THE SOUND PRESSURE MICROFLOWN

A NOVEL WAY OF TRANSDUCING SOUND PRESSURE

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SUMMARY

A Microflown has been realised that is able to detect sound pressure instead of particle velocity. This Microflown is packaged in such way that the usable bandwidth is 3.4kHz which makes is suitable for mass markets like mobile telephones and toys.

Keywords: Microflown, microphone sound pressure.

Introduction

When an acoustic element is used in a battery-powered application, a number of conditions have to be met. Low power dissipation and operating voltage are required and physical dimensions must be limited. It must be moisture resistant and shock proof. For a telecom application, the bandwidth is limited to 3.4kHz and the selfnoise should be in the order of 35dB(A). The number of additional electrical components should be limited.

In this paper a Microflown is packaged in such way that it becomes sensitive for sound pressure in stead of particle velocity. The Microflown itself exhibits a 700Hz-1kHz high frequency roll off. In previous applications the frequency dependent behaviour (the roll-off) was corrected by means of an electric equaliser or by post-processing. Here the package is designed that acts as an acoustic equaliser. It is based on the Helmholtz resonator.

The Microflown

The Microflown is an acoustic sensor based on a thermal principle [1]. Since its invention (in 1994 [2]) it is mostly used for measurement purposes (1D and 3D-sound intensity measurement [3], [4], [5], [6] or acoustic impedance [7], [8]). The Microflown is also used for measuring DC flows [9]. DC flow is in fact particle velocity with a frequency of 0Hz.

The Microflown itself consists of two very closely spaced thin wires (spacing 350µm) of silicon nitride with an electrically conducting platinum pattern on top of them. A SEM photograph of a Microflown is depicted in Fig 1. The size of the two wires is 1000×10×0.5 µm (l×w×h). The metal pattern is used as temperature sensor *and* heater. The silicon nitride layer is used as a mechanical carrier for the platinum resistor patterns. The sensors are powered by an electrical current, causing the sensors to heat up. The temperature difference of the two cantilevers is linear dependent on the particle velocity.

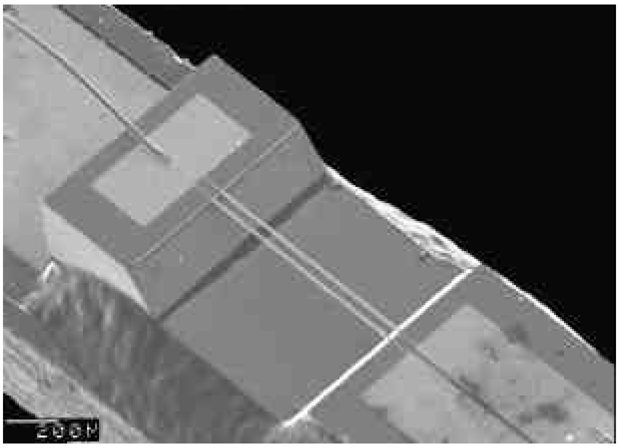

Fig. 1: SEM Photo of a part of a bridge type of Microflown. At the top of the sample a wire-bond is visible. The sample is glued on a printed circuit board, the glue can be seen at the side of the sample.

The Helmholtz resonator

A tube that is terminated by a volume of air creates a Helmholtz resonator. If the tube has a length *l* and a surface A, the air in the pipe can be described in an electro-acoustic analogy as an inductance $L=rl/A$. The volume V can be described as a capacitor $C=Vc^{-2}r^{-1}$. Using c=330 m/s *a*s the speed of sound in air. The resonance frequency is given by:

$$f_{Helmholtz} = \frac{c}{2p}\sqrt{\frac{A}{Vl}} \qquad (1)$$

To get an impression of dimensions: if a tube with a diameter of 5mm and a length of 7mm closes of a volume of a cubic centimetre of air, the resonance frequency will be 2800Hz. The Microflown will be positioned inside the tube and since the resonator is driven by sound pressure the assembly will be sensitive for sound pressure.

Realisation of the pressure Microflown

To be able to tune the Helmholtz housing, this experimental set up was made with a variable volume due to a movable piston. In this way the resonance frequency could be varied from 600Hz up to 4kHz. The Microflown was simply glued in the throat of the housing. Parts of the housing are depicted in Fig. 5.

