IEC 61094-8

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INTERNATIONAL STANDARD

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colour inside

Measurement microphones –
Part 8: Methods for determining the free-field sensitivity of working standard microphones by comparison

Microphones de mesure –
Partie 8: Méthodes pour la détermination de l'efficacité en champ libre par comparaison des microphones étalons de travail

IEC 61094-8:2012

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MEASUREMENT MICROPHONES –

Part 8: Methods for determining the free-field sensitivity of working standard microphones by comparison

FOREWORD

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

CDV	Report on voting
29/752/CDV	29/759/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 the parts in the IEC 61094 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 web site 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- withdrawn,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
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MEASUREMENT MICROPHONES –

Part 8: Methods for determining the free-field sensitivity of working standard microphones by comparison

1 Scope

This part of the IEC 61094 series is applicable to working standard microphones meeting the requirements of IEC 61094-4. It describes methods of determining the free-field sensitivity by comparison with a laboratory standard microphone or working standard microphone (where applicable) that has been calibrated according to either:

– IEC 61094-3,
– IEC 61094-2 or IEC 61094-5, and where factors given in IEC/TS 61094-7 have been applied,
– IEC 61094-6,
– this part of IEC 61094.

Methods performed in an acoustical environment that is a good approximation to an ideal free-field (e.g. a high quality free-field chamber), and methods that use post processing of results to minimise the effect of imperfections in the acoustical environment, to simulate free-field conditions, are both covered by this part of IEC 61094. Comparison methods based on the principles described in IEC 61094-3 are also possible but beyond the scope of this part of IEC 61094.

NOTE 1 This part of IEC 61094 is also applicable to laboratory standard microphones meeting the requirements of IEC 61094-1, noting that these microphones also meet the electroacoustic specifications for working standard microphones.

NOTE 2 This part of IEC 61094 is also applicable to combinations of microphone and preamplifier where the determined sensitivity is referred to the unloaded output voltage of the preamplifier.

NOTE 3 Other devices, for example, sound level meters can be calibrated using the principles of this part of IEC 61094, but are not within the scope of this standard.

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 61094-2, *Electroacoustics – Measurement microphones – Part 2: Primary method for pressure calibration of laboratory standard microphones by the reciprocity technique*

IEC 61094-3, *Measurement microphones – Part 3: Primary method for free-field calibration of laboratory standard microphones by the reciprocity technique*

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

IEC 61094-5, *Measurement microphones – Part 5: Methods for pressure calibration of working standard microphones by comparison*

IEC 61094-6, *Measurement microphones – Part 6: Electrostatic actuators for determination of frequency response*

IEC/TS 61094-7, *Measurement microphones – Part 7: Values for the difference between free-field and pressure sensitivity levels of laboratory standard microphones*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO 26101, *Acoustics – Test methods for the qualification of free-field environments*

3 Terms and definitions

For the purpose of this document, the terms and definitions given in IEC 61094-1 and IEC 61094-3, as well as the following apply.

3.1
reference microphone
laboratory standard microphone or working standard microphone where the free-field sensitivity has been previously determined

3.2
microphone under test
device under test
working standard microphone to be calibrated by comparison with a reference microphone

Note 1 to entry: Other devices, for example, sound level meters, can be calibrated using the principles of this part of IEC 61094, but are not within the scope of this standard.

3.3
monitor microphone
microphone used to detect changes in sound pressure in the test environment

3.4
microphone reference point
point specified on the microphone or close to it, to describe the position of the microphone

Note 1 to entry: The microphone reference point may be at the centre of the diaphragm of the microphone.

3.5
reference direction
inward direction toward the microphone reference point and specified for determining the acoustical response and directional response

Note 1 to entry: The reference direction may be specified with respect to an axis of symmetry.

3.6
angle of incidence
angle between the reference direction and a line between the acoustic centre of a sound source and the microphone reference point

Note 1 to entry: Angle of incidence is expressed in degrees.

4 Reference environmental conditions

The reference environmental conditions are:

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

5 Principles of free-field calibration by comparison

5.1 General principle

When a calibrated reference microphone and a microphone under test are exposed to the same free-field sound pressure, either simultaneously or sequentially, and under the same environmental conditions, then the ratio of their free-field sensitivities for those conditions is given by the ratio of their open-circuit output voltages. Then, both the modulus and phase of the free-field sensitivity of the microphone under test can be calculated from the known free-field sensitivity of the reference microphone. However, determination of the phase of the free-field sensitivity requires the definition of consistent reference phases at the acoustic centres of the microphones.

