Low Self Noise: The First Step to High-Performance MEMS Microphone Applications

By Jerad Lewis and Paul Schreier

Microelectromechanical system (MEMS) microphones offer plenty of advantages typical of MEMS devices, including tiny size, low power usage, and consistent performance over time and temperature. But the audio specifications of these microphones have not been sufficient for certain designs — including ones where you need to capture sound from a distance or use multiple microphones. Now high performance MEMS mics are changing what is possible, and many acoustics experts would say self noise is the first specification to consider.

Self Noise — What You Need to Know

Any microphone produces some level of noise: through its electronics, its transducer element, its housing. This inherent noise is known as self noise. It's a familiar sound to anyone using a cell phone. For example, self noise contributes to the hiss you hear when your mobile phone is on and nobody is talking.

For an electronics designer, microphone self noise is an ever-present constraint. The idea is to have the mic present as much signal as possible to the rest of the signal chain. But part of the signal you capture from the audio source will fall below the microphone's inherent self noise, which is also called its noise floor.

The noisier a microphone is, the less signal you have available. A lower noise microphone will give you room to isolate the sound you want from the noise that you don't. Then your processor — DSP or codec — has more signal to work with. As a result, the output from the signal chain sounds much better when you start with a quieter microphone.

A high signal-to-noise ratio (more about SNR in the next section) indicates a quiet microphone, and a lower SNR specification tells you the microphone has more self noise.

While a high SNR is always useful, you don't depend on it as much when your audio source is very close to the microphone. There is usually enough signal for these near-field applications. In far-field applications where the microphone isn't positioned next to the sound source, a noisy mic with a low SNR leaves you with a poor or unintelligible signal.

What the Specs Tell You

The self noise, or noise floor, of the microphone does a lot to define the quality of audio you are able to capture and pass onto the signal chain. Signal-to-noise ratio (SNR) and equivalent input noise (EIN) are two specifications that describe where that noise floor is.

And as we will soon discuss in more detail, the self noise of MEMS microphones has reached a level far better than past generations of the technology (Figure 1).

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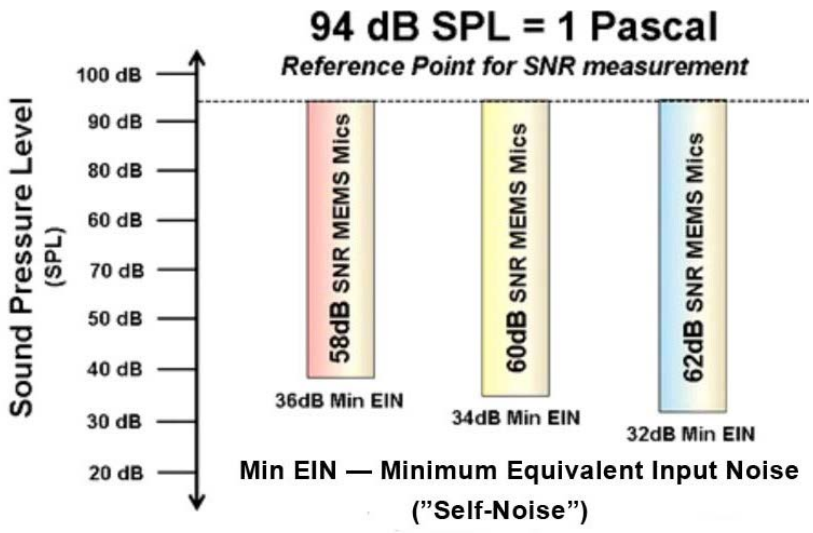

Figure 1

Signal-to-Noise Ratio (SNR)

SNR is the ratio of a reference signal to the noise floor of the microphone. A microphone's SNR is the difference between its inherent self noise level and a standard reference pressure, specifically 94 dB SPL (1 Pa) at 1 kHz.

You will typically see this specification presented as an A-weighted value (dBA) with a 20 kHz bandwidth. A-weighting means the SNR being presented includes a correction factor that corresponds to the human ear's sensitivity to sound at different frequencies.

When you compare the SNR of different microphones, make sure they are based on the same weighting and bandwidth. A comparison will not be accurate if the measurements don't use the same weighting and bandwidth.[i]

Equivalent Input Noise (EIN)

Equivalent input noise is the output noise level of the microphone represented as a theoretical acoustic noise source placed at the microphone's input. The unit of measurement is sound pressure level, measured in decibels (dB SPL). SPLs less than the EIN level are below the noise floor of the microphone.

