IEC 60318-1

Edition 2.0 2009-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Electroacoustics – Simulators of human head and ear –
Part 1: Ear simulator for the measurement of supra-aural and circumaural earphones**

**Electroacoustique – Simulateurs de tête et d'oreille humaines –
Partie 1: Simulateur d'oreille pour la mesure des écouteurs supra-auraux et circumauraux**

IEC 60318-1:2009

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROACOUSTICS – SIMULATORS OF HUMAN HEAD AND EAR –

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International Standard IEC 60318-1 has been prepared by IEC technical committee 29: Electroacoustics.

This second edition cancels and replaces the first edition published in 1998 as well as replacing IEC 60318-2, published in1998. It constitutes a technical revision.

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

- an extension of the frequency range to 16 kHz;
- a revised specification for the acoustical transfer impedance, including tolerances;
- a method for measuring the acoustical transfer impedance;
- expanded measurement uncertainties.

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

FDIS	Report on voting
29/683/FDIS	29/698/RVD

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

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

A list of all parts of IEC 60318 series, under the general title *Electroacoustics – Simulators of human head and ear*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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- withdrawn;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
- amended.

ELECTROACOUSTICS –
SIMULATORS OF HUMAN HEAD AND EAR –

Part 1: Ear simulator for the measurement of supra-aural and circumaural earphones

1 Scope

This part of IEC 60318 specifies an ear simulator for the measurement of supra-aural and circumaural earphones (used for example in audiometry and telephonometry) applied to the ear without acoustical leakage, in the frequency range from 20 Hz to 10 kHz. The same device can be used as an acoustic coupler at additional frequencies up to 16 kHz.

NOTE 1 This device has alternative configurations for supra-aural earphones and different types of circumaural earphones. In practice, the alternative configurations can be realised through the use of adapters where necessary.

NOTE 2 Repeatability for supra-aural and circumaural earphones may get significantly worse above 10 kHz.

2 Normative references

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

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

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
ear simulator
device for measuring the acoustic output of sound sources where the sound pressure is measured by a calibrated microphone coupled to the source so that the overall acoustic impedance of the device approximates that of the normal human ear at a given location and in a given frequency band

3.2
acoustic coupler
device for measuring the acoustic output of sound sources where the sound pressure is measured by a calibrated microphone coupled to the source by a cavity of predetermined shape and volume which does not necessarily approximate the acoustical impedance of the normal human ear

3.3
supra-aural earphone
earphone applied externally to the outer ear and intended to rest on the pinna

3.4
circumaural earphone
earphone which encloses the pinna and rests on the surrounding surface of the head

NOTE Contact with the head is normally maintained by compliant cushions. Circumaural earphones may touch but not significantly compress the pinna.

3.5
acoustic impedance
at a specified surface, quotient of the sound pressure by volume velocity through the surface

NOTE Unit: $Pa \cdot s \cdot m^{-3}$.

3.6
acoustic transfer impedance of the ear simulator
quotient of the sound pressure acting on the diaphragm of the microphone by volume velocity through the planar surface bounded by the upper rim of the ear simulator

NOTE Unit: $Pa \cdot s \cdot m^{-3}$.

3.7
level of acoustic transfer impedance
ten times the logarithm to the base of ten of the quotient of the absolute value (modulus) of the squared acoustic transfer impedance of the ear simulator by the squared reference acoustic transfer impedance of one pascal second per cubic meter ($Pa \cdot s \cdot m^{-3}$)

NOTE Unit: decibel (dB).

4 Construction

4.1 General

The measurements of supra-aural and circumaural earphones each require the ear simulator to have a different external configuration. Apart from this, the remaining specifications apply to both types of earphone.

For supra-aural earphones the coupling surface of the ear simulator has sloped sides to match the shape of the earphone cushions. For circumaural earphones, a flat coupling surface is specified to suit the variety of earphone designs that may be encountered. Figure 1 shows the ear simulator configuration for supra-aural earphones and Figure 2 shows that for circumaural earphones.

