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भारतीय मानक

इलेक्ट्रोअकूस्टिक्स – ऑक्टेव-बैंड और फ्रैक्शनल-ऑक्टेव-बैंड फिल्टर

(पहला पुनरीक्षण)

Indian Standard

ELECTROACOUSTICS — OCTAVE-BAND AND FRACTIONAL-OCTAVE-BAND FILTERS

(First Revision)

ICS 17.140.50

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Price Group 9

NATIONAL FOREWORD

This Indian Standard (First Revision) which is identical with IEC 61260 (1995) 'Electroacoustics — Octave-band and fractional-octave-band filters' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of Acoustics Sectional Committee and approval of the Electronics and Telecommunication Division Council.

This revision has been undertaken to align with the latest version of the corresponding IEC 61260.

The text of the IEC standard has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

Only the English language text in the International Standard has been retained while adopting it in this standard.

CROSS REFERENCES

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 50 (801) : 1994 International Electrotechnical Vocabulary (IEV) — Chapter 801 : Acoustics and electro-acoustics	IS 1885 (Part 3/Sec 2) : 1966 Electro-technical vocabulary : Part 3 Acoustics, Section 2 Acoustical and electro-acoustical systems	Not equivalent
IEC 651 : 1979 Sound level meters	IS 9779 : 1981 Sound level meters	Equivalent
ISO 266 : 1975 Acoustics — Preferred frequencies for measurements	IS 2264 : 1963 Preferred frequencies for acoustical measurements	Not equivalent

The technical committee responsible for the preparation of this standard has reviewed the provisions of the following International Standards and has decided that they are acceptable for use in conjunction with this standard :

IEC 801-2 :1991 Electromagnetic compatibility for industrial-process measurement and control equipment — Part 2 : Electrostatic discharge requirements

IEC 801-3 :1984 Electromagnetic compatibility for industrial-process measurement and control equipment — Part 3 : Radiated electromagnetic field requirements

IEC 804 : 1985 Integrating-averaging sound level meters

OIML : 1978 Vocabulary of legal metrology — Fundamental terms

Indian Standard

ELECTROACOUSTICS — OCTAVE-BAND AND FRACTIONAL-OCTAVE-BAND FILTERS

(First Revision)

1 Scope

1.1 This International Standard provides performance requirements and methods for testing the performance of analogue, sampled-data, and digital implementations of bandpass filters that comprise a filter set or spectrum analyser. The extent of the passband region of a filter's relative attenuation characteristic is a constant percentage of the midband frequency for all filters of a given bandwidth. An instrument complying with the requirements of this International Standard may contain any number of bandpass filters covering any desired frequency range.

1.2 Performance requirements are provided for three filter classes designated class 0, class 1, and class 2. Allowed tolerances increase as the class number increases.

1.3 Bandpass filters complying with the performance requirements of this standard may be part of various measurement systems or may be an integral component of a specific instrument and shall operate in real time. Performance requirements apply to any method that is selected by the manufacturer to implement the design of the filters.

1.4 Instruments complying with the requirements of this standard are capable of providing frequency-band-filtered spectral information for a wide variety of signals, for example, time-varying, intermittent, and steady; broadband and discrete frequency; and long and short durations. For applications involving transient signals, different realizations of filters meeting the requirements of this standard may give different results.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of the IEC and ISO maintain registers of currently valid International Standards.

IEC 50(801): 1994, *International Electrotechnical Vocabulary (IEV) - Chapter 801: Acoustics and electro-acoustics*

IEC 651: 1979, *Sound level meters*
Amendment 1: 1993

IEC 801-2: 1991, *Electromagnetic compatibility for industrial-process measurement and control equipment - Part 2: Electrostatic discharge requirements*

IEC 801-3: 1984, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 3: Radiated electromagnetic field requirements*

IEC 804: 1985, *Integrating-averaging sound level meters*
Amendment 1, 1989
Amendment 2, 1993

ISO 266: 1975, *Acoustics – Preferred frequencies for measurements*

OIML: 1978, *Vocabulary of legal metrology – Fundamental terms*

3 Definitions

For the purpose of this International Standard, the following definitions apply.

NOTE – For definitions of additional terms in this standard, reference should be made to IEC 50(801) and the OIML Vocabulary of legal metrology.

3.1 **bandpass filter:** Filter with a single transmission band (or passband with small relative attenuation) extending from a lower bandedge frequency greater than zero to a finite upper bandedge frequency.

3.2 **octave ratio:** Nominal frequency ratio of 2:1; general symbol G.

NOTES

1 This standard permits two options, designated base-ten and base-two, for determining an octave-band, or fractional-octave-band, frequency ratio.

2 For base-ten systems,

$$G_{10} = 10^{3/10} \tag{1}$$

3 For base-two systems,

$$G_2 = 2 \tag{2}$$

4 The base-ten system is preferred.

3.3 **bandwidth designator:** Reciprocal of a positive integer, including 1, to designate the fraction of an octave band; symbol $1/b$.

3.4 **reference frequency:** Frequency of 1 000 Hz, exactly; symbol f_r.

3.5 **exact midband frequency:** In hertz, a frequency that has a specified relationship to the reference frequency such that the ratio of the exact midband frequencies of any two contiguous bandpass filters is the same for all filters in a filter set of a specified bandwidth; symbol f_m. When the denominator of the bandwidth designator is an odd number, exact midband frequencies of any filter in a set of filters are determined from:

$$f_m = (G^{x/b})\,(f_r) \tag{3}$$

and when the denominator of the bandwidth designator is an even number, exact midband frequencies of any filter in a set of filters are determined from:

$$f_m = (G^{(2x+1)/(2b)})\,(f_r) \tag{4}$$

where x is any integer, positive, negative, or zero.

NOTES

1 Exact midband frequencies determined from equation (3) or (4) permit the output of narrow-fractional-octave-band filters to be combined to yield the band level of a filter of wider-bandwidth with a corresponding exact midband frequency and corresponding bandedge frequencies.

2 With the base-ten system, midband frequencies included within any 10:1 frequency range are the same as within any other 10:1 frequency range except for the position of the decimal sign. With the base-two system, midband frequencies are unique and do not repeat.

