

Introduction

Sound is a pressure wave that propagates through air with a direction and an amplitude. All microphones measure the amplitude and frequency of this wave. An omnidirectional microphone ignores direction and measures sound from all sources equally. A directional microphone will pick up sounds coming from a particular region while sources outside of this region will be rejected. Directional microphones are most beneficial when trying to record only an intended source (i.e., a person's voice) and remove the background noise as much as possible.

The proliferation of audio and voice capture in consumer devices has driven great advancements in the development of small, high performance, MEMS microphones. MEMS, or micro-electromechanical systems, refers to a class of systems that leverage microfabrication processing techniques to etch various structures into a semiconductor silicon wafer. Until now, only omnidirectional microphones have benefited from MEMS-scale manufacturing without extreme compromises on performance. Directional microphones currently only exist in large packages intended for professional audio or with extreme compromises on signal quality. Soundskrit is introducing the first high-performance directional MEMS microphone so that consumer electronics and other size-constrained applications can reduce background noise and improve vocal clarity. As shown in Figure 1, Soundskrit microphones are similar in size to modern omnidirectional microphones.

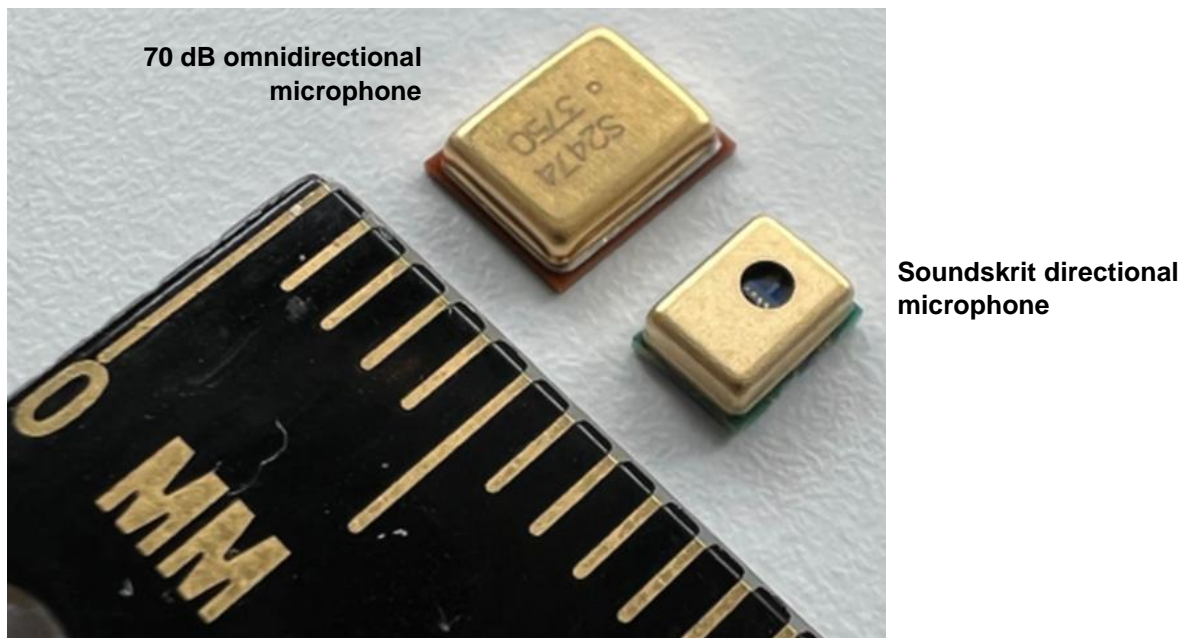


Figure 1: MEMS omnidirectional and Soundskrit microphones

The Traditional MEMS Omnidirectional Microphone

A standard MEMS microphone consists of three primary components: a MEMS acoustic sensor, an application-specific integrated circuit (ASIC), and a protective metal lid that covers the MEMS and ASIC, all mounted on a printed circuit board (PCB).

