Nov. 21, 1961 I. BEKEY 3,009,991

SOUND REPRODUCTION SYSTEM

Filed Dec. 1, 1955

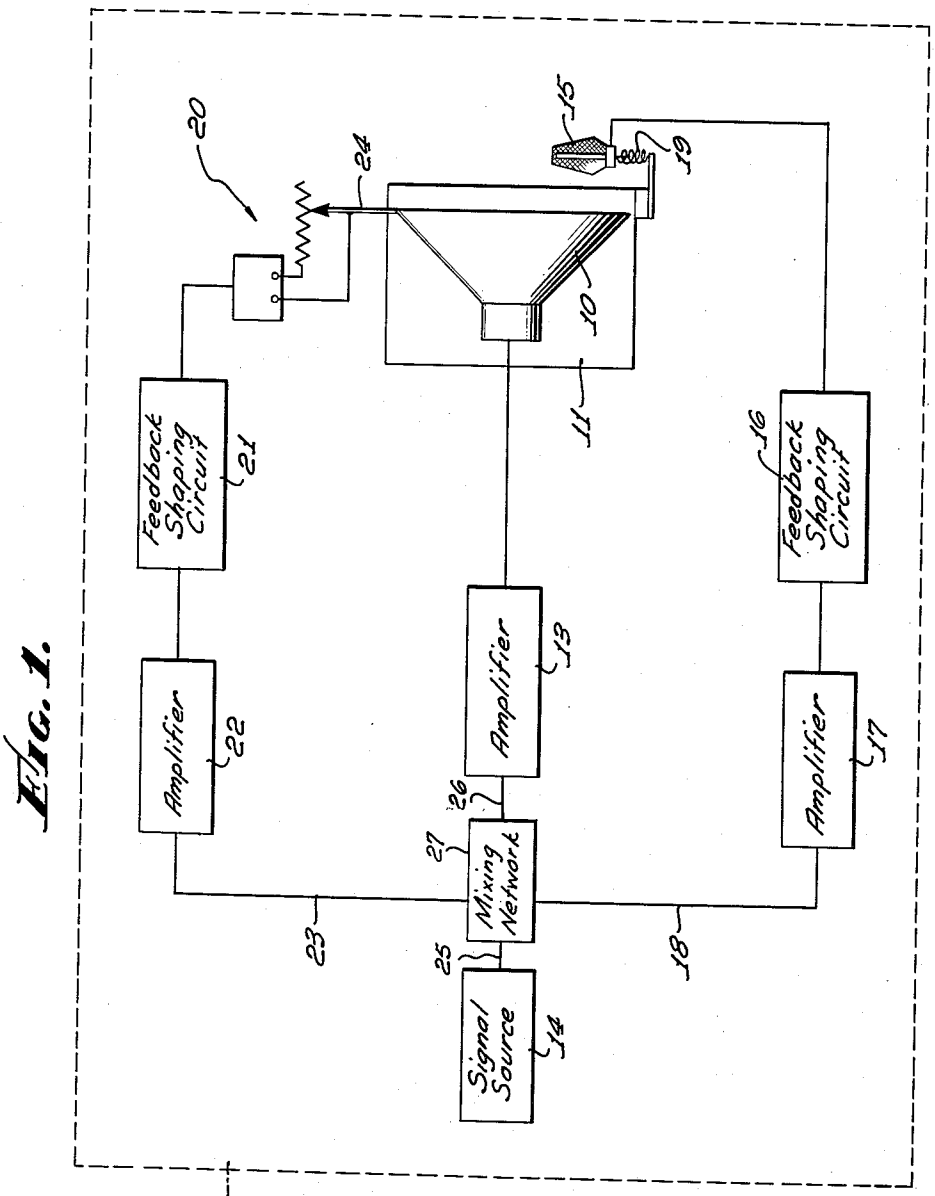


FIG. 1.

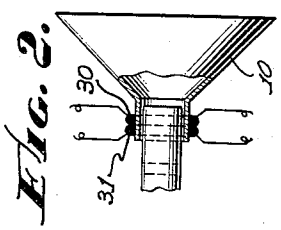


FIG. 2.

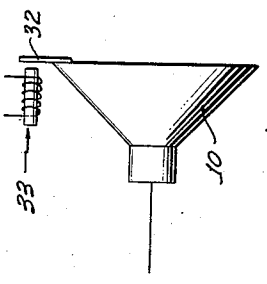


FIG. 3.

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United States Patent Office 3,009,991 Patented Nov. 21, 1961

3,009,991

SOUND REPRODUCTION SYSTEM

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Filed Dec. 1, 1955, Ser. No. 550,274
4 Claims. (Cl. 179—1)

This invention relates to sound reproduction, and particularly to apparatus for controlling the fidelity of the sound produced.

