IEC 61094-5

Edition 2.0 2016-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Electroacoustics – Measurement microphones –
Part 5: Methods for pressure calibration of working standard microphones by comparison

Électroacoustique – Microphones de mesure –
Partie 5: Méthodes pour l'étalonnage en pression par comparaison des microphones étalons de travail

IEC 61094-5:2016-05(en-fr)

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CONTENTS

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ELECTROACOUSTICS – MEASUREMENT MICROPHONES –

Part 5: Methods for pressure calibration of working standard microphones by comparison

FOREWORD

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International Standard IEC 61094-5 has been prepared by IEC technical committee 29: Electroacoustics.

This edition cancels and replaces the first edition published in 2001. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) details of additional components of uncertainty;
b) revised corrections for type WS3 microphones;
c) provision for the calibration of microphones in driven shield configuration.

The text of this standard is based on the following documents:

CDV	Report on voting
29/870/CDV	29/887A/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61904 series, published under the general title *Measurement microphones*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

ELECTROACOUSTICS – MEASUREMENT MICROPHONES –

Part 5: Methods for pressure calibration of working standard microphones by comparison

1 Scope

This part of IEC 61094-5 is applicable to working standard microphones with removable protection grids meeting the requirements of IEC 61094-4 and to laboratory standard microphones meeting the requirements of IEC 61094-1.

This part of IEC 61094 describes methods of determining the pressure sensitivity by comparison with either a laboratory standard microphone or another working standard microphone with known sensitivity in the respective frequency range.

Alternative comparison methods based on the principles described in IEC 61094-2 are possible but beyond the scope of this part of IEC 61094.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61094-1, *Measurement microphones – Part 1: Specifications for laboratory standard microphones*

IEC 61094-4, *Measurement microphones – Part 4: Specifications for working standard microphones*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61094-1 and the following apply.

3.1
reference microphone
laboratory standard microphone or working standard microphone with known pressure sensitivity

3.2
test microphone
laboratory standard microphone or working standard microphone to be calibrated by comparison with a reference microphone

3.3
monitor microphone
microphone used to measure changes in sound pressure

3.4
coupler
device which, when fitted with microphones, forms a cavity of predetermined shape and dimensions and provides an acoustic coupling element between the microphones and between the microphones and the sound source

3.5
jig
device which, when fitted with microphones, holds them with their diaphragms face to face separated by a small distance but does not enclose the space between them

4 Reference environmental conditions

The reference environmental conditions are:

- temperature 23,0 °C
- static pressure 101,325 kPa
- relative humidity 50 %

5 Principles of pressure calibration by comparison

5.1 Principles

5.1.1 General principle

The pressure sensitivity of a measurement microphone is defined in terms of a sound pressure applied uniformly over the diaphragm. Consequently, the pressure sensitivity can only be realised in principle for microphones from which the protection grid can be removed and the diaphragm exposed to the sound pressure stimulus.

The principle of these comparison methods is that when the reference microphone and the test microphone are exposed to the same sound pressure either simultaneously or sequentially, the ratio of their pressure sensitivities is given by the ratio of their open-circuit output voltages. The sensitivity (both modulus and phase) of the test microphone can then be calculated from the sensitivity of the reference microphone.

The principle of the method allows the test microphone to be attached to a particular preamplifier and the sensitivity of the system may be referred to the output of that preamplifier.

Multi-frequency measurements can be performed particularly rapidly if a wideband sound source is used and the output voltages of the microphones are analysed in narrow bands.

NOTE If the reference and test microphones have significantly different frequency response characteristics, e.g. around resonance frequencies, or when a pressure response microphone is compared with a free-field response microphone, this approach can lead to errors when the intention is to determine the pressure sensitivity at the test frequency, rather than the test frequency band. Due consideration of the analysis bandwidth is advised to avoid such errors. Typically, a bandwidth of 1/6th-octave or narrower will be sufficient to constrain any error to less than 0,01 dB. However further caution is advised on reducing the bandwidth too severely, as can be possible with FFT (fast Fourier transform) analysers, as this can highlight deficiencies such as standing waves in the sound field, which can also lead to errors (see [1][1] for further details).

5.1.2 General principles using simultaneous excitation

In order for the two microphones to be simultaneously exposed to essentially the same sound pressure it is usually necessary for the front surfaces of the two microphones to be separated

[1] Numbers in brackets refer to the bibliography.

by a small fraction of the wavelength at the highest frequency of interest. For frequencies up to 20 kHz, this can be achieved by mounting the two microphones face-to-face separated by approximately 1 mm in either a coupler or a jig.