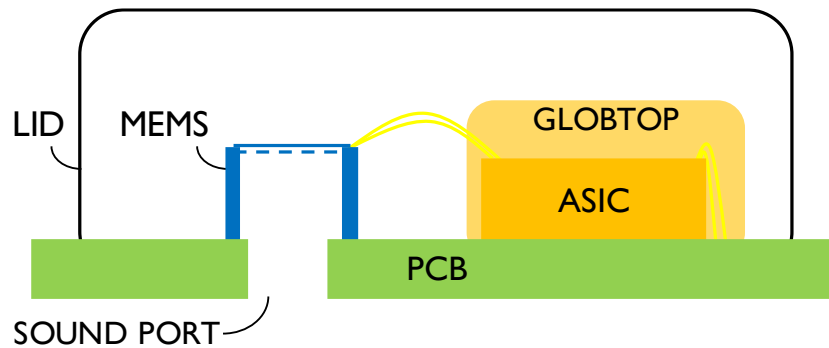


Figure 2: Omnidirectional MEMS microphone

An omnidirectional MEMS microphone has a single sound port to allow sound waves to enter the microphone. The MEMS transducer in the microphone consists of a thin, flexible diaphragm that can respond to changes in pressure. As an acoustic wave, or sound, travels across the sound port of the omnidirectional microphone, it compresses the air particles in the opening. This creates a pressure at the sound port, near the MEMS transducer, and causes the diaphragm of the transducer to vibrate at the frequency of the acoustic wave.

As the diaphragm vibrates, the distance between the diaphragm and a fixed electrode fluctuates, creating a change in capacitance that can be read by the ASIC. The ASIC further conditions the signal to prepare the signal for the next stage in the signal chain, such as an audio codec.

Since an acoustic wave compresses the air particles at the sound port regardless of the direction it propagates, the omnidirectional microphone picks up sound equally from every direction. It cannot distinguish sounds coming from different directions.

In most real-world applications, it is desirable to pick up the sound coming from a specific direction. For example, in applications where a user is talking to a microphone embedded in a laptop or smart speaker, there is often ambient noise around them. The omnidirectional microphone picks up both the user's voice and the ambient noise around them indiscriminately. This ambient noise can often overpower the user's voice and make them difficult to understand. Ideally, the microphone would be able to pick up the desired voice while ignoring the background noise from other directions.

Configuring multiple omnidirectional microphones in an array can create a directional pickup pattern. However, this requires large spacing between sensors, introduces additional noise, and requires closely matched microphones. Soundskrit has designed a unique microphone transducer that is inherently directional, bringing a new paradigm to the development of MEMS microphones.

The Soundskrit Directional Microphone

A microphone from Soundskrit will only respond to sound propagating in a specific direction. With this technology, Soundskrit microphones will pick up a user’s voice and ignore the unwanted background noise originating from other directions in a small form factor, MEMS-scale package. Figures 3 and 4 show a cross sectional schematic of a Soundskrit microphone subject to sound originating from two different directions.

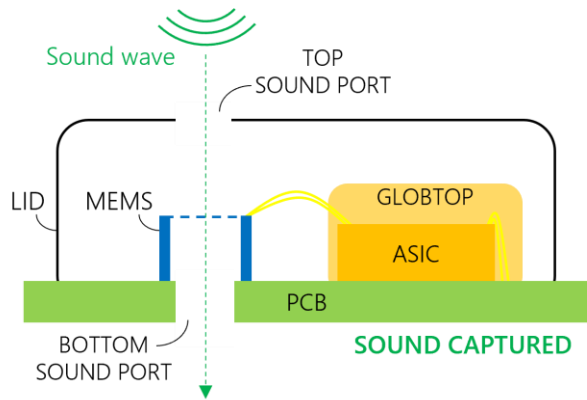


Figure 2: Soundskrit MEMS capturing sound from above

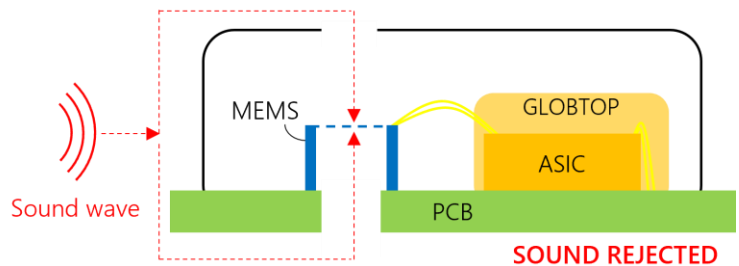


Figure 4: Soundskrit MEMS rejecting sound from sides

Unlike its omnidirectional counterpart, the Soundskrit microphone consists of two sound ports on opposing sides of the MEMS diaphragm. The MEMS diaphragm leverages a unique architecture built specifically with directional sound capture in mind. The diaphragm is designed to move efficiently with, and thus sense, the surrounding air motion.

As a sound wave propagates in a direction parallel to a line connecting the two sound ports, as shown in Figure 3, sound enters the top sound port and moves the air surrounding the diaphragm. The diaphragm is constructed to move with its surrounding air rather than restricting the air motion as traditional MEMS microphones do. The diaphragm vibrates in sync with the moving air and the sound wave effectively passes through the diaphragm. Electrodes then convert these mechanical vibrations into an electrical signal. These electrodes must be specifically designed to not impede this motion.

