Dec. 27, 1949 F. B. STONE 2,492,542

COMBINATION POWER AMPLIFIER

Filed Sept. 7, 1945 2 Sheets-Sheet 1

Fig. 1

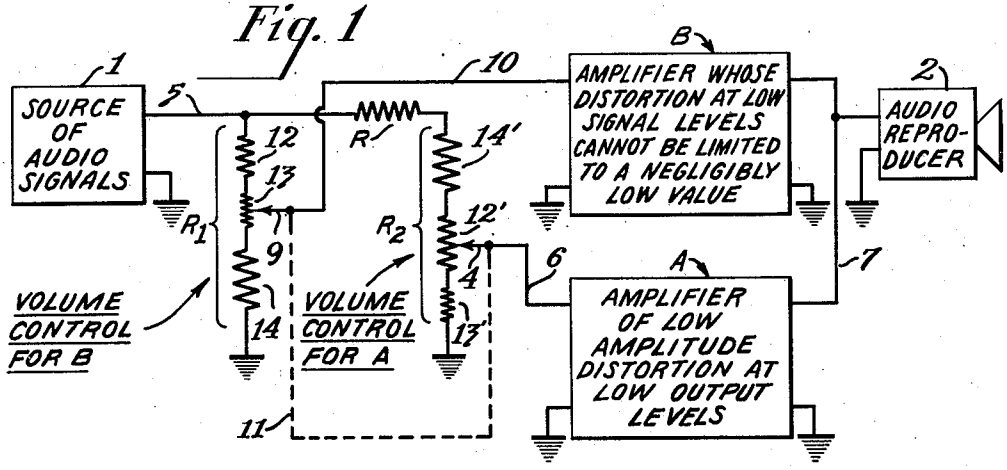
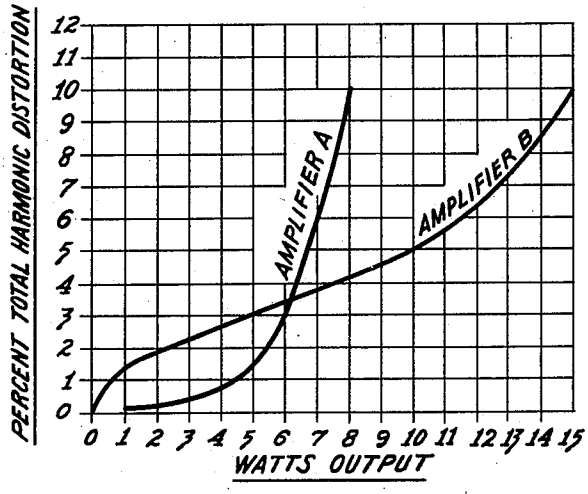


