INTERNATIONAL STANDARD

ISO 7029

Third edition
2017-01

Acoustics — Statistical distribution of hearing thresholds related to age and gender

Acoustique — Distribution statistique des seuils d'audition en fonction de l'âge et du sexe

Reference number
ISO 7029:2017(E)

Contents

Page

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 on 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 the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 43, *Acoustics*.

This third edition cancels and replaces the second edition (ISO 7029:2000), which has been technically revised with the following changes:

— new data has been adopted, as explained in the introduction;

— estimation accuracy of expected medians and statistical distributions of hearing thresholds were generally improved by modifying the formulae used;

— the age range for which the expected medians and statistical distributions of hearing thresholds are calculable was extended to the age of 80 years at audiometric frequencies of 2 000 Hz and below; it was up to 70 years for all frequencies in the previous editions.

Introduction

The sensitivity of human hearing is well known to decrease with age and the impairment of hearing develops more rapidly for sound at high frequencies than at low frequencies. Moreover, the magnitude of this effect varies considerably among individuals.

When testing the hearing of persons markedly over 18 years of age, part of any observed hearing loss will probably be associated with age. It is important to be aware of this when estimating the amount of hearing loss attributable to other causes under investigation.

It should be noted that a decrease in hearing ability may not necessarily be caused by ageing itself, but by many injurious influences during lifetime, which are not known in detail.

This document is based on a thorough examination of literature data on the differences between groups having different ages for populations of otologically normal persons as defined herein. Distinction is made between males and females since the difference is found to be of significance in the case of older age groups. The data have been derived from investigations using pure tones transmitted to the ear from an earphone, but no evidence is known that disqualifies their use for noise band stimuli.

This document is a revision of the second edition (ISO 7029:2000). The expected medians and statistical distributions of hearing thresholds were re-estimated using audiometric data published after the establishment of the first edition (ISO 7029:1984). All the data on which the second edition had been based were discarded. Thus, this third edition describes the hearing sensitivity profile of people in recent years.

Hearing thresholds presented in this document are generally lower at high frequencies than those in the previous editions of this document. The 4 kHz dip observed in males has become negligibly small. The source data of the previous editions might not have been screened rigorously in terms of hearing abnormalities. Problems related to instrumentation might also have affected measurement data.

The expected median hearing thresholds at the frequencies from 9 000 Hz to 12 500 Hz are presented for information. Audiometry at those frequencies is executable using an extended high-frequency audiometer.

Acoustics — Statistical distribution of hearing thresholds related to age and gender

1 Scope

This document provides descriptive statistics of the hearing threshold deviation for populations of otologically normal persons of various ages under monaural earphone listening conditions. It specifies the following, for populations within the age limits from 18 years to 80 years for the range of audiometric frequencies from 125 Hz to 8 000 Hz:

a) the expected median value of hearing thresholds given relative to the median hearing threshold at the age of 18 years;

b) the expected statistical distribution above and below the median value.

For the frequencies from 3 000 Hz to 8 000 Hz, the median and statistical distribution for populations above 70 years are presented for information only.

This document also provides for information the expected median values at audiometric frequencies from 9 000 Hz to 12 500 Hz within the age limits from 22 years to 80 years.

The data are applicable for estimating the amount of hearing loss caused by a specific agent in a population. Such a comparison is valid if the population under study consists of persons who are otologically normal except for the effect of the specific agent. Noise exposure is an example of a specific agent and for this application, selected data from this document are referred to as “database A” in ISO 1999.

NOTE 1 ISO 1999:2013, Database A is based on a previous edition of ISO 7029.

The data may also be used to assess an individual’s hearing in relation to the distribution of hearing thresholds which is normal for the person’s age group. However, it is not possible to determine for an individual precisely which part of an observed hearing loss is attributable to an accumulation of detrimental effects on the hearing which increase with age, and which part has been caused by other factors such as noise.

The hearing threshold deviation as defined herein and the hearing threshold level as defined in other International Standards (ISO 389-1, ISO 389-2, ISO 389-5, ISO 389-8, ISO 8253-1, ISO 8253-2, IEC 60645-1) express the hearing threshold of an individual or an individual ear, respectively, relative to

— the expected median hearing threshold of 18-year-old age group of the same gender, or

— a reference zero level specified in various parts of ISO 389.

To the extent that the reference zero level represents the median of the 18-year-old population, the values of the two terms will be the same.

