The Case for the Condenser Microphone

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"Incorporation of the electret capsule and the resultant increase in battery life, makes the use of superior condenser microphones as convenient as the use of dynamic microphones."

ACCURACY is the key factor in the design and performance of any audio component. There are many ways of measuring the deviation from absolute accuracy. *Total harmonic distortion, intermodulation distortion, frequency response, signal-to-noise ratio, phase response, impulse response,* and many more are terms describing the relative accuracy of a component. The aim of all these measurements is to show how closely the output of a device approximates the input to that device.

In studying the important characteristics of condenser and dynamic microphones, it quickly becomes apparent that a properly designed condenser microphone is *inherently more accurate* and thus better than a properly designed dynamic microphone.

A microphone is a device which converts acoustic energy into electrical energy. In other words, when sound of a given frequency and amplitude strikes the diaphragm of a microphone, alternating electrical current of equivalent frequency and amplitude is produced by the microphone. This transformation takes place in several well ordered steps, regardless of the type of microphone.

1. Acoustic energy (an alternating air pressure) strikes the diaphragm of the microphone.
2. The acoustic energy becomes mechanical energy as the diaphragm vibrates in accordance with the difference in pressure between front and rear sides of the diaphragm.
3. The mechanical energy (vibration) of the diaphragm is converted to electrical energy (alternating current) in accordance with the intensity and frequency of the sound pressure.

From the above, it is apparent that the distortion may first occur in step 2, where a diaphragm is required to react with extreme accuracy to a constantly varying sound pressure.

The diaphragm of a condenser microphone is a circular piece of extremely thin (typically 0.00025 in. thick) plastic or metal which is supported at its edge. (See Fig. 1-A). The diaphragm of a dynamic microphone is also a thin plastic or metal sheet supported at its edge. The diaphragm of the dynamic microphone is connected at its center to

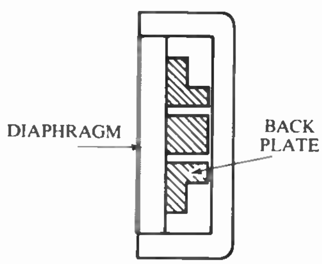

Fig. 1-A—Cross-section of a condenser microphone.

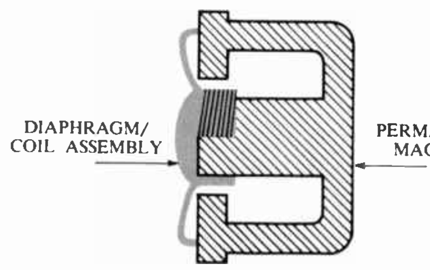

Fig. 1-B—Cross-section of a dynamic microphone.

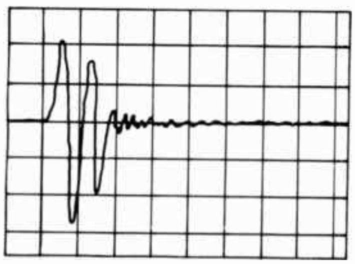

Fig. 2-A—Impulse response of a Sony condenser microphone.

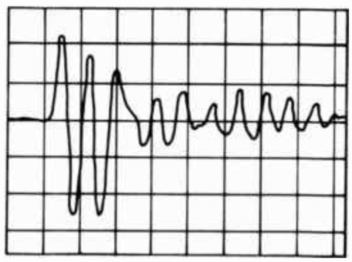

Fig. 2-B—Impulse response of a professional dynamic microphone.

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a coil of wire which moves in a magnetic field whenever sound pressure strikes the diaphragm. (See Fig. 1-B).

The coil attached to the diaphragm of the dynamic microphone is required to convert the mechanical vibration of the diaphragm into electrical current, whereas the condenser microphone does not require a coil. By adding enormously to the mass of the vibrating system, this coil prevents the dynamic microphone from responding accurately to variations in sound energy. [1]

A simple experiment can be performed to illustrate and verify this effect. Two microphones are placed side by side, a $50 Sony condenser and a well-known $150 dynamic. A spark gap (as in an automobile spark plug) is used to produce a sound impulse. The output of both microphones is displayed on an oscilloscope. (See Figs. 2-A and 2-B.)

Once set in motion by the impulse, the high mass of the dynamic microphone diaphragm causes it to continue in motion (and thus produce output) despite the complete absence of sound. The low-mass diaphragm of the Sony condenser microphone ceases to move as soon as the sound stops. From this experiment it can be deduced that whenever there is a change in sound pressure, either in amplitude or frequency, the condenser microphone will respond quickly and accurately to the change while the dynamic microphone will adjust to the change more slowly.

