeding back by line 1 a large fraction of the A. F. voltage of T'. On strong signals, however, the increasing rectified voltage at 10 cuts off the plate current of tube 9 and the resistance of 4 increases while that of 5 decreases, thus reducing the degenerative voltage fed back over line 1 to a small fraction of the A. F. voltage of T'. In this way the amount of degenerative feedback decreases as signal strength increases without appreciable waste of audio frequency power.

The inverse feedback may be provided through a tube, and the degree of feedback regulated by an audio energy rectifier. This manner of control is illustrated in Fig. 5 wherein there is shunted a resistor 13 across winding T'. A tube 14, say of the 6L7 type, is provided, and the cathode 15 thereof is connected by lead 16 to ground through bias resistor 17. The control grid 18 adjacent the cathode, is connected by an adjustable tap P to any desired point on resistor 13. The outer grid 19 is adjustably connected by tap R to any desired point on resistor 20; the latter being shunted across diode rectifier 21. Audio bypass condenser 22 connects the anode of diode 21 to the high potential end of resistor 13; the diode cathode is at ground potential.

Tube 21 rectifies the audio energy to produce negative bias on grid 19, filter 50 passing only slowly varying direct current voltage. Tube 14 amplifies a portion of the audio output of T' picked up off 13, and the amplified output developed at resistor 17 is conveyed through a large condenser 51 to the cathode of T₁ which is connected to ground through an audio choke 17' having in series a resistance 17' suitable for providing normal bias for the tube T₁. Thus audio voltage from T' is fed back in degenerative phase to the input of the amplifier. On weak signals there is strong degenerative feedback, but on strong signals sufficient bias develops across diode load 20 to cut off the feedback through 14, and thus reduce, or eliminate, the degenerative feedback. Tap R controls variation of feedback, P controls the amount.

The modification illustrated in Fig. 6 utilizes the motion of the cone of an electrodynamic loudspeaker to provide the feedback voltage. The voice coil 30 is shown positioned between the pole pieces 31-31'; numeral 32 denotes the movable cone. The cone is provided with a projecting support which carries the auxiliary feedback coil 33. The latter is positioned between the pole pieces 34-34' of the magnetic member 35. The support 33' may be hollow, and be arranged to reciprocate along the metallic guide projection 36. Coil 37 is wound around the projecting element 36 to vary the magnetization of the member 35 and hence of the pole pieces 34-34'. The tube 38 has coil 37 connected in the plate circuit thereof; the cathode of tube 38 is at ground potential. Rectifier 39, a diode, has its cathode connected to the high potential end of secondary winding T'. The anode of diode 39 is connected to ground through load resistor 40, the latter being shunted by an audio bypass condenser.

The auxiliary coil 33 is connected by leads 41 to the input circuit of the audio amplifier T₁.

The feedback over leads 41 is proportional to the cone velocity. The intensity of feedback is controlled by the rectified output of diode 39. More specifically, the arrangement of Fig. 6 functions in the following manner. On weak signals, little or no bias is developed at 40 so that a normal plate current flows through 38 and 37 thus creating a strong magnetic field in which coil 33 moves and generates a relatively large voltage of the same wave form as the motional wave form of cone 32. This voltage being fed back in degenerative phase to the input of the A. F. amplifier tends to make the motion of the cone a faithful reproduction of the signal wave impressed on the A. F. amplifier. In the presence of strong signals, however, bias developed across resistor 40 shuts off the plate current of 38, and thus removes the degenerative feedback.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In a class B audio amplifier system, a method of reducing distortion at low signal levels without reducing the high output and gain capabilities of the system at high signal levels, which comprises impressing audio signals upon the amplifier input, deriving from the amplified signals an audio voltage, impressing the derived voltage upon the amplifier input in degenerative phase along with the unamplified audio signals thereby to reduce said distortion at low signal levels, rectifying amplified signals to produce a unidirectional voltage whose magnitude depends on the audio modulation, and automatically decreasing the relative magnitude of said degenerative voltage with said unidirectional voltage at high signal levels thereby to produce a volume expansion effect.

2. In an audio amplifier provided with a reproducer of the moving diaphragm type, means responsive to the motion of said diaphragm for providing audio voltage which is fed back in degenerative phase to the amplifier input, and means, responsive to variations in audio signal strength, for controlling the magnitude of feedback, said first means comprising an auxiliary coil arranged to move in a magnetic field concurrently with said moving diaphragm and said control means including a device for controlling the intensity of said magnetic field.

3. In an audio system comprising a push-pull amplifier of the class B type having audio voltage input and output circuits, said amplifier being characterized by its distortion of audio signals at low input levels, and an audio reproducer of the moving diaphragm type having input connections to said amplifier output circuit; the improvement which comprises means responsive to the motion of said diaphragm for providing audio voltage which is fed back in degenerative phase to said amplifier input circuit thereby to reduce said distortion at the low input level, and means responsive to an increase in audio signals above said low input level for decreasing the magnitude of said feedback voltage thereby to produce a volume expansion effect.

4. In an audio system comprising a push-pull amplifier of the class B type having audio voltage input and output circuits, said amplifier be-

ing characterized by its distortion of audio signals at low input levels, and an audio reproducer of the moving diaphragm type having input connections to said amplifier output circuit; the improvement which comprises means responsive to the motion of said diaphragm for providing audio voltage which is fed back in degenerative phase to said amplifier input circuit thereby to reduce said distortion at the low input level, and means responsive to an increase in audio signals above said low input level for decreasing the magnitude of said feedback voltage thereby to produce a volume expansion effect, and said responsive means including a rectifier coupled to said amplifier output circuit and means for utilizing rectified audio voltage for control of said feedback voltage magnitude.

5 5. In an audio amplifier of the type which has high output and gain capabilities at high signal levels and considerable distortion at low signal levels, said amplifier having audio signal input and output terminals, an audio reproducer of the moving diaphragm type coupled to said amplifier output terminals, means responsive to motion of said diaphragm for providing an audio voltage, means impressing the latter voltage upon the amplifier input terminals in degenerative phase along with unamplified audio signals thereby to reduce said distortion at low signal levels, and means, responsive to amplified audio signals, for automatically decreasing the relative magnitude of said degenerative voltage at high signal levels thereby to produce a volume expansion effect.

15
WALTER VAN B. ROBERTS.