THE OMNIDIRECTIONAL BOUNDARY MICROPHONE

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What is that funny looking ŏplateòmicrophone, and how can you use it? Chances are itôs a boundary mic or boundary layer microphone. This special device was designed to be used on surfaces such as floors, walls, tables, or even piano lids. How can a microphone sound good on the floor? Read on to find out.

Boundary microphones come in two basic polar patterns: half-omnidirectional or half-cardioid (or half-supercardioid). The Crown PZM (Pressure Zone Microphone) models are the half-omni type. They have an unusual construction (see Figure 1). It includes a miniature condenser mic capsule, which is mounted face-down next to a sound-reflecting plate or boundary. The microphone diaphragm is parallel with and very close to the reflecting surface.

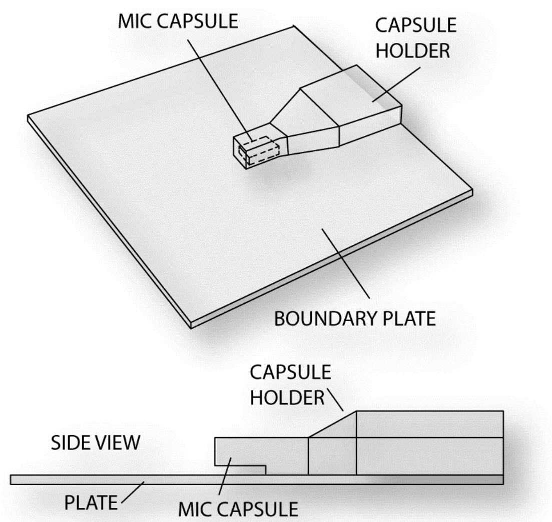

Figure 1. PZM construction.

Typical applications for PZMs are:
- grand piano
- ambience miking
- stereo recording of orchestras, symphonic bands and small ensembles
- drum overheads
- reinforcement of stage plays

Why is the PZM made as it is? To explain the construction, a little background is needed.

PZM THEORY

Sound engineers often must place microphones near hard reflective surfaces. Some situations where this occurs are reinforcing drama or opera with microphones near the stage floor, recording a piano with the mics near the open lid, or recording an instrument surrounded by reflective baffles.

In these situations, sound travels from the sound source to the microphone via two paths: directly from the source to the microphone, and reflected off the surface (as in Figure 2 top). Note that the reflected sound travels a longer distance than the direct sound, so the reflected sound is delayed relative to the direct sound. When the direct and delayed sounds combine at the microphone diaphragm, this results in phase cancellations of various frequencies. A series of peaks and dips is created in the net frequency response. This is called a comb-filter effect (Figure 2 bottom). It colors the tone quality and gives an unnatural sound.

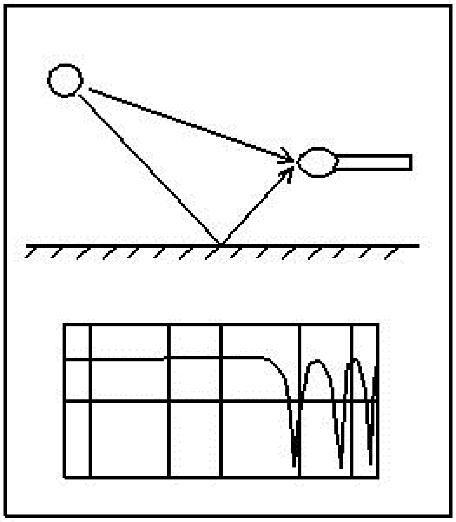

Figure 2. Top: Sound reaches a conventional mic by two paths: direct and reflected.
Bottom: The delayed reflected sound combines at the mic with the direct sound causing peaks and dips in the frequency response.

Here's how the phase cancellations occur. All frequencies in the reflected sound are delayed by the same time. Having the same signal delay for all frequencies produces different phase delays for each frequency, because different frequencies have different wavelengths. For example, a signal delay of one millisecond causes a 360-degree phase shift for a 1,000-Hz wave, but only a 180-degree phase shift for a 500 Hz wave.

Figure 3 illustrates this point. At frequencies where the direct and delayed sounds are in-phase (coherent), the signals add together. This doubles the pressure and boosts the amplitude 6 dB. At frequencies where the direct and delayed sounds are out-of-phase, the signals cancel each other, making a dip or notch in the response. So a series of peaks and dips (comb-filter) appears in the net frequency response.