NOTE 2 The values of these two are not always the same for some reasons. One reason is that the reference zero level has been determined based on the hearing threshold levels of persons older than 18 years, including those aged up to 25 years or to 30 years, who have slightly worse hearing sensitivity on average.

NOTE 3 ISO 28961 specifies the expected statistical distribution of hearing thresholds, expressed in sound pressure level in decibels, for populations of otologically normal persons of the age from 18 years to 25 years under binaural, free-field listening conditions. It enables the calculation not only at audiometric frequencies, but also for other frequencies at one-third-octave intervals from 20 Hz to 16 000 Hz.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp/

3.1
otologically normal person
person in a normal state of health who is free from all signs or symptoms of ear disease and from obstructing wax in the ear canal and who has no history of undue exposure to noise, exposure to potentially ototoxic substances or familial hearing loss

[SOURCE: ISO 8253-1:2010, 3.7, modified — The term “ototoxic drugs” has been changed to “ototoxic substances”.]

3.2
hearing threshold deviation
ΔH
threshold of hearing of an individual minus the median threshold of hearing of a population of 18-year-old *otologically normal persons* (3.1) of the same gender

Note 1 to entry: The term threshold of hearing is defined in ISO 389-1:1998, 3.4.

4 Specification

4.1 General

The statistical distribution of hearing threshold deviations for otologically normal persons of a specific age Y and a specific gender is given in terms of the median value (see 4.2) and the distribution around the median (see 4.3).

The range of Y is from 18 years to 80 years for audiometric frequencies from 125 Hz to 8 000 Hz. For the frequencies from 3 000 Hz to 8 000 Hz, the Y value above 70 years is given for information purposes only.

NOTE The statistical distribution estimation for the age above 70 years at 3 000 Hz and above is subject to a large uncertainty because the hearing threshold level from many subjects is not obtainable (“scales out”) at those frequencies.

Annex E presents expected median thresholds at audiometric frequencies from 9 000 Hz to 12 500 Hz.

Annex F discusses the derivation of the descriptive statistics of hearing thresholds.

Annex G shows root-mean-square error (RMSE) values and estimating the uncertainty of the statistical values.

4.2 Median

The median value $\Delta H_{md,Y}$, in decibels, at audiometric frequencies from 125 Hz to 8 000 Hz is given by Formula (1):

$$\Delta H_{md,Y} = \alpha_{md} \left(Y - 18\right)^{\beta_{md}} \tag{1}$$

where

α_{md} and β_{md} are dimensionless quantities as given in Table 1;

Y is the age in years.

The age of 18 years is the lower limit of the Y range for which Formula (1) is valid.

Table 1 — Values of α_{md} and β_{md} in Formula (1)

Frequency Hz	α_{md}		β_{md}	
	Males	**Females**	**Males**	**Females**
125	$2,50 \times 10^{-6}$	$6,16 \times 10^{-4}$	3,841	2,451
250	$1,39 \times 10^{-4}$	$3,98 \times 10^{-4}$	2,832	2,568
500	$4,59 \times 10^{-4}$	$2,61 \times 10^{-4}$	2,537	2,708
750	$5,70 \times 10^{-4}$	$2,25 \times 10^{-4}$	2,512	2,775
1 000	$7,02 \times 10^{-4}$	$2,21 \times 10^{-4}$	2,494	2,805
1 500	$1,09 \times 10^{-3}$	$2,53 \times 10^{-4}$	2,446	2,813
2 000	$1,56 \times 10^{-3}$	$3,12 \times 10^{-4}$	2,404	2,792
3 000	$2,54 \times 10^{-3}$	$4,88 \times 10^{-4}$	2,350	2,728
4 000	$3,40 \times 10^{-3}$	$7,37 \times 10^{-4}$	2,325	2,660
6 000	$4,53 \times 10^{-3}$	$1,47 \times 10^{-3}$	2,315	2,539
8 000	$5,06 \times 10^{-3}$	$2,53 \times 10^{-3}$	2,328	2,439

