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Kumon et al.

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[45] **Oct. 14, 1975**

[54] **PIEZOELECTRIC ACOUSTIC MULTIPLE TONE GENERATOR**

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[73] Assignee: **Sumitomo Electric Industries, Ltd.,** Osaka, Japan

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Related U.S. Application Data

[63] Continuation of Ser. No. 318,967, Dec. 27, 1972.

[30] **Foreign Application Priority Data**

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May 27, 1972	Japan	47-62369
Apr. 24, 1972	Japan	47-48516

[52] **U.S. Cl.** ..... **310/8.1;** 179/110 A; 84/1.24; 340/384 E; 310/8.2

[51] **Int. Cl.²** **H01L 41/10**

[58] **Field of Search** ..... 310/8.1, 8.2; 179/110 A, 179/138; 340/388, 384 E, 393, 384 R; 84/1.24

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[57] **ABSTRACT**

This invention provides an acoustic device including one sound generator for generating sound waves with a plurality of distinguishable tone colors. For this purpose, the sound generator is composed of a composite member, which consists of a piezoelectric element and a diaphragm adhered thereon, and an electric circuit connected thereto so that sound waves are generated according to the bending vibration of the composite member, that is, so-called piezoelectric sound generator, and the tone color of the generated sound wave is varied by means of making a change in the electric circuit. As ways for making a change in the electric circuit, the electric circuit is composed of an oscillator and a switching circuit and then the time constant or the switching frequency of the switching circuit is varied.

1 Claim, 8 Drawing Figures

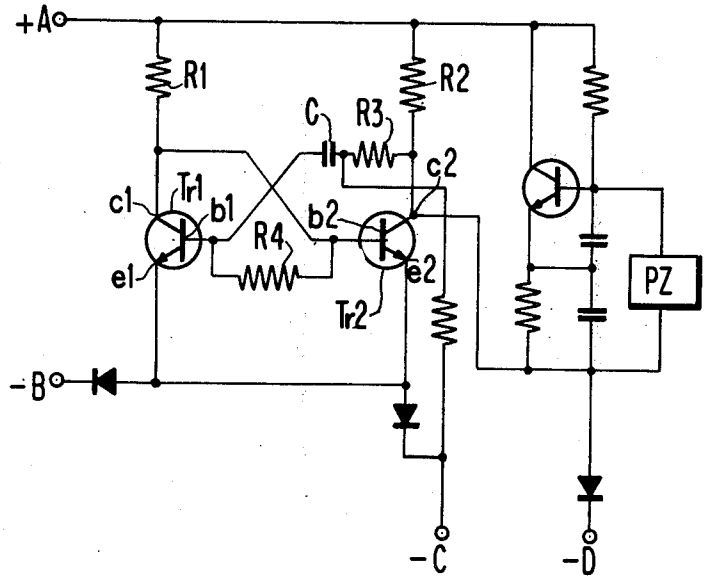


FIG.1

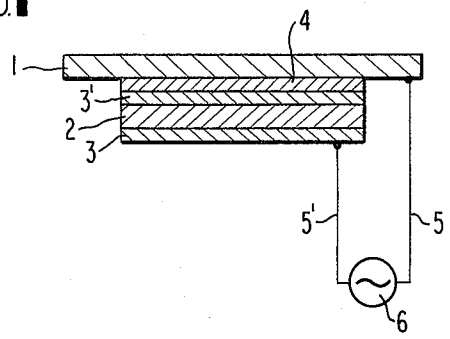
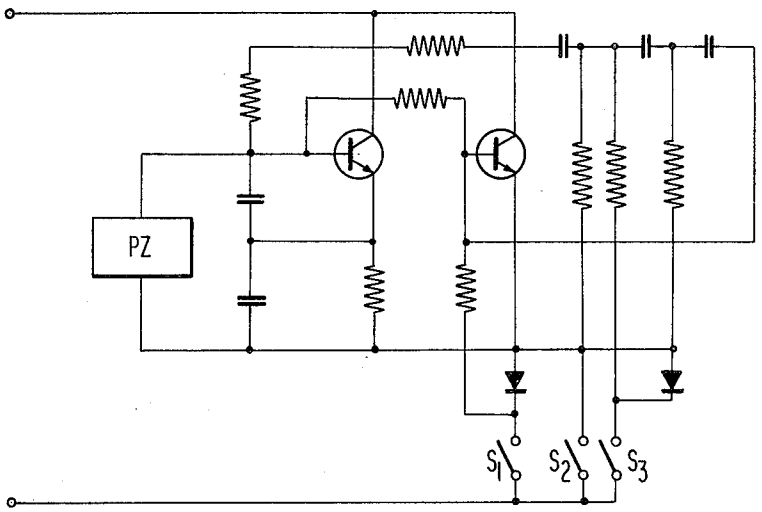


