Sept. 25, 1962

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LOUDSPEAKER

Filed Nov. 30, 1955

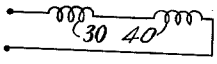


Fig. 5.

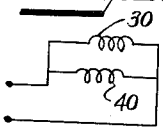


Fig. 6.

Fig. 2.

Fig. 3.

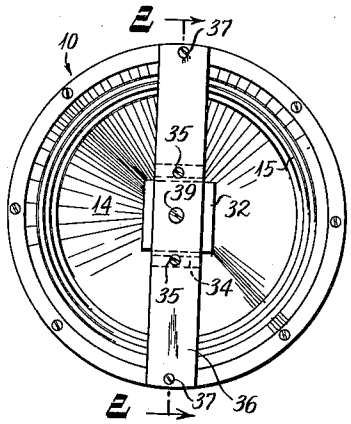


Fig. 1.

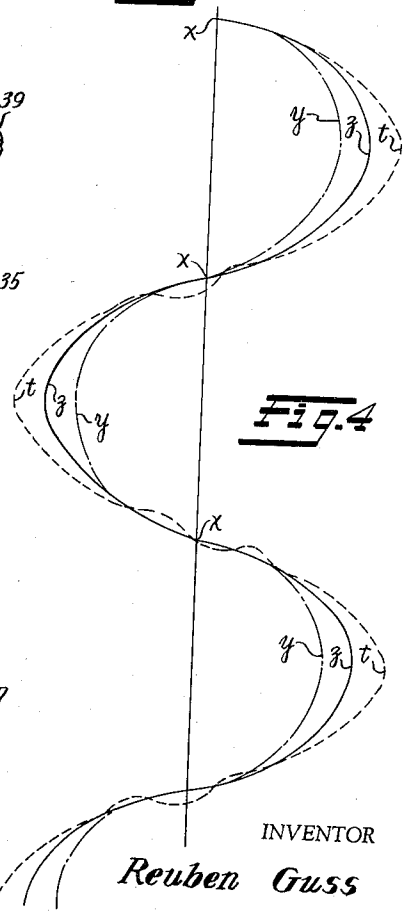


Fig. 4.

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LOUDSPEAKER

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The present invention relates generally to loudspeakers, and more particularly to an improved loudspeaker construction having means for controlling the vibrations of the speaker.

In the conventional magnet and voice coil assembly, audio signals are translated into mechanical vibrations. The voice coil reciprocates and makes excursions into and out of its voice coil gap as it reacts electromagnetically with its permanent magnet. The loudspeaker cone, which is attached to the voice coil, vibrates accordingly, reproducing the original sound. The reproduced sound, however, is distorted, particularly in the bass region. This distortion is due to the extraneous vibrations of the diaphragm caused by the momentum of the moving diaphragm, inertia and structural properities of the diaphragm.

In this application, the vibrations of the loudspeaker diaphragm which exactly correspond mechanically to the audio signals from the amplifier are referred to as "forced vibrations."

The primary object of this invention is to provide an improved loudspeaker having means which resist the "free vibrations" without disturbing the "forced vibrations" so that the resulting vibrations of the loudspeaker cone will be a more exact mechanical translation from the audio signal.

Another object of this invention is to provide a loudspeaker of the character described which resists distortion, "hangover," cone "breakup" and most of the other extraneous mechanical vibrations not associated with the audio signal.

Another object of this invention is to provide a loudspeaker of the character described which reproduces low frequency audio signals with a minimum of "free vibrations" ordinarily associated with such signals.

Further objects of this invention are to provide a loudspeaker of the character described which is of simple construction, inexpensive to manufacture, and which will outperform loudspeakers costing many times the cost of the speaker of this invention.

Other objects of this invention will be apparent hereafter from the specification and from the recital in the appended claims.

In the drawing;

FIG. 1 is the front view of a loudspeaker constructed according to one embodiment of this invention;

FIG. 2 is a section, on an enlarged scale, taken on the line 2—2 of FIG. 1 and looking in the direction of the arrows;

FIG. 3 is a sectional view taken substantially on line 3—3 of FIG. 2;

FIG. 4 is a graphic illustration of an audio curve illustrating the manner in which the loudspeaker of this invention operates;

FIG. 5 is a circuit diagram showing the voice coils mounted in series, and;

FIG. 6 is a circuit diagram showing the voice coils mounted in parallel.

Referring now to the drawing by numerals of reference and particularly FIGS. 1–3, 10 indicates the frame of the loudspeaker. Frame 10 comprises a U-shaped portion 11 and a cone-shaped portion 12. Mounted within frame 10 is cone-shaped diaphragm 14 having a bellow-like portion 15 to permit vibratory movement of the diaphragm. Diaphragm 14 is connected at its outer end 16 to frame 10 and at its inner end 18 to a cylindrical, non-magnetic voice coil form 20.

Also mounted within frame 10 and surrounding opposite ends of coil form 20 are two magnet and voice coil assemblies, namely, an inner assembly 22 and an outer assembly 24.

