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(54) LOUDSPEAKER, APPARATUS COMPRISING THE SAME, AND METHOD OF OPERATING A LOUDSPEAKER

(57) The present invention provides a loudspeaker (10) at least comprising a field coil (4), a plurality of voice coils (6a, 6b, 6c) having different numbers of windings from each other, and a diaphragm (8) having a mechanically adjustable size. The invention also provides an apparatus at least comprising such a loudspeaker, as well as a variable voltage and/or current source (24) connected to the field coil (4), a voice coil drive circuit (26) switchably connectable to at least one of the plurality of voice coils (6a, 6b, 6c), and a mechanical actuator (28) connected to the diaphragm (8) for adjusting its size. The apparatus may further comprise a controller (30, 30a, 30b) of the variable voltage and/or current source (24), of the voice coil drive circuit (26) and of the mechanical actuator (28). Such a controller (30) is configured, in response to a frequency of an input electronic audio signal, to vary the voltage and/or current supplied to the field coil (4) by the variable voltage and/or current source (24) in order to vary the strength of a magnetic field produced by the field coil (4), to select at least one of the plurality of voice coils (6a, 6b, 6c) to be driven by the voice coil drive circuit (26), and/or to control the mechanical actuator (28) to adjust the size of the diaphragm (8). The invention also provides a method of operating a loudspeaker in such a manner. Thus the loudspeaker (10) is effectively an adaptive loudspeaker, which can become any one of a woofer, a mid-range speaker or a tweeter, according to how it is adjusted and controlled. This obviates the need to provide a separate woofer, mid-range speaker and tweeter to cover the whole range of normal human hearing.

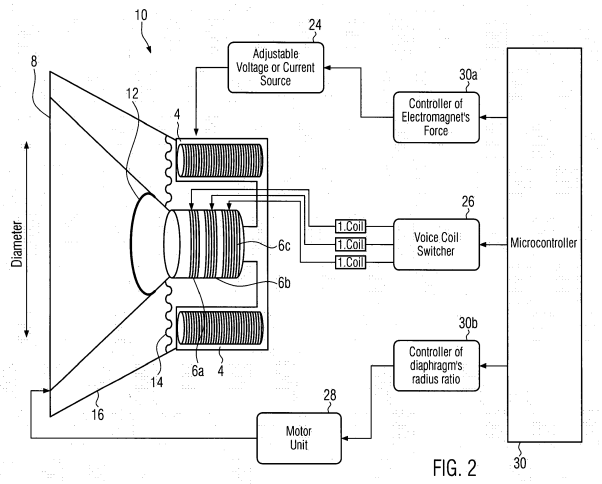

FIG. 2

EP 3 355 590 A1

Description

[0001] The present invention relates to a loudspeaker according to claim 1, an apparatus comprising a loudspeaker according to claim 7, and a method of operating a loudspeaker according to claim 11.

Background of the Invention

[0002] Loudspeakers are well known as electroacoustic transducers for producing sound from an input electrical audio signal. Such loudspeakers typically comprise a voice coil suspended in a magnetic field and connected to a moveable diaphragm. When a current derived from an input audio signal passes through the voice coil, it generates its own magnetic field, which interacts with the magnetic field in which the voice coil is suspended to produce a force, tending to move the voice coil. The movement of the voice coil is translated to the diaphragm, which vibrates the surrounding air, to convert the input audio signal into a sound wave.

[0003] Nowadays, the magnetic field in which the voice coil is suspended is usually provided by a strong permanent magnet. However, before advances in the technology of permanent magnets made this possible in about the 1980s, the magnetic field in which the voice coil used to be suspended was most often instead provided by an electromagnet. Such an electromagnet used to comprise a field coil fed by a strong direct current (typically of the order of 100 volts or more). Field coil loudspeakers can still sometimes be found today in some specialist applications; see for example, US patent no. 8 958 597 B.

[0004] As is well known, loudspeakers of different sizes are best suited to produce sounds of different frequencies. Sounds in the range of from about 20 Hz to about 250 Hz are best produced by large loudspeakers, generally called woofers. Sounds in the range of from about 250 Hz to about 2 kHz are best produced by medium-sized loudspeakers, generally called mid-range speakers. Sounds in the range of from about 2 kHz up to about 20 or more kHz are best produced by small loudspeakers, generally called tweeters.

[0005] On the other hand, the range of human hearing normally covers from about 20 Hz up to about 20,000 or even 22,000 Hz, although this varies between individuals. The ability for humans to detect frequencies at the top end of this range also particularly diminishes with increasing age. In order to reproduce sounds well across the entire range of normal human hearing from about 20 Hz up to about 20 or 22 kHz therefore traditionally requires the use of at least three different sizes of loudspeaker: a woofer, a mid-range speaker, and a tweeter. This is especially true for the faithful reproduction of music.

[0006] Thus it exists a problem in the prior art, in that either at least three different loudspeakers must be used in order to faithfully reproduce an input audio signal across the entire range of human hearing, which is undesirable both in terms of cost and the space occupied by three loudspeakers, or some fidelity of the sound reproduction must be sacrificed in order to save space and/or cost by using a smaller number of loudspeakers: namely, only two or one.

Object of the Invention

[0007] It is therefore an object of the invention to provide a loudspeaker, an apparatus comprising a loudspeaker, and a method of operating a loudspeaker.