Fig. 2



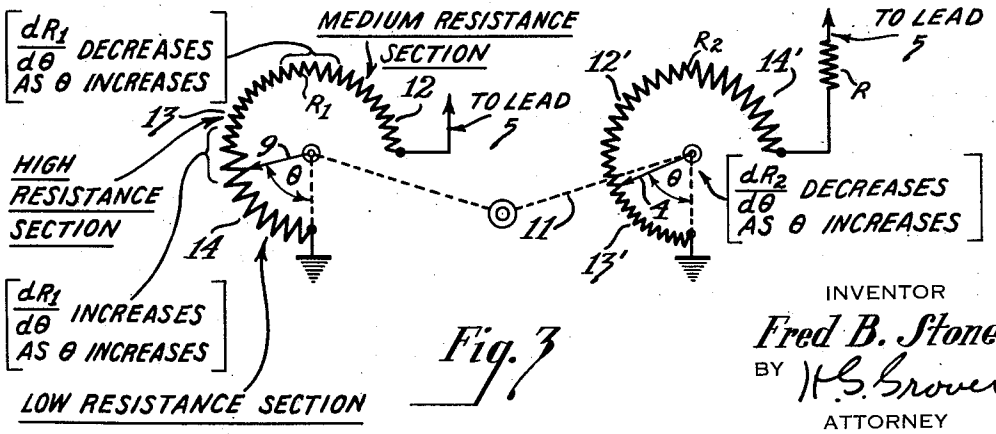


Fig. 3

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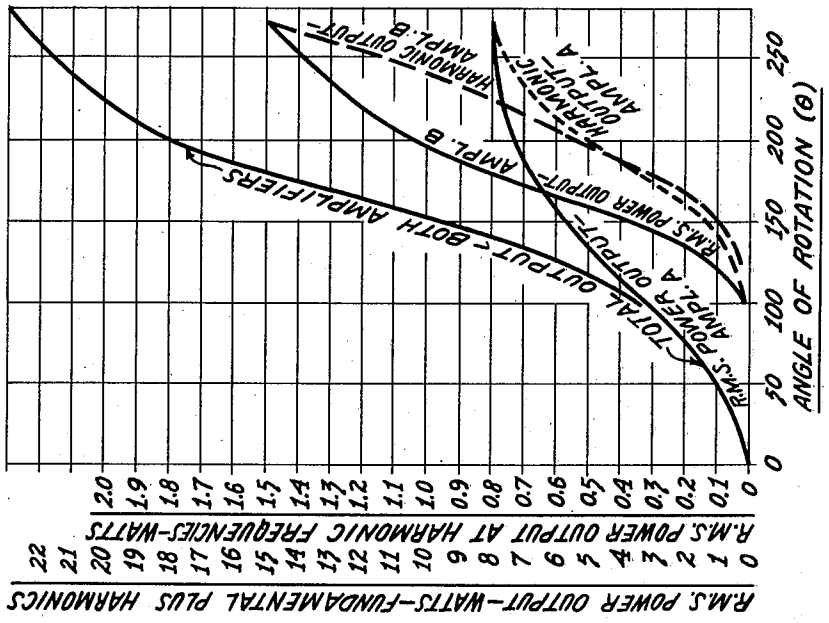


Fig. 6

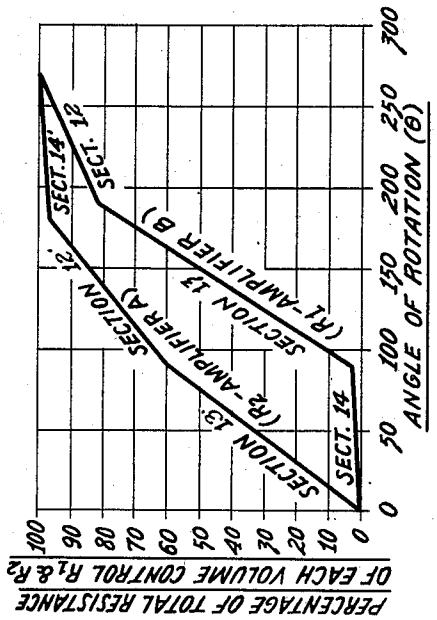


Fig. 4

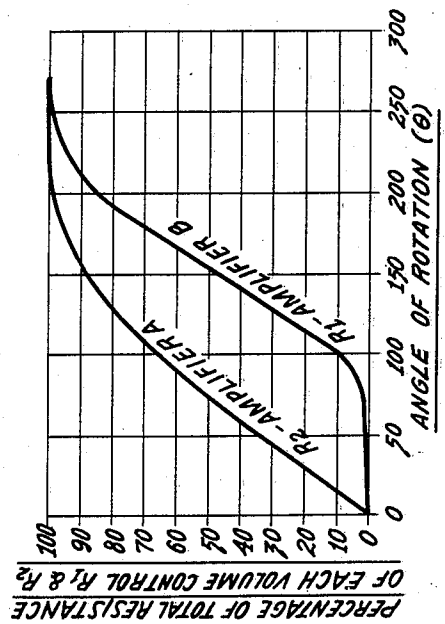


Fig. 5

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2,492,542

COMBINATION POWER AMPLIFIER

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Application September 7, 1945, Serial No. 614,955

5 Claims. (Cl. 179—171)

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My present invention relates generally to improvements in audio frequency amplifier systems, and more particularly to improvements in volume adjusting devices for audio frequency amplifier systems.

