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COVER STORY

The Growing Importance of Innovative MEMS Microphones

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Microphone technology is becoming increasingly important as audio applications and features proliferate. Different factors have to be considered for a variety of applications, ranging from audio quality to water and dust robustness to size and cost. Infineon offers a portfolio of XENSIV™ MEMS microphones that ranges from low-cost models to products that deliver the highest performance levels.

Voice is set to replace buttons in the future as a means of intuitively interacting with the environment around us. Reaching beyond conventional audio devices such as phones and recorders, voice control is now being incorporated into billions of other devices. Sensors such as MEMS microphones are key enablers of the trend toward human-machine communication. According to a report published by SAR Insight,[1] nearly 6 billion devices are expected to have voice interfaces supporting features such as voice triggers, voice biometrics, and embedded digital assistants by 2023. The current Covid-19 crisis has highlighted two areas where high-performance microphones can play a key role in developing sophisticated solutions: online meetings with high-quality audio and health tracking.

Many people are working from home because of the coronavirus pandemic. As a result, video conferencing has become the main way for employees to communicate with their colleagues. In these situations, advanced audio features can help reduce the perceived distance between friends and colleagues. Teams all over the world are using advanced video conference systems (**Figure 1**) to communicate more effectively — something that is particularly important in times when people are not able to meet in person.

Figure 1: *Video conferences benefit from improved audio quality based on high-performance microphones.*

High-quality video and audio are vital for ensuring that online meetings are efficient and convenient. If you think back to your last Skype or Zoom video call, what was more important: seeing your colleagues or hearing them? In terms of poor quality, what would bother you more: a blurry image or only hearing a part of each word? Audio often is noticed only when it is poor quality. And once we are used to good quality, nothing else will do. The main goal here is to ensure that each speaker's voice is reproduced as naturally as possible.

A new class of high-performance microphones is paving the way for smarter video calls and a host of other features. Smart cameras can pan and zoom in on people and objects to keep up with the action. They can also automatically pivot to keep everyone in view. Smart sound enhances the voice of the person talking while minimizing background noise. To improve performance levels, high-performance MEMS microphones are increasingly combined with advanced audio processing functions such as blind source separation or beamforming to localize the position of the user and blur out the background sounds. Today's video conference systems are fully integrated units that include a codec, display, camera microphones, and loudspeakers.

RISING DEMAND FOR HIGH-QUALITY AUDIO

High-quality video conferencing is no longer limited to the business world. The need to communicate with family and friends — be it in a "virtual happy hour" or digital Easter celebration — has led to the emergence of a number of new tools. New consumer devices such as Facebook's Portal, which combines video and audio features, all benefit from high-performance microphones that offer a high-quality audio experience. Other new applications are also being developed. Robots that can communicate with people in hospitals or retirement homes, for example, already exist today. Better sensors will make these interactions increasingly natural. In recent years, true wireless stereo (TWS) earbuds have emerged as a new device category in the field of hearables. TWS earbuds are not connected to each other or an audio source by wires. Instead, they are connected over Bluetooth. Like their larger, over-ear cousins, TWS earbuds are equipped with a range of audio features in which microphones, once again, play a key role.

Active noise cancellation (ANC), for example, was originally developed to reduce the static noise of engines on flights. Nowadays, more powerful algorithms and better microphones have pushed ANC beyond the world of travel, enabling users to eliminate background noise and voices in the office or at home. It is even a feature in today's TWS headsets. Beamforming with microphone arrays enables people to have clear conversations, whether they are working from home or in a noisy environment.