3 As examples, for one-third-octave-band filters, the exact midband frequency for the band with a nominal midband frequency of 5 000 Hz is 5 011,872 Hz to three decimal places by the base-ten system and 5 039,684 Hz by the base-two system, or a difference of approximately 0,6 %. At a nominal midband frequency of 50 000 Hz, the exact midband frequency is 50 118,723 Hz by the base-ten system and 50 796,834 Hz by the base-two system, or an approximate difference of 1,4 %.

4 When the denominator of the bandwidth designator is an odd number, one of the filters in a complete filter set may have a midband frequency of 1 000 Hz. When the denominator of the bandwidth designator is an even number, the bandedge frequency of one adjacent pair of filters in a complete filter set may be at 1 000 Hz and therefore none of the filters will have a midband frequency of 1 000 Hz.

5 Exact midband frequencies for octave-band and one-third-octave-band filters are given in table A.1 for the usual range of audio frequencies.

3.6 **nominal midband frequencies:** In hertz, rounded midband frequencies for the designation of bandpass filters.

3.7 **bandedge frequencies:** In hertz, frequencies of the lower and upper edges of the passband of a bandpass filter such that the exact midband frequency is the geometric mean of the lower and upper bandedge frequencies; symbols f_1 and f_2, respectively. Bandedge frequencies are determined from:

$$f_1 = (G^{-1/(2b)})\,(f_m) \tag{5}$$

and

$$f_2 = (G^{+1/(2b)})\,(f_m) \tag{6}$$

where

G represents an octave frequency ratio calculated according to equation (1) for base-ten systems or (2) for base-two systems;

f_m is an exact midband frequency determined from equation (3) or (4).

3.8 **normalized frequency:** For a bandpass filter, ratio of frequency to the exact midband frequency; symbol f/f_m.

3.9 **filter bandwidth:** In hertz, for a given filter, upper bandedge frequency f_2 minus the corresponding lower bandedge frequency f_1 calculated from equations (5) and (6).

3.10 **octave-band filter:** Bandpass filter for which the nominal ratio of upper bandedge frequency to lower bandedge frequency is two.

3.11 fractional-octave-band filter: Bandpass filter for which the ratio of upper bandedge frequency f_2 to lower bandedge frequency f_1 is an octave ratio raised to an exponent equal to the applicable bandwidth designator.

NOTE – In symbols, a bandedge frequency ratio is $f_2/f_1 = G^{1/b}$.

3.12 filter attenuation: In decibels, for a bandpass filter, at any frequency, the level of the time-mean-square input signal minus the level of the indicated time-mean-square output signal, with both signal levels relative to the same reference quantity; symbol A.

NOTE – In symbols, a time-mean-square input signal level L_{in}, in decibels, is represented by:

$$L_{in} = 10 \lg \left([(1/T) \int_0^T V_{in}^2 (t)\, dt] / V_0^2 \right) \text{ dB} \qquad (7)$$

where

$V_{in}(t)$ is the instantaneous input signal as a function of time t;

T is the elapsed time for integration;

V_o is an appropriate reference quantity such as 20 µV.

A corresponding expression applies for the level of the time-mean-square output signal.

3.13 reference attenuation: In decibels, for all bandpass filters in an instrument, nominal filter attenuation in the passband as specified by the manufacturer for determining relative attenuation; symbol A_{ref}.

3.14 relative attenuation: In decibels, for a bandpass filter, at any frequency, filter attenuation minus the reference attenuation; symbol ΔA.

NOTE – At any normalized frequency f/f_m, relative attenuation $\Delta A(f/f_m)$, in decibels, is determined from:

$$\Delta A(f/f_m) = A(f/f_m) - A_{ref} \qquad (8)$$

where

$A\,(f/f_m)$ is the filter attenuation at normalized frequency f/f_m;

A_{ref} is the reference attenuation.

Exact midband frequencies f_m are calculated from equation (3) or (4).

3.15 normalized effective bandwidth: For constant-amplitude sinusoidal electrical input signals, integral over normalized frequency of the ratio of the time-mean-square signal indicated by the readout device at the output of the filter set to the time-mean-square input signal; the ratio of time-mean-square signal is normalized by multiplying by a constant equal to $10^{0,1\,A_{ref}}$ where A_{ref} is the reference attenuation, in decibels; symbol B_e.

NOTE – The analytical expression for normalized effective bandwidth is given in 4.5.2.

3.16 **normalized reference bandwidth**: For a bandpass filter, ratio of filter bandwidth to the exact midband frequency; symbol B_r.

NOTE – Normalized reference bandwidth B_r is determined from:

$$B_r = (f_2 - f_1)/f_m \tag{9}$$

$$= [G^{+1/(2b)} - G^{-1/(2b)}]$$

3.17 **filter integrated response:** In decibels, ten times the logarithm to the base 10 of the ratio of the normalized effective bandwidth of a filter to the normalized reference bandwidth; symbol ΔB.

NOTE – The analytical expression for ΔB is given in 4.5.1.

3.18 **reference level range:** In decibels, one of the available level ranges specified by the manufacturer for testing electrical performance characteristics.

3.19 **reference input signal level:** In decibels, level of the input signal, specified by the manufacturer, on the reference level range.

3.20 **level difference:** In decibels, for a bandpass filter on any level range, output signal level minus the input signal level plus the nominal attenuation of the level range control, if applicable.

3.21 **reference level difference:** In decibels, on the reference level range, level difference for an input signal at the applicable reference input signal level at the midband frequency.

3.22 **level linearity error:** In decibels, on any level range, a level difference at the midband frequency minus the reference level difference.

3.23 **linear operating range:** In decibels, for a stated filter bandwidth and a stated level range, the extent of steady sinusoidal input signal levels over which level linearity errors are maintained within specified tolerances from a lower boundary to an upper boundary.

3.24 **level range control:** A device for adjusting the sensitivity of an instrument in response to changes in the level of the input signal in order to maintain the overall operation of the instrument within the linear operating range.

3.25 **measurement range:** In decibels, for any nominal midband frequency, the upper boundary of the input signal level for the linear operating range on the least-sensitive level range minus the lower boundary of the input signal level for the linear operating range on the most-sensitive level range.

3.26 **analogue filter:** Filter that operates continuously on the input signal to produce a filtered output.

