BS EN 62585:2012

BSI Standards Publication

Electroacoustics — Methods to determine corrections to obtain the free-field response of a sound level meter

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National foreword

This British Standard is the UK implementation of EN 62585:2012. It is identical to IEC 62585:2012.

The UK participation in its preparation was entrusted to Technical Committee EPL/29, Electroacoustics.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Published by BSI Standards Limited 2012

ISBN 978 0 580 65656 9

ICS 17.140.50

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 November 2012.

Amendments issued since publication

Amd. No.	Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 62585

October 2012

ICS 17.140.50

English version

Electroacoustics - Methods to determine corrections to obtain the free-field response of a sound level meter
(IEC 62585:2012)

Électroacoustique -
Méthode de détermination de corrections pour obtenir la réponse en champ libre d'un sonomètre
(CEI 62585:2012)

Elektroakustik -
Verfahren zur Ermittlung von Korrekturwerten für die Bestimmung des Freifeld-Frequenzgangs eines Schallpegelmessers
(IEC 62585:2012)

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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 text of document 29/770/FDIS, future edition 1 of IEC 62585, prepared by IEC/TC 29 "Electroacoustics" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62585:2012.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2013-05-29
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2015-08-29

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 62585:2012 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 61094-8	NOTE	Harmonised as EN 61094-8.
IEC 61260	NOTE	Harmonised as EN 61260.
IEC 61094-2	NOTE	Harmonised as EN 61094-2.
IEC 61094-3	NOTE	Harmonised as EN 61094-3.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60942	-	Electroacoustics - Sound calibrators	EN 60942	-
IEC 61094-1	-	Measurement microphones - Part 1: Specifications for laboratory standard microphones	EN 61094-1	-
IEC 61094-5	-	Measurement microphones - Part 5: Methods for pressure calibration of working standard microphones by comparison	EN 61094-5	-
IEC 61094-6	-	Measurement microphones - Part 6: Electrostatic actuators for determination of frequency response	EN 61094-6	-
IEC/TS 61094-7	-	Measurement microphones - Part 7: Values for the difference between free-field and pressure sensitivity levels of laboratory standard microphones	-	-
IEC 61183	-	Electroacoustics - Random-incidence and diffuse-field calibration of sound level meters	EN 61183	-
IEC 61672-1	-	Electroacoustics - Sound level meters - Part 1: Specifications	EN 61672-1	-
IEC 61672-2	-	Electroacoustics - Sound level meters - Part 2: Pattern evaluation tests	EN 61672-2	-
IEC 61672-3	-	Electroacoustics - Sound level meters - Part 3: Periodic tests	EN 61672-3	-
ISO/IEC Guide 98-3	-	Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM)	-	-
ISO/IEC Guide 99	-	International vocabulary of metrology - Basic and general concepts and associated terms (VIM)	-	-

CONTENTS

INTRODUCTION

The performance specification International Standard for sound level meters, IEC 61672-1, requires that at least one model of sound calibrator, conforming to the requirements of IEC 60942 be specified in the instruction manual for checking and maintaining the correct indication on the display of the sound level meter at the calibration check frequency. The sound level meter manufacturer specifies the adjustment value to be applied to obtain the required indication on the display in response to the sound pressure level generated by the sound calibrator, in order to optimize performance over the complete frequency range.

In addition, various corrections need to be available over a range of frequencies in order for a periodic test of a sound level meter to be performed according to IEC 61672-3. For example, corrections are needed for any effects of the sound level meter case or of accessories such as windscreens on the equivalent free-field sound level. Information on these corrections is also required by users of sound level meters and sound calibrators on a regular basis.

Also, a manufacturer producing a sound level meter to the specifications of IEC 61672-1, may recommend, in the instruction manual, the use of a sound calibrator, comparison coupler or electrostatic actuator to determine the acoustical response of a sound level meter at various frequencies. In this case the manufacturer is required to provide corrections to obtain equivalent sound levels that would be displayed under reference environmental conditions in response to plane progressive sinusoidal waves that are incident from the reference direction at each frequency used for periodic testing. These corrections will either be given in the instruction manual, or the instruction manual will state where they can be found.

ELECTROACOUSTICS – METHODS TO DETERMINE CORRECTIONS TO OBTAIN THE FREE-FIELD RESPONSE OF A SOUND LEVEL METER

1 Scope

This International Standard provides information on the corrections required over a range of frequencies in order for a periodic test of a sound level meter to be performed according to IEC 61672-3. These corrections include:

- corrections for the typical effects of reflections from the case of the sound level meter and diffraction of sound around the microphone;
- corrections for the deviation of the typical microphone frequency response from a uniform frequency response, where the actual microphone response cannot be measured;
- corrections for the influence on the frequency response of a typical microphone of a specified windscreen and any other accessory that is part of the configuration for normal use of the particular sound level meter submitted for testing.

This International Standard includes discussion about uncertainties of measurement of the required corrections. In some instances a maximum permitted expanded uncertainty for the manufacturer or testing laboratory is given. This maximum permitted expanded uncertainty excludes any component due to the variability of different samples of artefact (for example, microphone or windscreen). It should be noted that if large uncertainties of measurement are quoted for each of the individual corrections, when they are combined to account for the configuration of sound level meter under test, the large individual uncertainties may result in a failure to conform to the maximum permitted expanded uncertainties of measurement given in Table A.1 of IEC 61672-1:—[1] and hence a failure of the sound level meter to conform to IEC 61672-1

In addition, this International Standard describes methods for determining these corrections, over the frequency range of interest, and explains the adjustment value at the calibration check frequency to be quoted by the manufacturer of the sound level meter (also required by IEC 61672-3).

When the sound level meter manufacturer recommends the use of a sound calibrator, comparison coupler, or an electrostatic actuator for periodic testing of the acoustical response of a sound level meter at various frequencies, this International Standard describes methods of measurement of the corrections required to adjust the indication on the sound level meter to an equivalent free-field level, over the frequency range of interest. These corrections relate to a specific model of sound calibrator, comparison coupler or electrostatic actuator, microphone and sound level meter (also required by IEC 61672-3).

The aim of this International Standard is to ensure that the adjustment value at the calibration check frequency and all corrections are determined using consistent and appropriate methods.

It is intended that this International Standard will be used by manufacturers to determine adjustment values and corrections, by laboratories performing pattern evaluation tests according to IEC 61672-2, and by laboratories performing periodic tests according to IEC 61672-3. Laboratories performing periodic tests according to IEC 61672-3 will also need to consult this International Standard to ensure that the expanded uncertainties of

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1 Second edition to be published. (A revision of 61672-1:2002.)

measurement for the corrections quoted by the manufacturer do not exceed the maximum permitted values.

The corrections obtained by use of the methods given in this International Standard are the result of measurements made using samples of the devices. It is possible that these corrections may not be totally representative either for all batches produced or over time. Repeating the measurements at regular intervals is recommended to ensure that no changes are required to the corrections stated in the instruction manual.

This International Standard does not specifically cover the case where the sound level meter is fitted with a microphone intended for use in random-incidence sound fields, as information is given in IEC 61183.

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 60942, *Electroacoustics – Sound calibrators*

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

IEC 61183, *Electroacoustics-Random-incidence and diffuse-field calibration of sound level meters*

IEC 61672-1: —[2], *Electroacoustics – Sound level meters – Part 1: Specifications*

IEC 61672-2, *Electroacoustics – Sound level meters – Part 2: Pattern evaluation tests*

IEC 61672-3, *Electroacoustics – Sound level meters – Part 3: Periodic tests*

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

ISO/IEC Guide 99, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the ISO/IEC Guide 99, as well as the following apply.

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2 Second edition to be published. (A revision of 61672-1:2002.)

3.1
adjustment value at the calibration check frequency
value, at the calibration check frequency, for adjusting the sensitivity of the sound level meter, as specified by the manufacturer to be added to the displayed value of the sound level meter to obtain the stated sound pressure level from the calibrator while the sound level meter is exposed to the sound pressure in the calibrator, in order to optimise performance of the sound level meter over the complete frequency range

Note 1 to entry: The adjustment value is expressed in decibels (dB).

3.2
microphone
microphone cartridge
electroacoustic transducer by which electrical signals are obtained from acoustic oscillations

3.3
microphone reference point
point specified on, or close to, the microphone to describe the position of the microphone

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

3.4
free-field correction for sound level meter
value, at a particular frequency, that, during calibration or verification, is added to the level displayed by the sound level meter to obtain its response to a progressive sound wave in the free field of sound pressure level equal to that produced or simulated by the sound source, dependent on the specific models and configurations of sound level meter and sound source

Note 1 to entry: The IEC 61672 series permits the use of a sound calibrator, a comparison coupler or an electrostatic actuator as the sound source. The values of the corrections for these sound sources are not necessarily equal.

Note 2 to entry: The value of this correction depends on the direction of incidence of the progressive sound wave.

Note 3 to entry: When the free-field correction is stated, the reference direction is assumed unless an alternative direction is given.

Note 4 to entry: A measurement with an electrostatic actuator is not an absolute measurement, but is referenced to a sensitivity at a particular frequency, for example the calibration check frequency.

Note 5 to entry: Corrections are expressed in decibels (dB).

4 Reference environmental conditions

Reference environmental conditions for specifying the adjustment value and corrections are:

– temperature: 23 °C
– static air pressure: 101,325 kPa
– relative humidity: 50 %

5 Uncertainties of measurement

Laboratories performing measurements of the corrections shall calculate the uncertainties associated with all measurements in accordance with the guidelines given in ISO/IEC Guide 98-3. Actual expanded uncertainties shall be calculated for a level of confidence of 95 %, using the necessary coverage factor, which shall be stated.

NOTE 1 Generally a coverage factor of 2 approximates to a level of confidence of 95 %, unless the contributions are such that it is necessary to use a different coverage factor to maintain the 95 % level of confidence.