Headphones, by design, isolate wearers from the outside world. While this can provide valuable passive isolation from annoying sounds, it is not always convenient. In many situations, we also want to hear what's going on around us without having to remove our devices — for instance, to tune in to announcements in train stations, pick up on surrounding sounds while running in a park, or talk to others. Transparent hearing modes have been developed that enable users to create blended augmented audio experiences by telling their high-performance microphones how much of the outside sound environment they wish to capture. Sound is picked up just before it enters the ears and is altered and played back in real time, creating a transparent, augmented hearing experience. Some manufacturers provide smart features, such as the automatic activation of transparent hearing when the wearer's name is called. In the future, it may be possible for microphones to be activated automatically when they detect an approaching car or a boarding announcement in an airport, for instance.

While transparent hearing is a first step toward emulating human ears, the experience can be taken one step further with 360° audio recordings. This technology involves equipping earbuds with microphones that have a low noise floor. The wearer can then use these earbuds to record sound experiences such as concerts in 360° audio. This creates an immersive experience that can be played back and relived later or shared with friends. The listener feels like they are actually at the concert; without any hiss noise, the recording cannot

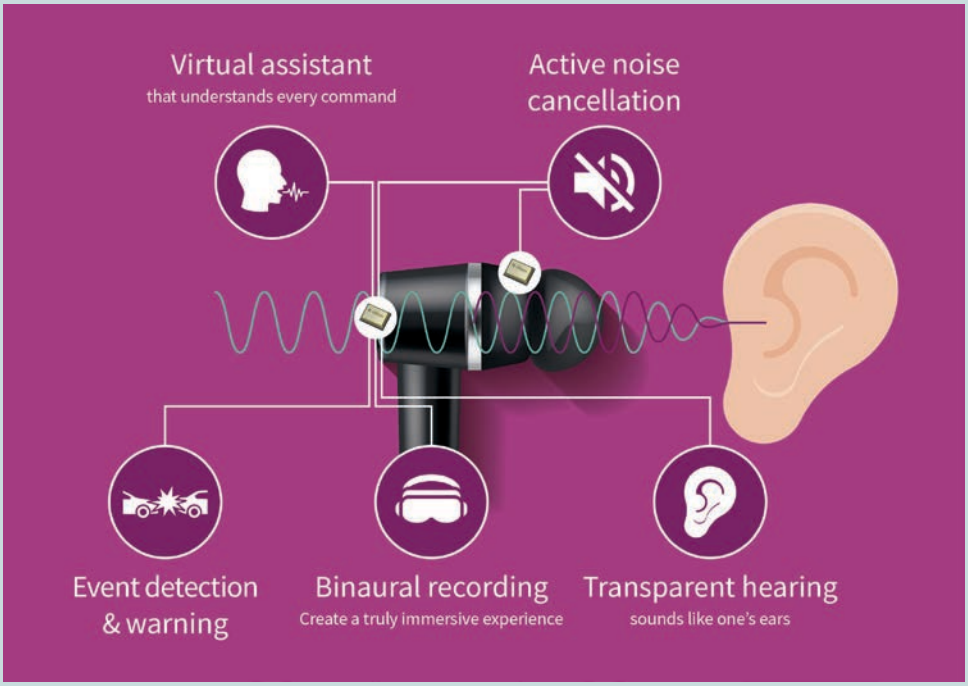

Figure 2: *High-performance microphones are vital in a wide range of voice-control features and applications.*

be distinguished from the real thing. Microphones are vital for providing the high-quality input that all of the applications mentioned here need in order to deliver an outstanding user experience and excellent audio quality (**Figure 2**). MEMS microphones with best-in-class audio quality specifications can deliver the required performance.

HEALTH TRACKING

Monitoring vital signs with optical sensors is an established technology. In some instances, however, space constraints limit the use of existing sensors. One way to save space here is to combine several sensors — creating, for example, a microphone that can also monitor body temperature. Health tracking is a growing market for mobile devices. Tracking applications will become more appealing as users become more health-conscious. High-performance microphones with ANC can be combined with body temperature sensors to provide a useful solution for tracking health and detecting a high temperature. A TWS headset with the ability to track the wearer's temperature and issue a warning at the onset of a fever provides peace of mind; users can rest assured that their health is being monitored. Detecting fevers at an early stage means that treatment can be started promptly. Having a record of a patient's body temperature can also help with diagnosis and treatment. Infineon has developed an ASIC that features an I^2C temperature sensor. Combining this with the MEMS produces a high-performance microphone with temperature-sensing functionality — a solution that saves space by combining the two sensors.

