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(54) AN OUTPUT SIGNAL CORRECTING CIRCUIT

(71) I, WAI LIT YEN, a citizen of Hong Kong, residing at 92 Pokfulam Road, La Clare, 7-B Hong Kong, do hereby declare the invention, for which I pray that a patent may be granted to me and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a circuit for correcting the AC output signal from an electronic device, such as an amplifier, which responds to a variable input signal, and to a method of correcting the output of such a device.

An AC output signal from an electronic device, such as an amplifier, which responds to an AC input signal, is affected by the load on the output signal, the design constraints on the electronic device, and extraneous degradation such as noise or parasitic capacitances which may be picked up by or inherent in the apparatus which carries the output signal. Each of these factors degrades the amplitude and phase accuracy of the output signal relative to that desired from the input signal.

The accuracy with which the output signal corresponds to the input signal, however, is often important to the use of the electronic device. For this reason, for example, the distortion of the output signal relative to the input signal is a well-known way of gauging the quality of amplifiers.

One common use of amplifiers in which the accuracy of the output signal relative to the input signal is important is in high fidelity sound playback equipment. In these popular components, recorded or broadcast music (and voice) signals are amplified to drive a loudspeaker. The amplifier must accurately amplify the input signal so that the loudspeaker can accurately reproduce the recorded sound.

Design constraints of both cost and technical considerations such as gain, however, often require a trade of compromise between the cost of the amplifier or its gain and the accuracy of signal reproduction. Similarly, design considerations of cost or space often make it difficult to fully shield the output side of the amplifier from noise and parasitic

capacitances which degrade the output signal. These factors, however, arise substantially within the amplifier component and thus, within the design constraints, can be controlled by the manufacturer.

Many high fidelity amplifier components are sold separately from the loudspeaker loads to be driven by the amplifier. Inasmuch as all loudspeakers are not alike, the exact characteristics of the load to be coupled to the component cannot be determined in advance. In addition, the load characteristics of loudspeakers are not uniform (as is often assumed in the design of high fidelity amplifiers). Many speakers, for example, have a resonant frequency within the range of audio frequencies which they reproduce which significantly affects the electrical characteristics of the speaker load. In addition, many loudspeakers have frequency responsive crossover networks between an array of individual speakers within the loudspeaker which can further change the electrical characteristics of the loudspeaker load in response to the frequency of the output signal.

The present invention provides a circuit for correcting the AC output signal from an electronic device which responds to a variable input signal, such as an amplifier, the circuit comprising first and second amplifiers, the input of the first amplifier being provided directly to receive the AC portion of the input signal; a variable input resistance with one end attached to the input of the first amplifier and the other end attached to the input of the second amplifier; means to combine the output signals from the first and second amplifiers and to supply the combined AC signals to the input of the electronic device; and variable resistance feedback means to supply a selected portion of the AC output signal from the electronic device to the first amplifier only, said feedback means changing the signal from the first amplifier as a function of the difference between the input signal and the output signal, whereby the output signal from the electronic device, in response to the combined signals from the first and second amplifiers, more closely corresponds to the input signal, than would the output signal from the elec-

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tronic device, if the electronic device received the input signal directly.

It is important, of course, that the signals from the first and second amplifiers be accurate. These amplifiers, however, only have a function in the correcting circuit and are not, therefore, subject to other design constraints such as gain. In addition, the load which they drive, the electronic device, is known so that its load characteristics can be fully considered by the designer and, still further, electronic devices are usually designed with a high input impedance, so that changes in the signal to the electronic device will be minimally affected by the load characteristics of the device. It is therefore much easier to design inexpensive, highly accurate first and second amplifiers for the correcting circuit than it is to design a highly accurate electronic device such as a high gain amplifier for an unknown, variable loudspeaker load.