The maximum permitted expanded uncertainties of measurement are given separately in the following clauses for the appropriate corrections. If the actual expanded uncertainty of measurement exceeds any of the maximum permitted values, the measurement shall not be used to evaluate the corrections provided in the instruction manual for the sound level meter.

NOTE 2 It is not possible to derive corrections for use in demonstrating conformance of the sound level meter to the requirements of IEC 61672-1 if the actual expanded uncertainty of measurement exceeds any of the maximum permitted values.

Calculation of the expanded uncertainty of measurement for a particular measurement should consider all relevant components. An example calculation is given in Annex I.

6 General requirements for measurement of adjustment value and corrections

For all measurements the laboratory shall use instruments that have been calibrated for the appropriate quantities at appropriate intervals. As required, the calibrations shall be traceable to national standards.

Measurements shall be performed within the following ranges of environmental conditions: 80 kPa to 105 kPa for static air pressure, 20 °C to 26 °C for air temperature and 25 % to 70 % for relative humidity. If the measurements are performed at a static pressure below 97 kPa an additional uncertainty component shall be included in the calculation of the uncertainty of the measured corrections to account for the deviations from the values at reference conditions. If specific data are not available this additional uncertainty component shall be an expanded uncertainty (k=2) of 0,15 dB at frequencies less than and equal to 3 kHz and 0,25 dB for frequencies above 3 kHz.

Static air pressure, air temperature and relative humidity at the time of a measurement shall be recorded. Sufficient time shall be allowed for the components to stabilize before any measurements are performed. The range in air temperature during each test shall not exceed 1 °C.

For the sound calibrators used in the determination of the adjustment value at the calibration check frequency, evidence shall be available to demonstrate that the actual specimens of sound calibrator conform to the requirements for periodic testing of IEC 60942 for the appropriate performance class. In addition, where a sound calibrator is used in the determinations of corrections at various frequencies, evidence shall be available to demonstrate that the actual specimens of sound calibrator used conform to the requirements for periodic testing of IEC 60942 for a class 1 sound calibrator.

Where the sound level meter manufacturer recommends the use of a comparison coupler for periodic testing of the acoustical response of the sound level meter at various test frequencies, the comparison coupler used should preferably be designed in accordance with the examples given in IEC 61094-5.

Where the sound level meter manufacturer recommends the use of an electrostatic actuator for periodic testing of the acoustical response of the sound level meter at various test frequencies, the actuator used shall conform to the requirements of IEC 61094-6.

Where a sound calibrator is used, as applicable, the effect of the prevailing environmental conditions during the measurements on the sound pressure level produced in the coupler of the sound calibrator, relative to the sound pressure level produced under the reference environmental conditions, shall be accounted for in accordance with the procedure from the instruction manual for the sound calibrator and data from the most recent calibration of the sound calibrator.

For any measurements performed in a free-field as part of the determination of the adjustment value or corrections, in order to avoid inclusion of unwanted effects, all microphones and microphone/preamplifier combinations, including reference microphones shall be mounted on a rod the diameter of which is nominally the same as the diameter of the microphone. In addition, the distance from the source to the microphone shall be greater than 1 m, with the minimum distance from the source being at least six times the longest dimension of the sound level meter. Sound shall be incident in the reference direction.

It is recommended that the length of the mounting rod between the microphone and any mounting point of the rod should be at least 1 m.

The sound level meter shall be suspended in a free-field using a non-vertical rod at the rear, and accurate positioning shall be obtained, for example by use of laser alignment. Two suitable methods of mounting, 1 and 2, are shown in Figure 1. For mounting method 2 the angle θ shall be less than 60º. Mounting method 3 is not suitable and shall not be used – see [1][3].

For reliable results to be obtained, particularly for mounting method 1, care should be taken to minimise the bulk of the mounting structure and to avoid any sharp edges.

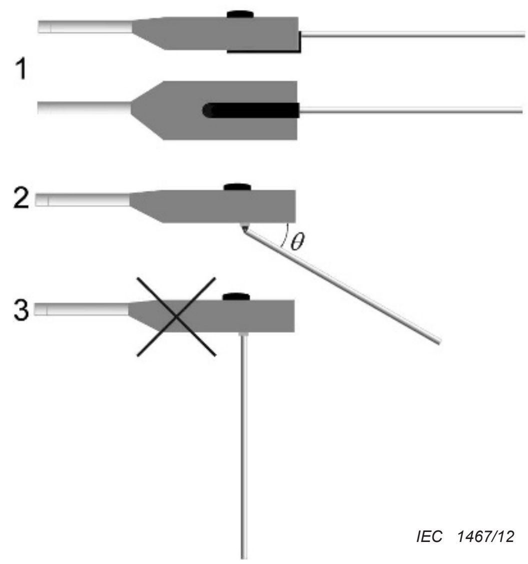


Figure 1 – Mounting methods for the sound level meter

Where the acoustic frequency response of the sound level meter is required, the measured response needs to be compared with the response of a known reference microphone, for which the calibration is traceable to national standards. A calibrated reference microphone is also required if absolute measurements in a sound calibrator or comparison coupler are required.

Where an a.c. output or equivalent from the sound level meter is used, the testing laboratory shall verify that changes in the levels of applied signals produce changes in the signal levels indicated on the display device of the sound level meter and at the output in accordance with IEC 61672-1.

Where corrections are applied in software, it will be necessary not to change these corrections (for example by switching ‘in’ or ‘out’) during measurements described in this International Standard.

3 Numbers in square brackets refer to the Bibliography.

Clauses 9 to 14 give further information on determination of various corrections that may be required in order for a periodic test of a sound level meter to be performed according to IEC 61672-3, or during testing to IEC 61672-2 to verify the data provided in the instruction manual, or by a manufacturer during the design process. Wherever possible the data for these corrections shall be provided separately.

NOTE If the configuration of the sound level meter includes use of extension cables this can result in a different value for the correction to that obtained when the microphone is directly mounted on the sound level meter case.

Care should be taken to ensure that ambient noise does not affect the measurement results, and this should be considered in the evaluation of the uncertainty components.

7 Submission and inspection

In general for all the test methods described, as applicable, at least three sound calibrators of the same model, one electrostatic actuator, one comparison coupler, three microphones of the same model and one sound level meter shall be submitted, allowing for various combinations to be tested. If the typical frequency response of a microphone is to be measured, at least five microphones shall be submitted. Appropriate instruction manuals applicable to the model and version of the sound level meter, the sound calibrator, comparison coupler and electrostatic actuator shall be supplied.

At least three samples of all relevant accessories, such as adaptors for the sound calibrator, and at least five samples of windscreen as appropriate, shall also be supplied.

If possible the five samples of windscreen should be taken from different production batches.

Prior to any measurements the sound level meter, sound calibrators, comparison couplers and electrostatic actuators, as appropriate, shall be visually inspected for any damage, and all appropriate controls shall be operated to ensure that they are in working order. It shall also be ensured that any power supplies are functioning within the specified operating limits.

8 Determination of the adjustment value at the calibration check frequency

According to IEC 61672-1 at least one model of sound calibrator, conforming to the requirements of IEC 60942, shall be specified in the instruction manual of the sound level meter for checking and maintaining the required indication on the display of the sound level meter at the calibration check frequency. Annex A of this International Standard gives the method for obtaining a suitable adjustment value at the calibration check frequency when adjusting the sensitivity of the sound level meter by application of the recommended sound calibrator.

IEC 61672-1 requires the manufacturer to specify the adjustment value, at reference conditions, to be applied to obtain the required indication on the display in response to the sound pressure level generated by the sound calibrator to optimize performance over the complete frequency range. The adjustment level shall account for the model of microphone, reflections from the sound level meter case and any diffraction effects, and may depend on the configuration in which the sound level meter is to be used, for example with or without extension cable. Any adaptor used with the sound calibrator shall be clearly identified, and referred to in the statement of the adjustment value. IEC 61672-3 requires that an adaptor of the same model shall then be used for any periodic testing of the sound level meter.

NOTE 1 As the manufacturer is optimizing over the complete frequency range it is possible that the adjustment value will not result in an indication at the calibration check frequency equivalent to the sound pressure level that would be indicated in response to plane progressive sound waves incident in the reference direction. There can be a small ‘offset’ to optimise performance of the sound level meter over the complete frequency range.

NOTE 2 An incorrect adjustment value could cause the sound level meter to not conform to the relevant specifications of IEC 61672-1.

The adjustment value has no associated uncertainty of measurement.

9 Determination of corrections for the typical effects of reflections from the case of the sound level meter and diffraction of sound around the microphone

IEC 61672-3 requires the use of corrections for the typical effects of reflections from the case of the sound level meter and diffraction of sound around the microphone of the sound level meter.

Annex B gives recommendations on methods for determining the corrections for the typical effects of reflections from the case of the sound level meter and diffraction of sound around the microphone, and possible measurement methods are given in Annex G.

The expanded uncertainty of measurement for the corrections for the typical effects of reflections from the case of the sound level meter and diffraction of sound around the microphone shall not exceed 0,25 dB up to and including 4 kHz, and 0,35 dB at all frequencies above 4 kHz. The manufacturer or testing laboratory shall state the expanded uncertainty of the actual measurements performed, together with the associated coverage factor, in the documentation supplied.

10 Determination of corrections for the deviation of the microphone free-field frequency response from a uniform frequency response

IEC 61672-3 requires the use of corrections for the deviation of the typical microphone free-field response from a uniform frequency response. This shall be interpreted as the deviation of the actual microphone response from a uniform frequency response, unless it is not possible to measure this, in which case the deviation of the typical microphone response shall be used.

Methods of measuring the frequency response are given in IEC 61094 (all parts).

Where a sound calibrator, comparison coupler or electrostatic actuator is used to measure the actual microphone response, corrections shall be available to obtain the microphone free-field response over the required range of frequencies.

Measurements shall be made at octave intervals over the frequency range 63 Hz to 16 kHz for microphones used on class 1 sound level meters, and from 63 Hz to 8 kHz for microphones used on class 2 sound level meters. Exact frequencies shall be used for the measurements and in reporting the results.

