

(19)



(11)

EP 3 415 243 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
21.07.2021 Bulletin 2021/29

(51) Int Cl.:
B06B 1/02 (2006.01) **G10K 9/122** (2006.01)
G08B 3/10 (2006.01)

(21) Application number: **18172887.4**

(22) Date of filing: **17.05.2018**

(54) ACOUSTIC DEVICE FOR WARNING SOUND AND ACOUSTIC SYSTEM

AKUSTISCHE VORRICHTUNG FÜR WARNTON UND AKUSTISCHES SYSTEM

DISPOSITIF ACOUSTIQUE D'AVERTISSEMENT SONORE ET SYSTÈME ACOUSTIQUE

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(30) Priority: **22.05.2017 JP 2017101053**

(43) Date of publication of application:
19.12.2018 Bulletin 2018/51

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Description**Technical Field**

5 [0001] The present invention generally relates to acoustic devices for warning sound and acoustic systems. The present invention specifically relates to an acoustic device for warning sound including a piezoelectric buzzer and an acoustic system including the acoustic device.

Background Art

10 [0002] A warning device including a piezoelectric buzzer (piezoelectric diaphragm) and an acoustic controller configured to control the piezoelectric buzzer is known (see, for example, Patent Literature 1: JP 2009-157447 A). The piezoelectric buzzer is formed by bonding together a piezoelectric element polarized in a thickness direction and a thin metal plate. The acoustic controller periodically changes a drive voltage to be applied to the piezoelectric element so as to vibrate the piezoelectric buzzer to generate a sound wave.

15 [0003] In the warning device as described above, the frequency of a drive voltage at which a sound pressure of an output sound from the piezoelectric buzzer is maximum depends on characteristics of the piezoelectric buzzer. Thus, for example, when the piezoelectric buzzer is caused to output a warning sound at a frequency lower than the frequency at which the sound pressure of the output sound from the piezoelectric buzzer is maximum, the sound pressure of the warning sound is not maximum, and thus, it is difficult to increase the sound pressure level of the warning sound.

20 [0004] EP 1 507 603 discloses an acoustic device for warning sound, configured to mechanically vibrate a piezoelectric buzzer to output an warning sound, the acoustic device comprising: a switching circuit configured to periodically repeat a time period including an ON time period and an OFF time period and to output a first voltage, a voltage level of the first voltage during the ON time period being a high level, the voltage level of the first voltage during the OFF time period being a low level; and the piezoelectric element being configured to receive the first voltage and resonate free wherein a relationship among a frequency f_n of an Nth harmonic, a fundamental frequency f_0 of the drive voltage, and the resonant frequency f_r of the piezoelectric element is $f_n - 1/2f_0 \leq f_r \leq f_n + 1/2f_0$, where the Nth harmonic is one harmonic of a plurality of harmonics of the drive voltage, a sound pressure level of an output sound from the piezoelectric buzzer at the Nth harmonic being higher than a sound pressure level of the output sound from the piezoelectric buzzer at the fundamental frequency f_0 .

Summary of Invention

35 [0005] In view of the foregoing, it is an object of the present invention to provide an acoustic device for warning sound and an acoustic system which are configured to increase, also when a warning sound at a relatively low frequency is output, a sound pressure level of the warning sound.

[0006] The present invention relates to an acoustic device according to claim 1 and an acoustic system according to claim 8. Claims 2 to 7 refer to specifically advantageous realizations of the acoustic device according to claim 1.

40 [0007] An acoustic device for warning sound according to one aspect of the present invention is an acoustic device for warning sound configured to mechanically vibrate a piezoelectric buzzer to output a warning sound. The acoustic device for warning sound includes a resonance circuit and a switching circuit. The switching circuit is configured to periodically repeat a time period including an ON time period and an OFF time period and to output a first voltage. A voltage level of the first voltage during the ON time period is a high level. The voltage level of the first voltage during the OFF time period is a low level. The resonance circuit is configured to receive the first voltage. The resonance circuit is configured to generate, from electrical energy applied during the ON time period, a second voltage which oscillates at an oscillation frequency f_1 during the OFF time period and to output a composite voltage of the first voltage and the second voltage to the piezoelectric buzzer. The composite voltage serves as a drive voltage. A relationship among a frequency f_n of an Nth harmonic, a fundamental frequency f_0 of the drive voltage, and the oscillation frequency f_1 is $f_n - 1/2f_0 \leq f_1 \leq f_n + 1/2f_0$, where the Nth harmonic is one harmonic of a plurality of harmonics of the drive voltage, a sound pressure level of an output sound from the piezoelectric buzzer at Nth harmonic being higher than a sound pressure level of the output sound from the piezoelectric buzzer at the fundamental frequency f_0 .

50 [0008] An acoustic system according to another aspect of the present invention includes the acoustic device for warning sound and the piezoelectric buzzer.

Brief Description of Drawings

55 [0009]

FIG. 1 is a block diagram schematically illustrating an acoustic system including an acoustic device for warning sound according to a first embodiment of the present invention;

FIG. 2 is a waveform diagram illustrating a control signal and a drive voltage of the acoustic device for warning sound;

FIG. 3 is a graph illustrating a frequency characteristic of a piezoelectric buzzer, a frequency characteristic of a drive voltage of a comparative example, and a frequency characteristic of a warning sound of the comparative example;

FIG. 4 is a graph illustrating the frequency characteristic of the piezoelectric buzzer, a frequency characteristic of the drive voltage, and a frequency characteristic of the warning sound of the acoustic system of the first embodiment; and

FIG. 5 is a block diagram schematically illustrating a main part of an acoustic device for warning sound according to a second embodiment of the present invention.

Description of Embodiments

[0010] With reference the FIGS. 1 to 4, an acoustic device 1 for warning sound and an acoustic system 100 according to an embodiment of the present invention will be described below. Note that a first embodiment (including variations) and a second embodiment described below are mere examples of various embodiments of the present invention. The following embodiments may be modified in various ways depending on design and the like as long as the object of the present invention is achieved.

First Embodiment

(1) Schema of Acoustic System

[0011] As illustrated in FIG. 1, an acoustic system 100 includes an acoustic device 1 for warning sound (hereinafter also referred to simply as an acoustic device 1) and a piezoelectric buzzer 10. The acoustic system 100 is a system which outputs from the piezoelectric buzzer 10 a warning sound based on the frequency of an alternating-current (AC) voltage applied to the piezoelectric buzzer 10. A voltage applied to the piezoelectric buzzer 10 (the AC voltage) is hereinafter referred to as a "drive voltage".

[0012] The piezoelectric buzzer 10 includes, for example, two piezoelectric elements and a diaphragm forming a bimorph structure. Each of the piezoelectric elements and the diaphragm is disk-shaped, and the diaphragm is disposed between the two piezoelectric elements. The piezoelectric buzzer 10 further includes a housing that holds the diaphragm. Each piezoelectric element expands and contracts due to the AC voltage applied between two input terminals 11 and 12 of the piezoelectric buzzer 10, thereby vibrating the diaphragm of the piezoelectric buzzer 10 in a thickness direction thereof. The diaphragm (and the housing) is(are) mechanically vibrated at a frequency of the drive voltage applied to each piezoelectric element, so that the piezoelectric buzzer 10 outputs an output sound. Note that the piezoelectric buzzer 10 may have a unimorph structure instead of the bimorph structure.

[0013] The relationship between a frequency and a sound pressure of the output sound from the piezoelectric buzzer 10 is determined based on, for example, characteristics (e.g., the quality of materials, shapes, and sizes) of the two piezoelectric elements, the diaphragm, and the housing of the piezoelectric buzzer 10. The relationship between the frequency and a sound pressure level of the output sound from the piezoelectric buzzer 10 is hereinafter also referred to as a frequency characteristic of the piezoelectric buzzer 10.

[0014] The frequency and the sound pressure level of the output sound from the piezoelectric buzzer 10 have, for example, a relationship (frequency characteristic) as shown in the upper section in FIG. 3. The sound pressure level denotes the magnitude of the sound pressure with respect to a reference sound pressure (e.g., 20×10^{-6} Pa). The piezoelectric buzzer 10 has, for example, a frequency characteristic which achieves a maximum sound pressure level at, for example, about 4 kHz.

[0015] According to the frequency characteristic of the piezoelectric buzzer 10, a frequency closer to a prescribed frequency band tends to correspond to a higher sound pressure level, and a frequency farther away from the prescribed frequency band tends to correspond to a lower sound pressure level. For example, when a plurality of AC voltages having the same amplitude and different frequencies are applied to the piezoelectric buzzer 10, the sound pressure level of the output sound from the piezoelectric buzzer 10 at a frequency closer to the prescribed frequency band is higher, whereas the sound pressure level of the output sound from the piezoelectric buzzer 10 at a frequency farther away from the prescribed frequency band is lower.

[0016] When the frequency of the warning sound is about 1 kHz, a piezoelectric buzzer having a frequency characteristic according to which the sound pressure level peaks (has a global maximum) at about 1 kHz is at least adopted in order to increase the sound pressure level of the warning sound. In general, the size (e.g., diameter) of a piezoelectric buzzer and power consumption of the piezoelectric buzzer for outputting an output sound increase with a reduction in frequency at which a sound pressure level of the output sound shows a peak. Thus, when the size of the piezoelectric buzzer is

not allowed to be increased or when the power consumption is not allowed to be increased, it becomes difficult to adopt a piezoelectric buzzer having a frequency characteristic according to which the sound pressure level peaks at about 1 kHz.