When sound comes from the side of the microphone, as in Figure 4, the acoustic wave wraps around the microphone and enters both the top and bottom sound ports simultaneously. As a result, the sound wave hits each side of the MEMS diaphragm at the same time. The pressure, and thus air motion, on each side of the diaphragm is equal and the identical waves cancel each other out. This results in no air motion around the MEMS transducer and therefore no signal. The microphone only picks up sound traveling along one direction. As the diaphragm vibrates proportionally to the amplitude of the sound, the microphone provides both amplitude and directional information. By using Soundskrit microphones, devices can filter out unwanted sounds and amplify the desired speech of a user.

The Challenge of Noise

In the past years, a tremendous amount of effort has been dedicated to improving the performance of MEMS omnidirectional microphones, especially in terms of their signal-to-noise-ratio (SNR). Microphone noise is an unwanted artifact inherent to any microphone due to random air motion and electrical noise. It manifests as an electrical signal that corrupts the true audio signal captured by the microphone. If the microphone noise is too high, it can mask the desired audio and be very displeasing to a listener.

Due to modern advancements, self-noise is rarely the bottleneck to achieving high audio quality. Rather, noise in the environment is the most significant impediment to clear audio pickup. MEMS microphones are often placed in scenarios where it is desirable to pick up a specific sound, like the voice of a user, while ignoring surrounding noise that can be distracting (e.g., noise from a TV, people talking in the background, etc.).

Typical conversational speech has a sound level of ~60dB SPL at 1m away. As the microphone is placed farther and farther away from the user, the amplitude of the speech captured is reduced and vice versa. For example, a microphone placed ~5m away from the user might hear speech at 45dB SPL. Today’s state-of-the-art microphones have self-noise floors ranging from ~21-30dB. This is well below the usual level of human speech, even at long listening ranges.

In contrast, the environmental noise is typically much higher than the noise floors of modern MEMS microphones. As shown in Figure 5, the environmental noise in a home setting can be as loud as 50dB SPL, an office can be as loud as 65dB SPL, and an outdoor environment in a busy city can reach 80dB SPL. Further, interfering noise from TVs and loudspeakers can exasperate this problem.

When ambient sound levels are much louder than the microphone noise, they are also often louder than the desired speech. As a result, the microphone leaves the user with unintelligible speech and inaccurate voice recognition leading to the many frustrating audio-related experiences we face on a day-to-day basis. Unwanted environmental noise is currently the largest impediment to high performance products with superior audio quality. A focus on background noise reduction will have a large impact on the user experience, while reducing signal noise only provides diminishing returns in today’s MEMS microphone design space.

Sound Levels of Typical Environments

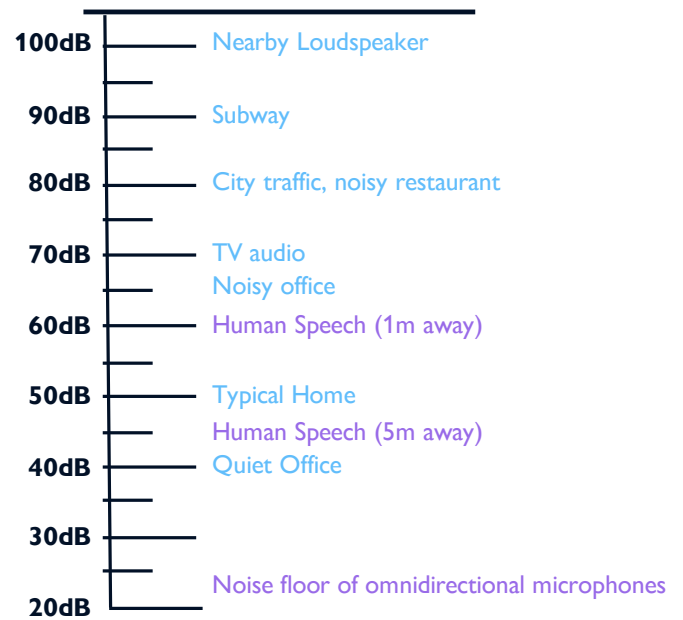


Figure 5: Noise levels from different sources

Directivity Pattern

The sensitivity of Soundskrit’s microphones with respect to the incoming angle of a sound wave can be represented as a dipole pattern, or figure-8. In contrast, the typical omnidirectional microphone maintains an equal response regardless of the incoming direction of the sound. Representations of these polar patterns are shown in Figure 6 below.