3.27 **sampled-data filter:** Computational process that operates on samples of the input signal to produce a filtered output.

3.28 **digital filter:** Subset of sampled-data filters that operates on digitized samples of input data.

3.29 **real-time operation:** An operational mode or capability of a sampled-data filter system to produce bandpass-filtered output signal levels and for which, on average, the computing associated with each sampling interval is completed in a time period less than or equal to the sampling interval such that all input data are processed within the sampling interval and all samples of an input signal contribute with equal weight to the resulting filtered output signal levels.

3.30 **aliased frequency components:** Spurious frequency components in the output signal from a sampled-data bandpass filter that result when a time-varying, but continuous, input signal is sampled at a rate that is too low compared with the highest frequency component of the input signal.

3.31 **anti-alias filter:** Low-pass filter to reduce the contribution of aliased frequency components in the output to an insignificant level.

4 Performance requirements

4.1 *General*

Electrical response characteristics specified in this standard for octave-band and fractional-octave-band filters apply under the reference environmental conditions of 4.13.

Any filter design realization, with a base-ten or a base-two octave frequency ratio, may be utilized providing the resulting instrument complies with all applicable requirements of this standard.

4.2 *Nominal midband frequencies*

Octave-band and fractional-octave-band filters shall be identified, or labelled, by nominal midband frequencies that are suitably rounded values of exact midband frequencies. Annex A provides exact and nominal midband frequencies for octave-band and one-third-octave-band filters. A procedure is described for determining the nominal midband frequencies for fractional-octave-band filters with bandwidth designators from 1/4 to 1/24.

4.3 *Reference attenuation*

The manufacturer shall specify the reference attenuation in the passband. The reference attenuation shall be the same for all filters in a set of filters.

4.4 *Relative attenuation*

4.4.1 For octave-band filters of class 0, 1, or 2, the relative attenuation of any filter shall be within the limits in table 1 for the minimum and maximum relative attenuations at the specified values of octave-band normalized frequency $f/f_m = \Omega$.

4.4.2 For a fractional-octave-band filter with bandwidth designator $1/b$, the high-frequency fractional-octave-band normalized frequency $\Omega_{h(1/b)}$, corresponding to a finite relative attenuation limit for the accuracy class shall be calculated, for $\Omega \geq 1$, from:

$$\Omega_{h(1/b)} = 1 + [(G^{1/(2b)} - 1)/(G^{1/2} - 1)](\Omega - 1) \tag{10}$$

For $\Omega < 1$, the low-frequency fractional-octave-band normalized frequency $\Omega_{l(1/b)}$ shall be calculated from:

$$\Omega_{l(1/b)} = 1/\Omega_{h(1/b)} \tag{11}$$

for the same limit on relative attenuation.

NOTE – Annex B provides an example calculation of the normalized frequencies at the breakpoints for the limits on minimum and maximum relative attenuation for one-third-octave-band filters.

4.4.3 At normalized frequencies Ω_a and Ω_b given in table 1 for octave-band filters, or between comparable normalized fractional-octave-band frequencies calculated according to equation (10) or (11) for fractional-octave-band filters, the limit for relative attenuation ΔA_x at normalized frequency Ω_x shall be determined from the linear interpolation relation:

$$\Delta A_x = \Delta A_a + [\Delta A_b - \Delta A_a][\lg(\Omega_x/\Omega_a)/\lg(\Omega_b/\Omega_a)] \tag{12}$$

where

ΔA_a is a relative attenuation limit at normalized frequency Ω_a;

ΔA_b is a relative attenuation limit at normalized frequency Ω_b.

Table 1 – Limits on relative attenuation for octave-band filters

Normalized frequency $f/f_m = \Omega$	Minimum; maximum attenuation limits dB		
	Filter class		
	0	1	2
G^0	−0,15; +0,15	−0,3; +0,3	−0,5; +0,5
$G^{\pm 1/8}$	−0,15; +0,2	−0,3; +0,4	−0,5; +0,6
$G^{\pm 1/4}$	−0,15; +0,4	−0,3; +0,6	−0,5; +0,8
$G^{\pm 3/8}$	−0,15; +1,1	−0,3; +1,3	−0,5; +1,6
$<G^{+1/2}$ / $>G^{-1/2}$	−0,15; +4,5	−0,3; +5,0	−0,5; +5,5
$G^{\pm 1/2}$*	+2,3; +4,5	+2,0; +5,0	+1,6; +5,5
$G^{\pm 1}$	+18,0; +∞	+17,5; +∞	+16,5; +∞
$G^{\pm 2}$	+42,5; +∞	+42; +∞	+41; +∞
$G^{\pm 3}$	+62; +∞	+61; +∞	+55; +∞
$\geq G^{+4}$	+75; +∞	+70; +∞	+60; +∞
$\leq G^{-4}$	+75; +∞	+70; +∞	+60; +∞

* At frequencies less than the lower band-edge frequency and greater than the upper band-edge frequency, the limit on maximum relative attenuation is + ∞; see figure 1.

4.4.4 Figure 1 illustrates the limits on minimum and maximum relative attenuation for an octave-band filter. The figure also shows the discontinuous changes in minimum and maximum relative attenuation at the band-edge frequencies and the linear variation of relative attenuation limits between the breakpoint normalized frequencies of table 1.