[0017] In contrast, the acoustic system 100 of the present embodiment emphasizes at least one harmonic included in the drive voltage to increase the sound pressure level of the warning sound. That is, the drive voltage includes a fundamental wave and a plurality of harmonics. In the present disclosure, the term "harmonics" denotes frequency components that are integral multiples of the fundamental frequency of the drive voltage. Moreover, "fundamental frequency" mentioned in the present disclosure means the frequency of the fundamental wave. The plurality of harmonics of the drive voltage include at least one harmonic that causes the sound pressure level of the output sound from the piezoelectric buzzer 10 to be higher than at the fundamental frequency of the drive voltage. In the acoustic system 100, emphasizing the at least one harmonic enables the sound pressure level of the harmonic of the warning sound to be increased, which consequently enables the sound pressure level of the warning sound to be increased. In particular, emphasizing a harmonic in the vicinity of the peak of the sound pressure level of the output sound in the frequency characteristic of the piezoelectric buzzer 10 enables the sound pressure level of the warning sound to be increased significantly.

(2) Configuration of Acoustic Device for Warning Sound

[0018] The acoustic device 1 is configured to vibrate the piezoelectric buzzer 10. As illustrated in FIG. 1, the acoustic device 1 includes a resonance circuit 2 and a switching circuit 3. The acoustic device 1 further includes a voltage measuring device 4 and a voltage controller 5.

[0019] The resonance circuit 2 is electrically connected between the two input terminals 11 and 12 of the piezoelectric buzzer 10. That is, the resonance circuit 2 is electrically connected in parallel to the piezoelectric buzzer 10.

[0020] The voltage controller 5 includes a voltage control circuit including, for example, a three-terminal regulator. The voltage controller 5 controls the magnitude of a direct-current (DC) voltage applied from a power supply 200 to output a DC voltage V1. The voltage controller 5 controls the magnitude of the DC voltage V1 based on, for example, a control signal provided from a controller 31 of the switching circuit 3. The voltage controller 5 is electrically connected to the one input terminal 11 of the two input terminals 11 and 12 of the piezoelectric buzzer 10. The voltage controller 5 applies the DC voltage V1 to a parallel circuit of the piezoelectric buzzer 10 and the resonance circuit 2 with the other input terminal 12 of the two input terminals 11 and 12 of the piezoelectric buzzer 10 being electrically connected to a circuit ground via a transistor 32 of the switching circuit 3. Note that the voltage controller 5 is not limited to including the three-terminal regulator but may include a step-down chopper circuit or a step-up/down chopper circuit.

[0021] The switching circuit 3 includes the controller 31 and the transistor 32. The transistor 32 is, for example, an NPN transistor. The transistor 32 has a collector end electrically connected to the input terminal 12 of the piezoelectric buzzer 10. The transistor 32 has an emitter end electrically connected to the circuit ground. The transistor 32 has a base end connected to the controller 31. The transistor 32 is provided to switch between a state where the DC voltage V1 is applied to the piezoelectric buzzer 10 from the voltage controller 5 and a state where the DC voltage V1 is not applied to the piezoelectric buzzer 10 from the voltage controller 5.

[0022] The controller 31 is realized, for example, in such a way that a microcomputer included in the acoustic device 1 reads a program from memory included in the microcomputer, external memory included in the acoustic device 1, or the like and executes the program. The controller 31 outputs a control signal VB by a pulse width modulation (PWM) control method. As illustrated in FIG. 2, the control signal VB is a voltage signal whose voltage level alternately switches between a high level and a low level. The voltage waveform of the control signal VB is, for example, a square waveform.

[0023] The controller 31 outputs the control signal VB to the base end of the transistor 32. The controller 31 realizes a conduction state (so-called ON state) between the collector end and the emitter end of the transistor 32 when the voltage level of the control signal VB is the high level. The controller 31 realizes a non-conduction state (so-called OFF state) between the collector end and the emitter end of the transistor 32 when the voltage level of the control signal VB is the low level. That is, the controller 31 outputs the control signal VB to the base end of the transistor 32 to periodically alternates between a state where the DC voltage V1 is applied to the piezoelectric buzzer 10 and a state where the DC voltage V1 is not applied to the piezoelectric buzzer 10. Thus, the resonance circuit 2 receives a first voltage having a square waveform in which the voltage level periodically alternates between the high level and the low level. A voltage value of a case where the voltage level of the first voltage is the high level is, for example, substantially equal to the voltage value of the DC voltage V1. A voltage value of a case where the voltage level of the first voltage is the low level is, for example, substantially zero. Note that in the present embodiment, a drive voltage V2 including a composite voltage of the first voltage and a second voltage which will be described later appears across the resonance circuit 2, but the appearance of only the first voltage across the resonance circuit 2 does not occur.

[0024] That is, the switching circuit 3 is configured to periodically repeat a time period including an ON time period and an OFF time period and to output the first voltage to the resonance circuit 2. A voltage level of the first voltage during the ON time period is a high level, and the voltage level of the first voltage during the OFF time period is a low level.

[0025] The resonance circuit 2 includes, for example, a coil L1. The coil L1 is connected between the two input terminals 11 and 12 of the piezoelectric buzzer 10 and is electrically connected in parallel to the piezoelectric buzzer 10. The piezoelectric buzzer 10 includes a capacitance component including piezoelectric elements and a diaphragm, and therefore, the coil L1 and the capacitance component of the piezoelectric buzzer 10 form an LC resonance circuit. That is, the piezoelectric buzzer 10 serves as both a buzzer for outputting a warning sound and a capacitance component of the LC resonance circuit. The resonance circuit 2 generates, from electrical energy applied during the ON time period, the second voltage which oscillates at an oscillation frequency f1 during the OFF time period. The resonance circuit 2 outputs to the piezoelectric buzzer 10a composite voltage of the second voltage and the first voltage as the drive voltage V2. The oscillation frequency f1 of the second voltage is adjusted by, for example, an inductive component of the coil L1.

[0026] The resonance circuit 2 can generate the second voltage through the capacitance component of the piezoelectric buzzer 10 without being provided with an additional capacitor. Thus, the resonance circuit 2 realizes downsizing and a reduction in manufacturing cost of the acoustic device 1.

[0027] The voltage measuring device 4 is connected between the two input terminals 11 and 12 of the piezoelectric buzzer 10 and is electrically connected in parallel to the resonance circuit 2. The voltage measuring device 4 performs A/D conversion of a voltage across the resonance circuit 2 by, for example, an A/D conversion function of the micro-computer included in the acoustic device 1 to measure a value of the voltage. The voltage measuring device 4 measures, for example, voltage values of the second voltage during a period longer than one period so as to measure a peak-to-peak value of the second voltage. The peak-to-peak value means an absolute value of the difference between a maximum value and a minimum value of the second voltage during one period.

[0028] Here, based on the peak-to-peak value of the second voltage measured by the voltage measuring device 4, the controller 31 of the switching circuit 3 performs feedback control of the magnitude of the DC voltage V1 to be output from the voltage controller 5. For example, when the peak-to-peak value of the second voltage is larger than a specified value, the controller 31 controls the voltage controller 5 such that the magnitude of the DC voltage V1 is reduced and the peak-to-peak value of the second voltage approximates to the specified value. Thus, the voltage controller 5 at least increases the voltage level (i.e., the DC voltage V1) of the first voltage of the ON time period as the peak-to-peak value of the second voltage measured by the voltage measuring device 4 decreases.

[0029] Note that the peak-to-peak value of a case where the second voltage is not the AC voltage means, for example, an absolute value of the difference between a maximum value and a minimum value during one time period of a case where the second voltage periodically changes.

(3) Operation of Acoustic Device for Warning Sound

[0030] Next, with reference to FIGS. 2 to 4, operation of the acoustic device 1 will be described in detail. Basic operation of an acoustic device 1, operation of a comparative example, and operation of the acoustic device 1 according to the present embodiment are sequentially described below. The comparative example mentioned herein denotes an acoustic device including a resistance component instead of the resonance circuit 2 of the acoustic device 1 of the present embodiment.

(3.1) Basic Operation

[0031] The controller 31 is configured to cause the piezoelectric buzzer 10 to periodically output a warning sound for about several seconds (two to three seconds), but in the following description, a warning sound which the piezoelectric buzzer 10 outputs during a predetermined time (e.g., one second) will be described.

[0032] The controller 31 includes a timer configured to measure an elapsed time, and based on the elapsed time measured by the timer, the controller 31 sets a time period T0, an ON time period T1, and an OFF time period T2 as shown in FIG. 2. The time period T0 is a time period corresponding to the sum of the ON time period T1 and the OFF time period T2. FIG. 2 shows waveforms of the control signal VB and the drive voltage V2, where the abscissa is a time axis.

[0033] The controller 31 maintains the voltage level of the control signal VB at a high level (denoted by "H" in FIG. 2) during the ON time period T1. When the voltage level of the control signal VB input to the base end of the transistor 32 transitions to the high level, the transistor 32 of the switching circuit 3 conducts between the collector end and the emitter end. As a result, the first voltage (DC voltage V1) having a high voltage level is applied to the piezoelectric buzzer 10 and the resonance circuit 2 during the ON time period T1, and the magnitude of the drive voltage V2 applied to the piezoelectric buzzer 10 becomes substantially equal to the magnitude of the DC voltage V1.