4.3 Distribution around the median

The distribution around the median shall be approximated by the upper and lower halves, respectively, of two Gaussian distributions, each with their standard deviation s_u and s_l, in decibels, given by Formulae (2) and (3):

$$s_u = \gamma_{0,su} + \gamma_{1,su}\left(Y - 18\right) + \gamma_{2,su}\left(Y - 18\right)^2 + \gamma_{3,su}\left(Y - 18\right)^3 + \gamma_{4,su}\left(Y - 18\right)^4 + \gamma_{5,su}\left(Y - 18\right)^5 \tag{2}$$

$$s_l = \gamma_{0,sl} + \gamma_{1,sl}\left(Y - 18\right) + \gamma_{2,sl}\left(Y - 18\right)^2 + \gamma_{3,sl}\left(Y - 18\right)^3 + \gamma_{4,sl}\left(Y - 18\right)^4 + \gamma_{5,sl}\left(Y - 18\right)^5 \tag{3}$$

The values of coefficients $\gamma_{n,su}$ and $\gamma_{n,sl}$ (n = 0, 1, 2, ..., 5) are given in Tables 2 and 3 for males and in Tables 4 and 5 for females. The age of 18 years is the lower limit of the Y range for which Formulae (2) and (3) are valid.

Table 2 — Values of $\gamma_{n,\text{su}}$ (n = 0, 1, 2, ..., 5) in Formula (2) for males

Frequency Hz	$\gamma_{0,\text{su}}$	$\gamma_{1,\text{su}}$	$\gamma_{2,\text{su}}$	$\gamma_{3,\text{su}}$	$\gamma_{4,\text{su}}$	$\gamma_{5,\text{su}}$
125	4,63	0,645	$-8{,}85 \times 10^{-2}$	$3{,}69 \times 10^{-3}$	$-5{,}98 \times 10^{-5}$	$3{,}39 \times 10^{-7}$
250	5,27	0,710	$-9{,}13 \times 10^{-2}$	$3{,}64 \times 10^{-3}$	$-5{,}74 \times 10^{-5}$	$3{,}22 \times 10^{-7}$
500	4,98	0,751	$-9{,}20 \times 10^{-2}$	$3{,}68 \times 10^{-3}$	$-5{,}84 \times 10^{-5}$	$3{,}28 \times 10^{-7}$
750	4,65	0,733	$-8{,}81 \times 10^{-2}$	$3{,}59 \times 10^{-3}$	$-5{,}76 \times 10^{-5}$	$3{,}24 \times 10^{-7}$
1 000	4,42	0,714	$-8{,}54 \times 10^{-2}$	$3{,}57 \times 10^{-3}$	$-5{,}82 \times 10^{-5}$	$3{,}29 \times 10^{-7}$
1 500	4,14	0,679	$-8{,}04 \times 10^{-2}$	$3{,}52 \times 10^{-3}$	$-5{,}89 \times 10^{-5}$	$3{,}35 \times 10^{-7}$
2 000	4,10	0,632	$-7{,}53 \times 10^{-2}$	$3{,}46 \times 10^{-3}$	$-5{,}94 \times 10^{-5}$	$3{,}40 \times 10^{-7}$
3 000	4,29	0,530	$-6{,}28 \times 10^{-2}$	$3{,}09 \times 10^{-3}$	$-5{,}37 \times 10^{-5}$	$2{,}95 \times 10^{-7}$
4 000	4,68	0,455	$-5{,}52 \times 10^{-2}$	$2{,}95 \times 10^{-3}$	$-5{,}30 \times 10^{-5}$	$2{,}92 \times 10^{-7}$
6 000	5,61	0,363	$-4{,}72 \times 10^{-2}$	$2{,}92 \times 10^{-3}$	$-5{,}58 \times 10^{-5}$	$3{,}12 \times 10^{-7}$
8 000	6,62	0,291	$-4{,}16 \times 10^{-2}$	$2{,}92 \times 10^{-3}$	$-5{,}85 \times 10^{-5}$	$3{,}33 \times 10^{-7}$

Table 3 — Values of $\gamma_{n,\text{sl}}$ (n =0, 1, 2, ..., 5) in Formula (3) for males

