On The Bench: Microphones
We all use 'em, but what are they and how do they work?

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Since I began these articles for AudioTechnology it's been on the back burner to write a series of articles covering different types and topologies within a particular class of equipment. For example, compressors – FET, opto, vari-mu and amplifiers – class A, B and C. Does anyone know much about what all these different designs mean or do?

It makes sense to me to kick this series off with the beginning of the chain for any acoustic music recording and production: Microphones. But first… a bit of housekeeping is in order. Last issue's article on Levels had, due to a layout problem, a yawning chasm in it. The box item which clarified some of the facts was deleted by accident, so here it is finally, on page 74. Now… microphones, what are they?

THE CATCHER'S MITT

While we can emulate all sorts of instruments with quite good results these days, until someone comes up with a 'plug-in vocalist' we will at least require microphones for recording the voice. The human voice with which we have an innate familiarity is often the greatest test of a microphone's characteristics, strengths and deficiencies. Indeed, within my workshop, listening to my own voice tells me a lot about the character and performance of a microphone following repair or servicing.

In essence a microphone is a transducer that converts acoustical sound pressure into an electrical signal. There are a number of ways this has been achieved over the years, ranging from granulated carbon microphones in the early days of telephony to esoteric approaches involving optics and lasers. The microphones that we're most familiar with in the recording studio are built around either ribbon, moving coil or condenser transducers. So let's check these three staple designs out.

RIBBON MICROPHONES

The first ribbon microphone, the RCA 44A was introduced in 1932, and as a testament to the unique quality of this microphone it is still considered the 'go to' microphone for some applications – in particular, horns and brass instruments. The essence of a ribbon microphone is very simple, being a ribbon or strip of very thin foil – usually aluminium – suspended within the field of a magnet [see Fig.1]. The foil is corrugated to give lateral stiffness and longitudinal flexibility. When the ribbon vibrates within the magnetic field, a current is generated across the length of the ribbon. This current is very small and all ribbon microphones require a step-up transformer to yield an output that is useful and compatible with the typical gain ranges available on most microphone preamps.

Figure 1

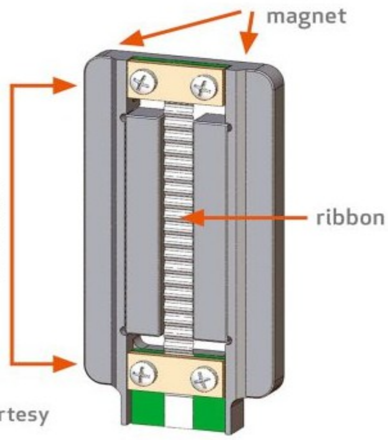


Diagram courtesy of Royer.

A simple ribbon microphone with no surrounding acoustic baffling or treatment is a pure pressure gradient transducer, meaning the ribbon moves and therefore generates its signal output in response to the instantaneous pressure difference between the front and rear sides of the ribbon. The nature of this response gives rise to the figure-8 or bi-directional pickup pattern of ribbon microphones, as sound that arrives from the side direction and presenting 'edge on' to the ribbon will not cause a pressure difference between the front and rear sides of the ribbon. Thus, the ribbon doesn't move and there's no signal output. Ribbon microphones are capable of very deep nulls in their side-on response, making them useful for not capturing a particular sound source in a recording situation. [See Stav's article in Issue 56 on the use of a figure-8 pickup pattern microphone for headphone-less vocal recording.]

When introduced, the first ribbon microphones were a significant improvement in the quality available from microphones of the day. While ribbon microphones typically have a frequency response that tapers off at high frequencies, their definition and accuracy at middle frequencies sets them apart. This is primarily why they've been 'rediscovered' in recent years. Much of this is to do with the simplicity of its design; the ribbon is freely exposed to the air with no baffling or acoustic treatment – this yields a pure and simple transducer.