As a first stage a low noise preamplifier was used, see Fig. 2. The particle velocity induced differential temperature variation of the sensors will cause a differential resistance variation that represents it self as a varying voltage. The output voltage (the signal) of the Microflown, V_{base}, is defined as: $V_{base}=1/2E\cdot(DR/R)$. Using $R=R1=R2$ and DR as the differential resistance variation.

At 94dB (the acoustic reference level) the particle velocity is 2.5mm/s, the differential resistor variation at this velocity is DR/R = 0.09‰.

If the capacitor C_E is chosen large enough, the gain of the preamplifier is 38 times the voltage over the resistor R_C. This gain will not alter the signal to noise ratio.

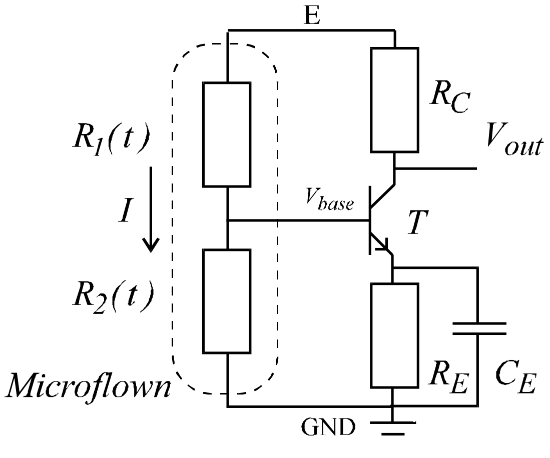

Fig. 2: Microflown with preamplifier.

The noise of the complete system consists on the transistor noise and the noise of the Microflown. It can be calculated to the base of the transistor ($e_{noise\ base}$)

The noise components of the transistor consist of the thermal noise of the base series resistance (r_{base}) and the current noise. The latter can be neglected if the following transistor bias current is chosen:

$$I_C = \frac{50mV}{R}\sqrt{a_{fe}}$$

a_{fe} is the forward current gain of the transistor. The signal to noise ratio can be expressed like:

$$\frac{S}{N} = \frac{I\cdot R\frac{\Delta R}{R}}{\sqrt{2kT_sR\cdot Bw}} = \frac{1}{\sqrt{2kBw}}\times\sqrt{\frac{P}{T_s}}\times\frac{\Delta R}{R}$$

Using k as Boltzmann's constant 1.38×10^{-23} JK^{-1} and Bw as the bandwidth of the signal. The signal to noise ratio of a differential resistive sensor is proportional to the square root of the ratio of its absolute temperature (T_s) and the dissipated power (P) in one resistor.

The packaging won't contribute to the noise level because it only alters the acoustic performance of the Microflown.

Measurements

For comparison, a naked (non-packaged) Microflown was measured and after that put into the throat of the Helmholtz resonator. As can be seen in Fig. 4, the frequency response changes dramatically. Due to the package, the sensitivity of the Microflown is reduced 10dB to 15dB for lower frequencies and at around 3kHz the sensitivity is increased 23dB. The term "sensitivity gain" is arbitrary since the naked Microflown is sensitive for particle velocity and the Helmholtz-packaged Microflown is sensitive for sound pressure.

In a standing wave tube, the difference between the sound pressure and particle velocity sensitivity becomes clear. A sound pressure maximum can be expected at frequencies where the particle velocity is minimal and vice versa [6]. The result of a measurement is shown in Fig. 3.

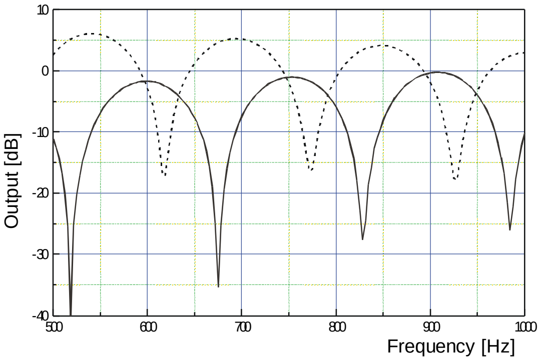

Fig. 3: Output as function of frequency for a non-packaged Microflown (dotted) and one in the throat of a Helmholtz resonator, both measured in a standing wave tube.