Particular attention has been given to design of amplifiers and other components of sound reproducing equipment to ensure faithful reproduction. Heretofore, the sound produced by the usual form of acoustic system is far from a faithful reproduction of the signal input to the loud speaker. This is due to the frequency response characteristics of the speaker and its cabinet, which is normally very poor in comparison with the frequency response characteristics of high quality amplifiers, and other electrical components. Improvements in loud speakers and cabinet designs are, of course, constantly attempted, and at substantial expense. At best, these attempts are ineffective to overcome any but the more extreme distortions. The principle of degenerative feedback has been successfully used in the design of amplifiers to reduce noise and distortions, and to achieve relative independence between the sound produced and the characteristics of the amplifiers. Speaker systems for use with high fidelity amplifiers have been used without the sound produced thereby being included in the feedback loop.

The primary object of this invention is to provide a sound reproduction system in which noises and distortions due to the speaker system and the room in which it is located are largely eliminated, and in which the sound produced is largely independent of the characteristics of the speaker, enclosure or room. This is made possible by utilizing a degenerative feedback arrangement in which the sound produced is the controlled variable and the program material is the reference input.

Use is made of a unidirectional mechano-electrical transducer associated with the source of sound and a feedback circuit connecting the transducer to an intermediate or input stage of the amplifier.

This arrangement makes possible a less critical design of speaker systems, reduces the cost of equipment, and materially enhance the faithfulness of the sound produced.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of one embodiment of the invention. For this purpose, there is shown a form in the drawings accompanying and forming part of the present specification. This form will now be described in detail, illustrating the general principles of the invention; but it is to be understood that this detailed description is not to be taken in a limiting sense, since the scope of this invention is best defined by the appended claims.

Referring to the drawings:

FIGURE 1 is a diagrammatic representation of a sound reproducing system incorporating the present invention; and

FIGS. 2 and 3 are diagrammatic representations of alternate pick-up constructions for use in the system.

In the drawings, there is shown a loud speaker **10** accommodated in a suitable cabinet **11**. The enclosure **11** is located in a room **12** which preferably has highly sound absorbent walls to eliminate distortions due to the selective reflection characteristics. The room **12** and cabinet **11** determine the loading of the speaker **10**, and hence influence the sound emitted from the speaker. Connected to the speaker **10** is an amplifier system **13** which is, in turn, connected to an audio signal source **14** through a subtracting or mixing network **27** to be referred to hereinafter.

In order to make the sound produced correspond to the actual signal supplied to the loud speaker, use is made of a degenerative feedback circuit forming, with the amplifier and speaker, a sound servomechanism. This feedback circuit comprises a microphone **15**, a feedback shaping circuit **16**, an amplifier **17**, and a connection **18** to the subtracting or mixing network **27**. In this instance, the mixing network is located between the main amplifier **13** and the signal source **14**. Optionally, the mixing network **27** could be located at an intermediate stage of the amplifier **13**.

The microphone **15** is placed as close as possible to the cone of the loud speaker and has unidirectional characteristics in order that it be responsive to the sound produced by the loud speaker and not to whatever reflections might be produced by the room **12**. In order to prevent mechanical vibrations other than sounds from affecting the microphone **15**, it is resiliently mounted in an appropriate manner, as diagrammatically illustrated at **19**.

The signal corresponding to the sound at the microphone is fed back degeneratively or at a phase angle of 180°. Since the cabinet and room influence the sound emitted, the signal created by the microphone takes into account the characteristics of the cabinet and room. In this arrangement, the sound produced is the variable, controlled by the signal at the input to the amplifier **13**. Depending upon the factors in the feedback shaping circuit **16** and amplifier **17**, the sound produced is made to be independent, more or less, of the characteristics of the loud speaker enclosure **11** and room **12**. Distortions are largely eliminated.

The time required for the sound to reach the microphone **15** causes an additional phase lag in the feedback loop **15, 16, 17, 18**. This added phase difference varies directly in accordance with the frequency of the signal. The additional phase lag due to this spatial relationship poses a possibility of oscillations at a certain frequency if the gain for that frequency is sufficiently large. Thus, for example, the spacing between the microphone **15** and the loud speaker **10** will correspond to a half wave length (or a 180° added phase shift) of a certain frequency sound wave. If the spacing is one-half of a foot, a wave having a frequency of about 1000 cycles per second may cause oscillations since the feedback circuit also introduces a 180° lag.

In order to prevent this spatial time lag from creating oscillations, the feedback shaping circuit **16** may be so designed as to attenuate those frequencies that would tend to cause oscillations. It is unnecessary to attenuate those frequencies that have wave lengths longer than twice the spacing between the microphone and the speaker. Since most significant distortions occur in the low frequency range, the attenuation of high frequencies does not detract from the effectiveness of the system.

