
Acoustics — Hearing protectors —

Part 6:

**Determination of sound attenuation of
active noise reduction earmuffs**

Acoustique — Protecteurs individuels contre le bruit —

*Partie 6: Détermination de l'affaiblissement acoustique des serre-tête
à réduction active du bruit*

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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Contents

	Page
Foreword	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Symbols and abbreviated terms	2
5 Testing	3
5.1 Specimens and conditioning.....	3
5.2 Test conditions.....	3
5.3 Test signals.....	3
5.3.1 Broadband noise for measuring active insertion loss.....	3
5.3.2 Red noise for testing linear operation.....	3
5.4 Test method.....	4
5.4.1 General.....	4
5.4.2 Oscillation and acoustic malfunction.....	4
5.4.3 Active insertion loss.....	4
5.4.4 Maximum sound pressure level for linear operation.....	4
5.5 Calculation of the total attenuation.....	5
5.6 Test report.....	5
Annex A (normative) Uncertainty of the mean active insertion loss of ANR earmuffs	7
Bibliography	11

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

A list of all the parts in the ISO 4869 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Active noise reduction earmuffs are designed to provide additional attenuation of external sounds by means of a noise cancellation circuit. This additional attenuation is generally more effective at low frequencies. Such earmuffs can be selected for use in low-frequency dominated high noise environments.

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Acoustics — Hearing protectors —

Part 6:

Determination of sound attenuation of active noise reduction earmuffs

1 Scope

This document is concerned with active noise reduction (ANR) earmuffs. It specifies the test methods for the determination of the active insertion loss and calculation procedures for deriving the total attenuation. For this aim, the values of sound attenuation in the passive mode also have to be known and are determined according to ISO 4869-1. These methods are intended for steady noise exposures and are not applicable to noises containing impulsive components.

The test methods account for the acoustical interaction between the wearer and the device using measurements of passive (REAT) and active microphone-in-real-ear (MIRE) measurements as specified in ISO 4869-1 and ISO 11904-1, respectively.

2 Normative references

The following documents are referred to in the text in such way that some or all of their content constitutes requirements 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.

ISO 4869-1, *Acoustics — Hearing protectors — Part 1: Subjective method for the measurement of sound attenuation*

ISO 4869-2, *Acoustics — Hearing protectors — Part 2: Estimation of effective A-weighted sound pressure levels when hearing protectors are worn*

ISO 11904-1, *Acoustics — Determination of sound immission from sound sources placed close to the ear — Part 1: Technique using a microphone in a real ear (MIRE technique)*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4869-1, ISO 4869-2, ISO 11904-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

active noise reduction earmuff **ANR earmuff**

earmuff that provides additional attenuation of external sounds by means of a noise cancellation circuit

3.2

active mode

operation of the *ANR earmuff* (3.1) with the ANR circuit active

3.3

passive mode

operation of the *ANR earmuff* (3.1) with the ANR circuit not active

3.4

active insertion loss

AIL

additional sound attenuation of the *ANR earmuff* (3.1) provided in the *active mode* (3.2) compared to the *passive mode* (3.3)

Note 1 to entry: The active insertion loss is measured according to 5.4.3.

3.5

red noise

random noise signal with a spectral density that decreases by 6 dB per octave over a frequency range which does not include DC

Note 1 to entry: The definition is often phrased as noise whose power spectral density is proportional to $1/f^2$.

3.6

pink noise

random noise signal with a spectral density that decreases by 3 dB per octave, giving constant energy per octave

Note 1 to entry: The definition is often phrased as noise whose power spectral density is inversely proportional to frequency.

[SOURCE: ISO 7240-24:2016, 3.1.11; modified — Note 1 to entry added]

4 Symbols and abbreviated terms

α	Active insertion loss
A_{total}	Total attenuation
ANR	Active noise reduction
REAT	Real-ear attenuation at threshold
MIRE	Microphone in a real ear
FFT	Fast Fourier transform
APV	Assumed protection value of the hearing protector
H	High frequency attenuation value
M	Medium frequency attenuation value
L	Low frequency attenuation value
HML	Method based on H, M, L
SNR	Single number rating

5 Testing

5.1 Specimens and conditioning

Four pairs of earmuffs shall be submitted for testing. Each individual earmuff cup shall be uniquely marked for identification. The power source shall be fully operational.

All specimens shall be conditioned and tested in an environment having a temperature of $(22 \pm 5) ^\circ\text{C}$ and a relative humidity of not more than 85 %.