Description of the Invention

[0008] The object of the invention is solved by a loudspeaker according to claim 1. The loudspeaker at least comprises a field coil, a plurality of voice coils having different numbers of windings from each other, and a diaphragm having a mechanically adjustable size.

[0009] This solution is beneficial because the frequency range of the input electrical audio signal may be analysed, and based on the frequency of the input audio signal, at least one of the electrical current and/or voltage suppled to the field coil, one or more than one of the plurality of voice coils to drive from the input audio signal, and the size of the diaphragm, can be selected. In other words, such a loudspeaker provides an adaptive loudspeaker, which can function as any one of a woofer, a mid-range loudspeaker or a tweeter, in response to the frequency of the input audio signal, thereby saving both cost and space, without having to sacrifice the fidelity of the sound reproduction in order to do so.

[0010] Advantageous embodiments of the invention may be configured according to any claim and/or part of the following description.

[0011] Preferably, the plurality of voice coils are coaxial. This allows them to be aligned with each other and with the field coil, as well as with the diaphragm, for more faithful sound reproduction.

[0012] In one possible preferred embodiment, the plurality of voice coils have the same radii as each other. This is beneficial because it allows them to be subject to the same magnetic field from the field coil as each other, for more faithful sound reproduction, and is also beneficial in producing a more compact design.

[0013] Preferably, at least two of the plurality of voice coils are connectable to each other in series. This is beneficial in producing a more compact design, since, for example, a first one of the plurality of voice coils having a first number of windings, a, may then be connected to a second one of the plurality of voice coils having a second number of windings, b, to effectively produce a third voice coil having a third number of windings, c = a + b, instead of requiring a separate third voice coil having c windings.

[0014] In particular, the size of the diaphragm is dynamically adjustable during playback of an audio signal. This is beneficial because it allows the loudspeaker to adapt to a changing frequency range of the input audio signal.

[0015] In one possible preferred embodiment, the diaphragm is generally conical or frusto-conical in shape, and adjustment of the size of the diaphragm alters the ratio of the radius of the cone or conical frustum to its height.

[0016] The present invention also relates to an apparatus at least comprising a loudspeaker as herein described, as well as a variable voltage and/or current source connected to the field coil, a voice coil drive circuit switchably connectable to at least one of the plurality of voice coils, and a mechanical actuator connected to the diaphragm for adjusting its size. The variable voltage and/or current source is for altering the strength of the magnetic field created by the field coil. The voice coil drive circuit is for driving a selected one or more than one of the plurality of voice coils.

[0017] In one possible preferred embodiment, the mechanical actuator may be configured to alter the radius of the diaphragm, whilst keeping its height or depth substantially constant. Preferably, the apparatus further comprises a controller of the variable voltage and/or current source, of the voice coil drive circuit and of the mechanical actuator, wherein the controller is configured, in response to a frequency of an input audio signal, to vary the voltage and/or current supplied to the field coil by the variable voltage and/or current source, to select at least one of the plurality of voice coils to be driven by the voice coil drive circuit, and/or to control the mechanical actuator to adjust the size of the diaphragm.

[0018] Preferably, the controller is a microcontroller comprising a digital signal processor, which is configured to analyse the frequency of the input audio signal to determine its frequency range.

[0019] The present invention further relates to a method of operating a loudspeaker as herein described. The method at least comprises receiving an input audio signal, analysing the input audio signal to determine its frequency range, and in response to the frequency of the input audio signal, performing at least one of: varying the voltage and/or current supplied to the field coil of the loudspeaker, selecting at least one of the plurality of voice coils to drive, and adjusting the size of the diaphragm.

[0020] In a possible preferred embodiment, the method may comprise simultaneously varying the voltage and/or current supplied to the field coil of the loudspeaker, selecting at least one of the plurality of voice coils to drive, and adjusting the size of the diaphragm in response to the frequency of the input audio signal.

[0021] Preferably, the method further comprises transforming the input audio signal into the frequency domain using a fast Fourier transform, and analysing the input audio signal to determine its frequency range comprises performing the analysis in the frequency domain.

[0022] In particular, analysing the input audio signal to determine its frequency range comprises determining a dominant frequency range of the input audio signal. In other words, the frequency range of the input audio signal may be determined to cover a range r1, but a majority of the input audio signal may be determined to lie in a range r2 (the dominant frequency range), wherein r1 contains r2. This is beneficial because it allows the loudspeaker to be adapted either to suit the dominant frequency range, r2, or to be adapted to accentuate sounds lying outside the dominant frequency range, which might otherwise be lost.

[0023] If the method does comprise determining a dominant frequency range of the input audio signal, the method preferably also comprises adjusting a frequency range of the loudspeaker to substantially overlap with the dominant frequency range of the input audio signal.

[0024] The present invention further relates to a computer program product or a program code or system for executing one or more than one of the herein described methods.

[0025] Further features, goals and advantages of the present invention will now be described in association with the accompanying drawings, in which exemplary components of the invention are illustrated. Components of the devices and methods according to the invention which are at least essentially equivalent to each other with respect to their function can be marked by the same reference numerals, wherein such components do not have to be marked or described in all of the drawings.

[0026] In the following description, the invention is described by way of example only with respect to the accompanying drawings.