At some frequencies, the measured free-field sensitivity of a microphone is strongly dependent on the mounting configuration and results for the microphone cannot be considered in isolation to the mounting configuration used (see 6.7).

The principle of the method also allows the microphone under test to be attached to measuring equipment, e.g. a particular preamplifier, and the sensitivity may be referred to the unloaded output of that measuring equipment.

5.2 General principles using sequential excitation

In order for the two microphones to be sequentially exposed to essentially the same sound pressure, the output of the sound source and the environment conditions should not change. Where there is potential for changes in the sound field, this shall be detected and corrected for, for example by using a monitor microphone. Examples of practical arrangements are given in Annex A.

NOTE In principle it is possible to substitute a number of microphones under test sequentially into the sound field once the reference sound field has been established, but this places greater demands on the stability and spatial uniformity of the sound source and can increase the measurement uncertainty.

5.3 General principles using simultaneous excitation

Simultaneous exposure of the reference and one or more microphones under test to the sound field overcomes the issue of the sound field changing with time, but requires identification of different points in the sound field where the sound pressures are the same. This may be achieved by configuring the test space and sound source to ensure a symmetrical sound field. If the effects of perturbations in the sound source are to be eliminated, it is essential that the output voltages from the microphone under test and the reference microphone be measured simultaneously when determining the open-circuit output voltage ratio.

In simultaneous comparison calibration, it is important that the presence of the reference microphone does not disturb the field incident on the microphone under test, and vice versa.

The requirement for the source to provide two or more points in the sound field where the sound pressure is expected to be the same, places severe demands on the stability of the source's directional characteristics. It may only be possible to achieve this by relaxing uncertainty requirements or by developing a source especially for this purpose.

6 General requirements

6.1 The test space

The test space shall be as free as possible of any effects that cause instabilities in the sound field, for example between measurements with the microphone under test and the reference microphone. These include changing environment conditions, air flows, thermal gradients and electro-magnetic disturbances.

The test space shall have a level of background noise and vibration that enables the measurements to meet the signal-to-noise requirements of the measurement system used. In practice steps should be taken to reduce the background noise as much as possible.

NOTE Heat sources in the test space can lead to some of the types of disturbance described above.

6.2 Methods of establishing the free-field

6.2.1 General

There are two general approaches that can be taken in making free-field measurements. The first is to create an environment that attempts to establish a free field by using a test space with sound absorbing surfaces to prevent reflections of the sound coming directly from the source. The second is to use signal processing methods that enable the removal of signal content corresponding to indirectly received sound, thus simulating a free-field environment. There are many ways to implement both of these approaches. They can also be used in combination for the most demanding measurements.

6.2.2 Using a test space with sound absorbing surfaces

Options for realising a true free-field environment range from free-field rooms (also known as anechoic chambers) to smaller scale enclosures and test boxes.

A free-field room typically has its surfaces covered with sound absorbing material, configured to present a gradually changing acoustic impedance to an incident sound wave. Often this is in the form of wedges that protrude into the room, though other configurations can be used. The depth of this absorbent layer, as well as its shape and design, determines the lowest frequency where sound absorption is effective. A hemi-anechoic room, where one of the room surfaces is formed by a reflecting plane, can also be used. In this case the sound source should be mounted flush with the reflecting surface, so that the surface acts as an ‘infinite’ baffle. Secondary sound radiation, from the edges of the sound source or its mounting, are thus avoided.

NOTE 1 Although edge diffraction from the sound source is eliminated, diffraction from the boundaries of the reflecting plane will still be present.

The room shall have an identified region where the sound field can be assumed to contain only plane progressive wave emanating from sound source (i.e. approximates a free sound field). The sound source and measurement positions shall be located within this region.

For low frequencies long wedges with very high sound absorption are required, leading to the need for a very large room to enable measurements to be made at a sufficient distance from the wedge tip. Free-field calibration using a room with sound absorbing surface therefore becomes impractical and an alternative method may be needed.

One approach is to mount the microphone, complete with its pressure equalisation vent mechanism, inside a small enclosure, within which a low frequency sound pressure can be generated. Although there is no acoustic propagation, the sensitivity determined in such a field will nevertheless be a good approximation to the free-field sensitivity, because diffraction effects are minimal when the sound wavelength is significantly greater than the dimensions of the microphone.

