(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 085 194**
A1

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: **82200060.0**

(22) Date of filing: **19.01.82**

(51) Int. Cl.³: **H 04 R 1/22**
H 04 R 17/00

(43) Date of publication of application:
10.08.83 Bulletin 83/32

(84) Designated Contracting States:
AT BE CH DE FR GB IT LI LU NL SE

(71) Applicant: **Michiels, Hugo R.**
Hamstraat 2
B-9170 Waasmunster(BE)

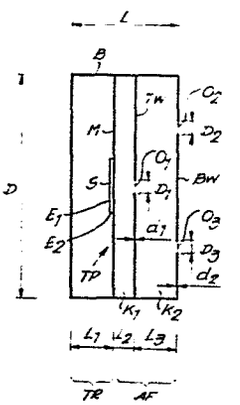
(72) Inventor: **Michiels, Hugo R.**
Hamstraat 2
B-9170 Waasmunster(BE)

(74) Representative: **Donné, Eddy**
M.F.J.Bockstael Arenbergstraat 13
B-2000 Anvers(BE)

(54) **Electro-acoustical converter.**

(57) Electro-acoustical converter with a closed vibration space, one wall of which is formed by a vibrating plate consisting of a metal diaphragm, clamped along its circumferential edge, on which is fixed a disk made of a piezo-electric material, characterized in that the vibrating plate (TP) is acoustically coupled with an acoustical filter (AF) which is formed by at least two successive chambers (K_1, K_2), which are communicating the one with the other through at least one aperture (O_1) in an intermediate wall (TW), the first (K_1) of these chambers being separated from the vibration space by this vibrating plate and the second (K_2) of these chambers communicating with the ambient air through at least one second aperture (O_2,O_3) in an outer wall (BW).

Fig. 1



EP 0 085 194 A1

"Electro-acoustical converter"

The present invention relates to an electro-acoustical converter with a closed vibration space, one wall of which is formed by a vibrating plate consisting of a metallic diaphragm clamped at its peripheral edge, on which diaphragm is fixed a disk made of a piezo-electric material.

Such an electro-acoustical converter is well known in engineering and the invention has in view to provide a suchlike converter with a nearly flat sound intensity/frequency characteristic in the range of the lower frequencies from about 800 Hz to about 4000 Hz.

According to the invention, this objective is attained through the fact that this vibrating plate is acoustically coupled with an acoustical filter which is formed by at least two successive chambers that are communicating via at least one first aperture in an intermediate wall, the first of these chambers of this vibration space being separated by this vibrating plate and the second of these chambers communicating with the ambient air via at least one second aperture in an outside wall.

The acoustical filter ameliorates the acoustical adaption between the vibration space and ambient air, whereby the aforesaid lower frequency range is reproduced more strongly and about uniformly.

At the same time, the reproduction of the higher frequency range is weakened.

The invention will be described hereinafter, reference being made to the attached drawings, wherein :

figure 1 shows a schematical longitudinal section of an electro-acoustical converter according to the invention, the relative dimensions of the components and distances between these components, however, not having their real values;
figure 2 shows an equivalent electric diagram of the acoustical filter AF of figure 1.

This converter comprises a cylindrical housing B with a diameter D and length L and provided with a vibration space TR with the length L_1 and with an acoustical filter AF, acoustically coupled therewith, with the length $L_2 + L_3$. This filter comprises two successive chambers K_1 and K_2 with the respective lengths L_2 and L_3. The ratios $\frac{D}{L_1}$, $\frac{D}{L_2}$ and $\frac{D}{L_3}$ are respectively comprised between 4 and 10; 10 and 60; and 9 and 30.

The vibration chamber TR is completely closed and separated from the filter chamber K_1 by a vibrating plate TP. This vibrating plate TP consists of a circular metal diaphragm M which at its circumferential edge is fixed to the housing B and which, in its central zone, is firmly assembled, for instance by means of glue, with a circular disk S which is made of a piezo-electric material, for instance piezo-electric ceramics. The disk S is connected with two electric connecting cables E_1 and E_2. The metal of this diaphragm has a modulus of elasticity comprised between $6{,}5.10^3$ N/mm^2 and 210.10^3 N/mm^2 and its density is comprised between $1{,}5.10^3$ kg/m^3 and 10.10^3 kg/m^3. The thickness of this diaphragm M is comprised between 0,5 and 1,2 times the thickness of the disk S and the

diameter of this disk is comprised between 0,3 and 0,9 times the diameter of the diaphragm M.

The filter chamber K_1 with a volume V_1 communicates with the filter chamber K_2 with a volume V_2 via a circular aperture O_1 with a diameter D_1 in a intermediate wall TW with a tickness d_1, the product $d_1.D_1$ being comprised between 2 mm^2 and 12 mm^2.