INNOVATIVE APPLICATION EXAMPLE: FLUSENSE

An innovative device invented in the U.S. at the University of Massachusetts Amherst demonstrates the possibilities of using microphones in medical tracking (*https://www.umass.edu/gateway/feature/flusense*). Designed to analyze coughing and detect crowd sizes, the FluSense device is made up of three components: a camera, a microphone, and a computer (**Figure 3**). The challenge for the developers was to find an early way to predict and monitor the outbreak of influenza-like illnesses — characterized by key symptoms such as fever and coughing — as feeding lab-confirmed cases into epidemic models takes time.

The FluSense solution captures crowd-level non-speech body sounds such as coughs in an unobtrusive and passive manner, combining this data with patient counts estimated using thermal images taken in hospital waiting rooms. Together, these elements provide key predictive information on epidemiological trends for a given demographic. The FluSense platform processes low-cost microphone array and thermal imaging data at the edge using a Raspberry Pi and a neural computing engine (the Intel Movidius). None of the information stored is personally identifiable.

The solution can run deep-learning–based acoustic models and algorithms for estimating crowd sizes based on thermal imaging in real time. The system can detect coughs with an accuracy of up to 87%. The developers now aim to validate the model in non-clinical settings such as restaurants, public transportation, and classrooms. High-performance microphones could increase detection rates further under such conditions.

MICROPHONE PERFORMANCE

Taking a closer look at microphone performance, there are several factors to take into consideration: What are high-performance microphones? Which microphone parameters are important and which ones are relevant for different use cases? Every microphone is capable of recording a range of sound pressure levels (SPLs); this is known as the dynamic range of a microphone. The upper limit of the dynamic range is defined as the acoustic overload point (AOP), while the lower limit is defined by the microphone's self-noise. A microphone can pick up only signals with an SPL above its self-noise. This lower threshold is known as the "noise floor" of a microphone, and it defines the signal-to-noise ratio (SNR). A microphone cannot record any sound below its noise floor. A microphone with a noise floor of 30 dB SPL, for example, cannot capture a human whisper at 25 dB SPL amplitude. Therefore, microphones with a higher SNR (i.e., a lower noise floor) are well suited to picking up low-amplitude audio signals.

SNR and AOP are important parameters for assessing individual microphone performance. However, most devices today use several microphones in an array. Smartphones, for example, have three or four microphones, while TWS incorporates up to six microphones (three per earbud). The numbers are even higher in conference systems. In short, microphone arrays can contain anywhere from two to 32 microphones. The performance of a microphone array depends on a combination of individual microphone characteristics and combined array characteristics. The individual characteristics include the AOP and SNR, while the combined array characteristics include factors such as sensitivity matching (whether all mics have almost the same sensitivity) and phase matching (whether all mics have a similar phase response). These features combine to improve overall audio capture and to ensure that the array produces higher-quality sound and has lower self-noise levels — comparable in many ways to watching a movie in normal resolution or full HD.

THE IMPORTANCE OF HIGH-QUALITY AUDIO RAW DATA

Virtual assistants like Siri and Alexa are voice user interfaces (VUIs) present in smart speakers. VUIs comprise an array of microphones that are used to capture higher-quality raw audio data as input for the application processor. The raw data input from high-SNR