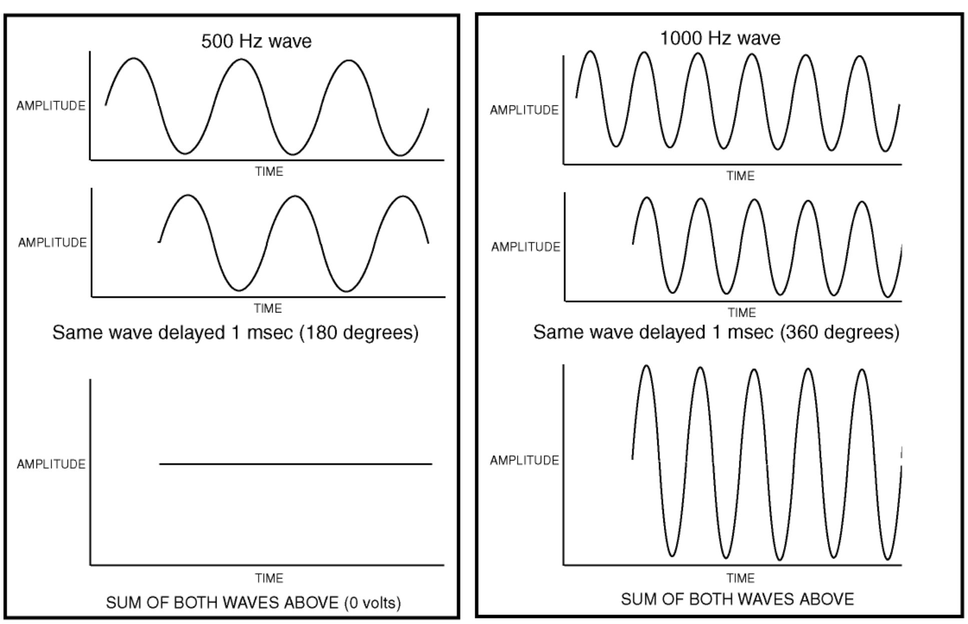

Figure 3. Left: The sum of a 500 Hz wave and its 1 msec delayed replica -- no signal.
Right: The sum of a 1000 Hz wave and its 1 msec delayed replica -- twice the signal amplitude.

This rough frequency response colors the tonal reproduction and yields an unnatural sound. To solve this problem, we need to shorten the delay of the reflected sound so that it arrives at the mic at the same time as the direct sound.

Here's where the PZM's construction comes into play. By orienting the diaphragm parallel with the surface (as in a PZM, Figure 4), the diaphragm can he placed as close to the surface as desired. Then the direct and reflected waves arrive at the microphone at the same time, in phase. This eliminates phase cancellations and results in a smooth frequency response.

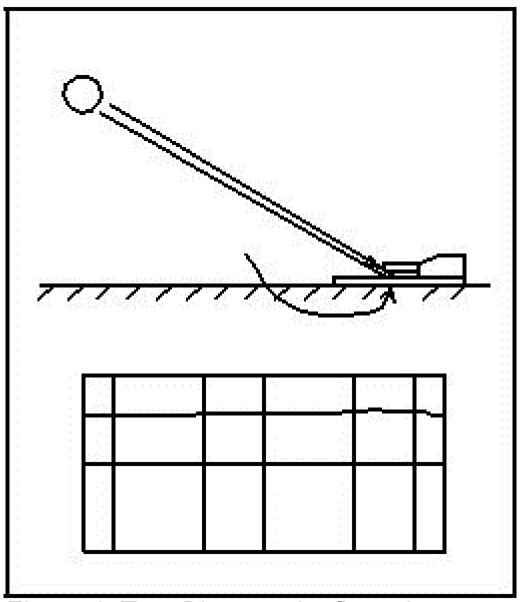

Figure 4. Top: Direct and reflected waves arrive at the diaphragm simultaneously.
Bottom: The resulting frequency response.

Note that the plate is not a transducer; it does not convert sound into an electrical signal. Instead, the plate serves as a hard surface to reflect sound into the microphone diaphragm.

The diaphragm is mounted in the "pressure zone" just above the plate, a region where the direct and reflected waves are effectively in-phase. Typical mic-to-plate spacings are .020 to .050 inch. Such a small spacing is needed to maintain an extended high-frequency response.