The invention also provides a method of correcting the AC output signal of an electronic device, such as an amplifier, relative to an AC input signal, which method is carried out with a circuit comprising first and second amplifiers having inputs respectively to receive the AC input signal and an adjusted value thereof, the first and second amplifiers having respective outputs both connected to an input of the electronic device, and adjustable feedback means connected between an output of the electronic device and an input to the first amplifier, the method comprising the steps of disconnecting the output of the first amplifier from the input of the electronic device and adjusting the amplitude of the AC output signal fed back, from the output of the electronic device to the input of the first amplifier, so that the output signal of the first amplifier is substantially null, the feedback adjustment being carried out when the AC input signal has a given value and when the operating conditions of the electronic device are such that the AC output signal deviates least relative to the AC input signal; and reconnecting the output of the first amplifier to the input of the electronic device so as to combine the output signals of the first and second amplifiers whereby the combined signal varies as an inverse function of deviation of the AC output signal to correct the output signal into closer correspondence with the input signal.

The above method, which is applicable to the previously described circuit, accommodates nonuniformity of the load as well as nonuniformity of operation of the electronic device. For example, the nonuniformity of loudspeaker loads have already been mentioned and the response of many amplifiers is also nonuniform over the entire range of input signal frequencies and gains at which a particular amplifier may be operated. The method, can therefore, be used to determine

the input signal frequency and amplitude, and the gain at which the electronic device, or third amplifier, most accurately responds to the signal from the second amplifier. The amplitude of the feedback applied to the first amplifier is then adjusted until the AC signal output of the first amplifier is substantially null.

In use, distortion is corrected as follows, if the output signal of the electronic device tends to decrease, the output of the first amplifier decreases so as to increase the value of the combined signal tending to increase the level of the output signal of the electronic device. Conversely, if the output signal tends to increase and become phase shifted from the input signal, the output of the first amplifier adjusts the level of the combined signal to offset these effects. The first and second amplifiers thereby act as a correcting circuit, the operation of which is independent of the cause of an error in the output signal of the electronic device. This correcting circuit can also correct errors which may be caused internally within the electronic device, due to noise or parasitic factors at its output, or by variations in the load on the electronic device.

A preferred embodiment of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a generalized schematic of the preferred embodiment; and

Figure 2 is a more specific schematic of the preferred embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENT AND METHOD OF ITS OPERATION

The Preferred Embodiment

Figure 1 shows the arrangement of the correcting circuit with a first amplifier 10 and a second amplifier 12 each illustrated generally. The electronic device 14 which provides the output signal at 16 to be corrected by the correcting circuit is also generally illustrated as a third amplifier. This electronic device 14 may be, for example, one of the known types of amplifiers used in commercially available high fidelity sound reproduction components with its feedback stage removed. The output load (indicated, but not shown) which is connected to the output signal at terminal 16 then may be a loudspeaker. In other embodiments, however, the electronic device 14 may be another type of electronic device which produces an AC output signal in response to an AC signal input.

The output signal at 16 is fed back along a path including variable resistor 18 to an input terminal of the first correcting circuit amplifier 10. The first amplifier 10 then provides a signal output to terminal 20 which is a function of the difference between the input

signal applied at terminal 22 and the feedback (output) signal.

The input signal at terminal 22 is also provided to the second correcting circuit amplifier 12 along a path including a variable resistor 24. The signal from the second amplifier 12 is provided to the third amplifier 14 along path 26. As later described with reference to the preferred method of operating the circuit, the signal from amplifier 10 is combined with the signal from amplifier 12 via a path 28 to be also provided as part of the signal input to the amplifier 14. The path 28 is shown in dashed lines to indicate that it is open circuited for the initial steps of the method during which the correcting circuit is preset for operation with a particular electronic device 14 and then closed to the path 26 for operation of the correcting circuit.

Figure 2 shows the preferred embodiment of Figure 1 with the first and second correcting circuit amplifiers 10 and 12 illustrated in greater detail. As shown in Figure 2, the first and second amplifiers are each single transistor amplifiers in which the transistors 30, 32 may be of a type designated 2SC945 which is commercially available from N.E.C. The base of each transistor is connected to receive the input signal from terminal 22 and the collector of each transistor is, in operation, commonly connected via paths 26 and 28 to provide the combined signal input to amplifier 14.

