

Specification for

Measurement microphones —

Part 2: Primary method for pressure calibration of laboratory standard microphones by the reciprocity technique

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National foreword

This British Standard has been prepared under the direction of the Electronic Equipment Standards Policy Committee and is the English language version of EN 61094-2:1993 *Measurement microphones — Part 2: Primary method for pressure calibration of laboratory standard microphones by the reciprocity technique*, published by the European Committee for Electrotechnical Standardization (CENELEC). It is identical with IEC 1094-2:1992 published by the International Electrotechnical Commission (IEC).

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 28, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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English version

Measurement microphones
Part 2: Primary method for pressure calibration of
laboratory standard microphones by the reciprocity
technique

(IEC 1094-2:1992)

Microphones de mesure
Partie 2: Méthode primaire pour l'étalonnage
en pression des microphones étalons de
laboratoire par la méthode de réciprocité
(CEI 1094-2:1992)

Meßmikrofone
Teil 2: Primärverfahren zur
Druckkammer-Kalibrierung von
Laboratorium-Normalmikrofonen nach der
Reziprozitätsmethode
(IEC 1094-2:1992)

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The CENELEC questionnaire procedure, performed for finding out whether or not the International Standard IEC 1094-2:1992 could be accepted without textual changes, has shown that no common modifications were necessary for acceptance as a European Standard.

The reference document was submitted to the CENELEC members for formal vote and was approved by CENELEC as EN 61094-2 on 22 September 1993.

The following dates were fixed:

- latest date of publication of an identical national standard (dop) 1994-09-01
- latest date of withdrawal of conflicting national standards (dow) 1994-09-01

Annexes designated “normative” are part of the body of the standard. Annexes designated “informative” are given only for information. In this standard, Annex A, Annex B and Annex ZA are normative and Annex C, Annex D, Annex E and Annex F are informative.

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1 Scope

This part of IEC 1094

- is applicable to laboratory standard microphones meeting the requirements of IEC 1094-1 and other types of condenser microphones having the same mechanical dimensions;
- specifies a primary method of determining the pressure sensitivity so as to establish a reproducible and accurate basis for the measurement of sound pressure.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 1094. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 1094 are encouraged to investigate the possibility of applying the most recent editions of the normative documents listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 27:1972, *Letter symbols to be used in electrical technology — Part 2: Telecommunications and electronics*.

IEC 1094-1:1991, *Measurement microphones — Part 1: Specifications for laboratory standard microphones*.

3 Definitions

For the purpose of this part of IEC 1094, the following definitions apply in addition to the definitions given in IEC 1094-1.

3.1

reciprocal microphone

a linear passive microphone for which the open-circuit reverse and forward transfer impedances (see 206 in IEC 27-2) are equal in magnitude

3.2

phase angle of pressure sensitivity of a microphone

for a given frequency, the phase angle between the open-circuit voltage and the uniform sound pressure acting on the diaphragm

unit: degree or radian ($^{\circ}$ or rad)

3.3

electrical transfer impedance

for a system of two acoustically coupled microphones the quotient of the open-circuit voltage of the microphone used as a receiver by the input current through the electrical terminals of the microphone used as a transmitter

unit: ohm (Ω)

NOTE This impedance is defined for the ground-shield configuration given in 7.2 of IEC 1094-1.

3.4

acoustic transfer impedance

for a system of two acoustically coupled microphones the quotient of the sound pressure acting on the diaphragm of the microphone used as a receiver by the short-circuit volume velocity produced by the microphone used as a transmitter

unit: pascal second per cubic metre (Pa s/m^3)

3.5

coupler

a device which, when fitted with microphones, forms a cavity of predetermined shape and dimensions acting as an acoustic coupling element between the microphones

4 Reference environmental conditions

The reference environmental conditions are:

Temperature:	t_r	= 23,0 °C
Static pressure:	$P_{s,r}$	= 101,325 kPa
Relative humidity:	H_r	= 50 %

NOTE The reference temperature is chosen to be 23,0 °C because practical considerations require that most calibrations be carried out at, or near, this temperature.

