DRAFT FOR DEVELOPMENT

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Measurement microphones —

Part 7: Values for the difference between free-field and pressure sensitivity levels of laboratory standard microphones

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Part 7: Values for the difference between free-field and pressure sensitivity levels of laboratory standard microphones

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MEASUREMENT MICROPHONES –

Part 7: Values for the difference between free-field and pressure sensitivity levels of laboratory standard microphones

1 Scope

This part of IEC 61094

– gives a polynomial function derived from a least square fit to data from several laboratories, for the differences between free-field and pressure sensitivity levels of laboratory standard microphones as specified in IEC 61094-1,

– enables determination of the free-field sensitivity level of a laboratory standard microphone for zero-degrees incidence in air by adding values of these differences to the pressure sensitivity level,

– gives tabulated values for the polynomial function for a range of frequency and temperature,

– is applicable when a suitable free-field calibration is not available.

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

IEC 61094-2:1992, *Measurement Microphones – Part 2: Primary method for pressure calibration of laboratory standard microphones by the reciprocity technique*

IEC 61094-3:1995, *Measurement Microphones – Part 3: Primary method for free-field calibration of laboratory standard microphones by the reciprocity technique*

3 Terms and definitions

For the purpose of this part of IEC 61094, the following definition applies in addition to the definitions given in IEC 61094-1, IEC 61094-2:1992 and IEC 61094-3:1995.

3.1
zero-degrees incidence
for a frontal incident sound wave, direction perpendicular to the diaphragm of the microphone

4 Reference environmental conditions

The reference environmental conditions are:

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

5 Background

According to the definitions of the free-field and pressure sensitivities of a microphone, the two sensitivities will differ from each other for the following reasons:

– owing to diffraction and reflection, the introduction of a microphone into a free progressive sound wave disturbs the sound field. Thus the sound pressure at the microphone diaphragm is not the same as that of the undisturbed free field,

– owing to diffraction and reflection the sound pressure over the diaphragm of the microphone is not uniform and, for a specific microphone, is affected by the acoustic impedance of its diaphragm.

The values given have been derived from theoretical considerations combined with measurements of the pressure and free-field sensitivity levels of a number of microphones carried out in accordance with IEC 61094-2 and IEC 61094-3, respectively, to which reference should be made concerning terminology, microphone preamplifier configurations, etc.

6 Difference values of free-field and pressure sensitivity levels

6.1 General

The difference between free-field and pressure sensitivity is determined by two factors, see 5.4 of IEC 61094-3:1995.

The major part is determined by the geometrical diffraction around the microphone and its support. This is a wavelength phenomenon and thus a function of temperature.

A minor part is determined by the interaction between the impedance of the microphone diaphragm and its radiation impedance. As the radiation impedance depends on the static pressure and temperature this part will be a function of both these variables. Although this part also depends on the individual microphone impedance, the variations between microphones of the same model can be neglected in comparison with the overall uncertainty on the difference values.

For type LS2 microphones the interaction between the impedance of the microphone diaphragm and its radiation impedance is insignificant.

6.2 Data sources

Values for the difference between free-field and pressure sensitivity levels have been derived experimentally and by calculation at a number of institutions. The average of the individual results, together with further details is reported in Annex A. A weighted average of these results forms a basis of the expressions for the difference values given in 6.3.

6.3 Expression for the difference between free-field and pressure sensitivity levels

Due to its physical nature the difference values between the free-field and pressure sensitivity levels will be a smooth function of frequency, which has no discontinuities and tends to zero at low frequencies. Thus the difference values can be expressed by a polynomial function in terms of normalized frequency. The dependence on temperature can also be accounted for by including this parameter in the polynomial function.

The difference values between the free-field and pressure sensitivity levels in dB for zero-degrees incidence Δ_{ff}, can then be expressed by

$$\Delta_{ff} = c_1 \cdot R^1(f,t) + c_2 \cdot R^2(f,t) + c_3 \cdot R^3(f,t) + \cdots \cdots + c_n \cdot R^n(f,t) \quad \text{dB} \tag{1}$$

where

$R(f,t) = f\sqrt{\dfrac{296{,}15}{t+273{,}15}}$;

f frequency, kHz;

t temperature, °C;

c_n polynomial coefficients given in Table 1.