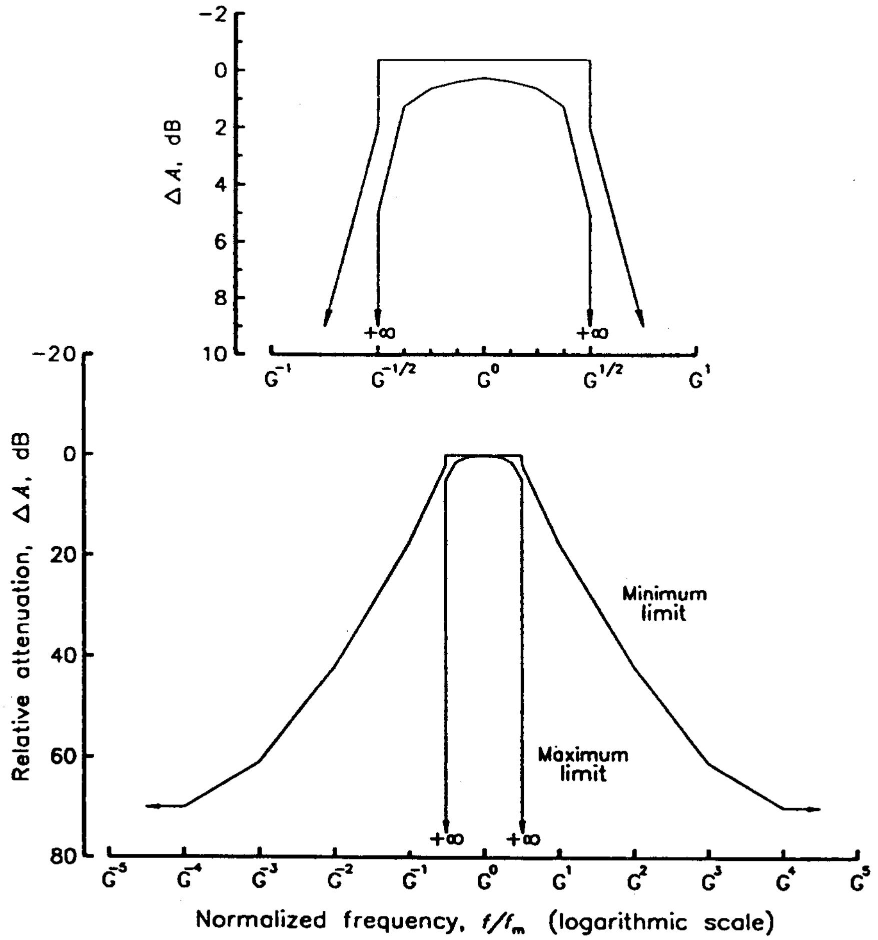

Figure 1 – Illustration of minimum and maximum limits on relative attenuation for class 1 octave-band filters

4.5 *Filter integrated response*

4.5.1 For a bandpass filter, filter integrated response ΔB, in decibels, shall be determined from

$$\Delta B = 10 \lg(B_e/B_r) \qquad (13)$$

where

B_e is the normalized effective bandwidth;

B_r is the normalized reference bandwidth from equation (9) for the same midband frequency.

4.5.2 For any filter of exact midband frequency f_m, normalized effective bandwidth is represented by:

$$B_e = \int_0^{\infty} 10^{-0,1\,\Delta A(f/f_m)} \quad \mathrm{d}\,(f/f_m) \qquad (14)$$

where

$\Delta A(f/f_m)$ is the continuous relative-attenuation filter response, in decibels. In practice, the integral in equation (14) is evaluated numerically; see 5.4.

4.5.3 For each bandpass filter in an instrument, the filter integrated response shall not exceed ±0,15 dB, ±0,3 dB, and ±0,5 dB for classes 0, 1 and 2 instruments, respectively.

4.6 *Linear operating range*

4.6.1 For all filter bandwidths, and for the flat frequency response if provided, and for each available level range, the level linearity errors on the linear operating range shall not exceed ±0,3 dB, ±0,4 dB, and ±0,5 dB respectively over linear operating ranges of at least 60 dB, 50 dB, and 40 dB for classes 0, 1, and 2 filters, respectively.

4.6.2 Level ranges, if more than one is provided, shall overlap such that the linear operating ranges overlap by at least 40 dB for class 0 and class 1 filters and at least 30 dB for class 2 filters.

4.6.3 For filters with more than one level range, a reduced linear operating range is allowed on the most sensitive range, provided it is not the reference level range.

4.6.4 For filters where a display is an integral component, or when the filter output is transferred to an external display or to another system, and the range of the display is greater than the linear operating range, the manufacturer shall specify the tolerances on level linearity that are maintained outside the linear operating range.

4.7 *Real-time operation*

The manufacturer shall state the bandwidth designators and corresponding frequency ranges for which the level of the output signal in response to a constant-amplitude sinusoidal input signal, the logarithm of the frequency of which is varied at a constant rate, is within ±0,3 dB of the theoretical output signal level for class 0 and class 1 instruments, and within ±0,5 dB for class 2 instruments. The expression for the theoretical output signal level in response to a constant-amplitude swept-frequency sinusoidal input signal is given in 5.6.

4.8 *Anti-alias filters*

The manufacturer shall include anti-alias filters, analogue and digital as appropriate, in a sampled-data or digital filter system. Anti-alias filters shall minimize interference between an input signal and the sampling process that would create aliased frequency components of the input signal and cause the relative attenuation response of a filter to exceed the greatest value of the applicable minimum limits of table 1.

4.9 *Summation of output signals*

For a sinusoidal input signal at any frequency between two consecutive octave or fractional-octave midband frequencies, the difference between (a) the level of the input signal minus the reference attenuation and (b) the level of the sum of the time-mean-square output signals from various filters of specified filter bandwidth shall not exceed ±1,0 dB; +1,0 dB, −2,0 dB and +2,0 dB, −4,0 dB for classes 0, 1, and 2 instruments, respectively.

4.10 *Flat frequency response*

If an instrument has a range of frequency-independent (i.e. "flat") transmission, the manufacturer shall state a range of frequencies over which the relative attenuation is within ±0,15 dB, ±0,3 dB, and ±0,5 dB of the relative attenuation at the reference frequency for classes 0, 1, and 2 instruments, respectively. The reference attenuation for measurements of relative attenuation with flat frequency response is the same as that for the relative attenuation of a bandpass filter.

4.11 *Maximum input signal*

The manufacturer shall state the maximum root-mean-square voltage of the sinusoidal input signal on each level range for which every filter in the instrument meets the requirements of this standard.

4.12 *Terminating impedances*

If applicable, the manufacturer shall state the input and output terminating impedances necessary to ensure proper operation of the instrument.

4.13 *Reference environmental conditions*

Reference environmental conditions include an ambient air temperature of 20 °C, a relative humidity of 65 %, and an atmospheric pressure of 101,3 kPa.

4.14 *Sensitivity to various environments*

4.14.1 *Ambient air temperature*

Over the minimum range of ambient temperature from 0 °C to + 50 °C, the relative attenuation for any filter available in the instrument and at the nominal midband frequency shall not deviate from the relative attenuation at the same frequency under reference environmental conditions by more than ±0,15 dB, ±0,3 dB, and ±0,5 dB for classes 0, 1, and 2 instruments, respectively.