The sound produced by the loud speaker **10** is a function of the character and extent of loading of the loud speaker in the particular room **12**. The microphone **15**, accordingly, is responsive to the characteristics of the room **12** as well as to the normal infinite baffle characteristics of the loud speaker **10**. The feedback arrangement produces a linear distortionless sound heretofore not achieved by refinements merely in cabinet or loud speaker design.

The foregoing considerations assume that there are no material resonant characteristics of the acoustic system in the range under consideration. Actually, however, there may be definite physical resonances at low frequencies within the range operated upon by the feedback circuit. Since a physical resonance is accompanied by phase shifts which reverse sign through each resonant frequency,

it is possible that this also might produce a condition in which oscillations could occur.

In order to ensure against the possibility of inherent physical resonances creating a condition of possible oscillations and to create a system having greater flexibility of control over the sound produced, use is made of the pick-up structure **20** responsive to a function of axial movement of the loud speaker cone. A degenerative feedback circuit, including a feedback shaping circuit **21**, amplifier **22**, and connection **23**, serves to control the motion of the loud speaker cone and minimize whatever resonant tendencies there may be in the acoustic system. In the present instance, the connection **23** connects with the mixing network **27**. It will be understood that a separate mixing network could be used.

The pick-up **20** in this instance is diagrammatically illustrated as a potentiometer type. The potentiometer contact arm **24** is mounted on the cone.

Instead of using a potentiometer type pick-up responsive to the amplitude of motion of the loud speaker cone, various other arrangements could be provided, such as piezoelectric crystals, magnetic pick-up or the like. For example, in FIG. 2 there is shown a coil **30** operatively associated with the voice coil **31** of the loud speaker. The current of the voice coil determines the motion of the speaker cone. The pick-up coil **30** is also responsive to this function.

In FIG. 3 a magnetic element **32** carried by the loud speaker cone induces a current in a magnetic pick-up **33**.

It will be understood that the pick-up **20** or either of the pick-ups shown in FIGS. 2 and 3 itself is insufficient completely to control the sound produced since, unlike the microphone **15**, it is responsive to the motion of the speaker and not the sound produced.

Resonant tendencies, such as might upset the balance of the feedback circuit associated with the microphone, are prevented from causing any condition which might tend to sustain oscillations.

The closer the microphone **15** is to the loud speaker cone, the greater the range of frequencies to which the feedback circuit may be made responsive. The closer the microphone **15** is to the ear of the listener, the more the feedback system reflects and controls the sound reaching the listener's ear. This, however, may be at a sacrifice of the frequency range of operation.

Usual servomechanism techniques well known in the art may be applied to the feedback circuits to achieve appropriate stability and sufficient range of operation.

Thus, in accordance with the present invention, the acoustical feedback starting with the electrical-sonic transducer or microphone **15** effects an improvement in the frequency response curve of the speaker system, tending to flatten that curve, particularly by increasing the response at lower frequencies. This improvement, however, tends to produce an undesirable secondary effect of introducing undesired harmonics due to over driving of the speaker. The feedback starting with the motion sensing electrical transducer **20**, however, substantially nullifies the aforestated undesirable secondary effect, in that it acts to depress or partially suppress the motion of the speaker cone **10**. As a result of the combined effects of both feedback systems, a substantial improvement in acoustic output characteristics is thereby obtained.

The inventor claims:

1. A sound servomechanism for cooperation with an audio frequency electrical signal source coupled to a loud speaker output for said source, said servomechanism comprising an electrical-sonic energy transducer spaced from said speaker and responsive to the sonic output of said speaker for producing an electrical signal related to said sonic output, degenerative feedback means coupling an electrical signal derived from the last-mentioned signal to said signal source, a motion sensing electrical transducer positioned to detect physical movements of said speaker and convert the same into a related electrical signal, and degenerative feedback means coupling an electrical signal derived from the last-mentioned signal to said signal source simultaneously with the feedback of the first-mentioned derived electrical signal.

2. In combination, an audio frequency electrical signal source, an acoustic output means coupled to said source for converting the electrical energy signal of said source to an acoustic energy signal, an electrical-sonic energy transducer spaced from said output means and responsive to sonic output of said output means for producing an electrical signal related to said sonic output, degenerative feedback means coupling an electrical signal derived from the last-mentioned signal to said signal source, a motion sensing electrical transducer positioned to detect physical movements of said output means and convert the same into a related electrical signal, and degenerative feedback means coupling an electrical signal derived from the last-mentioned signal to said signal source simultaneously with the feedback of the first-mentioned derived electrical signal, whereby the first-mentioned feedback means functions to effect a more uniform frequency response of said output means, and the second mentioned feedback means functions to depress the motion of said output means.

3. In the combination of claim 2, said motion sensing transducer comprising a potentiometer pick up.

4. In the combination of claim 2, said motion sensing transducer comprising a magnetic induction pick up.

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