MEMS Microphones for Active Noise Cancellation Applications

MEMS microphones are an attractive choice to use in active noise cancellation (ANC) applications. They provide high-performance audio-acoustic specifications in a small size, and have very stable part-to-part performance and across a part's lifetime. A description of specific performance characteristics and their relevance to ANC follows.

FREQUENCY RESPONSE – MAGNITUDE

The microphone's magnitude response at low frequencies is important for several reasons, mostly related to its phase response. A microphone optimized for ANC should have a low-frequency corner, as low as possible. A microphone with a good low frequency extension has well-matched part-to-part phase characteristics, minimal phase lead, and maximum low frequency SNR. The phase effects are discussed in the next section. In general, the lower the microphone's low frequency corner, the lower the limit frequency at which the ANC algorithm is stable and performs well.

The microphone's high-frequency response is not as important for ANC since active noise cancellation is not practical at frequencies above a few kHz.

FREQUENCY RESPONSE – PHASE

Understanding a microphone's phase response, and its effects on the performance of an ANC algorithm, is critical to selecting an appropriate microphone and designing a high-performance system. Both the absolute phase response of a single microphone, and the phase response variations from one microphone to the next, are important.

Absolute Phase

A microphone is a minimum-phase device, and its phase response is directly related to its magnitude response. For this discussion, we will just consider the low frequency phase response. The microphone's low frequency corner is defined as the point at which the amplitude response is at −3 dB from the nominal response at 1 kHz, and also the point at which the phase response is at +45°. At frequencies below this point, the amplitude response continues to roll off at −6 dB/octave and the phase lead continues to grow. In Figure 1, you can see that the low frequency corner of this microphone is at 22 Hz, both from the −3 dB point of the magnitude response and the +45° phase shift.

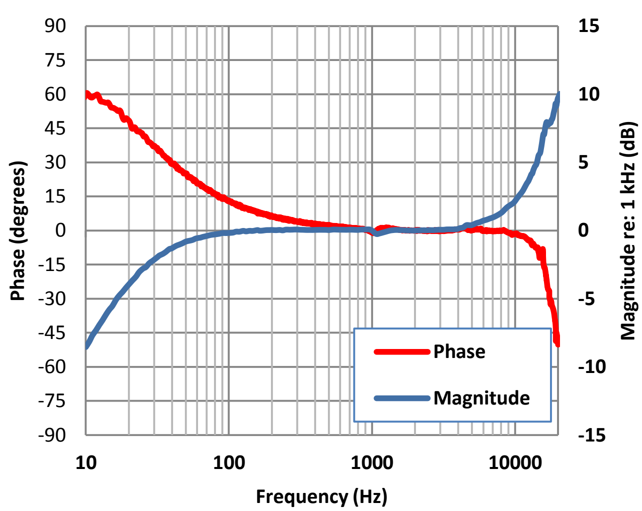

Figure 1. Example Microphone Phase and Magnitude Response

Relative Phase

The relative phase from part-to-part describes the difference in response between all microphones that may be used in production. This is usually specified as a deviation (±X°) from the nominal phase response; see an example in Figure 2. As the microphone's phase response is directly related to the magnitude response, a tightly matched magnitude response results in a similarly tightly matched phase response. At frequencies a couple of octaves above the low frequency corner, the phase variation specification is excellent; it may be only ±2-3°. Even at the corner frequency, the phase variation from the typical response may be only ±5°. This tightly matched response allows the ANC processing to be done with greater confidence in a consistent output from any microphone.

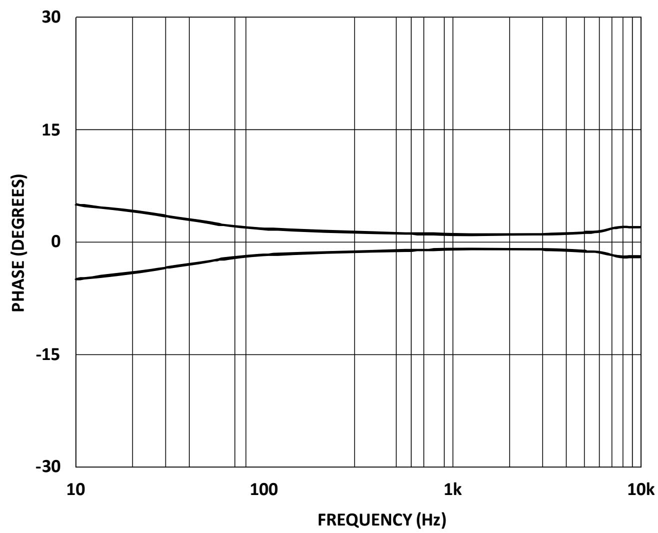

Figure 2. Example of Phase Variation from Typical Response of a MEMS Microphone

ECMs have a wide manufacturing tolerance for low-frequency corner, resulting in greater low frequency phase response variations between microphones. To avoid the undesired phase variations within the ANC algorithms functional frequency range, an ECM's low-frequency corner has to be much lower than is strictly necessary for the microphone's operation in the system. This results in less part-to-part phase variation at frequencies higher than the low-frequency corner. In turn, this often results in undesired overload of the ANC system by low frequency signals with very high amplitudes, such as wind noise. This limits the ANC performance, and causes unpleasant audible artifacts.

Codec Contribution to Phase Response

The codec connected to the microphone's output also contributes to the low frequency phase response. The connection between the microphone and the codec is typically AC-coupled, so the system includes another high pass filter that adds to the low frequency phase lead. The corner frequency of this high pass filter should be very low to minimize its effect. When the codec input's first order high pass filter corner is designed to be one decade below that of the microphone's, the effect will be an additional 5° of phase lead at the microphone's corner frequency. Figure 3 shows the phase response of the microphone itself (same as in Figure 1), as well as the phase of the microphone and the codec input, where the codec's high-pass filter corner is one decade below that of the microphones.