FIG.2



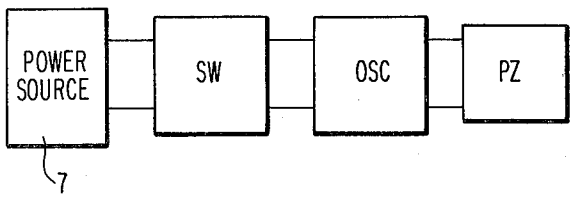


FIG.3

FIG.5

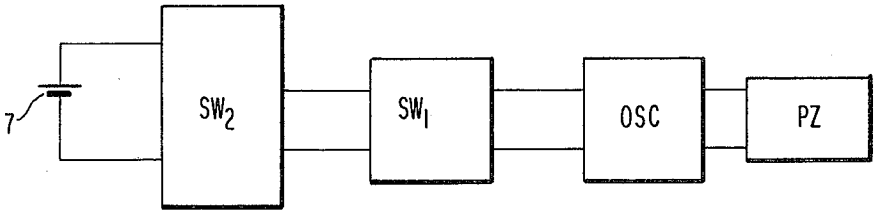
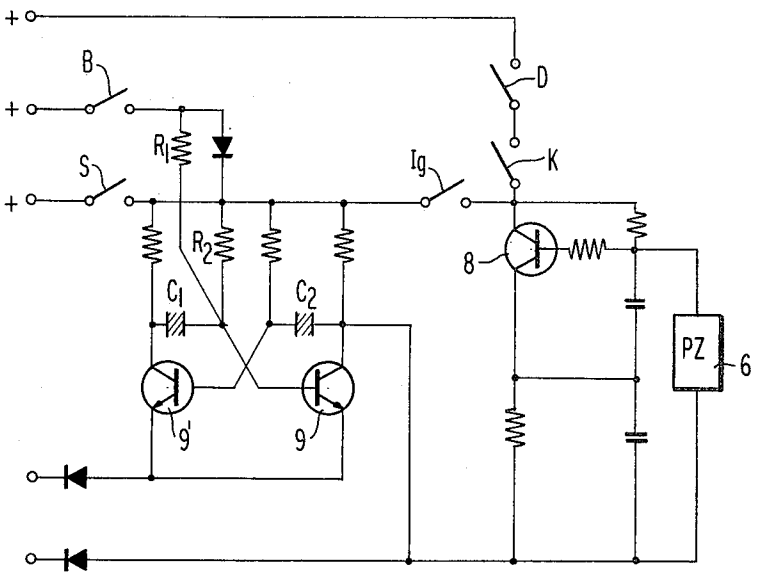