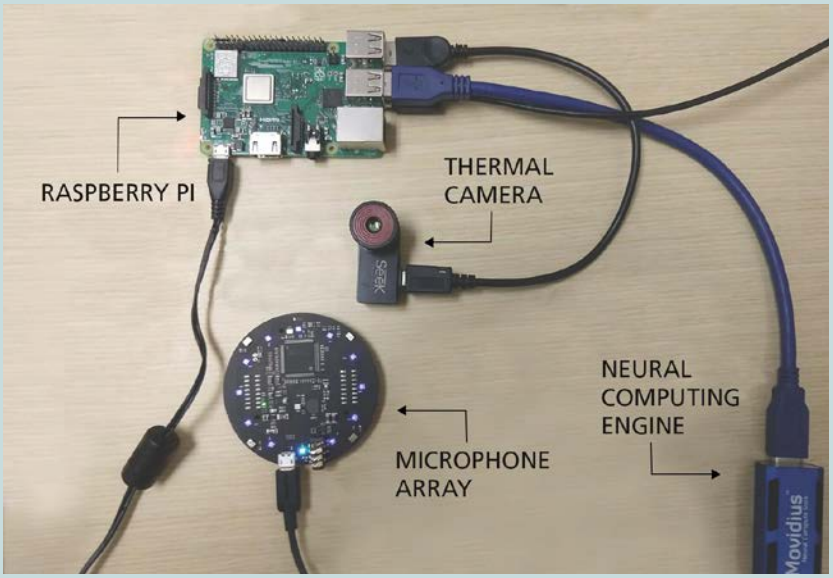

Figure 3: *FluSense is an innovative concept for monitoring influenza trends. It combines a microphone array with a camera to analyze coughing and patient counts.* (Image: University of Massachusetts)

microphones contains more information and less self-noise, which makes the subsequent processing on the edge processor and in the cloud more efficient. Better raw audio data input results in a higher hit rate, lower false acceptance instances, and, subsequently, a lower error rate for system wakeup. In short, having better microphones in your smart speaker means that the next time you ask it a question, you won't have to repeat yourself.

In general, each acoustic parameter has its own importance and enables certain specific use cases (**Figure 4**). High SNR, for example, is important for picking up distant and whispered voices in smart speakers, video conferencing devices, and similar far-field applications. A study conducted by Infineon showed that higher-SNR microphones can capture whisper audio 40% better than standard microphones. High AOP is key for undistorted concert music recordings and echo cancellation when a microphone is placed close to a speaker. Good phase matching is important for microphone arrays and improving the performance of beamforming algorithms. In other words, if you are building a system that has to perform beamforming, pick up audio from a distance, and cancel echoes, you need an array of microphones with all of the above-mentioned features.

In addition to providing all of the audio parameters for the use cases mentioned above, microphones should be robust against water and dust. They must also work within their specifications under variations in temperature, humidity, pressure, and other environmental factors. In an ideal world, microphones would not generate any self-noise at all but would emulate the human ear, which has an extremely low noise floor. In reality, however, there are technical limitations defined by physics. There are typically four noise contributors in MEMS microphone systems: the MEMS itself, the ASIC, the package, and its sound port. The highest noise contributor for state-of-the-art microphones used in smartphones is the MEMS component. Infineon has improved the MEMS component, pushing the boundaries of MEMS microphone performance beyond even the current best-in-class dual-backplate technology. The company's efforts here culminated in the development of Infineon's innovative, patented sealed dual-membrane (SDM) MEMS technology.

A LOOK INSIDE A MEMS MICROPHONE

Before explaining how the new SDM works, it makes sense to take a quick look at the inside of a MEMS microphone and see what challenges the different components have to overcome to deliver the best performance. A typical design combines a MEMS sensor and an ASIC. MEMS microphones extract audio pressure changes as electrical signals. The ASIC then processes these signals either in differential analog or in digital format at the output. The first challenge is handling the pressure levels of loud sounds, as they produce large mechanical movements in