NOTE 1 Exact frequencies are specified in Annex H.

For microphones where the reference direction is not along the principal axis e.g. some microphones used outdoors, the reference direction defines a range of directions. In this case at least four measurements at equally spaced rotational intervals shall be made, and the mean value and the maximum deviation from the mean value shall be calculated and reported for each microphone measured. If the variation in the results obtained is greater than the applicable tolerance limit, the correction shall not be used to demonstrate conformance of the sound level meter to IEC 61672-1.

NOTE 2 This method is being used whilst further experience is gained for microphones where the reference direction is not along the principal axis.

Where a typical free-field response is determined by the manufacturer for inclusion in the instruction manual, measurements shall be made on at least five samples of the model of microphone. The mean value shall be calculated at each frequency, and this is considered to be the typical response. The maximum deviation from the mean shall also be specified.

The corrections for the deviation from a uniform frequency response shall be calculated for either the actual microphone response or the typical microphone response, as applicable.

The expanded uncertainty of measurement, for the manufacturer or testing laboratory determining the corrections for the deviation of the microphone response from a uniform frequency response, shall not exceed 0,25 dB from 63 Hz up to and including 4 kHz, 0,35 dB at all frequencies above 4 kHz up to and including 8 kHz, and 0,45 dB at all frequencies above 8 kHz, when the ‘reproducibility component’ due to the variability of different samples of the microphone under test is excluded. The manufacturer or testing laboratory shall state the expanded uncertainty of the actual measurements performed, together with the associated coverage factor, in the documentation supplied.

11 Determination of corrections for the use of windscreens and similar accessories

IEC 61672-3 requires the use of corrections, for the influence on the frequency response of a typical microphone, of a specified windscreen and any other accessory that is part of the configuration for normal use of the particular sound level meter submitted for testing.

A windscreen is considered to be in the form of a porous object of various shapes that can be placed over a microphone. A similar accessory is one that can be mounted on a microphone without altering the position of the microphone and retains the same reference direction.

Where an accessory is an integral part of the sound level meter for the meter to conform to the requirements of IEC 61672-1, the complete sound level meter with the accessory fitted shall be tested. Possible examples are outdoor microphone enclosures, automatic calibration systems etc.

Further details on measuring these corrections are given in Annex C, and possible measurement methods are given in Annex G.

For microphones where the reference direction is not along the principal axis, for example some microphones used outdoors, at least four measurements at equally spaced rotational intervals shall be made, and the mean value calculated for each microphone measured.

NOTE In some instances combined data covering the corrections described in Clauses 10 and 11 can be provided.

The expanded uncertainty of measurement for the manufacturer or testing laboratory determining corrections for the use of accessories, including windscreens, shall not exceed 0,20 dB for all frequencies up to and including 4 kHz, and 0,30 dB at all frequencies above 4 kHz when the ‘reproducibility component’ due to the variability of different samples of the accessory under test is excluded. The manufacturer or testing laboratory shall state the expanded uncertainty of the actual measurements performed, together with the associated coverage factor, in the documentation supplied.

12 Determination of corrections over a range of frequencies when a sound calibrator is recommended for use by the sound level meter manufacturer

When the sound level meter manufacturer recommends the use of a multi-frequency sound calibrator for periodic testing of the acoustical response of the sound level meter at various test frequencies, IEC 61672-3 requires the use of corrections to adjust the indication on the sound level meter to an equivalent free-field level.

At each test frequency the sound pressure level in the coupler of the sound calibrator shall be in the range from 70 dB to 125 dB, and preferably the reference sound pressure level at 1 kHz.

In some cases, depending on the construction of the multi-frequency calibrator and the particular model of microphone on the sound level meter, it will be necessary to replace the microphone protection grid with an adaptor ring to avoid resonances at the higher frequencies. The model of adaptor ring shall be specified by the manufacturer of the sound level meter and shall be available for general purchase. Any adaptor used with the sound calibrator shall be clearly identified, and referred to in the corrections. IEC 61672-3 requires that adaptors and adaptor rings of the same model shall be used for periodic testing of the sound level meter. If the range of correction values at each frequency measured using a sample of three microphones exceeds the maximum permitted expanded uncertainty of measurement, the microphone shall be considered as unsuitable for testing with a multi-frequency calibrator unless further testing of more samples can demonstrate otherwise.

Recommended methods for measuring these corrections, to adjust the indication on the sound level meter to an equivalent free-field level over the frequency range of interest, are given in Annex D and Annex G. These corrections are applicable to a specific model of sound calibrator, microphone and sound level meter and depend on the configuration in which the sound level meter is used, e.g. with or without extension cable.

The expanded uncertainty of measurement of the corrections required to adjust the indication on the sound level meter to an equivalent free-field level shall not exceed 0,25 dB for all frequencies up to and including 4 kHz, 0,35 dB at all frequencies above 4 kHz up to 10 kHz, and 0,50 dB at and above 10 kHz. These uncertainties of measurement apply for both the microphone alone and for the combination of microphone fitted to the sound level meter case. The manufacturer or testing laboratory shall state the expanded uncertainty of the actual measurements performed, together with the associated coverage factor, in the documentation supplied.

13 Determination of corrections over a range of frequencies when a comparison coupler is recommended for use by the sound level meter manufacturer

When the sound level meter manufacturer recommends the use of a comparison coupler for periodic testing of the acoustical response of the sound level meter at various test frequencies, the use of corrections to adjust the indication on the sound level meter to an equivalent free-field level is required by IEC 61672-1.

Where a model of microphone has a back equalization vent, care should be taken to ensure it is appropriate to use a closed coupler. The frequency response at low frequencies is not equal to the sum of the cartridge and preamplifier free-field response.

At each test frequency the sound pressure level in the comparison coupler shall be in the range from 70 dB to 125 dB, and preferably the reference sound pressure level at 1 kHz.

In some cases an adaptor for fitting the sound level meter microphone to the comparison coupler is necessary, either because the coupler opening diameter is larger than the microphone diameter, or because the microphone grid causes poor repeatability at high frequencies and shall be substituted by an adaptor ring. The model of adaptor or adaptor ring shall be specified by the manufacturer of the sound level meter and shall be available for general purchase. IEC 61672-3 requires that adaptors of the same model shall be used for periodic testing of the sound level meter.

If the range of correction values at each frequency measured using a sample of three microphones exceeds the maximum permitted expanded uncertainty of measurement, the microphone shall be considered as unsuitable for testing with a comparison coupler unless further testing of more samples can demonstrate otherwise.

Recommended methods for measuring these corrections, required to adjust the indication on the sound level meter to an equivalent free-field level, over the frequency range of interest are given in Annex E and Annex G. These corrections are applicable to a specific model of comparison coupler, microphone and sound level meter and depend on the configuration in which the sound level meter is used, e.g. with or without extension cable.

The expanded uncertainty of measurement of the corrections required to adjust the indication on the sound level meter to an equivalent free-field level shall not exceed 0,25 dB for all frequencies up to and including 4 kHz, 0,35 dB for all frequencies above 4 kHz up to 10 kHz, and 0,50 dB at and above 10 kHz. The manufacturer or testing laboratory shall state the expanded uncertainty of the actual measurements performed, together with the associated coverage factor, in the documentation supplied.

14 Determination of corrections over a range of frequencies when an electrostatic actuator is recommended for use by the sound level meter manufacturer

When the sound level meter manufacturer recommends the use of an electrostatic actuator for periodic testing of the acoustical response of the sound level meter at various test frequencies, IEC 61672-3 requires the use of corrections to adjust the indication on the sound level meter to an equivalent free-field level.

At 1 kHz the signal level displayed shall be in the range 80 dB to 105 dB.

If the range of correction values at each frequency measured using a sample of three microphones exceeds the maximum permitted expanded uncertainty of measurement, the microphone shall be considered as unsuitable for testing with an electrostatic actuator unless further testing of more samples can demonstrate otherwise.

Recommended methods for measuring these corrections, which are normalized to the calibration check frequency, required to adjust the indication on the sound level meter to an equivalent free-field level, over the frequency range of interest are given in Annex F and Annex G. These corrections are applicable to a specific model of electrostatic actuator, microphone and sound level meter and depend on the configuration in which the sound level meter is used, for example, with or without extension cable.

The expanded uncertainty of measurement of the corrections required to adjust the indication on the sound level meter to an equivalent free-field level shall not exceed 0,25 dB for all frequencies up to and including 4 kHz, 0,35 dB for all frequencies above 4 kHz up to 10 kHz, and 0,50 dB at and above 10 kHz. The manufacturer or testing laboratory shall state the expanded uncertainty of the actual measurements performed, together with the associated coverage factor, in the documentation supplied.

15 Documentation

After completion of the tests the laboratory shall issue a document containing, as a minimum and as applicable, the following information:

a) the date(s) when the measurements were performed;

b) the name and location of the laboratory performing the measurements;

c) the name of the manufacturer or supplier, model designation and serial number of the sound level meter and, if applicable, the version of the internal operating software loaded in the sound level meter;

d) the name of the manufacturer or supplier, model designation and serial number of the microphones;

e) the name of the manufacturer or supplier, model designation and any unique identification of the preamplifiers, if separate;

f) details of the instruction manual that was provided for the sound level meter including, as applicable, the publication date and version number;

g) the name of the manufacturer or supplier, model designation and serial numbers of the sound calibrators, together with details of any adaptors used;

h) the name of the manufacturer or supplier, model designation and serial numbers (if any) of the comparison coupler, together with details of any adaptors used;

i) the name of the manufacturer or supplier, model designation and serial numbers (if any) of the electrostatic actuator, together with details of any adaptors used;

j) information on the calibration of the sound calibrator at the required frequencies and evidence of conformance to the appropriate class of IEC 60942;

k) a description of the configuration of the sound level meter during the measurements including any connecting cables that were provided to operate the sound level meter and where corrections are applied in software a description of the setting used during the measurements;

l) a description of any accessories used during the measurements;

m) a statement detailing the methods used from IEC 62585:2012 to perform the measurements;

n) the corrections obtained as a result of the measurements, together with the actual associated expanded uncertainties of measurement and the coverage factor;

o) a statement on whether the measured expanded uncertainties of measurement are within the maximum permitted values given in this International Standard;

p) a statement, as to whether the supplied corrections conform to the requirements of IEC 61672-1 in terms of the deviations of the measured values from the supplied corrections, and hence whether the corrections and uncertainties supplied may be used during a periodic test of a sound level meter according to IEC 61672-3;

q) the ranges of static air pressure, temperature and relative humidity at the time the measurements were performed.