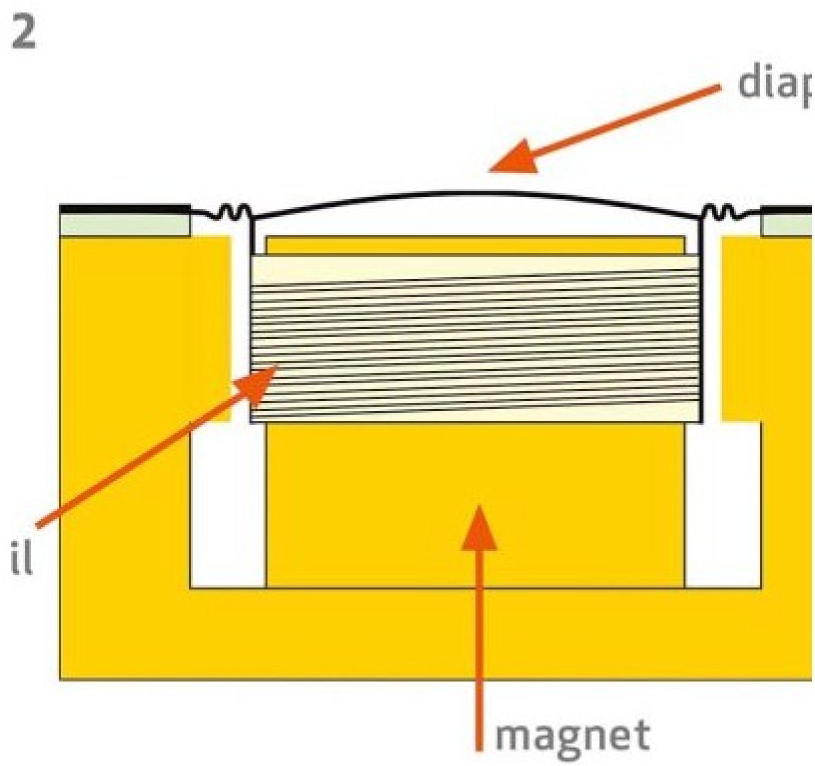
CUT TO RIBBONS

Ribbon microphones are fragile; the ribbon thickness ranges from 0.6 to 2 microns and a good gust of wind or breath from a singer can break it. Replacing a ribbon is not a trivial matter either, requiring a steady hand and a beady eye. This is why most ribbon microphone manufacturers today recommend that a microphone with a 'blown' ribbon be returned to the factory for repair.

One important thing that takes place in the assembly of a ribbon microphone element, or indeed replacement of ribbon, is the 'tuning' of the ribbon. The ribbon is lightly tensioned and thus tuned to a very low frequency. This tensioning is critical to the 'sound' of the microphone. As mentioned the ribbon transducer requires a step-up transformer and this transformer contributes significantly to the qualities of the microphone. Indeed the interaction of the complete ribbon microphone and the input impedance of the microphone preamp to which it is connected can change the tonal characteristics of the microphone significantly, more so than any other type of microphone. In response to this we are now seeing ribbon microphones with integrated amplifiers, either transistor or tube. In this situation the manufacturer has complete control over the impedance that the transformer 'sees' and can thus optimise the relationship to enable the best and most consistent frequency response.

MOVING COIL OR 'DYNAMIC' MICROPHONES

Just as the ribbon microphone produces a current flow as the ribbon moves within a magnetic field, a moving coil (or as it's commonly known, dynamic microphone) produces a current flow when a coil of wire moves in a magnetic field. Dynamic microphones are, in simple terms, of the same construction as a loudspeaker, consisting of a diaphragm attached to a coil of wire suspended within a magnet [see Fig. 2]. Dynamic microphones are essentially pressure transducers where the diaphragm moves and generates a signal in response to sound wave pressure. This makes a simple dynamic microphone omni-directional in its pickup pattern. However, most dynamic microphones have acoustic cavities and porting from the rear of the capsule to modify the pickup response to achieve a cardioid (directional) pattern. The design of this complex acoustic modification affects the frequency response and how that response changes with the proximity of the sound source. Compared to a ribbon microphone, the design of a good dynamic microphone has a complex acoustical design aspect which yields a greater variation in its frequency response and off-axis performance. When a microphone has a pickup pattern with directional characteristics it will exhibit the 'proximity effect' whereby the bass response increases as the sound source moves closer to the microphone.