It is an important object of my present invention to provide an audio amplifier system having relatively high audio output capability with negligible harmonic distortion over the range of low volume adjustment.

Another object of my invention is to provide an audio frequency amplifier system between a source of the audio frequency signals and a reproducer for such signals, the amplifier system being characterized by the fact that is consists of a pair of channels of adjustable amplitude transmission, such channels having substantially different characteristics relating harmonic distortion to output power.

In accordance with still another object of my invention, a pair of separate audio frequency signal amplifier channels are connected in parallel, one of the channels having appreciably less harmonic distortion at low signal output amplitudes than the other channel, and there being utilized respective, uni-controlled volume control devices of such construction that negligible signal input exists at the input terminals of the amplifier channel having the higher harmonic distortion until the output of the lower distortion channel contains harmonic distortion comparable to that of the higher distortion channel at relatively low output levels.

Other objects, advantages and features will appear in the following description, taken in connection with the drawings, in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

Referring to the drawings:

Fig. 1 shows schematically an audio frequency amplifier system embodying my invention;

Fig. 2 depicts harmonic distortion vs. output power characteristics for the parallel signal amplifier channels shown in Fig. 1;

Fig. 3 shows the manner of constructing the volume control devices;

Fig. 4 illustrates the resistance vs. angle of rotation characteristics for the respective volume control devices shown in Figure 3;

Fig. 5 shows idealized characteristics of Fig. 4, each volume control resistor being assumed to consist of additional resistance sections; and

Fig. 6 illustrates the relationships between the angular settings of the tandem volume control and the respective outputs, including that at

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harmonic frequencies as well as the combined output, from both amplifiers.

In Fig. 1 I have shown the various networks of the system embodying my invention, the networks being schematically represented. The schematic represenation is believed sufficient to indicate to those skilled in the art of constructing and operating an audio frequency amplifier system the nature of the circuits used in the various networks indicated. The numeral 1 denotes a source of audio frequency signal currents. The source 1 may be of any suitable type. For example, it may be the audio demodulator or detector of a radio receiver, whether of the amplitude modulated type or frequency modulated type. The source 1 may, also, be the electrical pickup device of a disc or film type of sound reproducing system, or it may be the microphone of a public address system or industrial sound system. My invention is independent of the specific construction or electrical connections of the source of audio frequency currents. Indeed, the source 1 may even extend beyond the audio frequency range, and hence the expression "signal currents" is to be understood as comprising a range of frequency components extending into the superaudible frequency band.

The numeral 2 denotes a reproducer for translating the signals of source 1 into sound waves, where the signals at source 1 are in the audio frequency range. The reproducer 2 may be of any suitable type. In the case of a radio receiver, it will be the usual receiver loudspeaker. Between the transducers 1 and 2 there is connected the amplifying system embodying my present invention. Essentially the amplifier system consists of a pair of amplifier networks having respective volume control, or signal output level adjusting, devices. The amplifier networks are connected in parallel relation, and the characteristics thereof are correlated in a predetermined manner with the respective volume control devices thereof.

The amplifier network A is essentially characterized by the fact that it has a low production of harmonic distortion at relatively low signal output levels. It is provided with a volume control device which consists of a resistor R_2 having a slider or adjustable contact 4. The resistor R_2 is connected by resistance R and lead 5 to the high potential output terminal of source 1, while the lower end of resistor R_2 is grounded. In other words the device R_2, 4 is a potentiometer, or potential divider, device shunted across source 1. The adjustable tap 4 is connected by lead 6

to the high potential input terminal of amplifier A, the second input terminal being at ground potential. The lead 7 connects the high potential output terminal of amplifier A to the high potential input terminal of reproducer 2. The grounded output terminal of amplifier A returns to the grounded input terminal of reproducer 2.

The amplifier B is characterized by a relatively higher harmonic distortion than amplifier A at the low signal output levels. The amplifier B is a conventional, relatively low-cost amplifier such as might be designed for radio receivers or public address systems in which, due to cost factors involved, the distortion at low signal levels cannot be limited to a negligibly low value and the amplifier still be built to provide high power output. Amplifier A on the other hand does not have to supply a high output (for example, about 5 to 8 watts maximum for radio receiver use), and, therefore, low distortion can be given greater consideration in the construction of amplifier A.