[0034] The controller 31 sets the OFF time period T2 following the ON time period T1 in the time period T1 and switches the voltage level of the control signal VB from the high level to the low level (denoted by "L" in FIG. 2). The OFF time period T2 corresponds to a length obtained by subtracting the length of the ON time period T1 from the length of the time period T0. The OFF time period T2 is, for example, longer than or equal to one period of the second voltage. The length of the OFF time period T2 is determined such that the OFF time period T2 includes a plurality of periods of the

second voltage.

[0035] The controller 31 maintains the voltage level of the control signal VB at the low level during the OFF time period T2. When the voltage level of the control signal VB input to the base end of the transistor 32 transitions to the low level, the transistor 32 of the switching circuit 3 does not conduct between the collector end and the emitter end. As a result, the first voltage whose voltage level is the low level is applied to the piezoelectric buzzer 10 and resonance circuit 2 during the OFF time period T2. In other words, during the OFF time period T2, the DC voltage V1 is no longer applied to the piezoelectric buzzer 10 and the resonance circuit 2.

[0036] That is, the switching circuit 3 periodically repeats the time period T0 including the ON time period T1 and the OFF time period T2 and outputs the first voltage to the resonance circuit 2. The voltage level of the first voltage during the ON time period T1 is the high level, and the voltage level of the first voltage during the OFF time period T2 is the low level.

[0037] In the present embodiment, the length of a period, namely the time period T1 is set to, for example, 1/1,000[sec] in length, where the voltage level of the first voltage is switched from the low level to the high level at beginning and end of the period. In other words, the period of the first voltage is 1/1,000[sec], and the frequency of the first voltage is 1 kHz. In this embodiment, the frequency of the first voltage is a fundamental frequency f0 of the drive voltage V2 applied to the piezoelectric buzzer 10. Thus, the time period T0 (=1/f0) which is a period of the drive voltage V2 is 1/1,000[sec], and the fundamental frequency f0 of the drive voltage V2 is 1 kHz. Moreover, the length of the ON time period T1 is, for example, 1/8,000[sec].

[0038] During the OFF time period T2 during which the DC voltage V1 is no longer applied to the resonance circuit 2, electrical energy applied to the coil L1 during the ON time period T1 is supplied from the coil L1 to the piezoelectric buzzer 10, thereby generating a second voltage which oscillates at the oscillation frequency f1. The second voltage is generated across the resonance circuit 2 (coil L1). Thus, a composite voltage of the first voltage and the second voltage as the drive voltage V2 is applied to the piezoelectric buzzer 10. Thus, as illustrated in FIG. 2, the drive voltage V2 oscillates at the oscillation frequency f1 during the OFF time period T2.

[0039] In the present embodiment, the oscillation frequency f1 of the second voltage is, for example, 4 kHz, and the period T3 (=1/f1) of the second voltage is 1/4,000[sec]. The OFF time period T2 includes a plurality of periods of (in this embodiment, at least three periods of) the second voltage. Moreover, since the switching circuit 3 and the coil L1 serve as a step-up circuit, the peak-to-peak value of the second voltage is relatively larger than the peak-to-peak value of the first voltage. However, the embodiment is not limited to this example, but the peak-to-peak value of the second voltage may be relatively smaller than the peak-to-peak value of the first voltage.

(3.2) Operation of Comparative Example

[0040] Next, with reference to FIG. 3, operation of a comparative example will be described. The comparative example includes a resistance component instead of the resonance circuit 2 of the acoustic device 1 according to the present embodiment. The configuration of the acoustic device according to the comparative example is the same as the configuration of the acoustic device 1 according to the present embodiment except that the resistance component is included instead of the resonance circuit 2. Therefore, in the following description, elements similar to those in the acoustic device 1 according to the present embodiment are denoted by the same reference signs as those in the present embodiment, and the description thereof is accordingly omitted. The upper section, middle section, and lower section in FIG. 3 respectively show the frequency characteristic of the piezoelectric buzzer 10, the frequency characteristic of a drive voltage Vc2 of the comparative example, and the frequency characteristic of a warning sound of the comparative example.

[0041] The first voltage is a voltage applied to a parallel circuit of the resonance circuit 2 and the piezoelectric buzzer 10, and therefore, when the resonance circuit 2 is omitted, the first voltage equals to the drive voltage Vc2. In this case, the voltage waveform of the first voltage is a square waveform, and therefore, the drive voltage Vc2 includes a fundamental wave and a plurality of harmonics. The frequency of the fundamental wave is denoted by f0. The fundamental frequency (the frequency of the fundamental wave) f0 in this case is 1 kHz. Moreover, as illustrated in FIG. 3, the plurality of harmonics of the drive voltage Vc2 include a second harmonic whose frequency is denoted by 2f0 and a third harmonic whose frequency is denoted by 3f0. The drive voltage Vc2 further includes, for example, a fourth harmonic whose frequency is denoted by 4f0, a fifth harmonic whose frequency is denoted by 5f0, and a sixth harmonic whose frequency is denoted by 6f0. Here, the fundamental frequency f0 in the present comparative example is 1 kHz, and therefore, the frequencies 2f0, 3f0, 4f0, 5f0, and 6f0 respectively correspond to 2 kHz, 3 kHz, 4 kHz, 5 kHz, and 6 kHz. As illustrated in FIG. 3, a component of the fundamental frequency f0 of frequency components included in the drive voltage Vc2 has the largest peak-to-peak value, and the peak-to-peak value of each harmonic component decreases as the order of the harmonic increases.

[0042] Here, according to the frequency characteristic of the piezoelectric buzzer 10, as illustrated in FIG. 3, the sound pressure level of the output sound from the piezoelectric buzzer 10 is higher at each of the frequencies 2f0, 3f0, 4f0, 5f0, and 6f0 of the second to sixth harmonics of the drive voltage Vc2 than at the fundamental frequency f0 of the drive voltage Vc2. In other words, the drive voltage Vc2 includes harmonics at frequencies of which the sound pressure level

of the output sound from the piezoelectric buzzer 10 is higher than at the fundamental frequency f_0 . In the example in FIG. 3, when the sound pressure level of the output sound from the piezoelectric buzzer 10 at the fundamental frequency f_0 is assumed to correspond to a prescribed value f_N , the sound pressure level of the output sound from the piezoelectric buzzer 10 at each of the frequencies $2f_0$, $3f_0$, $4f_0$, $5f_0$, and $6f_0$ is higher than the prescribed value f_N . In particular, in the example in FIG. 3, the sound pressure level peaks (has a global maximum) at about the frequency $4f_0$ ($=4$ kHz) of the fourth harmonic. Here, a frequency at which the sound pressure level peaks in the frequency characteristic is a synonymous with a frequency at which the sound pressure level of the output sound from the piezoelectric buzzer 10 becomes maximum within a prescribed frequency range (e.g., 0 kHz to $6f_0$).

[0043] Thus, the frequency characteristic of a warning sound provided from the piezoelectric buzzer 10 at the time of application of the drive voltage V_{c2} to the piezoelectric buzzer 10 is as shown in the lower section in FIG. 3. That is, in the warning sound of the comparative example, the sound pressure level at the frequency $4f_0$ of the fourth harmonic is higher than sound pressure levels at the frequencies of the harmonics other than the fourth harmonic or a sound pressure level at the fundamental frequency f_0 .

(3.3) Operation of Acoustic Device According to Present Embodiment

[0044] Next, operation of the acoustic device 1 according to the present embodiment will be described with reference to FIG. 4. The upper section, middle section, and lower section in FIG. 4 respectively show the frequency characteristic of the piezoelectric buzzer 10, the frequency characteristic of the drive voltage V_2 , and the frequency characteristic of the warning sound.

[0045] The oscillation frequency f_1 of the second voltage is adjusted by the inductive component and the like of the coil L_1 as described above. In the present embodiment, the oscillation frequency f_1 of the second voltage has a relationship satisfying the following Formula 1

$$f_{n-1/2f_0} \leq f_1 \leq f_{n+1/2f_0}, \dots \text{ (Formula 1)}$$

where f_n is a frequency of an N th harmonic, and f_0 is the fundamental frequency.

[0046] Here, the N th harmonic is one harmonic of the plurality of harmonics of the drive voltage V_2 , a sound pressure level of an output sound from the piezoelectric buzzer 10 at the N th harmonic being higher than a sound pressure level of the output sound from the piezoelectric buzzer 10 at the fundamental frequency f_0 of the drive voltage V_2 . As illustrated in FIG. 4, when the sound pressure level of the output sound from the piezoelectric buzzer 10 at the fundamental frequency f_0 is assumed to correspond to a prescribed value f_N , the sound pressure level of the output sound from the piezoelectric buzzer 10 at each of the frequencies $2f_0$, $3f_0$, $4f_0$, $5f_0$, and $6f_0$ is higher than the prescribed value f_N . Thus, each of the second to sixth harmonics of the drive voltage V_2 can correspond to the N th harmonic of the specific frequency. In the present embodiment, the sound pressure level peaks (has a global maximum) at about the frequency $4f_0$ ($=4$ kHz) of the fourth harmonic, and therefore, the fourth harmonic is defined as the N th harmonic. In sum, the oscillation frequency f_1 of the second voltage has a relationship satisfying the following Formula 2

$$4f_0 - 1/2f_0 \leq f_1 \leq 4f_0 + 1/2f_0, \dots \text{ (Formula 2)}$$

where f_0 is the fundamental frequency.