5 Principles of pressure calibration by reciprocity

5.1 General principle

A reciprocity calibration of microphones may be carried out by means of three microphones, two of which shall be reciprocal, or by means of an auxiliary sound source and two microphones, one of which must be reciprocal.

NOTE If one of the microphones is not reciprocal it can only be used as a sound receiver.

5.1.1 General principles using three microphones

Let two of the microphones be connected acoustically by a coupler. Using one of them as a sound source and the other as a sound receiver, the electrical transfer impedance is measured. When the acoustic transfer impedance of the system is known, the product of the pressure sensitivities of the two coupled microphones can be determined. Using pair-wise combinations of microphones (1), (2) and (3), three such mutually independent products are available, from which an expression for the pressure sensitivity of each of the three microphones can be derived.

5.1.2 General principles using two microphones and an auxiliary sound source

First, let the two microphones be connected acoustically by a coupler, and the product of the pressure sensitivities of the two microphones be determined, see 5.1.1. Next, let the two microphones be presented to the same sound pressure, set up by the auxiliary sound source. The ratio of the two output voltages will then equal the ratio of the two pressure sensitivities. Thus, from the product and the ratio of the pressure sensitivities of the two microphones, an expression for the pressure sensitivity of each of the two microphones can be derived.

NOTE In order to obtain the ratio of pressure sensitivities, a direct comparison method may be used, and the auxiliary sound source may be a third microphone having mechanical or acoustical characteristics which differ from those of the microphones being calibrated.

5.2 Basic expressions

Laboratory standard microphones and similar microphones are considered reciprocal and thus the two-port equations of the microphones can be written as:

$$\begin{aligned} z_{11} i + z_{12} q &= U \\ z_{21} i + z_{22} q &= P \end{aligned} \quad (1)$$

where

P is the sound pressure, uniformly applied, at the acoustical terminals (diaphragm) of the microphone;

U is the signal voltage at the electrical terminals of the microphone;

q is the volume velocity through the acoustical terminals (diaphragm) of the microphone;

i is the current through the electrical terminals of the microphone;

$z_{11} = Z_e$ is the electrical impedance of the microphone when the diaphragm is blocked;

$z_{22} = Z_a$ is the acoustic impedance of the microphone when the electrical terminals are unloaded;

$z_{12} = z_{21} = \underline{M}_p Z_a$ is equal to the reverse and forward transfer impedances, $\underline{M}_p$ being the pressure sensitivity of the microphone.

Equations (1) may then be rewritten as:

$$\begin{aligned} Z_e i + \underline{M}_p Z_a q &= U \\ \underline{M}_p Z_a i + Z_a q &= P \end{aligned} \quad (1a)$$

which constitute the equations of reciprocity for the microphone.

Let microphones (1) and (2) with the pressure sensitivities $\underline{M}_{p,1}$ and $\underline{M}_{p,2}$ be connected acoustically by a coupler. From equations (1a) it is seen that a current $\underline{i}_1$ through the electrical terminals of microphone (1) will produce a short-circuit volume velocity ($\underline{p} = 0$ at the diaphragm) of $\underline{M}_{p,1} \underline{i}_1$ and thus a sound pressure $\underline{p}_2 = \underline{Z}_{a,12} \underline{M}_{p,1} \underline{i}_1$ at the acoustical terminals of microphone (2), where $\underline{Z}_{a,12}$ is the acoustic transfer impedance of the system.