Brief Description of the Drawings

[0027]

Fig. 1 is a schematic flow diagram of a known method of operating a loudspeaker;

Fig. 2 is a schematic diagram of an embodiment of an apparatus comprising a loudspeaker;

Fig. 3 is a schematic flow diagram of an embodiment of a method of operating a loudspeaker; and

Fig. 4 is a schematic flow diagram showing three alternative possibilities for how a loudspeaker may be made to behave either as a woofer, or as a mid-range speaker, or as a tweeter.

Detailed Description

[0028] Fig. 1 schematically shows a known method of operating a loudspeaker. According to this known method, an electrical audio signal from an audio input source is transmitted, S1, to a microcontroller. Audio signal processing, S2, of the input audio signal occurs in a digital signal processing (DSP) block of the microcontroller, before the audio signal is transmitted, S3, from the microcontroller to an audio amplifier integrated circuit (IC). The amplified signal is then applied, S4, as an alternating current to the voice coil of the loudspeaker. The voice coil creates a magnetic field, S5, when an electric current flows through it. Interaction of this magnetic field with the field of, for example, a powerful permanent magnet forces the voice coil to move back and forth, S6, as a result of Faraday's law of induction. When the voice coil moves, it pushes and pulls, S7, on the diaphragm of the loudspeaker. Motion of the diaphragm vibrates the air in front of the speaker, S8, thereby creating sound waves.

[0029] Fig. 2 is a schematic diagram of an apparatus comprising a loudspeaker according to an embodiment of the invention. The loudspeaker 10 comprises a field coil 4, a plurality of voice coils 6a, 6b, 6c having different numbers of windings from each other, and a diaphragm 8 having a mechanically adjustable size. A dust cap 12 covers the apex of the diaphragm 8. The diaphragm 8 and its dust cap 12 are rigidly connected to the voice coils 6a, 6b, 6c, and all of them are suspended by a spider 14 in a basket 16, so as to be movable relative thereto and to the field coil 4. The plurality of voice coils 6a, 6b, 6c are coaxial and have the same radii as each other.

[0030] In the illustrated embodiment, the plurality of voice coils 6a, 6b, 6c are not electrically connected to each other. However, in an alternative possible embodiment, at least two of the plurality of voice coils 6a, 6b, 6c may be connected to each other in series. Thus, for example, if a first one of the voice coils has 5 000 windings and a second one of the voice coils has 10 000 windings, a voice coil having 15 000 windings can be made by connecting the first and second voice coils together in series.

[0031] The diaphragm 8 has a generally conical or frusto-conical shape, and adjustment of the size of the diaphragm alters the ratio of its radius to its height. As used herein, the term "height" refers to the height of such a cone or frustum from its base, and is therefore equivalent to the depth of the diaphragm 8. The size of the diaphragm 8 may be mechanically adjustable in one of several different ways. For example, it may be constructed by rolling a single flat membrane into a conical or frusto-conical shape. The size of the diaphragm may then be adjusted by tightening or loosening the degree to which the membrane is rolled up, thereby altering the ratio of the radius of the cone or frustum to its height. In the illustrated embodiment, the size of the diaphragm 8 is dynamically adjustable during playback of an audio signal; in other words, as the loudspeaker produces sound.

[0032] As may be seen in Fig. 2, the apparatus further comprises a variable voltage and/or current source 24, a voice coil drive circuit 26, and a mechanical actuator 28. The variable voltage and/or current source 24 is connected to the field coil 4 for altering the strength of the magnetic field created by the field coil 4. The voice coil drive circuit 26 is switchably connectable to at least one of the plurality of voice coils 6a, 6b, 6c. The mechanical actuator 28 is connected to the diaphragm 8 for adjusting its size. The mechanical actuator 28 is configured to alter the radius of the diaphragm 8, whilst keeping its height substantially constant.

[0033] The apparatus also comprises a microcontroller 30, which comprises as sub-elements thereof, a controller 30a of the variable voltage and/or current source 24, and a controller 30b of the mechanical actuator 28. The controller 30a controls the strength of the magnetic field generated by the field coil 4, and the controller 30b controls the ratio of the radius of the diaphragm 8 to its height. The microcontroller 30 also controls which one or ones of the plurality of voice coils 6a, 6b, 6c the voice coil drive circuit 26 is connected to. The microcontroller 30 further comprises a digital signal processor (not visible in Fig. 2), which is configured to analyse the frequency of an input audio signal to determine its frequency range. In response to the frequency of the input audio signal as determined by this analysis, the microcontroller 30, including its sub-elements 30a, 30b, is configured to vary the voltage and/or current supplied to the field coil 4 by the variable voltage and/or current source 24, to select at least one of the plurality of voice coils 6a, 6b, 6c to be driven by the voice coil drive circuit 26, and/or to control the mechanical actuator 28 to adjust the size of the diaphragm 8.

[0034] Operation of the apparatus of Fig. 2 will now be explained with reference to Fig. 3, which schematically shows a method of operating a loudspeaker, such as the loudspeaker 10 shown in Fig. 2. The method comprises receiving an input audio signal and analysing it in the digital signal processing (DSP) block of the microcontroller 30. The audio signal is converted, 99, from its original (time) domain to a representation in the frequency domain by using a fast Fourier transform (FFT). The frequency range of the audio signal is then determined, 100. In response to the frequency of the

input audio signal as thus determined, at least one of three parameters of the loudspeaker 10 are then adjusted, as follows: the voltage and/or current supplied to the field coil 4 of the loudspeaker is increased or decreased, 101, according to the frequency of the audio signal, at least one of the plurality of voice coils 6a, 6b, 6c is selected, 102, to be driven according to the frequency of the audio signal, and the radius ratio of the diaphragm 8 is increased or decreased, 103, again according to the frequency of the audio signal. In most cases, all three of these parameters will be adjusted in response to the frequency of the input audio signal, simultaneously.