[0047] That is, the oscillation frequency f_1 of the second voltage is adjusted to correspond to integral multiples of (in the present embodiment, four times) the fundamental frequency f_0 of the drive voltage V_2 . The term "integral multiples" mentioned herein does not strictly mean the integral multiples but may include a tolerance. That is, the oscillation frequency f_1 of the second voltage is not strictly integral multiples of the oscillation frequency (fundamental frequency f_0) of the first voltage but may include a tolerance. In this embodiment, for example, the fundamental frequency f_0 is 1 kHz, and the oscillation frequency f_1 is adjusted to be about 4 kHz corresponding to a frequency four times the fundamental frequency f_0 . Thus, the oscillation frequency f_1 is substantially equal to the frequency of the fourth harmonic of the drive voltage V_2 (i.e., $f_1 = 4f_0$). Thus, in the drive voltage V_2 applied to the piezoelectric buzzer 10, the N th harmonic (here, fourth harmonic) is emphasized as illustrated in FIG. 4.

[0048] Thus, the frequency characteristic of the warning sound provided from the piezoelectric buzzer 10 at the time of application of the drive voltage V_2 to the piezoelectric buzzer 10 is as shown in the lower section in FIG. 4. That is, in the acoustic device 1 according to the present embodiment, a warning sound in which the fourth harmonic of the frequency $4f_0$ is emphasized more than in the warning sound (see FIG. 3) of the comparative example is output from the piezoelectric buzzer 10. Moreover, as illustrated in FIG. 4, in the acoustic device 1 according to the present embodiment, not only the fourth harmonic but also the third harmonic and the fifth harmonic around the fourth harmonic are

emphasized in the warning sound.

[0049] An increased sound pressure level of a harmonic corresponding to an integer multiple of the fundamental frequency f_0 in the warning sound provides an effect that a person who hears the warning sound is more likely to sense the sound at the fundamental frequency f_0 . This effect is known as a missing fundamental based on psychoacoustics. In other words, emphasizing the harmonic of the warning sound simulatively causes the warning sound at the fundamental frequency f_0 to sound loud to a person who hears the warning sound. Thus, as a result of the emphasis of the Nth harmonic (here, fourth harmonic) of the warning sound as described above, a person who hears the warning sound is more likely to sense a sound at the fundamental frequency f_0 due to the missing fundamental based on psychoacoustics. In other words, also when the piezoelectric buzzer 10 is caused to output a warning sound at a frequency (here, 1 kHz) lower than a frequency (here, 4 kHz) at which the sound pressure of the output sound from the piezoelectric buzzer 10 is maximum, the sound pressure level of the warning sound can be increased.

[0050] In order to emphasize the Nth harmonic of the drive voltage V_2 , the oscillation frequency f_1 of the second voltage is at least set to satisfy Formula 1, but as described above, the oscillation frequency f_1 does not have to correspond to integer multiples of the fundamental frequency f_0 of the drive voltage V_2 . That is, when the fourth harmonic is emphasized as described above, the oscillation frequency f_1 is only required to be within a range of $\pm 1/2f_0$ from $4f_0$. That is, the oscillation frequency f_1 is only required to be within a range indicated by A1 in FIG. 4. In FIG. 4, "fa" denotes " $4f_0 - 1/2f_0$ ", and "fb" denotes " $4f_0 + 1/2f_0$ ". That is, of the plurality of harmonics of the drive voltage V_2 , a harmonic which is closest to the oscillation frequency f_1 is emphasized, and therefore, when the oscillation frequency f_1 satisfies Formula 1, the Nth harmonic of the frequency f_n is emphasized.

[0051] Moreover, as described in the present embodiment, a difference between the frequency of the Nth harmonic and a frequency at which the sound pressure level of the output sound from the piezoelectric buzzer 10 becomes maximum within a prescribed frequency range is preferably smaller than or equal to the fundamental frequency f_0 . In other words, the Nth harmonic is preferably a harmonic included in the plurality of harmonics of the drive voltage V_2 and having a frequency which is different by at most the fundamental frequency f_0 from the frequency $4f_0$ at which the sound pressure level of the output sound from the piezoelectric buzzer 10 peaks (has a global maximum). Thus, a harmonic closest to the frequency which is included in the plurality of harmonics of the drive voltage V_2 and at which the sound pressure level of the output sound from the piezoelectric buzzer 10 peaks is emphasized, so that the Nth harmonic is emphasized, which enables the sound pressure level of the warning sound to be further increased.

[0052] Here, the oscillation frequency f_1 of the second voltage can be determined by, for example, adjusting the inductive component of the coil L1 of the resonance circuit 2. The oscillation frequency f_1 of the second voltage is set at least to satisfy Formula 1, and thus, an adjustment width of the inductive component of the coil L1 of the resonance circuit 2 is relatively large. Thus, the inductive component of the coil L1 is easily adjusted. Moreover, even when a temperature change or aging degrades the inductive component of the coil L1, the piezoelectric buzzer 10 can maintain a state where the sound pressure of the warning sound is high as long as Formula 1 is satisfied.

[0053] An example in which in the frequency characteristic of the piezoelectric buzzer 10, the sound pressure level of the output sound peaks (has global maximum) at 4 kHz has been described. However, the frequency is not limited to this example, and the sound pressure level of the output sound may peak at any frequency lower than or equal to 4 kHz or higher than or equal to 4 kHz. Moreover, the fundamental frequency f_0 of the drive voltage V_2 is not limited to 1 kHz but is required only to be a frequency lower than the frequency (in the present embodiment, 4 kHz) at which the sound pressure level of the output sound from the piezoelectric buzzer 10 shows a peak. Moreover, the oscillation frequency f_1 of the second voltage is not limited to 4 kHz but may have any value that satisfies Formula 1. For example, when the sound pressure level of the output sound from the piezoelectric buzzer 10 peaks (has a global maximum) at the frequency $2f_0$ of the second harmonic of the drive voltage V_2 , the sound pressure of the warning sound becomes high with the oscillation frequency f_1 of the second voltage being set to about the frequency $2f_0$ (within the range of $\pm f_0$ from $2f_0$).

(4) Summary

[0054] As described above, the acoustic device 1 for warning sound in the first embodiment is an acoustic device for warning sound configured to mechanically vibrate the piezoelectric buzzer 10 to output a warning sound. The acoustic device 1 for warning sound includes the resonance circuit 2 and the switching circuit 3. The switching circuit 3 is configured to periodically repeat the time period T_0 including the ON time period T_1 and the OFF time period T_2 . The switching circuit 3 is configured to output a first voltage. A voltage level of the first voltage during the ON time period T_1 is a high level. The voltage level of the first voltage during the OFF time period T_2 is a low level. The resonance circuit 2 is configured to receive the first voltage. The resonance circuit 2 is configured to generate, from electrical energy applied during the ON time period T_1 , a second voltage which oscillates at an oscillation frequency f_1 during the OFF time period T_2 and to output a composite voltage of the first voltage and the second voltage to the piezoelectric buzzer 10. The composite voltage serves as a drive voltage V_2 . A relationship among a frequency f_n of an Nth harmonic, a fundamental frequency f_0 , and the oscillation frequency f_1 is $f_n - 1/2f_0 \leq f_1 \leq f_n + 1/2f_0$, where the Nth harmonic is one harmonic of a

plurality of harmonics of the drive voltage V2, a sound pressure level of an output sound from the piezoelectric buzzer 10 at the Nth harmonic being higher than a sound pressure level of the output sound from the piezoelectric buzzer 10 at the fundamental frequency f0 of the drive voltage V2.

[0055] With this configuration, the resonance circuit 2 generates the second voltage of the oscillation frequency f1 to emphasize the Nth harmonic in the drive voltage V2 to be output to the piezoelectric buzzer 10. The Nth harmonic is one harmonic of the plurality of harmonics of the drive voltage V2, the sound pressure level of the output sound from the piezoelectric buzzer 10 at the Nth harmonic being higher than a sound pressure level of the output sound from the piezoelectric buzzer 10 at the fundamental frequency f0 of the drive voltage V2. Thus, emphasizing the Nth harmonic of the drive voltage V2 enables the sound pressure level of the warning sound to be increased. Thus, for example, also when the piezoelectric buzzer 10 is caused to output a warning sound of a frequency lower than a frequency at which the sound pressure of the output sound from the piezoelectric buzzer 10 is maximum, the sound pressure level of the warning sound can be increased. Consequently, the acoustic device 1 provides the advantage that the sound pressure level of the warning sound can be increased also when a warning sound at a relatively low frequency is output.

[0056] In the acoustic device 1 for warning sound of the present embodiment, a difference between the frequency of the Nth harmonic and a frequency at which the sound pressure level of the output sound from the piezoelectric buzzer 10 becomes maximum within a prescribed frequency range is preferably smaller than or equal to the fundamental frequency f0. Thus, emphasizing the Nth harmonic of the drive voltage V2 can increase the sound pressure level of the warning sound at about the frequency at which the sound pressure level of the output sound from the piezoelectric buzzer 10 becomes maximum within the prescribed frequency range. Thus, the sound pressure level of the warning sound can be further increased.

