

# Dual Back Plate Silicon MEMS Microphone: Balancing High Performance!

Marc Földner and Alfons Dehé

*Infineon Technologies AG, 85579 Neubiberg, marc.fueldner@infineon.com*

## Abstract

Ten years of production of silicon MEMS microphones and intense application in smartphones have raised the level of requirements, significantly. Key performance parameters are a high signal-to-noise ratio for high audio quality and speech recognition, a high acoustical overload point for wind noise suppression and video recording and small microphone device size for thin and miniaturized consumer goods.

In this article, the design, technology and performance of a true differential microphone with dual back plate MEMS is presented to support such application requirements.

## Introduction

The MEMS microphone market is continuously growing by average ~30%/year (Figure 1). In 2013, more than 2.5 Billion microphones have been used. The strong demand is mainly driven by high performance requirements in applications like mobile handsets, media tablets and headsets. Figure 2 highlights the evolution of some key MEMS microphone performance parameters over the past years. While the volume of the microphone modules has been reduced from around 30mm<sup>3</sup> down to 5mm<sup>3</sup>, the signal-to-noise-ratio SNR has been increased from 58dB(A) up to 66dB(A). This development enabled multiple microphones in smartphones for telephony, video recording and noise cancellation. Current modern smartphones comprise up to 3 microphones. More microphones per smartphone are expected in future.

For an undistorted recording of videos in loud environments (e.g. rock concerts), a high acoustic overload point (AOL) is needed. The AOL defines the maximum sound pressure level (SPL) where the total harmonic distortion THD exceeds the 10% level. While early specifications afforded an AOL level of 120dB SPL, today 135dB SPL is a must.

The next section will introduce the technology to realize such performance levels.

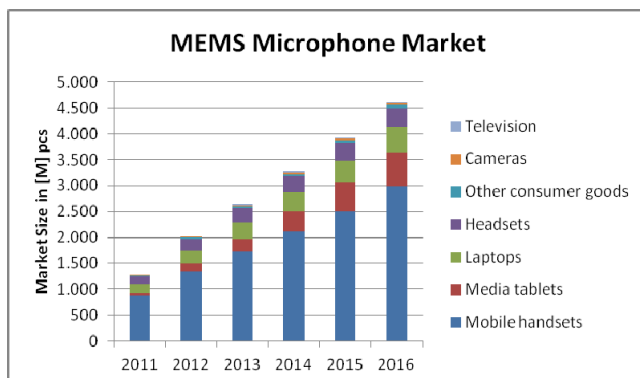


Figure 1: MEMS microphone market development [1]

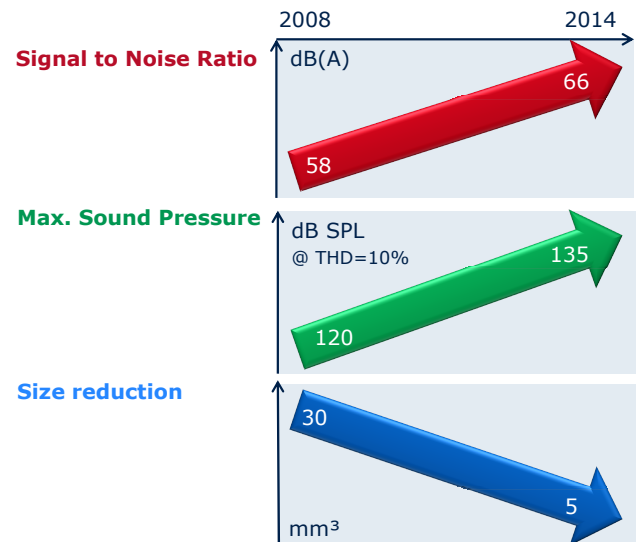


Figure 2: Evolution of key MEMS microphone specification parameters.

## True-Differential Microphone

High SNR, small device size and high AOL are counteracting requirements from a technology point of view. In a small package, the back volume air compliance is reducing the microphone signal and as a consequence reducing the SNR. For high AOL, the membrane compliance is designed to avoid contact with the back plate. This limits the microphone sensitivity and SNR.

To raise such limitations to a new level of performance, a true differential microphone was developed at Infineon Technologies. Figure 3 shows an open microphone package with MEMS sensor chip (1.4x1.4 mm<sup>2</sup>) and ASIC chip covered by protective globtop. Both chips are assembled on a printed wiring board (PWB) and electrically contacted by wire bonding. Not shown in the photograph is a metallic lid for final housing.

In Figure 4, a comparison between single-ended microphones, pseudo-differential microphones and true-differential microphones is outlined. In a state-of-the-art single-ended microphone approach, one MEMS electrode is connected to the ASIC input (here the back plate) and another MEMS electrode is used for applying a biasing voltage (here the membrane). This approach results in poor linearity/AOL and poor suppression of common-mode noise such as electromagnetic interference (EMI) and power supply hum (expressed by power supply rejection ratio, PSRR). In

a pseudo-differential microphone approach, the single-ended MEMS signal is routed through two amplifier stages. This concept helps to reduce ASIC distortion but does not improve linearity of the MEMS sensor itself. Also, common-mode noise entering through the MEMS sensor cannot be canceled out but is amplified.