The amplifier B is provided with its respective potentiometer, or potential divider, whose ungrounded end of resistor R_1 is connected in common with lead 5 to the ungrounded terminal of source 1. The slider 9 of potentiometer resistor R_1 is connected by lead 10 to the ungrounded input terminal of amplifier B. The output terminals of amplifier B are connected in parallel with the output terminals of amplifier A to the input terminals of reproducer 2. The numeral 11 designates schematically, by a dashed line, any suitable mechanical adjusting device for concurrently varying the positions of sliders 4 and 9 on their respective resistors R_2 and R_1.

In Fig. 3 I have indicated the respective volume control resistors R_1 and R_2 with their corresponding sliders 9 and 4. It will be seen that the common adjusting means 11 concurrently varies the angular rotation of sliders 9 and 4. The angle of rotation of each slider with respect to the grounded end of its respective resistance has been indicated by the letter θ. In the present exemplification of my invention, resistor R_1 has been shown as consisting, in order between lead 5 and ground, of a medium resistance section 12, a high resistance section 13 and a low resistance section 14. As the slider 9 is moved upward in position from the grounded end

$$\frac{dR_1}{d\theta}$$

first increases, and then over the upper part of the range

$$\frac{dR_1}{d\theta}$$

decreases to an intermediate value.

The resistor R_2 has a high resistance section 13' at its ground end, a low resistance section 14' at its ungrounded end, and a medium resistance section 12' between the other sections. In this case

$$\frac{dR_2}{d\theta}$$

decreases as θ increases. A resistor R in series with R_2 functions to limit the input to the low distortion amplifier A so that the latter may not be overloaded, at least until the higher distortion amplifier B is badly overloaded also. For this reason resistor R is connected between lead 5 and the upper end of resistance section 14'. It is pointed out that overload of the low distortion amplifier A can be prevented by limiting the input thereto as shown in Fig. 1, or by proportioning the gain of the amplifier channel A with respect to channel B such that both amplifier channels preferably overload at about the same point.

In Fig. 2 I have depicted typical characteristics for amplifiers A and B. The characteristic curves in Fig. 2 for the amplifier networks relate "Watts output" against "Percent total harmonic distortion." It will be noted that amplifier channel A has a slowly rising distortion characteristic for low output levels so that for low signal output the harmonic distortion is negligibly low. On the other hand, amplifier channel B has a relatively high harmonic distortion percentage output for relatively low signal output amplitudes, while at higher output levels the harmonic distortion is proportionately higher.

From this graph chart it is seen that over the lower output range (say up to 5 watts) amplifier A shows considerably less distortion than would be obtained from amplifier B worked over the same output range.

Amplifier B may be of any suitable construction, as, for example, the type of audio frequency amplifier commonly employed in a radio receiver. Such an amplifier usually employs pentodes, or beam power tubes in the output stage. In such an amplifier the distortion although low may be appreciable even at low output levels, and may contain high order components. Amplifier A is constructed so as to have very low amplitude distortion especially at the low signal output levels, and this may be done, for example, by employing a properly designed triode class A amplifier system. An amplifier employing two type 45 triodes in push-pull may be used. Reference is made to RCA application note No. 40 entitled "Application note on high power output from type 45 tubes" (Copyright 1934 by RCA Radiotron Co. Inc.), particularly to Fig. 2C thereof, for suitable characteristics to enable one skilled in the art to design a suitable low distortion amplifier. In that type of amplifier circuit the power output is 5 watts with 0.6 percent distortion. Such a system will give less objectionable distortion at low amplitudes than for channel B.

The class A system becomes costly, however, when it is required to deliver high power due to the lower plate efficiency. Alternatively, amplifier B may be a so-called class B amplifier of the type employing a suitable tube, e. g., the 46 type triode using zero grid bias. Such a class B amplifier has a relatively high total percent harmonic distortion at power outputs up to 2 watts. In general, I do not wish to limit my invention to any particular tubes or circuit connections in amplifier networks A and B, since those skilled in the art of radio communication will readily be able to construct suitable amplifier networks from the characteristics of Fig. 2 and my aforesaid description.

