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New Capacitive MEMS Design Boosts Audio Pickup Quality

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The latest generation of microelectromechanical system (MEMS) microphones based on Infineon's unique sealed dual-membrane technology defines a new benchmark for high-end applications, enabling a whole new audio experience for a large range of consumer devices.

In theory, it's simple: Microphones convert sound pressure waves into electrical signals. In reality, microphones offer different levels of performance, and several parameters are key in determining the performance of dedicated features and applications. The potential of today's cutting-edge devices can be severely limited by poor quality of the provided audio raw data.

In recent years, microphones based on MEMS technology have been adopted in a wide range of applications. Downsizing and acoustic characteristic improvements have given rise to applications that allow us to share information and experiences with smartphone videos and FaceTime (**Figure 1**). Smartwatches can be used to make voice calls. We communicate with digital assistants, ask our smart speakers to play our favorite songs, or control smart home appliances via voice. Furthermore, MEMS microphones are used for active noise cancellation during long flights or while listening to music.

Figure 1: *Sharing information and experiences via FaceTime*

Figure 2: *To make virtual reality a truly immersive experience, high fidelity audio pickup is key.*

Figure 3: *Third-order Ambisonics audio recorder with 19 Infineon XENSIV MEMS microphones*

CREATE A TRULY IMMERSIVE EXPERIENCE WITH VIRTUAL REALITY

Imagine putting on virtual reality goggles and finding yourself on a sunny island in the Pacific Ocean. You are on a beautiful beach, admiring the scenery, walking among the palm trees and listening to the sounds of the waves. Colorful parrots are screeching over your head. The hardware required to create these 360° video experiences is here today and is exploding in popularity (**Figure 2**). However, the ability to easily create the accompanying 360° audio has lagged behind.

Zylia, a Polish recording technology developer, has enabled the world's first portable recording studio by using Infineon's class-leading 69-dB SNR digital XENSIV MEMS microphones. The third-order Ambisonics audio recorder Zylia ZM-1 microphone array can capture immersive 3D audio for virtual and augmented reality (VR/AR) (**Figure 3**). By using multiple devices, even six-degrees-of-freedom sound recordings are possible. To make virtual reality a truly immersive experience, high-fidelity audio pickup of Infineon's MEMS microphones combined with Zylia's advanced digital signal-processing algorithms and microphone array technology was key. Not missing any audio detail requires microphones close to studio microphone quality. MEMS microphones can not only provide this performance but also help to further miniaturize 360° audio recording devices.

AMPLIFY OR ATTENUATE SURROUNDING SOUNDS

Several headphones have been designed for an optimal 360° audio listening. With VR/AR goggles, users can transform their environment into an interactive audiovisual soundscape and capture, touch, and shape sounds. By integrating premium microphones in the headset, surrounding sounds can be attenuated or amplified. Active noise cancellation makes sure that the user hears only his favorite beats and no airplane noise for a comfortable sleep.

Transparent hearing modes have been developed so that the user can choose how much of the outside sound environment, captured through premium microphones, blends into the augmented audio experience. The headphones complement the AR experience by replicating spatial effects with incredible realism, helping the user perceive and locate virtual sounds with pinpoint accuracy. By mixing the right level of external acoustic environment with the specific virtual audio world, there is the option to create truly immersive and social experiences. These headphones can shut out distracting external noise so that the listener can focus undisturbed on the audio content of interest. Combining active noise cancellation with active speech enhancement means that every word of a conversation can be heard even in a noisy environment.

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Figure 4: *Today's video conference systems are fully integrated units including codec, display, camera microphones, and loudspeakers.*

COMMUNICATION SYSTEMS OF TOMORROW

Advanced audio features reduce the perceived distance between friends and colleagues. Teams all over the world are starting to use advanced video conference systems to increase the communication quality. To improve the performance of such devices, premium MEMS microphones are increasingly combined with advanced audio processing like blind source separation or beam forming (**Figure 4**). Today's video conference systems are fully integrated units including codec, display, camera microphones, and loudspeakers.

What works for companies might soon change people's social lives, too. For example, Facebook uses such technologies to enhance the communication between friends and family. In the future, devices will also include virtual and augmented audio and video features. The next generation of MEMS microphones will be the key to advanced communication features in even smaller form factors like smartphones.

POWERFUL AUDIO AND VIDEO EXPERIENCE WITH SMARTPHONES

What previously required a bulky video camera can now be captured with a hand-sized device. Smartphone video capturing has turned us all into storytellers, giving us the opportunity to share our experiences not only with family and friends but also with an audience of millions via social media.

While smartphone video recording has made remarkable progress and offers features like slow motion or time lapse, audio capture has not developed to the same extent. Even the most sophisticated smartphones are still capturing only mono audio, with only a few supporting stereo. No wonder the sound that smartphones produce is poor, flat, and uninspiring — not matching the superior visuals.