The resistor 18 may then have a range of resistances around 10 times the output impedance of the electronic device 14 or about 100 to 300 ohms for many commercially available amplifier components which preferably embody the electronic device 14. The resistor 24 should have a range of relatively high values; for example, a range about 500K ohms. Selecting the values of the other resistors, capacitors, and bias potentials indicated in Figure 2 are design choices well within the capabilities of those in the art.

The Method

In order to make sure that the correcting circuit does not introduce additional inaccuracy into the output signal at 16, it is preferred to preset the correcting circuit to have no effect on the output signal when the output signal is most accurately related to the input signal at 22. The method, therefore, contemplates first determining the conditions of, for example, input signal frequency, and third amplifier gain and output load at which the output signal at 16 most accurately corresponds to the input signal. This condition is often achieved at a particular frequency input signal and full gain in the amplifier. The most accurate condition, however, can be established with a variety of known in-

struments and techniques such as, for example an oscilloscope.

The signal which produces the least distortion in the output signal at 16 is then provided at 22 and resistor 24 adjusted so that the signal from amplifier 12 which is input to the electronic device 14 along path 26 is of an appropriate amplitude for providing the least distorted output signal at 16. Path 28 is open circuited during this operation so that only the signal on path 26 from amplifier 12 is provided to the electronic device 14.

The feedback signal to amplifier 10 is then adjusted by adjusting resistor 18 until the AC signal at now open-circuited terminal 20 from amplifier 10 is a null. The correcting circuit is then preset in such a way that when the output signal at 16 is least distorted relative to the input signal at 22, the correcting circuit will have no effect on the output signal. The correcting circuit thus cannot introduce additional distortion into the output signal.

Path 28 is then closed to path 26 to carry the signal from amplifier 10 to line 26 for input to the electronic device 14 and the input signal at 22 no longer has to be held at the signal which produced the least distortion in the output signal. The correcting circuit is thus preset to leave the minimum distortion in the output signal unchanged, but, as now described, arranged to correct greater distortion in the output signal.

Operation

If the input signal at 22 continues at the frequency and amplitude which produce the least distortion in the output signal at 16, the AC signal output from amplifier 10 continues to be a null. The input signal, as operated on by resistor 24 and amplifier 12, however, is provided via path 26 to the electronic device 14 to produce an AC output signal at 16 which most accurately corresponds to the input signal. If, however, the input signal at 22 changes, both amplifiers 10 and 12 produce signals which are combined as inputs to electronic device 14 to produce the output signal at 16.

The electronic device 14 has been described as a high fidelity sound signal amplifier. Such amplifiers are linear. The amplifiers shown at 10 and 12 in Figure 2 are also linear. An increase in the amplitude of the input signal at 22 therefore produces a signal on path 26 which is increased by the gain of amplifier 12 and an output signal at 16 which is increased by the gain of amplifier 14. Assuming an absolute gain of more than one for these amplifiers, the output signal at 16 is then increased in amplitude relative to the input signal. If the increase in the output signal is proportional to that of the input signal by the gain of amplifiers 12 and 14, the AC signal

output from amplifier 10 remains a null. If, however, the output signal at 16 is too large relative to the input signal as by distortion in amplifier 14, a change in the output load (not shown), or a change in noise pickup at the output end of amplifier 14, the feedback signal through resistor 18 to amplifier 10 no longer nulls the input signal to amplifier 10 and the AC output signal from the amplifier 10 decreases. The decreasing signal from amplifier 10 is combined with the signal output from amplifier 12 on path 26 to decrease the signal input to the amplifier 14 and thereby decrease the output signal at 16 proportionally to its distortion. Conversely, if the distortion of the AC output signal diminishes the AC output signal relative to the AC input signal, the feedback of the output signal through resistor 18 to amplifier 10 decreases to increase the signal from amplifier 10 and thereby increase the signal input to amplifier 14 to increase the output signal.