[0057] In the acoustic device 1 for warning sound of the present embodiment, the OFF time period T2 preferably has a length longer than or equal to one period (here, period T3) of the second voltage. Thus, the second voltage corresponding to at least one period is included in the OFF time period T2, and therefore, the sound pressure of the warning sound can be increased more than in a case where the second voltage is not included in the OFF time period T2.

[0058] In the acoustic device 1 for warning sound of the present embodiment, the OFF time period T2 preferably includes a plurality of periods (here, three periods) of the second voltage. For example, as the number of periods of the second voltage included in the OFF time period T2 increases, the sound pressure of the warning sound increases.

[0059] The acoustic device 1 for warning sound of the present embodiment preferably further includes the voltage measuring device 4 and the voltage controller 5. The voltage measuring device 4 is configured to measure a peak-to-peak value of the second voltage. The voltage controller 5 is configured to increase the voltage level of the first voltage (here, DC voltage V1) of the ON time period T1 as the peak-to-peak value decreases. With this configuration, the voltage controller 5 increases the voltage level of the first voltage of the ON time period T1 as the peak-to-peak value of the second voltage decreases, which can suppress a reduction of the peak-to-peak value of the second voltage. On the other hand, the voltage controller 5 reduces the voltage level of the first voltage of the ON time period T1 as the peak-to-peak value of the second voltage of the OFF time period T2 increases, which can suppress an increase of the peak-to-peak value of the second voltage. The peak-to-peak value of the second voltage may vary for each OFF time period T2 due to, for example, a temperature change around the resonance circuit 2, the aging of the resonance circuit 2, or the like. In this case, the acoustic device 1 for warning sound is capable of adjusting the voltage level of the ON time period T1 based on the peak-to-peak value of the second voltage, and therefore, variations of the sound pressure of the warning sound can be reduced.

[0060] The acoustic system 100 of the present embodiment includes the acoustic device 1 for warning sound and the piezoelectric buzzer 10. With this configuration, since the acoustic system 100 includes the acoustic device 1 for warning sound, the acoustic system 100 provides the advantage that the sound pressure level of the warning sound can be increased also when a warning sound at a relatively low frequency is output.

[0061] The resonance circuit 2 may include a resistor, a capacitor, and the like in addition to the coil L1. The switching circuit 3 may include a semiconductor switching element such as a metal-oxide-semiconductor field-effect transistor (MOSFET) instead of the transistor 32.

[0062] A case where as illustrated in FIG. 2, the peak-to-peak value of the second voltage becomes maximum during a time period corresponding to the first half period has been described, but the time period is not limited to this example. A timing at which the peak-to-peak value of the second voltage becomes maximum is determined based on resonance characteristics of the resonance circuit 2 and the piezoelectric buzzer 10. Thus, the peak-to-peak value of the second voltage may become maximum after the first half period.

[0063] The ON time period T1 is at least a time period during which the voltage level of the first voltage is the high level. For example, the ON time period T1 is not limited to a time period during which the controller 31 of the switching circuit 3 turns on the transistor 32, but the ON time period T1 may be a time period during which the controller 31 turns off the transistor 32. Similarly, the OFF time period T2 is at least a time period during which the voltage level of the first voltage is the low level. For example, the OFF time period T2 is not limited to a time period during which the controller 31 turns off the transistor 32, but the OFF time period T2 may be a time period during which the controller 31 turns on

the transistor 32.

[0064] Moreover, the fundamental frequency f_0 (i.e., frequency of the first voltage) of the drive voltage V_2 applied to the piezoelectric buzzer 10 is not necessarily fixed but may continuously change (sweep) or may be switched between a plurality of frequencies.

First Variation

[0065] An acoustic device for warning sound according to a first variation of the first embodiment is configured such that a switching circuit 3 varies the length of an ON time period T_1 and the length of an OFF time period T_2 .

[0066] The acoustic device for warning sound of the first variation includes a voltage measuring device 4 configured to measure a peak-to-peak value of a second voltage. The switching circuit 3 is configured to increase the ON time period T_1 and to reduce the length of the OFF time period T_2 as the peak-to-peak value decreases. When the ON time period T_1 increases, electrical energy accumulated in a coil L1 increases, thereby increasing the peak-to-peak value of the second voltage. On the other hand, the switching circuit 3 reduces the ON time period T_1 and increases the length of the OFF time period T_2 as the peak-to-peak value increases. Thus, the acoustic device for warning sound of the first variation can reduce variations of the sound pressure of the warning sound also when the peak-to-peak value of the second voltage varies for each OFF time period T_2 . Here, the peak-to-peak value of the second voltage may be, for example, a maximum peak-to-peak value of the second voltage during the OFF time period T_2 or the peak-to-peak value of the second voltage during any period (e.g., first period) during the OFF time period T_2 .

Second Embodiment

[0067] An acoustic device 1A for warning sound according to a second embodiment will be described with reference to FIG. 5. Note that components similar to those in the acoustic device 1 for warning sound of the first embodiment are denoted by the same reference signs as those in the first embodiment, and the description thereof will be omitted.

[0068] The acoustic device 1A for warning sound (hereinafter also referred to as an acoustic device 1A) is configured to control a current flowing through a resonance circuit 2A based on a peak-to-peak value of a second voltage. The acoustic device 1A is different from the acoustic device 1 for warning sound according to the first embodiment in the configurations of the resonance circuit 2A, a switching circuit 3A, and a voltage measuring device 4A.

[0069] The resonance circuit 2A includes a coil L1 and a current controller 6 (61). The current controller 61 includes, for example, two resistors 64 and 65, and a switch 63. The resistor 65 is connected in series to the coil L1. The resistor 64 and the switch 63 are connected in series to each other. A series circuit of the resistor 64 and the switch 63 is connected in parallel to the resistor 65. The current controller 61 limits a current which flows to the coil L1.

[0070] The switch 63 includes, for example, a semiconductor switch such as a transistor and switches between a conduction state and a non-conduction state depending on a control signal from a controller 31. The switch 63 is, for example, a normally open switch. When the switch 63 is in the non-conduction state, the resistor 65 connected to the coil L1 is in a connected state, and the resistor 65 limits a current flowing to the coil L1. On the other hand, when the switch 63 is in the conduction state, a resistance component connected to the coil L1 serves as a composite resistor of the resistors 64 and 65. Therefore, the resistance value of the resistance component is smaller than the resistance value of the resistor 65 alone, and the current flowing to the coil L1 increases. The peak-to-peak value of the second voltage increases as the current flowing to the coil L1 increases, whereas the peak-to-peak value of the second voltage decreases as the current flowing to the coil L1 decreases.

[0071] The voltage measuring device 4A is connected between two input terminals 11 and 12 of a piezoelectric buzzer 10 and is electrically connected in parallel to the resonance circuit 2A. The voltage measuring device 4A has a similar configuration to the voltage measuring device 4.

[0072] The switching circuit 3A includes the controller 31, a transistor 32, and a current controller 6 (62). The current controller 62 has a similar configuration to the current controller 61. The current controller 62 has one end electrically connected to the controller 31 and the other end electrically connected to a base end of the transistor 32. The current controller 62 is configured to limit a current (control signal VB) provided from the controller 31 to the base end of the transistor 32. In the present embodiment, the control signal VB is a current signal. When the switch 63 transitions from the non-conduction state to the conduction state, a current flowing from the controller 31 to the base end of the transistor 32 increases. Thus, the current level of the control signal VB increases. When the current level of the control signal VB increases, the current flowing between the collector end and the emitter end of the transistor 32 increases. Thus, the current flowing through the resonance circuit 2A increases.

[0073] When the peak-to-peak value of the second voltage becomes smaller than or equal to a specified value, the controller 31 of the switching circuit 3A brings both the switches 63 of the two current controllers 6 into the conduction state. Thus, the current flowing to the coil L1 increases, and therefore, it is possible to increase the magnitude of a DC voltage V_1 and the peak-to-peak value of the second voltage. On the other hand, when the controller 31 causes both

the switches 63 of the two current controllers 6 to be in the non-conduction state, the current flowing through the coil L1 decreases, and therefore, it is possible to reduce the magnitude of the DC voltage V1 and the peak-to-peak value of the second voltage.

[0074] As described above, the acoustic device 1A for warning sound in the second embodiment includes the voltage measuring device 4A and the current controllers 6. The voltage measuring device 4A is configured to measure the peak-to-peak value of the second voltage. Each current controller 6 is configured to control a current flowing through the resonance circuit 2A based on the magnitude of the peak-to-peak value. With this configuration, the acoustic device 1A can reduce variations of the sound pressure of the warning sound also when the peak-to-peak value of the second voltage varies and the peak-to-peak value of the second voltage varies.

[0075] Note that the current controller 6 may be only one of the current controller 61 and the current controller 62.

