United States Patent [19]

Okamoto

[11] **3,842,205**

[45] **Oct. 15, 1974**

[54] **TREMOLO EFFECT PRODUCING ACOUSTIC FILTER SYSTEM**

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[73] Assignee: **Nippon Gakki Seizo Kabushiki Kaisha,** Shizuoka-ken, Japan

[22] Filed: **July 16, 1973**

[21] Appl. No.: **379,317**

[30] **Foreign Application Priority Data**

July 18, 1972 Japan 47-84573
July 20, 1972 Japan 47-85492

[52] **U.S. Cl.** ..... **179/1 J,** 179/1 D, 84/1.25
[51] **Int. Cl.** **H04r 1/02,** H04r 1/20
[58] **Field of Search** ..... 179/1 J, 1 AT, 1 D; 181/31 A, 31 B, 31 R, .5 F; 84/1.25

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Primary Examiner—Kathleen H. Claffy
Assistant Examiner—Douglas W. Olms
Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

The apparatus of the invention comprises a loudspeaker, preferably, having a nearly flat diaphragm, and a plurality of microphones disposed in confronting relationship to the diaphragm of the loudspeaker at different positions in a sound radiation plane of the diaphragm, so that the microphones can individually pick up sounds radiating from different portions of the diaphragm where vibrational modes are expected to be different from one another. Further to finish a tremolo effect to the sounds finally produced, the sound waves from the loudspeaker to the microphones are periodically interrupted. According to one example of the invention, such periodical sound interruption may be caused by rotating the loudspeaker itself, and according to another example thereof, there may be employed a sound interrupting member having therein sound passages for selectively and locally passing the sound waves emitted from the different portions of the loudspeaker to the respective microphones, such sound interrupting member being disposed rotatably between the loudspeaker and the microphones.

