

EP. 5: **Inside the Microphone**

Take a closer look inside one of the most essential tools in every recording studio. In this episode, Aleyna Neivandt-Brown unpacks how microphones convert sound into electrical signals with approachable scientific breakdowns of dynamic, ribbon, condenser, and piezoelectric microphones. Learn how diaphragm size, polar patterns, phantom power, and transduction principles influence the sound you capture in the studio and in the field. Whether selecting your first microphone or expanding your engineering knowledge, this episode provides a practical foundation for understanding modern microphone technology.

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In This Episode

[00:00] **Introduction**
- Welcome Back
- In this Episode

[01:24] **Microphone Basics**
- Signal Flow Review
- Transducers
- Diaphragms
- The Human Ear

[05:20] **Transduction Methods**
- Magnetic Induction: Dynamic and Ribbon Mics
- Electrostatic Induction: Condenser/Capacitor Mics

[11:52] **Diaphragm Size**
- Small-Diaphragm
- Large-Diaphragm

[15:55] **Polar Patterns**
- Cardioid + Variations
- Bidirectional/Figure-8
- Omnidirectional
- Lobar

[18:04] **Piezoelectric Principle**
- Contact Mics
- Pickups

[20:11] **Specialized Mic Types**
- Hydrophone
- PZM
- Immersive/3D-Capture

[23:12] **The Mic Behind the Voice**
- Mic Testing & Selection
- Sibilance & Proximity Effect

[26:49] **Conclusion**
- Get in Touch
- Thanks

Welcome to the Red Pin Podcast. From wherever and whenever you may be listening, I'm glad you're here. I'm your host, Aleyna Neivandt-Brown, the Founder of Red Pin Productions. I created this platform to share with you my complete toolbox of audio engineering skills. Originally based on the curriculum I designed for my college students, this podcast expands the scope and outreach to audiences from hobbyist to professional all in part of my mission to make audio engineering education more accessible and the music industry a little less intimidating. In this episode, I'm dissecting one of the most essential tools in the studio: the microphone.

[Red Pin Podcast Intro Music]

[1:24] Before we actually take a look *inside* the microphone, let's do a quick signal flow review to put it in context. Microphones are **transducers**, so they are responsible for converting the mechanical energy from the sound source into electrical energy, which will travel as a signal through the rest of our gear. Microphones most typically use an XLR connection, and this is a 3-pin connection that can transmit balanced audio from our mic to our gear. Let me briefly review balanced cables—there is an episode on this topic coming up on season two, but here's a quick review—Pin 1 is ground and the other two are positive and negative, hot and cold. The ground just basically provides a line for electrical noise to be discharged without causing noise to our audio signal. The positive pin carries the hot signal and the negative carries the cold (inverted phase signal). Our signal is then going to travel into our mic panel and be routed to a preamp, whether that be our little interface or an outboard analog pre or an analog console channel preamp on your SSL or Neve or whatever your studio uses. Then, with the amplified signal that has been brought up to line level to be usable across other gear like external FX and returns, it will then go through the Analog to the Digital Conversion process. If you want to know more about that process, check out Episode 2: The Digital Audio Domain—and then our mic signal shows up in our DAW like Pro Tools or Logic looking like a perfect replica of the electrical signal that the microphone captured.

So how exactly do microphones create an electrical signal? Microphones have very sensitive **diaphragms** that capture the amplitude and frequency of the incoming vibrations of the particles in the air. As I speak into my mic here, it is moving sympathetically to the disturbance in the air I'm causing with my vocal tones and speech artifacts. And the mic diaphragm receives that just like our eardrum does. In fact, to understand how mics work, it's worthwhile to discuss how our **ears** work. In a way, our ears are a great example of transduction. The eardrum receives the vibrations just like a mic diaphragm; the bones in the middle ear amplify it just like a preamp; the cochlea fluid ripples sympathetically to the amplitude and frequency of the sound, which is picked up by hair cells that create channels as the stereocilia bend,

which allows chemicals to move through those channels into the cells, creating electrical signals that will travel through the auditory nerve to our brain! So our ears convert mechanical energy into electrical energy just like microphones do!

So back to mics—they obviously don't have cochlea and hair cells. But engineers have really creatively harnessed similar natural and technological forces to perform the transduction—like magnetic fields and even some rocks and gemstones. Let's start with magnets.

