

PATENT SPECIFICATION

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(54) ELECTRONIC BUZZER

(71) We, KABUSHIKI KAISHA DAINI SEIKOSHA, a Japanese body corporate of 6-31-1, Kameido, Koto-ku, Tokyo, Japan, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an electronic buzzer.

It is well known that the oscillation of an oscillatable plate in the neighbourhood of its resonant frequency is an efficient way of producing sound, and is particularly suitable for use in an electronic buzzer since such a buzzer uses little power and it is a prime requisite that electronic buzzers for use in small portable equipment, e.g. an electronic wrist watch or pocket alarm should operate on as low as a power as possible.

In a conventional electronic buzzer which uses one oscillatable plate having, say, resonant frequency f_1 , the characteristic curve of sound intensity against frequency of oscillation of a driving current shows a sharp peak at frequency f_1 . The band of frequencies over which a sufficient sound intensity is emitted by the oscillating plate is thus extremely narrow and it is therefore necessary to provide means for matching a driving frequency which oscillates the plate with a resonant frequency f_1 of the plate. Further, in such electronic buzzers it is very difficult to alter the pitch of the note at which the buzzer sounds.

According to the present invention there is provided an electronic buzzer having a closed fluid-filled chamber opposite walls of which comprise oscillatable plates each of which has an audible resonant frequency which differs from that of the other plate, there being no direct connection or contact between the central portions of the plates at any time, and electrically driven means arranged to effect direct oscillation of one only of the said plates, the arrangement being such that the oscillation of said one plate is transmitted through the fluid in the chamber to effect the

oscillation of the other plate without the plates contacting each other.

The electrically driven means preferably comprise an electromagnetic means.

The chamber may, for example, be filled with air so that the oscillation of the said one plate is transmitted through the air in the chamber to effect the oscillation of the other plate.

Preferably, the electro-magnetic means comprises a member composed of a magnetically permeable material attached to the said one plate, and a coil having an end face thereof arranged adjacent to and spaced from the said member, such that the passing of a driving alternating electric current through the coil causes the oscillation of the member, and consequently of the said one plate, which in turn causes oscillation of the other plate.

Means may be provided for passing through the coil a driving alternating electric current which has a frequency which is substantially identical to the resonant frequency of one of the plates. Alternatively, means may be provided for passing through the coil a driving alternating electric current which has a waveform the fourier transform of which contains frequencies which are substantially identical to the resonant frequencies of the two said plates.

In the preferred embodiment of the present invention, the said two plates have resonant frequencies which are sufficiently close to one another such that the oscillation of the said one plate at its resonant frequency effects the resonance of the other plate. Alternatively, the two said plates may have resonant frequencies which are sufficiently far apart from one another such that the oscillation of the said one plate at its resonant frequency does not effect the resonance of the other plate.

The invention will now be described, merely by way of example, with reference to the accompanying drawings, in which:—

Figure 1 shows an elevational view in section of a known electronic buzzer,

Figure 2 shows an elevational view in

section of an electronic buzzer having two oscillatable plates according to the present invention,

5 Figure 3 shows an elevational view in section of an electronic buzzer having three oscillatable plates according to the present invention,

10 Figure 4 shows a characteristic curve of sound intensity against frequency of oscillation for the electronic buzzer of Figure 1,

15 Figures 5 and 6 show two different characteristic curves of sound intensity against frequency of oscillation relating to the electronic buzzer of Figure 2,

20 Figures 7 and 8 show two different characteristic curves of sound intensity against frequency of oscillation relating to the electronic buzzer of Figure 3,

25 Figure 9 shows an electronic circuit which is equivalent to the electronic buzzer of Figure 1,

30 Figure 10 shows an electronic circuit which is equivalent to the electronic buzzer of Figure 2,

35 Figure 11 shows an electronic circuit which is equivalent to the electronic buzzer of Figure 3, and

40 Figure 12 shows a waveform of an alternating electric current for driving the electronic buzzer of Figure 2, the buzzer having plates having resonant frequencies f_1 and f_2 and a characteristic curve of sound intensity against frequency as shown in Figure 5.