The two signal output amplitude control devices are so constructed that substantially no signal input is applied to amplifier B until amplifier A is operating at a fairly high level of signal output. Preferably, signal is delivered to the amplifier B at the point where the harmonic distortion produced at amplifier A has attained the value of distortion which amplifier B exhibits at the lower end of its signal output range. This effect can be accomplished by constructing resistors R_1 and R_2 as shown. As previously explained, the rotation of sliders 9 and 4 do not produce

like resistance changes. The resistors are provided with such relative tapering that the aforesaid relation of signal input to amplifiers A and B is secured.

In Fig. 4 there is shown a pair of curves relating "Angle of rotation" and "Percentage of total resistance of each volume control R_1 and R_2," the latter term referring to the resistance between the slider arms and ground in relation to the total resistance. From these curves it will be noted that the volume control device for amplifier B has substantially less change in resistance than the volume control device for amplifier A for the early part of the angle of rotation of adjusting device 11. At 270° of rotation both volume control devices have maximum resistance magnitude. The respective use of three resistive sections 12, 13 and 14 provides the characteristics shown in Fig. 4. By the use of a number of additional resistive sections for the two voltage dividers R_1 and R_2 smoother control characteristics can be obtained approaching those shown in Fig. 5.

In Fig. 6 I have charted the relationships between the angular settings of the tandem volume control and the respective outputs, including that at harmonic frequencies as well as the combined output, from both amplifiers. The abscissae are "Angle of rotation," while the two ordinates are "R. M. S. power output-watts-fundamental plus harmonics" and "R. M. S. power output at harmonic frequencies-watts." The calculated relationships are based on full output from both amplifiers when the volume control is at the maximum volume setting. At lower volume settings, the power output will vary directly as the square of the percentage values of Fig. 4.

The amplifier B does not start to contribute, as can be seen from the curves of Fig. 6, until the tandem volume control has been rotated through about 105 degrees of the available 270 degrees rotation. At that point the output from amplifier A is 3.5 watts with 20 milliwatts harmonic output (about 0.6 percent distortion). At 170 degrees rotation both amplifiers develop about the same power (6.5 watts), and have approximately the same harmonic output. Over the remainder of the volume control range of 170 to 270 degrees, the output from amplifier B predominates.

Note that the volume control for amplifier B is constructed to decrease the slope of the output versus angular rotation characteristics over the last 70 degrees rotation (Fig. 4). This shape of control characteristic is necessary in order to have the output of amplifier B coordinate in the desired manner with that of amplifier A, and use the full 270 degrees rotation. This shape of characteristic is, also, desirable from the standpoint of smooth overload.

By means of the present arrangement it is possible to secure relatively undistorted signal input at the input terminals of the reproducer 2 at normal output levels with an amplifier of limited power capability. From the curves of Fig. 2 it is seen that at high output signal levels, where very low harmonic distortion is not required, the signal output is supplemented by amplifier B. At the low signal output levels of the parallel channels the signal input to amplifier B is negligible, while the amplifier A which receives the signal input produces negligibly small harmonic distortion.

While I have indicated and described a system 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 organization shown and described, but that many modifications may be made without departing from the scope of my invention.

What I claim is:

1. In an amplifier system of the type employing a source of electrical signals including frequency components of a predetermined frequency range and a reproducer for such signals; the improvement comprising at least two amplifying channels, each of said channels being provided with a pair of input terminals and a pair of output terminals, means for connecting the output terminals of said channels in parallel connection to said reproducer, one channel being constructed to produce relatively low harmonic distortion at low signal output levels, a second channel being of relatively high power output and of such construction that the distortion at low signal levels cannot be limited to a value as low as that of said one channel, a first volume control device coupling said source to the input terminals of said one channel, a second volume control device coupling said source to the input terminals of the second channel, a common means connected to adjust said volume control devices for selectable overall power output levels, and the volume control device electrically associated with the second channel being so constructed and arranged that substantially no signals are applied to the second channel at low volume adjustment of said common means while signals are delivered thereto at the point where the harmonic distortion produced in said one channel has attained the value of distortion which the second channel exhibits at the lower end of its signal output range.