Internally, the ear simulator is composed of three acoustically coupled cavities. The primary cavity is conical in shape and houses the microphone at its lower surface. The key dimensions of the primary cavity and the acoustical compliances of each cavity are specified in Figure 1 (and replicated in Figure 2). The secondary cavities are coupled to the primary cavity by elements having acoustical mass and resistance. The lumped-parameter values of the coupling elements shall be as follows:

M_{a2} = 4,5 × 10^2 $Pa \cdot s^2 \cdot m^{-3}$

M_{a3} = 1,06 × 10^4 $Pa \cdot s^2 \cdot m^{-3}$

R_{a2} = 6,05 × 10^6 $Pa \cdot s \cdot m^{-3}$

R_{a3} = 2 × 10^7 $Pa \cdot s \cdot m^{-3}$

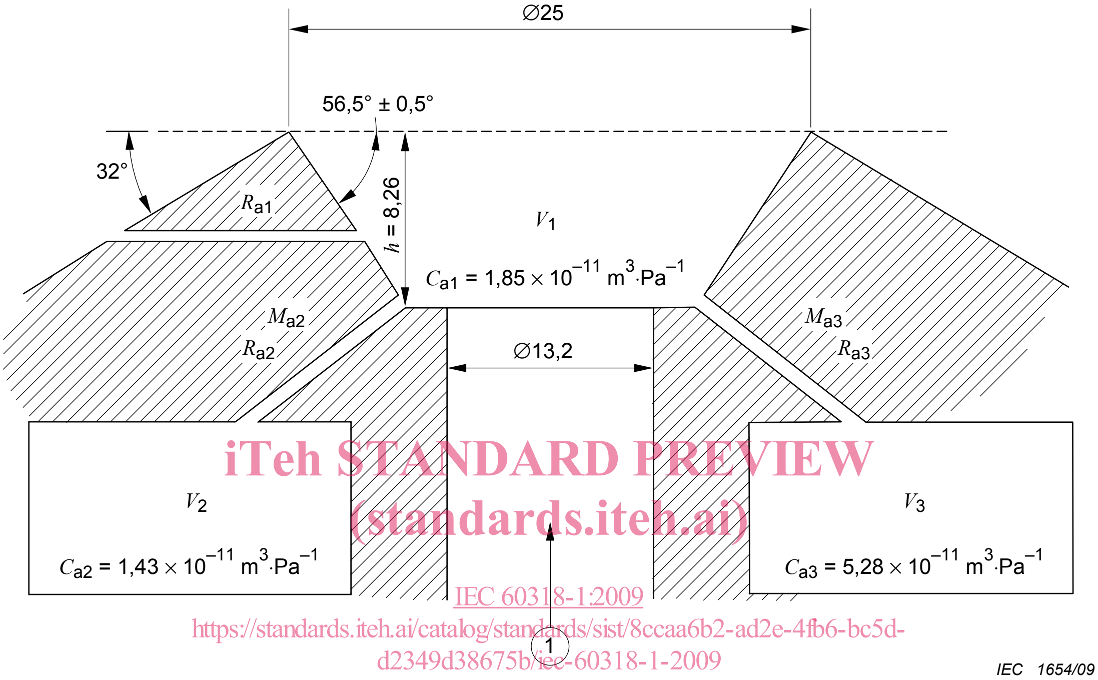
M_{a2} and M_{a3} represent acoustic masses, R_{a2} and R_{a3} represent acoustic resistances. These values are applicable for the reference environment conditions and are subject to the tolerances of 4.2.

A pressure equalization mechanism (R_{a1}) is included.

An electrical analogue of the ear simulator is given in Annex A.

The general construction of the ear simulator and mounting of the microphone shall aim to reduce the response to vibration of any earphone or to sound outside the cavity.

Dimensions in millimeters



Key

1 microphone

NOTE 1 The volume of cavity V_1 includes the total effective volume of the microphone capsule, a corresponding correction for the presence of a protective grid also being taken into account.