NOTE 2 For WS1 microphones at reference environmental conditions, diffraction effects will contribute less than 0,1 dB to the free-field sensitivity level below 500 Hz. For WS2 and WS3 microphones the contribution will be even smaller.

NOTE 3 By using alternative techniques at low frequency, a practical low frequency limit for a free-field room of around 500 Hz will suffice.

NOTE 4 Even an alternative calibration method for low frequency will be limited to frequencies above the low frequency limit of the test or reference microphone, or by the ability to calibrate the reference microphone at low frequencies.

Free-field calibration can also be carried out in smaller scale test boxes. However their limited dimensions and depth of absorbent lining will restrict the frequency range over which they will be effective and their overall performance.

When the measurement method used assumes that a free field exists, the performance of the room shall be quantified in this respect. A method is described in ISO 26101.

6.2.3 Time selective methods for obtaining the free-field sensitivity

The use of time selective methods provides a possibility to measure the free-field sensitivity of a microphone in conditions that might otherwise be unsuitable for direct free-field calibration. With a suitable test arrangement it can be possible to distinguish between the component of the output signal resulting from the directly received acoustic wave and that received indirectly, as a result of reflection. Reflected sound travels a longer path to reach the microphone and therefore takes a greater time to do so. If the direct wave propagation and any settling effects within the microphone occur before the arrival of the first reflection, some form of time-selective technique or time gating can be used to consider the response to the direct sound only, thus simulating what would occur in an ideal free field.

NOTE Methods based on this approach for establishing the free-field response are sometimes referred to as quasi-free-field techniques.

Time selective techniques often have their own low frequency limitations, which need to be considered along with test space limitations noted above.

A variety of time-selective techniques have been developed and examples are described in Annex B.

6.3 The sound source

The sound source typically consists of a loudspeaker fitted in an enclosure or baffle. However alternative types of sound source may be deployed. Examples of sound sources can be found in Annex A.

NOTE 1 A reciprocal microphone may be driven electrically and used as a sound source.

The sound source shall be capable of generating plane progressive waves at the measurement position. In practice the sound source may not radiate plane waves, but at a sufficiently long distance from the source, wave fronts can be considered plane across the region occupied by the reference or microphone under test.

If the sound source is used for simultaneous calibration, the directivity pattern shall also be known to enable a suitable choice of measurement points to be determined. The directivity pattern shall be stable over the time period of a test.

If more than one measurement position is used, it may be desirable to use a sound source having an omni-directional directivity pattern in the frequency range of use.

To fulfill the plane wave requirement along the length of the test object, measurements shall be made within the region where the field is purely progressive.

The further requirements listed below may have greater or lesser importance depending on the calibration method adopted.

The sound source shall be capable of generating sufficient sound pressure level at the test location(s) at all the frequencies of interest. Sound pressure levels typically between 70 dB and 80 dB are usually sufficient, but the chosen level will depend on the sensitivity of the microphones to be tested and the signal-to-noise ratio requirement of the measurement system. The sound source shall produce a stable output over the time period of a test.

The stability of a loudspeaker sound source should be monitored by some means during the course of a calibration. Options for monitoring the sound source include the use of an auxiliary monitor microphone and using the repeatability in results.

At higher output levels, the loudspeaker may exhibit instabilities. The stability of the sound source shall therefore be established for the type of test signal used. Use of the minimum electrical input signal that provides an adequate signal-to-noise ratio in the measurement setup is also recommended.

The sound source shall not produce distortion components that may generate a significant response from the microphone under test and/or reference microphone at frequencies other than the test frequency.

NOTE 2 The use of suitable band pass filters can reduce this effect with sinusoidal or narrow band test signals.

NOTE 3 Distortion can also be a problem for impulsive stimuli when high peak output levels are required.

The size of the sound source shall be small relative to the distance to the measurement position(s), so that sound radiated or diffracted from off-axis elements of the source or its mounting does not cause significant deviations from ideal free-field behaviour of a point source, as the measurement distance changes.

It may be necessary to use a number of sound sources each covering different parts of the frequency range.

6.4 Reference microphone

The reference microphone shall be a laboratory standard (LS) microphone or working standard (WS) microphone having a known free-field sensitivity and corresponding uncertainty at the desired range of calibration frequencies.

Table 1 shows the available calibration options and the typical measurement uncertainty for the free-field sensitivity, for the reference microphone types available.