You can determine the EIN directly from the microphone's SNR specification:[ii]

$$EIN = 94\ \text{dB} - SNR$$

MEMS Microphones Double Their SNR Performance

The MEMS industry's earlier generations of microphones offered an SNR around 58 to 60 dB, which did not equal the acoustic performance you could get from electret condenser microphones (ECMs). The situation is changing now that leading manufacturers are making dramatic improvements to the performance of MEMS microphones.

The low noise InvenSense ADMP504 and ADMP521 MEMS microphones have lowered the noise floor of earlier MEMS mics by more than 2x. The ADMP504 and ADMP521 are the first MEMS microphones to reach the level of 65 dBA SNR (29 dBA EIN).

An SNR spec of 65 dBA is good even for an electret microphone, but ECMs tend to be much larger than MEMS mics with comparable SNRs. As the size of an ECM gets smaller, its SNR drops quickly (Figure 2). ECMs also don't offer the other advantages that MEMS mics do, such as a consistent response to sound across all operating temperatures.

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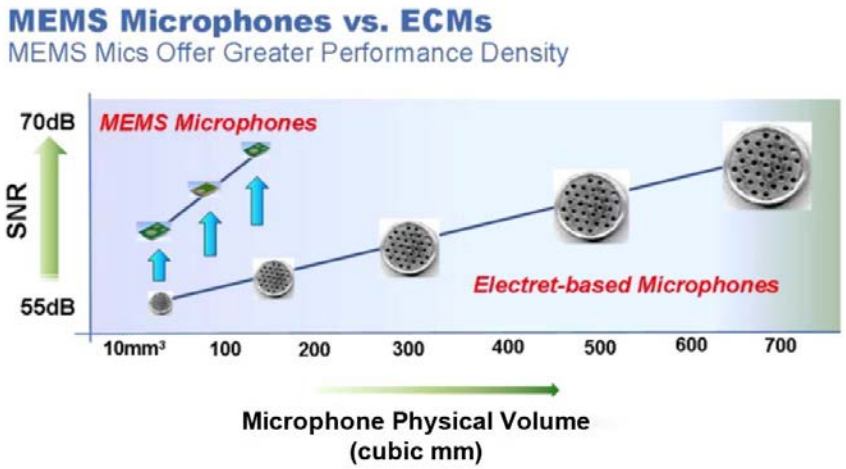

Figure 2

Capturing Sound at a Distance

Where can you take advantage of the SNR of a very high performance MEMS microphone? Though almost any application would benefit, you can now consider these microphones where you might not have been able to before.

In applications such as video conferencing, professional audio, and industrial systems, the source of the sound is often not next to the mic. Far-field applications like these are good examples of where a low-noise MEMS microphone will be beneficial.

One specific example is video calling (think Skype) with webcams and tablet computers. Now MEMS microphones can enable high-definition audio capture for these products, and MEMS mic packages are compact enough to place inside even the smallest consumer electronics devices.

Using MEMS microphones as acoustic sensors is another possibility. In industrial equipment designs, positioning a microphone inside the housing of a machine isn't always practical. However, you sacrifice a lot of signal when the microphone has to pick up sound transmitted through a solid barrier.

A microphone with low self noise will be more capable of acquiring an adequate signal. For instance, a microphone in a flow control application could identify production problems by listening for material flowing through a tube.

Multiple Microphone Applications

A low noise floor is also critical for any multi-microphone beamforming algorithm. Beamforming algorithms often result in a higher system noise level, as compared with a single microphone in the array. Therefore it becomes critical for each mic in the array to have a high SNR.

Because beamforming increases the directionality of a microphone array, these arrays are popular in videoconferencing systems. That includes stationary videoconference equipment for corporate conference rooms, as well as the TV set-top boxes people use to make video calls from their living rooms.

Multi-microphone beamforming is also used in security applications. Security and surveillance equipment is normally mounted in a fixed spot, and of course, not all suspicious activity will take place within the camera's field of view. With low-noise MEMS microphones, security cameras on homes and commercial buildings can use audio to detect which direction a sound is coming from and point the camera lens at that target.

Consider How Low the Microphone Can Go

Though you will ultimately consider more than one aspect of a microphone's performance, a low noise floor is a make-or-break spec for challenging audio capture applications. So if you needed high SNR in the past, you would probably have had to choose an electret mic. These days your options are no longer limited to traditional microphone technology.

MEMS microphones are ready for many new high performance applications now that some mics offer more than double the SNR of their predecessors. The maturing of MEMS microphone technology has added ultra-low noise to the compact size, reflow-compatible packaging, and everything else you expect from modern MEMS microphones.

[1, 2] For more about MEMS microphone specifications, see *Microphone Specifications Explained* by Jerad Lewis (InvenSense Application Note AN-1112).

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