45 Terms such as "upwardly", "uppermost" and "lower" as used in the description below are to be understood to refer to directions as seen in the accompanying drawings.

Referring firstly to Figure 1, there is shown an electronic buzzer of a conventional type which comprises a base plate 1 having a central magnetic pole 2 which is integral with the base plate 1 and which extends upwardly from one side thereof, the base plate 1 and central pole 2 being composed of a magnetically permeable material; a coil 3 wound onto the central magnetic pole 2; and a magnetic ring member 4 which is arranged coaxially around and in an engagement with the coil 3. An oscillatable plate 5 is mounted at its periphery on supports 7 and has one side thereof disposed adjacent to and spaced from the uppermost face of the combination of the base plate 1, central pole 2, coil 3, and ring member 4, and a further magnetically permeable plate member 6 is fixed to the opposite side of the oscillatable plate 5. Thus a magnetic loop is formed by the plate member 6, ring member 4, base plate 1 and central magnetic pole 2.

65 If an alternating electric current $I = I_0 \sin \omega t$ is applied to the coil 3, then the driving

power F which drives the oscillatable plate 5 can be represented as

$$F = KI_0 \sin \omega t \quad (1)$$

where K is a constant determined by the particular apparatus used and ω is the angular frequency of the driving current I .

Figure 9 shows an electrical circuit which is equivalent to the mechanical system of Figure 1. In the circuit of Figure 9, the driving voltage V is analogous to the above driving power F , and the current flowing through the circuit is analogous to the amplitude of the oscillation of the above plate 5. Cm_1 , m_1 and r_1 represent, respectively, the compliance of plate 5, together with plate member 6, that is, the initial energy needed to set them oscillating, the mass of the plate 5 together with plate member 6 and the mechanical resistance to motion of the plate 5 together with plate member 6. Further ZA is an impedance which represents the sound energy lost by the system of Figure 1.

If the driving power F , on driving voltage V in the circuit of Figure 9 is frequency independent, then the electric current flow in the impedance ZA reaches a maximum at a frequency f_1 , where f_1 is given as

$$f_1 = \frac{1}{2\pi} \sqrt{cm_1 \cdot m_1} \quad (2)$$

Thus the system of Figure 1 has a characteristic curve of sound intensity (related to the oscillational amplitude of plate 5) against frequency of oscillation of the driving electric current in coil 3 as shown in Figure 4.

Figure 2 shows an embodiment of an electronic buzzer according to the present invention, of which components similar to those used in the electronic buzzer of Figure 1 have been designated by like reference numerals, supplemented by the suffix a and so will not be described again. It will be seen that the electronic buzzer of Figure 2 displays two spaced apart oscillatable plates $5a$ and $8a$ mounted parallel to one another which form opposite walls of an air chamber $9a$, there being no direct connection or contact between the central portions of the plates $5a$, $8a$ at any time. The plates $5a$ and $8a$ are supported at their peripheries by a support $7a$ such that, when oscillating, the displacement of the plates $5a$ and $8a$ at the support $7a$ is zero, and rises to a maximum displacement centrally of the support $7a$. If one regards this as being equivalent to the motion of a piston, then the equivalent mass of the piston is the effective mass of each plate, and the equivalent area of the piston face is the effective area of each plate.

As for the known electronic buzzer of Figure 1, the power which drives the oscillable plate 5a can be represented by F, where F is given by equation (1).

In operation, a driving alternating electric current through the coil 3a causes the oscillation of a magnetically permeable plate member 6a, and consequently causes direct oscillation of the plate 5a only. The oscillatory motion of plate 5a is then transmitted across the air chamber 9a and causes the oscillation of plate 8a without the plates 5a, 8a contacting each other.

