United States Patent

Guss

[15] **3,688,864**

[45] **Sept. 5, 1972**

[54] **INFINITE DYNAMIC DAMPING LOUDSPEAKER SYSTEMS**

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[73] Assignee: **Talbot American Corporation,** 2, New York, N.Y.

[22] Filed: **April 16, 1970**

[21] Appl. No.: **29,084**

[52] **U.S. Cl.** .....**181/31 B**
[51] **Int. Cl.**.....**G10k 13/00,** H04r 1/28
[58] **Field of Search** .....181/31 B, 32

[56] **References Cited**

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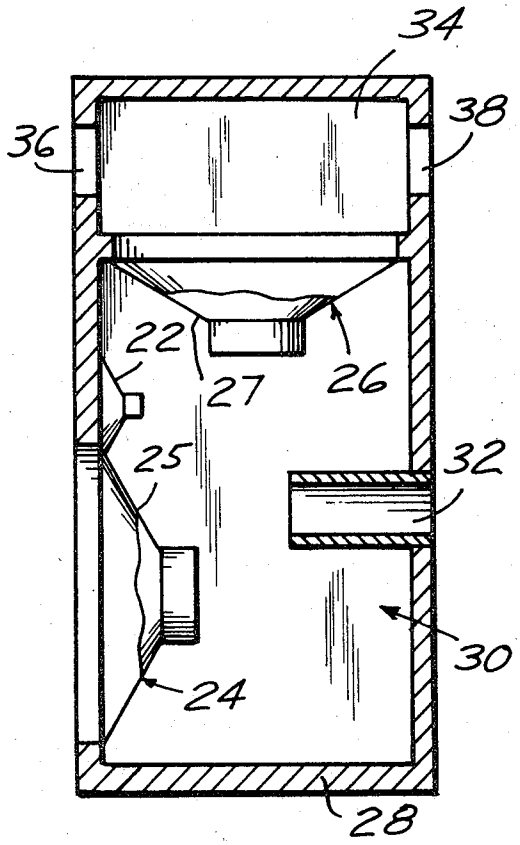
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Primary Examiner—Richard B. Williamson
Attorney—Hane, Baxley & Spiecens

[57] **ABSTRACT**

An infinite dynamic damping loudspeaker system includes at least two similar loudspeakers which radiate from an enclosure in response to the simultaneous receipt of the same signals. The diaphragms of the loudspeakers are acoustically coupled by an air chamber and a tuning duct connects the air chamber to the atmosphere. The diaphragms vibrate in a phase such that they produce the same phase of pressure changes on the air in the chamber to provide mutual damping.