Reference Signs List

[0076]

1, 1A	ACOUSTIC DEVICE FOR WARNING SOUND
10	PIEZOELECTRIC BUZZER
100	ACOUSTIC SYSTEM
2, 2A	RESONANCE CIRCUIT
3, 3A	SWITCHING CIRCUIT
4, 4A	VOLTAGE MEASURING DEVICE
5	VOLTAGE CONTROLLER
6	CURRENT CONTROLLER
T1	ON TIME PERIOD
T2	OFF TIME PERIOD

Claims

1. An acoustic device (1, 1A) configured to mechanically vibrate a piezoelectric buzzer (10) to output a warning sound, the acoustic device comprising:

a switching circuit (3, 3A) configured to periodically repeat a time period including an ON time period (T1) and an OFF time period (T2) and to output a first voltage having a square waveform in which a voltage level periodically alternates between a high level and a low level, the voltage level of the first voltage during the ON time period (T1) being the high level, the voltage level of the first voltage during the OFF time period (T2) being the low level; and

a resonance circuit (2, 2A) configured to receive the first voltage, the resonance circuit (2, 2A) being configured to generate, from electrical energy applied during the ON time period (T1), a second voltage which oscillates at an oscillation frequency f1 during the OFF time period (T2) and to output a composite voltage of the first voltage and the second voltage to the piezoelectric buzzer (10), the composite voltage serving as a drive voltage, wherein

a relationship among a frequency fn in kHz of an Nth harmonic, a fundamental frequency f0 in kHz of the drive voltage, and the oscillation frequency f1 in kHz is $f_n - 1/2f_0 \leq f_1 \leq f_n + 1/2f_0$, where the Nth harmonic is one harmonic of a plurality of harmonics of the drive voltage, a sound pressure level of an output sound from the piezoelectric buzzer (10) at the Nth harmonic being higher than a sound pressure level of the output sound from the piezoelectric buzzer (10) at the fundamental frequency f0.

2. The acoustic device (1, 1A) according to claim 1, wherein

a difference between the frequency of the Nth harmonic and a frequency at which the sound pressure level of the output sound from the piezoelectric buzzer (10) becomes maximum within a prescribed frequency range is smaller than or equal to the fundamental frequency f0.

3. The acoustic device (1, 1A) according to claim 1 or 2, wherein

the OFF time period (T2) is longer than or equal to one period of the second voltage.

4. The acoustic device (1, 1A) according to any one of claims 1 to 3, wherein

the OFF time period (T2) includes a plurality of periods of the second voltage.

5. The acoustic device (1, 1A) according to any one of claims 1 to 4, further comprising:

a voltage measuring device (5) configured to measure a peak-to-peak value of the second voltage; and
a voltage controller (4, 4A) configured to increase the voltage level of the first voltage of the ON time period (T1) as the peak-to-peak value decreases.

6. The acoustic device (1, 1A) according to any one of claims 1 to 5, further comprising: a voltage measuring device (5) configured to measure a peak-to-peak value of the second voltage, wherein the switching circuit (3, 3A) is configured to increase the ON time period (T1) and to reduce the OFF time period (T2) as the peak-to-peak value decreases.

7. The acoustic device (1, 1A) according to any one of claims 1 to 5, further comprising:

a voltage measuring device (5) configured to measure a peak-to-peak value of the second voltage; and
a current controller (6) configured to control a current flowing through the resonance circuit (2, 2A) based on a magnitude of the peak-to-peak value.

8. An acoustic system (100) comprising:

the acoustic device (1, 1A) according to any one of claims 1 to 7; and
the piezoelectric buzzer (10).

Patentansprüche

1. Akustische Vorrichtung (1, 1A), die so konfiguriert ist, dass sie einen piezoelektrischen Summer (10) mechanisch in Schwingung versetzt, um einen Warnton auszugeben, wobei die akustische Vorrichtung aufweist:

einen Schaltkreis (3, 3A), der konfiguriert ist, um periodisch eine Zeitperiode zu wiederholen, die eine EIN-Zeitperiode (T1) und eine AUS-Zeitperiode (T2) umfasst, und eine erste Spannung mit einer Rechteckwellenform auszugeben, bei der ein Spannungspegel periodisch zwischen einem hohen Pegel und einem niedrigen Pegel wechselt, wobei der Spannungspegel der ersten Spannung während der EIN-Zeitperiode (T1) der hohe Pegel ist und der Spannungspegel der ersten Spannung während der AUS-Zeitperiode (T2) der niedrige Pegel ist; und einen Resonanzkreis (2, 2A), der konfiguriert ist, um die erste Spannung zu empfangen, wobei der Resonanzkreis (2, 2A) konfiguriert ist, um aus elektrischer Energie, die während der EIN-Zeitperiode (T1) angelegt wird, eine zweite Spannung zu erzeugen, die während der AUS-Zeitperiode (T2) mit einer Oszillationsfrequenz f_1 oszilliert, und eine zusammengesetzte Spannung aus der ersten Spannung und der zweiten Spannung an den piezoelektrischen Summer (10) auszugeben, wobei die zusammengesetzte Spannung als Ansteuerspannung dient, wobei eine Beziehung zwischen einer Frequenz f_n in kHz einer N-ten Harmonischen, einer Grundfrequenz f_0 in kHz der Ansteuerspannung und der Oszillationsfrequenz f_1 in kHz $f_n - 1/2f_0 \leq f_1 \leq f_n + 1/2f_0$ ist, wobei die N-te Harmonische eine Harmonische aus mehreren Harmonischen der Ansteuerspannung ist, wobei ein Schalldruckpegel eines Ausgabeschalls des piezoelektrischen Summers (10) bei der N-ten Harmonischen höher ist als ein Schalldruckpegel des Ausgabeschalls des piezoelektrischen Summers (10) bei der Grundfrequenz f_0 .

2. Akustische Vorrichtung (1, 1A) nach Anspruch 1, wobei eine Differenz zwischen der Frequenz der N-ten Harmonischen und einer Frequenz, bei der der Schalldruckpegel des Ausgabeschalls des piezoelektrischen Summers (10) innerhalb eines vorgegebenen Frequenzbereichs maximal wird, kleiner oder gleich der Grundfrequenz f_0 ist.

3. Akustische Vorrichtung (1, 1A) nach Anspruch 1 oder 2, wobei die AUS-Zeitperiode (T2) länger als oder gleich einer Periode der zweiten Spannung ist.

4. Akustische Vorrichtung (1, 1A) nach einem der Ansprüche 1 bis 3, wobei die AUS-Zeitperiode (T2) mehrere Perioden der zweiten Spannung umfasst.

5. Akustische Vorrichtung (1, 1A) nach einem der Ansprüche 1 bis 4, ferner aufweisend:

eine Spannungsmessvorrichtung (5), die konfiguriert ist, um einen Spitze-Spitze-Wert der zweiten Spannung zu messen; und
einen Spannungsregler (4, 4A), der konfiguriert ist, um den Spannungspegel der ersten Spannung der EIN-Zeitperiode (T1) zu erhöhen, wenn der Spitze-Spitze-Wert abnimmt.

6. Akustische Vorrichtung (1, 1A) nach einem der Ansprüche 1 bis 5, ferner aufweisend: eine Spannungsmessvorrichtung (5), die konfiguriert ist, um einen Spitze-Spitze-Wert der zweiten Spannung zu messen, wobei der Schaltkreis (3, 3A) konfiguriert ist, um die EIN-Zeitperiode (T1) zu erhöhen und die AUS-Zeitperiode (T2) zu verringern, wenn der Spitze-Spitze-Wert abnimmt.

7. Akustische Vorrichtung (1, 1A) nach einem der Ansprüche 1 bis 5, ferner aufweisend:

eine Spannungsmessvorrichtung (5), die konfiguriert ist, um einen Spitze-Spitze-Wert der zweiten Spannung zu messen; und
einen Stromregler (6), der konfiguriert ist, um einen Strom, der durch den Resonanzkreis (2, 2A) fließt, auf der Grundlage einer Größe des Spitze-Spitze-Wertes zu steuern.

8. Akustisches System (100), aufweisend:

die akustische Vorrichtung (1, 1A) nach einem der Ansprüche 1 bis 7; und
den piezoelektrischen Summer (10).

Revendications

1. Dispositif acoustique (1, 1A) configuré de manière à faire vibrer mécaniquement un vibreur piézoélectrique (10) en vue de fournir en sortie un avertissement sonore, le dispositif acoustique comprenant :

un circuit de commutation (3, 3A) configuré de manière à répéter périodiquement une période de temps incluant une période de temps de MARCHE (T1) et une période de temps d'ARRÊT (T2), et à fournir en sortie une première tension présentant une forme d'onde carrée dans laquelle un niveau de tension alterne périodiquement entre un niveau haut et un niveau bas, le niveau de tension de la première tension pendant la période de temps de MARCHE (T1) étant le niveau haut, le niveau de tension de la première tension pendant la période de temps d'ARRÊT (T2) étant le niveau bas; et

un circuit résonnant (2, 2A) configuré de manière à recevoir la première tension, le circuit résonnant (2, 2A) étant configuré de manière à générer, à partir de l'énergie électrique appliquée pendant la période de temps de MARCHE (T1), une seconde tension qui oscille à une fréquence d'oscillation f1 pendant la période de temps d'ARRÊT (T2), et à fournir en sortie une tension composite de la première tension et de la seconde tension, au vibreur piézoélectrique (10), la tension composite servant de tension d'attaque, dans lequel :

une relation entre une fréquence fn en kHz d'une Nième harmonique, une fréquence fondamentale f0 en kHz de la tension d'attaque, et la fréquence d'oscillation f1 en kHz est $fn - 1/2f0 \leq f1 \leq fn + 1/2f0$, où la Nième harmonique est une harmonique parmi une pluralité d'harmoniques de la tension d'attaque, et dans lequel un niveau de pression acoustique d'un son de sortie provenant du vibreur piézoélectrique (10) à la Nième harmonique est supérieur à un niveau de pression acoustique du son de sortie provenant du vibreur piézoélectrique (10) à la fréquence fondamentale f0.

