Replacing ECMs with XENSIV^{TM} MEMS microphones

About this document

Scope and purpose

This document provides reasons to replace Electret Condenser Microphones (ECMs) with premium Micro-Electro-Mechanical System (MEMS) microphones.

Intended audience

Infineon XENSIV^{TM} MEMS microphone customers.

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1 Abstract

Smartphones and many other consumer electronics devices have switched from Electret Condenser Microphones (ECMs) to Micro-Electro-Mechanical System (MEMS) microphones. Due to the great improvements in MEMS technology, the change is also happening in applications with high performance requirements. The performance/size and performance/cost ratios of modern MEMS microphones, as well as their reliability, have reached levels at which any remaining reasons to stick with ECMs have vanished.

2 New high-SNR digital MEMS microphones vs. ECMs

2.1 Performance: SNR and AOP

The performance of MEMS microphones has improved tremendously in the past 10 years. The Signal-to-Noise Ratio (SNR) of Infineon's IM69D130 microphone is more than 10 dB higher than MEMS microphones that were available in the market a decade ago. High SNR improves modern sound-capturing systems in terms of:

- Better far-field audio signal pick-up
- Capturing of low-volume audio and whispers

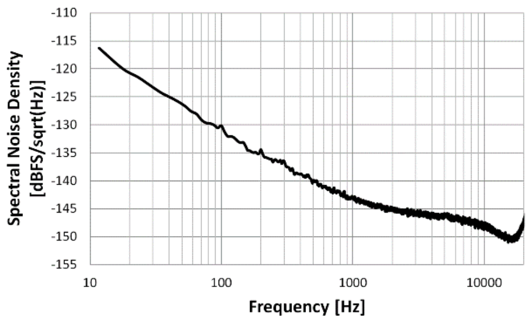


Figure 1 IM69D130 typical noise floor

The ability of microphones to capture high sound pressure levels, quantified by the Acoustic Over-load Point (AOP), has also increased dramatically. The 130 dB_{SPL} AOP of IM69D130 is well suited to the variety of acoustic conditions and environments experienced by modern devices.

AOP is defined as the acoustic input level that results in 10 percent total harmonic distortion (THD) at the output. Ten percent THD is clearly audible and unpleasant to the listener, meaning this legacy standard does not fully reflect the audio quality expected of modern devices. Most audio equipment, such as professional headphones and studio microphones, are specified instead to an AOP referencing 1 percent THD.

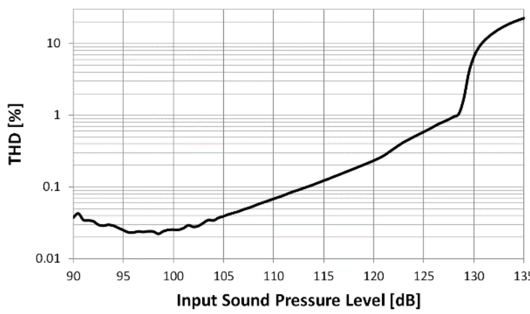


Figure 2 IM69D130 THD vs. SPL

The THD of IM69D130 remains less than 1 percent up to input levels as high as 128 dB_{SPL}. Maintaining low THD is important in use cases where even moderate distortion causes reduced system performance or audible signal quality degradation. Examples are systems based on speech recognition (in which voice commands may compete with music from adjacent speakers) and noise cancelation systems where an undistorted audio signal is required in order to achieve proper noise canceling. Furthermore, low distortion benefits the recording of music or other content. The AOPs of moderately priced ECMs tend to be low, and the THD levels already rise significantly at relatively low sound pressure levels.

High-pressure acoustic signals do not only come from loud music. The performance of smartphones or noise-canceling headsets can be degraded easily by low-frequency wind noise. Outdoor wind noise tends to over-load traditional microphones and cause clipping. Clipping is perceived as unpleasant by the listener and greatly reduces the performance of active noise cancelation algorithms.

The IM69D130 features a high dynamic range of 105 dB, which is enabled by the fully differential dual back-plate sensor, the ultra-low-noise preamplifier and an ultra-high-performance sigma delta ADC. ECMs with comparable performance levels tend to be very large and expensive.