FIG. 4



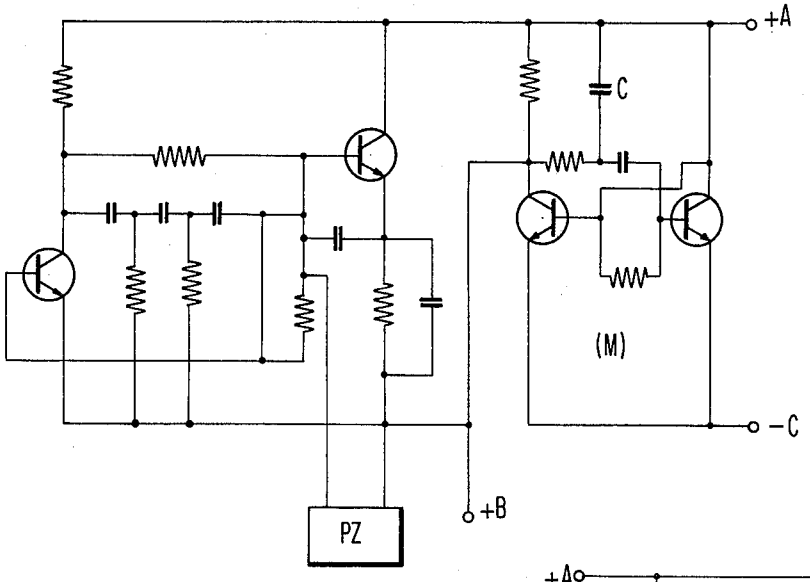


FIG. 6

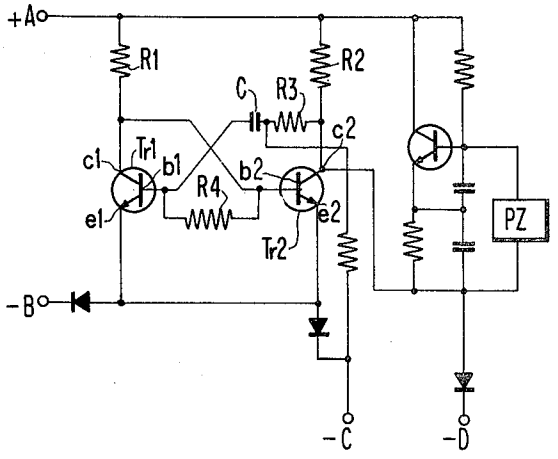
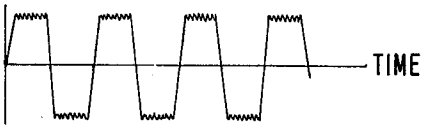


FIG. 7

FIG. 8



PIEZOELECTRIC ACOUSTIC MULTIPLE TONE GENERATOR

This is a continuation, of application Ser. No. 318,967, filed Dec. 27, 1972.

BACKGROUND OF THE INVENTION

Recently there have been made attempts in which information is distinguished according to the generation of different sounds for the purpose of warning or detection. These attempts demand the following special characteristics of a sound source.

1. It generates a variety of distinguishable tone colors.
2. It is small in size and light in weight.
3. It has high reliability.

For example, in a warning device of an automobile, it is required to generate different warning sounds in such cases of: (*a*) driving at excessive speed, (*b*) leaving a key in the ignition, (*c*) a safety belt being off, etc. The prior electromagnetic buzzers, however, are not able to generate distinctly different sounds so that it is difficult to distinguish their tone colors. It is, therefore, necessary to use different buzzers according to the above-mentioned three or more cases. Moreover, such buzzers have the disadvantages of large size, high cost, short life, and, furthermore, tone color change due to long time use.

SUMMARY OF THE INVENTION

This invention has been made with the intention of overcoming the above-described difficulties. It is, therefore, an object of this invention to provide a piezoelectric acoustic device able to generate distinguishable different sounds.

It is another object of this invention to provide a piezoelectric acoustic device, particularly a piezoelectric buzzer, able to generate many sorts of sounds which are distinguishable and pleasant to the ear, such as quasi warbles.

According to this invention, a sound-generator is composed of a composite member, which is made of a piezoelectric element and a diaphragm, and electric circuit connected thereto. Some distinguishable different sound waves are thereby generated by adjusting the electric circuit. The electric circuit is composed of an oscillator and a switching circuit such as phase-shifting oscillator, multivibrator, thyristor circuit or other means. Thus, the tone color of sound to be generated is varied by changing the time constant of the switching circuit. Furthermore, according to this invention, the electric circuit includes two or more switching circuits and thereby the sound generated by one switching circuit is intermitted additionally by another switching circuit so as to generate a new unique and distinguishable sound.

Other features of this invention and the advantages thereof will be apparent by perusal of the following detailed description of the embodiments of this invention, with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a sectional view of the sound-generator member, which shows the principle of a piezoelectric acoustic device.

FIGS. **2, 4, 6** and **7** are circuit diagrams of the electric circuit according to this invention.

FIGS. **3** and **5** are block diagrams of the electric circuit according to this invention.

FIG. **8** is a waveform of the electrical output of the circuit of FIG. **7.**

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** illustrates the principle of a piezoelectric buzzer wherein a metal plate **1** and a piezoelectric element **2** with silver electrodes **3, 3'** on both sides thereof are adhered to each other through adhesives **4** so as to form a composite member of sound generator, and the composite member is connected to an electric circuit **6** through lead wires **5, 5'**. The composite member is excited into bending vibration at its natural frequency so as to generate a sound wave.

The electric circuit **6** is composed of the combination of an oscillator and a switching circuit such as phase-shifting oscillator, multivibrator, thyristor circuit, etc. The oscillation of the oscillator is intermittently controlled by the switching circuit and the rate of intermittence is changed by adjusting the time constant of the switching circuit.

FIG. **2** shows an example of the electric circuit using a phase-shifting oscillator. In the drawing, PZ is the composite member and D.C. voltage is applied to terminals A and B. This sound generator makes continuous sound when switch S_1 is closed and intermittent sounds when switches S_2 and S_3 are closed. These sounds have distinguishable tone colors similar to warbles of birds or insects.