In a true-differential microphone, both MEMS sensor and ASIC are differential. By using the differential signal at the two ASIC outputs, one have twice the output signal compared to a single-ended construction. Such an approach is beneficial for SNR, AOL and common-mode noise since it cancels electrostatic forces, 2<sup>nd</sup> order harmonics and common mode noise. Design, technology and performance of a true-differential microphone are described in more detail in the next sections.

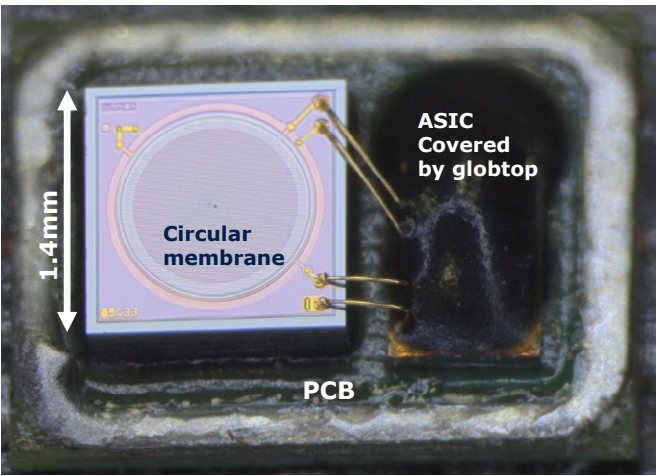


Figure 3: Open microphone package with MEMS chip wire bonded to the read out ASIC chip that is covered.

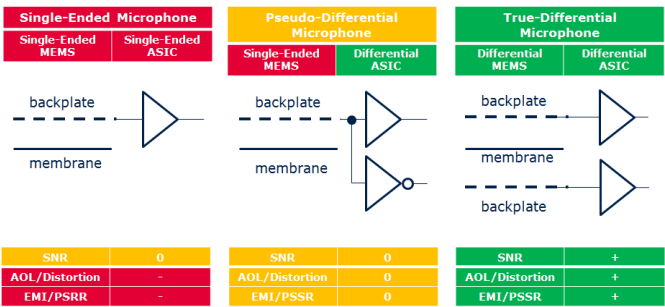


Figure 4: Superior performance of true differential microphones against pseudo differential and single-ended systems.

Dual Back Plate Design & Technology

The fundamental part of a true-differential microphone is a differential MEMS sensor in dual back plate technology. Figure 5 presents a cross sectional view with a bottom back plate as first signal electrode, a top back plate as second signal electrode and a flexible membrane between the two

electrodes. This dual capacitive construction provides two symmetrical 180° phase shifted signals when the membrane is moving in sound.

All layers are made of silicon and the air gaps are formed by a sacrificial oxide micromachining technique. The back plates are highly perforated to minimize acoustical noise and squeeze film damping. The height of the air gaps are approximately 2µm only.

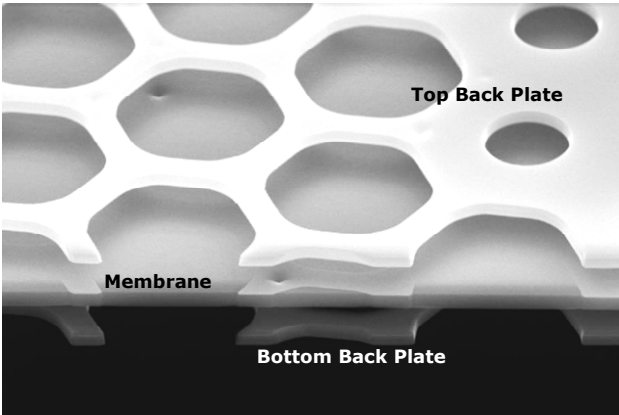


Figure 5: SEM cross-section of dual back plate MEMS.

The dual back plate process flow (Figure 6) is an extension of the standard MEMS microphone process by adding process blocks for the lower back plate and the first air gap. All subsequent processes (deposition of membrane, 2<sup>nd</sup> air gap formation, deposition of top back plate, back side etch, sacrificial oxide etching and metallization) are identical to standard MEMS microphone fabrication. This secures the high volume manufacturability at high yield and reliability.