[0035] If the analysis, 100, of the input audio signal determines that its frequency range is wider than a range which can be faithfully reproduced by just a single loudspeaker having the properties of a tweeter, a mid-range speaker or a woofer, the analysis may further comprise determining a dominant frequency range of the input audio signal and adjusting the three parameters of the loudspeaker 10 described above, on the basis thereof, for example either so that the frequency range of the loudspeaker is adjusted to substantially overlap with the dominant frequency range of the input audio signal, or so that the loudspeaker is best suited to reproduce frequencies outside the dominant frequency range. So, for example, if the analysis, 100, of the input audio signal determines that its total frequency range is from about 50 Hz to about 18 kHz, which covers about 9 octaves, but that the dominant frequency range is only from about 200 Hz to about 1 600 Hz, which covers only about 3 octaves, the parameters of the loudspeaker 10 may be adjusted by the microcontroller 30 to give the loudspeaker the properties of a mid-range speaker having a range of from about 250 Hz to about 2 kHz.

[0036] Fig. 4 schematically shows three possible alternative ways in which a loudspeaker such as that shown in Fig. 2 may be made to behave either as a woofer, or as a mid-range speaker, or as a tweeter. Firstly, the audio signal is converted, 99, from its original (time) domain to a representation in the frequency domain by using a fast Fourier transform (FFT). The type (i.e. frequency range) of the speaker is then determined, 100, according to the frequency of the audio signal. As shown in the left-hand column of Fig. 4, if the speaker is determined to be a woofer having a frequency range of from about 20 Hz to about 250 Hz, the one of the plurality of voice coils with the maximum number of windings is chosen by the microcontroller, the electromagnetic force created by the field coil is adjusted to its maximum level by the microcontroller, and the radius ratio of the diaphragm is also adjusted to its maximum level by the microcontroller. On the other hand, if the speaker is determined to be a mid-range speaker having a frequency range of from about 250 Hz to about 2 kHz, as shown in the central column of Fig. 4, the one of the plurality of voice coils with the medium number of windings is chosen by the microcontroller, the electromagnetic force created by the field coil is adjusted to its medium level by the microcontroller, and the radius ratio of the diaphragm is also adjusted to its medium level by the microcontroller. Finally, if the speaker is determined to be a tweeter having a frequency range of from about 2 kHz to about 20 kHz, as shown in the right-hand column of Fig. 4, the one of the plurality of voice coils with the minimum number of windings is chosen by the microcontroller, the electromagnetic force created by the field coil is adjusted to its minimum level by the microcontroller, and the radius ratio of the diaphragm is also adjusted to its minimum level by the microcontroller.

[0037] In summary, therefore, the present invention provides a loudspeaker at least comprising a field coil, a plurality of voice coils having different numbers of windings from each other, and a diaphragm having a mechanically adjustable size. The invention also provides an apparatus at least comprising such a loudspeaker, as well as a variable voltage and/or current source connected to the field coil, a voice coil drive circuit switchably connectable to at least one of the plurality of voice coils, and a mechanical actuator connected to the diaphragm for adjusting its size. The apparatus may further comprise a controller of the variable voltage and/or current source, of the voice coil drive circuit and of the mechanical actuator. Such a controller is configured, in response to a frequency of an input electronic audio signal, to vary the voltage and/or current supplied to the field coil by the variable voltage and/or current source in order to vary the strength of a magnetic field produced by the field coil, to select at least one of the plurality of voice coils to be driven by the voice coil drive circuit, and/or to control the mechanical actuator to adjust the size of the diaphragm. The invention also provides a method of operating a loudspeaker in such a manner. Thus the loudspeaker is effectively an adaptive loudspeaker, which can behave as any one of a woofer, a mid-range speaker or a tweeter, according to how it is adjusted and controlled. This obviates the need to provide a separate woofer, mid-range speaker and tweeter to cover the entire range of normal human hearing.

Reference Numerals:

4	Field coil	30	Microcontroller
6a, 6b, 6c	Voice coils	30a, 30b	Sub-elements of microcontroller
8	Diaphragm	99	Fast Fourier transform
10	Loudspeaker	100	Determination of frequency range of audio signal and adjustment of speaker in response thereto
12	Dust cap		
14	Spider	101	Variation of voltage and/or current supplied to field coil
16	Basket		

(continued)

24	Variable voltage and/or current source	102	Selection of voice coil(s)
		103	Adjustment of size of diaphragm
26	Voice coil drive circuit	S1 to S8	Steps of known method
28	Mechanical actuator		

Claims

1. A loudspeaker (10) at least comprising:

a field coil (4);
a plurality of voice coils (6a, 6b, 6c) having different numbers of windings from each other; and
a diaphragm (8) having a mechanically adjustable size.

2. A loudspeaker according to claim 1, wherein the plurality of voice coils (6a, 6b, 6c) are coaxial.

3. A loudspeaker according to claim 1 or claim 2, wherein the plurality of voice coils (6a, 6b, 6c) have the same radii as each other.

4. A loudspeaker according to any one of the preceding claims, wherein at least two of the plurality of voice coils (6a, 6b, 6c) are connectable to each other in series.