5.2 Test conditions

Random incidence sound field conditions at the reference point as described in ISO 4869-1 are required for all one-third-octave bands of the test signals specified in 5.3.

5.3 Test signals

5.3.1 Broadband noise for measuring active insertion loss

A broadband noise signal shall be used to determine the diffuse-field related sound pressure levels. The test signal at the reference point shall be a broadband random noise in each one-third-octave band centred from 50 Hz (or 100 Hz) to 10 000 Hz, and shall be at least 3 dB down at the one-third-octave bands below and above these limit bands, and roll off at least 12 dB/octave for the bands below and above that. Adjacent one-third-octave-band levels shall not differ by more than 3 dB. The difference between the maximum and minimum one-third-octave-band levels shall not exceed 10 dB from 50 Hz (or 100 Hz) to 10 000 Hz.

NOTE 1 Pink noise is a suitable broadband noise signal.

If the total attenuation is to be determined for the frequency range from 63 Hz to 8 000 Hz, the test signal shall extend from 50 Hz to 10 000 Hz. If the test signal is only available for 100 Hz and above, the total attenuation can only be determined from 125 Hz upwards.

The measurements described above shall be conducted with a WS2P or WS2D microphone (working standard, ½ inch, pressure field/random incidence) according to IEC 61094-4.

The use of digital pseudorandom white and pink noise sources is restricted to measurements of passive hearing protectors. Some FFT analyzers with internally generated digital pseudorandom white and pink noise sources with known statistical characteristics, i.e. wide sense stationary, can potentially overestimate the active insertion loss with some ANR hearing protectors.

The sound pressure level measured under the hearing protector (occluded condition) in each one-third-octave band with the test noise on shall be at least 10 dB higher than the sound pressure level measured under the hearing protector with the test noise off. The test signal shall be presented up to an A-weighted sound pressure level of 95 dB.

NOTE 2 Test signals up to an A-weighted sound pressure level of 110 dB can be necessary if the device incorporates a threshold level only above which the active attenuation is working.

5.3.2 Red noise for testing linear operation

Red noise shall be used with the maximum of the spectrum in the 125 Hz one-third-octave band and one-third-octave-band levels in the 100 Hz and 80 Hz band of 1 dB and 3 dB less than the maximum. The signal shall be presented up to an A-weighted sound pressure level of 110 dB.

5.4 Test method

5.4.1 General

The measurements described in [5.4.3](#) determine the active contribution (active insertion loss) to the total attenuation of the earmuff. This quantity is derived from two separately measured data sets:

- a) the sound pressure level at the wearers' ears in the active mode,
- b) the sound pressure level at the wearers' ears in the passive mode of the ANR earmuff.

The difference of these two data sets yields the active insertion loss.

For both measurements a) and b), the microphone-in-real-ear technique (MIRE) with closed earcanals shall be used according to ISO 11904-1, including the requirements for averaging times.

Sixteen test subjects, with separate measurements made on both ears, shall be used. Each specimen shall be tested by four test subjects.

5.4.2 Oscillation and acoustic malfunction

If any subject reports sustained oscillations or acoustic malfunctions when the ANR system is switched on, the subject shall be asked to switch the ANR system off, remove the earmuffs and then refit them, according to the manufacturer's instructions. If the oscillation persists when the ANR system is switched on again, the specimen should be rejected and replaced by a new one. If the malfunction is caused by some characteristics of the subject, the subject may be replaced. In any case, the occurrence of sustained oscillation or acoustic malfunction shall be reported.

5.4.3 Active insertion loss

For the two measurements in the active and passive modes from which the active insertion loss is calculated, the broadband noise as described in [5.3.1](#) shall be set at an overall A-weighted sound pressure level in the range from 85 dB to 95 dB. The timespan between the two measurements shall be as short as possible and the test conditions shall be unaltered, especially the fitting of the earmuff and the positions of the microphone in real-ear. The measurements shall be performed with the same test subjects as the measurements of the passive sound attenuation according to ISO 4869-1. The spectra in active and passive mode shall be determined for the one-third-octave bands between 50 Hz (or 100 Hz) and 10 000 Hz. For each of the 16 test subjects, the difference between passive and active mode shall be calculated to derive the active insertion loss as per [5.5](#).

For devices that incorporate a threshold level only above which the active attenuation is working, the measurements are to be carried out 5 dB above that threshold (specified by the manufacturer), but not lower than 85 dB or above 110 dB.