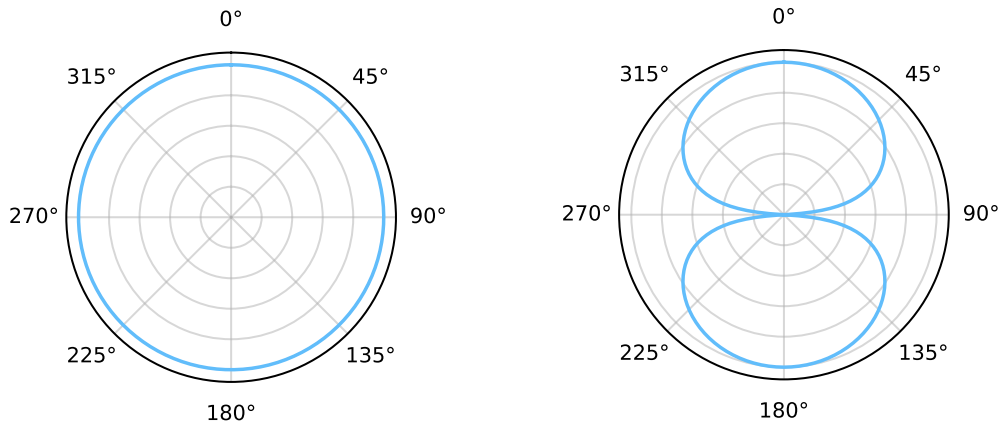


Figure 6: Polar pattern of an omnidirectional microphone (left) and Soundskrit microphone (right)

For the Soundskrit microphone, the direction of the dipole (i.e., where the 0° and 180° angles are oriented) is determined by the placement of the sound ports. The dipole pattern will be centered along a straight line drawn through the center of each sound port. The proper orientation of the polar pattern can be achieved by strategically placing the sound ports in an end-product. Soundskrit’s dipole pattern will have the highest sensitivity along the 0° and 180° directions while significantly rejecting sounds coming off to the sides at 90° and 270°. It should be noted that that dipole pattern is 3D symmetric about the line connecting the two sound ports of the microphone as illustrated in Figure 7 below.

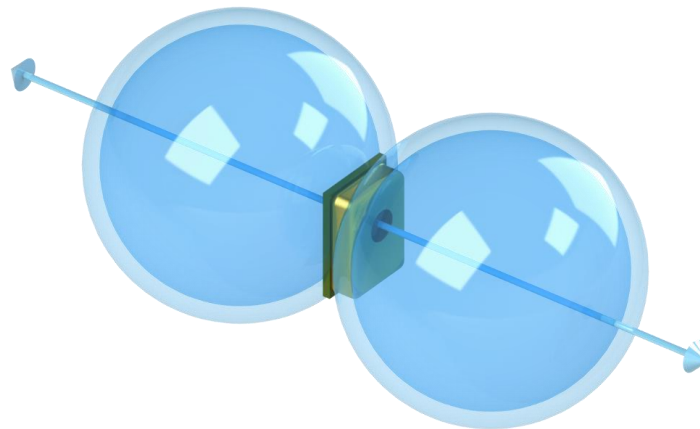


Figure 7: 3D rendering of the dipole beam pattern provided by the Soundskrit microphone

360° Sound Capture Using Two Soundskrit Microphones

Using two directional microphones provides information on both the amplitude and direction of sounds across 360°. With this information, one may select to hear sound from a specific direction and reject sound that is not in that direction of interest. Two Soundskrit microphones can be oriented such that their axes of sensitivity are orthogonal to one another, or separate by an angle of 90°, as illustrated in Figure 8.

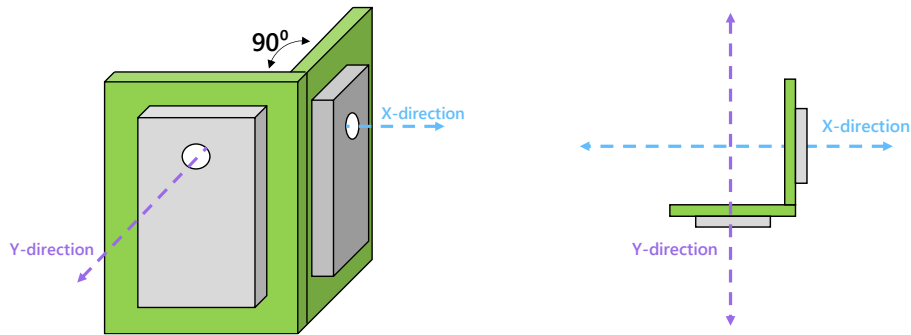


Figure 8: Two Soundskrit microphones for 360° sound capture in perspective view (left) and top view (right)

In this configuration, one Soundskrit microphone is oriented such that it captures sound from the “X” direction, while a second microphone captures sound from the “Y” direction, as on a coordinate grid. Just like many other physical phenomena, sound waves are a vector that propagate with a specific direction that can be broken down into components that are traveling in the “X” direction, and components that are traveling in the “Y” direction. An example of this is illustrated in Figure 9.