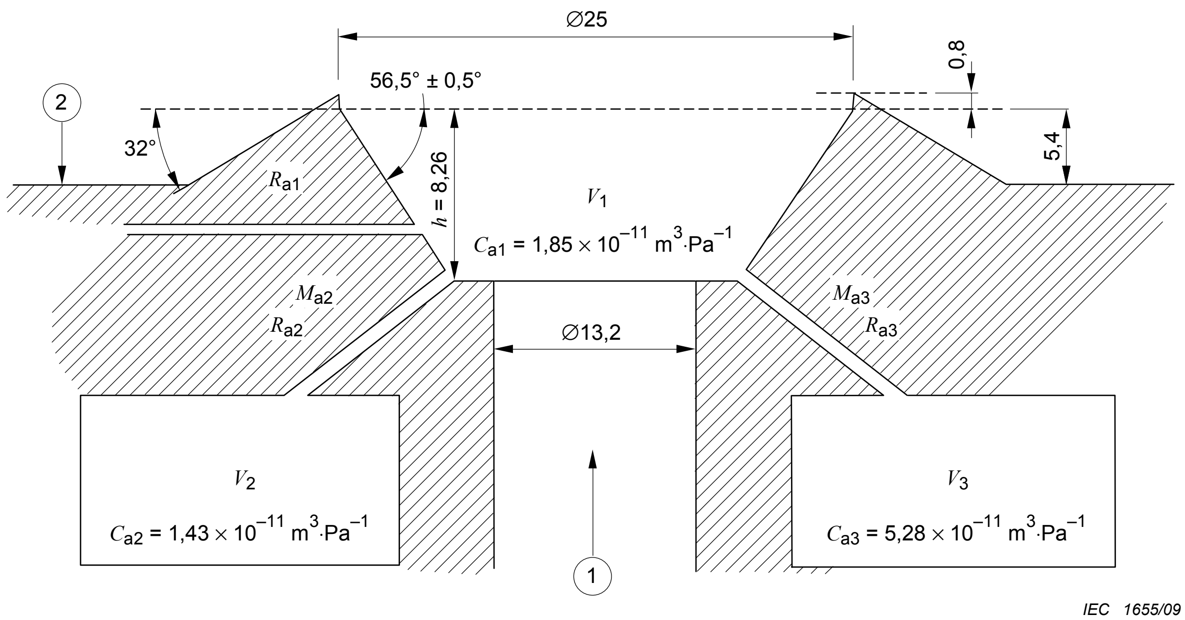
NOTE 2 The acoustical compliance of the cavities may depend on the shape as well as the volume.

NOTE 3 Tolerances on dimensions are specified in 4.2.

Figure 1 – Schematic cross-section of the ear simulator configured for supra-aural earphones

An ear simulator only capable of having the configuration shown in Figure 1, but meeting all other specifications in this standard shall be considered as conforming to this part of IEC 60318 for supra-aural earphones only.

Dimensions in millimeters



Key

1 microphone

2 flat coupling surface

NOTE 1 The external face of the flat surface should be marked with a series of rings concentric with the opening in the ear simulator to aid alignment of the earphone.

NOTE 2 The 0,8 mm lip at the entrance to the ear simulator is an artefact of a typical practical realisation of this configuration, where a flat plate adapter is inserted between the body of the ear simulator and a removable conical ring (see Annex B for details).

NOTE 3 Tolerances on dimensions are specified in 4.2.

Figure 2 – Schematic cross-section of the ear simulator configured for circumaural earphones

The dimensions of the flat coupling surface are not critical, but shall be sized to accommodate the range of circumaural earphones to be measured (together with their headbands. if appropriate), noting that these are often non-circular. A size of approximately 100 mm × 120 mm is appropriate.

An ear simulator only capable of having the configuration shown in Figure 2, but meeting all other specifications in this standard shall be considered as conforming to this part of IEC 60318 for circumaural earphones only.

An example of a design of the ear simulator, including the adapter to convert from supra-aural to circumaural configuration, is shown in Annex B.

4.2 Tolerances

The following specified tolerances are for manufacturing the ear simulator and are not normally subject to checking by a test laboratory. The specified dimensions determine the acoustic transfer impedance of the device, which can be tested for conformance (see 4.7).