5 Claims, 15 Drawing Figures



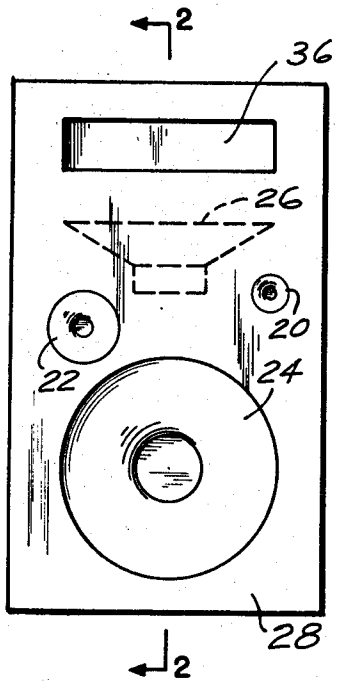


FIG. 1

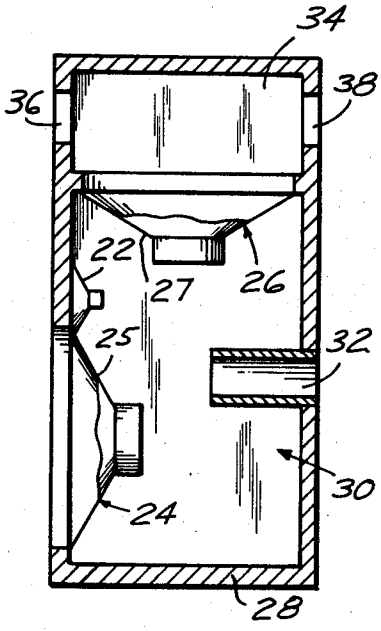


FIG. 2

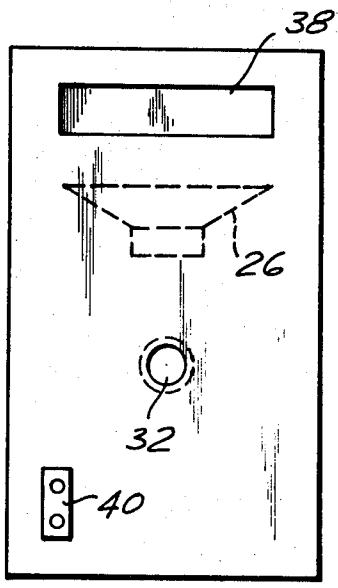


FIG. 3

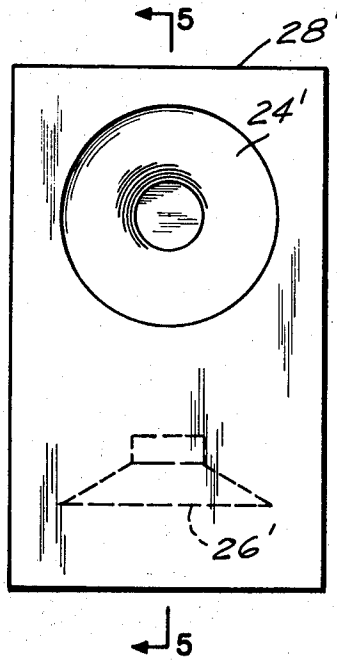


FIG. 4

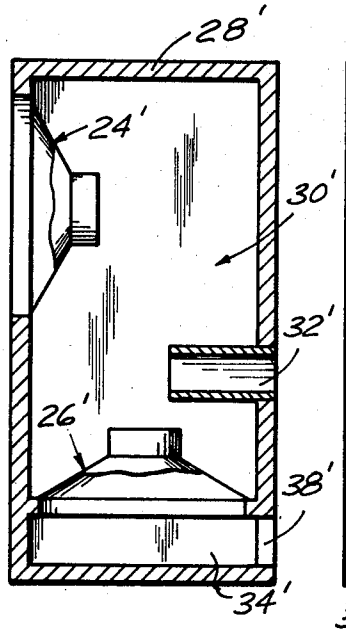


FIG. 5

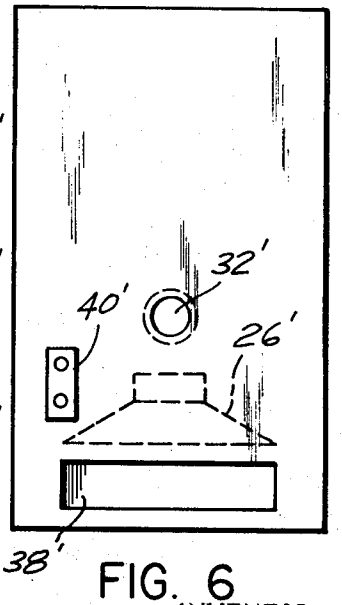


FIG. 6

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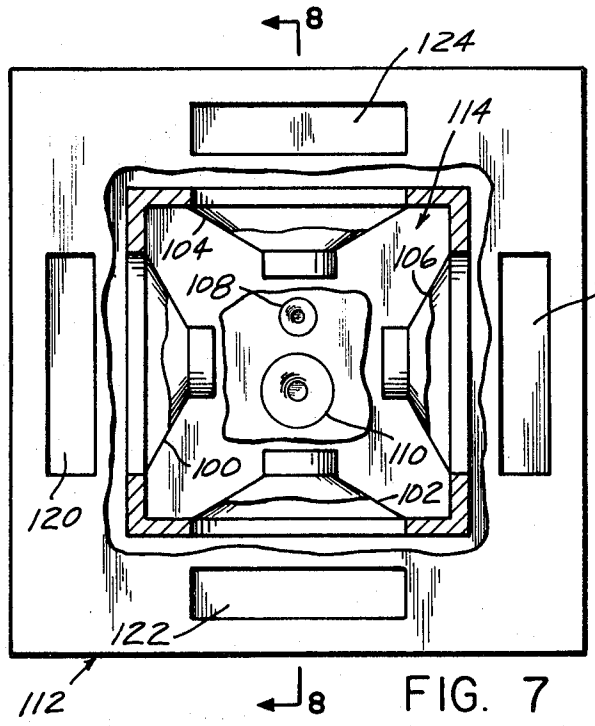