Assembly 22 comprises a permanent magnet 25 which fits within U-shaped portion 11 of frame 10. Magnet 25 has a core 26 which projects into the inner end of form 20. Core member 26 and the magnet pole faces are made of magnetic flux conducting material. The opposed pole faces of the magnet assembly form a gap 45, which receives the inner end of coil form 20. Magnet 25 and its core 26 are connected to frame 10 by means of screw 28. Mounted on the inner end of form 20 with respect to diaphragm 14 is a voice coil 30 which, as shown in FIG. 2 is "out of gap" with respect to permanent magnet 25. Voice coil 30 is positioned inwardly of diaphragm 14; and, interposed between the voice coil and diaphragm 14 is a spider 31 which connects the inner end of form 20 to magnet 25.

The magnet and voice coil assembly mounted outwardly of diaphragm 14 is exactly similar in construction to assembly 22. It comprises a U-shaped magnet 32 mounted in a U-shaped bracket 34 connected by nut and bolt means 35 to a metal strap 36 which extends diametrically across the outer end of the speaker. Strap 36 is connected to frame 10 by means of nuts and bolt means 37. Magnet 32 has a core 38 which extends into the outer end of voice coil form 20. The magnet 32 and its core are held within bracket 34 by a screw 39. Mounted on the outer end of form 20 with respect to diaphragm 14 is a second voice coil 40, similar to coil 30. A spider 41 is provided to connect the outer end of form 20 to magnet 32.

The two magnet and voice coil assemblies 22 and 24 may be wired either in series or in parallel (FIGS. 4 and 5) and out of phase so that when one coil is energized to push diaphragm 14 in one direction, the other coil is energized to pull diaphragm 14 in the same direction, and vice versa.

Voice coils 30 and 40 must be mounted so that they extend far enough out of their voice coil gaps, 45 and 46, respectively, so that each voice coil will pull diaphragm 14 over a longer distance than it will push the diaphragm. This is accomplished when the displacements of the voice coil out of their gaps is great enough to cause the pushing voice coil to completely leave the field of its permanent magnet so that it ceases to push, leaving the pulling voice coil the task of pulling the diaphragm the remaining distance.

Referring now to FIG. 4, the unbroken line represents the "forced vibrations" of the diaphragm which is the mechanical equivalent of the audio signal. The broken line represents the "free vibrations," which is the excess vibration of the cone due to its forward and reverse momentum, inertia, the physical properties of the cone and any other mechanical vibrations which do not correspond to the audio signal. The partly broken line indicates the beginning of deceleration occurring at point *y* where the pushing voice coil leaves its magnetic field and ceases to operate, leaving the pulling voice coil to operate alone. This graph shows the manner in which "free vibrations" are eliminated so that vibrations of diaphragm 14 will be an exact mechanical translation from the audio signals. In this figure *xy* indicates the distance the voice coils move when they are pushing diaphragm 14 and *xz* the distance they move when they are pulling the diaphragm. Over the distance *xy*, the diaphragm 14 is being pushed and pulled simultaneously in the same direction with a force that is the resultant

of both the push and pull force created by the two magnet-voice-coil assemblies **22** and **24**. However, the distance from *y* to *z* must be achieved only by the pulling voice coil, without the assistance of the pushing voice coil, as the case may be. The resulting force over the distance indicated *yz* is, therefore, a decelerating force.

The voice-coils **30** and **40** must be placed out of their voice coil gaps (the factors of diaphragm structure, the strength of the permanent magnets, the size of the speaker enclosure, etc. being taken into consideration) so that the deceleration from *y* to *z* will be of sufficient magnitude to cancel out the free vibrations from *z* to *t* which result from inertia and other causes previously mentioned. This results in a forced vibration which corresponds to the audio signal.

The advantage achieved by having coils at opposite sides of diaphragm **14** is dynamic damping, in which most of the distorting, extraneous "free vibrations" caused by inertia are cancelled out by an equal and opposite force of deceleration.

Another advantage of this "dynamic damping" over existing methods of damping is the uniformity of damping action which results because both the magnitude of the free vibrations and the magnitude of deceleration are produced by the same source, the audio, resulting in the equal and opposite force of deceleration herein described.

In order to make clearly understood the actions of voice coils **22** and **24** one operating cycle of the loudspeaker will be described.

When voice coil **30** moves outward of its magnetic field, it pushes form **20** and diaphragm **14** over the distance *xy* and voice coil **40** simultaneously pulls the form **20** and diaphragm **14** over the distance *xz*. The resultant force propelling diaphragm **14** over the distance *xy* is the combination of the push of voice coil **30** and the pull of voice coil **40**. Furthermore, from *x* to *y*, the interaction between the electromagnetism of the voice coils in the fields of their permanent magnets is constant, or as voice coil **30** moves out of its field, voice coil **40** moves into its field. However, because voice coil **30** ceases to push past point *y*, the force from *y* to *z* is derived solely from voice coil **40**. Therefore, the *y* to *z* force will be a decelerating one. This deceleration will be of sufficient magnitude to cancel out "free vibrations" from *z* to *t*, which would have resulted had the force over the distance *x* to *z* been constant.