The distance h between a plane through the upper rim of the ear simulator and the diaphragm of the microphone shall be 8,26 mm ± 0,30 mm.

Other specified linear dimensions shall have a tolerance of ± 0,3 mm.

The angular dimensions 56,5° shall have a tolerance of ± 0,5°.

The angular dimension 32° shall have a tolerance of $^{+3^\circ}_{-1^\circ}$.

The acoustical compliances, masses and resistances shall each have a tolerance of ± 10 %.

4.3 Static pressure equalization

Any change in the static pressure within the ear simulator caused by assembly of the earphone to the cavity and microphone shall decay toward the static ambient pressure with a time constant less than 1,5 s. If this necessitates the introduction of a controlled leak in the ear simulator, it shall have the following characteristics:

a) it shall not alter the total cavity volume by more than 20 mm^3;
b) it shall attenuate external sound reaching the cavity, with the entrance blocked, by at least 16 dB at 100 Hz, increasing by 6 dB per octave for increasing frequency.

NOTE 1 This specification for the static pressure equalization is equivalent to a value for R_{a1} of nominally 500 × 10^6 Pa·s·m^{-3}.

NOTE 2 Equalization can be realised, for example, by a capillary tube with a diameter of 0,3 mm and a length of 9 mm.

4.4 Calibrated pressure-type microphone

A calibrated microphone is located at the base of cavity V_1. The acoustic impedance of the microphone diaphragm shall be high, so that the equivalent volume is less than 20 mm^3 over the specified range of frequencies.

In the frequency range from 20 Hz to 10 kHz, the overall pressure sensitivity level of the microphone and associated measuring system shall be known with an uncertainty not exceeding 0,2 dB for a level of confidence of 95 %. The microphone shall be coupled to the cavity V_1 with a protective grid and without leakage. The microphone shall conform to the requirements of IEC 61094-4 for a type WS2P microphone.

For measurements above 10 kHz the overall pressure sensitivity level of the microphone and associated measuring system over the specified frequency range shall be known with an uncertainty not exceeding 0,5 dB for a level of confidence of 95 %. Furthermore there shall be no protection grid or other obstruction between the microphone diaphragm and cavity V_1.

The make and model of the microphone shall be specified, together with any adapter used.

NOTE 1 The obstruction caused by the protection grid may cause the sound pressure acting on the microphone diaphragm to be non-uniform.

NOTE 2 A microphone conforming with the requirements of IEC 61094-1 [1][1] for a type LS2aP microphone provides a suitable configuration for use above 10 kHz. For some models of type WS2P microphone the manufacturer supplies an ring to be used in place of the grid, that enables the microphone to be converted to type LS2aP.

4.5 Material

The ear simulator and the adapters shall be made of a material that has no negative influences on its performance. For example it should be acoustically hard and dimensionally stable.

[1] Figures in brackets refer to the bibliography.

4.6 Measurement plane

The plane of the microphone diaphragm shall be understood to represent the entrance of the mean human ear canal, up to 10 kHz. Beyond this frequency, the device can only be considered as an acoustic coupler having no direct relation to the mean human ear canal.

4.7 Acoustic transfer impedance

In the frequency range below 10 kHz, the ear simulator is designed so that its acoustic transfer impedance matches the input impedance of the average human ear under sealed conditions. Under reference environmental conditions, the ear simulator shall couple an applied earphone to the microphone with an acoustic transfer impedance given in Table 1. The tolerance on the frequency specified in Table 1 is 0,1 %.

NOTE 1 The acoustic transfer impedance is specified, because for practical reasons the locations of the earphone and microphone are physically separated within the ear simulator. By modelling the acoustic input impedance of real ears with the acoustic transfer impedance of the ear simulator, the sound pressure measured by the microphone represents the sound pressure applied to the entrance of the ear canal.

NOTE 2 The acoustic impedance of an applied earphone will add in parallel to the specified acoustic transfer impedance, when the earphone is modelled by a source of volume velocity in parallel with the acoustic impedance of the earphone.