2.2 Frequency response

MEMS technology achieves a flat frequency response. The small, lightweight membrane has a high resonance frequency, enabling the reception of very high frequencies. With a -3 dB cut-off point at 28 Hz, the IM69D130 is able to cover almost the entire audible frequency range of the human ear, enabling a balanced and high-fidelity sound capture. The frequency response of ECMs tends to be limited and irregular, with a high- to mid-frequency bias due to the lower resonance frequencies of much larger ECM sensor membranes.

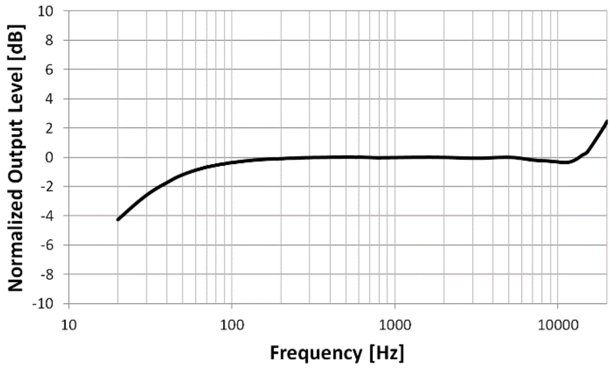


Figure 3 IM69D130 typical free-field frequency response

2.3 Digital interface

Digital interfaces are more robust to electrical noise sources encountered in long signal chains. MEMS microphones are available with PDM interfaces, which make microphone integration easier, more reliable and faster than analog ECMs. Digital microphones reduce the need to design and execute disturbance mitigation. PDM is widely supported by audio processing systems used in consumer electronics devices. The digital signal chain of the IM69D130 is designed for low-latency operation (6 µs at 1 kHz), which does not compromise system performance.

Using board-mounted MEMS microphones allows for better control of routing and shorter traces, which further improves the interference immunity of the overall system.

2.4 Matching and stability

Modern MEMS microphones use highly accurate semiconductor production processes, allowing for better part-to-part matching compared to ECMs. MEMS microphones are very stable over time and with varying environmental conditions, such as humidity and temperature. ECMs purchased in pairs might achieve a similar short-term matching. However, ECMs are susceptible to drift due to environmental conditions, and may lose their match in the long term.

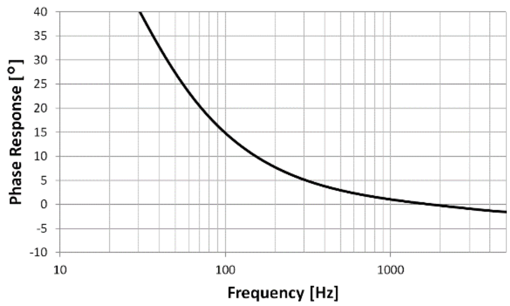


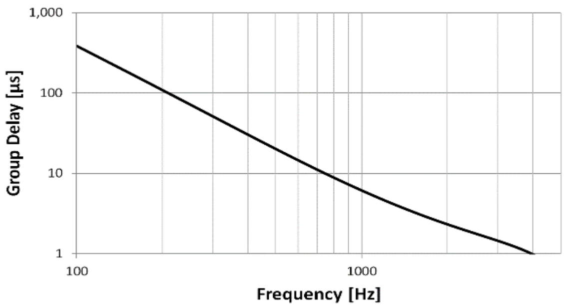
Figure 4 IM69D130 – typical phase response vs. frequency

ECM microphones are biased using a fixed charge on the electret to set the sensitivity. The charge is applied during the manufacturing process and doesn't get renewed after the microphone is shipped. Over time the set charge escapes from the electret material. In the case of surface-mount components, the often-used reflow process causes a drop in the charge. Charge loss is further accelerated by environmental factors such as temperature and mechanical shock. The loss of charge cannot be accurately predicted, causes sensitivity loss and compromises the frequency response.

Infineon's MEMS microphones, by contrast, use a charge pump to deliver the biasing voltage during operation. The charge pump output level is calibrated during the manufacturing process to guarantee a sensitivity match of ±1 dB in all microphones. MEMS microphones don't change their properties due to environmental conditions, and maintain accuracy throughout their lifetime. 100 percent of the parameters in Infineon's datasheets are

tested to ensure high performance and a match in sensitivity and phase (±1 dB and ±2 degrees, respectively). The excellent phase match makes Infineon's microphones ideally suited to high-performance multi-microphone applications such as beam forming, speech recognition, background noise cancelation, audio source detection and stereo recording.