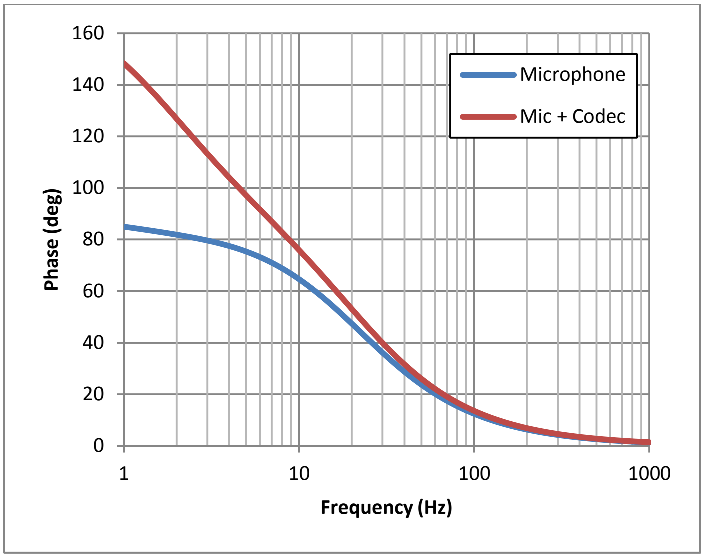

Figure 3. Effect of Codec High Pass Filter on System Phase Response

NOISE

A microphone's noise floor has a 1/f increase at low frequencies. The frequency at which this noise starts to rise is related to the microphone's low frequency corner. By designing the microphone's low frequency corner to be as low as possible, this increase in the low frequency noise level will also be pushed to very low frequencies where it can have less impact on the ANC performance.

A microphone's noise is typically specified by its SNR: its A-weighted noise floor relative to a 1 kHz tone at 94 dB SPL. This SNR specification measures the noise level of the microphone integrated across the full 20 kHz audio bandwidth, but this single dB value does not provide enough information to fully understand the noise level in the bandwidth of interest for ANC. For this application, it is important to understand the microphone's noise level at lower frequencies, where the ANC algorithm is operating.

The low frequency noise could be specified as a 1/3-octave noise level or with a spectral density plot (see Figure 4). Either of these provide more specific information about the noise in a specific bandwidth than the full-bandwidth SNR value on its own.

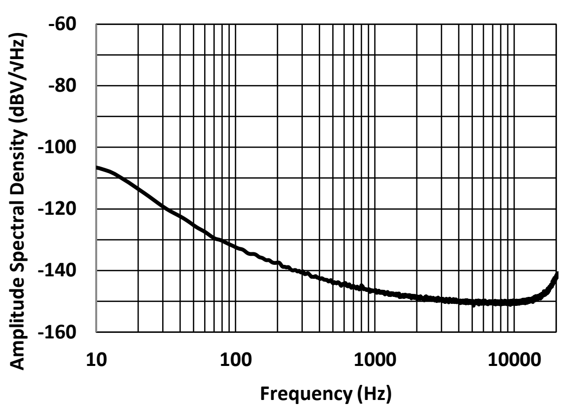

Figure 4. Typical Microphone Noise Spectrum

Still, a microphone with high SNR (low noise) will typically have lower noise levels across all frequencies than a similar microphone with lower SNR. If the noise spectral density or 1/3-octave noise plots are not published for a specific microphone, its SNR relative to other microphones will give a good indication of whether it is a good choice for ANC applications.

HIGH ACOUSTIC OVERLOAD POINT

An ANC algorithm does not work well with distorted or non-linear signals from the microphone. The noise cancellation algorithm does not produce non-linear cancellation signals, so it cannot cancel non-linear signals at its input. The input signals need to represent accurately the same acoustic signals that the ear hears so that the algorithm can generate an accurate cancellation signal to reduce the noise reaching the ear.

In practical use, the microphone's output is most distorted at high sound pressure levels (SPL) near its acoustic overload point (AOP). These high SPLs are caused by loud sounds, like a passing train, a car door slam, or rubbing of the microphone's port against clothing or headrests. Using a microphone with as high of an AOP as possible minimizes the chance that these high SPL acoustic signals overload the microphone.

Below a MEMS microphone's low-frequency corner, it can handle higher SPLs than its specified AOP, which is typically given at 1 kHz. As the magnitude response rolls off at low frequencies, there is a corresponding increase in the AOP at those frequencies. For example, if a microphone with a 126 dB SPL AOP has a response that rolls off by 9 dB at 10 Hz, then its AOP at that frequency will be 135 dB SPL, or 9 dB higher than what is specified at 1 kHz. In practical use, this roll-off is beneficial for an ANC system because it provides extra headroom for high-amplitude low-frequency signals, like wind noise, before they clip the microphone.

SIZE

ANC headphones come in different sizes, from large over-the-ear models to small earbud models. In large headphones, where there is not much space constraint on the ANC hardware, the microphone's size is not critical. Although in small, pocketable models, the microphones need to be as small as possible so that the ANC hardware does not increase the overall headphone system to an unwieldy size. Miniature MEMS microphones are ideal for these applications because of their high level of electro-acoustic performance in a small, thin package.

CONCLUSION

Microphones for active noise cancellation have a specific set of requirements to enable a high-performance system. The microphone is the first device in the ANC signal chain so any compromises on the microphone's performance will propagate downstream and limit the noise cancellation capability. MEMS microphones provide unique advantages in relative phase response, acoustic overload point and size over existing ECMs for ANC.

REVISION HISTORY

REVISION DATE	REVISION	DESCRIPTION
05/12/2015	1.0	Initial Release

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