An equivalent electrical circuit to the mechanical system of Figure 2 is shown in Figure 10. C_{m_1} , m_1 and r_1 relate to the same quantities as previously described with respect to the plate 5 and C_{m_2} , m_2 and r_2 are the same quantities again but with respect to the plate 8a. CA_1 represents the compliance of the air chamber 9a, that is the initial amount of energy needed to transmit the oscillation of plate 5a across the air chamber 9a to plate 8a and assuming that the effective area of plates 5a and 8a are equal, CA_1 is given by

$$CA_1 = W_1 / C^2 \rho S^2 \quad (3)$$

where

W_1 = volume of air chamber 9

C = speed of sound

ρ = density of air in air chamber

S = effective area of plates 5 and 8.

Furthermore, ZA represents the sound energy lost by plate 8a when oscillating.

If the driving power F , and hence the driving voltage V of the electrical circuit of Figure 10, is independent of frequency, there are two points at which the electric current flowing in ZA reaches a maximum. Thus, by analogy, the mechanical system of Figure 2 has a characteristic curve of sound intensity against frequency of oscillation of the driving electric current in coil 3a as shown in Figure 5, the two maxima being at frequencies f_1 and f_2 . With reference to Figure 10 if the resistances r_1 and r_2 are regarded as being smaller than the impedance ZA , then the current flowing through impedance ZA , and hence by analogy, the amplitude of oscillation of the plate 8a, varies as

$$[F \cdot m_1 \cdot cm \omega / (AW^2 - BW^2 + C)] \cos \omega t \quad (4)$$

where ω is the angular frequency of oscillation of the oscillatable plate 8a,

$$A = m_1 \cdot m_2 \cdot C_{m_2} \cdot C_{m_1} \cdot CA_1$$

$$B = (m_1 \cdot C_{m_1} \cdot C_{m_2}) + (m_1 \cdot C_{m_1} \cdot CA_1) + (m_2 \cdot C_{m_2} \cdot CA_1) + (C_{m_1} \cdot m_2 \cdot C_{m_2})$$

and

$$C = C_{m_1} + C_{m_2} + CA_1$$

According to formula (4), therefore the amplitude of oscillation of the oscillatable plate 8a reaches a maximum when

$$A\omega^4 - B\omega^2 + C = 0$$

that is, at two frequencies f_1 and f_2 , where f_1 and f_2 are given by

$$f_1 = \frac{1}{2\pi} \sqrt{\left(\frac{B - \sqrt{B^2 - 4AC}}{2A} \right)} \quad (5)$$

and

$$f_2 = \frac{1}{2\pi} \sqrt{\left(\frac{B + \sqrt{B^2 - 4AC}}{2A} \right)} \quad (6)$$

As shown in Figure 5, the two peaks in sound intensity at frequencies f_1 and f_2 are well spaced apart, but it can be seen from equations (5) and (6) that f_1 and f_2 can be made to approach each other by making the value of

$$\sqrt{B^2 - 4AC}$$

small compared with the value of B .

Figure 3 shows a further embodiment of the present invention, which differs from the embodiment of Figure 2 only in the provision of a third oscillatable plate 10b which is spaced from plate 8b by an air chamber 11b. Like parts of the two embodiments have been designated by like reference numerals with the addition of suffixes b , and so will not be described again. In operation, the oscillation of plate 8b is transmitted through the air chamber 11b to effect the oscillation of plate 10b.

Figure 11 shows the equivalent electrical circuit of the embodiment shown in Figure 3. The circuit components are as hereinbefore described, with C_{m_3} , m_3 and r_3 referring to the third plate 10b, and CA_2 being as compliance of the air chamber 11b, that is, the initial amount of energy required to transmit the oscillation of plate 8b across the air chamber 11b to the plate 10b. As before, assuming that the effective area of plates 8b and 10b are equal, CA_2 is given by

$$CA_2 = W_2 / (C^2 \rho S^2)$$

where

W_2 = volume of air chamber 11b

C = speed of sound

ρ = density of air in air chamber 11b and

S = area of plates 8b and 10b.