For future reference, the testing laboratory should retain the measured data and a copy of the documentation.

Annex A
(normative)

Calibration check frequency – Determination of the adjustment value

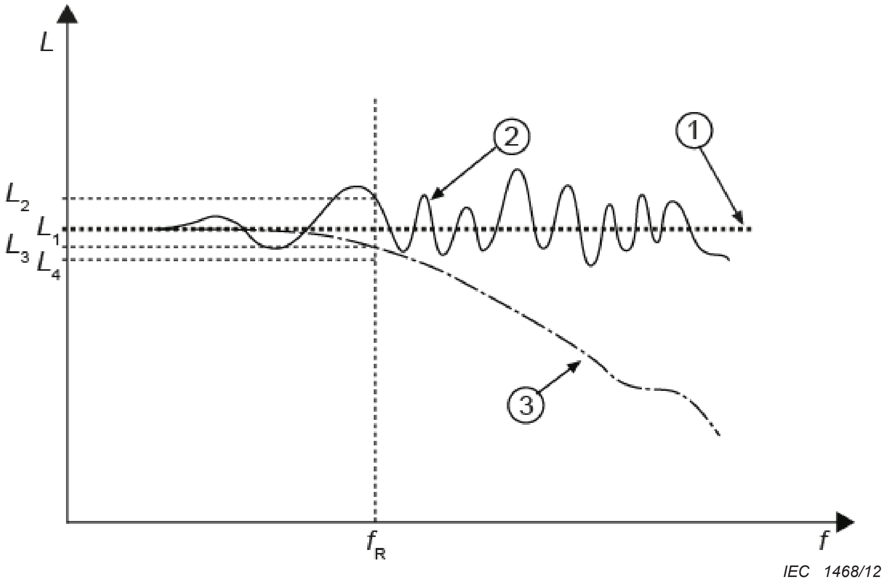
The manufacturer of the sound level meter shall specify the adjustment value, valid at reference conditions, to be applied to obtain the required indication on the display of the sound level meter in response to the sound pressure level generated by the recommended model of sound calibrator. The value shall be selected by the manufacturer to optimize performance over the complete frequency range (see Clause 8), and may result in a deliberate ‘offset’ from the exact value at the calibration check frequency.

This adjustment value shall take into account the model of microphone, reflections from the sound level meter case and any diffraction effects, and may depend on the configuration in which the sound level meter is to be used, for example, with or without extension cable.

Figure A.1 illustrates the considerations that shall be made by the sound level meter manufacturer in optimizing the adjustment value over the complete frequency range, in terms of the free-field response, pressure response and sound calibrator response.

The response of the sound level meter, when placed in an acoustic field of approximately plane progressive waves (free-field) with where possible a measured level equal to the stated level for the recommended sound calibrator, shall be measured for the range of frequencies appropriate for the class of sound level meter. The level stated for the sound calibrator is indicated as level L_1 in Figure A.1. Where it is not possible to generate a measured free-field level equal to that generated by the sound calibrator, the difference between the achievable free-field level and that generated by the sound calibrator shall be determined and allowance made for this difference in the subsequent calculations. The sensitivity of the sound level meter shall be adjusted to minimise the averaged deviation in the indicated level from the sound pressure level of the incident progressive wave in a free sound field at different frequencies. The tolerance limits, which are stated in IEC 61672-1, vary with frequency and these differences shall be taken into account by the manufacturer when determining the adjustment value to optimize performance over the complete frequency range. In Figure A.1, the free-field response for the sound level meter is shown as (2) and the sound pressure level of the incident progressive wave in a free sound field as (1).

After adjustment of the sensitivity using the method above, the microphone of the sound level meter shall be exposed to the sound from the sound calibrator. The indicated value is shown as level L_4 in Figure A.1.



Key

1 design goal for the free-field response

2 free-field response

3 pressure response

L_1 reference sound pressure level

L_2 indicated level when the instrument is exposed to a free-field sound at the reference level and calibration check frequency

L_3 indicated level when the instrument is exposed to a sound pressure at the reference level and calibration check frequency

L_4 indicated level when the instrument is exposed to the sound pressure from a sound calibrator producing the reference level at the calibration check frequency

f_R calibration check frequency in hertz

NOTE The difference ($L_3 – L_4$) can be either positive or negative, due to the loading of the sound calibrator by the microphone of the sound level meter.

Figure A.1 – Diagrammatic representation of factors for consideration in optimising adjustment value at the calibration check frequency

The adjustment value to be added to the indication of the sound level meter when exposed to the sound generated by the sound calibrator is $\Delta L = L_1 – L_4$. The instruction manual for the sound level meter shall state this value as a fixed number without associated expanded uncertainty of measurement.

In Figure A.1, a typical pressure field response for a sound level meter, at different frequencies, when the microphone is exposed to a sound pressure with a level equal to the stated level for the recommended sound calibrator is shown as (3). The difference between the free-field level (1) and the indicated levels when the sound level meter is exposed to the pressure field (3) shall be the pressure-to-free-field correction for the sound level meter.

Annex B
(normative)

Determination of the effects of reflections from the case of the sound level meter and diffraction of sound around the microphone

B.1 General

Measurements to determine the effects of reflections from the case of the sound level meter, and diffraction of sound around the microphone, shall be performed using a comparison technique. Guidelines for comparison techniques are given in Annex G.

B.2 Measurements

One of the methods given in Annex G shall be used.

For the methods given in Annex G, the configurations shall be as follows:

- set-up 1 is with the microphone from the sound level meter alone;
- set-up 2 is with the complete sound level meter with the microphone fitted

  or with the microphone fitted with a dummy sound level meter case;

  or with the microphone connected to the sound level meter via an extension cable as applicable for the configuration under test.

For some of the methods given in Annex G an a.c. output needs to be available.

Any dummy case shall be constructed from material similar to that used for the case of the actual sound level meter.

The reference point of the microphone of the sound level meter in set-up 2 shall occupy the same position as that previously occupied by the reference point of the microphone alone in set-up 1.

Where the same preamplifier is not used for both measurements, corrections shall be applied to account for any differences in the frequency responses of the two preamplifiers, or for differences in the gain.

For the method given in G.4 any reflections shall travel at least 1,5 m further to the microphone than the direct sound, with the exception of reflections from the sound level meter mounting rod.

For both class 1 and class 2 sound level meters, the frequency intervals and frequency ranges over which measurements shall be performed are given in IEC 61672-1. The results of the measurements shall be valid for, and reported at, exact frequencies (base 10), as given in Annex H.

Annex C
(normative)

Determination of the effects of the use of windscreens and similar accessories

C.1 General

Measurements to determine the effects of accessories, including windscreens, shall be performed using a comparison technique. Guidelines for comparison techniques are given in Annex G.

C.2 Measurements

For the methods given in Annex G, the configurations shall be as follows:

- set-up 1 is either with the microphone from the sound level meter alone or the complete sound level meter;
- set-up 2 is with the accessory fitted to the microphone or with the accessory fitted to the complete sound level meter, as applicable.

Whether a microphone, rather than the sound level meter, can be used will depend on the accessory under test.

For each accessory, including outdoor enclosures, measurements shall be performed on three samples of the accessory, apart from where the accessory is a windscreen in which case five samples shall be used.

The frequency interval for the measurement of accessories shall not be greater than one-third octave. The frequency range to be tested for both class 1 and class 2 sound level meters shall be that given in IEC 61672-1 for the appropriate accessory. The results of the measurements shall be valid for, and reported at, exact frequencies (base 10), as given in Annex H.

NOTE Different frequency ranges can apply for different accessories, as IEC 61672-1 provides a more limited frequency range for testing of windscreens.

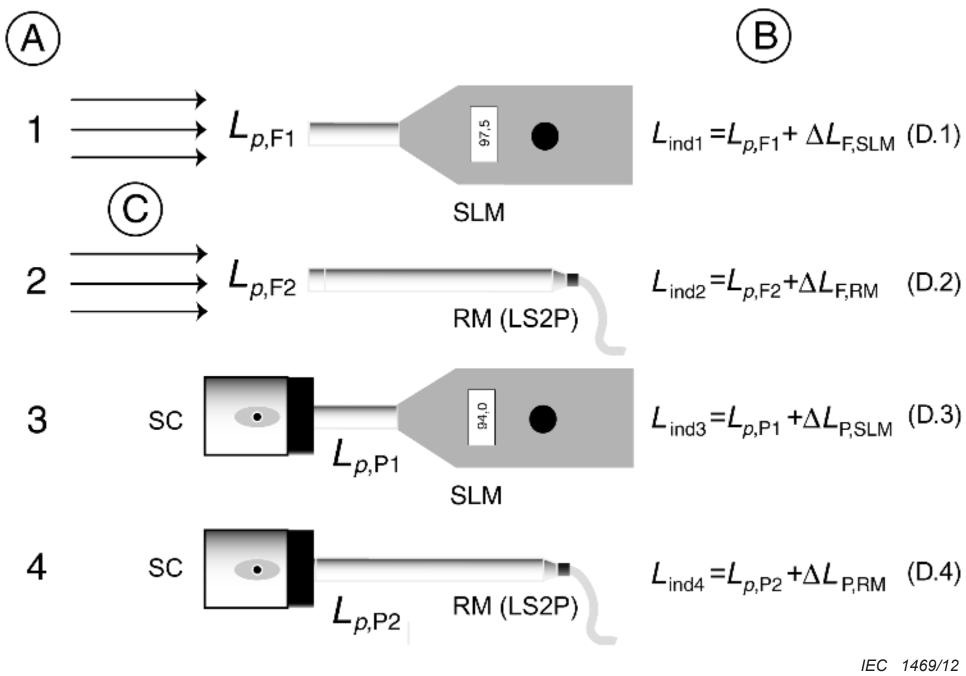
Annex D
(informative)

Determination of corrections for use with sound calibrators to determine equivalent free-field response at all frequencies of interest

D.1 Principle of measurement methodology

Free-field corrections valid for a model of sound level meter and a model of sound calibrator may be determined by the method below. The method requires a laboratory standard microphone (IEC 61094-1, LS2P), for which the free-field corrections are known, but it requires neither absolute measurements nor an absolutely calibrated sound level meter and sound calibrator. Four measurements are to be performed, as shown in Figure D.1. The Equations (D.1), (D.2), (D.3) and (D.4) describe the levels indicated by the sound level meter and the reference microphone channel and what they represent. Considering the free-field levels and the pressure levels, respectively, to be equal, the resulting correction can be calculated from the four indicated levels and from the reference microphone free-field correction (given in IEC/TS 61094-7).