NOTE 3 The specification is only given in the frequency range where the device acts as an ear simulator.

Annex C gives details of a method for determining the acoustic transfer impedance. The specified tolerance shall be reduced by an amount equal to the expanded uncertainty of measurement before deciding if a device conforms to this specification.

5 Coupling of earphone to ear simulator

5.1 Supra-aural earphones

Supra-aural earphones shall be measured with the ear simulator having the configuration shown in Figure 1.

The earphone to be measured shall be applied to the ear simulator without acoustic leakage with a force 4,5 N ± 0,5 N, not including the weight of the earphone itself. If, for a specific earphone, a different coupling force is specified this shall be stated.

The earphone shall not rest on the sloping side of the ear simulator, but only on the upper rim.

In the case of earphones with a hard ear cushion, a thin film of sealing material or a thin soft rubber ring shall be used on the lip in order to produce an effective seal between the earphone and the upper edge of the coupler.

5.2 Circumaural earphones

Circumaural earphones shall be measured with the ear simulator having the configuration shown in Figure 2.

The earphone shall be positioned symmetrically. For earphones with an asymmetric cushion the manner of placement on the coupler shall be stated by the manufacturer. The coupling force applied for the calibration shall be stated.

Table 1 – Specification for the acoustic transfer impedance level

Frequency Hz	**Impedance level (ref. 1 Pa·s·m^{-3})** dB	**Tolerance on level** ± dB
100	145,8	1,5
126	144,4	1,5
158	143,2	1,5
200	143,0	1,5
251	143,5	1,5
316	144,1	1,5
398	143,4	1,5
501	141,4	1,5
631	139,0	1,5
750*	137,2	1,5
794	136,6	1,5
1 000	134,4	1,5
1 259	132,5	1,5
1 500*	131,4	1,5
1 585	131,1	1,5
1 995	131,5	1,5
2 512	131,5	1,5
3 000*	130,8	1,5
3 162	130,6	1,5
3 982	128,5	1,5
5 012	126,0	1,5
6 000*	124,0	1,5
6 310	123,6	1,5
7 943	121,1	1,5
9 000*	119,9	1,5
10 000	118,5	1,5

NOTE 1 The values of frequency in Table 1 are calculated from 1 000 × $10^{n/10}$, where n is a positive or negative integer or zero, except those marked * which are used specifically in audiometry.

NOTE 2 Using the measurement method described in Annex C, it is not easy to measure the acoustic transfer impedance level below 100 Hz, due to the effects of an imperfectly sealed measurement configuration. However, the acoustic transfer impedance between 20 Hz and 125 Hz is governed predominantly by the volumetric elements of the ear simulator, and their contribution to the overall acoustic transfer impedance can be validated by the measurements at higher frequencies.

6 Calibration

6.1 Reference environmental conditions

The reference environmental conditions are the following:

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

6.2 Method of calibration

The manufacturer shall describe in an instruction manual a method of calibration for the complete ear simulator, including the microphone, and for determining stability.

The quantity to be measured and the calibration method may vary depending on the intended application.

The calibration shall be performed at the reference environmental conditions with the following tolerances:

– static pressure: ± 3 kPa
– temperature: ± 3 °C
– relative humidity ± 20 %

If it is not possible to meet these requirements, or the application requires other conditions to be used, the actual values shall be stated.

7 Maximum permitted expanded uncertainty of measurements

Table 2 specifies the maximum permitted expanded uncertainty U_{max}, calculated with a coverage factor of k = 2 to give a level of confidence of approximately 95 %, associated with the measurements undertaken in this standard, according to ISO/IEC Guide 98-3. One set of values for U_{max} is given for basic type approval measurements.

The expanded uncertainties of measurements given in Table 2 are the maximum permitted for demonstration of conformance to the requirements of this standard. If the actual expanded uncertainty of a measurement performed by the test laboratory exceeds the maximum permitted value in Table 2, the measurement shall not be used to demonstrate conformance to the requirements of this part of IEC 60318.