8 Claims, 18 Drawing Figures

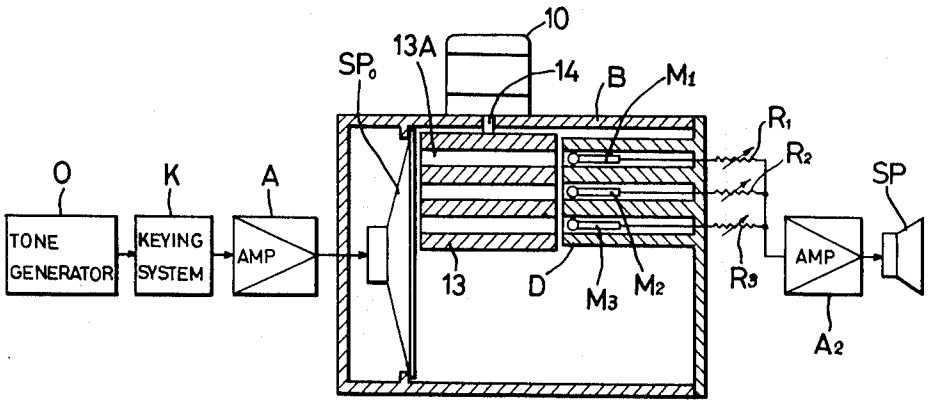


FIG. 1
PRIOR ART

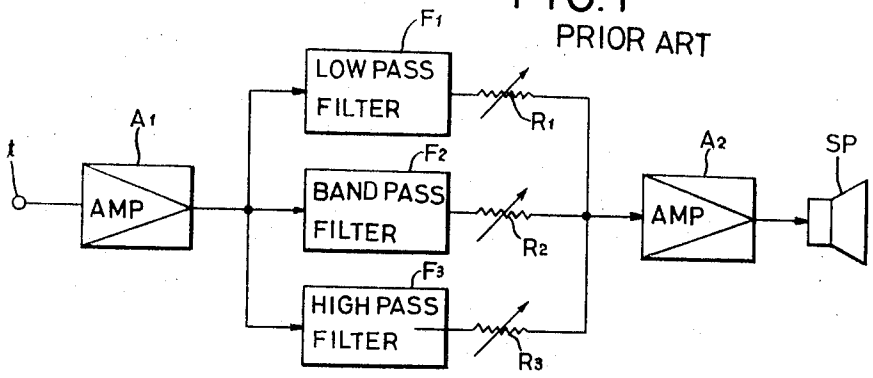


FIG. 2
PRIOR ART

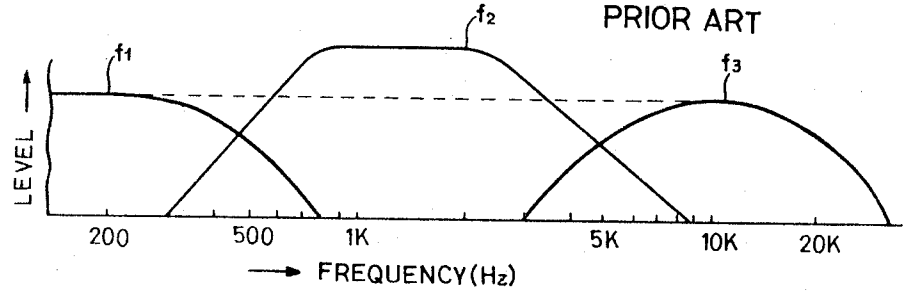


FIG.3

PRIOR ART

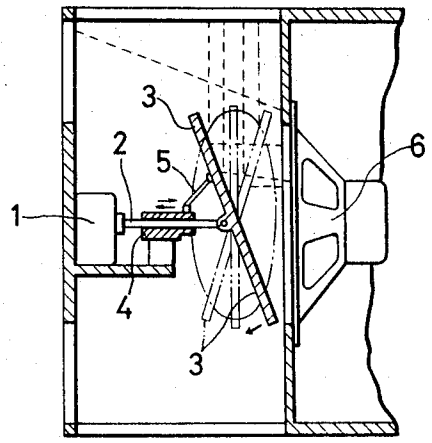


FIG.6

PRIOR ART

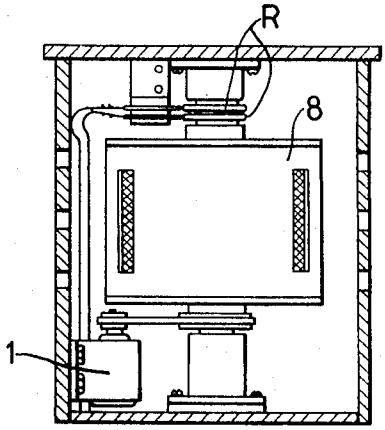


FIG.4

PRIOR ART