The higher mass of the dynamic microphone's moving system also creates other problems, the most important of which is resonance. Any object possesses one or more resonances, as determined by the object's mass and other factors. Generally speaking, the larger the mass, the lower the resonance. [2]

In a microphone, the output will increase sharply at the resonant frequency of the diaphragm. Ideally, the resonance of a microphone diaphragm should be well above the audio frequency range in order to avoid an audibly peaked output. Only the very finest (and most costly) dynamic microphones have resonances restricted to the frequency range above 15 kHz because of the inherent high mass of their diaphragms. In contrast, the resonance of the low-mass diaphragm of a condenser microphone will be at an extremely high frequency, resulting in smooth, peak-free response throughout the audio range. [3]

The characteristics of condenser microphones will give the sound a natural quality which is unattainable with any but the most expensive dynamic microphones. Furthermore, in public address applications where feedback is a problem, a dynamic microphone will often cause feedback at its resonant frequency, thus reducing the maximum volume capability of the system. The smooth response of a condenser microphone will generally permit substantially higher volume levels before feedback occurs.

The low-mass diaphragm of a condenser microphone provides many advantages relative to the dynamic system. The sensitive condenser diaphragm will produce less harmonic and intermodulation distortion at a wider range of frequencies than the dynamic diaphragm. The condenser diaphragm is less sensitive to low frequency mechanical vibration transmitted through the stand and microphone case to the diaphragm. Finally, condenser microphones, with built-in pre-amps, generally have a higher output level than dynamic microphones. Therefore, the condenser microphone will produce an acceptable signal-to-noise ratio, even when used with less than ideal microphone preamplifiers. (See Figs. 3-A and 3-B.)

[1] As an analogy, take a baseball player and two bats. One bat weights 38 ozs., the other weighs only 28 ozs. The player steps to the plate with the heavier bat. The first pitch looks good so the player starts to swing the bat. In the middle of his swing, he realizes that the pitch is not a strike, so he attempts to stop his swing, but the inertia of the heavy bat causes it to continue forward, and a strike is called. The player then switches to the lighter bat and the same situation reoccurs. This time, as soon as the player attempts to stop his swing, the bat stops. In this example, it can be seen that the higher the mass of a moving object, the more the object resists a change in motion.

[2] As an example, take an empty 16 oz. glass and an empty 4 oz. glass. Strike both with a spoon. The larger, more massive glass will resonate at a lower frequency than the small glass.

[3] Although the problem of diaphragm resonance differs in cardioid microphones and omni-directional microphones, it is generally true that the frequency response curves of dynamic microphones show more peaks and dips as well as narrower bandwidth than those of condenser microphones because of the low frequency resonance of the dynamic microphone's diaphragm and its associated acoustic circuit. A detailed explanation of the factors involved is too complex to present here. Please see references 1 to 4 for information on this subject.

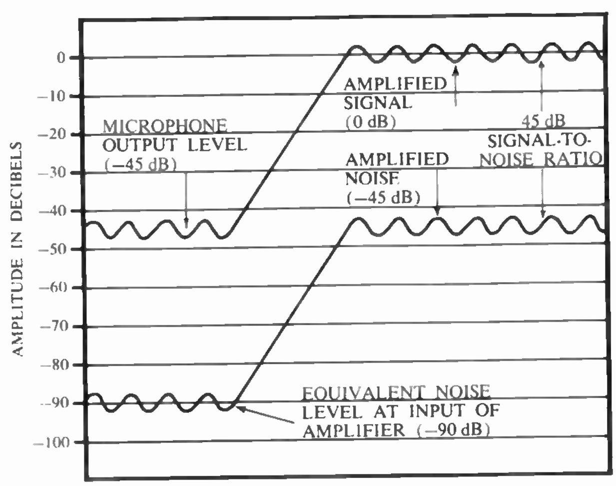

Fig. 3-A—Signal-to-noise ratio of a condenser microphone with an output level of -45 dB when used with a microphone preamplifier having a high noise level.

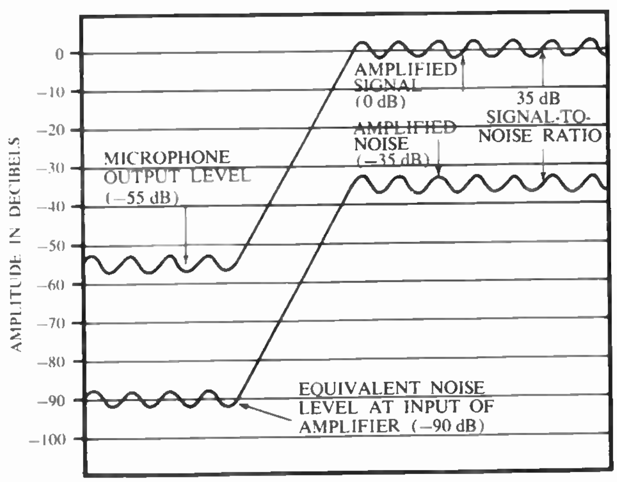

Fig. 3-B—Signal-to-noise ratio of a dynamic microphone with an output level of -55 dB when used with a microphone preamplifier having a high noise level.