5. A loudspeaker according to any one of the preceding claims, wherein the size of the diaphragm (8) is dynamically adjustable during playback of an audio signal.

6. A loudspeaker according to any one of the preceding claims, wherein the diaphragm (8) is generally conical or frusto-conical in shape, and adjustment of the size of the diaphragm alters the ratio of its radius to its height.

7. An apparatus at least comprising:

a loudspeaker (10) according to any one of claims 1 to 6;
a variable voltage and/or current source (24) connected to the field coil (4);
a voice coil drive circuit (26) switchably connectable to at least one of the plurality of voice coils (6a, 6b, 6c); and
a mechanical actuator (28) connected to the diaphragm (8) for adjusting its size.

8. An apparatus according to claim 7, wherein the mechanical actuator (28) is configured to alter the radius of the diaphragm (8), whilst keeping its height substantially constant.

9. An apparatus according to claim 7 or claim 8, further comprising a controller (30) of the variable voltage and/or current source, of the voice coil drive circuit and of the mechanical actuator, wherein the controller is configured, in response to a frequency of an input audio signal, to vary the voltage and/or current supplied to the field coil by the variable voltage and/or current source, to select at least one of the plurality of voice coils to be driven by the voice coil drive circuit, and/or to control the mechanical actuator to adjust the size of the diaphragm.

10. An apparatus according to claim 9, wherein the controller is a microcontroller comprising a digital signal processor, and wherein the digital signal processor is configured to analyse the frequency of the input audio signal to determine its frequency range.

11. A method of operating a loudspeaker according to any one of claims 1 to 6, the method at least comprising:

receiving an input audio signal;
analysing (100) the input audio signal to determine its frequency range; and
in response to the frequency of the input audio signal, performing at least one of:

varying (101) the voltage and/or current supplied to the field coil of the loudspeaker;
selecting (102) at least one of the plurality of voice coils to drive; and

adjusting (103) the size of the diaphragm.

12. A method according to claim 11, comprising, in response to the frequency of the input audio signal, simultaneously:

varying (101) the voltage and/or current supplied to the field coil of the loudspeaker;
selecting (102) at least one of the plurality of voice coils to drive; and
adjusting (103) the size of the diaphragm.

13. A method according to claim 11 or claim 12, further comprising transforming (99) the input audio signal into the frequency domain using a fast Fourier transform, and wherein analysing (100) the input audio signal to determine its frequency range comprises performing the analysis in the frequency domain.

14. A method according to any one of claims 11 to 13, wherein analysing (100) the input audio signal to determine its frequency range comprises determining a dominant frequency range of the input audio signal.

15. A method according to claim 14, further comprising adjusting a frequency range of the loudspeaker to substantially overlap with the dominant frequency range of the input audio signal.

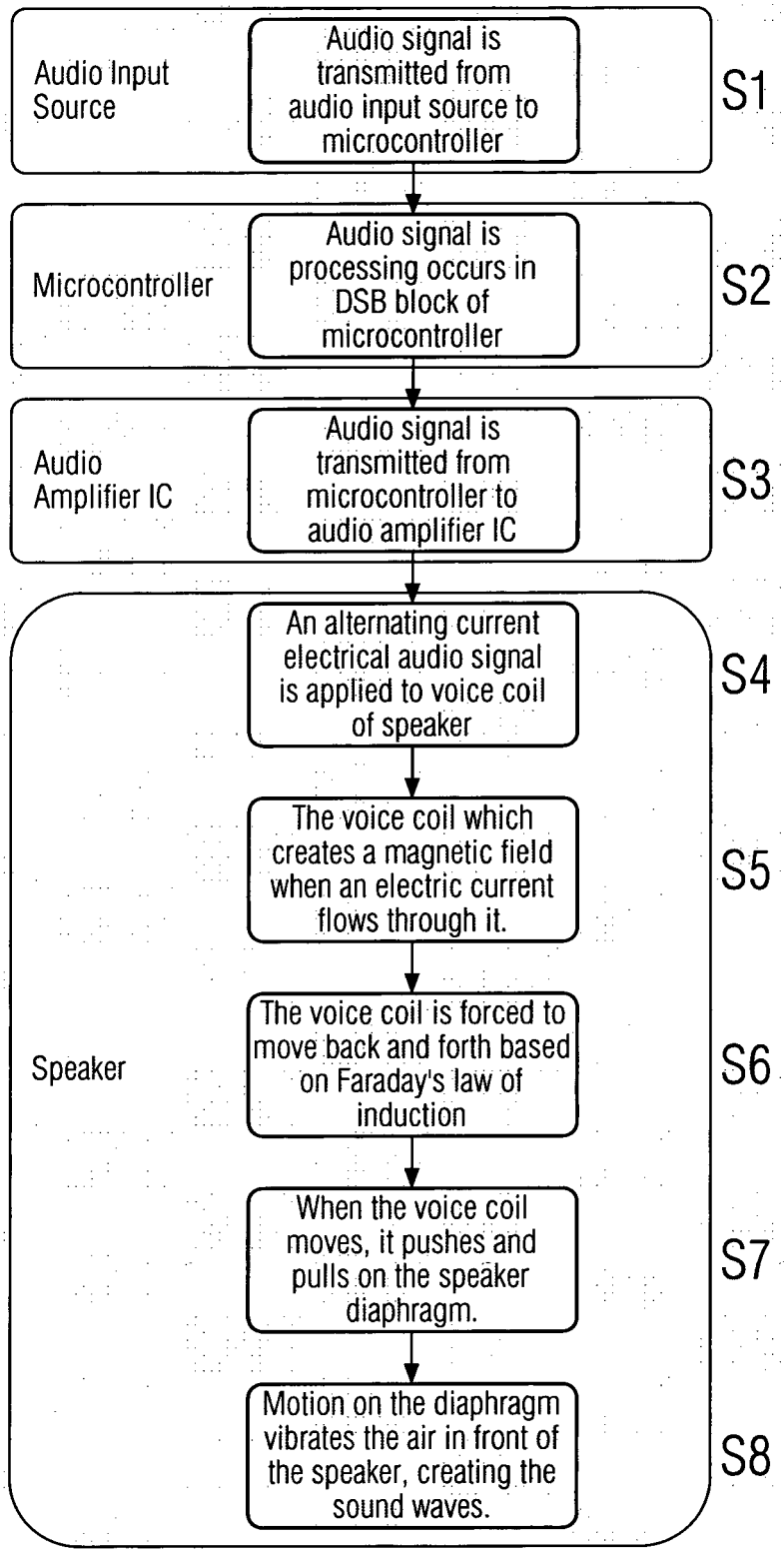
Audio Input Source
Audio signal is transmitted from audio input source to microcontroller
S1
Microcontroller
Audio signal is processing occurs in DSB block of microcontroller
S2
Audio Amplifier IC
Audio signal is transmitted from microcontroller to audio amplifier IC
S3
Speaker
An alternating current electrical audio signal is applied to voice coil of speaker
S4
The voice coil which creates a magnetic field when an electric current flows through it.
S5
The voice coil is forced to move back and forth based on Faraday's law of induction
S6
When the voice coil moves, it pushes and pulls on the speaker diaphragm.
S7
Motion on the diaphragm vibrates the air in front of the speaker, creating the sound waves.
S8