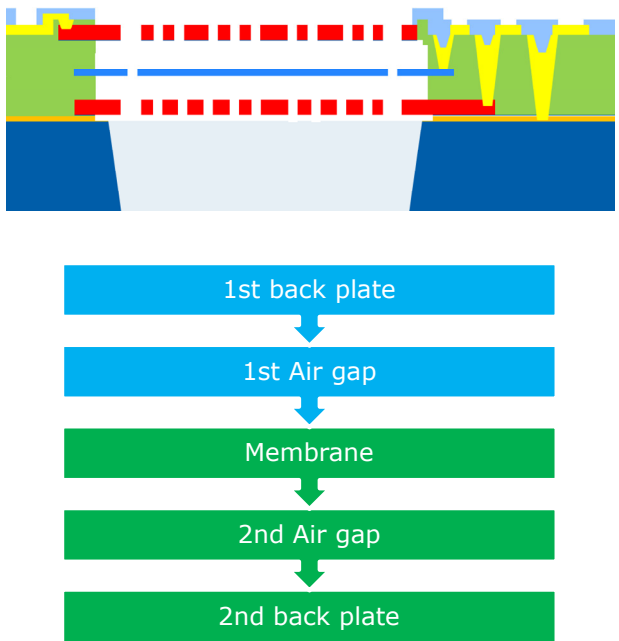


Figure 6: Basic process flow for a dual back plate MEMS microphone sensor.

## Performance Measurements

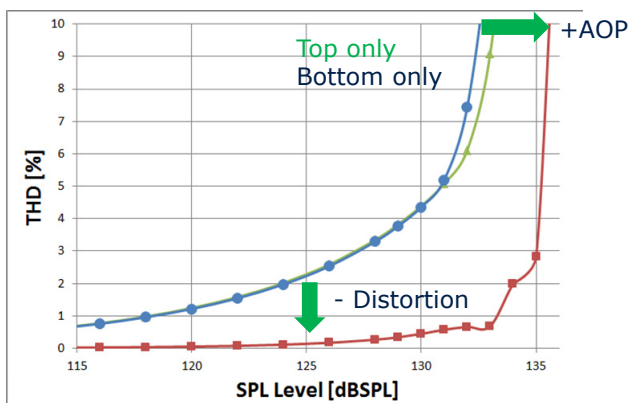
The distortion of a microphone at high sound pressure levels is commonly expressed by the total harmonic distortion (THD) in percentage and the acoustical overload point (AOL) in decibel:

$$\text{THD}^2 = (A_2^2 + A_3^2 + \dots + A_n^2) / A_1^2$$

$A_1 \dots A_n$  = Harmonics of output signal

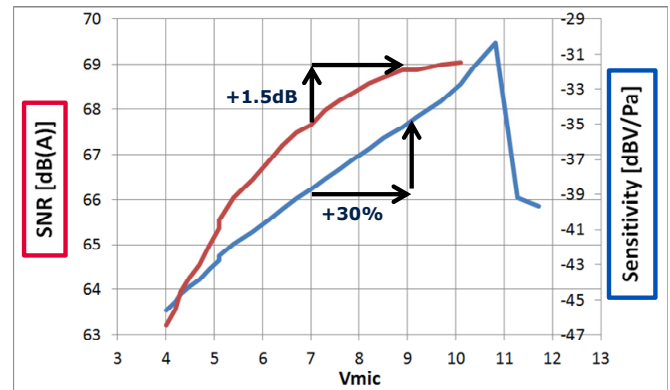
AOL = Sound pressure in dB (ref. 1Pa) at which THD=10%

The data of Figure 7 is a typical total harmonic distortion measurement for different sound pressure levels of a true-differential microphone in dual back plate technology. The green and blue line is the THD in single-ended configuration by using only the top (green) or bottom electrode (blue) for signal processing. In the differential configuration (red line), the THD is significantly reduced from ~2% to less than 0.2% at 125dB SPL. Also, the AOL point is shifted by ~+3dB towards higher sound pressure levels resulting in an AOL of 136dB(A). For both improvements, the underlying cause is a cancellation of 2<sup>nd</sup> order harmonics in the differential output signal.



**Figure 7:** THD measurement of a true-differential microphone in dual back plate technology.

The benefit in SNR for a dual back plate design is not obvious. At first glance, the second back plate with perforation holes is adding an additional source of acoustical noise. On the other hand, the symmetric capacitive configuration can handle higher biasing voltage. Analytical investigations on the so-called pull-in voltage [2] show that a dual back plate MEMS sensor can allow ~30% higher biasing voltage compared to a single-ended microphone. This 30% higher bias voltage can be used for higher sensitivity without any compromise on biasing stability. Figure 8 shows an exemplary measurement of sensitivity and SNR versus the biasing voltage  $V_{mic}$ . As a result of the 30% higher biasing voltage  $V_{mic}$ , a 4dB higher sensitivity and 1.5dB higher signal-to-noise ratio can be obtained. The achieved signal-to-noise of this microphone was 69dB(A).



**Figure 8:** Dual back plate MEMS with higher biasing capability for increased sensitivity and SNR.

## Conclusion

MEMS microphone performance requirements have been increased significantly over the past years. A further high demand for such high performance microphones in miniaturized devices is expected in future. The true-differential microphone concept in dual back plate technology is supporting this demand by superior linearity and SNR. Measurement results demonstrated an AOL of up to 136dB SPL and a SNR of up to 69dB(A).

## References

- [1] IHS MEMS Microphone Report, March, 2014
- [2] Design, Fabrication and Characterization of a MEMS Dual-BackPlate Capacitive Microphone, D. Martin, PHD thesis, 2007