As thus described, the correcting circuit corrects the amplitude of the output signal relative to the input signal to a level which approaches that of the least amplitude distortion in the output signal for which the correcting circuit was preset by the method described. A similar operation occurs for phase aberrations in the output signal. If the output signal lags the input signal in phase, the input signal will produce a signal from amplifier 10 ahead of the feedback signal to thereby advance the phase of the signal on path 26 to amplifier 14 and thereby advance the phase of the output signal at 16. Conversely, if the phase of the output signal leads the input signal, the output signal from amplifier 10 will lag the input signal and correspondingly adjust the output signal.

From the described operation of the correcting circuit it will be appreciated that its operation can be adapted to pulse signal (square wave) devices or nonlinear amplifiers and that the AC signals described throughout are signals of variable amplitude but not necessarily reversing absolute polarity. The linear, high fidelity sound signal amplifier 14, and the linear amplifiers 10 and 12 are thus merely the preferred embodiment of the invention contemplated as within the scope of the following claims.

WHAT I CLAIM IS:—

1. A circuit for correcting the AC output signal from an electronic device which responds to a variable input signal, such as an amplifier, the circuit comprising; first and second amplifiers, the input of the first amplifier being provided directly to receive the AC portion of the input signal; a variable input resistance with one end attached to the input of the first amplifier and the other end attached to the input of the second amplifier; means to combine the output signals from

the first and second amplifiers and to supply the combined AC signals to the input of the electronic device; and variable resistance feedback means to supply a selected portion of the output signal from the electronic device to the first amplifier only, said feedback means changing the signal from the first amplifier as a function of the difference between the input signal and the output signal, whereby the output signal from the electronic device, in response to the combined signals from the first and second amplifiers, more closely corresponds to the input signal, than would the output signal from the electronic device, if the electronic device received the input signal directly.

2. A circuit as set forth in claim 1 wherein the first and second amplifiers are linear amplifiers; the function by which the feedback means changes the signal output from the one amplifier as linear; and the electronic device is a third linear amplifier, whereby a change in the output signal which does not correspond to a change in the input signal produces an inversely proportional change in the signal to the electronic device for correspondingly correcting the output signal from the electronic device.

3. A circuit for correcting the AC output signal from a third linear amplifier relative to a variable input signal, the circuit comprising; first and second linear, single transistor amplifiers having the base of the transistor of the first amplifier arranged for directly receiving the AC portion of the input signal; a variable input resistance connecting the bases of the two transistors of the first and second amplifiers; means commonly connecting one of the collector and emitter of each amplifier transistor to supply a combined AC signal from the first and second amplifiers to the input of the third amplifier; and variable resistance feedback means to supply a selected portion of the AC output signal to one of the base and emitter of the transistor of only the first amplifier to change the signal from the first amplifier linearly with the difference between the input and output signals whereby the output signal from the third amplifier, in response to the combined signals from the first and second amplifiers, more closely corresponds to the input signals than would the output signal from the third amplifier if the third amplifier received the input signal directly.

4. A method of correcting the AC output signal of an electronic device, such as an amplifier, relative to an AC input signal, which method is carried out with a circuit comprising first and second amplifiers having inputs respectively to receive the AC input signal and an adjusted value thereof, the first and second amplifiers having respective outputs both connected to an input of the electronic device, and adjustable feedback

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output from amplifier 10 remains a null. If, however, the output signal at 16 is too large relative to the input signal as by distortion in amplifier 14, a change in the output load (not shown), or a change in noise pickup at the output end of amplifier 14, the feedback signal through resistor 18 to amplifier 10 no longer nulls the input signal to amplifier 10 and the AC output signal from the amplifier 10 decreases. The decreasing signal from amplifier 10 is combined with the signal output from amplifier 12 on path 26 to decrease the signal input to the amplifier 14 and thereby decrease the output signal at 16 proportionally to its distortion. Conversely, if the distortion of the AC output signal diminishes the AC output signal relative to the AC input signal, the feedback of the output signal through resistor 18 to amplifier 10 decreases to increase the signal from amplifier 10 and thereby increase the signal input to amplifier 14 to increase the output signal.