Compared to a matched pair of ECMs, Infineon's high-quality MEMS microphones of the same make and model have a closer match in sensitivity, phase response, frequency response and SNR. The process of selecting paired ECM microphones is logistically cumbersome. It adds costly testing and matching steps, and the need to track and handle known pairs in system manufacturing. Furthermore, having matched pairs does not mitigate the problem of ECM properties changing over time. The poor momentary and lifetime accuracies of ECMs makes them not well suited to applications that require high accuracy of sensitivity and phase.



2.5 Quality and reliability

Microphones are subjected to harsh usage conditions such as dropping, temperature changes and other potential hazards, especially in portable devices such as smartphones and wearables. Infineon's high-quality robust MEMS sensor technologies endure everything the device endures. The high reliability and quality of the microphones is verified with industry-standard testing during component development and mass manufacturing.

2.6 Power supply rejection

Power supply rejection measures the microphone's ability to maintain a clean output signal in the presence of unwanted interference on the power supply line, coupled with injection of radiated disturbers. All Infineon MEMS microphones internally regulate their power supply, suppressing any disturbing supply voltage variations or spikes. ECM microphones are two-wire phantom powered and typically contain only a JFET buffer, and do not regulate their power supply, resulting in high sensitivity to any variations in the supply voltage.

2.7 Vibration sensitivity

Vibration or structure-borne noise can be an issue in many applications. It is important that the microphone acoustic sensing element does not detect this mechanical vibration as an acoustic signal. As vibration sensitivity scales with membrane mass there is a clear advantage of MEMS microphones with membrane thickness of less than 1 µm and a membrane surface of typically 1 mm^2 or less. These values compare to typically 6 µm membrane thickness and 5 to 10 mm^2 surface for ECMs, whose increased volume results in higher mass and higher vibration sensitivity.

2.8 Small size

The small size of MEMS microphones enables many improvements in device design:

- For a single omnidirectional microphone application, the performance/size ratio offered by Infineon's MEMS microphones is clearly superior to traditional ECM technologies
  - The higher performance density means that the same, or even higher, microphone performance is available in a greatly reduced package size
- Reduced microphone size can allow for optimization of system size or parameters, e.g. reduced bezel width
- Microphone implementation in tight places where ECMs may not fit
  - The smaller height or width of a MEMS microphone may suit the implementation better
- Small size and cost allows for easier and cheaper implementation of microphone arrays
- Multiple MEMS microphones can replace an ECM while maintaining a small implementation size
  - Two or more microphones can be used to create a variable directivity microphone system; the added versatility helps optimize the capturing capabilities of multi-purpose devices in all their use cases

2.9 Directivity and versatility

Multiple omnidirectional MEMS microphones can be used to create directional capturing systems, enabling very versatile solutions which adapt to multiple use cases. Fixed directionality ECMs can be replaced by adaptable MEMS arrays. This versatility is needed for:

- Teleconference, with one person using the device vs. multiple participants using the same device
- Capturing sounds from the front of the camera vs. behind the camera (narration by the camera operator, or creating a cardioid mic pattern to focus on the front of the camera)
- Capturing the sound of the object in the film frame vs. capturing the ambient soundscape

Versatile directivity can be achieved without significantly increasing the size of the implementation when compared to directional ECM capsules. A simple switchable-directionality system can be formed with two small MEMS microphones. Using three or four MEMS microphones and simple electronics enables creating a multi-directional capturing system with a wide variety of directivity patterns: mono, directional mono (cardioid, figure-eight, etc.), audio zoom (variable directional pattern), adaptive beam steering, stereo, directional stereo, multi-channel surround, etc. The accurate performance of MEMS microphones enables very high-array performances. Using omnidirectional microphones for directional systems also improves signal quality in windy conditions by choosing the microphone with the cleanest output and/or switching to an omnidirectional mode. This is not as easily achieved with directional ECMs.

2.10 Production

MEMS microphones are compatible with standard consumer electronics production processes and methods. Some ECMs must be hand soldered onto the device circuit board, which is an expensive manufacturing requirement. MEMS microphones can be mounted in the existing solder reflow stage and do not require special treatment or handling steps apart from sound port protection.

MEMS microphones are typically supplied on tape and reel.

For further advice on mounting MEMS microphones, please refer to application note AN557.

Revision history

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V1.0	2019-03-26	Final release

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