NOTE This option exists with some devices that combine level-dependence and active attenuation. For these and other devices, it is possible that active attenuation will not function at A-weighted sound pressure levels as low as 85 dB to 95 dB, even if switched on.

5.4.4 Maximum sound pressure level for linear operation

For each subject and each ear, the linearity in the active mode shall be checked in the 125 Hz octave band (calculated from the three one-third-octave bands 100 Hz, 125 Hz and 160 Hz). Red noise as described in [5.3.2](#) shall be used. The sound pressure level at the subject's ear shall be monitored, starting at the overall sound pressure level set for the measurement of active insertion loss (see [5.4.3](#)) and increasing the sound pressure level in 5 dB steps. It shall be checked that the sound pressure level at the ear also increases by 5 dB (with a tolerance of ± 1 dB). The maximum external A-weighted sound pressure level to be applied shall be 110 dB.

The highest external sound pressure level for which this linear relationship remains valid for all samples and subjects shall be reported. If the linear relationship remains valid up to an external A-weighted sound pressure level of 110 dB, this shall be stated.

5.5 Calculation of the total attenuation

The total (active plus passive) attenuation shall be derived in octave bands. It shall be calculated using the active insertion loss measured according to 5.4.3 and the passive sound attenuation determined according to ISO 4869-1 (REAT method) combining these two datasets for each test subject individually.

The detailed computations are described below and an example is given in <http://standards.iso.org/iso/4869/-6/ed-1/en>.

- a) For each subject, the passive sound attenuation data (REAT) shall be linearly interpolated in one-third-octave bands between 63 Hz (or 125 Hz) and 8 000 Hz and extrapolated to 50 Hz (or 100 Hz, if applicable) and 10 000 Hz.
- b) For each subject, and in each one-third-octave band, only the ear with the lower value of the active insertion loss shall be chosen.
- c) For each subject, the results from steps a) and b) shall be arithmetically added in each one-third-octave band to gain the total attenuation per subject, $A_{\text{total},f,j}$.

NOTE The subscript f represents each one-third-octave mid-band frequency. The subscript j represents the number of the test subject as per ISO 4869-2.

- d) To obtain the total attenuation in octave bands for each subject, the octave-band attenuations shall be calculated from their respective one-third-octave-band attenuations. The appropriate individual one-third-octave-band attenuations at frequencies f_1 , f_2 and f_3 shall be energetically averaged to estimate each required octave-band attenuation according to [Formula \(1\)](#):

$$A_{\text{total,oct},j} = -10 \cdot \lg \left[\left(10^{-0,1 \cdot A_{\text{total},f_1,j}} + 10^{-0,1 \cdot A_{\text{total},f_2,j}} + 10^{-0,1 \cdot A_{\text{total},f_3,j}} \right) / 3 \right] \text{dB} \quad (1)$$

- e) The sixteen data sets of total attenuation in octave bands shall be used to calculate the mean and standard deviation and the APV, HML values and SNR value according to ISO 4869-2 with a protection performance of 84 %.

5.6 Test report

The test report shall include the following information.

- a) Manufacturer, model and description of the device;
- b) Date of the test;
- c) Reference to this document, i.e. ISO 4869-6:2019
- d) The active insertion loss for all 16 test subjects (left and right ear) for all frequencies tested;
- e) Mean and standard deviation of the ears with the lower value of the active insertion loss as per 5.5 e) over all 16 test subjects for all frequencies tested and the expanded uncertainty, according to [Annex A](#);
- f) The passive sound attenuation according to ISO 4869-1 for all 16 test subjects and all frequencies tested;
- g) The total attenuation for all 16 test subjects in one-third-octave bands and in octave bands;
- h) The mean, the standard deviation and the calculated APV for each test frequency band (63 Hz or 125 Hz to 8 000 Hz) for the total attenuation together with the derived HML and SNR values;

- i) The highest external A-weighted sound pressure level for which the sound pressure level at the ear remains linearly related for all samples and subjects tested. If the test reached 110 dB, this shall also be stated (“... remained linearly related up to 110 dB, the highest level tested”);
- j) The occurrence or not of any oscillations or acoustic malfunction in the course of testing;
- k) Details of the measurement environment, including ambient temperature, atmospheric pressure and humidity.