Such a sound generator is also able to generate distinguishable different sounds by changing the frequency of oscillation or by changing it with time. For example, composing a sound generator of power source **7,** switching circuit SW, oscillator OSC and composite member PZ, it is possible to generate two or more sorts of intermittent sounds by changing the time constant of switching circuit SW and the frequency thereof. Moreover, disabling the operation of switching circuit SW so as to generate continuous sound, it is also possible to generate three or more sorts of distinguishable sounds including continuous sound and intermittent sounds.

For example, in the case that the fundamental oscillation frequency is 2.7 kHz, it is possible to generate cosmic sound when the switching frequency is 2 to 5 Hz, cricket sound when it is 10 Hz, another insectsound when it is 15 Hz, and so forth.

In addition, the natural frequency of piezoelectric element is able to be varied between 0.4 and 15 kHz according to the design of dimensions, so that it will be possible to generate other sorts of sounds by changing the fundamental oscillation frequency.

FIG. **4** shows another example of the electric circuit, which is composed of oscillator portion including transistor **8** and multivibrator portion including transistors **9, 9'** for intermitting the operation of the oscillator portion. By varying resistances R_1 and R_2 so as to change the time constant of the multivibrator, some tone colors are obtained. For example, in the case that the continuous sound has 2.6 kHz, it is possible to generate quasi sounds with remarkably different tone colors, such as cosmic sound at the intermittent frequency of 1 to 3 Hz, cricket sound at 8 to 10 Hz, and so forth.

The sound generator shown in FIG. **4** is used as the warning device for the following three cases in an automobile:

1. forgetting to take a key out of the ignition (This warning is made when a door is opened leaving a key in the ignition.);
2. forgetting to lock a safety belt (This warning is made when a safety belt is unlocked while the engine is running.);
3. making excessive speed (This warning is made when driving speed exceeds a predetermined limit while the engine is running.).

There are provided switches D, K, Ig, B and S for these cases as shown in FIG. **4**, so that K is turned on only when the key is put in the ignition, D is turned on only when the door is opened, Ig is turned on only when the engine is running, B is turned on only when the safety belt is unlocked, and S is turned on only when the driving speed exceeds the predetermined limit. Accordingly, continuous sound is generated in the case (1), and intermittent sounds are generated in the cases (2) and (3). In the cases (2) and (3), distinguishable tone colors are obtained according to the variation of resistances R_1 and R_2.

Although capacitances C_1 and C_2 may be varied generally for changing the time constant, it is possible to make the device at much lower cost if the resistances R_1 and R_2. Furthermore, since the frequency of the intermittent sound is made changeable, according to this invention, it is possible to generate two or more sorts of distinguishable sounds by use of only one sound generator.

Then we show another example in FIG. **7** which uses multi-vibrator circuit. In this circuit, +A, −B, −C, and −D are D.C. source terminals, + and − are shown the polarity of the source.

In FIG. **7**, the use of terminals A and B for applying the power source generates an alarm sound, the use of terminals A and C generates wobbles of insects, and the use of terminals A and D generates a continuous sound.

The FIG. 7 circuit is more efficient for the following reasons:

FIG. **7** employs only one capacitor C. Furthermore, in FIG. **7**, the positive terminal A is provided as a common terminal whereas the minus terminals B, C and D are individually selected, thereby providing an extremely convenient arrangement for changing the tone color. By contrast, the circuit shown in FIG. **4** requires five terminals, thereby resulting in a more complicated connection arrangement.

In the FIG. 7 circuit, the large variation in tone color, i.e., a large difference in switching frequencies, can be obtained, thereby providing tone colors which can be easily distinguished. More specifically, in the FIG. **7** circuit, the ratio of switching frequencies is 15:1, whereas in the conventional art only a range of 3:1 is available.

As far as the construction of the FIG. **7** circuit is concerned, both emitters *e*1 and *e*2 of the transistors Tr1 and Tr2 are connected in common to the negative supply terminals, the collectors *c*1 and *c*2 thereof are connected to the positive supply terminal through respective resistors R_1 and R_2, and the bases *b*1 and *b*2 are connected to each other through the resistor R_4. Further, one end of the capacitor C and the resistor R_3 connected in series is connected to the base *b*1, and the other end thereof is connected to the oscillator. And, the base *b*2 is connected between the collector *c*1 and resistor R_1.