The filter chamber K_2 communicates with the ambient air via a multiplicity of circular apertures as are O_2 and O_3, in the outer wall BW with a tickness d_1. These apertures have respectively diameters D_2 and D_3 and the product of the sum of the diameters of all the apertures, that is to say $D_2 + D_3 + \ldots$, and the thickness d_2 is comprised between 10 mm^2 and 20 mm^2. The intermediate wall TW and outer wall BW are both made of a vibration damping plastic material, for instance polyamide, in order that these walls should not form parasitary sources of vibration.

Due to the presence of the closed vibration space, the sound intensity/frequency characteristic is being ameliorated. As a matter of fact, due to this, the own frequency of the mechanical system is being heightened. The frequency range extending between the first and second resonance frequencies of the vibrating plate TP is, however, being reproduced too weakly.

Through the application of the acoustical filter AF, this drawback is being suppressed, because this filter extending within the frequency band that extends between the aforesaid first and second frequencies has an impedance-transforming action, whereby the adaption between the vibrating plate and air becomes ameliorated. Furthermore, this filter acts as a low pass filter, the tipping over frequency being chosen so that the higher frequency band is being strongly weakened. This is a consequence of the values chosen of the aforesaid ratios $\frac{D}{L_1}$, $\frac{D}{L_2}$ and $\frac{D}{L_3}$, thicknesses d_1 and d_2 and products

$D_1.d_1$ and $(D_2+D_3+...).d_2$.

The equivalent electric diagram of the acoustical filter is shown in figure 2 and comprises :

- the capacity CK_1 and self-induction LK_1 due to the chamber K_1;

- the capacity CK_2, self-induction LK_2 and resistance RK of the apertures as are O_2 and O_3 in the wall of BW;

- the radiation resistance Z.

the values of CK_1, CK_2, LK_1, LK_2 and RK are given by the following formulas, if one supposes that the outside wall BW is provided with n apertures with a radius a_2 and the intermediate wall is provided with one aperture with a radius a_1. The radius a_1 of the aperture O_1 in the intermediate wall TW is chosen so great that the resistance of this aperture may be so low as to be neglected.

$$CK_1 = \frac{V_1}{\gamma P_o} \qquad CK_2 = \frac{V_2}{\gamma P_o}$$

$$RK = \frac{\rho_o}{\eta \cdot \pi\ a_1^2} \sqrt{2\omega\mu}\ \left(\frac{d_2}{a_2} + 2\right)$$

$$LK_1 = \frac{\rho_o}{\eta \cdot \pi\ a_1^2} \quad (d_1 + 1{,}7\ a_1)$$

$$LK_2 = \frac{\rho_o}{\eta \cdot \pi\ a_2^2} \quad (d_2 + 1{,}7\ a_2)$$

ρ_o = density of the air
γ = 1,4 for air
P_o = static pressure
ω = $2\pi f$ with f = frequency

μ = cinematic viscosity coefficient of air = $1,56 \times 10^{-5}$ m^2/sec (20° - 0,76 mhg)

a_1= radius aperture in TW

a_2= radius aperture in BW

V_1= volume of chamber K_1

V_2= volume of chamber K_2

d_1= thickness of wall TW

d_2= thickness of wall BW

RK = resistance of holes in BW (0_2 - 0_3 etc.)

η = number of holes in BW.

Claims.

1.- Electro-acoustical converter with a closed vibration space, one wall of which is formed by a vibrating plate consisting of a metallic diaphragm clamped along its circumferential edge, on which is fixed a disk of piezo-electric material, characterized in that this vibration plate (TP) is acoustically coupled with an acoustical filter (AF), which is formed by at least two successive chambers (K_1, K_2), which are communicating by at least one first aperture (0_1) in an intermediate wall (TW), the first (K_1) of these chambers being separated from the vibration space (TR) by this vibrating plate (TP) and the second (K_2) of these chambers communicating with the ambient air through at least one second aperture (0_2, 0_3) in an other wall.

2.- Electro-acoustical converter according to claim 1, characterized in that this intermediate wall is provided with a first aperture (0_1), whilst this outer wall (BW) is provided with a multiplicity of second apertures (0_2, 0_3).

3.- Electro-acoustical converter according to claim 1 or 2, characterized in that the disk (B) is made of a piezo-electric material and the diaphragm (M) and disk (S) are circular, the thickness of this diaphragm (M) being comprised between 0,5 and 1,2 times the thickness of the disk (S) and the diameter of the disk (S) being comprised between 0,3 and 0,9 times the diameter (D) of the diaphragm.

4.- Electro-acoustical converter according to claim 1, 2 or 3, characterized in that the metal of the diaphragm (M) has a modulus of elasticity comprised between 65.10^3 N/mm^2 and 210.10^3 N/mm^2, whilst the density is comprised between $1,5.10^3$ kg/m^3 and 10.10^3 kg/m^3.