FIG. 7

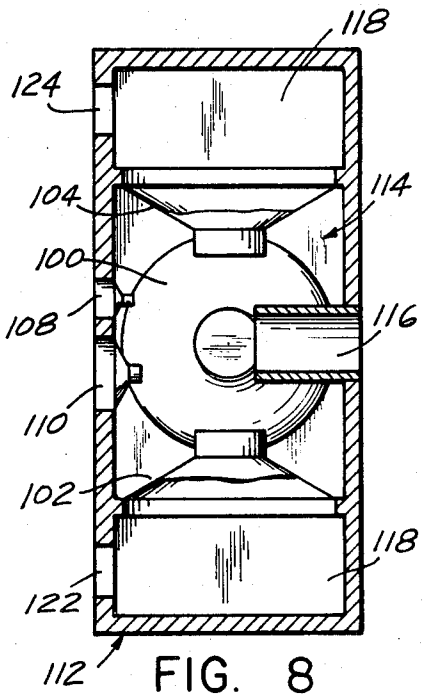


FIG. 8

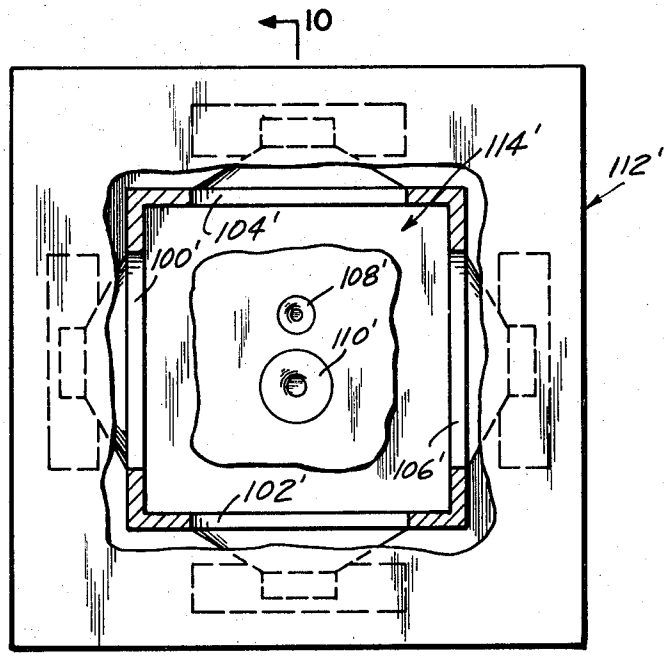


FIG. 9

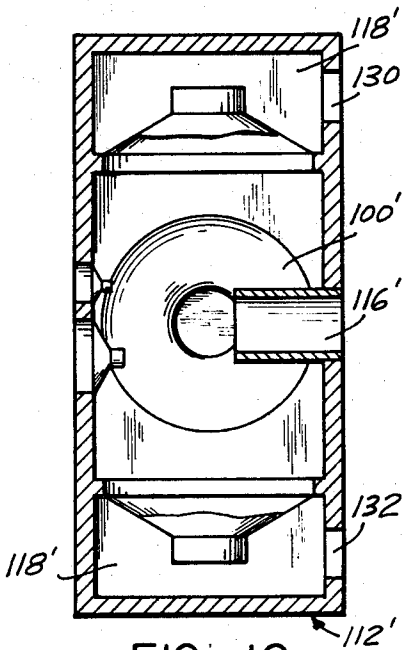


FIG. 10

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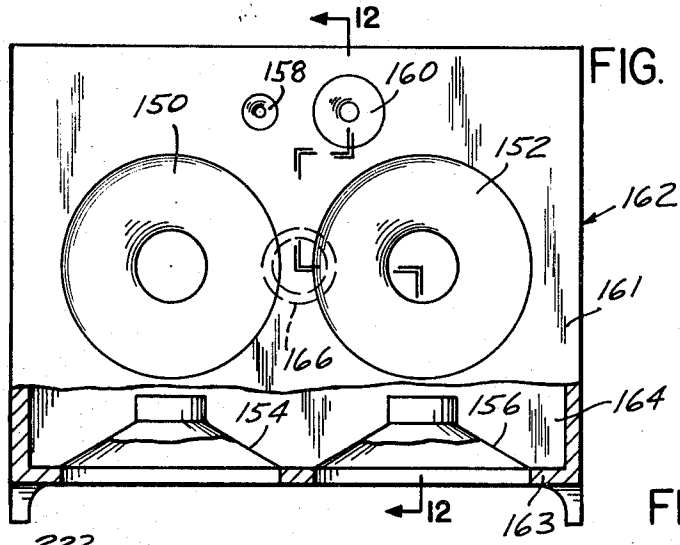