[5:20] **Magnetic induction** is one of the big categories of mic mechanics that two of our popular mic types fall into, **dynamic** and **ribbon**. The principle of electromagnetic induction, as proven by Faraday's Law among other scientific applications, tells us that when a conductive metal cuts across the flux lines of a magnetic field, a signal of proportionate amplitude and frequency is created. In the case of a dynamic microphone, like your handy SM57, a wire coil is attached to the mic diaphragm and suspended within a magnetic field, so that when the diaphragm vibrates with an incoming sound wave, the wire oscillates, hence the term "moving coil." The movement creates an induced voltage which generates an alternating current, which flows through our XLR as our audio signal. I know that was a lot of terminology to throw out there, so let's step back briefly for some definitions: **Voltage** is a measurement of pressure moving the electricity through a circuit. **Current** refers to the actual flow of electrons. And **signal** is what we would use to describe the meaningful information traveling through that flow—in this case, our audio. So our dynamic microphones use a moving coil, what about our ribbon mics? The term ribbon actually refers to a thin corrugated strip of conductive material suspended within a magnetic field. This time, rather than a coil attached to a diaphragm that will move up and down with incoming sound waves, we have this strip of ribbon that will move back and forth. No separate diaphragm, the ribbon is doing both jobs, receiving the incoming sound and inducing a voltage. This makes ribbon microphones unique in that based on their construction, they have a polar pattern known as figure-8 or bidirectional, meaning they pick up sound from both the front and the back. More on polar patterns later.

Moving on from magnets, let's talk about **electrostatic induction**. The principles of electrostatic induction describe the redistribution of electrical charge in an object caused by the influence of a nearby electrical field. And if we're talking about electric charges, we're not talking about a coil and a magnet anymore. The microphones using this method are constructed much differently. Inside these mics are a **capacito**—giving name to the very category of mic they are, capacitor microphones, which are also known as **condenser mics**. The names capacitor versus condenser is just more of a historical and

translation carryover, but both can be used and are generally considered synonymous. I am in the condenser camp based on my training, so I'm just going to use the term condenser as the microphone type, but let's actually dig into that component: the capacitor. A capacitor is a device that has the ability to hold a charge. It's built using two conductive plates, positioned in parallel, close together but separated by an insulating material called a dielectric, which prevents the plates from actually touching. How this looks inside a condenser microphone is that one plate, relatively small and circular, strong and lightweight to be able to withstand incoming sound pressure yet flexible and sensitive to pick up soft amplitudes and high frequencies, is the diaphragm. This diaphragm is connected, but not directly touching, a fixed back plate, of the same size and shape. These two plates, and the space between them, is our capacitor. It requires power to operate, so these types of microphones are what use that +48V button on your preamp known as **Phantom Power**. This power being sent by the preamp allows the microphone's capacitor to maintain a charge. The only way this charge would change is if something changes in the relationship between the plates. Enter: sound wave. Sound vibrations will cause the front plate—diaphragm—to move sympathetically to the incoming sound wave, causing the distance between the front and back plates to change, getting closer together and farther away, varying the charge. This **variable capacitance**, this charging and discharging, causes the current to flow one way or another, proportional to the incoming sound wave. That sounds a whole lot like a signal, right? A quick note on phantom power, it is important to use safe practices in the studio for the sake of your gear and microphones. Only turn on phantom power once everything is properly connected. Avoid what we call "hot-patching." And only use phantom power on microphones that require it. Dynamics and typical ribbon mics—known as passive—do not use phantom power, and it can even damage them. Condenser mics and active ribbon mics need phantom power, but again, get your mic set up, plugged in, and patched or routed properly before turning on that +48V.