Theory shows that the current in the impedance ZA reaches a peak at three separate values of the frequency of driving voltage in the circuit of Figure 11. Thus by analogy, the characteristic curve of sound intensity against

frequency of oscillation of the driving electric current in coil 3b is of the shape shown in Figure 7, with peaks at three different frequencies f_1 , f_2 and f_3 . Figure 7 shows the three peaks well separated from one another, but, as with the embodiment shown in Figure 2, it is possible to arrange that the three peaks, or even just two of them, occur at substantially the same frequency by carefully selecting the constants of the oscillating system.

Thus, according to the above two embodiments of the present invention, it is possible to obtain an electronic buzzer whose pitch is either constant at, or alternates between either of two frequencies f_1 and f_2 , or any of three frequencies f_1 , f_2 and f_3 , by simply arranging that the frequency of the driving current I in the coil 3 is constant at, or is varied between any of the frequencies f_1 , f_2 and f_3 .

Alternatively, it is possible to simultaneously resonate two or more of the oscillatable plates by arranging that the driving alternating electric current in the coil 3a or 3b has a waveform the fourier transform of which contains frequencies which are substantially identical to the resonant frequencies of at least two of the plates.

A further possibility is that two or three of the oscillating plates could be arranged to have resonant frequencies which are sufficiently close to one another such that the oscillation of one of the plates at its resonant frequency effects the resonance of the or each other plate. In this case, a driving alternating electric current in the coil 3a or 3b need have only a single frequency to effect the resonance of the electronic buzzer at two or more notes.

It is to be understood that the number of resonance points in an electronic buzzer according to the present invention can be increased by simply increasing the number of oscillatable plates and air chambers therebetween.

It should finally be noted that it is well known that conventional electric buzzers such as shown in Figure 1 have a thin synthetic resin membrane disposed immediately above and spaced from a single oscillatable plate, such a membrane being used as a dust and moisture proof cover for the buzzer. However, whilst the membrane necessarily oscillates when the buzzer is in operation, it does not have an audible resonance frequency and therefore does not

affect the pitch of the note at which the buzzer sounds.

WHAT WE CLAIM IS:—

1. An electronic buzzer having a closed fluid-filled chamber opposite walls of which comprise oscillatable plates each of which has an audible resonant frequency which differs from that of the other plate, there being no direct connection or contact between the central portions of the plates at any time, and electrically driven means arranged to effect direct oscillation of one only of the said plates, the arrangement being such that the oscillation of said one plate is transmitted through the fluid in the chamber to effect the oscillation of the other plate without the plates contacting each other.

2. An electronic buzzer as claimed in claim 1 in which the electrically driven means comprises an electro-magnetic means.

3. An electronic buzzer as claimed in claim 2 in which the electro-magnetic means comprises a member comprised of a magnetically permeable material attached to the said one plate, and a coil having an end face thereof arranged adjacent to and spaced from the said member, such that the passing of a driving alternating electric current through the coil causes the oscillation of the member, and consequently of the said one plate, which in turn causes oscillation of the other plate.

4. An electronic buzzer as claimed in claim 3 in which means are provided for passing through the coil a driving alternating electric current which has a frequency which is substantially identical to the resonant frequency of one of the plates.

5. An electronic buzzer as claimed in claim 3 in which means are provided for passing through the coil a driving alternating electric current which has a waveform the fourier transform of which contains frequencies which are substantially identical to the resonant frequencies of the two said plates.

6. An electronic buzzer as claimed in any preceding claim in which the two said plates have resonant frequencies which are sufficiently close to one another such that the oscillation of the said one plate at its resonant frequency effects the resonance of the other plate.