FIG. 1

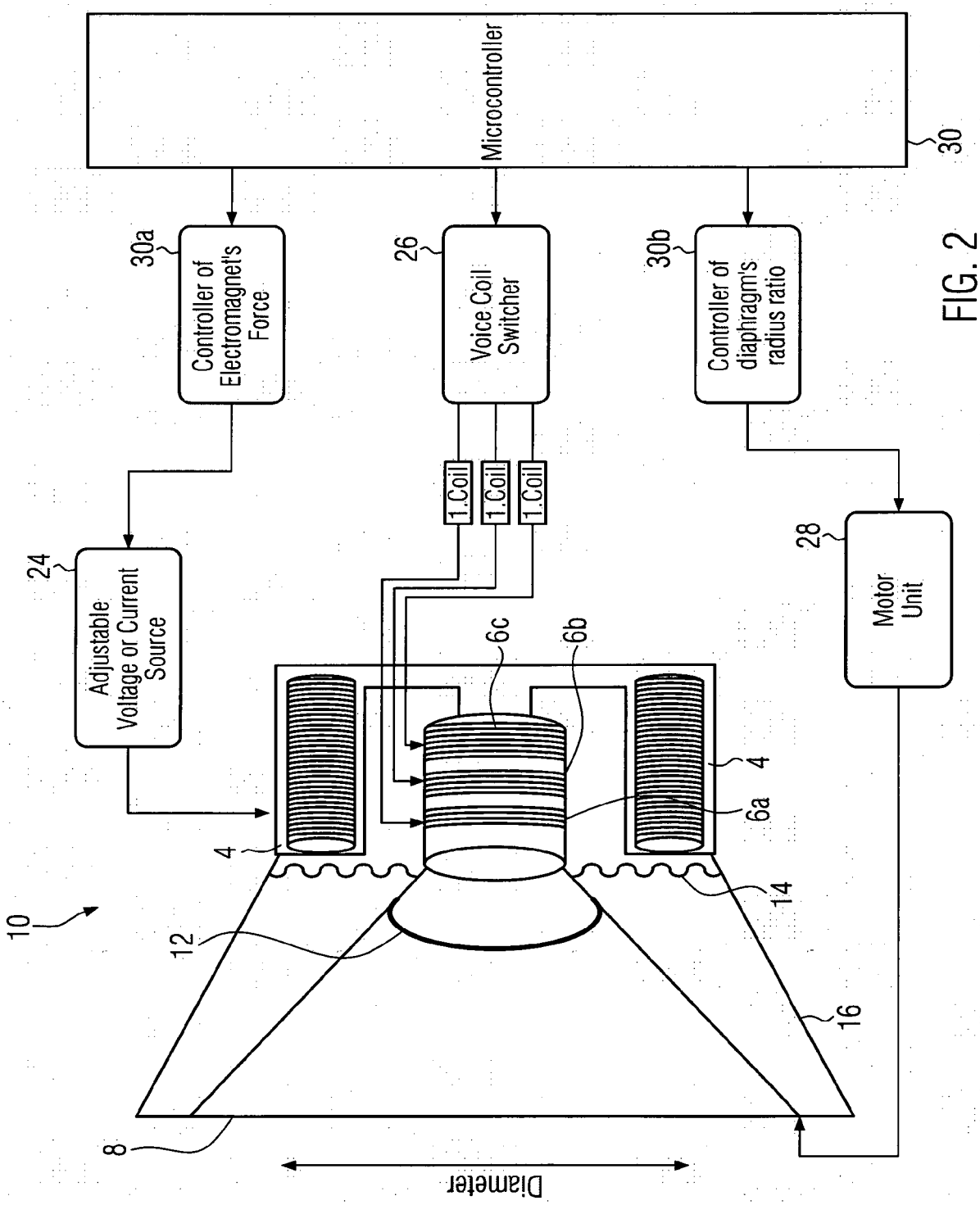
Microcontroller
30
30a
Controller of Electromagnet's Force
26
Voice Coil Switcher
30b
Controller of diaphragm's radius ratio
1.Coil
1.Coil
1.Coil
24
Adjustable Voltage or Current Source
28
Motor Unit
6c
6b
6a
4
4
14
10
12
16
8
Diameter