After reviewing the preceding facts, which clearly indicate that the condenser microphone is technically superior to the dynamic microphone, a natural question is "Why do dynamic microphones out-sell condenser microphones by a margin of at least 10 to 1?" Up until now, three negative characteristics of condenser microphones have made these technically superior products unusable for all but the most professional applications.

First, since the condenser microphone is an electronic device (each contains an amplifier), a power source is required for it to operate. Originally, the amplifier used a vacuum tube and the microphone required three different voltages: 4 to 12 volts for the filament, B+ for the plate, and 64 to 200 volts to polarize the condenser capsule. As a result, a bulky, complex, and costly external power supply was required, with a huge multiconductor cable interconnecting the power supply and the microphone. See photos.

With the introduction of transistors, the power requirements were simplified, but the condenser microphone still required two voltages, 1.5 to 12 volts for the transistor amplifier, and 65 to 200 volts to polarize the capsule. A few condenser microphones with self-contained battery power supplies appeared on the market, but battery life was still comparatively short. The majority of condenser microphones still required an external power supply. The microphones were still too complex for general purpose use.

Sony C-37A and power supply (1955)

Sony C-37FET (1964)


Sony ECM-22

In 1969, Sony Corporation manufactured the first electret condenser microphone, the ECM-22. The incorporation of an electret capsule [4] further reduces the power requirements. A single voltage, from 1.5 to 9 volts, is required. Since no high voltage is required for polarizing the capsule, battery life is extended (up to 1100 hours in the ECM-22; up to 15,000 hours in other Sony condenser microphones).

Each of these technical advances reduced the complexity of the condenser microphone, thus making it usable for a wider variety of purposes. The latest advance, the incorporation of the electret capsule and the resultant increase in battery life, makes the use of superior condenser microphones as convenient as the use of dynamic microphones.

Secondly, because the condenser microphone is very complex, it was also extremely susceptible to damage from shock, moisture, humidity, and heat. The reduced complexity of the modern condenser microphone design has resulted in a dramatic improvement in durability. Sony condenser microphones, for example, are extremely rugged and will withstand without any ill effects the normal accidents which occur, as for example, falling off a table. However, these condenser microphones cannot be used to hammer nails (a capability one well-known manufacturer of dynamic microphones claims for his product), since they are precision audio components and must be treated as such.

Finally, prior to 1969, the least expensive high quality condenser microphone cost over $200 with the majority of such microphones costing from $275 to $500 each. At these prices, the only users of condenser microphones were professional recording engineers, whose income depended entirely on the quality of their recordings, and acoustical engineers, who used condenser microphones for audio measurements which required greater precision and quality than any available dynamic microphone could provide. After designing the electret condenser microphone, Sony manufacturing engineers were faced with the task of producing these microphones at prices which were competitive with dynamic microphones. They were able to meet this challenge, and as a result, Sony condenser microphones are available at prices starting below $20.00. Each is a true condenser microphone, and thus incorporates all of the inherent advantages of even the most expensive condenser types. Æ

[4] A discussion of electret capsules, or of operating principles of condenser microphones, would be too complex to present here. Please see references 5 to 7 for information on these subjects.

REFERENCES

1. L. E. Kinsler, A. R. Frey, Fundamentals of Acoustics, 2nd Ed. (John Wiley, New York, 1962).
2. H. T. Souther, "An Adventure in Microphone Design," *J. Audio Eng. Soc.* 1, 180 (1953).
3. R.H. Fisher, R. Booth, "Design and Development of Condenser Microphone," *British Kinematography Sound & Television* 50, 80 (1968).
4. H. F. Olson, "Directional Microphones," *J. Audio Eng. Soc.* 15, 420 (1967).
5. G. M. Sessler, J. E. West, "Condenser Microphones with Electret Foil," *J. Audio Eng. Soc.* 12, 129 (1964).
6. J. J. Noble, "Design Evolution of a FET Condenser Microphone System," *J. Audio Eng. Soc.* 15, 273 (1967).
7. P. V. Murphy, F. W. Fraim, "Electret Condenser Microphones of High Quality and Reliability," *J. Audio Eng. Soc.* 16, 450 (1968).