Silicon Microphone for High Volume Consumer Electronic Applications

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Introduction

In 2004 more than 1 billion microphones had been used in consumer electronic devices such as mobile phones, PDA´s, digital cameras as well as MP3 players. Most commonly used are Electret Condenser Microphones (ECMs) which are temperature sensitive and therefore either hand placed with springs and rubber boots or inserted with specialized off-line equipment into the applications. A MEMS based Silicon Microphone has been developed which is tolerant of high temperatures used in lead-free solder processes and hence ideal for surface mounting with standard equipment.

Simulation of Diaphragm tension

For a high volume consumer microphone it is essential that a low variation of the microphone sensitivity is achieved by the MEMS design. Various simulations of different diaphragm designs have been made. A section of a 1um poly silicon diaphragm with a diameter of 600um is shown in Figure 1 below. The diaphragm is attached with 36 anchors.

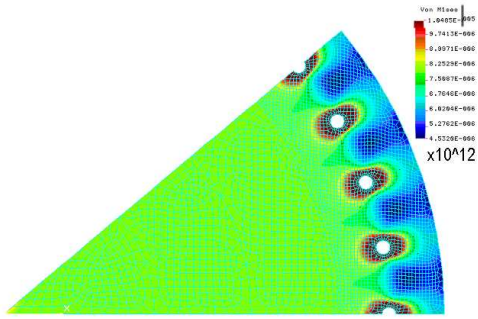

Fig 1: 1um Poly-silicon diaphragm with 36 anchors, diameter 600um

The expected microphone sensitivity over film stress is shown for a 9, respectively a 36 anchor design (Fig. 2). The distance of the diaphragm to the back-plate is 4um.

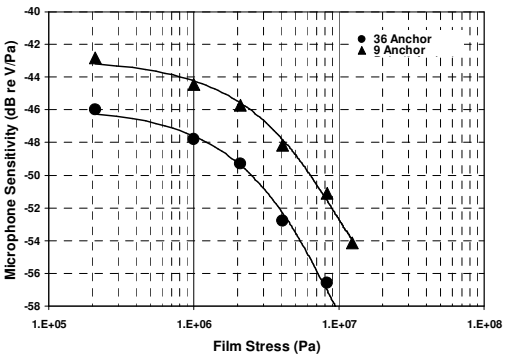

Fig 2: Microphone sensitivity over film stress with 600um diaphragm, 36 anchor and 9 anchor design.

The microphone sensitivity of the simulated design is strongly dependent on the film stress, causing a variation in sensitivity of 8dB within a common range of film stress variance. Obviously this high sensitivity variation is a major disadvantage of the rigidly attached diaphragm design.

MEMS design with free-floating diaphragm

In order to avoid the influence of stress an approach with a free-floating diaphragm has been pursued. As shown in Fig.3 only one physical connection had been created which allows an electrical connection to charge the diaphragm.

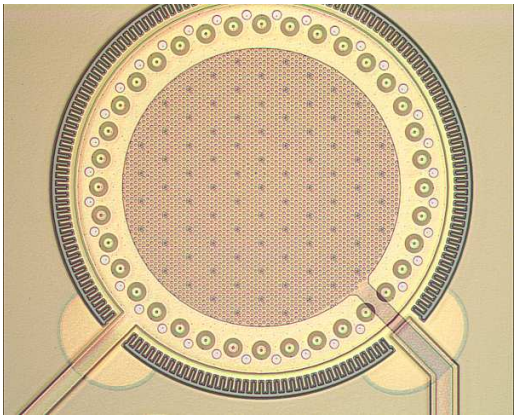

Fig 3: Free-plate MEMS microphone design with just one physical connection of diaphragm and 36 support posts

The microphone diaphragm is supported, but not physically attached, by posts that follow a circular pattern around the edge of the diaphragm. Thus, the diaphragm is said to be 'free-floating' within the MEMS structure. In the electrostatically charged state (bias voltage is 11V), these diaphragm support posts establish a gap between the diaphragm and the back-plate of 4 microns resulting in an active capacity of 0.5pF. A cross section of the MEMS design is shown in Fig.4.

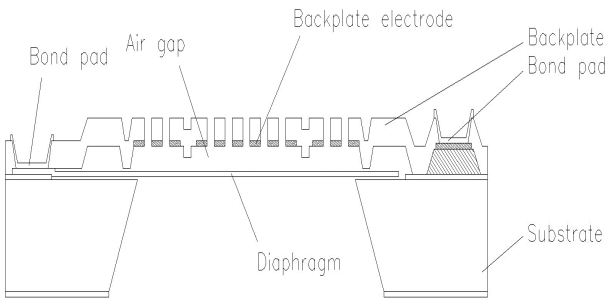

Fig 4: Cross-section of MEMS microphone design

When all other parameters are kept constant, the compliance of the diaphragm is depending on the thickness and the distance between the support posts. The sensitivity of the microphone can therefore be changed by modifying the distance between the support posts which is achieved by a simple mask change.