An LS2P microphone should be used regardless of the size of microphone fitted to the sound level meter.



Key

A	measurement sequence
B	indicated levels
C	free progressive sound field
SLM	sound level meter
RM	reference microphone
SC	sound calibrator

Figure D.1 – Measurement steps using a sound calibrator

$$\Delta L_{F,SLM} - \Delta L_{P,SLM} = L_{ind1} - L_{ind2} - L_{ind3} + L_{ind4} - L_{p,F1} + L_{p,F2} + L_{p,P1} - L_{p,P2} + \Delta L_{F,RM} - \Delta L_{P,RM} \quad (D.5)$$

$$\Delta L_{F,SLM} - \Delta L_{P,SLM} = (L_{ind1} - L_{ind3}) - (L_{ind2} - L_{ind4}) - (L_{p,F1} - L_{p,F2}) + (L_{p,P1} - L_{p,P2}) + \Delta L_{F,RM} - \Delta L_{P,RM} \quad (D.6)$$

$$C_{FF,SLM} = (L_{ind1} - L_{ind3}) - (L_{ind2} - L_{ind4}) - (L_{p,F1} - L_{p,F2}) + (L_{p,P1} - L_{p,P2}) + C_{FF,RM} \quad (D.7)$$

NOTE 1 Equations (D.5), (D.6) and (D.7) have been written in expanded form to demonstrate fully the components for which contributions are required in the calculation of the uncertainty of measurement. Also although some components are intended to be equal, for example, $L_{p,F1}$ and $L_{p,F2}$, it is possible there can be some small discrepancy between them which is to be included in the calculation.

where

L_{ind1}, L_{ind2}, L_{ind3}, L_{ind4}	are the levels indicated during measurements 1, 2, 3 and 4 respectively;
$L_{p,F1}$, $L_{p,F2}$	are the free-field sound pressure levels during measurements 1 and 2 respectively;
$L_{p,P1}$, $L_{p,P2}$	are the sound pressure levels measured with sound calibrator applied during measurements 3 and 4 respectively;
$\Delta L_{F,SLM}$	is the deviation between free-field level and level indicated by SLM (measurement 1);
$\Delta L_{F,RM}$	is the deviation between free-field level and level indicated by reference microphone channel (measurement 2);
$\Delta L_{P,SLM}$	is the deviation between sound calibrator pressure level and level indicated by SLM (measurement 3);
$\Delta L_{P,RM}$	is the deviation between sound calibrator pressure level and level indicated by reference microphone channel (measurement 4);
$C_{FF,SLM}$	is the free-field correction valid with applied SLM and sound calibrator;
$C_{FF,RM}$	is the free-field correction of reference microphone (given in IEC/TS 61094-7).

NOTE 2 The levels $L_{p,F1}$ and $L_{p,F2}$ can either, with a stable sound source, be considered to be equal or the difference can be determined with a monitor microphone placed in front of and close to the sound source.

NOTE 3 The levels $L_{p,P1}$ and $L_{p,P2}$ are, with a stable sound calibrator, defined to be the same.

NOTE 4 Measured levels are expressed in decibels (dB).

D.2 Measurement methodology

Step 1 – The sound level meter in the configuration in which it is to be tested (e.g. with or without extension cable), with the grid in place on the microphone, is placed in a free progressive sound field. The output from the sound level meter is measured (in decibels) either via the display of the sound level meter, or preferably by using a suitable device to measure the output from the meter, at each frequency where corrections are given in the instruction manual for the sound level meter. Where a free progressive sound field is not available, other techniques such as those described in Annex G, may be used.

Step 2 – Without changing the level of the free progressive sound field, the sound level meter is replaced by a reference laboratory standard (LS2P) microphone (as described in IEC 61094-1), for which the pressure-to-free-field correction is known at all the frequencies of interest (from IEC/TS 61094-7). The reference point of the microphone should occupy the same position as that previously occupied by the reference point of the microphone of the sound level meter. The level of the sound field (in decibels) is measured using the reference microphone at all required frequencies, by measuring the level of the output voltage from the microphone.

Step 3 – The sound calibrator, of a model recommended by the sound level meter manufacturer for use during periodic testing, is applied to the sound level meter and the output from the sound level meter (in decibels) noted at all required frequencies using the same method and instrumentation as in Step 1. The nominal sound pressure level of the sound calibrator is the reference sound pressure level. In some cases, depending on the construction of the multi-frequency calibrator and the particular model of microphone on the sound level meter, it will be necessary to replace the microphone protection grid with the adaptor ring specified by the sound level meter manufacturer to avoid resonances at the higher frequencies. Any adaptor used with the sound calibrator should be clearly identified, and referred to in the corrections.

Step 4 – The same sound calibrator is applied to the reference microphone and the output from the microphone (in decibels) noted using the same method and instrumentation as in Step 2.

Step 5 – For each measurement, the correction at each frequency is calculated according to Equation (D.7).

Step 6 – Steps 1 to 5 are repeated for each other combination of microphone and sound calibrator, required as described in Clause 7, to give a minimum of nine measurements, using one source to receiver distance only. The correction for each combination of microphone and sound calibrator, at each required frequency, is calculated as the mean of these measurements.

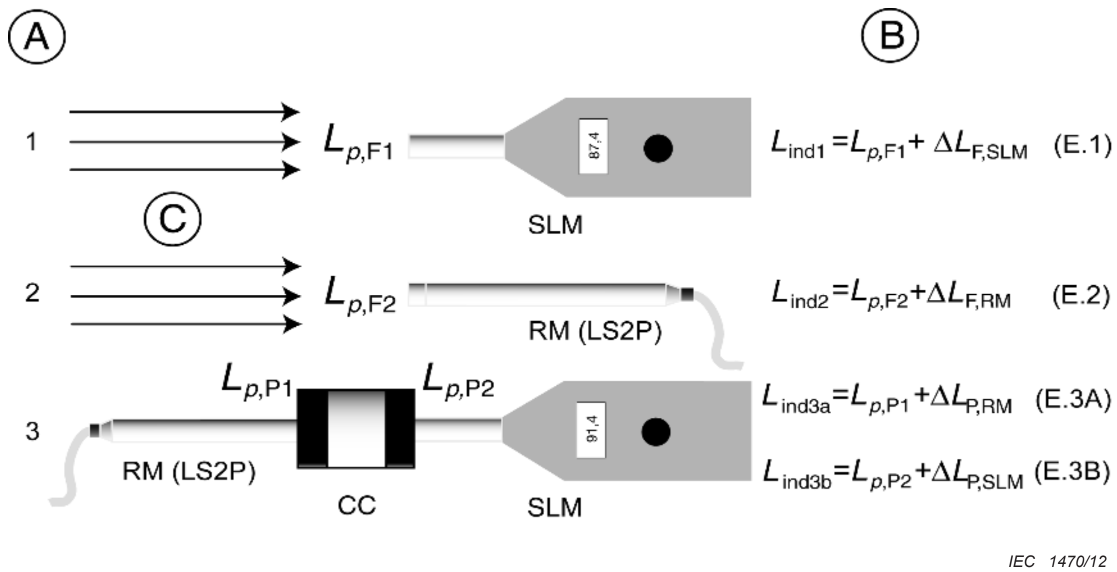
NOTE For practical reasons it can be easier to perform the measurements with the first microphone and the three calibrators described in Clause 7, and then change to the second microphone etc.

Annex E
(informative)

Determination of corrections for use with comparison couplers to determine equivalent free-field frequency response at all frequencies of interest

E.1 Principle of measurement methodology

Free-field corrections valid for a model of sound level meter and a model of comparison calibration coupler (IEC 61094-5) may be determined by the method below. A comparison coupler is a sound source that produces a pressure sound field in a cavity that has two openings in which two microphones may be mounted face to face. The method requires a laboratory standard microphone (IEC 61094-1, LS2P), for which the free-field corrections are known, but it requires neither absolute measurements nor an absolutely calibrated sound level meter nor a reference LS2P microphone. Four measurements are to be performed, as shown in Figure E.1. The Equations (E.1), (E.2), (E.3A) and (E.3B) describe the levels indicated by the sound level meter and the reference microphone channel and what they represent. Considering the free-field levels to be equal, the resulting correction can be calculated from the four indicated levels and from the reference microphone free-field correction (given in IEC/TS 61094-7).