4.14.2 *Relative humidity*

The manufacturer shall state the range of relative humidity and corresponding air temperature over which the instrument can operate continuously. After a 24 h exposure to the humid atmosphere at a relative humidity of 75 %, and at an ambient air temperature of +40 °C and without condensation on internal components of the instrument under test, the relative attenuation at the nominal midband frequency for any filter available in the instrument shall not deviate from the relative attenuation at the same frequency under reference environmental conditions by more than ±0,15 dB, ±0,3 dB, and ±0,5 dB for classes 0, 1, and 2 instruments, respectively.

4.14.3 *Alternating magnetic fields*

The influence of magnetic fields alternating at 50 Hz or 60 Hz (and at harmonics of the fundamental frequency) on the operation of a filter set shall be reduced as far as practicable.

4.14.4 *Electrostatic discharges*

The influence of electrostatic discharge on the operation of a filter set shall be reduced as far as practicable.

4.14.5 *Radio-frequency electromagnetic fields*

The influence of radio-frequency electromagnetic fields on the operation of a filter set shall be reduced as far as practicable.

4.15 *Power supply check*

For instruments that require a battery power supply, the manufacturer shall provide a suitable means to check that the power supply is adequate, at the time of checking, to operate the instrument according to all requirements of this standard.

5 Test methods

5.1 *General*

This clause describes methods of tests that may be performed for pattern evaluation or for periodic verification to determine that the performance of a filter set continues to remain within the tolerances specified in clause 4. The manufacturer may recommend equivalent tests as alternatives to those described in this clause 5 for demonstrating compliance with the requirements of this standard. Annex C indicates recommendations for tests that may be performed for pattern evaluation and periodic verification.

All test results shall be referred to the reference environmental conditions of 4.13. The instrument under test shall be connected to a source of electrical power, turned on, and operated for at least the minimum time specified by the manufacturer before initiating any tests.

5.2 *Test instruments*

5.2.1 All tests to demonstrate compliance with the requirements of clause 4, except the tests to determine compliance with the frequency limit for real-time operation, utilize steady sinusoidal signals of various frequencies and signal levels. The tests for determining the frequency limits for real-time operation use a constant-amplitude sinusoidal signal the frequency of which is varied, or swept, at a logarithmic rate. The signal generator, or generators, shall be capable of producing sinusoidal test signals over the range of frequencies needed for the relative-attenuation tests of all filters in the instrument to be tested and for all filter bandwidths or bandwidth designators.

NOTE – The interval between the test frequencies is given in equation (15).

5.2.2 At any frequency, the total distortion of a steady sinusoidal signal, including spurious components, at the output of the signal generator shall not exceed 0,01 % at the maximum signal level used for a test. The frequency of a sinusoidal test signal shall be accurate within ±0,01 % of the indicated frequency.

5.2.3 The level of the steady sinusoidal test signals shall be variable over at least an 80 dB range.

5.2.4 For bandpass filters that are designed to operate with measuring devices that comply with the requirements for sound level meters, the display indicator of the device should be used to measure the level of the output signal from the filter set.

5.2.5 For filter sets with digital readout devices, or with output that is available in a manufacturer-specified digital format (for example over a digital interface connection), the level of the output should be determined from the numeric readout or via the digital output to a suitable recording device.

5.2.6 For tests of real-time operation, the output level of the sweep-frequency signal generator shall be known and shall be maintained constant within ±0,1 dB of the nominal signal level over the frequency range for the selected range of nominal midband frequencies. For each 10:1 ratio of frequency over the range of frequencies covered by the frequency sweep, the logarithmic rate at which the frequency of the test signal is varied shall be constant within ±1 % of the nominal sweep-frequency rate.

5.3 *Relative attenuation*

5.3.1 The relative attenuation characteristic of each filter in a filter set shall be measured on the reference level range. The level of the input signals shall be within 1 dB of the upper boundary of the linear operating range.

5.3.2 With the input and output of the instrument terminated, if necessary, with the impedances specified by the manufacturer, a steady sinusoidal signal is applied to the input of the filter set. The levels of input and output signals at appropriate frequencies are measured.

5.3.3 For pattern-evaluation tests, and other filter-performance-evaluation tests where the frequency of the test signal (and the measurement of input and output signal levels) is controlled automatically by a programmable device, the frequencies of the sinusoidal test signal are spaced preferably at equal intervals on a logarithmic scale centred around the exact midband frequency. If S is the number of test frequencies per filter bandwidth, the normalized frequency f_i/f_m of the i test signal is determined from:

$$f_i / f_m = [G^{1/(bS)}]^i \qquad (15)$$

where

i is a positive or negative integer, including zero. The number of test frequencies per filter bandwidth, S, shall be not less than 24. The number of test frequencies shall be increased to more than 24 per filter bandwidth when the rate of change of relative attenuation with frequency is large. The increase in the number of test frequencies per bandwidth shall be in steps of 12 until the calculated filter integrated response is independent of S to the nearest tenth of a decibel.

5.3.4 Relative attenuation $\Delta A(f/f_m)$ at any frequency f is determined from equation (8).

5.3.5 For periodic verification of compliance with the relative-attenuation requirements of 4.4, the input signal frequencies may be restricted to the 17 octave or fractional-octave-band normalized frequencies corresponding to the normalized frequencies Ω in table 1. An actual test frequency for a fractional-octave-band filter is calculated from equations (10) and (11) according to the specified system for determining an octave frequency ratio and the specified bandwidth designator.

5.4 *Filter integrated response*

5.4.1 Filter integrated response shall be determined from equation (13) based on numerical evaluation of the integral expression in equation (14) for normalized effective bandwidth, with relative attenuations measured as described in 5.3.

5.4.2 For each filter in a filter set, the recommended procedure for numerical integration of equation (14) is by the trapezoidal rule for summation of elemental areas according to:

$$B_e = \sum_{i=-N}^{i=N} \frac{1}{2} \left\{10^{-0,1\,\Delta A(f_i/f_m)} + 10^{-0,1\,\Delta A(f_{i+1}/f_m)}\right\}\left[(f_{i+1}/f_m) - (f_i/f_m)\right] \tag{16}$$

where

$\Delta A(f_i/f_m)$ is the relative attenuation in decibels measured at the ith normalized test frequency;

N shall be equal to or greater than 5S = 120 for any filter bandwidth and accuracy class.