2. Dispositif acoustique (1, 1A) selon la revendication 1, dans lequel :
une différence entre la fréquence de la Nième harmonique et une fréquence à laquelle le niveau de pression acoustique du son de sortie provenant du vibreur piézoélectrique (10) devient maximal dans une plage de fréquences prescrite est inférieure ou égale à la fréquence fondamentale f0.

3. Dispositif acoustique (1, 1A) selon la revendication 1 ou 2, dans lequel :
la période de temps d'ARRÊT (T2) est supérieure ou égale à une période de la seconde tension.

4. Dispositif acoustique (1, 1A) selon l'une quelconque des revendications 1 à 3, dans lequel :
la période de temps d'ARRÊT (T2) inclut une pluralité de périodes de la seconde tension.

5. Dispositif acoustique (1, 1A) selon l'une quelconque des revendications 1 à 4, comprenant en outre :

un dispositif de mesure de tension (5) configuré de manière à mesurer une valeur crête à crête de la seconde tension ; et

un contrôleur de tension (4, 4A) configuré de manière à augmenter le niveau de tension de la première tension de la période de temps de MARCHE (T1) à mesure que la valeur crête à crête diminue.

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6. Dispositif acoustique (1, 1A) selon l'une quelconque des revendications 1 à 5, comprenant en outre : un dispositif de mesure de tension (5) configuré de manière à mesurer une valeur crête à crête de la seconde tension, dans lequel le circuit de commutation (3, 3A) est configuré de manière à augmenter la période de temps de MARCHE (T1) et à diminuer la période de temps d'ARRÊT (T2) à mesure que la valeur crête à crête diminue.

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7. Dispositif acoustique (1, 1A) selon l'une quelconque des revendications 1 à 5, comprenant en outre :

un dispositif de mesure de tension (5) configuré de manière à mesurer une valeur crête à crête de la seconde tension ; et

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un contrôleur de courant (6) configuré de manière à commander un courant circulant à travers le circuit résonnant (2, 2A) sur la base d'une amplitude de la valeur crête à crête.

8. Système acoustique (100) comprenant :

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le dispositif acoustique (1, 1A) selon l'une quelconque des revendications 1 à 7 ; et
le vibreur piézoélectrique (10).