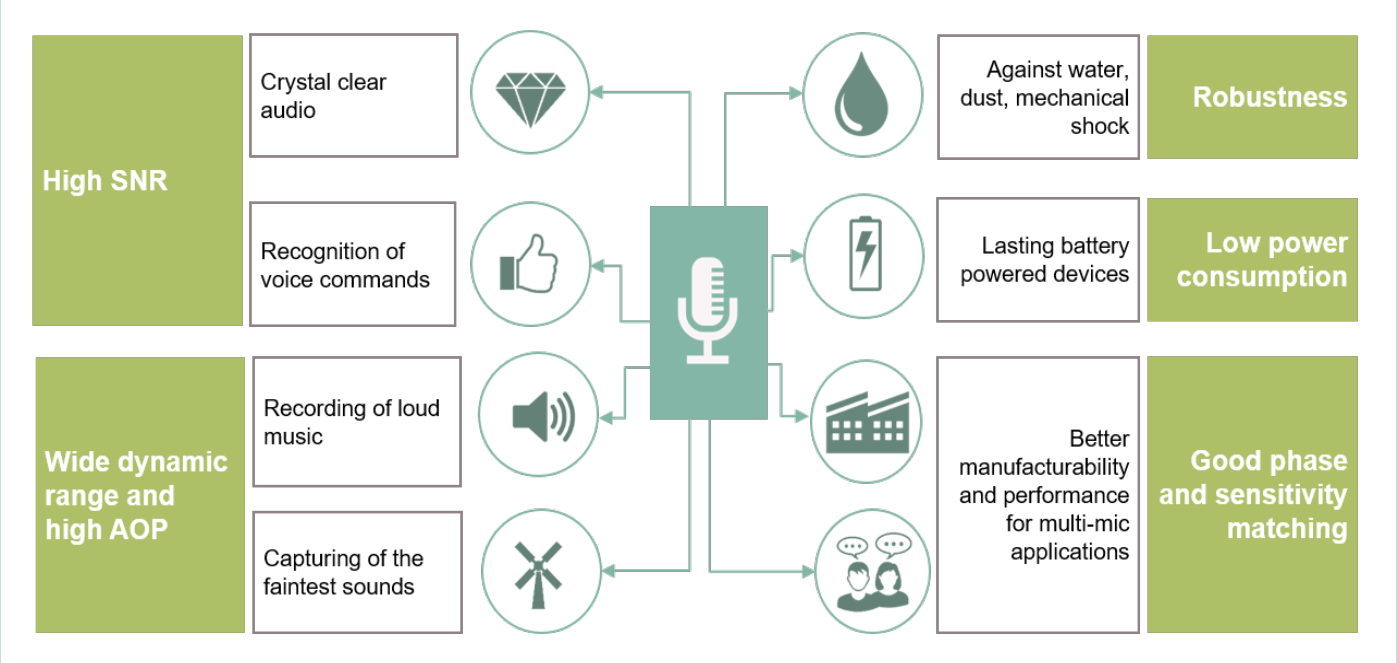

Figure 4: *High-performance microphones are characterized by a number of different parameters.*

the membrane. These kinds of extreme membrane displacements cause distortion. The second challenge is to design an ASIC capable of handling 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, or DBP). A DBP 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).

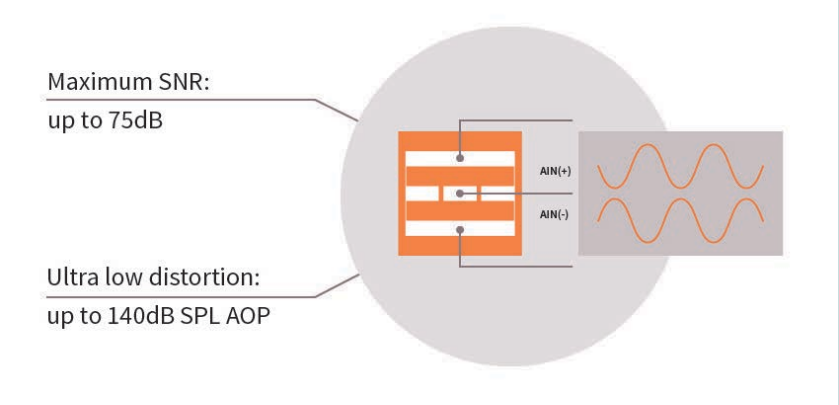

Figure 5: *MEMS microphones with robust sealed dual-membrane technology (SDM) set the SNR and AOP benchmarks.*