As thus described, the correcting circuit corrects the amplitude of the output signal relative to the input signal to a level which approaches that of the least amplitude distortion in the output signal for which the correcting circuit was preset by the method described. A similar operation occurs for phase aberrations in the output signal. If the output signal lags the input signal in phase, the input signal will produce a signal from amplifier 10 ahead of the feedback signal to thereby advance the phase of the signal on path 26 to amplifier 14 and thereby advance the phase of the output signal at 16. Conversely, if the phase of the output signal leads the input signal, the output signal from amplifier 10 will lag the input signal and correspondingly adjust the output signal.

From the described operation of the correcting circuit it will be appreciated that its operation can be adapted to pulse signal (square wave) devices or nonlinear amplifiers and that the AC signals described throughout are signals of variable amplitude but not necessarily reversing absolute polarity. The linear, high fidelity sound signal amplifier 14 and the linear amplifiers 10 and 12 are thus merely the preferred embodiment of the invention contemplated as within the scope of the following claims.

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the first and second amplifiers and to supply the combined AC signals to the input of the electronic device; and variable resistance feedback means to supply a selected portion of the output signal from the electronic device to the first amplifier only, said feedback means changing the signal from the first amplifier as a function of the difference between the input signal and the output signal, whereby the output signal from the electronic device, in response to the combined signals from the first and second amplifiers, more closely corresponds to the input signal, than would the output signal from the electronic device, if the electronic device received the input signal directly.

2. A circuit as set forth in claim 1 wherein the first and second amplifiers are linear amplifiers; the function by which the feedback means changes the signal output from the one amplifier as linear; and the electronic device is a third linear amplifier, whereby a change in the output signal which does not correspond to a change in the input signal produces an inversely proportional change in the signal to the electronic device for correspondingly correcting the output signal from the electronic device.

3. A circuit for correcting the AC output signal from a third linear amplifier relative to a variable input signal, the circuit comprising; first and second linear, single transistor amplifiers having the base of the transistor of the first amplifier arranged for directly receiving the AC portion of the input signal; a variable input resistance connecting the bases of the two transistors of the first and second amplifiers; means commonly connecting one of the collector and emitter of each amplifier transistor to supply a combined AC signal from the first and second amplifiers to the input of the third amplifier; and variable resistance feedback means to supply a selected portion of the AC output signal to one of the base and emitter of the transistor of only the first amplifier to change the signal from the first amplifier linearly with the difference between the input and output signals whereby the output signal from the third amplifier, in response to the combined signals from the first and second amplifiers, more closely corresponds to the input signals than would the output signal from the third amplifier if the third amplifier received the input signal directly.

4. A method of correcting the AC output signal of an electronic device, such as an amplifier, relative to an AC input signal, which method is carried out with a circuit comprising first and second amplifiers having inputs respectively to receive the AC input signal and an adjusted value thereof, the first and second amplifiers having respective outputs both connected to an input of the electronic device, and adjustable feedback



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- 5 means connected between an output of the electronic device and an input to the first amplifier, the method comprising the steps of disconnecting the output of the first amplifier from the input of the electronic device and adjusting the amplitude of the AC output signal fed back, from the output of the electronic device to the input of the first amplifier, so that the output signal of the first amplifier is substantially null, the feedback adjustment being carried out when the AC input signal has a given value and when the operating conditions of the electronic device are such that the AC output signal deviates least relative to the AC input signal; and reconnecting the output of the first amplifier to the input of the electronic device so as to combine the output signals of the first and second amplifiers whereby the combined signal varies as an inverse function of deviation of the AC output signal to correct the output signal into closer correspondence with the input signal. 20
5. A correcting circuit substantially as herein described with reference to the accompanying drawings. 25

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