CMOS circuit

The CMOS circuitry of the SiSonic microphone contains the Bias Voltage Supply, a low impedance output stage as well as a voltage regulator. The Bias Voltage Supply generates a Bias of 11V to charge the diaphragm. Due to the fact that no electret material is being used, the microphone does not lose any sensitivity over time or due to exposure to high temperatures. The voltage regulator allows high variations of the supply voltage in a wide range of 1.5 to 5.5V without any change in sensitivity. As a result any modulations of the power supply voltage, as they occur in applications where RF is demodulated, are highly suppressed. The PSRR (Power Supply Rejection Ratio) of the MEMS microphone is -30dB compared to ECMs with -2dB.

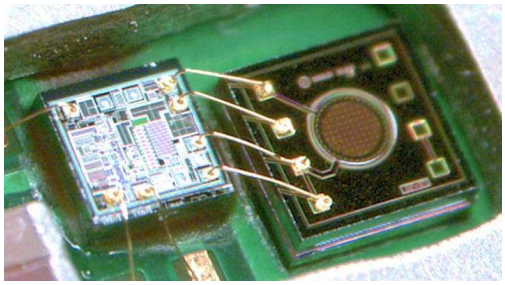

Fig 5: CMOS circuit with bond wires to MEMS die

Microphone Packaging

One of the challenging parts was the Packaging of the microphone. Besides size and cost constraints it was mandatory to take into account reproducibility , batch fabrication as well as an efficient shielding. All points could be covered by utilizing PCB (FR4) material for the terminal plate and the wall of the housing which had been metal plated at the inside to create a “Faraday Cage”. The package withstands temperatures of 100C continuously and can handle the heat produced during the reflow soldering process of typically 260C for 30secs.

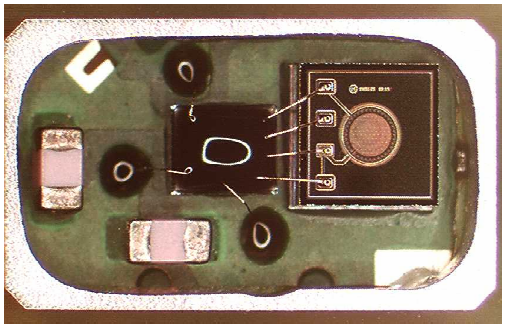

Fig 6: MEMS die and CMOS circuit (coated) with filter capacitors in open FR4 housing

Performance and Technical Data

The silicon MEMS microphone shows equivalent technical data as ECMs. The nominal inherent noise level is 37dB despite the fact that the diaphragm surface is only 4% of the smallest state-of-the-art 4mm ECM. The nominal sensitivity is -42dBV (0dB=1V/Pa). The typical frequency response curve is shown in Fig.7. (10Hz..10kHz).

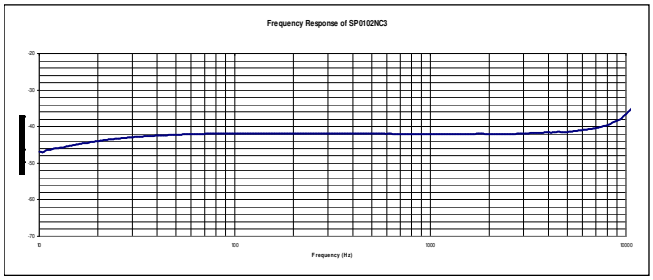

Fig 7: Typical frequency response curve of the MEMS silicon microphone, frequency band 10Hz … 10kHz

Due to the low mass of the diapraghm and the mass of the air in vicinity of the diaphragm the MEMS microphone is less sensitive to vibrations. Fig. 8 shows a comparison of the vibration sensitivity of the MEMS microphone (directly attached to a PCB), a 6mm ECM with and without a rubber holder.

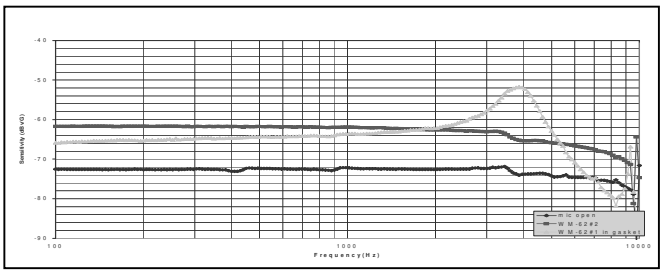

Fig 8: Vibration sensitivity of the MEMS microphone (black), a 6mm ECM without (grey) and with a rubber holder (light grey). All microphones were attached to a PCB.

Adding a rubber gasket to the ECM couples another mass-spring load. The resonance peak of this assembly at 3.8kHz leads to a higher vibration sensitivity in the frequency band from 2-5kHz, there is only a slight improvement below 1kHz. The MEMS microphone shows a vibration sensitivity of 10dB below a 6mm ECM without rubber holder.

Conclusion

A MEMS microphone has been developed which is suitable for surface mounting and reflow solder processes. The shielded FR4 housing contains MEMS die, filter capacitors and a CMOS circuitry with voltage regulator, microphone bias supply as well as a low impedance amplifier. The MEMS microphone shows a stable sensitivity over time and temperature, a high PSRR as well as a low vibration sensitivity. Standard assembly techniques are utilized which leads to a cost efficient mass production of the component.