SEALED DUAL-MEMBRANE TECHNOLOGY

The introduction of DBP technology has produced a significant increase in linearity specifications compared with MEMS microphones with a single backplate. The next evolutionary step is capacitive MEMS microphones with an SDM. Sealing the capacitance area enables practically noise-free audio signal capture. This increases the SNR further, from 70 dB up to 75 dB (**Figure 5**). The first prototypes have already achieved an SNR of 75 dB and an AOP of 135 dB SPL. The first devices in this new generation have already been used to demonstrate the advanced audio features discussed above. By the end of 2020, Infineon will introduce further shrunk-sealed dual-membrane microphones targeted at space-constrained devices.

CONCLUSION

Microphone technology is becoming increasingly important as the number of audio applications and features rise. Different factors have to be considered for a variety of applications, ranging from audio quality to water and dust robustness to size and cost. Infineon offers a portfolio of XENSIV™ MEMS microphones that ranges from low-cost models to products that deliver the highest performance levels. Devices with a single backplate are robust and cost-effective but have limited acoustic performance, whereas MEMS devices with DBP provide improved acoustics. SDM technology combines the highest acoustic performance (SNR up to 75 dB) with high robustness (IP 57). SDM MEMS microphones with best-in-class SNR are robust against dust and water and are the ideal choice for emerging applications such as high-quality video/audio conferencing and medical tracking. ■

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[1]Digital and Voice Interface Forecast, October 2018

NEWS

Imagination Inquiry Exposes Wider Risk of IP Sales to China

Imagination Technologies' now-defunct plan to add four Chinese investors to its executive board has touched a raw nerve in the U.K. and triggered a series of events leading to a full-blown government inquiry. In a three-hour hearing before the U.K. Parliament's Foreign Affairs Committee, three Imagination CEOs, past and present, were grilled in a public battle to preserve the IP developer's legacy. The public debate centered on the suitability of Imagination owner Canyon Bridge Partners' recent attempt to add new Chinese directors to the board and the government's role — if any — in protecting home-grown intellectual property (IP).

Tech industry executives watched the live online event as factions within Imagination's past and present senior leadership defended their business strategies. Imagination's revenue has steadily declined since 2017, and its recovery path has pitted former CEOs Hossein Yassaie and Ron Black, as well as former senior executive John Rayfield, against interim CEO Ray Bingham, who favored the involvement of Chinese backers.

None of the issues were resolved. The committee tried to unravel the drama that sparked the questions — the departure of Black and Rayfield as well as former senior executive Steve Evans — and fears that Imagination would relocate to China.

The bigger picture — IP licensing and security risks represented by China — isn't unique to the U.K. Electronics companies view the lucrative Chinese electronics market as fiscal salvation; governments greet China's foreign-investment plans with suspicion.

IC Unit Shipments Face First-Ever Back-to-Back Decline

Market researcher IC Insights forecasts that worldwide IC unit shipments will register their first-ever back-to-back annual decline in 2020. Prior to 2019, the previous four years that IC unit shipments declined were 1985, 2001, 2009, and 2012. From 2013 through 2018, IC unit shipments were on a respectable growth path, with an 8% increase logged in 2013, a 9% jump registered in 2014, a 5% increase displayed in 2015, a 7% increase shown in 2016, a double-digit growth rate of 15% in 2017, and a 10% increase in 2018.

In contrast to the double-digit increases in 2017 and 2018, 2019 marked only the fifth time in the history of the IC industry that IC unit shipments registered a decline, according to IC Insights.