When Equation (1) is used to obtain the free-field sensitivity level of a laboratory standard microphone at arbitrary environmental conditions it should be recalled that the pressure sensitivity level of the microphone shall refer to the same environmental conditions. The pressure sensitivity level of the microphones is a function of static pressure and temperature, see 6.5 of IEC 61094-2:1992.

When the polynomial coefficients in Table 1 are used, Equation (1) is valid from 200 Hz to 12,5 kHz for type LS1 microphones and from 400 Hz to 25 kHz for type LS2 microphones. Below these frequency ranges the difference values are less than 0,01 dB and can be neglected.

The coefficients shall be used with the precision shown in Table 1 during the calculation, in which case the maximum deviation on the estimate derived from Equation (1) is within 0,05 dB from a weighted average of the source data given in Annex A.

Tabulated values, derived from Equation (1) for a number of temperatures, are given in Table 2 for type LS1 and LS2a microphones.

6.4 Uncertainty on the calculated free-field sensitivity level

When Equation (1) is used to obtain the free-field sensitivity level of a laboratory standard microphone, the resulting uncertainty is the combined uncertainty derived from the uncertainties of

– the pressure sensitivity level of the microphone at the relevant environmental conditions,

– the source data for the difference values, see Table A.1,

– the uncertainty, 0,05 dB, on the polynomial approach, see 6.3.

Table 1 – Polynomial coefficients for calculation of the difference between the free-field and pressure sensitivity of laboratory standard microphones for zero-degrees incidence

Coefficient	Microphone type LS1 (without protection grid)	Microphone type LS2a
c_1	–0,007 7	–0,038 2
c_2	0,311 6	0,104 94
c_3	–0,056 26	–0,012 918
c_4	0,020 861	0,002 105 8
c_5	–0,004 656 1	–0,000 218 5
c_6	0,000 484 13	$1{,}189\,645 \times 10^{-5}$
c_7	$-2{,}372\,15 \times 10^{-5}$	$-3{,}480\,9 \times 10^{-7}$
c_8	$4{,}471 \times 10^{-7}$	$5{,}238\,03 \times 10^{-9}$
c_9	0	$-3{,}196\,42 \times 10^{-11}$

Table 2 – Difference values of free-field and pressure sensitivity levels in dB for different ambient temperatures and for zero-degrees incidence, calculated from Equation (1)

Frequency kHz	Microphone type LS1 (without protection grid)				Microphone type LS2a			
	Temperature °C				Temperature °C			
	18	23	28	33	18	23	28	33
0,500	0,069	0,068	0,067	0,066	0,006	0,006	0,005	0,005
0,630	0,109	0,108	0,106	0,104	0,015	0,015	0,014	0,014
0,800	0,174	0,172	0,169	0,166	0,032	0,031	0,030	0,029
1,000	0,269	0,264	0,260	0,256	0,057	0,056	0,055	0,053
1,250	0,412	0,406	0,399	0,393	0,097	0,096	0,094	0,092
1,600	0,661	0,650	0,640	0,630	0,169	0,166	0,163	0,160
2,000	1,010	0,994	0,978	0,963	0,272	0,267	0,263	0,258
2,500	1,538	1,514	1,490	1,467	0,429	0,422	0,415	0,408
3,150	2,360	2,323	2,288	2,254	0,679	0,667	0,657	0,646
4,000	3,602	3,550	3,500	3,451	1,076	1,058	1,041	1,025
5,000	5,158	5,093	5,029	4,966	1,637	1,612	1,587	1,563
6,300	7,008	6,940	6,873	6,807	2,500	2,462	2,425	2,390
8,000	8,664	8,617	8,569	8,522	3,788	3,734	3,682	3,632
10,00	9,463	9,448	9,432	9,416	5,376	5,309	5,245	5,181
12,50	9,210	9,254	9,293	9,328	7,152	7,086	7,021	6,956
16,00					8,721	8,683	8,645	8,606
20,00					9,138	9,141	9,144	9,144
25,00					8,714	8,738	8,761	8,784

Annex A
(informative)

Source data

Values for the difference between free-field and pressure sensitivity levels have been determined by experiments and calculations by a number of institutions.