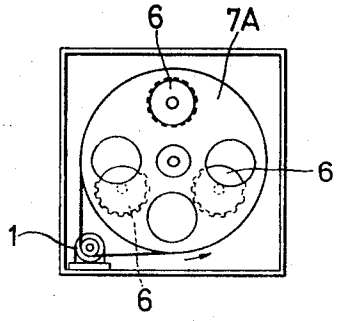


FIG.7

PRIOR ART

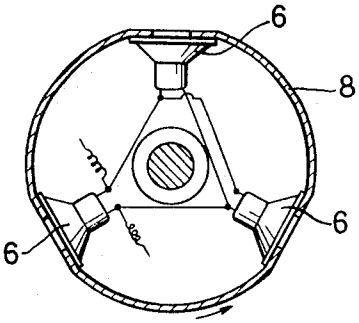


FIG.5

PRIOR ART

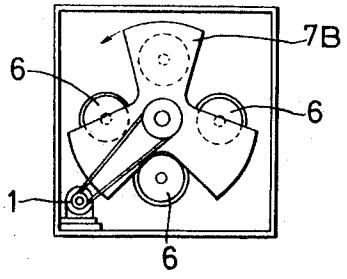


FIG. 8
PRIOR ART

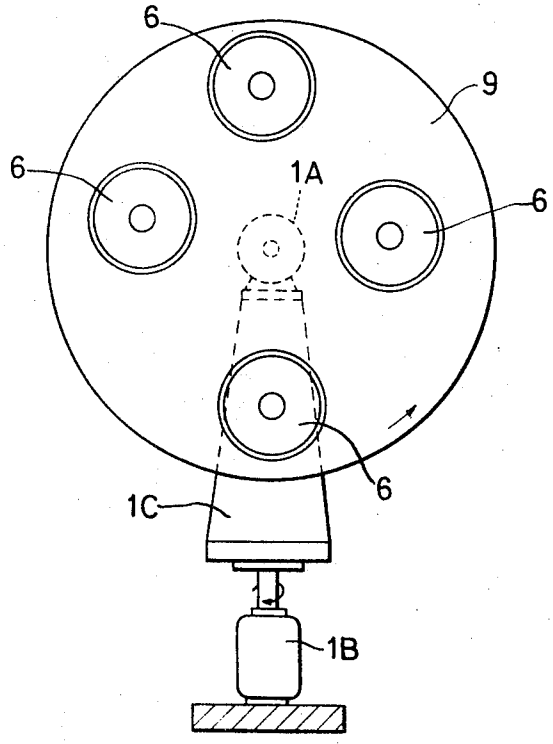


FIG. 9

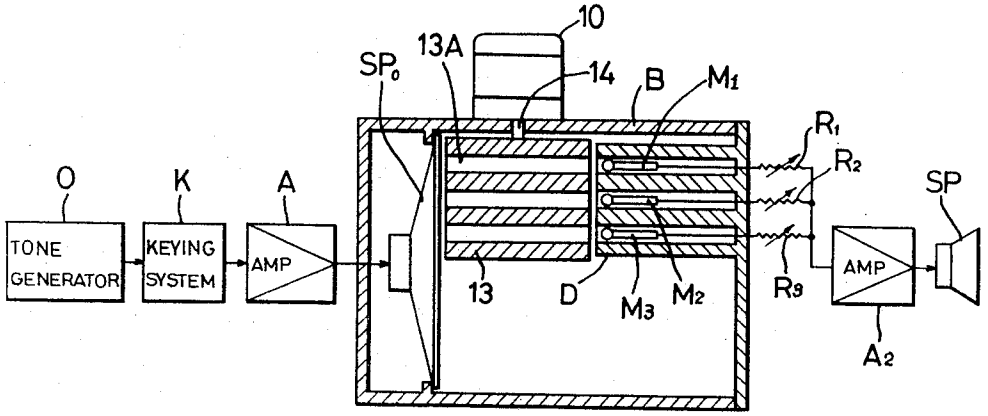


FIG.10A

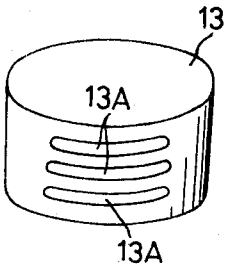
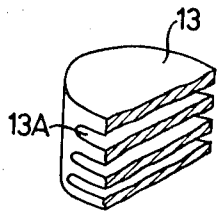