5.- Electro-acoustical converter according to one of the preceding claims, characterized in that the vibration space (TR)

is cylindrical and has a ratio diameter/length ($\frac{D}{L_1}$) that is comprised between 4 and 10.

6.- Electro-acoustical converter according to one of the preceding claims, characterized in that the acoustical filter is cylindrical, the ratios diameter/length ($\frac{D}{L_2}$,$\frac{D}{L_3}$) of the first chamber (K_1) and second chamber (K_2) being respectively comprised between 10 and 60 and 9 and 30.

7.- Electro-acoustical converter according to claim 2,characterized in that the first aperture (0_1) in this intermediate wall (TW) is circular, the product of the diameter (D_1) of this aperture and thickness (d_1) of this intermediate wall being comprised between 2 mm^2 and 12 mm^2.

8.- Electro-acoustical converter according to claim 2, characterized in that the second apertures (0_2, 0_3) in this outer wall (BW) are circular, the product of the sum of the diameters (D_2, D_3) of these apertures and thickness (d_2) of this outer wall (BW) being comprised between 10 mm^2 and 20 mm^2.

9.- Electro-acoustical converter according to one of the preceding claims, characterized in that the intermediate wall (TW) and outer wall (BW) are made of a plastic material, as is polyamide, which has vibration damping properties.

Fig. 1

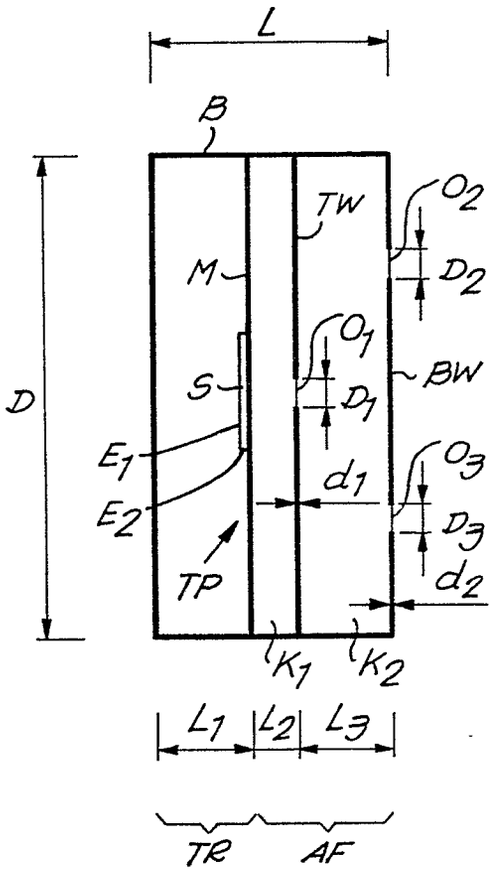
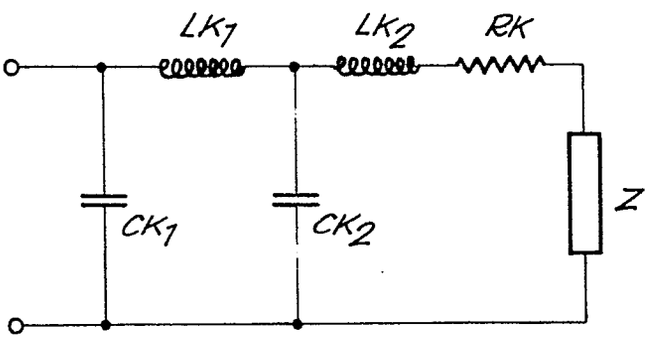

L
B
TW
O2
D2
M
O1
D1
BW
S
D
E1
E2
d1
O3
D3
d2
TP
K1
K2
L1
L2
L3
TR
AF

Fig. 2


LK1
LK2
RK
CK1
CK2
Z

0085194

European Patent Office

EUROPEAN SEARCH REPORT

Application number
EP 82 20 0060

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
X,A	GB-A-2 025 734 (SIEMENS) *Page 2, lines 31 to 37; page 3, lines 25 to 29; figures 2,3*	1,2,3-9	H 04 R 1/22 H 04 R 17/00
X,A	DE-A-3 007 773 (SIEMENS) *Page 5, lines 15 to 25; claim 1; figure 1*	1,2,3-9	
A	US-A-4 006 371 (P.C.QUIRKE) *Column 3, line 17 to column 6, line 43; figures*	1-9	

TECHNICAL FIELDS SEARCHED (Int. Cl. ³)

H 04 R 1/22
H 04 R 17/00
H 04 R 17/02

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21-09-1982	MINNOYE G.W.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document