Conclusion

Based on the Microflown technology, a sound pressure microphone has been realised. The Microphone has acoustic properties that are comparable to low cost electrets. The selfnoise however has to be improved from 44dB(A) to 35dB(A). This would make it suitable to battery powered mass-market applications like toys and mobile telephones.

The authors are optimistic about finding possibilities to improve the selfnoise.

Acknowledgements

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References

[1] H-E. de Bree et al., The Microflown: a novel device measuring acoustical flows, Sensors and Actuators A 54 (1996) 552-557

[2] H-E. de Bree, Lammerink, Elwenspoek, Fluitman, Patent PCT/NL95/00220, Use of a fluid flow measuring device as a microphone and system comprising such a microphone.

[3] W.F. Druyvesteyn et al, A new sound intensity probe; comparison to the Bruel & Kjaer p-p probe, 104th AES Convention Amsterdam; pre-print 4651, 1998

[4] W.F. Druyvesteyn et al., A New acoustic measurement probe; the Microflown, IOA London, 1999.

[5] H-E. de Bree et al., Three-dimensional sound intensity measurements using microflown particle velocity sensors, MEMS '99, Orlando.

[6] H-E. de Bree et al., Realisation and calibration of a novel half inch p-u sound intensity probe, 106th AES Munchen, 1999.

[7] H. Schurer et al., Comparison of two methods for measurement of horn input impedance, Published in the Proceedings of the 100th AES convention, Copenhagen, 1996.

[8] F.J.M. van der Eerden et al., Experiments with a new acoustic particle velocity sensor in an impedance tube Sensors and Actuators A69, (1998) 126-133.

[9] H-E. de Bree et al., Bi-directional fast flow sensor with a large dynamic range, MME, 1998

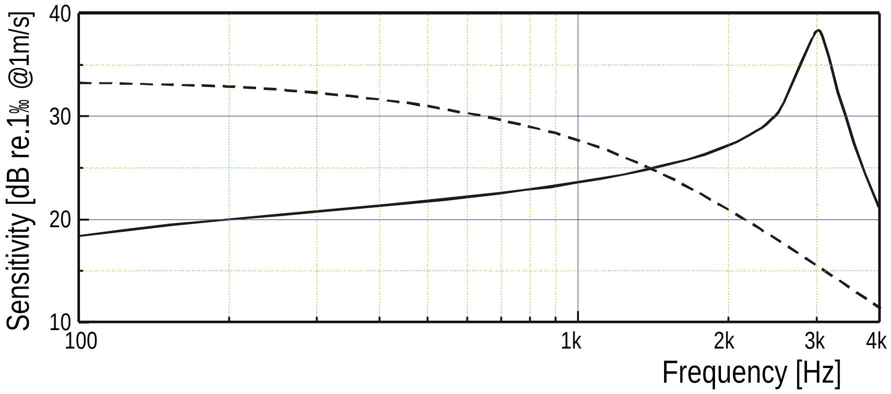

Fig. 4: Sensitivity as function of frequency for a non-packaged Microflown (dotted) and one in the throat of a Helmholtz resonator.

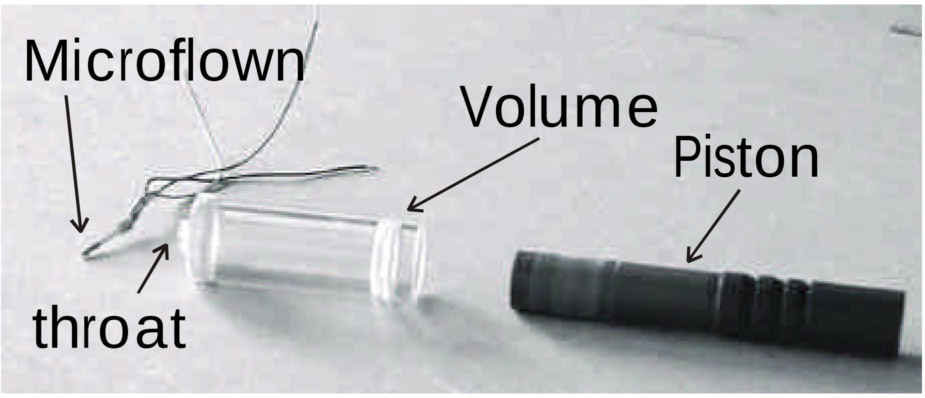

Fig. 5: Parts of the Helmholtz Housing (inner diameter of the tube is 1cm).