FIG.10B



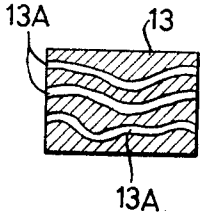


FIG.10C

FIG.11

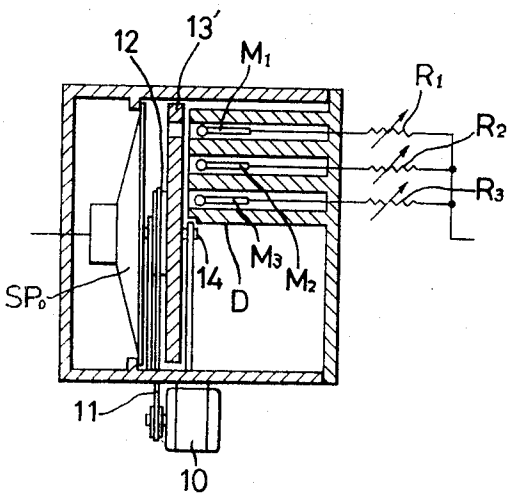


FIG.12

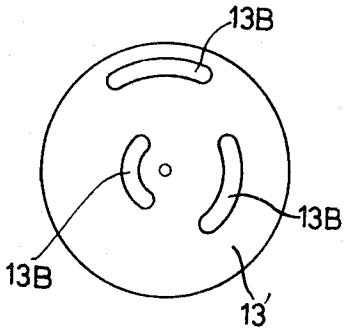


FIG.13

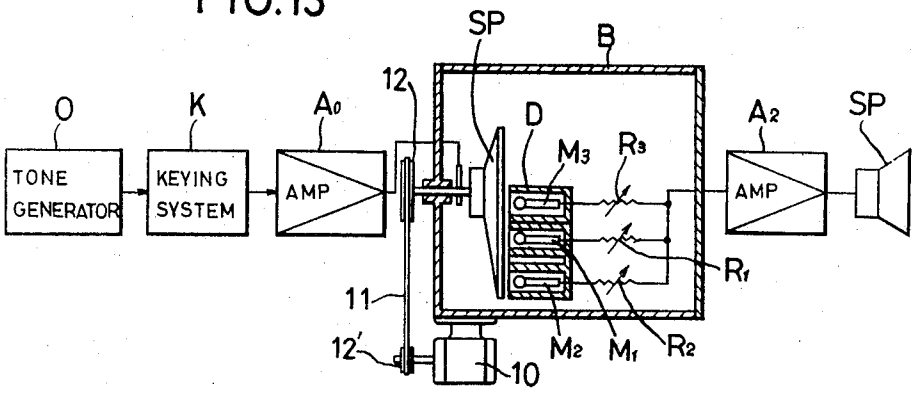


FIG.15

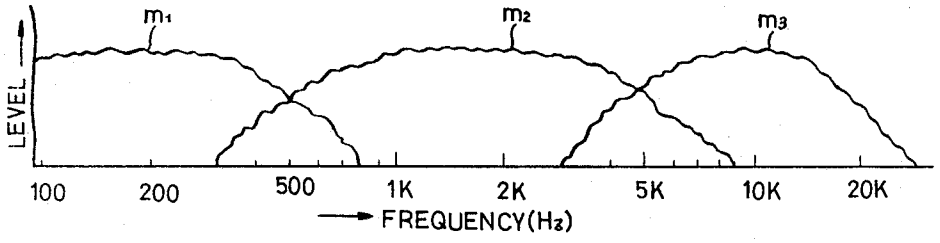


FIG.16

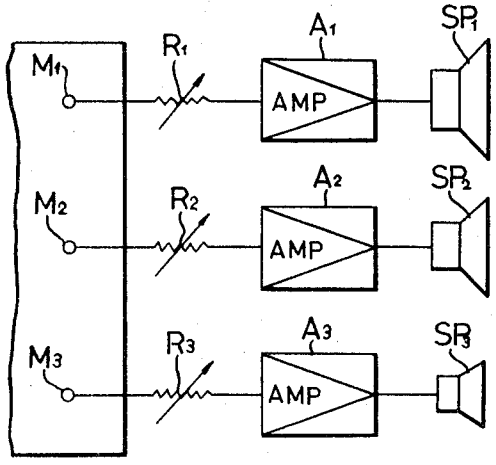
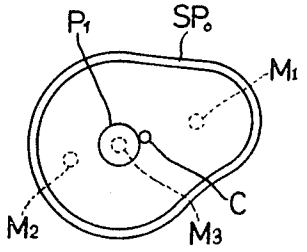


FIG.14



TREMOLO EFFECT PRODUCING ACOUSTIC FILTER SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the invention

The present invention relates to sound production systems capable of producing tremolo effects and tone coloring effects, and, more particularly, to novel tremolo effect producing acoustic filter apparatus of compact structure and also providing desired tone coloring, which are most suitable for use with electronic musical instrument.

2. Description of the prior art

Many tone coloring devices have conventionally employed electrical filter circuits composed of only electronic components such as resistors and capacitors. Tone colors produced by such an electrical tone coloring device are poor in variety and variations, and are less in acoustic interest.

For good understanding of the prior art device an example of the conventionally used tone coloring means is now discussed with reference to FIG. **1.** In FIG. **1,** an audio signal from keyers, for example, of an electronic mucical instrument or other program sources is fed through an input terminal to a pre-amplifier circuit A_1 and amplified thereby, and then this amplified audio signal is supplied to a tone coloring circuit which comprises a low pass filter F_1, a band pass filter F_2 and a high pass filter F_3 in parallel connection and individual variable resistance resistors R_1, R_2 and R_3 having one ends connected in series with the respective filters F_1, F_2 and F_3 at their output ends and having the other ends connected at a common juncture and for mixing the outputs of the filter circuits F_1, F_2 and F_3 at a desired ratio of mixing. At the common juncture will be developed in mixed condition three kinds of audio signals respectively having different frequency to level characteristics i.e., different frequency ranges as shown by f_1, f_2 and f_3 in FIG. **2.** These mixed audio signals are fed to a power amplifier A_2 and thereby amplified and then reproduced by a loudspeaker SP.

Thus, in the conventional tone coloring device, the frequency characteristics of the reproduced sound wave are inherently determined by the frequency band characteristics of the filter circuits employed and the parameters of the mixing variable resistance resistors. Therefore, the tone coloring device employing electrical circuits alone has a great disadvantage in that a realistic and interesting sound resembling that of a natural musical instrument may not be obtained since the reproduced sound wave fails to be rich in variety.

As the conventional sound reproducing system for producing a tremolo effect on sounds as they are generated by an electronic musical instrument, there is known the type having a rotational disc located in front of a loudspeaker or speakers to thereby provide a tremolo effect, as disclosed in, for example, Japanese Utility Model Publication No. 22436/1965 and U.S. Pat. No. 3,204,722.

Said Utility Model Publication, as shown in FIG. **3,** discloses a tremolo effect producing apparatus comprising a motor **1,** a rotary shaft **2** operatively connected with the motor, an acoustic reflecting plate **3** of which the center is supported by the end of the shaft so as to be rotatable in any plane involving the shaft, a bearing **4** slidably engaged with the shaft **2,** a connecting lever **5** connecting the bearing **4** with the side portion of the reflecting plate **3,** and a loudspeaker **6** in front of which is located the reflecting plate **3** so as to face it, whereby the sounds from the speaker provides a tremolo effect through the reflecting plate as the plate is rotated with respect to the direction of the shaft, namely, axially of the loudspeaker.

Said U.S. patent, as shown in FIGS. **4** and **5,** discloses another system for generating a tremolo effect on the sound waves from speakers including a sound reproducing speaker enclosing cabinet, a vertically disposed speaker supporting panel spaced inwardly from an open side of the cabinet, a plurality of sound reproducing speakers **6** mounted on the panel, a rotating disc **7A** spaced from and operating in a plane parallel with the speaker supporting panel and having openings corresponding in diameter to the diaphragms of the speakers or a rotating plate **7B** having cutouts and a motor for rotating the disc or the plate at a required revolution speed.