5.5 *Linear operating range*

5.5.1 Linearity of the response of a filter resulting from changes in the level of the signal at the input shall be tested with steady sinusoidal signals. Linear operating ranges shall be measured at least for the filters with the lowest and highest nominal midband frequencies of all filter bandwidths for which compliance with the requirements of this standard is claimed, and with flat frequency response, if provided, at least for the manufacturer-stated lowest and highest frequencies of the range of flat frequency response.

5.5.2 For each test frequency, level linearity errors on any level range shall be determined in accordance with definition 3.22 with steps of input signal level that are not greater than 5 dB. The difference between successive steps of input signal level shall be reduced to 1 dB to determine the lower and upper boundaries of a linear operating range.

5.5.3 The averaging time during a measurement shall be long enough to establish a stable indication considering the influence of internally generated noise at low input signal levels.

5.5.4 If recommended by the manufacturer, the requirements of 4.6.4 for linear operating range may be demonstrated with an input signal composed of two sinusoidal signals, one of which is the test signal and the other a subsidiary signal at a constant level 20 dB below the upper boundary of the linear operating range and at a frequency above or below the test frequency, in the frequency range for the greatest value of the applicable minimum limit for relative attenuation of filter response given in 4.4.

5.6 *Real-time operation*

5.6.1 The frequency range over which a filter operates in real-time shall be determined from a swept-frequency test.

5.6.2 The time-average or equivalent-continuous output signal level, L_o, indicated by the readout device at the output of the instrument should be the same for all filters when a constant-amplitude sinusoidal signal is applied to the input and the logarithm of the frequency of the signal is varied at a constant rate over the frequency range of all filters of any given bandwidth.

5.6.3 For a given swept-frequency sinusoidal input signal, the theoretical time-average output signal level, L_c, in decibels, that would be indicated at the output, with a relative attenuation equal to the reference attenuation of the actual filter and infinite attenuation outside the bandedge frequencies, is given by:

$$L_c = L_{in} - A_{ref} + 10 \lg\{(T_{sweep}/T_{avg})[\lg(f_2/f_1)/\lg(f_{end}/f_{start})]\} \text{ dB} \quad (17)$$

where

L_{in} is the measured time-average signal level of the constant-amplitude input signal;

T_{sweep} is the time required to sweep at a logarithmic rate from the starting frequency f_{start}, to the ending frequency f_{end};

f_1 and f_2 are the bandedge frequencies;

T_{avg} is the averaging time selected for measurement of the output signal level L_o.

NOTE – In equation (17), $\lg(f_2/f_1)$ equals $3/(10b)$ for base-ten systems and $(1/b)$ lg (2) for base-two systems.

5.6.4 The difference δ between a measured output time-average signal level, L_o, and the corresponding constant theoretical output time-average signal level, L_c, and the measured value of the filter integrated response, ΔB, is given by:

$$\delta = L_o - \Delta B - L_c \quad (18)$$

5.6.5 The test for real-time operation shall be conducted on the reference level range. The level of the input signals shall be 3 dB less than the upper boundary of the linear operating range on the reference level range. The logarithmic frequency sweep rate shall be low enough to permit reliable measurements of the relative attenuation in the passbands of the filters as appropriate for the filter bandwidth. The frequency at the start of the sweep f_{start} shall be approximately half the lowest nominal midband frequency for the filter bandwidth. The frequency at the end of the sweep f_{end} shall be approximately twice the corresponding greatest nominal midband frequency. The averaging time T_{avg} shall be greater than the total sweep time by at least 5 s.

NOTES

1 A logarithmic sweep rate in "decades" per second is determined from:

$$[\lg(f_{end}/f_{start})]/T_{sweep}$$

where

f_{end} is the frequency at the end of the sweep;

f_{start} is the frequency at the start of the sweep;

T_{sweep} is the sweep time, in seconds.

2 The sweep rate should be not greater than 0,5 "decade" per second (or 1,6 "octave" per second).

5.6.6 Within 3 s after initiation of the averaging time period, the frequency sweep shall be started and swept once over the frequency range from f_{start} to f_{end}. Time-average output signal levels shall be measured and compared with the calculated output signal level in accordance with equation (18). For any filter bandwidth available in the instrument, the nominal midband frequencies where the absolute value of the difference δ first exceeds the applicable tolerances in 4.7 define the low- and high-frequency limits of the frequency range for real-time operation.

5.7 *Anti-alias filters*

5.7.1 For sampled-data filters, the test of the ability of anti-alias filters to adequately attenuate spurious spectral components of an input signal shall be performed with steady sinusoidal signals applied to the input. The level of the input signal shall equal the upper boundary of the linear operating range on the reference level range.

5.7.2 For each filter bandwidth designator available in the instrument, the frequencies of the input test signal shall equal the applicable sampling frequency minus the nominal midband frequency of at least one filter in each 1:10 frequency ratio of the complete frequency range applicable to the bandwidth designator. As an example, for a range of nominal midband frequencies from 20 Hz to 20 kHz, select one nominal midband frequency in the range from 20 Hz to 200 Hz, one in the range from 200 Hz to 2 kHz, and one in the range from 2 kHz to 20 kHz.

5.7.3 For each test frequency, the level of the output signal shall not exceed the level of the input signal minus the applicable limit from table 1 on the greatest value of minimum relative attenuation.

5.8 *Summation of output signals*

5.8.1 Let j identify a filter in a set of filters with j − 1 and j + 1 representing the contiguous filters with midband frequencies lower and higher than for the jth filter. Let ΔA_j, ΔA_{j-1}, and ΔA_{j+1} represent measured relative attenuations of the three filters, respectively, at any test frequency.

5.8.2 With S equal to the number of frequencies per filter bandwidth from the relative attenuation tests conducted according to the requirements of 5.3, let M be equal to the largest integer just less than or equal to S/2 and let i be any integer between −M and +M to determine a frequency f_i for a measurement of relative attenuation in accordance with equation (15).

