Sigma-Delta ADC for Audio Applications

Most of the present cordless and mobile telephony sets and audio multimedia devices are employing an electret microphone as audio input device. These microphones are small, reliable, cheap and have electro-acoustical characteristics well suited for low- to moderate-quality audio applications. The microphones can be manufactured in different sizes, larger diameter devices showing better acoustic sensitivity at the expense of increasing costs, especially when used in mobile phones [41].

A schematic of the A/D conversion chain commonly used in mobile phones is shown in Fig. 6.1, (left). The JFET packaged along with the microphone $M$ is used as voltage-to-current converter. The signal is AC coupled to the Codec chip by a large-valued capacitor $C$. The cost of the system can be reduced by integrating $R$ along with the JFET and designing new Codec chips that can be connected directly to the JFET drain [7].

However, other disadvantages of this system remain. At approximately 60dB dynamic range and 1% total harmonic distortion the performance is limited by the JFET’s noise and nonlinearity, even when it is biased at a relatively high drain current. The transconductance $g_m$ of the JFET is not very large and the voltage gain is $g_mR$, $R$ being limited in value by the available voltage span to $V_{dd}$. With decreasing supply voltages, the voltage gain available decreases as well, hence the amplitude of the signal at JFET’s drain. This analog signal is sensitive to externally generated electrical noise because it is connected through an un-shielded, single wire to the Codec chip. This sensitivity is especially not desired when the microphone is used in mobile phone designs where digital and RF components generate powerful noise fields.

The concept developed in this project is illustrated in Fig. 6.1, (right).
The JFET is replaced by a chip containing an ADC and a voltage reference. The ADC is connected directly to the microphone, without making use of an amplifier or filter for signal conditioning. By moving the ADC closer to the microphone the most sensitive node in the system, namely the output of the microphone, remains inside the shielding metal capsule and therefore protected from external noise sources. There is no need of external (discrete) components anymore.

The voltage reference is placed on the same chip with the ADC, so no sensitive analog connections are taken outside the metal package. The number of external connections is also minimized: only the digital Clock input and 1-bit Data output are needed besides ground and supply.

Section 6.1 describes the electret microphone as a high-impedance voltage source. Section 6.2 covers the various aspects of system design, explaining how the constraints are leading to a certain architectural choice for the ΣΔ ADC. Section 6.3 gives a detailed description of the circuits used in the ADC. The analysis of conversion linearity, limited by the performance of the first integrator, is presented in Section 6.4. The measurement results are presented in Section 6.5.

6.1 The Electret Microphone

The structure of the electret microphone is shown in Fig. 6.2. The capacitor inside is built as one stiff, teflon-covered plate and one flexible membrane consisting of mylar covered with a conductive material. The sound waves entering the Sound Port make the flexible membrane vibrate, thus inducing capacitance variations. The electret is the teflon layer.