Table A.1 gives values for the difference between free-field and pressure sensitivity levels in decibels for two microphone types. It refers to a plane progressive wave incident at an angle of zero-degrees relative to the normal of the microphone diaphragm ("zero-degree incidence").

The values given in the table are the mean values of the data presented and the quoted uncertainties refer to the experimental standard deviation of the mean values of these data using a coverage factor 2.

NOTE 1 The free-field sensitivity of a microphone refers to a microphone mounted on the end of a long cylinder, whose diameter is equal to the nominal diameter of the microphone (see 6.4 of IEC 61094-3:1995). The values quoted are derived for cylinder lengths in excess of five times the diameter.

NOTE 2 The tabulated values are derived at the prevailing environmental conditions at the participating institutions. Thus the temperature dependence of the geometrical diffraction has not been accounted for and therefore is included in the uncertainty of the quoted average value.

NOTE 3 The experimental data were all derived for microphones of Brüel & Kjær Type 4160 and Brüel & Kjær Type 4180 only. Slightly different values may be found for other type LS1 microphones if the acoustic impedance of the diaphragm is significantly different from that of Brüel & Kjær Type 4160.

Table A.1 – Source data for the difference between free-field and pressure sensitivity levels in dB for zero-degrees incidence

Frequency kHz	Microphone type LS1 (without protection grid)		Microphone type LS2a	
	Difference	Uncertainty U (k = 2)	Difference	Uncertainty U (k = 2)
0,500	0,070	0,032		
0,630	0,125	0,044		
0,800	0,186	0,045		
1,000	0,279	0,056	0,080	0,060
1,250	0,432	0,056	0,120	0,044
1,600	0,680	0,064	0,192	0,071
2,000	1,019	0,054	0,281	0,097
2,500	1,548	0,062	0,422	0,112
3,150	2,331	0,058	0,662	0,123
4,000	3,526	0,094	1,032	0,120
5,000	5,063	0,096	1,562	0,108
6,300	6,911	0,081	2,394	0,122
8,000	8,491	0,226	3,619	0,170
10,00	9,382	0,230	5,125	0,272
12,50	9,147	0,294	6,924	0,333
16,00			8,569	0,229
20,00			9,037	0,167
25,00			8,642	0,172

Annex B
(informative)

Acknowledgements

The data used for deriving the values quoted in Table A.1 in Annex A have kindly been contributed by the institutes listed in alphabetical order below.

Danish Primary Laboratory of Acoustics, Denmark,

Danish Technical University, Department of Acoustic Technology, Denmark,

Japan Quality Assurance Organization, Japan,

Laboratoire national de métrologie et d'essais, France,

National Physical Laboratory, United Kingdom,

Physikalisch-Technische Bundesanstalt, Germany.

Annex C
(informative)

Historical data

The previous standard IEC 655 (1979), which has been withdrawn, contained similar sets of data for microphones now categorized as type LS1Po and LS1Pn. The origin of these data is unknown and the uncertainty on the figures is referred to as “The estimated accuracy is approximately ±0,2 dB”.

Table C.1 below refers the values from this previous standard for type LS1Po and LS1Pn without protection grid and for zero-degrees incidence.

Table C.1 – Historical data for the difference between free-field and pressure sensitivity levels in dB for type LS1Po and LS1Pn microphones and for zero-degrees incidence

Frequency kHz	Microphone type LS1Po	Microphone type LS1Pn
0,500	0,1	0,1
0,630	0,1	0,1
0,800	0,2	0,2
1,000	0,3	0,3
1,250	0,5	0,5
1,600	0,7	0,7
2,000	1,0	1,0
2,500	1,5	1,6
3,150	2,4	2,4
4,000	3,6	3,6
5,000	5,0	5,0
6,300	6,9	6,9
8,000	8,7	8,5
10,00	9,5	9,2
12,50	9,2	8,8
16,00	8,1	7,5
20,00	7,0	6,2

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