7. An electronic buzzer as claimed in any of claims 1 to 5 in which the two said plates

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frequency of oscillation of the driving electric current in coil 3b is of the shape shown in Figure 7, with peaks at three different frequencies f_1 , f_2 and f_3 . Figure 7 shows the three peaks well separated from one another, but, as with the embodiment shown in Figure 2, it is possible to arrange that the three peaks, or even just two of them, occur at substantially the same frequency by carefully selecting the constants of the oscillating system.

Thus, according to the above two embodiments of the present invention, it is possible to obtain an electronic buzzer whose pitch is either constant at, or alternates between either of two frequencies f_1 and f_2 , or any of three frequencies f_1 , f_2 and f_3 , by simply arranging that the frequency of the driving current I in the coil 3 is constant at, or is varied between any of the frequencies f_1 , f_2 and f_3 .

Alternatively, it is possible to simultaneously resonate two or more of the oscillatable plates by arranging that the driving alternating electric current in the coil 3a or 3b has a waveform the fourier transform of which contains frequencies which are substantially identical to the resonant frequencies of at least two of the plates.

A further possibility is that two or three of the oscillating plates could be arranged to have resonant frequencies which are sufficiently close to one another such that the oscillation of one of the plates at its resonant frequency effects the resonance of the or each other plate. In this case, a driving alternating electric current in the coil 3a or 3b need have only a single frequency to effect the resonance of the electronic buzzer at two or more notes.

It is to be understood that the number of resonance points in an electronic buzzer according to the present invention can be increased by simply increasing the number of oscillatable plates and air chambers therebetween.

It should finally be noted that it is well known that conventional electric buzzers such as shown in Figure 1 have a thin synthetic resin membrane disposed immediately above and spaced from a single oscillatable plate, such a membrane being used as a dust and moisture proof cover for the buzzer. However, whilst the membrane necessarily oscillates when the buzzer is in operation, it does not have an audible resonance frequency and therefore does not

affect the pitch of the note at which the buzzer sounds.

WHAT WE CLAIM IS:—

1. An electronic buzzer having a closed fluid-filled chamber opposite walls of which comprise oscillatable plates each of which has an audible resonant frequency which differs from that of the other plate, there being no direct connection or contact between the central portions of the plates at any time, and electrically driven means arranged to effect direct oscillation of one only of the said plates, the arrangement being such that the oscillation of said one plate is transmitted through the fluid in the chamber to effect the oscillation of the other plate without the plates contacting each other.

2. An electronic buzzer as claimed in claim 1 in which the electrically driven means comprises an electro-magnetic means.

3. An electronic buzzer as claimed in claim 2 in which the electro-magnetic means comprises a member comprised of a magnetically permeable material attached to the said one plate, and a coil having an end face thereof arranged adjacent to and spaced from the said member, such that the passing of a driving alternating electric current through the coil causes the oscillation of the member, and consequently of the said one plate, which in turn causes oscillation of the other plate.

4. An electronic buzzer as claimed in claim 3 in which means are provided for passing through the coil a driving alternating electric current which has a frequency which is substantially identical to the resonant frequency of one of the plates.

5. An electronic buzzer as claimed in claim 3 in which means are provided for passing through the coil a driving alternating electric current which has a waveform the fourier transform of which contains frequencies which are substantially identical to the resonant frequencies of the two said plates.

6. An electronic buzzer as claimed in any preceding claim in which the two said plates have resonant frequencies which are sufficiently close to one another such that the oscillation of the said one plate at its resonant frequency effects the resonance of the other plate.

7. An electronic buzzer as claimed in any of claims 1 to 5 in which the two said plates

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have resonant frequencies which are sufficiently far apart from one another such that oscillation of the said one plate at its resonant frequency does not effect the resonance of the other plate.

8. An electronic buzzer substantially as hereinbefore described with reference to and as shown in Figure 2 or Figure 3.

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