Key

A	measurement sequence
B	indicated levels
C	free progressive sound field
SLM	sound level meter
RM	reference microphone
CC	comparison coupler

Figure E.1 – Measurement steps using a comparison coupler

$$\Delta L_{F,SLM} - \Delta L_{P,SLM} = L_{ind1} - L_{ind2} - L_{ind3a} + L_{ind3b} - L_{p,F1} + L_{p,F2} + L_{p,P1} - L_{p,P2} + \Delta L_{F,RM} - \Delta L_{P,RM} \quad (E.4)$$

$$\Delta L_{F,SLM} - \Delta L_{P,SLM} = (L_{ind1} - L_{ind3a}) - (L_{ind2} - L_{ind3b}) - (L_{p,F1} - L_{p,F2}) + (L_{p,P1} - L_{p,P2}) + \Delta L_{F,RM} - \Delta L_{P,RM} \quad (E.5)$$

$$C_{FF,SLM} = (L_{ind1} - L_{ind3a}) - (L_{ind2} - L_{ind3b}) - (L_{p,F1} - L_{p,F2}) + (L_{p,P1} - L_{p,P2}) + C_{FF,RM} \quad (E.6)$$

NOTE 1 Equations (E.4), (E.5) and (E.6) have been written in expanded form to demonstrate fully the components for which contributions are required in the calculation of the uncertainty of measurement. Also although some components are intended to be equal, for example, L_{F1} and L_{F2}, it is possible there can be some small discrepancy between them which is to be included in the calculation.

where

L_{ind1}, L_{ind2}, L_{ind3a}, L_{ind3b}	are the levels indicated during measurements 1, 2, and 3 respectively;
$L_{p,F1}$, $L_{p,F2}$	are the free-field sound pressure levels during measurements 1 and 2 respectively;
$L_{p.P1}$	is the sound pressure level at reference microphone in the comparison coupler during measurements 3;
$L_{p.P2}$	is the sound pressure level at sound level meter in the comparison coupler during measurements 3;
$\Delta L_{F,SLM}$	is the deviation between free-field level and level indicated by SLM (measurement 1);
$\Delta L_{F,RM}$	is the deviation between free-field level and level indicated by reference microphone channel (measurement 2);
$\Delta L_{P,SLM}$	is the deviation between comparison coupler level and level indicated by SLM (measurement 3);
$\Delta L_{P,RM}$	is the deviation between comparison coupler level and level indicated by reference microphone channel (measurement 3);
$C_{FF,SLM}$	is the free-field correction valid with applied SLM and comparison coupler;
$C_{FF,RM}$	is the free-field correction of reference microphone (IEC/TS 61094-7).

NOTE 2 The levels $L_{p,F1}$ and $L_{p,F2}$ can either, with a stable sound source, be considered to be equal, or the difference can be determined with a monitor microphone placed in front of and close to the sound source.

NOTE 3 Measured levels are expressed in decibels (dB).

E.2 Measurement methodology

Step 1 – The sound level meter in the configuration in which it is to be tested (e.g. with or without extension cable), with the grid in place on the microphone, is placed in a free progressive sound field. The output from the sound level meter is measured (in decibels) either via the display of the sound level meter, or preferably by using a suitable device to measure the output from the meter, at each frequency where corrections are given in the instruction manual for the sound level meter. Where a free progressive sound field is not available, other techniques such as those described in Annex G, may be used.

Step 2 – Without changing the level of the free progressive sound field, the sound level meter is replaced by a reference laboratory standard (LS2P) microphone (as described in IEC 61094-1), for which the pressure-to-free-field correction is known at all the frequencies of interest (from IEC/TS 61094-7). The reference point of the microphone should occupy the same position as that previously occupied by the reference point of the microphone of the sound level meter. The level of the sound field (in decibels) is measured using the reference microphone at all required frequencies, by measuring the level of the output voltage from the microphone.

Step 3 – Both the SLM and the reference microphone are applied to the two openings of the comparison coupler. The comparison coupler model is recommended by the sound level meter manufacturer for use during periodic testing, and the corrections obtained using the method given in this Annex are only applicable to comparison couplers of the same model. In some cases use of the specified adaptor or adaptor ring in place of the microphone grid for fitting the sound level meter microphone to the comparison coupler is necessary. The levels (in decibels) proportional to the frequency response of the SLM and of the reference microphone at all required frequencies may be measured simultaneously or sequentially. IEC 61094-5 gives a procedure for performing the measurement and a guide for the calculation of the uncertainty of measurement.

Where an adaptor ring is used the uncertainty pertaining to the variability of the adaptor ring should be determined by repeating the measurement on the same sound level meter with an adequate number of rings.

Step 4 – The correction at the required frequencies is calculated according to Equation (E.6).

Step 5 – Steps 1 to 4 are repeated using at least two other microphones of the same model on the sound level meter, required as described in Clause 7. The correction for each combination of microphone and comparison coupler, at each required frequency, is calculated as the mean of these measurements.

The influence of the reference microphone and of the comparison coupler does not need to be determined as the effects of their variability is estimated to be significantly lower than that of the sound level meter microphone/grid or microphone/ring adaptor combinations.

Annex F
(informative)

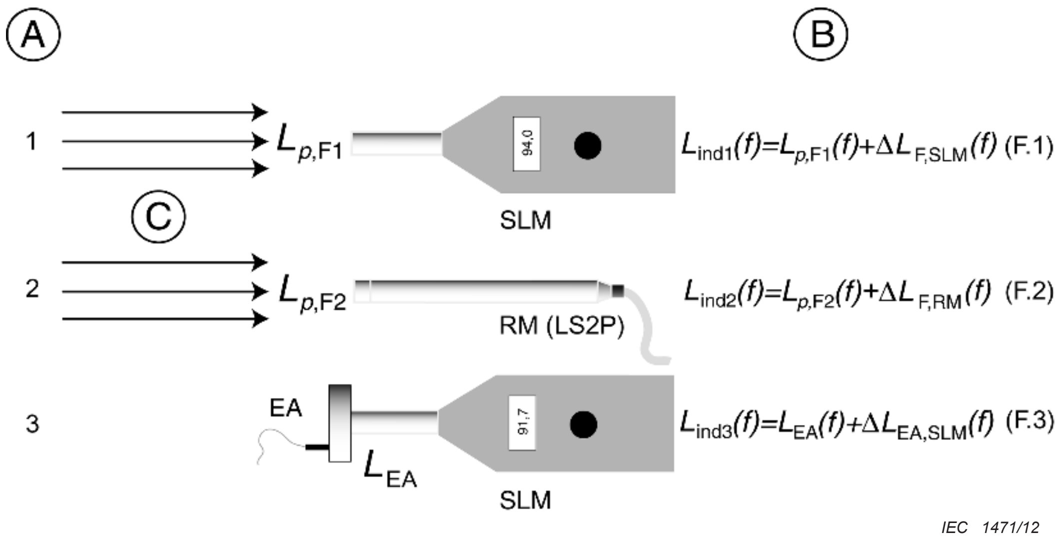
Determination of corrections for use with electrostatic actuators to determine equivalent free-field frequency response at all frequencies of interest

F.1 Principle of measurement methodology

The free-field correction, normalized to the value at the calibration check frequency, valid for a model of sound level meter and a model of electrostatic actuator (IEC 61094-6) may be determined by the method below. The method requires an electrostatic actuator and a laboratory standard microphone (IEC 61094-1, LS2P), for which the free-field sensitivity is known at all frequencies of interest, but it does not require an absolutely calibrated sound level meter. The frequency response of the reference microphone channel must be known, but the channel is not required to be absolutely calibrated. Three measurements are to be performed at the actual frequency and at the calibration check frequency (the normalization frequency), as shown in Figure F.1. Equations (F.1), (F.2) and (F.3) describe the levels indicated by the sound level meter and the reference microphone channel and what they represent. Considering the free-field levels to be equal, the resulting correction can be calculated from the levels indicated at the two frequencies and from the reference microphone free-field sensitivity.

NOTE 1 Further guidance on the use of electrostatic actuators can be found in IEC 61094-6.

NOTE 2 Holes or cracks in the microphone diaphragm are likely to produce errors in the measurements, particularly at low frequencies. A visual inspection of the microphone is therefore recommended prior to any measurements.



Key

A measurement sequence
B indicated levels
C free progressive sound field
SLM sound level meter
RM reference microphone
EA electrostatic actuator

Figure F.1 – Measurement steps using an electrostatic actuator

$$\Delta L_{F,SLM} - \Delta L_{EA,SLM} = L_{ind1} - L_{ind2} - L_{p,F1} + L_{p,F2} + S_{RM} + G_{RC} - L_{ind3} + L_{EA} \quad \text{(F.4)}$$

$$R_{N,ind1} = L_{ind1}(f) - L_{ind1}(f_0) \quad \text{(F.5)}$$

$$R_{N,ind2} = L_{ind2}(f) - L_{ind2}(f_0) \quad \text{(F.6)}$$

$$R_{N,ind3} = L_{ind3}(f) - L_{ind3}(f_0) \quad \text{(F.7)}$$

$$R_{N,p,F1} = L_{p,F1}(f) - L_{p,F1}(f_0) \quad \text{(F.8)}$$

$$R_{N,p,F2} = L_{p,F2}(f) - L_{p,F2}(f_0) \quad \text{(F.9)}$$

$$R_{N,EA} = L_{EA}(f) - L_{EA}(f_0) \quad \text{(F.10)}$$

$$S_{N,RM} = S_{RM}(f) - S_{RM}(f_0) \quad \text{(F.11)}$$

$$G_{N,RC} = G_{RC}(f) - G_{RC}(f_0) \quad \text{(F.12)}$$

$$C_{N,FF,SLM} = R_{N,ind1} - R_{N,ind2} - (R_{N,p,F1} - R_{N,p,F2}) + S_{N,RM} + G_{N,RC} - (R_{N,ind3} - R_{N,EA}) \quad \text{(F.13)}$$

where

L_{ind1}, L_{ind2}, L_{ind3}	are the levels indicated during measurements 1, 2 and 3 respectively;
$L_{p,F1}$, $L_{p,F2}$	are the free-field sound pressure levels during measurements 1 and 2 respectively;
L_{EA}	is the simulated sound pressure level of electrostatic actuator during measurements 3;
$\Delta L_{F,SLM}$	is the deviation between free-field level and level indicated by SLM (measurement 1);
$\Delta L_{EA,SLM}$	is the deviation between simulated level from electrostatic actuator and level indicated by SLM (measurement 3);
$R_{N,X}$	is the response of parameter as indicated in the index, normalised at the calibration check frequency;
S_{RM}, $S_{N,RM}$	is the free field (open circuit) sensitivity of reference microphone and free field sensitivity of reference microphone normalised at the calibration check frequency, respectively;
G_{RC}, $G_{N,RC}$	is the gain of reference channel and gain of reference channel normalised at the calibration check frequency, respectively;
f	is the frequency;
f_0	is the normalization and calibration check frequency;
$C_{N,FF,SLM}$	is the normalised free-field correction valid with applied SLM and electrostatic actuator.