Another known device of the type in which a plurality of speakers are rotated in a plane to produce a tremolo effect and a vibrato effect is referred to in the following two U.S. patents. That is, U.S. Pat. No. 3,100,024, as shown in FIGS. **6** and **7,** discloses an apparatus for producing vibrato or tremolo effects, comprising a motor **1,** a drum **8** arranged on the inside of a peripheral wall on which a plurality of speakers **6** are revoluvably mounted for rotation about an axis, the drum being operatively connected with the motor through a belt so as to be rotated, and slip rings R through which low frequency currents are supplied to the respective speakers, whereby the sounds from the speakers are given vibrato or tremolo effects as these speakers are horizontally rotated in the same plane with that of rotation of the drum driven by the motor.

As shown in FIG. **8,** U.S. Pat. No. 3,084,585 indicates an acoustic modulator comprising a speaker mounting disc **9** having circumferentially disposed plural speakers **6** which may be rotated about a horizontal axis, namely, circumferentially by means of a suitable motor MA and may be rotated about a vertical axis of a vertical standard **1C,** namely, perpendicularly to the vertically diametric direction of the disc, by means of another motor MB, to produce a Doppler effect and a tremolo effect.

However, these known tremolo effect producing systems have the following disadvantages.

First, the known tremolo effect producing apparatus are inconveniently bulky, occupying a large space and complicated in mechanism and are impossible to effectively produce a tremolo effect when reproduced by means of headphones in an electronic musical instrument. Furthermore, when incorporated in an electronic musical instrument, such an apparatus generally requires a fixed loudspeaker for sound reproduction having non-tremolo effect, as well as a rotating loudspeaker for providing a tremolo effect, and also separate power amplifiers therefor. Accordingly, such an apparatus not only tends to be very expensive but also is impossible to radiate tremolo and non-tremolo sounds from the same loudspeaker, resulting in the lack of naturalness of sound in the performance of the electronic musical instrument.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a novel electro-acoustic system for producing interesting tremolo and tone coloring effects which are quite close to the sound effects of a natural musical instrument.

Another object of the present invention is to provide a tremolo effect producing apparatus with tone coloring effects suitable for use with an electronic musical instrument, which comprises, a closed housing or a sealed box containing therein a sound radiating member such as a loudspeaker, a plurality of microphones opposed to a sound radiating surface of the loudspeaker at different positions, and a rotatable sound interrupting member disposed between the loudspeaker and the plurality of microphones so as to be quite close to both and having openings or cutouts constituting sound passages for passing sound from the loudspeaker to said microphones, and a drive means for rotating the sound interrupting member at a desired speed of revolution, whereby an audio signal applied to the loudspeaker of the apparatus is reproduced into a sound wave and then the sound wave is modulated by means of the rotating sound interrupting member and picked up by the microphones to thereby produce electrical audio signals having tremolo effects rich in variety, the individual signals thus produced also having different frequency ranges i.e., different tone colors due to the difference in vibration mode at different locations in the diaphragm of the loudspeaker.

Still another object of the present invention is to provide a tremolo effect producing apparatus capable of concurrently providing desired tone coloring, which is of the arrangement comprising a rotatable sound radiating means such as a loudspeaker disposed in a closed chamber, and a plurality of sound pickup means such as microphones arranged in a sound radiating plane of the loudspeaker at different locations thereof in the vicinity of the diaphram of the loudspeaker, whereby an audio signal from a tone generator is reproduced by the rotating loudspeaker into a sound wave and this sound wave is picked up by the individual microphones at different positions as sound signals, so that each sound signal thus obtained has a tremolo effect due to the rotation of the loudspeaker and concurrently has a specific frequency range (or a specific tone color) due to the difference in vibration mode at a portion of the diaphram of the loudspeaker.

Yet another object of the present invention is to provide a tremolo effect producing system with acoustic filters, which is small in size and is compact and is simple in construction, and is possible to dispense with such a conventional specifically designed loudspeaker as has been used exclusively for obtaining a tremolo effect in an electronic musical instrument.

A further object of the present invention is to provide a system for producing a tremolo effect with tone coloring, which is suitably adaptable for a headphone when it is used as a sound radiating system of an electronic musical instrument.

A significant object of the present invention is to provide a tremolo effect producing acoustic filter device comprising: a sound reproducing member such as a flat-type loudspeaker capable of radiating a sound wave in full range and having different frequency characteristics in accordance with the position of the sound radiating portion such as a diaphram; a plurality of microphones disposed at different positions in the foreground of said sound radiating portion so as to pick up positional variations in the frequency characteristics of the radiating portion of the sound reproducing member; thereby constituting acoustic filters and a drive means for rotating the sound radiating member, whereby producing a tremolo effect in a picked-up audio signal.