[*brief musical transition*]

[11:52] So we've covered dynamic, ribbon, and condenser mics so far. And I have talked about diaphragms quite a bit with regard to how they participate in generating the signal, so let's take a moment to consider **diaphragm sizes**. You may have seen mics get categorized into small diaphragm and large diaphragm mics. So what's the difference? To generalize, we can say small diaphragms are under ¾". Because they're smaller, they don't have to move as much. They can be a bit more rigid therefore handle higher SPLs—sound pressure levels—and they can capture those quick transients and really high frequencies because those wavelengths are small, but the diaphragm is smaller. Large diaphragms could

be categorized as bigger than ¾". These tend to have lower self-noise, and higher sensitivity—meaning this diaphragm is capturing more sound because it has a larger surface area so can it can intercept more sound waves, and because it's bigger it's generating a stronger signal based on the same incoming acoustic energy as compared to a small diaphragm condenser. That's what we mean by **sensitivity**. It's not a subjective term, it's a data measurement. How much signal is the mic output compared to the acoustic input. Mics with higher sensitivity are outputting a stronger output signal voltage. Now for some subjectivity that does have some scientific ground but tends to be tossed around a bit more like an opinion. "Large diaphragm condensers are warmer and smoother." Why would we say that? Well, let's talk about those quick transients and high frequencies I mentioned. The highest frequency we can hear is 20 kHz. You can calculate the wavelength of a 20 kHz sound wave by dividing velocity by the frequency. For velocity, we can use the speed of sound in air at room temperature at roughly 1130 ft/sec. Then divide by 20,000, and that is 0.675 inches. So now take our large diaphragm, which may very well be an inch or more, compared to that little sound wave, the diaphragm is a downright wall. It becomes an obstacle. Yes, the material of that front plate is designed to be flexible to move, but at some point physics is physics. The pattern of the air molecules vibrating with that little sound wave can be interrupted by that solid. That's where the coloration comes in—the warmth we talk about with a large diaphragm condenser. It does have the ability to shape and color some high frequency content in such a way that makes the mids and high mids, like vocals, sound smoother and warmer. So yes, it sounds subjective, and yes, you should question if someone is trying to sell you on a piece of gear by telling you how it will feel instead of how it works. But there is some science behind this one, and I encourage you to dive into the science of any piece of gear you're getting. Look at the spec sheet. Learn what it means, so that you can apply your gear with the full force of scientific proof behind your techniques.

[15:55] Another important spec you might consider when choosing a mic and understanding how they work, is the **polar pattern**. Our SM57 example of a dynamic mic has a cardioid polar pattern. Our ribbon mic has a figure-8 polar pattern. These are referring to directionality or pickup area. If you point your mic at a sound source, how much of that sound is the mic able to capture, and how much of the surrounding space as well? Cardioid, like the SM57, is a pattern that picks up only what's in front, but there is some buffer zone around the sides, but it's really good at rejecting the rear. That's partly why the SM57 and 58 are commonly used on stage, because as long as it's pointing away from other instruments, amps, or onstage monitors, it's less likely to feed back. Hypercardioid and supercardioid patterns are similar to the standard cardioid pattern, but they shave off the sides for a bit more narrow field, but they do compromise with allowing a bit more from the rear. Figure-8, also known as

bidirectional, pick up both front and back, and have excellent side rejection. Omnidirectional—as the prefix suggests—picks up all around. And a more specialized pattern often used on film and TV sets or for field recordings is the lobar pattern also known as shotgun, which has the most extreme narrow field and rejection of anything off-axis, basically—it's only going to pick up what it's pointing at.

[*brief musical transition*]

[18:04] The last method of transduction I want to talk about doesn't involve magnets, capacitors, or even polar patterns at all. It's entirely based on contact and materials. The **piezoelectric** principle demonstrates that certain crystals, ceramics, and organic materials like quartz, Rochelle salt, and even bone, have the ability to generate an electric charge when under mechanical stress. Harnessing that by attaching a vibration-sensing diaphragm or contact surface to a piezoelectric material allows it to become a transducer, converting mechanical energy to electrical energy. In the case of a crystal microphone, sound waves strike the diaphragm as vibrations, and that mechanical stress temporarily deforms the crystalline structure of the attached polarized crystal, causing positive and negative charges proportional to the incoming sound wave. Where do you see piezoelectric microphones in the audio world? Well, they are commonly used as pickups inside of acoustic guitars, harps, and other hollow-bodied string instruments as a great method of recording or amplifying the instrument without needing a standalone mic. Piezo pickups are handy because they won't have any magnetic interference and they are only going to pick up what they are literally attached to, with the exception of some feedback tendencies, because vibrations are vibrations, intentional or not. There are also some tonal characteristics that some people don't prefer, and they output a high-impedance signal that usually requires an impedance-matching preamp before the signal hits the amp or goes into the mixer.

