DISTORTION IN

Electrostatic Loudspeakers

CONDITIONS NECESSARY FOR LINEAR OPERATION

AFTER holding undisputed supremacy for a quarter of a century the moving coil principle of drive for loudspeakers must now meet growing competition from the electrostatic principle, which has been shown to be capable of intrinsically better performance from the point of view of non-linearity distortion.

Basic Formulæ

$$Q = CV = \frac{\kappa AV}{d}$$

$$C = \frac{\kappa A}{d}$$

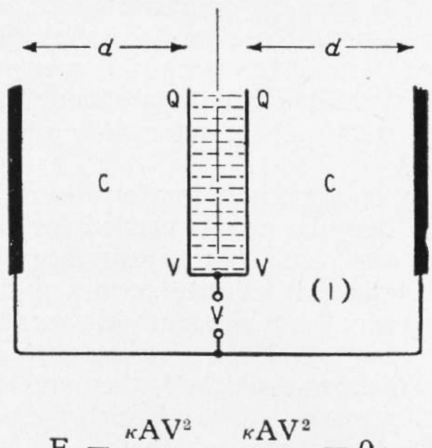
$$V = \frac{Qd}{\kappa A}$$

$$F = \frac{QV}{2d} = \frac{\kappa AV^2}{2d^2}$$

Recent articles [1, 2, 3] have reviewed the theoretical basis and given some pointers to the practical requirements for the realization of low distortion levels. The material presented was voluminous and to those readers who remember the Vogt loudspeaker[1] of the late '20s may not have seemed to include any new feature. Like the latest designs it operated on the push-pull system with a polarizing voltage applied through a resistance to a thin diaphragm supported midway between perforated metal plates, to which the signal was applied "differentially" (i.e., in push-pull).

This form of construction gave a marked improvement over the single fixed plate electrostatic loudspeaker, but non-linearity due to the increased force as the diaphragm approached either of the two fixed plates was acknowledged and to some extent compensated by adjustment of the elasticity and diameter of the diaphragm.

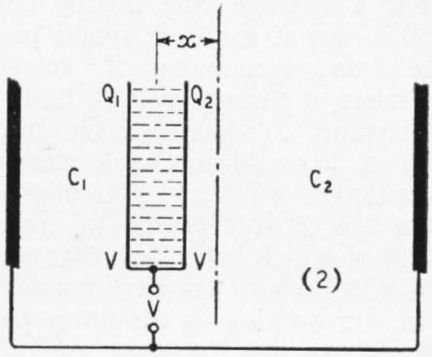
This non-linearity arises because the force acting on the diaphragm, which is always zero in the mid position, increases when the diaphragm is displaced —except in one particular set of circumstances, which we shall discuss later. The displacement need not be due to the applied signal voltage and can be mechanical. It is, in fact, convenient at this stage to forget the effect of the signal and to concentrate only on the stability of the diaphragm under the influence of the polarizing voltage alone, for if there is a non-linear force already in action the signal can only add to it.



$$F = \frac{\kappa AV^2}{2d^2} - \frac{\kappa AV^2}{2d^2} = 0$$

(1) Conducting diaphragm, mid position, directly connected

Some useful basic electrostatic formulæ are given in the accompanying panel, and if we apply them to the four diagrams we should be able to see why some electrostatic loudspeakers distort and others do not. The formulæ assume the use of rationalized MKS units and that κ=total permittivity of the space between electrodes, A=area of electrodes,



$$F = \frac{\kappa AV^2}{2(d-x)^2} - \frac{\kappa AV^2}{2(d+x)^2} = \frac{2\kappa AV^2dx}{(d^2-x^2)^2}$$

$$Q_1 = \frac{\kappa AV}{(d-x)} \qquad Q_2 = \frac{\kappa AV}{(d+x)}$$

(2) Conducting diaphragm, directly connected and displaced from mid position

C=capacitance, Q=charge, V=voltage and F=force. The thickness of the central diaphragm has been exaggerated so that the existence of conductivity between the two surfaces can be shown by horizontal shading.

Diagram (1) represents a diaphragm exactly centred between the fixed plates with a polarizing voltage V, which will be the same on both sides, since the diaphragm is a conductor. The capacitance on both sides is the same, so the charges will also be equal. While the diaphragm remains central it will experience no resultant force.

In diagram (2) the diaphragm has been displaced a distance x. Both faces are still at the same potential, but the capacitances on each side are unequal and there must be a redistribution of charge. There

[1] A. A. Janszen, *Journal Acoustical Engineering Society*, Vol. 3, No. 2, April, 1955.
[2] P. J. Walker, *Wireless World*, May, June, August, 1955.
[3] H. J. Leak, *The Gramophone*, May, 1955.
[4] *Wireless World*, 12th September, 1928, p. 309 and 29th May, 1929, p. 553.
[5] *Wireless Engineer*, May, 1955, p. 119.