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Annex A (normative)

Uncertainty of the mean active insertion loss of ANR earmuffs

A.1 General

Uncertainties in the measurement of the mean active insertion loss of ANR earmuffs according to this document arise from various sources, such as the selection of the test subject group, fitting of the earmuff on the test subjects, variation in the tester and administration of the test protocol, positioning of the MIRE microphone, specimen variability, influence from the sound field, test signal generation and MIRE data acquisition equipment. The description below follows the outline given in ISO/IEC Guide 98-3.

The model, including uncertainties, for the calculation of the active insertion loss, α , for the test signals specified in this document is

$$\alpha = \beta + \delta_{\text{meth}} + \delta_{\text{eq}} + \delta_{\text{env}} \quad (\text{A.1})$$

where

- β is the outcome for an active insertion loss measured according to this document;
- δ_{meth} is the input quantity to allow for the variation due to the selection of the test subject group, fitting of the earmuff, variation in tester and administration of protocol, positioning of the MIRE microphone, and specimen variability including electronic circuitry;
- δ_{eq} is the input quantity to allow for any deviation in the performance of the test signal generation equipment and variations in the measured sound levels due to nonlinearities and other errors associated with the MIRE microphone, preamplifier and/or sound analysis system;
- δ_{env} is the input quantity to allow for influence from non-ideal or varying environmental conditions, such as sound field and ambient noise.

A probability density function is associated with each source of uncertainty. The best estimate of each source is the mean value. The mean values of the δ -terms in [Formula \(A.1\)](#) are assumed to be zero, and thus β is the best estimate of α . The standard deviation of each source, i , is an estimate of the standard uncertainty, u_i , associated with that source.

The combined uncertainty, u , depends on the standard uncertainties, u_i , from all sources and their sensitivity coefficients, c_i . The sensitivity coefficient is a measure of how the value of active insertion loss is affected by the change in its respective input quantity. The combined standard uncertainty is given by the square root of the sum of the squares of the separate standard uncertainties weighted by the sensitivity coefficients [see [Formula \(A.2\)](#)].

$$u = \sqrt{\sum_i (c_i u_i)^2} \quad (\text{A.2})$$

where

- u is the combined uncertainty;
- c_i is the sensitivity coefficient of source i ;
- u_i is the standard uncertainty of source i .

In the model [Formula (A.1)], all of the probability distributions for the standard uncertainties, u_i , are assumed to be normal and all sensitivity coefficients, c_i , have a value of 1.

Table A.1 illustrates the general estimation of the input quantities for δ_{meth} , δ_{eq} , and δ_{env} . The value of the standard uncertainty, u_{meth} , associated with input quantity, δ_{meth} , is frequency dependent, but for the estimates in this annex, frequency dependence is presumed minimal. The uncertainty value, u_{meth} , is greater between laboratories than within laboratories. The values of u_{eq} and u_{env} are assumed to be independent of test frequency.

The standard uncertainty values supplied in this annex are considered representative of the measurements and equipment that would normally be used in active insertion loss testing.

Table A.1 — General form of an uncertainty budget for ANR earmuff active insertion loss determinations

Source	Mean estimate	Standard uncertainty	Probability distribution	Sensitivity coefficient	Uncertainty contribution
	dB	u_i dB		c_i	$u_i \cdot c_i$ dB
δ_{meth}	0	u_{meth}	Normal	1	u_{meth}
δ_{eq}	0	u_{eq}	Normal	1	u_{eq}
δ_{env}	0	u_{env}	Normal	1	u_{env}

The expanded uncertainty, U_{95} , is computed by multiplying the combined standard uncertainty, u , by a coverage factor $k = 2$ (appropriate for normally distributed parameters), such that an interval from $\alpha - U_{95}$ to $\alpha + U_{95}$ covers 95 % of the values of α .

A.2 Uncertainty within a laboratory

The combined uncertainty, u , within a laboratory is the standard deviation of the mean active insertion loss. At each test frequency, this is estimated from a calculation of the standard deviation of the individual active insertion loss data divided by the square root of the number of test subjects, i.e. $\sqrt{16} = 4$. In principle, for each test subject, values for the left and the right ear are available. According to 5.5 b), only the ear with the lower value of the active insertion loss is chosen and used for the calculation of the total attenuation. This leads to a data set of 16 values.

Table A.2 shows the estimated uncertainty contributions within a laboratory for ANR earmuffs for such a data set of 16 values. It also shows the combined and expanded uncertainties. The numbers given here are typical uncertainty values based on the experience obtained in laboratories around the world.