The open-circuit voltage of microphone (2) will then be:

$$\underline{U}_2 = \underline{M}_{p,2} \underline{p}_2 = \underline{M}_{p,1} \underline{M}_{p,2} \underline{Z}_{a,12} \underline{i}_1$$

Thus the product of the pressure sensitivities is given by:

$$\underline{M}_{p,1} \underline{M}_{p,2} = \frac{1}{\underline{Z}_{a,12}} \frac{\underline{U}_2}{\underline{i}_1} \quad (2)$$

5.3 Insert voltage technique

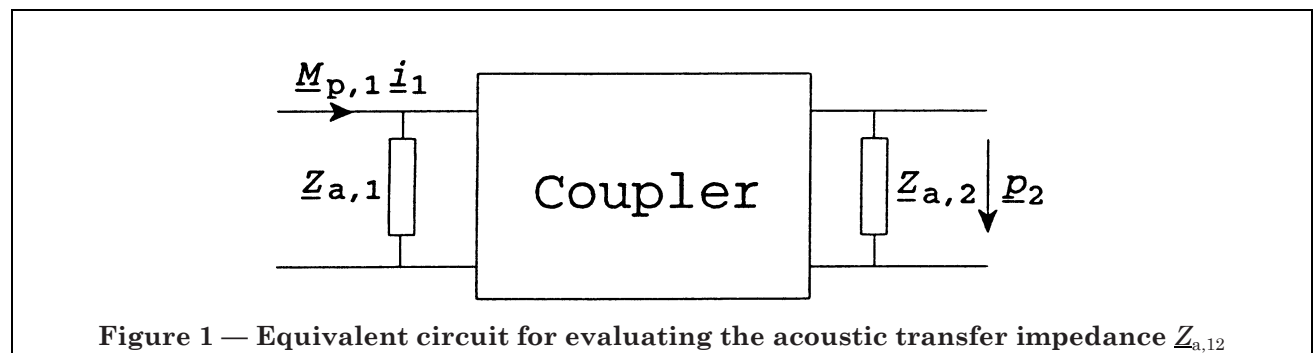
The insert voltage technique is used to determine the open-circuit voltage of a microphone when it is electrically loaded.

Let a microphone having a certain open-circuit voltage and internal impedance be connected to a load impedance. To measure the open-circuit voltage, an impedance, small compared to the load impedance, is connected in series to the microphone and a calibrating voltage applied across it.

Let a sound pressure and a calibrating voltage of the same frequency be applied alternately. When the calibrating voltage is adjusted until it gives the same voltage drop across the load impedance as results from the sound pressure on the microphone, the open-circuit voltage will be equal in magnitude to the calibrating voltage.

5.4 Evaluation of the acoustic transfer impedance

The acoustic transfer impedance $\underline{Z}_{a,12} = \underline{p}_2 / (\underline{M}_{p,1} \underline{i}_1)$ can be evaluated from the equivalent circuit in Figure 1, where $\underline{Z}_{a,1}$ and $\underline{Z}_{a,2}$ are the acoustic impedances of microphones (1) and (2) respectively.



In several cases, $\underline{Z}_{a,12}$ can be evaluated theoretically. Assume the sound pressure to be the same at any point inside the coupler (this will take place when the physical dimensions of the coupler are very small compared to the wavelength). The gas in the coupler then behaves as a pure compliance and, from the equivalent circuit in Figure 2, $\underline{Z}_{a,12}$ is given by $\underline{Z}_{a,12}$ (assuming adiabatic compression and expansion of the gas):

$$\frac{1}{\underline{Z}'_{a,12}} = \frac{1}{\underline{Z}_{a,V}} + \frac{1}{\underline{Z}_{a,1}} + \frac{1}{\underline{Z}_{a,2}} = j\omega \left(\frac{V}{\kappa p_s} + \frac{V_{e,1}}{\kappa_t p_{s,r}} + \frac{V_{e,2}}{\kappa_t p_{s,r}} \right) \quad (3)$$

where

V is the total geometrical volume of the coupler, m^3 ;

$V_{e,1}$ is the equivalent volume of microphone (1), m^3 ;

$V_{e,2}$ is the equivalent volume of microphone (2), m^3 ;

$\underline{Z}_{a,V} = \frac{\kappa p_s}{j\omega V}$ is the acoustic impedance of the gas enclosed in the coupler, Pa s/m^3 ;