A still further object of the present invention is to provide a musical sound reproduction system utilizing the above-mentioned specific tremolo effect producing acoustic filter device of the electro-acoustic type in which an audio signal from the sound program is acoustically processed into one having desired tremolo effects and tone colors and then is reproduced into a musical sound, so that the reproduced sound effects give the listener a realistic sound image without any impression of an artificial electrical sound.

Other objects, features and advantages of the present invention will become apparent from the following detailed description of some preferred embodiments only by way of example when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram illustrating an example of the conventional acoustic filter circuit system.

FIG. **2** is a chart of frequency characteristic curves for explaining the filter circuit system of FIG. **1**.

FIGS. **3** through **8** are structural views illustrating some examples of the conventional tremolo effect producing devices.

FIG. **9** is a schematic diagram showing the construction of an embodiment of the present invention.

FIGS. **10A**, **10B** and **10C** are, respectively, an oblique view, a perspective section and a longitudinal section of a sound interrupting rotary member used in the embodiment of FIG. **1**.

FIG. **11** is a view, partly in section, of a modification of the rotary member in the closed housing of the preceding embodiment.

FIG. **12** is a plan view of the rotary member illustrated in FIG. **11**.

FIG. **13** is a schematic diagram showing another embodiment of the present invention.

FIG. **14** is a view showing the positional relation between the loudspeaker and the individual microphones of the present tremolo effect-producing acoustic filter device.

FIG. **15** is a chart of frequency characteristic curves for explaining the present invention.

FIG. **16** is a schematic diagram of a further modification of the present invention.

In the drawings, like reference numerals and letters indicate like parts throughout the embodiments of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. **9**, there is schematically illustrated an electronic musical instrument circuit system incorporating the present invention, which comprises: a tone generator circuit O for generating audio signals; a key-operated keying system K at which these audio signals are selected through tone keyers by the key operation of the player of the instrument; an amplifier cir-

cuit A_0 for amplifying the selected audio signal; a tremolo effect producing acoustic filter assembly connected with the output end of the amplifier A_0 to receive the audio signal from the tone generator circuit and thereby to produce audio signals each with a tremolo effect as well as a tone color; a mixing circuit consisting of variable resistance resistors for mixing individual audio signals derived from the acoustic filter assembly at a desired ratio; a power amplifier circuit A_2 for amplifying the mixed audio signals; and a loudspeaker SP for radiating a sound wave having the audio signals. The acoustic filter assembly according to an embodiment of the present invention includes a closed box or a hermetically sealed housing B within which loudspeaker SP_0 having, preferably, a nearly flat diaphragm driven by the audio signal from the pre-amplifier A_0 is fixedly disposed on one side of the interior of the housing and also a plurality of microphones M_1, M_2 and M_3 are disposed opposite to the sound radiating surface of the loudspeaker SP_0 at different positions in the same plane relative to one another. A microphone housing member D having parallel arranged compartments therein is provided on the other side of the interior of the housing B. Each compartment is open at one end and accommodates one of the microphones, thereby preventing them from their acoustically interfering with each other.

The housing B rotatably mounts therein a sound wave interrupting member **13** between the radiating surface of the loudspeaker SP_0 and the microphone housing member D supporting therein the microphones M_1, M_2 and M_3. The sound wave interrupting member **13** are mechanically connected with a drive motor **10** so that it may revolve about an axis perpendicular to that of the loudspeaker SP_0 at a speed of 0.5 – 15 revolutions per second.

At the resepctive output ends of the microphones M_1, M_2 and M_3 are connected individual variable resistance resistors R_1, R_2 and R_3 at each one end the other ends of which are connected at a common junction to thereby mix the outputs derived from the respective microphones. The mixed audio signal is amplified by the power amplifier A_2 and reproduced by the loudspeaker SP into a desired sound wave.

The sound wave interrupting member **13** may be a cylindrical solid body having therein a plurality of diametrical openings or through-holes **13A** which are in parallel relation with each other only at each open end of the cylindrical surface of the body as shown in FIGS. **10A** and **10B**. Each opening in the member **13** corresponds to one of the microphones M_1, M_2 and M_3. Each sound passage **13A** may be formed in the cylindrical solid body **13** to pass sound therethrough in an arbitrary manner, for example, as shown by a section in FIG. **10C**.