The optimum microphone separation is somewhat dependent on the acoustic environment and should be determined for a particular set-up. Details of likely levels of performance can be found in [1][1]

Couplers usually contain an integral sound source; jig mounted microphones are usually exposed to an externally produced sound field. In order to reduce the effect of systematic differences in sound pressure between the two microphone positions, for example caused by some asymmetries, the following procedure shall be used: after the ratio of the microphone pressure sensitivities is first determined, the microphones shall be interchanged, and the measurement repeated. The sensitivity is then calculated from the mean of the two ratios. Examples of practical arrangements and precautions to be taken are given in Annex A.

NOTE Avoiding asymmetry and standing waves in the sound field, especially in jig configurations, has a significant beneficial impact on the reliability of the results.

5.1.3 General principles using sequential excitation

In order for the two microphones to be sequentially exposed to essentially the same sound pressure, either the exchange of microphones shall not change the sound pressure significantly or any significant change shall be detected and corrected. This can be achieved by incorporating a sound source, a monitor microphone, and the test/reference microphone in a coupler. In any design of coupler, the monitor microphone shall accurately sense changes in the sound pressure at the test/reference microphone position. Examples of practical arrangements are given in Annex B.

5.2 Measuring the output voltages of the microphones

The output of a test or reference microphone may be determined as the open-circuit voltage by use of the insert voltage technique (see 5.3 of IEC 61094-2:2009) or by using a measuring system consisting of a high input impedance microphone preamplifier and a voltmeter (see Annex C).

The method used to measure the output voltage of the test microphone shall be stated on any calibration certificate.

6 Factors influencing the pressure sensitivity

6.1 General

The pressure sensitivity of a measurement microphone can depend on environmental conditions. Further, the definition of the pressure sensitivity implies that certain requirements be fulfilled by the measurements. It is essential during a calibration that these conditions are controlled sufficiently well if the resulting uncertainty components are to remain small.

6.2 Microphone pressure equalization mechanism

The normal construction of a measurement microphone has the cavity behind the diaphragm fitted with a narrow pressure-equalizing tube to permit the static pressure to be the same on both sides of the diaphragm. Consequently, at very low frequencies, this tube also partially equalizes the sound pressure. If, during the calibration, the sound which is coherent with that on the diaphragm is incident on the pressure-equalizing tube, then this could change the apparent sensitivity at low frequencies and the result would not be the true pressure sensitivity.

In a jig, where sound is incident on the pressure equalizing tube, the size of this change shall be determined by comparing calibrations made in the jig with calibrations made in a coupler that does not expose the pressure equalizing tube to the sound field.

In a coupler an "O" ring can be used to seal the gap between the coupler and the microphone. If this is done, care shall be taken to ensure that the "O" ring does not exert undue force on the microphone and cause a change in sensitivity.

6.3 Polarising voltage

If the test microphone requires an external polarising voltage, then the polarising voltage used during the calibration shall be reported.

If the reference microphone requires an external polarising voltage, then any difference between that applied when it was calibrated and that applied when it is used as the reference microphone shall be allowed for in the uncertainty calculations (see Annex D).

6.4 Reference shield configuration

When the open-circuit voltage is measured, the shield configurations given in IEC 61094-1 or IEC 61094-4 shall be used.

If a microphone is intended to be used with a preamplifier having a non-standard shield configuration, then it shall be calibrated as a system along with its preamplifier.

When insert voltage calibrations are performed, it shall be stated whether output voltage from the microphone is applied to the shield (driven shield configuration), or whether the shield is grounded.

If the instruction manual specifies a maximum mechanical force to be applied to the central electrical contact of the microphone, this limit shall not be exceeded.

6.5 Pressure distribution over the diaphragms

The definition of the pressure sensitivity assumes that the sound pressure over the diaphragm is applied uniformly. The output voltage of a microphone presented with a non-uniform pressure distribution over the surface of the diaphragm will differ from the output voltage of the microphone when presented with a uniform pressure distribution having the same mean value, because the microphone is usually more sensitive to a sound pressure at the centre of the diaphragm.

Uniformity of sound pressure over the diaphragm of the microphone can be optimised by maintaining the radial symmetry of the sound field around the circumferences of the microphones. This can be achieved using a radially symmetric sound source positioned coaxially with the microphones and, when the microphones are mounted in a jig, with the microphones positioned in the far field of the sound source. Although pressure non-uniformity over the surface of the diaphragm can be minimised by using a radially symmetric sound source, some non-uniformity at high frequencies can remain even with a perfect source.

It is difficult to control the uniformity of the sound field in an actual calibration set-up. However, the combined effect of asymmetries in the sound field and in the microphones becomes evident when the microphones are rotated relative to each other about their axis of symmetry. Thus, the related component of measurement uncertainty can be reduced by averaging results from a number of such measurement configurations.

NOTE When comparing microphones of the same model, the requirement for uniformity of the sound field reduces to a requirement of rotational symmetry of the sound field.