In operation, in the ON state of the transistor Tr1 and the OFF state of the transistor Tr2, immediately before reversal, the capacitor C is being charged through the resistors R_2 and R_3. Then, the capacitor C begins to discharge through the resistors R_4 and R_1 when it is saturated. The potential of the transistor Tr1 drops due to the discharge, transistors Tr1 and Tr2 becoming OFF and ON, respectively. Simultaneously with the reversal of the transistors Tr1 and Tr2, the capacitor C is charged through the resistances R_2 and R_3, which results in saturation of the transistor Tr2. As the potential of the transistor Tr2 drops at this time, a current flows to the transistor Tr1 from the resistor R_4 and the collector *c*1. When the potential of the capacitor C is lower than that of the time constant CR3, the transistors Tr1 and Tr2 are reversed. As a result, the operation is repeated.

The waveform of the output obtained by the above operation is of sawtooth wave having small amplitude at the top and the bottom portions, as shown in FIG. **8**, which is suitable for vibration of the piezoelectric element PZ.

In the above-described examples, electric circuit **6** is composed of one oscillator or one oscillator and one switching circuit, so that continuous sound or intermittent sound, in addition, both sounds in some cases, are generated; for example, with a unique tone color similar to cricket warble at the switching frequency of about 10 Hz. However, in the case of the switching frequency above 10 Hz, it will be difficult to distinguish the continuous and intermittent sounds because of echo phenomenon, particularly in a big room or in a building. Moreover, such a piezoelectric acoustic device makes use of resonance phenomenon in principle, so that it has simple frequency characteristics and therefore the disadvantage of generating non-harmonic and unpleasant sounds.

In order to generate many unique sounds being pleasant to the ears, such as quasi warbles, this invention will propose to switch additionally one or more times the intermittent sound generated by the switching operation in the above-mentioned sound generator. FIG. **5** shows the block diagram of a sound generator suitable for this purpose. OSC is the oscillator and SW_1 is the switching circuit. There is provided additional switching circuit SW_2 between switching circuit SW_1 and power source **7** so as to generate quasi warbles of birds or insects and many sorts of distinguishable different sounds.

There is shown a preferred example for the above-mentioned purpose in FIG. **6**. In this example, the first switching circuit is a phase-shifting oscillator and the second switching circuit is made of a modified multivibrator. When D.C. source is applied to +A and −C, there is generated such sound as a cricket warbles intermittently. Capacitor C in multivibrator M permits electric current to flow during the intermitted interval, so that it is possible to make a unique effect such as echo-effect and therefore to generate much pleasant sounds. When D.C. source is applied to +B and −C, multivibrator M is not operated and cricket sounds are generated.

As described above, according to this invention, since the frequency of the intermittent sound is made changeable, it is possible to generate two or more sorts of distinguishable sounds by use of only one sound generator. In addition, the sound generator of this inven-

tion is made in contactless construction, so it has the advantages of long life, high reliability and low power consumption.

We claim:

1. A piezoelectric acoustic system comprising:

a. a single composite electroacoustical member including a piezoelectric element and a diaphragm adhered to each other;

b. phase-shift oscillator means electrically coupled to said member for applying electrical oscillation signals thereto, thereby inducing bending vibration in said member to generate a sound wave;

c. cross-coupled multivibrator circuit means comprising a resistance-capacitance time constant circuit which determines the switching frequency of said multivibrator means;

d. means for electrically coupling the output of said multi-vibrator circuit means to said oscillator means to intermittently interrupt said oscillation signals and thereby said sound wave; and

e. means for varying the resistance of said time constant circuit to vary the switching frequency of said multivibrator means, and thereby the frequency at which said oscillation signals are intermittently interrupted so as to produce a plurality of distinguishable tone colors from said single composite member;

said multivibrator circuit further comprising first and second cross-coupled transistors of the same conductivity type; the collector of said first transistor being directly connected to the base of said second transistor to form a first cross-coupling path; said resistance-capacitance time constant circuit being connected between the collector of said second transistor and the base of said first transistor to form a second cross-coupling path; the emitters of said transistors being connected to a common point; a resistor connected directly between the bases of said transistors; individual resistors connecting the collectors of said transistors to a common power input terminal; first, second and third additional power input terminals connected respectively to said emitter common point, to the juncture of the resistance and capacitor in said time constant circuit, and directly to said oscillator means; whereby a D.C. power source selectively connected between said common power input terminal and individual ones of said first, second and third power input terminals produces, respectively, said plurality of distinguishable tone colors.

* * * * *