5.8.3 At any frequency between the lower and upper bandedge frequencies of the jth filter with exact midband frequency f_m, the difference $\Delta P(f_i)$ between the level of the input signal minus the reference attenuation and the level of the summed output signals is determined from the relationship:

$$\Delta P(f_i) = 10 \lg \left[10^{-0,1\,\Delta A_{j-1}} + 10^{-0,1\,\Delta A_j} + 10^{-0,1\,\Delta A_{j+1}}\right] \mathrm{dB} \qquad (19)$$

where

ΔA_{j-1} is the relative attenuation measured at normalized frequency $G^{[i/(bS)+1/b]}$;

ΔA_j is the relative attenuation measured at normalized frequency $G^{[i/(bS)]}$;

ΔA_{j+1} is the relative attenuation measured at normalized frequency $G^{[i/(bS)-1/b]}$.

5.8.4 The test shall be carried out from the lowest midband frequency to the highest midband frequency of the filter set.

5.8.5 For any filter bandwidth provided, the difference $\Delta P(f_i)$ calculated according to equation (19) shall be within the tolerances given in 4.9 at any test frequency between any two octave or fractional-octave midband frequencies.

5.9 *Flat frequency response*

For filter sets that provide a range of flat frequency response, the extent of the frequency range over which the tolerances on relative attenuation in 4.10 are maintained, shall be tested by applying constant-level sinusoidal signals to the input and noting the corresponding output signal levels. The level of the input signals shall equal the reference input signal level on the reference level range. The frequencies of the test signals include the manufacturer's stated lower and upper limits of the range of flat frequency response and the nominal midband frequencies of the octave-band filters between the lower and upper frequency limits.

5.10 *Sensitivity to variations of the environment*

Tests shall be carried out to ensure that the filter satisfies the requirements for the range of ambient air temperatures given in 4.14.1 and for the effect of relative humidity given in 4.14.2. For temperature tests, the exposure time at each ambient temperature shall be long enough to permit the instrument under test to reach equilibrium with the prevailing temperature.

5.11 *Sensitivity to electrostatic discharge*

The manufacturer should determine the influence of electrostatic discharge in accordance with IEC 801-2.

5.12 *Sensitivity to radio-frequency electromagnetic fields*

The manufacturer should determine the influence of radio-frequency electromagnetic fields in accordance with IEC 801-3.

6 Instrument marking

A filter set that complies with all requirements of this standard shall be marked "YYY-band filter, class X, IEC 1260:1995" where YYY is the bandwidth, for example, octave and X is 0, 1 or 2, as appropriate. The filter set shall also be marked with the name of the manufacturer, the model, and serial number, if practical.

7 Instruction manual

The instruction manual for a filter set shall include at least the information listed below:

a) a statement that all filters of all nominal filter bandwidths available in each analysis channel of a filter (if more than one channel is available) comply with all performance requirements of this standard within the tolerances for an accuracy class;

b) a description of the analytical method that was selected to implement the design of the filters;

c) for digital and sampled-data filters, the sampling frequency or frequencies applicable to the various filters;

d) for each analysis channel available, a list of the nominal midband frequencies for all filters of each available filter bandwidth, in accordance with the guidelines in annex A;

e) a statement of the system, base-ten or base-two, selected to determine the octave frequency ratio;

f) the reference level range;

g) the reference input signal level;

h) the reference attenuation;

i) the linear operating range and the linearity tolerances (maximum level linearity error) of displayed output signal levels outside the linear operating range;

j) for each level range, recommendations on operation of the instrument to ensure that measurements are made within the linear operating range;

k) for each nominal filter bandwidth available, the frequency range for real-time operation and other information pertinent to real-time spectral analyses of transient and time-varying signals;

l) if available, the frequency range of nominally flat frequency response;

m) the maximum root-mean-square voltage of a sinusoidal input signal at any frequency in the range of the instrument and for each level range;

n) if required, the real and reactive components of the terminating impedances that should be placed at the input and output of the instrument;

o) the temperature limits and corresponding exposure times which, if exceeded, will result in permanent damage to the instrument;

p) limitations on the use of the instrument in proximity to a source of alternating magnetic fields;

q) limitations on operation of the instrument in proximity to sources of electrostatic discharge, especially under low humidity conditions;

r) limitations on operation of the instrument in proximity to sources of radio-frequency electromagnetic fields;

s) if battery powered, the recommended means to check that electrical power supplied by batteries is sufficient to operate the instrument within all applicable tolerances at the time of checking;

t) if the filter is intended to be operated in conjunction with a sound level meter or equivalent instrument, the specific instrument shall be identified;

u) the maximum time needed, after turning on a filter which had been off sufficiently long at the prevailing ambient air temperature to reach thermal equilibrium, before the instrument may be used to measure filtered output signal levels that comply with the requirements of this standard for all applicable ambient air temperatures; and

v) any additional information required to conduct tests to verify that the filter complies with the performance requirements of this standard within the applicable tolerances or to use the instrument to obtain bandpass-filtered output signal levels within the accuracy tolerances for the class.

Annex A
(informative)

Midband frequencies

A.1 Exact and nominal midband frequencies for octave and one-third-octave-band filters are given in table A.1. Exact midband frequencies are calculated from equation (3) to five significant digits. Exact values marked by †.

A.2 For either octave frequency ratio defined in 3.2 and, for bandwidth designators from 1/4 to 1/24 inclusive, exact midband frequencies are calculated from equation (3) or equation (4), as appropriate, for the base-ten version of the octave frequency ratio in equation (1).

A.3 When the most significant digit (that is, left-most) of an exact midband frequency is between 1 and 4 inclusive, the calculated nominal midband frequency is rounded to the first three significant digits.

A.4 When the most significant digit of an exact midband frequency is between 5 and 9 inclusive, the calculated nominal midband frequency is rounded to two significant digits.

As an example, for the base-10 system with $G = 10^{3/10}$, $1/b = 1/24$ and $x = -111$, the exact midband frequency from equation (4) is 41,567 Hz to five figures. The corresponding nominal midband frequency is 41,6 Hz. For $x = +75$, the exact midband frequency is 8 785,2 Hz to five figures and the corresponding nominal midband frequency is 8 800 Hz.

A.5 When the denominator b of a bandwidth designator is greater than 24, increase the number of significant digits to provide unique values for the nominal midband frequencies in any 1:10 frequency ratio.