PZM HISTORY
The PZM began as a mic technique, not a product. In 1978, audio consultant Ed Long and recording engineer Ron Wickersham came up with an unusual concept: they mounted a small omnidirectional mic capsule face down very close to a surface. This eliminated the comb filtering caused by delayed reflections off the surface, and gave a very clear, natural sound quality.

In specifying the mic capsule�s frequency response, Long and Wickersham had two choices: flat free-field response or flat pressure response. A mic with a flat free-field response measures flat when tested in a free field, in open space away from any surfaces. A mic with a pressure response has a rising high-frequency response when used in a free field, but has a flat frequency response when mounted flush with, or very near, a boundary. So a pressure-response omni mic capsule was deemed the best choice when used next to a boundary.

There�s a tiny slit between the mic diaphragm and the surface. This slit has acoustic inertance, which rolls off the highs if the slit is long enough. To prevent this rolloff, the slit has to be short, so the diaphragm diameter must be small. That’s why a very small mic capsule is used in the PZM. A bigger mic capsule could be used, but then the high-frequency response would be poor.

Ken Wahrenbrock, a graduate of the Syn Aud Con audio seminar, developed the first PZM prototype. Using a suggestion of Don Davis, Ken mounted a miniature hearing-aid mic face down next to a plate. He marketed these mics on a small scale.

In 1980, Ken approached Crown with his invention. He asked them if they wanted to manufacture a radically new microphone that nobody else was making. They agreed to manufacture and market the PZM. Crown engineers gave the PZM a facelift so that it looked slick and professional. That was the only microphone Crown made back then.

When PZMs were introduced at the Audio Engineering Society, they were controversial and caused a great stir because they were so different. Eventually they caught on, and now almost every other microphone company makes their own version, even Radio Shack. They are generically called “boundary mics.” All models except Crown and Radio Shack have the capsule flush-mounted in the boundary aiming up, rather than near the boundary aiming down.

BENEFITS OF PZMs

In addition to eliminating phase cancellations, PZMs provide several other benefits. Let's look at these in detail.

High sensitivity. Since the direct and reflected waves add together in phase, the sound pressure doubles at the microphone, giving a 6 dB increase in acoustic level. This is free gain. Thus the effective microphone sensitivity increases 6 dB, and the signal-to-noise ratio improves by 6 dB.

Unchanging tone quality. The microphone placement shown in Figure 2 causes another problem in addition to rough response. As the sound source moves up or down relative to the surface, the reflected path length changes, which varies the comb-filter notch frequencies. Consequently, the effective frequency response changes as the source moves.

But with the PZM, the reflected path length stays equal to the direct path length, regardless of the sound-source position. There is no change in tone quality as the source moves.

Lack of off-axis coloration. PZMs solve another problem that plagues conventional microphones: off-axis coloration. While a microphone may have a flat response to sounds arriving from straight ahead (on-axis), it often has a rolled-off or colored response to sounds arriving from other directions (off-axis).

That fault is mainly due to the size of conventional microphones and their forward orientation. When sound strikes a typical mic diaphragm on-axis, a pressure boost occurs at frequencies where the wavelength is comparable to the mic diameter (usually above 10 kHz). Sounds approaching the microphone from the sides or rear, however, do not cause a pressure boost at high frequencies. Consequently, the high-frequency response is greater on-axis than off-axis. The frequency response varies with the position of the sound source around the microphone.

But with a PZM, the mic capsule is very small, and all sound enters the capsule through a tiny radially symmetric slit. This keeps the response constant regardless of the angle at which sound approaches the microphone. The effective frequency response is the same for sounds from the sides or rear as it is for sounds from the front. In other words, there is little or no off-axis coloration with the PZM. The reproduced tone quality doesn't change when the sound source moves.

Off-axis coloration also can affect the reproduction of room ambience or reverberation. Reverberation is sound reflected off the walls, ceiling, and floor of the recording environment. Most of it arrives at the microphone off-axis.

With most conventional mics, the response to reverberant sound (room ambience) is weak in the high frequencies compared to the response to direct sound from the source. But with a PZM, the response to reverberation is just as accurate as the response to the direct sound. As a result, the PZMÕs reproduction of reverb is brighter and clearer.