NOTE 3 The levels $L_{p,F1}$ and $L_{p,F2}$ can either, with a stable sound source, be considered to be equal, or the difference can be determined with a monitor microphone placed in front of and close to the sound source.

NOTE 4 If the a.c. voltage on the electrostatic actuator is independent of frequency the simulated sound pressure level can be considered to be the same at the test frequency and at the calibration check frequency (normalization frequency).

NOTE 5 Measured levels are in decibels (dB).

NOTE 6 The response to a real sound pressure and an electrostatic pressure produced by an actuator will differ, especially at higher frequencies, due to different loading of the diaphragm of the microphone.

F.2 Measurement methodology

Step 1 – The sound level meter in the configuration in which it is to be tested (e.g. with or without extension cable), is placed in a free progressive sound field. The output from the sound level meter (in decibels) is measured either via the display of the sound level meter, or preferably by using a suitable device to measure the output from the sound level meter at the calibration check frequency and at each frequency where corrections are given in the instruction manual for the sound level meter. Where a free progressive sound field is not available, other techniques such as those described in Annex G, may be used.

Step 2 – Without changing the level of the free progressive sound field, the sound level meter is replaced by a reference laboratory standard (LS2P) microphone (as described in IEC 61094-1), for which the free-field sensitivity is known at all the frequencies of interest. The reference point of the microphone should occupy the same position as that previously occupied by the reference point of the microphone of the sound level meter. The level of the sound field (in decibels) is measured at all required frequencies, including the calibration check frequency, using the reference microphone, by measuring the level of the output voltage from the microphone.

Step 3 – The electrostatic actuator, of a model recommended by the sound level meter manufacturer for use during periodic testing, is applied to the microphone of the sound level meter using the method given by the manufacturer and the output from the sound level meter (in decibels) noted at all required frequencies, including the calibration check frequency, using the same method and instrumentation as in Step 1.

NOTE 1 Some microphones have a built-in electrostatic actuator.

Step 4 – The correction at the required frequencies, normalized to the calibration check frequency, is calculated according to Equation (F.13).

Step 5 – Steps 1 to 4 are repeated for each other combination of microphone and electrostatic actuator, required as described in Clause 7. The correction for the combination of microphone and electrostatic actuator, at each required frequency, normalised to the calibration check frequency, is calculated as the mean of these measurements.

NOTE 2 When an electrostatic actuator is used, the absolute response is measured at the calibration check frequency using a sound calibrator.

Annex G
(informative)

Comparison techniques

G.1 General

This annex gives guidelines for comparison techniques to determine the corrections to obtain the free-field response of a sound level meter. The techniques only cover comparison by substitution.

G.2 Comparison by substitution

G.2.1 General

The comparison by substitution method is based on two consecutive measurements of two different configurations. The ratio between the responses for the two configurations is determined. Initially, the response of the first configuration is measured. Subsequently this configuration is substituted with the second and the response of the second configuration is measured. When the responses are measured as levels, the ratio between the responses is found as the difference in level response between the two configurations.

As the result of the comparison is the ratio between the measured quantities, no absolute calibrations of the measuring instruments are required.

When only the measured ratio is of interest, for example when the influence of a windscreen is measured, the absolute values of the responses do not need to be known.

When one of the configurations is a known reference and the other configuration is a ‘set-up’ with unknown response to be measured, the response to be measured will then be given as the stated response of the known reference multiplied by the measured ratio.

Some of the techniques described in this annex have been compared in [2].

G.2.2 Method

The following method allows response differences at the frequencies of interest to be obtained between two different configurations – known as set-up 1 and set-up 2. The position of the microphone reference point and the orientation of the microphone are the same in set-up 1 and set-up 2. Set-up 2 is not present during the measurement of set-up 1 and vice versa.

In cases where the microphone is not the same in set-up 1 and set-up 2, the acoustic centres of the microphones should be placed in the same position in order to obtain optimum results. If however the position of the acoustic centres is not known, the microphone reference points should be used as the best approximation. The influence of the difference should be taken into account in the uncertainty calculations.

Using, as an example, the measurements required by Clause 9 and described in Annex B to determine the effects of reflections from the case of the sound level meter and diffraction of sound around the microphone for, say, a microphone close-coupled to the body of the sound level meter, the configurations are as follows:

- set-up 1 is with the microphone from the sound level meter alone mounted on a rod, as in Clause 6, and

- set-up 2 is with the complete sound level meter with the microphone fitted as specified in the instruction manual.

Set-up 1 is established in the sound field without the presence of set-up 2. The frequency response of set-up 1 (in the example above, the microphone detached from the sound level meter and mounted on a rod) in free field conditions is determined over the frequency range of interest, using one of the measurement techniques described below.

Set-up 1 is then removed and set-up 2 established (in the example above, the complete sound level meter with the microphone fitted). The frequency response of set-up 2 is then determined in the same free-field field conditions over the frequency range of interest, using the same method.

NOTE 1 A monitor microphone positioned near the sound source can be used to ensure that the same sound field is produced, or alternatively a repeat measurement of set-up 1 at the end of the measurements can be used to check the stability of the sound source.

The difference, in decibels, between the responses obtained for set-up 2 and set-up 1 gives the correction at each frequency.

NOTE 2 Although only one measurement is required for each set-up, it can be necessary to make repeated measurements to improve the signal-to-noise ratio, or to ensure that repeatability contributions to the total expanded uncertainty are known, or both.

The uncertainty contributions of particular importance to comparison by substitution with any of the techniques mentioned in the remainder of this annex, are expected to include the stability of the sound field and the reproducibility of the position and orientation of the microphone.

G.3 Time selective techniques

Time selective techniques are described in detail in Annex B of IEC 61094-8 [3] IEC 61094-8 describes the use of these techniques with microphones, but the techniques are equally applicable for measuring the corrections described in this International Standard for a sound level meter.

The details of the measurement methods in Annex B of IEC 61094-8 should be followed, replacing the term ‘microphone’ being measured with ‘sound level meter’ being measured.

For a time selective technique to be used with a sound level meter, an a.c. output needs to be available on the sound level meter.

Equivalent methods, not described in IEC 61094-8 are not excluded from use in the context of this International Standard.

G.4 Steady state response technique

This clause describes the technique of measuring with steady state or slowly swept sinusoidal signals. The steady state response technique is the only option for response measurements if an a.c. output is not available.

Steady state response measurements are made in a free field, that is, in an anechoic room or in anechoic conditions, in order to avoid reflections that influence the sound field. The set-up is such that reflections in the direction of the device being measured are minimised.

The excitation signal is either sinusoidal at discrete frequencies or a slowly swept sinusoidal signal. If a swept signal is used, the sweep rate needs to be sufficiently low so as to ensure that the transient behaviour of any detection devices does not contribute significantly to the uncertainty.

The output voltage from the preamplifier or sound level meter, if an a.c. output is available, in response to the sound field is measured at each frequency of interest. If the sound level meter is used and an a.c. output is not available, the level displayed by the sound level meter is used, or set-up 2 may be realised with the same microphone as in set-up 1 fitted with a dummy case of the same shape and of material similar to the actual case of the sound level meter, and the output voltage from the preamplifier measured.

NOTE Considerable care needs to be taken if a dummy case is used, as it can be difficult to achieve exactly the same reflection properties at the front of a dummy case as would be obtained for the actual sound level meter.

It is recommended that the measurements above are repeated at least twice to give a total of at least three measurements. The arithmetic mean of the responses, in decibels, is calculated and taken to represent the typical response.

Spatial averaging, that is, repeating the measurements with several set-ups with different measurement paths, can reduce the effects from room reflections and the uncertainty of the result. The position of supporting equipment that is not regarded as a part of the configuration being measured should also be varied relative to the measuring object. In comparison by substitution it is, however, important that measurements with set-up 1 and set-up 2 are made with the same positions for each set-up variation, as described in G.2.2.

The uncertainty contributions of particular importance to the steady state response technique include the influence of reflections, noise, reading of the voltage or indication levels, and time variation of both the configuration being measured and the sound source.

The influence of reflections is the dominant source of uncertainty in the steady state response technique, Reference [2] in the Bibliography. If spatial averaging is used, the variation of the individual responses can be used in the estimation of the uncertainty due to reflections. In cases where spatial averaging is not used, it is recommended that some measurements with different measurement paths are carried out in order to evaluate the uncertainty contribution due to reflections.

Annex H
(informative)

Exact one-twelfth-octave frequencies

H.1 General

This annex gives a calculation method and a list of frequencies at one-twelfth-octave intervals.

H.2 Calculation method

Any exact one-twelfth-octave frequency, f_x, can be calculated from the formula:

$$f_x = f_r \cdot 10^{3x/10b} \qquad \text{(H.1)}$$

where

x is any integer, positive, negative, or zero;

f_r is the reference frequency of 1000 Hz;

b = 12 is the step-width designator.

Exact frequencies for one-twelfth-octave steps in the decade from 1 kHz to 10 kHz are given in Table H.1. The table may be extended to any decade and will only differ in the placement of the decimal sign.

NOTE The exact frequencies specified in this annex correspond to the band-edge-frequencies for one-twelfth-octave filters according to [4], to ensure that the frequency of 1 kHz is included together with other midband frequencies for one-third-octave filters. 1 kHz is very commonly used as the calibration check frequency for sound level meters (as defined in IEC 61672-1).