Table A.1 – Midband frequencies for octave-band and one-third-octave-band filters in the audio range

Indice x	Base-ten exact f_m $(10^{x/10})$ (1 000) Hz	Base-two exact f_m $(2^{x/3})$ (1 000) Hz	Nominal midband frequency Hz	One-third octave	Octave
–16	25,119	24,803	25	•	
–15	31,623	31,250 †	31,5	•	•
–14	39,811	39,373	40	•	
–13	50,119	49,606	50	•	
–12	63,096	62,500 †	63	•	•
–11	79,433	78,745	80	•	
–10	100,00 †	99,213	100	•	
–9	125,89	125,00 †	125	•	•
–8	158,49	157,49	160	•	
–7	199,53	198,43	200	•	
–6	251,19	250,00 †	250	•	•
–5	316,23	314,98	315	•	
–4	398,11	396,85	400	•	
–3	501,19	500,00 †	500	•	•
–2	630,96	629,96	630	•	
–1	794,33	793,70	800	•	
0	1 000,0 †	1 000,0 †	1 000	•	•
1	1 258,9	1 259,9	1 250	•	
2	1 584,9	1 587,4	1 600	•	
3	1 995,3	2 000,0 †	2 000	•	•
4	2 511,9	2 519,8	2 500	•	
5	3 162,3	3 174,8	3 150	•	
6	3 981,1	4 000,0 †	4 000	•	•
7	5 011,9	5 039,7	5 000	•	
8	6 309,6	6 349,6	6 300	•	
9	7 943,3	8 000,0 †	8 000	•	•
10	10 000 †	10 079	10 000	•	
11	12 589	12 699	12 500	•	
12	15 849	16 000 †	16 000	•	•
13	19 953	20 159	20 000	•	

NOTES

1 Exact midband frequencies are calculated from equation (3) to five significant figures except for the exact values marked by †.

2 See ISO 266 for other nominal midband frequencies of octave and one-third-octave-band filters.

Annex B
(informative)

Normalized frequencies at breakpoints of limits on minimum and maximum relative attenuation for one-third-octave-band filters

B.1 This annex provides an example calculation of the normalized frequencies for the limits on minimum and maximum relative attenuation for a one-third-octave-band filter, i.e., for $1/b = 1/3$.

B.2 For the initial calculation, let $\Omega = G^{1/8}$. From equation (10), the high-frequency breakpoint is found from the general relationship:

$$\Omega_{h(1/3)} = 1 + [(G^{1/6} - 1)/(G^{1/2} - 1)](G^{1/8} - 1)$$

B.3 For base-ten systems with $G = 10^{3/10}$,

$$\Omega_{h(1/3)} = 1 + [(10^{1/20} - 1)/(10^{3/20} - 1)](10^{3/80} - 1)$$
$$\simeq 1{,}026\,67$$

B.4 For base-two systems with $G = 2$,

$$\Omega_{h(1/3)} = 1 + [(2^{1/6} - 1)/(2^{1/2} - 1)](2^{1/8} - 1)$$
$$\simeq 1{,}026\,76$$

B.5 From equation (11), the corresponding low-frequency breakpoints are:

$$\Omega_{l(1/3)} \simeq 0{,}974\,02 \text{ for base-ten}$$

and

$$\Omega_{l(1/3)} \simeq 0{,}973\,94 \text{ for base-two}$$

B.6 Application of equations (10) and (11) for the octave-band breakpoint frequencies in table 1 yielded the normalized frequencies in table B.1 for one-third-octave-band filters.

Table B.1 – Limits on relative attenuation for one-third-octave-band filters

Normalized frequency, f/f_m for Ω_h and Ω_l		Minimum; maximum attenuation limits dB		
		Filter class		
base 10	base 2	0	1	2
1,000 00	1,000 00	–0,15; +0,15	–0,3; +0,3	–0,5; +0,5
1,026 67 0,974 02	1,026 76 0,973 94	–0,15; +0,2	–0,3; +0,4	–0,5; +0,6
1,055 75 0,947 19	1,055 94 0,947 02	–0,15; +0,4	–0,3; +0,6	–0,5; +0,8
1,087 46 0,919 58	1,087 76 0,919 32	–0,15; +1,1	–0,3; +1,3	–0,5; +1,6
<1,122 02 >0,891 25	<1,122 46 >0,890 90	–0,15; +4,5*	–0,3; +5,0*	–0,5; +5,5*
>1,122 02 <0,891 25	>1,122 46 <0,890 90	+2,3; +4,5*	+2,0; +5,0*	+1,6; +5,5*
1,294 37 0,772 57	1,295 65 0,771 81	+18,0; +∞	+17,5; +∞	+16,5; +∞
1,881 73 0,531 43	1,886 95 0,529 96	+42,5; +∞	+42; +∞	+41; +∞
3,053 65 0,327 48	3,069 55 0,325 78	+62; +∞	+61; +∞	+55; +∞
≥5,391 95 ≤0,185 46	≥5,434 74 ≤0,184 00	+75; +∞	+70; +∞	+60; +∞

* At frequencies less than the lower bandedge frequency and greater than the upper bandedge frequency, the limit on maximum relative attenuation is +∞; see figure 1.

Annex C
(informative)

Recommendations for verification of the electrical performance characteristics of bandpass filters

C.1 This annex indicates which performance requirements from clause 4 should be confirmed by the methods given in clause 5 for pattern evaluation and which for periodic verification. Relevant subclause numbers from clauses 4 and 5 are noted within parentheses. An X in a column indicates that the test should be carried out; — indicates that no test should be carried out.

Characteristic to be tested	Pattern evaluation	Periodic verification
1 Relative attenuation (4.4; 5.3)	X	X (fewer frequencies)
2 Filter integrated response (4.5; 5.4)	X	—
3 Linear operating range (4.6; 5.5)	X	X
4 Real-time operation (4.7; 5.6)	X	—
5 Anti-alias filter (4.8; 5.7)	X	X
6 Summation of output signals (4.9; 5.8)	X	X
7 Flat frequency response (4.10; 5.9)	X (if provided)	X (if provided)
8 Sensitivity to air temperature (4.14.1; 5.10)	X	—
9 Sensitivity to humidity (4.14.2; 5.10)	X	—

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