FIG. 11

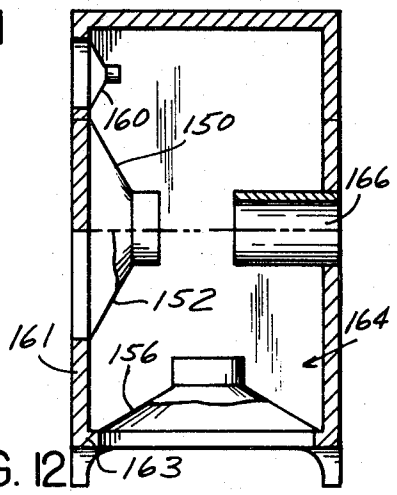


FIG. 12

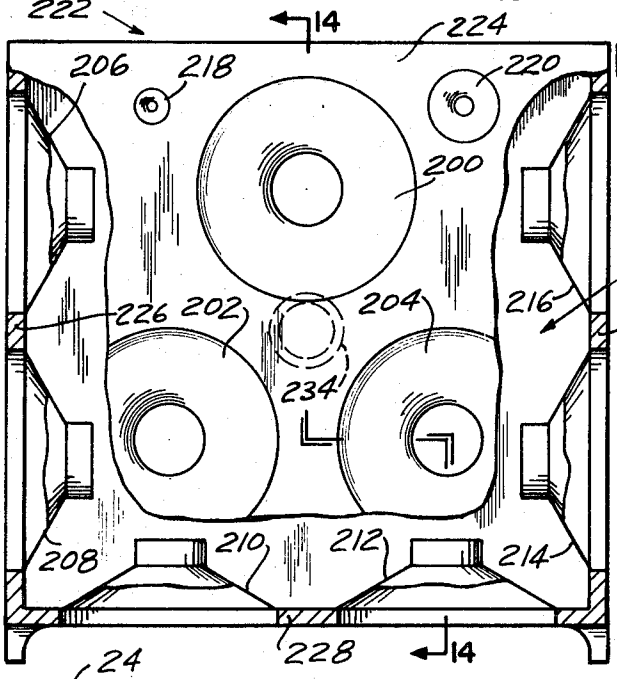


FIG. 13

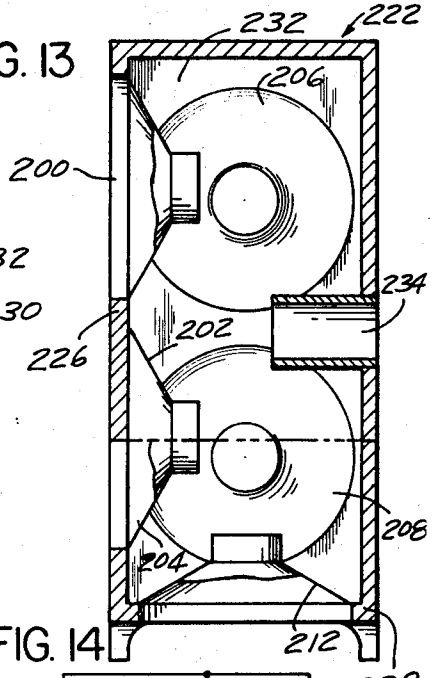


FIG. 14

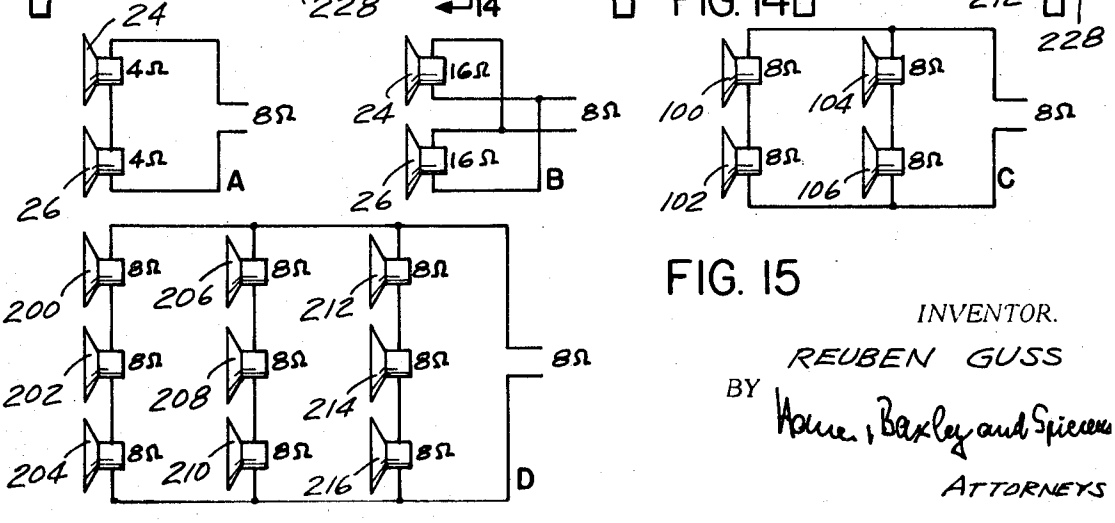


FIG. 15

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INFINITE DYNAMIC DAMPING LOUDSPEAKER SYSTEMS

This invention pertains to loudspeaker systems and more particularly to such systems whose frequency response is very low.

BACKGROUND

Experience shows that users of high fidelity equipment nowadays demand smaller and smaller loudspeaker enclosures to fit the decor of home environments such as the average living room. However, it is well known that the smaller the size of the enclosure, the higher becomes the resonance of the total system. Since the resonant frequency of the loudspeaker relates directly to the low frequency response of the total speaker system, it is seen that small enclosure size and deep low frequency response are inversely related.

There have been many efforts to obtain good low frequency response from loudspeaker systems using small enclosures in the range of 2 to 3 cubic feet.

Presently, a popular small-enclosure loudspeaker system, commonly known as an "acoustic suspension" system, employs a woofer with a free air resonance of approximately 10 Hz. so that the trapped air in the small enclosure raises the resonance to a relatively low 40 to 50 Hz. However, such systems when fully sealed create other problems. In particular, the greatest problem is that of very low efficiency. Such low efficiency is directly related to the fact that despite the lower initial free air resonance of the woofer, more power is required to have it perform in the bass region of the audio spectrum within a small enclosure because the small air volume resists the large excursions of the diaphragm required for a low frequency reproduction.

Another solution to the problem has been proposed in U.S. Pat. No. 2,993,091 wherein two loudspeakers are employed with an enclosure, one directly radiating loudspeaker and the other an inner loudspeaker mounted in the enclosure immediately behind the directly radiating loudspeaker. The inner loudspeaker damps the diaphragm of the directly radiating loudspeaker by vibrating sympathetically therewith. While such a system permits some reduction in enclosure size, the optimum reduction is not achieved.

THE INVENTION

It is a general object of the invention to provide an improved loudspeaker system having a very small enclosure volume and a very low frequency response.

It is another object of the invention to provide a very efficient loudspeaker system having not only small enclosure volume but also having a very low resonance and superior transient response.