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FIG. 1

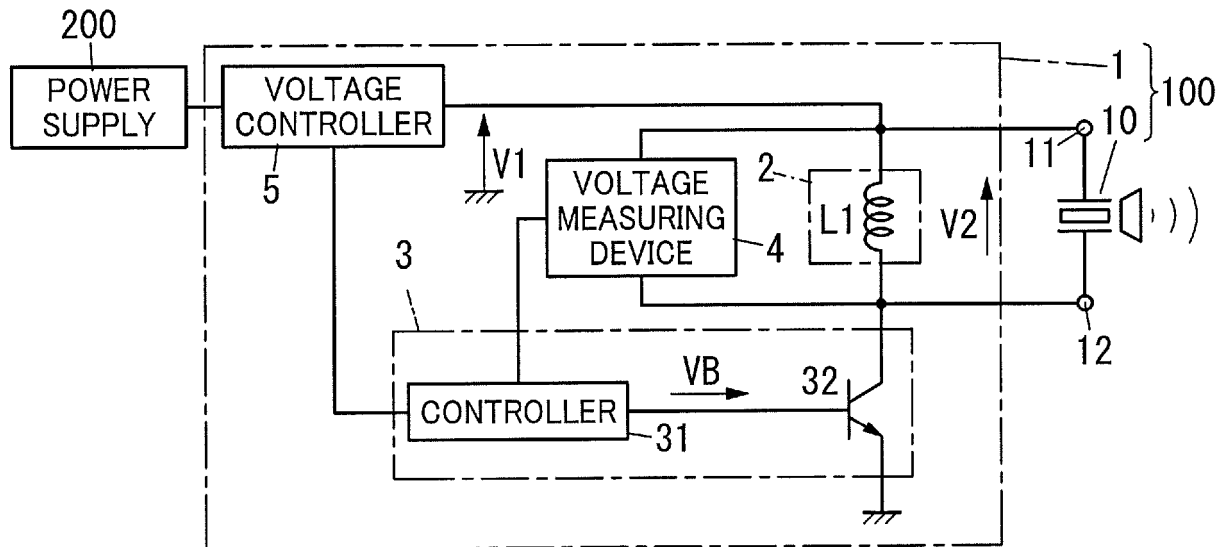


FIG. 2

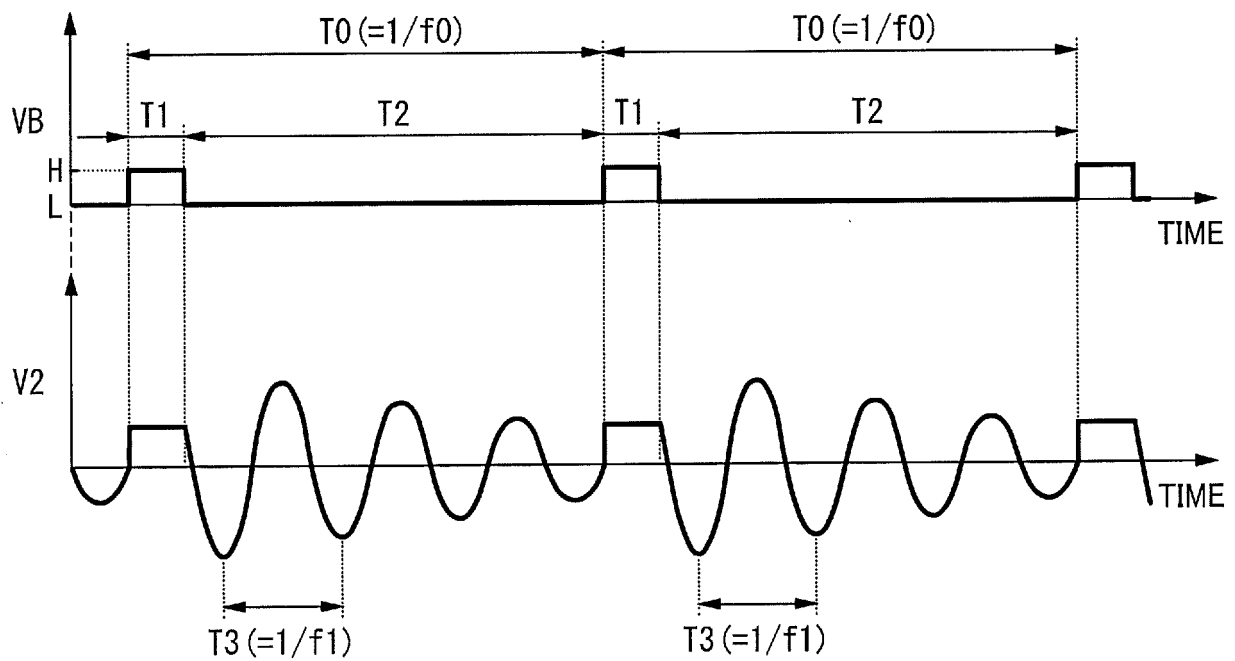


FIG. 3

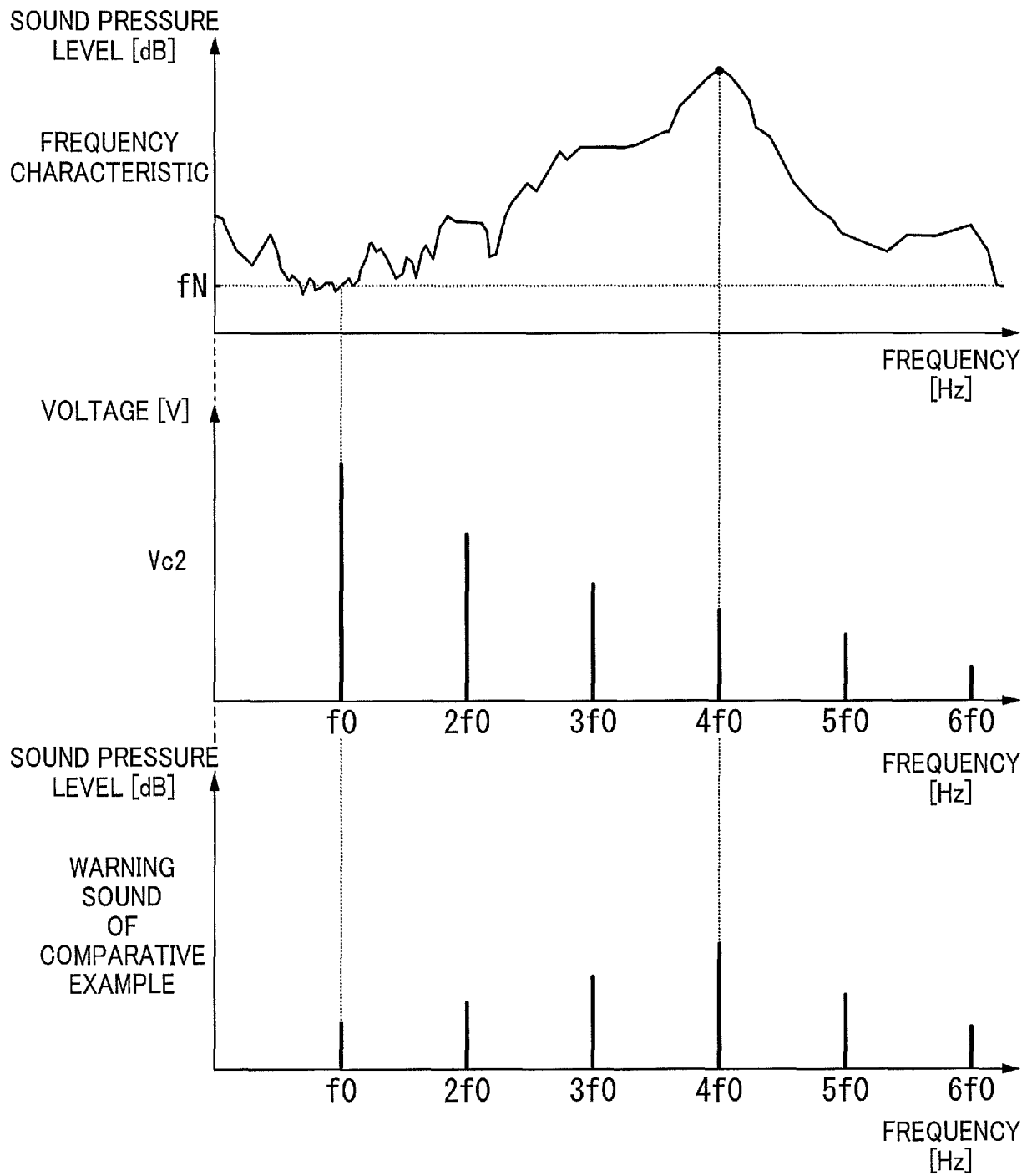


FIG. 4

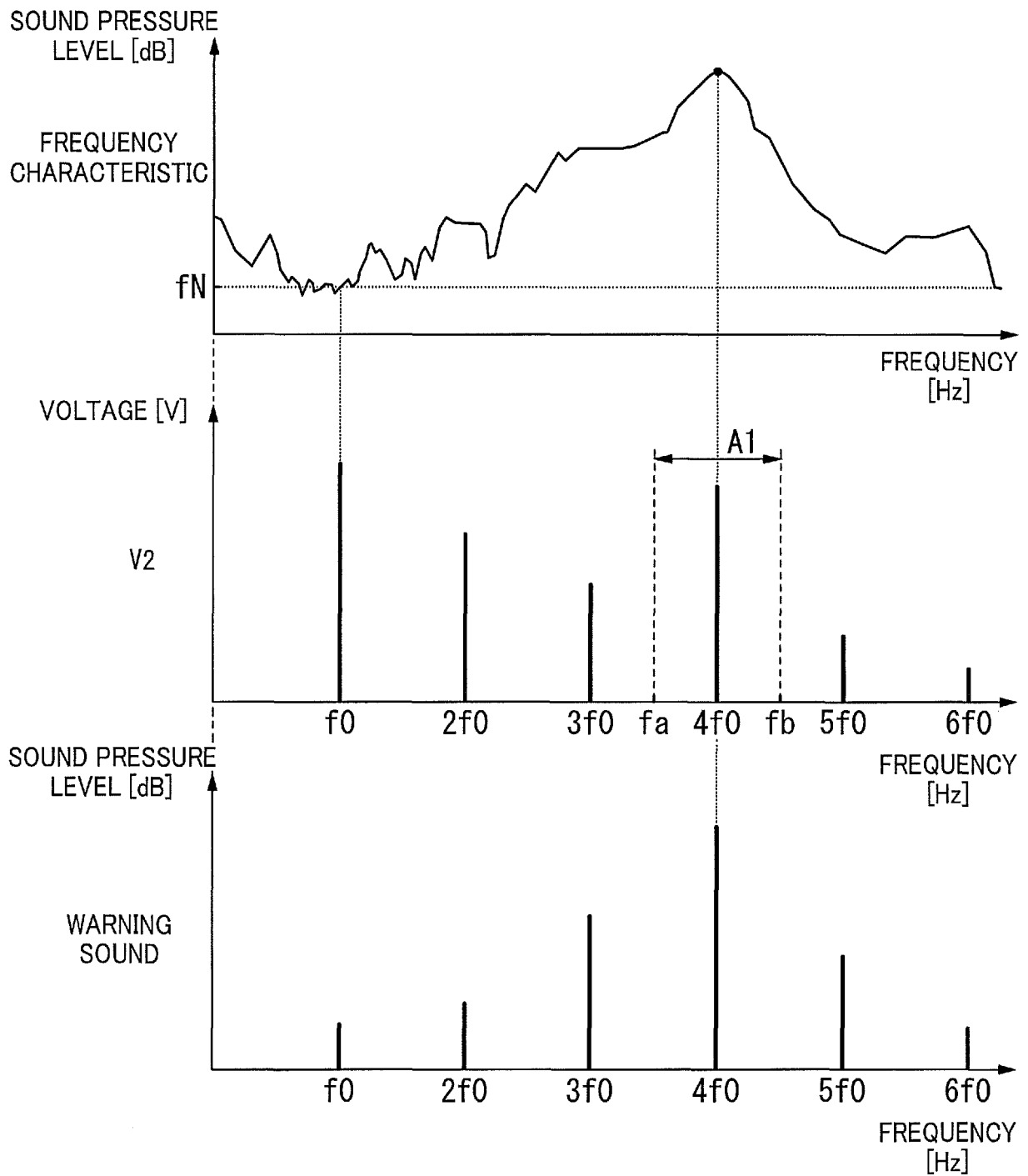
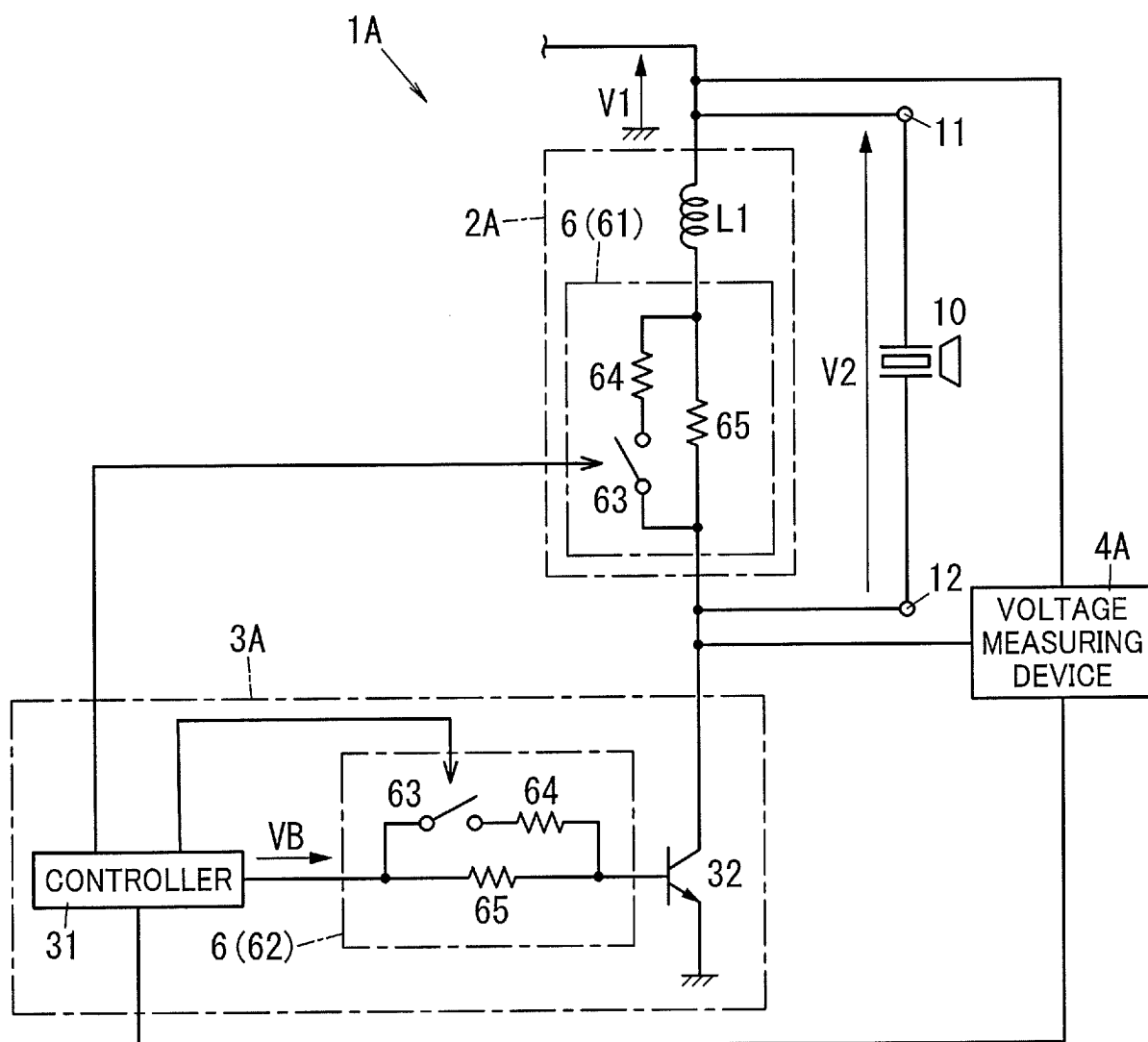


FIG. 5



REFERENCES CITED IN THE DESCRIPTION

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