Frequency Hz	$\gamma_{0,\text{sl}}$	$\gamma_{1,\text{sl}}$	$\gamma_{2,\text{sl}}$	$\gamma_{3,\text{sl}}$	$\gamma_{4,\text{sl}}$	$\gamma_{5,\text{sl}}$
125	3,34	0,131	$-2{,}02 \times 10^{-2}$	$1{,}12 \times 10^{-3}$	$-2{,}28 \times 10^{-5}$	$1{,}57 \times 10^{-7}$
250	3,32	0,230	$-2{,}54 \times 10^{-2}$	$1{,}20 \times 10^{-3}$	$-2{,}27 \times 10^{-5}$	$1{,}46 \times 10^{-7}$
500	3,43	0,362	$-4{,}11 \times 10^{-2}$	$1{,}87 \times 10^{-3}$	$-3{,}44 \times 10^{-5}$	$2{,}21 \times 10^{-7}$
750	3,60	0,384	$-4{,}43 \times 10^{-2}$	$1{,}98 \times 10^{-3}$	$-3{,}55 \times 10^{-5}$	$2{,}22 \times 10^{-7}$
1 000	3,77	0,363	$-4{,}19 \times 10^{-2}$	$1{,}82 \times 10^{-3}$	$-3{,}14 \times 10^{-5}$	$1{,}89 \times 10^{-7}$
1 500	3,93	0,365	$-4{,}22 \times 10^{-2}$	$1{,}79 \times 10^{-3}$	$-2{,}96 \times 10^{-5}$	$1{,}70 \times 10^{-7}$
2 000	4,01	0,387	$-4{,}47 \times 10^{-2}$	$1{,}87 \times 10^{-3}$	$-3{,}02 \times 10^{-5}$	$1{,}69 \times 10^{-7}$
3 000	4,11	0,405	$-4{,}56 \times 10^{-2}$	$1{,}86 \times 10^{-3}$	$-2{,}83 \times 10^{-5}$	$1{,}46 \times 10^{-7}$
4 000	4,09	0,439	$-4{,}78 \times 10^{-2}$	$1{,}92 \times 10^{-3}$	$-2{,}84 \times 10^{-5}$	$1{,}40 \times 10^{-7}$
6 000	4,01	0,497	$-4{,}97 \times 10^{-2}$	$1{,}93 \times 10^{-3}$	$-2{,}67 \times 10^{-5}$	$1{,}18 \times 10^{-7}$
8 000	3,90	0,559	$-5{,}62 \times 10^{-2}$	$2{,}40 \times 10^{-3}$	$-3{,}92 \times 10^{-5}$	$2{,}29 \times 10^{-7}$

Table 4 — Values of $\gamma_{n,\mathrm{su}}$ (n =0, 1, 2, ..., 5) in Formula (2) for females

Frequency Hz	$\gamma_{0,\mathrm{su}}$	$\gamma_{1,\mathrm{su}}$	$\gamma_{2,\mathrm{su}}$	$\gamma_{3,\mathrm{su}}$	$\gamma_{4,\mathrm{su}}$	$\gamma_{5,\mathrm{su}}$
125	5,05	0,400	$-4{,}60 \times 10^{-2}$	$1{,}73 \times 10^{-3}$	$-2{,}75 \times 10^{-5}$	$1{,}71 \times 10^{-7}$
250	5,01	0,481	$-4{,}88 \times 10^{-2}$	$1{,}80 \times 10^{-3}$	$-2{,}81 \times 10^{-5}$	$1{,}67 \times 10^{-7}$
500	4,68	0,510	$-5{,}16 \times 10^{-2}$	$1{,}95 \times 10^{-3}$	$-3{,}07 \times 10^{-5}$	$1{,}77 \times 10^{-7}$
750	4,45	0,511	$-5{,}25 \times 10^{-2}$	$2{,}03 \times 10^{-3}$	$-3{,}18 \times 10^{-5}$	$1{,}81 \times 10^{-7}$
1 000	4,34	0,492	$-5{,}15 \times 10^{-2}$	$2{,}03 \times 10^{-3}$	$-3{,}18 \times 10^{-5}$	$1{,}78 \times 10^{-7}$
1 500	4,23	0,479	$-5{,}12 \times 10^{-2}$	$2{,}07 \times 10^{-3}$	$-3{,}26 \times 10^{-5}$	$1{,}80 \times 10^{-7}$
2 000	4,26	0,456	$-4{,}91 \times 10^{-2}$	$2{,}01 \times 10^{-3}$	$-3{,}16 \times 10^{-5}$	$1{,}70 \times 10^{-7}$
3 000	4,36	0,476	$-5{,}15 \times 10^{-2}$	$2{,}19 \times 10^{-3}$	$-3{,}51 \times 10^{-5}$	$1{,}91 \times 10^{-7}$
4 000	4,61	0,477	$-5{,}07 \times 10^{-2}$	$2{,}19 \times 10^{-3}$	$-3{,}51 \times 10^{-5}$	$1{,}88 \times 10^{-7}$
6 000	5,22	0,483	$-4{,}83 \times 10^{-2}$	$2{,}13 \times 10^{-3}$	$-3{,}39 \times 10^{-5}$	$1{,}74 \times 10^{-7}$
8 000	5,84	0,516	$-4{,}89 \times 10^{-2}$	$2{,}18 \times 10^{-3}$	$-3{,}49 \times 10^{-5}$	$1{,}77 \times 10^{-7}$