Table H.1 – Exact frequencies for one-twelfth-octave steps over one decade

Index	Exact f_x kHz	Exact f_x calculated kHz
0	$10^{0/40}$	1,000 000
1	$10^{1/40}$	1,059 254
2	$10^{2/40}$	1,122 018
3	$10^{3/40}$	1,188 502
4	$10^{4/40}$	1,258 925
5	$10^{5/40}$	1,333 521
6	$10^{6/40}$	1,412 538
7	$10^{7/40}$	1,496 236
8	$10^{8/40}$	1,584 893
9	$10^{9/40}$	1,678 804
10	$10^{10/40}$	1,778 279
11	$10^{11/40}$	1,883 649
12	$10^{12/40}$	1,995 262
13	$10^{13/40}$	2,113 489
14	$10^{14/40}$	2,238 721
15	$10^{15/40}$	2,371 374
16	$10^{16/40}$	2,511 886
17	$10^{17/40}$	2,660 725
18	$10^{18/40}$	2,818 383
19	$10^{19/40}$	2,985 383
20	$10^{20/40}$	3,162 278
21	$10^{21/40}$	3,349 654
22	$10^{22/40}$	3,548 134
23	$10^{23/40}$	3,758 374
24	$10^{24/40}$	3,981 072
25	$10^{25/40}$	4,216 965
26	$10^{26/40}$	4,466 836
27	$10^{27/40}$	4,731 513
28	$10^{28/40}$	5,011 872
29	$10^{29/40}$	5,308 844
30	$10^{30/40}$	5,623 413
31	$10^{31/80}$	5,956 621
32	$10^{32/40}$	6,309 573
33	$10^{33/40}$	6,683 439
34	$10^{34/40}$	7,079 458
35	$10^{35/40}$	7,498 942
36	$10^{36/40}$	7,943 282
37	$10^{37/40}$	8,413 951
38	$10^{38/40}$	8,912 509
39	$10^{39/40}$	9,440 609
40	$10^{40/40}$	10,000 000

NOTE Exact frequencies are calculated from Equation (H.1) to seven significant digits.

Annex I
(informative)

Example calculations of expanded uncertainty of measurement

This annex gives simplified examples of uncertainty budgets and calculations of expanded uncertainty of measurement for laboratories performing measurements according to Annex E of this International Standard, to measure corrections for use with comparison couplers to determine equivalent free-field frequency response of a sound level meter, at all frequencies of interest. This annex is not intended to be a definitive guide, and certain simplifying assumptions were made, for example, it was assumed that none of the input quantities are correlated to any significant extent, and some contributions considered to be negligible are excluded from the calculations e.g. due to some environmental conditions. Further information on uncertainties of measurement, a description of probability distributions and divisors, and the detailed method of calculation can be found in ISO/IEC Guide 98-3.

The three tables included here provide:

- an example giving the likely contributions to be considered for inclusion in the uncertainty budget in general terms (Table I.1)
- two specific examples for measurements made at 1 kHz and 8 kHz including numerical values. Also included for guidance is a general description of the basis for the estimates of the values included. These tables (Table I.2 and Table I.3) highlight that contributions from the same source of uncertainty may vary considerably with frequency.

In addition, the calculation of the expanded uncertainty of measurement is included.

These uncertainty budgets should not be considered as definitive and are provided for guidance only. Each laboratory performing measurements according to Annex E (or according to other annexes within this International Standard) will need to consider separately each uncertainty component and any additional contributions which may be required, depending on the instruments, methodology, and facilities used.

NOTE Where there is an uncertainty contribution for reading the indication from a digital display device that indicates signal levels with a resolution of, for example, 0,1 dB, the uncertainty component should be taken as a rectangular distribution with semi-range of 0,05 dB.

Due to the small magnitude of some of the components of uncertainty, several decimal places are required in the calculations to ensure appropriate rounding of the final results.

Effective degrees of freedom of the combined standard uncertainty are calculated using the Welch-Satterthwaite equation (see ISO/IEC Guide 98-3) thereby enabling the coverage factor *k* to be selected to provide a level of confidence of 95 %.

Table I.1 – Description of likely uncertainty components

Symbol / name	Descriptor	Description and source of uncertainty component	Probability distribution (determines divisor)
L_{ind1}	a_1	Level measurement - sound level meter in free-field	Rectangular
L_{ind2}	a_2	Level measurement – reference microphone in free-field	Rectangular
L_{ind3a}	a_3	Level measurement – reference microphone in comparison coupler	Rectangular
L_{ind3b}	a_4	Level measurement – sound level meter in comparison coupler	Rectangular
$L_{p,F1} - L_{p,F2}$	a_5	(Uncorrected) drift in level of SPL in free-field between measurements with sound level meter and reference microphone	Rectangular
$L_{p,P1} - L_{p,P2}$	a_6	Difference in sound pressure level at sound level meter and reference microphone in comparison coupler	Rectangular
$C_{FF,RM}$	a_7	Free-field correction of reference microphone from IEC/TS 61094-7	Normal (k = 2, value obtained from an expanded uncertainty)
Gain of SLM	a_8	Maximum drift in gain of sound level meter during measurements	Rectangular
Gain of RM channel	a_9	Maximum drift in gain of reference microphone channel during measurements	Rectangular
Source to microphone distance	a_{10}	Resetting distance from sound source to reference microphone or sound level meter	Rectangular
Free-progressive sound wave	a_{11}	Due to reflections and non-uniform wave front	Rectangular
SLM and RM mountings	a_{12}	Due to reflection from mountings	Rectangular
Microphone diameters	a_{13}	Ratio of reference microphone and sound level meter microphone diameters	Rectangular
Rounding	a_{14}	Rounding of final result	Rectangular
Repeatability	a_{15}	Repeat measurements with combinations stated	Normal (k = 1, value obtained from statistical evaluation)

Table I.2 – Uncertainty example for a frequency of 1 kHz

Symbol / name	Descriptor	Value ± dB and derivation	Divisor	u_i ($C_{FF,SLM}$) ± dB	Degrees of freedom
L_{ind1}	a_1	0,005 – derived from output voltage measured to 0,01dB	√3	0,002 9	∞
L_{ind2}	a_2	0,005 – derived from output voltage measured to 0,01dB	√3	0,002 9	∞
L_{ind3a}	a_3	0,005 – derived from output voltage measured to 0,01dB	√3	0,002 9	∞
L_{ind3b}	a_4	0,005 – derived from output voltage measured to 0,01dB	√3	0,002 9	∞
$L_{p,F1} - L_{p,F2}$	a_5	0,05 – derived from estimated maximum difference	√3	0,028 9	∞
$L_{p,P1} - L_{p,P2}$	a_6	0 – assumed equal	√3	0	∞
$C_{FF,RM}$	a_7	0,06 – from IEC/TS 61094-7	2	0,03	∞
Gain of SLM	a_8	0,025 – derived from estimated maximum drift	√3	0,014 4	∞
Gain of RM channel	a_9	0,025 – derived from estimated maximum drift	√3	0,014 4	∞
Source to microphone distance	a_{10}	0,029 – derived from resetting distance deviation and uncertainty in acoustic centres (4 mm in 1 200 mm)	√3	0,016 7	∞
Free-progressive sound wave	a_{11}	0,013 – estimate from free-field room performance tests	√3	0,007 5	∞
SLM and RM mountings	a_{12}	0,013 – estimate of effect derived from measurement	√3	0,007 5	∞
Microphone diameters	a_{13}	0 – assumed equal	√3	0	∞
Rounding	a_{14}	0,005 – final correction quoted to 2 decimal places	√3	0,002 9	∞
Repeatability	a_{15}	0,03 – derived from repeat measurements	1	0,03	2
Combined standard uncertainty $u(C_{FF,SLM})$ dB				0,059 0	
Expanded uncertainty of $C_{FF,SLM}$; (normal) k = 2,11				$0,12_{(4)}$	Effective degree of freedom = 29,98

Table I.3 – Uncertainty example for a frequency of 8 kHz

Symbol / name	Descriptor	Value ± dB and derivation	Divisor	u_i ($C_{FF,SLM}$) ± dB	Degrees of freedom
L_{ind1}	a_1	0,005 – derived from output voltage measured to 0,01dB	√3	0,002 9	∞
L_{ind2}	a_2	0,005 – derived from output voltage measured to 0,01dB	√3	0,002 9	∞
L_{ind3a}	a_3	0,005 – derived from output voltage measured to 0,01dB	√3	0,002 9	∞
L_{ind3b}	a_4	0,005 – derived from output voltage measured to 0,01dB	√3	0,002 9	∞
$L_{p,F1} - L_{p,F2}$	a_5	0,05 – derived from estimated maximum difference	√3	0,028 9	∞
$L_{p,P1} - L_{p,P2}$	a_6	0 – assumed equal	√3	0	∞
$C_{FF,RM}$	a_7	0,17 – from IEC/TS 61094-7	2	0,085	∞
Gain of SLM	a_8	0,025 – derived from estimated maximum drift	√3	0,014 4	∞
Gain of RM channel	a_9	0,025 – derived from estimated maximum drift	√3	0,014 4	∞
Source to microphone distance	a_{10}	0,029 – derived from resetting distance deviation and uncertainty in acoustic centres (4 mm in 1200 mm)	√3	0,016 7	∞
Free-progressive sound wave	a_{11}	0,104 – estimate from free-field room performance tests	√3	0,060 0	∞
SLM and RM mountings	a_{12}	0,104 – estimate of effect derived from measurement	√3	0,060 0	∞
Microphone diameters	a_{13}	0 – assumed equal	√3	0	∞
Rounding	a_{14}	0,005 – final correction quoted to 2 decimal places	√3	0,002 9	∞
Repeatability	a_{15}	0,06 – derived from repeat measurements	1	0,06	2
Combined standard uncertainty $u(C_{FF,SLM})$ dB				0,140	
Expanded uncertainty of $C_{FF,SLM}$; (normal) $k = 2$				0,28	Effective degrees of freedom >30

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

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4 To be published.

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