Briefly, the invention contemplates a loudspeaker system having infinite dynamic damping comprising an enclosure and at least first and second substantially identical loudspeakers. The loudspeakers are connected to be electrically energized in phase while the diaphragms of the loudspeakers are acoustically coupled by an air chamber to vibrate in a mechanical out-of-phase relation, i.e., similar movements of the diaphragms produce similarly phased changes of air pressure in the chamber. In other words, an outward excursion of the diaphragm of the first loudspeaker creates a vacuum in the chamber and at the same time the outward excursion of the diaphragm of the second loudspeaker also creates a vacuum in the chamber. Thus, the second loudspeaker vacuum damps the first. Similarly, an inward movement of the diaphragm of the first loudspeaker raises the pressure in the chamber. At the same time, the diaphragm of the second loudspeaker moves inward to also raise the pressure. Thus, the second loudspeaker pressure damps the first.

It should be noted that by infinite dynamic damping is meant the inhibiting of free or distorting vibrations of the directly radiating loudspeaker diaphragm which is directly proportional to the amplitude of the audio signal energizing the loudspeaker over the entire frequency range of the directly radiating loudspeaker.

The loudspeaker system according to the invention has several distinct advantages over previous systems. If two identical "woofers" (bass loudspeakers) are used then the free air resonance of the simultaneously energized woofers is one-half the free air resonance of a single woofer. Therefore the frequency response of the system is similarly lowered.

Secondly, since each woofer has its own "motor" (electromagnetic structure of magnet and voice coil), two woofers used in accordance with the invention have more power and greater efficiency than one woofer.

Thirdly, the use of multiple woofers in as tight an air chamber as possible provides for a greater vacuum/pressure influence of one woofer diaphragm upon the other than would be possible in a large enclosure because there is very much less air in proportion to the total area of the woofer diaphragm than in larger conventional enclosures. Accordingly, there is greater damping action and superior transient response in the low frequency range.

Furthermore, such a loudspeaker system may use all walls of the enclosure for mounting the speakers, and internal walls as well. Accordingly, mere mechanical considerations do not control the size of the enclosure.

Finally, the use of a duct and preferably a tube duct, permits the enclosure to be even smaller because it acts as an inertance element. In addition, the duct minimizes the criticality of the match between enclosure size and the free air resonance of the multiple woofers.

Other objects, features and advantages of the invention will be apparent from the following detailed description when read with the accompanying drawing which shows several loudspeaker systems utilizing the invention.

DETAILED DESCRIPTION OF THE INVENTION

In the drawing:

FIG. 1 is a front elevational view of a two-woofer system in an enclosure according to the invention;

FIG. 2 is an elevational section view taken on line 2—2 in FIG. 1;

FIG. 3 is a rear elevation view of the enclosure of FIG. 1;

FIG. 4 is an elevation view of a modified form of the loudspeaker system and enclosure of FIG. 1;

FIG. 5 is an elevation section view taken on line 5—5 in FIG. 4;

FIG. 6 is a rear elevation view of the enclosure of FIG. 4;

FIG. 7 is a partially broken front elevation view of a four-woofer loudspeaker system in an enclosure according to the invention;

FIG. 8 is an elevation section view taken on line 8—8 of FIG. 7;

FIG. 9 is a partially broken front elevation view of a modified form of the loudspeaker system of FIG. 7;

FIG. 10 is an elevation section view, taken on line 10—10 of FIG. 9;

FIG. 11 is a partially broken front elevation view of a modification of the loudspeaker system of FIG. 7;

FIG. 12 is an elevation section view taken on line 12—12 of FIG. 11;

FIG. 13 is a partially broken front elevation view of a nine-woofer loudspeaker system according to the invention;

FIG. 14 is an elevation section view taken on line 14—14 of FIG. 13 generalized for clarity; and

FIG. 15 shows schematic diagrams for wiring the multiple loudspeakers of the invention.

FIGS. 1 to 3 show a two-woofer loudspeaker system according to the invention comprising a directly radiating tweeter 20, a directly radiating mid-range speaker 22, a directly radiating woofer 24 and an internal woofer 26 mounted in an enclosure 28. Both woofers which are substantially identical are shown with the backs of their diaphragms 25 and 27 in air chamber 30 which is connected to the ambient region by tube duct 32. The front of the diaphragm 25 of directly radiating woofer 24 faces a front opening of enclosure 28 while the front of diaphragm 27 of internal woofer 26 faces a secondary chamber 34 which has output ports 36 and 38 facing the front and rear of the enclosure, respectively.