2. In an amplifier system of the type employing a source of electrical signals including frequency components of a predetermined frequency range and a reproducer for such signals; the improvement comprising at least two amplifying channels, each of said channels being provided with a pair of input terminals and a pair of output terminals, means for connecting the output terminals of said channels in parallel connection to said reproducer, one channel being constructed to produce relatively low harmonic distortion at low signal output levels and having limited power output, a second channel being of relatively high power output but the distortion at low signal levels being substantial, a first volume control device coupling said source to the input terminals of said one channel, a second volume control device coupling said source to the input terminals of the second channel, common means connected to simultaneously adjust said volume control devices for selectable overall power levels, the volume control device electrically associated with the second channel being constructed and arranged to provide substantially no signal input to its associated channel at low volume adjustment of said common means and substantial signal input when the output of the first channel contains harmonic distortion comparable to that of the second channel at relatively low output levels, each of said volume control devices including a fixed resistor shunted across said source and a respective slider, and the electrical tapering of said fixed resistors being opposite over at least a portion of the provided range of adjustment.

3. In a system of the type including a source of audio frequency currents and an audio fre-

quency reproducer, a first audio signal transmission channel including a high output level amplifier whose distortion at low signal output levels cannot be limited to a relatively low value, a signal amplitude adjusting means coupling said source to the input terminals of said amplifier, said amplitude adjusting means being constructed to provide relatively negligible signal input to the amplifier at low amplitude settings thereof, a second signal transmission channel including an amplifier of relatively low harmonic distortion at low signal output levels, means feeding the signal output of said two channels to said reproducer, a second signal amplitude adjusting device coupling the input terminals of said source to said second channel amplifier, the second amplitude adjusting device being constructed to provide substantial signal input to said second channel amplifier at low amplitude settings thereof, and means for conjointly varying the settings of said two signal amplitude adjusting devices.

4. In an amplifier of the type employing a source of electrical signals including frequency components of a predetermined frequency range and a reproducer for such signals; an improvement comprising at least two amplifying channels including a separate output stage for each channel, means for connecting the output terminals of said channels in parallel to said reproducer, one of said channels being designed so as to produce relatively low harmonic distortion especially at low output amplitudes, the other channel being designed for relatively high power output but with higher harmonic distortion resulting from the requirements for such power output, means for connecting the inputs of the two channels to said source of signals, said last means consisting of separate volume control devices, the volume control devices being so constructed and relatively proportioned that substantially no input signals are applied to the higher distortion amplifier until the output signals from the lower distortion amplifier attain a predetermined amplitude value and as the signals fed from the source to the two channels are further increased in amplitude the rate of increase to the higher distortion amplifier increases over at least a portion of the provided range of adjustment while the rate of increase to the low distortion amplifier decreases, for preventing overloading of one channel substantially before the other.

5. In a high-level amplification system having a controllable power output level for amplifying electric signals and delivering the amplified signals at a selectable intensity level: a low-distortion amplification channel in which harmonic distortion is minimized and the resulting power output rapidly becomes excessively distorted when raised to relatively limited power output levels; a high-power output amplification channel in which the output intensity is maximized and the resulting harmonic distortion is relatively high even at low output levels; the high-power channel having a maximum power output higher than the low-distortion channel, said channels having input and output terminals connected for amplifying signals in parallel; output level control elements for each channel; and selector means having a single settable member for operating the control elements to furnish the desired overall power output level, said selector means being connected for utilizing essentially the low-distortion channel output at low overall power level settings, for adding high-power channel output when the settings increase to an overall power level at which the distortion of the low-distortion channel reaches approximately the distortion level of the high-power channel, and at still higher settings to add high-power channel output and low-distortion channel output in relative amounts that prevent excessive total distortion.

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