[20:11] To round out our dissection of microphones, I want to mention a few other specialized types and uses, so first on our specialized list is the **hydrophone**. Hydrophones are designed to operate under water. They use a piezoelectric transducer to detect sound and pressure changes in the water, so these can be used across a variety of fields like marine biology and oceanography, subsea seismology, and even naval operations. Hydrophones can of course also be used to record underwater audio, but if you read my article on the sound design from the Denis Villeneuve *Dune* movies in the *Red Pin Review* Vol. 2 Issue 2, you'd know that team used hydrophones in the desert, buried in the sand, to research, record and design the soundscape of the planet *Arrakis*. As always, you can read the *Red Pin Review* for free on redpinproductions.com. Next on our list of specialized mics is the **PZM**, pressure zone microphone. Originally developed by Crown International, the PZM is a boundary mic. A small condenser

mic faces a flat boundary plate and captures both the direct and reflected sound waves. This mitigates phasing issues and captures a flat frequency response. This makes it handy for miking the inside of a grand piano lid, capturing all the articulation and resonance from the strings, hammers, and soundboard, without worrying about the sound reflecting off the lid and back into the mic out of phase. It's also handy for mounting on the wall of a drum room for the same reason. But they aren't just used in studio settings, you may also find them on the table in a conference room, or placed on the stage to record a theater performance—many PZMs do have built-in shock absorption. Lastly on the topic of specialized mics—given the recent developments in immersive audio, microphone designers have created some new configurations to capture a more **immersive** or 3D sonic image. Binaural mics actually feature a design that includes basically a mannequin head and ears, with microphones placed inside the ears, to replicate and record how we actually hear sound in real life. Ambisonic mic configurations have multiple capsules picking up sound in multiple directions for a more complete 3D capture.

[23:12] All this talk of microphones, and well, this is an audio engineering podcast after all, so I'm going to give you a peek behind the curtain and tell you my exact microphone and recording setup. When I first embarked on this podcast journey, I had to reconsider my priorities when it comes to mic selection. I'm usually recording myself and my clients for music production, and recorded speech is a whole different ball game. Do I use my high sensitivity large-diaphragm condenser and compromise with some room noise and **sibilance**—those pesky ss's and high-frequency consonants in our speech? Or do I use my stage mic—the hardy, reliable SM58 that is subject to the **proximity effect**, which is when a dynamic mic boosts the bass frequencies as it gets closer to the sound source, which can make speech sound a bit boomy? Well I tried both in a mic shootout, along with a classic broadcast dynamic mic, the Electro Voice RE20, as well as the versatile dynamic mic, the Sennheiser MD 421. Back when I was an undergrad at Florida State and recording the very first ideations of my debut album on my dad's Fender Gemini II acoustic, I gravitated towards the sound of the MD 421 before I really understood why. Ten years later, here we are, and I was fully expecting to fall in love with that high-fidelity polish of the Electro Voice RE20, but I didn't. Its pronounced upper-mid detail wasn't especially flattering in my studio here at Red Pin Productions. I have plenty of acoustic treatment for both absorption and diffusion, but it's not completely soundproof. And I found myself, yet again, impressed by the clear sound and low noise floor of the Sennheiser MD 421, both in terms of my voice itself, and in how well it rejects the room noise. Part of that is due to the built-in incremental high-pass filter dial from M for music to S for speech, so you can dial in—literally—the right filter for your voice and your room. Comparing all four of these mics through my SSL preamps into Pro Tools, I could actually *see* the difference. I adjusted the gain

of each one so that they were consistently hitting the same levels, and when I paused between phrases, the waveforms revealed that the MD 421 had a much lower noise floor. Which makes sense! It required much less gain than the SM58 and the RE20, which improved the overall signal-to-noise ratio. It doesn't need phantom power. It isn't as susceptible to the proximity effect as the SM58, and as long as I have a windscreen on and speak slightly off-axis, it has no major plosive or sibilance issues. For me, for my voice and my space, the MD 421 was the clear winner. So now you know the microphone behind the voice.

[Red Pin Podcast Outro Music begins in the background]

[26:49] If you have a microphone you're curious about, let me know! I'm always on the hunt for more gear to review for the quarterly research journal the *Red Pin Review*. And if you have a topic you'd like to hear on the Red Pin Podcast, reach out on redpinproductions.com. I'm Aleyna Neivandt-Brown. Thanks for listening.

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