Condenser Microphone

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***Abstract*—For the application of accurate voice reproduction, a cost-effective condenser microphone design is considered. Analysis of theoretical characteristics such as sensitivity, dynamic range, and signal-to-noise ratio is presented. In conclusion, quantitative measurements from a working prototype are corroborated with the theoretical analysis.**

Keywords*—*Capacitive, Condenser, Microphone.

I. INTRODUCTION

THE accurate transduction of sound into an electrical signal is naturally useful for conveying the human voice. People generally speak at 40 to 60 dB SPL and can hear sound from 20 Hz up to 20 kHz with especial sensitivity to the 1 to 4 kHz region.[1] For the application of accurate sound reproduction, the designer should strive for unity-gain response in these ranges, particularly in the 1 to 4 kHz range.

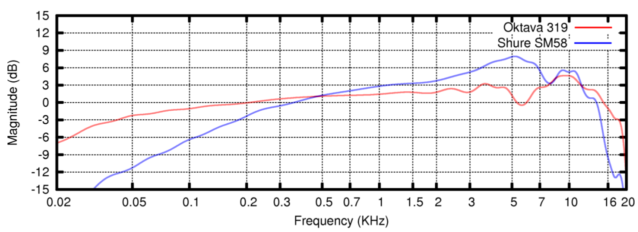


Fig. 1: *Oktava MK-319 condenser microphone*[2] *and Shure SM58 dynamic microphone*[3] *(20 Hz to 20 kHz)*

A variety of devices exist for transducing sound. Of commercially viable designs, condenser and dynamic microphones are the most common.[4] Fig. 1 plots the responses of a condenser microphone and a dynamic microphone. The condenser mic (in red) experiences less attenuation at the extremes and provides greater uniformity in between. It is not unusual for condenser mics to have an upper 20 kHz frequency limit compared to the typical 16 kHz limit experienced by dynamic mics.[5] Additionally, the condenser microphone has notably less gain in the 1 to 4 kHz region people are most sensitive to, providing a more balanced response. Generalizing these results, condenser microphones are preferable for applications desiring accurate reproduction.

II. SENSOR STRUCTURE AND MEASUREMENT PRINCIPLE

Condenser microphones work by converting sound pressure into a change in capacitance across a DC-biased condenser. The condenser has a diaphragm membrane that can be deflected by sound pressure. When sound causes membrane deflection, the capacitance of the condenser varies. This capacitance delta produces a corresponding change in voltage on the circuit the condenser is tied to. The resultant AC small-signal can then be extracted from the microphone circuit to obtain a voltage representation of the source sound.

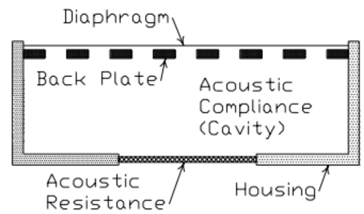
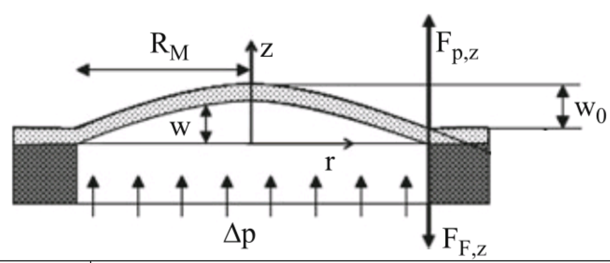


Fig. 2: *Diaphragm system vertical cross-section*[6]

The diaphragm portion of the condenser microphone has a cylindrical form-factor. Its vertical cross-section is depicted in Fig. 2. The diaphragm itself is a thin, tensioned membrane which is responsive to sound pressure in the target frequency range. The back-plate is a rigid structure with distributed holes leading to an internal cavity. Between the membrane and the back-plate is the air-gap which forms the condenser dielectric. An acoustic resistance at the rear of the internal cavity serves as a normalizing vent, allowing the cavity to equalize to atmospheric pressure.



Symbol	Description
r	radius in cylindrical coordinates
R_M	membrane radius
w	deflection along z-axis at a particular radius
w_0	apex of deflection, equal to $w(r = 0)$
P_0	atmospheric pressure
Δp	change in pressure relative to P_0 caused by sound
$F_{p,z}$	force due to uniform pressure across membrane
$F_{f,z}$	force due to membrane tension and frame

Fig. 3: *Modeled parabolic membrane deflection owing to uniform sound pressure*[7]

A. Membrane Deflection

When sound pressure impinges upon the membrane, it oscillates with the pressure according to its mechanical properties. Fig. 3 shows modeled parabolic deflection in cylindrical coordinates. The modeled parabolic deflection assumes sound pressure is uniformly distributed across the face of the membrane. This produces purely vertical membrane oscillation along the z-axis in cylindrical coordinates, with the apex deflection w_0 occurring at the center of the membrane owing to the maximized moment arm at that point.

Setting residual stress $\sigma_0 = 0$, we can solve for the apex deflection using the relation[7]:

$$\Delta p = \frac{4w_0 d_m}{R_M^2} \frac{E_M}{1 - v_M^2} \left(\frac{4}{3} \frac{d_M^2}{R_M^2} + \sigma_0 + \frac{64}{105} \frac{w_0^2}{R_M^2} \right) \quad (1)$$

Symbol	Description
σ_0	residual stress, modeled with $\sigma_0 = 0$
E_M	Young's Modulus of elasticity for the membrane
v_M	Poisson's ratio for the membrane

The apex deflection w_0 can then be used to calculate the modeled parabolic deflection at any radius r using:

$$w(r) = w_0 \left(1 - \frac{r^2}{R_M^2} \right) \quad (2)$$

B. Capacitance

Let the back-plate be held at $z = h_0$ above the membrane to create the dielectric air-gap. Assume the membrane has a positive apex deflection $w_0 > 0$ and is deflected up towards the back-plate due to sound pressure. If we treat the face of the membrane as a collection of cylindrical area differentials with $dA = r\,dr\,d\theta$ we can find the total capacitance under deflection by integrating the differential capacitances dC:

$$\int_A dC = \int_A \frac{\epsilon_0\, dA}{h_0 - w(r)} \quad (3)$$

$$C = \frac{\pi \epsilon_0 R_M^2}{w_0} \ln \left(\frac{h_0}{h_0 - w_0} \right) \quad (4)$$

Negative apex deflection $w_0 < 0$ indicates deflection *away* from the back-plate and produces the expression $h_0 + w_0$ in the denominator of the natural logarithm.

C. Voltage

III. Conclusion

The conclusion goes here.

Appendix A
Proof of the First Zonklar Equation

Appendix one text goes here.

Appendix B

Appendix two text goes here.

Acknowledgment

The authors would like to thank...

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