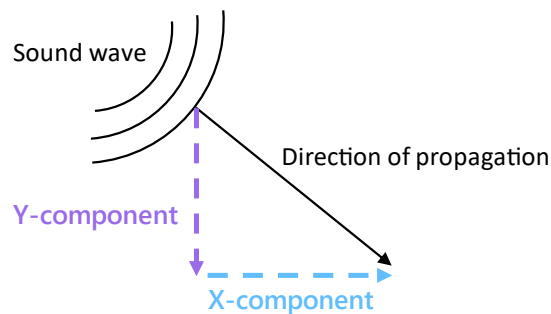


Figure 9: Illustration of the “X” and “Y” components of a sound wave

With two Soundskrit microphones measuring the “X” and “Y” components of the sound wave, the system can fully characterize the direction a sound wave is propagating from. For example, a sound wave traveling from a 45° angle relative to the microphones will have an equal amount of energy travelling in the “X” direction and the “Y” direction. Both Soundskrit microphones would see signals with equal amplitude. In contrast, if the sound wave were arriving from an angle of 15°, its “Y” component would have an amplitude three times greater than the amplitude of its “X” component. By comparing the relative amplitudes between the two microphones, the direction from the which the sound wave originates can be determined.

Similarly, the signals from the two microphones can be recombined to output a new dipole pattern pointed along a different direction. This can be used to steer the effective listening direction of the microphones to a desired angle and is done through simple addition of the two microphone signals. For example, the sum of the “X” and “Y” microphone with equal weighting creates a dipole polar pattern oriented along the 45° direction. But weighting the “Y” microphone three times more than the “X” microphone creates a dipole pointing at 15° as shown in figure 10. Weighting the “X” and “Y” components can steer the dipole in any desired direction.

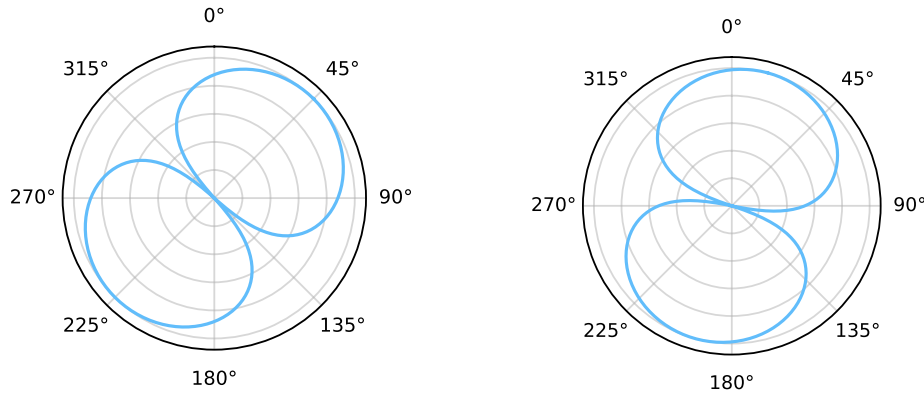


Figure 10: Recombination of two Soundskrit microphones to provide a dipole pointing at 45° (left) and 15° (right)

As illustrated, two Soundskrit microphones oriented orthogonally to one another provide the ability to locate the direction of any incoming sound and then isolate it by steering the dipole to that direction.

Additional Support

For further information on Soundskrit’s products, visit our website at <http://www.soundskrit.ca> where you can find more application notes, datasheets, and purchasing information. If you have any questions or need technical support, please reach out to applications@soundskrit.ca.

Revision Label	Revision Date	Sections Revised
-	April 2022	Initial release
A	February 2023	Updated Formatting



Soundskrit developed the first high-performance directional MEMS microphone on the market, leveraging years of research in bio-inspired MEMS based on how spiders and other insects in nature hear. In combination with Soundskrit's in-house audio processing algorithms, directional microphones can be used to capture and isolate any sound in an environment with a fraction of the size, power, and computation of traditional omnidirectional-based microphone arrays.

Soundskrit was founded in 2019 and is headquartered in Montreal, Quebec with an R&D facility in Ann Arbor, Michigan.