Audio signal input to the speakers of the system is made via jacks 40 which are connected to the speakers by the usual signal leads and cross-over networks (not shown). In FIG. 15 circuits A and B show the connections of the woofers 24 and 26 to an eight ohm source. Circuit A shows the woofers as four ohm speakers connected in series; circuit B shows the woofers as sixteen ohm speakers connected in parallel.

In operation both woofers 24 and 26 are simultaneously energized with the same phase of the audio signal. Thus, as the diaphragm 25 of directly radiating woofer 24 moves outwardly creating a vacuum in air chamber 30, so does diaphragm 27 of internal woofer 26 to further increase the vacuum and vacuum damp the diaphragm of woofer 24. Similarly, when the diaphragm 25 moves inward raising the pressure in air chamber 30, diaphragm 27 also moves inwardly to further increase the pressure and pressure damp the diaphragm 25 of directly radiating woofer 24. In other words, the woofers are acoustically coupled by the air in chamber 30 and the mechanical phases of the diaphragm movements are phased so that the movement of one damps the movement of the other.

The primary source of the bass sound heard by the listener is from the enclosure opening in the front of directly radiating woofer 24. However, inner woofer 26, in addition to performing the damping function, is a secondary source of the bass sound from ports 36 and 38. It should be realized that internal woofer 26 is also damped by directly radiating woofer 24 so that its resonance and transient response are the same and the secondary source of the bass sound is as true as the primary source.

FIGS. 4 to 6 show an alternative embodiment of the two-woofer loudspeaker system of FIGS. 1 to 3. Since there are considerable similarities between the systems, primed reference numbers will be used for like elements and only the differences will be discussed in detail. In particular, there is no tweeter or mid-range speaker so that the system is only a woofer system. Furthermore, the internal woofer 26' radiates only to the rear of the enclosure via port 38'.

FIGS. 7 and 8 show a four-woofer loudspeaker system according to the invention comprising four substantially identical internal woofers 100, 102, 104 and 106, direct radiating tweeter 108 and direct radiating mid-range speaker 110 mounted in enclosure 112. The backs of the diaphragms of all the woofers face air chamber 114 which acoustically couples the diaphragms. Air chamber 114 communicates with the ambient region via tube duct 116. The fronts of the diaphragms of the woofers all face sound chamber 118 which provides front radiating sound via output ports 120, 122, 124 and 126 in the front wall of the enclosure 112.

Circuit C of FIG. 15 shows the series combination of 8 ohm woofers 100 and 102, and the series combination of 8 ohm woofers 104 and 106 being fed in parallel from an 8 ohm source. Again, as for the embodiments of FIGS. 1 to 6, each of the woofers is fed in the same audio signal phase and the mechanical movements of the diaphragms mutually damp each other via the acoustic couplings of air chamber 114.

The loudspeaker system of FIGS. 9 and 10 is similar to the loudspeaker system of FIGS. 7 and 8. Accordingly, primed reference characters will be used for like elements and only the differences will be discussed. In particular, the fronts of the diaphragms of the woofers now face air chamber 114' and the backs of these diaphragms face sound chamber 118' which communicates with the ambient region via ports such as 130 and 132 in the back wall of enclosure 112'.

It should be realized that with respect to the system of FIGS. 7 and 8, the fronts on the diaphragms could face air chamber 114 without impairing the response of the system.

FIGS. 11 and 12 show another embodiment of a four-woofer loudspeaker system comprising direct radiating woofers 150 and 152, internal woofers 154 and 156, direct radiating tweeter 158 and direct radiating mid-range speaker 160 mounted in enclosure 162. Woofers 150 and 152 are mounted on the front wall 161 and woofers 154 and 156 are mounted on a bottom wall 163 of enclosure 164. The backs of the diaphragms of all woofers face air chamber 164 which provides the acoustic coupling. Air chamber 164 is connected via tube duct 166 to the ambient region.

The woofers can be connected in the same way as shown in circuit C of FIG. 15 to receive the audio signals in phase so that the mechanical movements of their diaphragms mutually damp each other via the acoustic couplings provided by air chamber 164.