Table 5 — Values of $\gamma_{n,\mathrm{sl}}$ (n =0, 1, 2, ..., 5) in Formula (3) for females

Frequency Hz	$\gamma_{0,\mathrm{sl}}$	$\gamma_{1,\mathrm{sl}}$	$\gamma_{2,\mathrm{sl}}$	$\gamma_{3,\mathrm{sl}}$	$\gamma_{4,\mathrm{sl}}$	$\gamma_{5,\mathrm{sl}}$
125	3,64	0,047	$2{,}28 \times 10^{-3}$	$-6{,}68 \times 10^{-5}$	$-8{,}72 \times 10^{-7}$	$2{,}30 \times 10^{-8}$
250	3,11	0,226	$-7{,}71 \times 10^{-3}$	$9{,}83 \times 10^{-5}$	$-7{,}11 \times 10^{-7}$	$9{,}02 \times 10^{-9}$
500	2,98	0,338	$-1{,}74 \times 10^{-2}$	$3{,}53 \times 10^{-4}$	$-2{,}78 \times 10^{-6}$	$1{,}01 \times 10^{-8}$
750	3,03	0,378	$-2{,}24 \times 10^{-2}$	$5{,}20 \times 10^{-4}$	$-4{,}60 \times 10^{-6}$	$1{,}50 \times 10^{-8}$
1 000	3,15	0,382	$-2{,}39 \times 10^{-2}$	$5{,}62 \times 10^{-4}$	$-4{,}60 \times 10^{-6}$	$9{,}87 \times 10^{-9}$
1 500	3,32	0,387	$-2{,}64 \times 10^{-2}$	$6{,}71 \times 10^{-4}$	$-5{,}76 \times 10^{-6}$	$1{,}07 \times 10^{-8}$
2 000	3,47	0,392	$-2{,}84 \times 10^{-2}$	$7{,}79 \times 10^{-4}$	$-7{,}35 \times 10^{-6}$	$1{,}71 \times 10^{-8}$
3 000	3,69	0,392	$-2{,}96 \times 10^{-2}$	$8{,}44 \times 10^{-4}$	$-7{,}55 \times 10^{-6}$	$8{,}16 \times 10^{-9}$
4 000	3,84	0,402	$-3{,}17 \times 10^{-2}$	$9{,}99 \times 10^{-4}$	$-1{,}08 \times 10^{-5}$	$2{,}99 \times 10^{-8}$
6 000	4,04	0,403	$-3{,}15 \times 10^{-2}$	$1{,}06 \times 10^{-3}$	$-1{,}21 \times 10^{-5}$	$3{,}44 \times 10^{-8}$
8 000	4,15	0,413	$-3{,}01 \times 10^{-2}$	$1{,}00 \times 10^{-3}$	$-9{,}97 \times 10^{-6}$	$8{,}74 \times 10^{-9}$

4.4 Application of data

The hearing threshold deviation $\Delta H_{Q,Y}$ which can be expected to be exceeded by a given fraction Q of an otologically normal population of given age Y and given gender, is given by Formula (4) or (5):

$$\Delta H_{Q,Y} = \Delta H_{\mathrm{md},Y} + k s_{\mathrm{u}} \tag{4}$$

$$\Delta H_{Q,Y} = \Delta H_{\mathrm{md,Y}} + k s_{\mathrm{l}} \tag{5}$$

Formula (4) applies when $0{,}05 \le Q \le 0{,}50$, whereas Formula (5) applies when $0{,}50 \le Q \le 0{,}95$. Values of the multiplier k correspond to the Gaussian distribution. For information, these values are given in Table A.1.

Due to uncertainties in the experimental data on which this document is based, tails of the statistical distributions are only reliable within the range of $0{,}05 \le Q \le 0{,}95$.

The values given in Tables 1 to 5 are the outcome of comprehensive statistical analyses. The resolution provided is for calculation only, and the final results should be rounded to the nearest integer of a decibel.

An example of a calculation is given in Annex B. Calculated values for a range of parameters are given in Figure C.1 and Table D.1.