In any case, the openings or through-holes **13A** are so formed that when one end of each opening **13A** comes close to the loudspeaker diaphragm, the other end of the opening **13A** is confronted with the corresponding microphone M_1, M_2 or M_3, thereby passing the sound waves from the loudspeaker through the opening **13A** to the microphone. The plurality of openings **13A** are further so arranged as to correspond to different portions of the loudspeaker diaphragm where vibrational modes are expected to be different from one another. When the member **13** is rotated, the sound passages **13A** are periodically formed and interrupted between the portions of the loudspeaker diaphragm and the respective microphones, whereby the sound waves emitted from the loudspeaker to the microphones are given fade-in and fade-out effects, resultantly heard as tremolo effect sounds.

Referring now to FIG. **11** a modification of the acoustic filter assembly of FIG. **9** is illustrated, in which a rotary disk **13'** is used in place of the rotational cylindrical body **13**. This disk **13'** has curved elongate openings or cutouts **13B** perforated along the circumference of the disk at different positions in its radius direction and provided at positions capable of confronting the respective microphones M_1, M_2 and M_3, as shown for example in FIG. **12**. The sound wave interrupting disk **13'** is mounted between the loudspeaker SP_0 and the microphones M_1, M_2 and M_3 in such a way that it may revolve about a shaft **14** disposed in parallel to the axis of the loudspeaker SP_0 by means of the drive motor **10** through a belt **11** and a pulley **12**.

Now, the operation of the assembly thus constructed will be described hereunder.

As will be appreciated from the construction of the acoustic filter assembly as shown in FIG. **9** or **11**, the microphone M_1 disposed opposite to the radiating surface of the flat-type loudspeaker SP_0 in the vicinity of its end portion receives an input sound wave of relatively lower frequency band components substantially below 400 Hz from the loudspeaker SP_0, whose characteristic curve is shown by m_1 in FIG. **15**. The microphone M_2 disposed opposite to an intermediate portion of the radiating surface of the loudspeaker SP_0 receives an input sound wave having frequency components of a middle sound range of from about 500 Hz to about 5kHz, as shown by a characteristic curve m_2 in FIG. **15**, while the microphone M_3 disposed opposite to the central portion of the loudspeaker SP_0 receives a sound wave having relatively higher frequency band components as shown by a characteristic curve m_3 in FIG. **15**. Acoustic filters are thus constituted and these filters can produce a tremolo effect by rotating the sound interrupting member **13** or **13'**.

Accordingly, when output signals from the respective microphones M_1, M_2 and M_3 are mixed through the variable resistance resistors R_1, R_2 and R_3 at the common juncture at a desired ratio, these signals are amplified by the amplifier A_2 and fed to the loudspeaker SP for musical sound reproduction. Thus, from the loudspeaker SP there is obtained a sound wave which constitutes a musical sound having desired tone colors and tremolo effects.

Since the above-mentioned loudspeaker SP_0 is not used for the listener to listen directly to the sound wave produced therefrom, it may be of a low reproduction power and a small size. The closed housing B employed may also be small in size.

The tremolo effect producing acoustic filter assembly enables the respective microphones M_1, M_2 and M_3 to pick up audio signals having different frequency bands as illustrated by its filter characteristic curves m_1, m_2 and m_3 in FIG. **15** respectively.

FIG. **16** shows an example of a sound reproduction system utilizing the thus produced audio signals, in which the respective output terminals of the microphones M_1, M_2 and M_3 are individually connected, via variable resistance resistors R_1, R_2 and R_3 and power amplifiers A_1, A_2 and A_3, to a low-frequency loudspeaker (woofer) SP_1, an intermediate-frequency loud-

speaker (squawker) SP_2 and a high-frequency loudspeaker (tweeter) SP_3, respectively, whereby the resulting sound waves from these loudspeakers provide tone colors quite resembling those of natural musical instruments.

In the above embodiments of the tremolo effect producing acoustic filter assembly, it will be easily understood that a plurality of parallely arranged microphones M_1, M_2 and M_3 isolated acoustically and physically from each other may face to substantially one half of the sound radiating surface of the fixed loudspeaker SP_0 within the closed housing B, and also that a number of directional microphones may be arranged in a manner as stated in connection with the microphones of the preceding embodiment.

Referring to FIG. **13**, another embodiment of the present invention is illustrated in a schematic diagram of a sound producing system similar to that of FIG. **9**, in which a closed housing B accommodates therein a small loudspeaker of preferably an asymmetrically shaped, oblong, flat type diaphragm as shown in FIG. **14**, mounted on a rotary shaft which is supported at one side wall of the housing, and a sound shielding compartment member D mounting therein a plurality of directional microphones M_1, M_2 and M_3 so as to be acoustically isolated from each other. The shaft connected to the loudspeaker SP_0 mounts thereon a pulley **12** outside the housing B and is connected, via a belt **11** and a pulley **12'**, with a drive motor **10** which, in turn, is mounted outside the housing B for rotating the loudspeaker. This loudspeaker SP_0 can be rotated about its central axis at a speed of from 0.5 to 15 revolutions per second by the motor **10** through the power transmission mechanism as mentioned previously.