But change is happening: Premium MEMS microphones and advanced audio processing are bringing smartphone audio recording to a new level. Special sound recording options allow smartphone users to amplify sound in any direction they choose to focus. Audio zoom provides the option to record what the user wants to hear and suppress other sounds.

NEXT GENERATIONS OF VOICE USER INTERFACES

Voice commands and conversations with digital voice assistants are becoming more and more popular. Unfortunately, they still often require unnaturally loud voice commands or even shouting from a distance. Speech-recognition companies are improving their processors and algorithms for the next generations of voice user interfaces. In its latest incarnation, Alexa can now identify you talking with a low voice and answer you in a whisper to avoid disturbing your sleeping family members at night. It will soon be possible to use voice commands to turn off lights or TVs across different rooms.

Premium MEMS microphones and cutting-edge audio processing are the key elements for making voice-controlled devices truly ready for everyday situations. That is why Infineon and its voice user interface ecosystem partners — Aaware, CEVA, Creoir, SoundAI, Sugr, and XMOS — are leveraging their technological expertise to provide innovative reference platforms and ready-to-use next-generation voice user interface solutions (**Figure 5**).

BASIC TECHNOLOGY

MEMS microphones are fabricated in high volume using semiconductor production processes. The typical design combines a MEMS sensor and an ASIC. The sensor creates an electrical signal that is amplified for analog microphones or processed by the ADC for digital microphones in the ASIC. The MEMS microphone, which converts the audio to an electrical signal, is basically a DC biased capacitor, in which movement of a membrane (or diaphragm) caused by audio pressure changes the voltage over a capacitor plate or plates.

The diaphragm and the backplate behave like a parallel plate capacitor. When the diaphragm vibrates due to incoming sound pressure, the gap and, therefore, the capacitance between diaphragm and backplate change. MEMS microphones extract these changes as electrical signals. The main challenge in handling the pressure level of loud sounds is

Figure 5: *Infineon and its voice user interface ecosystem partners — Creoir, XMOS, Sugr, CEVA, SoundAI, and Aaware (left to right, top to bottom) — provide innovative reference platforms and ready-to-use next-generation voice user interface solutions.*

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the large mechanical movement of the membrane, which will cause distortion when the membrane is displaced to its extremes. The second challenge is to design the ASIC to handle the large signal that the MEMS element generates. As audio-processing algorithms assume a linear signal, any distortions above 1% can cause a significant reduction of the audio quality on which advanced audio processing relies.

One approach is to implement a MEMS sensor element that places the moving membrane between two capacitor plates (dual backplate). This produces a fully differential (compared to single-ended) output, which has several advantages. A dual backplate MEMS microphone minimizes distortion due to its symmetrical construction. The same effect is achieved by moving two membranes that sandwich the capacitor plate (dual membrane).

NEXT GENERATION OF PREMIUM MEMS MICROPHONES: SEALED DUAL MEMBRANE

Compared to MEMS microphones with a single backplate, the introduction of the dual backplate technology enabled a significant increase in linearity specifications. The next evolutionary step is capacitive MEMS microphones with a sealed dual membrane (**Figure 6**). The sealing of the capacitance area enables practically noise-free audio signal capturing. The SNR is further increased from 70 dB up to 75 dB.

The first prototypes in 2018 have already achieved 75-dB SNR in a 4.0 × 3.0 × 1.2-mm package. The first premium MEMS microphones with the new sealed dual-membrane design will be available by the end of 2019. The first devices of the new generation have already been used to demonstrate the advanced audio features discussed above. Engineering samples are already available for lead customers in the field for advanced audio recordings, active noise cancellation, communication, and voice user interfaces. In 2020 and 2021, Infineon will introduce further shrunk-sealed dual-membrane microphones addressing devices with space constraints so that no matter where you are, you can be heard. ■

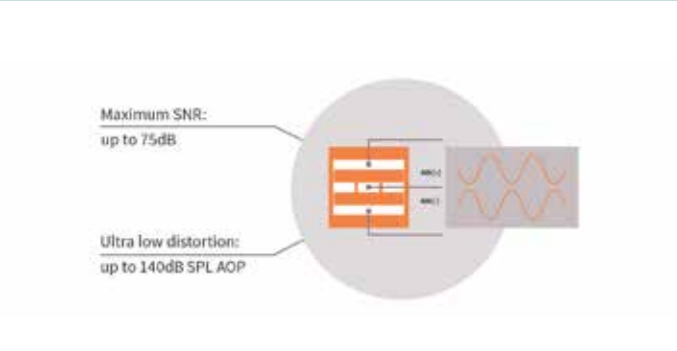

Figure 6: *Infineon's new sealed dual-membrane (SDM) technology*

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