Table 1 – Calibration options for the reference microphone and associated typical measurement uncertainty

Reference microphone type	Calibration method	Reference	Typical expanded uncertainty (k = 2) in dB	
			1 kHz	10 kHz
LS	Primary free-field calibration	IEC 61094-3	0,25	0,10
	Primary pressure calibration with the addition of a free-field to pressure sensitivity level difference	IEC 61094-2 and IEC/TS 61094-7	0,12	0,4
	Secondary pressure calibration with the addition of a free-field to pressure sensitivity level difference	IEC 61094-5 and IEC/TS 61094-7	0,15	0,5
LS and WS	Secondary free-field calibration	This part of IEC 61094	0,2	0,5
	Electrostatic actuator calibration with the addition of a free-field to actuator response level difference	IEC 61094-6	0,3	0,6

Where possible the reference microphone configuration should be chosen to match that of the microphone under test.

An LS1P reference microphone shall be used without protection grid (where available). Working standard microphones may be used with or without protection grid, noting that removal of the protection grid is likely to yield the lowest uncertainty. If a protection grid is used, the reference free-field sensitivity or quoted uncertainty shall allow for this.

6.5 Monitor microphone

A monitor microphone shall be used to detect changes in the sound field, if required to achieve the desired level of measurement uncertainty.

The monitor microphone shall be permanently located in a sound field close to the sound source.

The monitor microphone shall not perturb the sound field reaching the microphone being measured. This usually requires the use of a small microphone (for example a WS3 microphone), to avoid diffraction effect that could distort plane wave propagation.

It shall therefore be validated that the choice of monitor microphone and its location do not influence the results unduly, and that any influence is accounted for in the measurement uncertainty.

6.6 Test signals

The test signal will be determined largely by details of the application and calibration method. In particular signal processing methods may require specific types of signal to be used. The source characteristics and mode of operation can also affect the choice of test signal.

Test signals can include:

– pure tone,
– swept-sine or stepped-sine,
– wide-band white noise or pink noise,
– narrow-band noise (e.g. third-octave-band noise),
– pseudo-random or periodic noise (e.g. maximum length sequences),
– warble tones (e.g. frequency modulated (FM) tones),

– tone bursts or noise bursts,
– chirps,
– impulses (e.g. clicks, sparks etc.).

NOTE The test signal used can also place particular requirements on sound source, such as frequency response or dynamic range.

6.7 Configuration for the reference microphone and microphone under test

The microphone shall be mounted on a semi-infinite cylindrical rod having the same diameter as the body of the microphone. Any deviation from this configuration, including guide wires or other hardware used to support the mounting rod, may influence the free-field sensitivity of the microphone, and any such effects shall be allowed for in the measurement uncertainty. Alternatively if the free-field sensitivity of the microphone under test is to be determined in a specific mounting configuration, then this configuration shall be used to mount the microphone under test during calibration.

The preamplifier shall be integrated with the mounting rod and shall provide the reference ground-shield mechanical configuration appropriate for the type of microphone being tested, as specified in IEC 61094-1 or IEC 61094-4.

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

The requirement to use the reference ground-shield configuration does not apply to combinations of microphone and preamplifier used as an integral system.

If adapters are used to convert a preamplifier for use with different sized microphones, the adapter used shall also convert the ground-shield configuration accordingly.

7 Factors influencing the free-field sensitivity

7.1 General

The free-field sensitivity of a measurement microphone depends on the operational and environmental conditions, as well as the geometrical configuration used in the calibration, hence the need to specify these parameters in defining the sensitivity. In addition it is necessary to ensure that these parameters are sufficiently controlled in the calibration process, so that the resulting uncertainty components can be taken into account in the uncertainty budget (see Table 2).

In addition, the calibration process itself adds further components of uncertainty that are not directly connected with the operation of the microphone. These are listed in Clause 8.

7.2 Polarizing voltage

If the microphone under test requires an external polarizing voltage, the manufacturer’s recommendations shall be followed. The actual polarizing voltage used during the calibration shall be stated, along with the reported free-field sensitivity.

If the microphone is pre-polarized, care shall be taken not to apply an external polarizing voltage.

7.3 Acoustic centre of the microphone

The definition of the free-field sensitivity of a microphone refers to the sound pressure at the acoustic centre of the microphone, before the microphone is introduced into the field. When comparing microphones their acoustic centres shall be positioned at the measurement points.