The microphones juxtaposed in the compartment member D are seen to be opposite to and in proximity to the sound radiating surface of the flat type loudspeaker SP_0. These respective microphones are disposed at different positions relative to each other with respect to the sound radiating surface as shown, for example, in FIG. **14**. In this Figure, P_1 represents the driving point or voice coil of the flat type loudspeaker SP_0 having an asymmetrically elliptic shape, and C represents the rotational center of the sound radiating surface of the loudspeaker SP_0 at which center this loudspeaker is supported by the rotary shaft for revolution. An electrical signal picked up by each microphone M_1, M_2 or M_3 is fed, through a variable resistance resistor R_1, R_2 or R_3 and a common juncture, to an amplifier A_2 and then to a fixed loudspeaker SP.

The operation and effects of the above-constructed assembly for constituting acoustic filters are substantially similar to those of FIG. **9**. That is, the microphone M_1 disposed in the vicinity of an end portion of the rotating flat loudspeaker SP_0 picks up a sound wave of relatively low frequency components m_1, whereas the microphone M_2 disposed opposite to an intermediate portion of the sound radiating surface of the loudspeaker SP_0 picks up a sound wave of intermediate frequency components m_2, and the microphone M_3 disposed at a central portion P_1 of the sound radiating surface picks up a sound wave of relatively high frequency component m_3, thus constituting acoustic filters. The frequency characteristic curves given by m_1, m_2 and m_3 are as shown in FIG. **15**. The picked-up signals are bestowed with tremolo effects due to the rotation of the sound radiating surface of the loudspeaker SP_0.

The mixing resistors R_1, R_2 and R_3 may be provided outside the housing B as in the instance of FIG. **9**. In this embodiment, the loudspeaker SP_0 enclosed in the housing may be of a small output power and of a small size since it is not intended for being listened to directly by the listener. The housing B also may be small in size. The assembly of this embodiment is applicable also to the system shown in FIG. **16** with great advantages.

It will be understood from the foregoing statement that by the application of the present invention to, for example, an electronic musical instrument, there are obtained sound waves which are felt to be natural when heard and which are free of the so-called feeling of electrified sound, but instead which present musical sounds quite resembling those of natural musical instruments. Thus, it is possible for the listener to enjoy an interesting performance from an electronic musical instrument incorporating this invention, so that the present invention provides varying highly sophisticated acoustic effects.

I claim:

1. A tremolo effect producing acoustic filter system comprising: a closed housing, said housing including therein an electro-acoustic transducer having a sound radiating surface and capable of radiating sounds having a desired frequency band, a plurality of acousto-electric transducers for picking up the sounds radiated from said electro-acoustic transducer and converting the sounds into electric signals, said plurality of transducers being juxtaposed and acoustically isolated from each other and opposed to the sound radiating surface of said electro-acoustic transducer at different positions thereof, and a rotary sound interrupting member disposed relatively closely between said sound radiating surface of the electro-acoustic transducer and said plurality of the acousto-electric transducers, said rotary sound interrupting member periodically interrupting, in accordance with the revolution thereof, sound paths leading from said electro-acoustic transducer to said plurality of acousto-electric transducers, so as to provide fade-in and fade-out effects and different frequency band characteristics for the sounds picked up by the respective acousto-electric transducers; and means for giving rotation to said rotary sound interrupting member at a required speed.

2. The system according to claim **1**, in which said electro-acoustic transducer and said acousto-electric transducers are a loudspeaker and microphones, respectively.

3. The system according to claim **1**, in which said rotary sound interrupting member is of a cylindrical form having sound passages provided therein to open at different side surfaces thereof, said passages corresponding in number and position to said plurality of acousto-electric transducers.

4. The system according to claim **1**, in which said rotary sound interrupting member is a disc having cutout or opening patterns therein to selectively form sound passages.

5. The system according to claim **2**, in which said closed housing mounts therein a compartment member having juxtaposed compartments inside thereof each for accommodating each of said plurality of microphones therein separately.

6. The system according to claim **2**, in which said loudspeaker is of a nearly flat type diaphragm.

7. A tremolo effect producing acoustic filter system comprising: a hermetically sealed box, said box including therein a loudspeaker having a sound radiating surface with different positional frequency characteristics, and a plurality of microphones acoustically isolated and juxtaposed from each other and opposed to said sound radiating surface at different positions and disposed in proximity thereto; and means for giving rotation to said loudspeaker at a required speed of revolution, whereby the sounds picked up by the respective microphones may be given fade-in and fade-out effects and also different frequency band characteristics, respectively.

8. The system according to claim 7, in which said loudspeaker is of a flat type and has a sound radiating surface of an asymmetrical configuration.

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