FIGS. 13 and 14 show a nine-woofer loudspeaker system comprising direct radiating woofers 200, 202 and 204, woofers 206, 208, 210, 212, 214 and 216, direct radiating tweeter 218 and mid-range speaker

220 mounted in closure 222. Woofers 200, 202 and 204 are mounted on front wall 224, woofers 206 and 208 are on side wall 226, woofers 210 and 212 on bottom wall 228 and woofers 214 and 216 on side wall 230. The backs of the diaphragms of all woofers face air chamber 232 which is connected via tube duct 234 to the ambient region.

Circuit D of FIG. 15 shows the wiring diagram of the 8-ohm woofers connected to receive an audio signal of the same phase from an 8-ohm source (not shown). In particular, three branches, each comprising three woofers connected in series, are connected in parallel to the source.

Just as with all previous embodiments the woofers mutually damp each other because of the acoustic coupling of air chamber 232.

It should be noted that each of the embodiments of the invention employs a duct. Without a duct the size of the enclosure would have to be more critically matched to the resultant free air resonance of the multiple woofers. In addition, the duct permits the enclosure to be made smaller. In fact, by using a combination of the duct with multiple woofers the size of the enclosure can be reduced to its smallest physical limits with a low frequency response hitherto associated only with very large loudspeaker enclosures and to do so with even superior transient response.

Although the size of the ducts is known from "Hi-Fi Loudspeakers and Enclosures" by Abraham B. Cohen, published by John F. Rider, Inc., New York Seventh Printing, 1966 and Catalog 165—M, issued by the Jensen Manufacturing Division, The Muter Company, 5655 W. 73rd Street, Chicago, Ill. 60638, such ducts are for conventional enclosures and not for enclosures reduced to their smallest size. These ultra-small enclosures involve a tighter, more critical vacuum-pressure interaction among the woofers than would be true for the large conventional enclosures.

While the invention has been described in detail with respect to certain now preferred examples and embodiments of the invention, it will be understood by those skilled in the art, after understanding the invention, that various changes and modifications may be made without departing from the spirit and scope of the invention, and it is intended, therefore, to cover all such changes and modifications in the appended claims.

What is claimed is:

1. An infinite dynamic damping loudspeaker system occupying a minimum of space comprising: a multiwall enclosure; at least first and second substantially identical loudspeakers, each of said loudspeakers including a diaphragm and a motor, the motors of said loudspeakers being adapted to receive the same energizing signal so that the motors are energized electrically in phase; means for mounting said loudspeakers in said enclosure such that the axes of said speakers are orthogonal, the same one surface of each of said loudspeakers being acoustically coupled by an air chamber in such a way that the same movement of the diaphragms of each of the loudspeakers produces the same change of air pressure in the air chamber whereby each diaphragm damps the other diaphragm and said first loudspeaker directly radiates through an opening in the front wall of said enclosure; a tubular tuning duct inertance element extending inward from one of the walls of said enclosure for connecting the air chamber to the region outside said enclosure to minimize the size of said enclosure; a secondary chamber in said enclosure; and a port in said enclosure for connecting said secondary chamber to the region outside said enclosure, and said second loudspeaker radiating into said secondary chamber.

2. The loudspeaker system of claim 1 wherein said port is in the front wall of said enclosure.

3. The loudspeaker system of claim 1 wherein said port is in the rear wall of said enclosure.

4. An infinite dynamic damping loudspeaker system occupying a minimum of space comprising a multiwall enclosure divided into an air chamber and a sound chamber, said enclosure having ports for connecting said sound chamber to the region external to said enclosure, at least first and second substantially identical loudspeakers, each of said loudspeakers including a diaphragm and a motor, the motors of said loudspeakers being adapted to receive the same energizing signal so that the motors are energized electrically in phase, and means for mounting said loudspeakers in said enclosure such that the axes of said speakers are orthogonal, the same one surface of each of said loudspeakers are acoustically coupled by said air chamber in such a way that the same movement of the diaphragms of each of the loudspeakers produces the same change of air pressure in the air chamber whereby each diaphragm damps the other diaphragm, and said loudspeakers radiate into said sound chamber.

5. The loudspeaker system of claim 4 comprising four loudspeakers.

* * * * *