FIG. 2

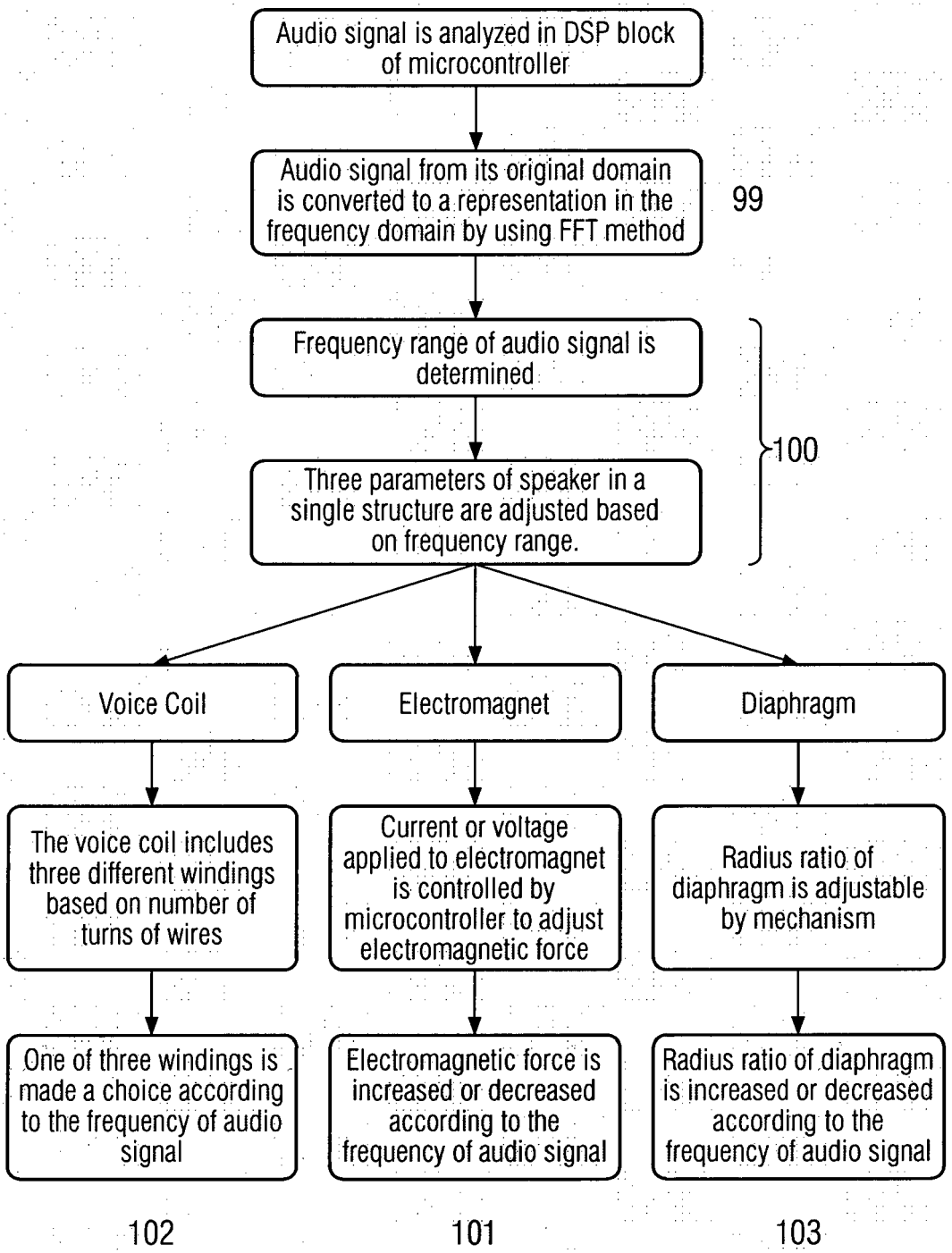
Audio signal is analyzed in DSP block of microcontroller
Audio signal from its original domain is converted to a representation in the frequency domain by using FFT method
99
Frequency range of audio signal is determined
Three parameters of speaker in a single structure are adjusted based on frequency range.
100
Voice Coil
Electromagnet
Diaphragm
The voice coil includes three different windings based on number of turns of wires
Current or voltage applied to electromagnet is controlled by microcontroller to adjust electromagnetic force
Radius ratio of diaphragm is adjustable by mechanism
One of three windings is made a choice according to the frequency of audio signal
Electromagnetic force is increased or decreased according to the frequency of audio signal
Radius ratio of diaphragm is increased or decreased according to the frequency of audio signal
102
101
103