Alternatively, issues with sound field non-uniformity can be overcome if excitation is made with a diffuse sound field, for example in a reverberation room. Care should be taken to avoid creating standing waves in the sound field surrounding the microphones as these can cause significant and unpredictable measurement errors. A broadband source, or repeated measurements at different positions within the field, is also necessary to achieve a sufficiently low measurement uncertainty.

The effect of a non-uniform pressure distribution over the surface of the diaphragm will be significantly greater if the test and reference microphones are of different diameters. A theoretical model which can be used to apply corrections and assess the uncertainties in this case is given in the literature (for example [1]).

6.6 Dependence on environmental conditions

The sensitivity of a microphone can depend on static pressure, temperature or humidity. This dependence can be determined by comparison with a well characterised laboratory standard microphone over a range of conditions.

If the reference microphone and the test microphone are different manufacturer models, then the sensitivity of the reference microphone shall be corrected to the actual environmental conditions during the test. Alternatively, if they are of the same model, there can be an advantage in assuming that they have the same dependence on environmental conditions so that the calibration of the test microphone can be referred to the conditions at which the calibration of the reference microphone is valid.

Alternatively, when reporting the results of a calibration, the pressure sensitivity can be corrected to the reference environmental conditions if reliable correction data are available.

The actual conditions during the calibration shall be reported.

6.7 Validation

Calibrations performed in any particular jig or coupler shall be validated by comparison with calibrations performed in other jigs and couplers and alternative sound sources. A separate validation is necessary for each different type of microphone. If the test microphone is a laboratory standard microphone, then the jig or coupler can be validated by comparing a comparison calibration with a reciprocity calibration. For some microphones, it can be necessary to use more than one jig and/or coupler to cover a full frequency range with low uncertainty.

7 Calibration uncertainty components

7.1 General

In addition to the factors influencing the pressure sensitivity mentioned in Clause 6, further uncertainty components are introduced by the method, the equipment and the degree of care under which the calibration is carried out. Factors which affect the calibration in a known way should be measured or calculated with an accuracy necessary to achieve the desired overall measurement uncertainty, and with as high an accuracy as practicable if their influence is to be minimised.

7.2 Sensitivity of the reference microphone

The uncertainty in the sensitivity of the reference microphone directly affects the uncertainty in the sensitivity of the test microphone.

7.3 Measurements of microphone output

Uncertainties of random or time-varying nature in the measurement of the outputs of the microphones directly affect the uncertainty in the sensitivity of the test microphone.

Uncertainties of systematic nature in the measurement of the outputs of the microphones can affect the uncertainty in the sensitivity of the test microphone. The uncertainty can be reduced if the same system is used for both the test and reference microphones.

If test and reference microphone are measured simultaneously, systematic uncertainty can be reduced using the procedure described in Annex C.

7.4 Differences between the sound pressure at the test microphone and that at the reference microphone

With simultaneous or sequential excitation, differences in the acoustic impedance between the test and reference microphones can cause the sound pressure at the test and reference microphones to differ. A theoretical model which may be used to assess the resulting uncertainty can be found in the literature (for example [2]).

7.5 Acoustic impedances of the microphones

When the reference microphone and the test microphone have significantly different acoustic impedances (for example, pressure and free-field response microphones at frequencies above 10 kHz), they can respond differently to the same sound field because of differing volume velocities at the diaphragms. It is recommended that wherever possible a reference microphone of similar acoustic impedance to that of the test microphone be used. If no suitable reference microphone is available, the size of the error caused should be estimated and added to the uncertainty budget.

7.6 Microphone separation distance

The ideal microphone separation distance used in simultaneous excitation measurements should be established for each acoustic environment in which jig measurements are to be carried out. The distance can be determined by making a series of measurements at different separations and comparing the results with a primary pressure calibration for the same microphone. Measurements made in some sound fields can be very sensitive to very small changes in microphone separation distance and microphone position relative to the sound field. In these cases it is preferable to improve the sound field rather than the positioning system because a very reproducible positioning system can introduce repeatable systematic errors that are not easily detected.

7.7 Microphone capacitance

In some calibration methods (for example the approach outlined in Annex C), the gain of the microphone preamplifier(s) used is assumed to be constant when fitted with different microphones. However the gain of the preamplifier is typically a function of the attached microphone capacitance.

Therefore a correction should be made or a component of uncertainty allowed if the capacitances of the reference microphone and test microphone are sufficiently different for the influence on the preamplifier gain to be significant.

NOTE This effect is avoided if the insert voltage technique is used.

7.8 Microphone configuration during calibration

It may be necessary to fit a microphone with one or more adapters suiting a particular calibration coupler or configuration. Such adapters may have an influence on the sensitivity of the microphone, and this shall be included as an uncertainty component.