In the reverse action, when the diaphragm **14** moves in an inward direction, voice coil **40** pushes the diaphragm over the distance *xy*, while voice coil **30** pulls it simultaneously over the distance *xz*. Again, there is sufficient deceleration from *y* to *z* when coil **40** moves out of its magnetic field to cancel the "free vibrations" from *z* to *t*.

It will thus be seen that the speaker has a push-pull action. Novelty of the invention, however, lies in providing dynamic damping in which deceleration from *y* to *z* is introduced, this deceleration element being of sufficient magnitude to cancel out, or damp out, the free vibrations from *z* to *t*. The push-pull action is utilized not to get a piston-like action of the cone, but rather to secure displacement of the voice coils sufficiently out of their gaps and thereby achieve deceleration. Since there is deceleration from *y* to *z* in either direction of movement of diaphragm **14**, the "free vibrations" from *z* to *t* are eliminated. As a result, the vibrations of the loudspeaker diaphragm more exactly correspond mechanically to the audio signals from the amplifier.

While the invention has been described in connection with several different embodiments thereof, it will be understood that it is capable of further modification. For example, voice coils **30** and **40** may be mounted so that they extend into rather than out of their voice coil gaps **45** and **46**, in which case each voice coil would

push the diaphragm **14** over a longer distance than it pulls the diaphragm. In this arrangement, the displacement of the voice coils into their gaps should be great enough to cause the pulling voice coil to leave the strongest part of the field of its permanent magnet, that is, the field located in the voice coil gaps, so that it ceases to pull, leaving the pushing voice coil the task of pushing the diaphragm the remaining distance. This modification need not be described in detail for it embodies the same principles of the invention point for point, with the exception that the invention, as it was described, was found superior in tests because the displacement of the voice coils out of their gaps, rather than into their gaps, allowed for a more complete escape of the voice coils from their permanent magnetic fields as described in this invention, with superior reproduction noted. This application is intended to cover this and any other variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which the invention pertains and as fall within the scope of the invention or the limits of the appended claims.

Having thus described my invention what I claim is:

1. A loudspeaker for damping free vibrations comprising a diaphragm, a pair of magnet assemblies, a coil form connected to said diaphragm and extending on both sides thereof, axially disposed voice coils mounted on said coil form on opposite sides of the diaphragm, a magnet assembly disposed at one end of each coil and having pole faces which form a gap into which the coils are received, said coils having less than half their length positioned in the gap between the pole faces and the axial distance between the medial points of the coils being less than the axial distance between the medial points of the field of the magnet assemblies, said magnet assemblies each having a supporting structure connected together to form a frame for said assemblies and the diaphragm, the diaphragm being connected to the frame at its outer end and being connected at its inner end to said form, said form being movably suspended within said frame and supported by a pair of spaced resilient spiders which support said form, the axial displacement permitted by said spiders being greater than the length of coil between the polefaces, whereby said magnets interact upon their respective voice coils to cause said coils to be moved under constant force during the initial and major distance of displacement from rest position and to move under a decelerating force during the remaining distance of displacement, said decelerating force damping said free vibrations from said diaphragm.

2. The loudspeaker as set forth in claim 1 wherein the length of each coil within the magnetic field between the magnet polefaces is less than the maximum diaphragm displacement for the speaker operating frequencies.

3. In a dynamic speaker, a frame, a diaphragm, a coil form, a pair of magnets, a pair of flux return structures to form high flux gaps, a rim compliance at the edge of said diaphragm, a coil form having voice coils thereon which react with the magnet flux across said gaps to oscillate the coil form, said diaphragm having a portion which is secured to said coil form, means including a pair of spaced spiders for constraining the movement of said coil form and relieving said rim compliance of coil form constraining functions, said voice coils wound oppositely to have polarities which coact with the flux across said gaps to push and pull said coil form simultaneously from opposite end portions and thereby relieve said rim compliance of the function of restoring said diaphragm to a rest position.

4. In a speaker which has a frame provided with a pair of frame sections connected at their outer edges, a diaphragm, a pair of magnets, a flux return structure slightly spaced from each magnet and co-acting there-

with to form a pair of flux gaps therebetween, said magnets and return structures secured to said frame sections, a coil form to which said diaphragm is attached, said diaphragm located between said sections, two voice coils, one coil immersed in the flux of each gap, means for applying a signal voltage to each coil and placing said coil in mechanical pushpull between said gaps and constituting the sole means for oscillating said diaphragm in two coaxial directions, a rim compliance at the edge of said diaphragm and connected with said frame, and the means consisting of at least one spider operatively associated with said coil form to restrict its oscillations to axial movement and thereby relieve said rim compliance of diaphragm motion constraining functions whereby said rim compliance may be constructed more flexibly.

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