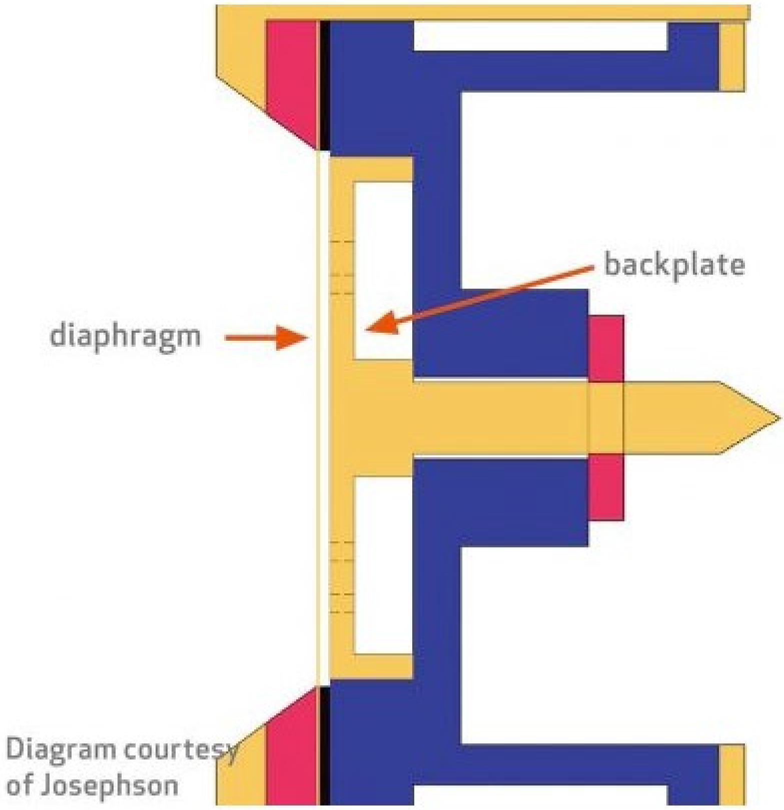


The moving coil of a dynamic mic generates a larger signal than a ribbon microphone because of the large number of turns and the narrow gap between this coil and the magnet. This results in some dynamic microphones not requiring a step-up output transformer at all, while some still retain a transformer with a smaller step-up ratio than that found in a ribbon microphone. Due to the tendency of a coil of wire to pickup stray electromagnetic fields (just like the pickup on your electric guitar seems to capture every hum and buzz floating around), many dynamic mics have a secondary coil wired in 'humbucking' fashion to cancel out the pickup of hum and buzz. Dynamic microphones are very robust, indeed there is video floating around the interweb showing the ubiquitous Shure SM58 being dropped, run over, immersed in water, microwaved… and still working!

"The accumulation of dust and other flotsam on the sensitive diaphragm can weigh it down, affecting the response of the microphone."

CONDENSER MICROPHONES

The term 'condenser' originates from the historical term applied in electronics to capacitors. If condenser microphones were invented today they could well be called 'capacitor' microphones. The capsule of a condenser microphone consists of a thin membrane, usually in the order of three- to six-microns stretched and fixed closely to a solid metal 'back-plate' [see Fig. 3]. The diaphragm is coated with a metallic layer, often gold, creating, in combination with the back-plate, a small capacitor. The gap between the diaphragm and back-plate needs to be very small in order to give a usable capacitance, and is typically 15 to 30 microns. The diaphragm is polarised with a high voltage typically ranging from 30 to 80 volts, creating a fixed charge on the capacitor. When exposed to sound pressure the diaphragm moves towards and away from the back-plate, causing a change in its capacitance and thus producing a voltage output. The impedance of this capsule is extremely high and requires a buffering circuit to translate this signal to a suitably low impedance, to drive cables and the inputs of microphone preamps. All condenser microphones therefore contain some electronic amplification circuitry requiring external power, whether it be a tube or transistor based. Most condensers also traditionally include an output transformer, although, increasingly, condenser microphones are being developed that contain an active, transformer-less output amplifier stage.