FIG. 3

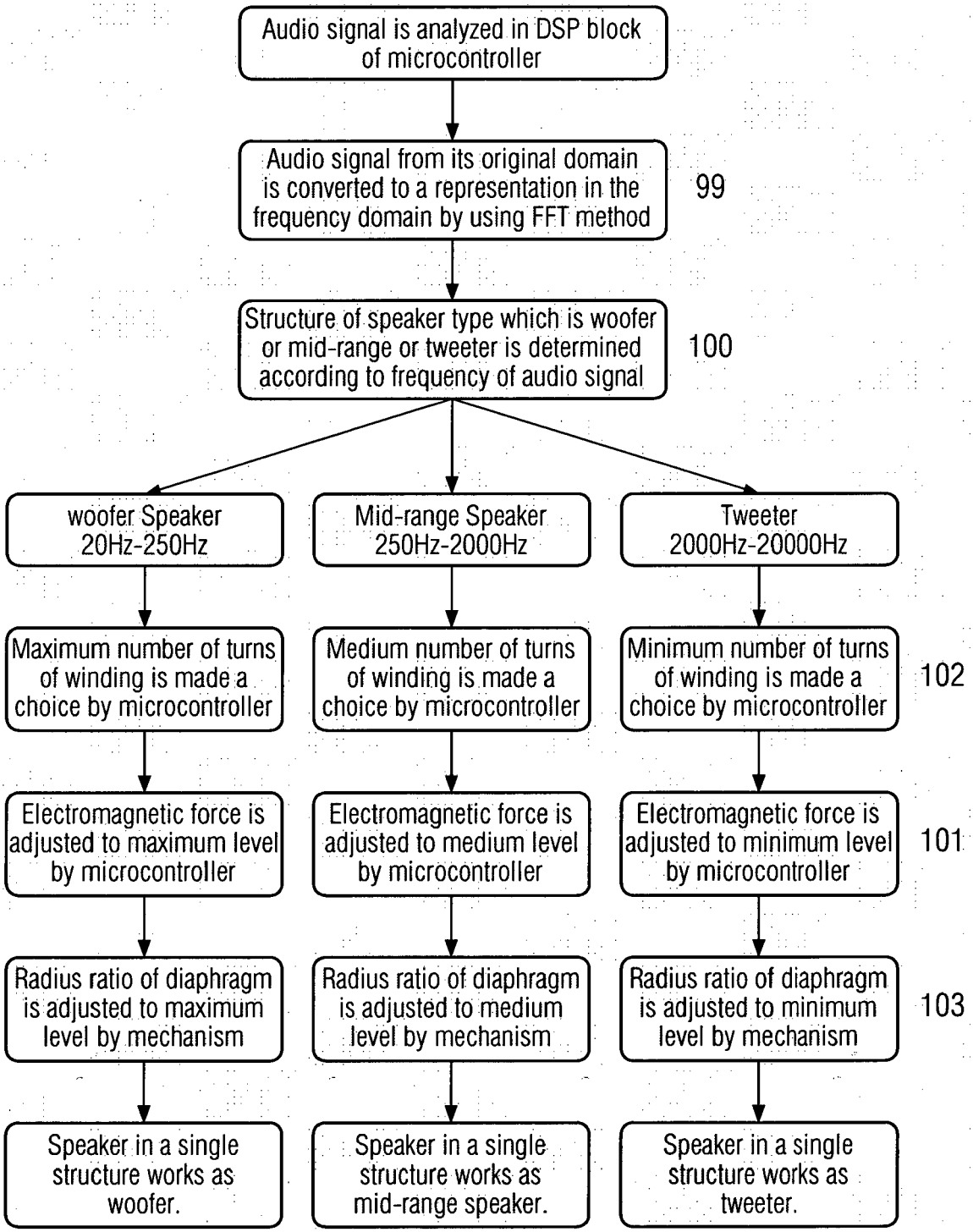
Audio signal is analyzed in DSP block of microcontroller
Audio signal from its original domain is converted to a representation in the frequency domain by using FFT method
99
Structure of speaker type which is woofer or mid-range or tweeter is determined according to frequency of audio signal
100
woofer Speaker 20Hz-250Hz
Mid-range Speaker 250Hz-2000Hz
Tweeter 2000Hz-20000Hz
Maximum number of turns of winding is made a choice by microcontroller
Medium number of turns of winding is made a choice by microcontroller
Minimum number of turns of winding is made a choice by microcontroller
102
Electromagnetic force is adjusted to maximum level by microcontroller
Electromagnetic force is adjusted to medium level by microcontroller
Electromagnetic force is adjusted to minimum level by microcontroller
101
Radius ratio of diaphragm is adjusted to maximum level by mechanism
Radius ratio of diaphragm is adjusted to medium level by mechanism
Radius ratio of diaphragm is adjusted to minimum level by mechanism
103
Speaker in a single structure works as woofer.
Speaker in a single structure works as mid-range speaker.
Speaker in a single structure works as tweeter.

FIG. 4

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 17 15 3225

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y,D	US 2013/272563 A1 (BOYD GEOFFREY A [US]) 17 October 2013 (2013-10-17) * abstract * * paragraphs [0238], [0030] * -----	1-15	INV. H04R7/12 H04R9/02
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TECHNICAL FIELDS SEARCHED (IPC)

H04R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	30 June 2017	Rogala, Tomasz

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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1

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REFERENCES CITED IN THE DESCRIPTION

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