Improved reach. Reach is the ability to pick up quiet distant sounds clearly. PZMs have excellent reach because they have a high signal-to-noise ratio and a wide smooth frequency response, and they pick up a high ratio of direct sound to reverberant sound.

The PZMÕs signal-to-noise ratio is high because the microphone capsule is inherently quiet, and because the signal level is boosted 6 dB at the surface. The frequency response is wide and smooth because comb filtering is eliminated, and because reverberant sound is picked up with an extended high-frequency response. The direct-to-reverberant sound ratio is high because the direct sound is boosted 6 dB near the surface, while the reverberant sound, being incoherent, is boosted only 3 dB. In other words, distant sources sound closer and clearer with the PZM than they do with a conventional omnidirectional microphone.

Low vibration sensitivity. The PZM is relatively insensitive to mechanical vibrations such as table and floor thumps, thanks to the low mass and high damping of its diaphragm. These thumps are only picked up acoustically through the air, not mechanically through the microphone housing. This means that PZMs can be placed on conference tables without shock mounting.

Small size. There are psychological benefits related to the PZM's low-profile design. Its inconspicuous appearance reduces "mic fright." Since the PZM does not point at the performers, they may feel more relaxed in not having to aim their instruments at the microphone.

In TV-studio applications, the PZM practically disappears on-camera. PZMs reduce clutter on conference tables and lecterns, giving the impression that no microphones are in use. They can also be hidden in theater sets.

Sometimes you can record concerts with PZMs placed on the floor. Then there's no need to hang microphones or to use bulky mic stands.

PZM POLAR PATTERN AND FREQUENCY RESPONSE
PZMs are usually placed near the sound source on a large hard surface, such as a table, wall, hard panel, or floor. Then the microphone has a hemispherical polar pattern. It picks up sounds equally well in all directions in front of the surface, much like an omnidirectional mic.

The frequency response of a PZM depends on the size of the surface it's mounted on. The larger the surface, the more extended is the low-frequency response. If you put a PZM on a mic stand, the small plate included with the microphone will allow the low frequency response to shelve down 6 dB at 377 Hz. This response may be desirable in some instances. A PZM mounted on a 2Õx 2Õpanel will have a response shelving down 6 dB at 83 to 124 Hz (depending on the panel angle), which is useful for many applications. In general, the response shelves down 6 dB at the frequency where the wavelength is about six times the boundary dimension.

For best bass and flattest response, place the PZM on a large hard boundary such as a floor, wall, table, or baffle at least 4-feet by 4-feet. This baffle or panel can be made of ¼ inch plywood, masonite, or clear plastic. To reduce bass response, just use the PZM with its own plate well away from other reflecting surfaces. Note that when a suspended PZM/plate is placed very close to its sound source, the full bass response returns.

APPLICATIONS
PZMs are placed much the same as conventional microphones, except that PZMs are used on a surface. Place the PZM a few feet from the sound source and monitor the results. If you hear too

much pickup of room acoustics, leakage from other instruments, back-ground noise, or feedback, move the PZM closer to the sound surce. Doing this may require mounting the PZM on a microphone stand and adding a panel. Move the PZM farther from the source to add ambience or "artistic leakage" to the recording.

Note that you can remove the capsule holder from the plate by unscrewing it. Then you can place the mic capsule in corners for extra sensitivity. Placing the capsule next to a single surface gives a 6 dB boost; placing it at the junction of two boundaries (say, wall and floor) gives a 12 dB boost, and placing it in a corner (two walls and ceiling) gives an 18 dB boost! Take advantage of this effect by mounting the mic capsule at the junction of multiple boundaries whenever possible.

In sound reinforcement situations, a half-omni boundary mic may not provide much gain-before-feedback. A better solution is a half-cardioid or half-supercardioid model, such as the Bartlett Audio Stage Floor Mic and Boundary Recording Mic. For more information, please see the article "Directional Boundary Mics (Why Put a Mic on the Floor?)" on the Bartlett Audio website.

CONCLUSION

The boundary microphone provides several benefits: A wide smooth frequency response free of phase cancellations, excellent clarity and reach, and little or no off-axis coloration. It is insensitive to mechanical vibrations and has an inconspicuous appearance.

It's not the ideal microphone for every application, but no mic is. It is a valuable tool for sound engineers, especially when microphones must he placed near reflective surfaces.