The weight of a condenser microphone diaphragm is light compared to a dynamic microphone and is therefore very sensitive and responsive to high frequencies. Just as a ribbon microphones ribbon is ‘tuned’, the diaphragm of a condenser microphone is also tuned, much like a drum skin, but to a high frequency, typically around 8 to 12kHz. (Think of it like this: if the ribbon mic is ‘tuned’ like a kick drum, the condenser is tuned like the snare.) This yields the characteristic quality of condenser microphones of having an extended high frequency response and often a small peak in the response around the ‘tuning’ frequency. The frequency response characteristics are also affected by tiny holes and pits machined into the face of the back-plate. This is akin to the acoustic treatment of a room whereby the tiny space between the diaphragm and back-plate is damped and tuned with these small cavities.

Because of the relatively thin and flat nature of a condenser microphone capsule it’s easy to place two capsules ‘back-to-back’, and through altering the relationship of the polarising voltage on the two capsules, affect the pattern response from the combination of the two capsules. Patterns ranging from omni-directional through cardioid to figure-8 are thus obtained.

REBALANCING LEVELS

This was the box item accidentally cut from last issue's article on levels.
"Decibels are the logarithmic expression of the measurement of a quantity (for example, signal voltage) relative to a fixed or reference level. For voltages, this logarithm of the ratio is multiplied by 20. So for example, if we measured a voltage of 3 volts and wanted to express that measurement in dB compared to 1 volt, the math would be: dB = 20 x (log 3 volt / 1 volt) which equals 9.54dB. For measurements involving power (Watts) rather than voltages, the logarithm is multiplied by 10 rather than 20.

Because of the logarithmic expression, when a measured quantity is less than the reference it becomes a negative number expressed in dB.

Note that one of the advantages of the logarithmic nature of decibels is that a wide range of voltages can be expressed with a comparatively small range of numbers. We can measure from microvolts (millionths of a volt) to tens of volts with a range of numbers in dB from –120 to 30. One other fundamental aspect of the use of logarithms is that our perception of sound both in terms of frequency (pitch) and loudness is largely logarithmic in nature and so there is an intrinsic relationship between how we measure audio levels in decibels and how we hear them. Perhaps the coolest thing about expressing signal levels in dB is that the maths is simpler – multiplication is replaced with addition. For example, if we measured in voltages, then a signal level of 3.16 millivolts after a gain of 40 times had been applied would be 3.16millivolts x 40 = 126.4millivolts. Once this is presented in dB the multiplication becomes a simple addition: a –72dBm signal with a gain of 32dB gives a signal with a level of –72dBm + 32dB = –40dBm. Simple!"

CARETAKER

More so than other microphone types, condenser microphones benefit most from care and maintenance. The accumulation of dust and other flotsam on the sensitive diaphragm can weigh it down, affecting the response of the microphone, and even cause it to 'bottom' out on the backplane on loud signals or vocal pops, effectively shorting out the capsule. Because of the magnet in dynamic microphones and ribbon microphones they need to be kept clear of 'tramp' (metal particles) that will be strongly attracted to the magnet. It's recommended that ribbon microphones in particular should be stored in a plastic or cloth bag when not in use. I have seen a dynamic microphone where fine iron particles have found their way onto the diaphragm, and due to the magnetic attraction, effectively clamped the diaphragm against the magnet behind it. Needless to say the microphone didn't sound too good. With larger ribbon microphones it's recommended that they be stored upright; longer ribbons will tend to sag over time if left lying horizontally affecting their tensioning and sound.

MICRO-ORGANISMS

Microphones are kind of like guitars, there are some really good ones, some very poor ones but between those extremes they are all different. As a tool whose primary function is simply to capture what we're hearing, the differences that a choice of microphone can make are enormous. Much has to do with the intrinsic 'type' of microphone it is, but within a particular type – the design of the acoustic chambers, the thickness of the diaphragm, the design of the transformer and the topology of the electronics – this gives designers and users a very wide palate.