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AMERICAN NATIONAL STANDARD

Acoustical Terminology

Secretariat:

Acoustical Society of America

Approved on October 13, 2013:

American National Standards Institute, Inc.

Abstract

This standard provides definitions for a wide variety of terms, abbreviations, and letter symbols used in acoustics and electroacoustics. Terms of general use in all branches of acoustics are defined, as well as many terms of special use for architectural acoustics, acoustical instruments, mechanical vibration and shock, physiological and psychological acoustics, underwater sound, sonics and ultrasonics, and music.

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AMERICAN NATIONAL STANDARD

Acoustical Terminology

ANSI/ASA S1.1-2013

Accredited Standards Committee S1, Acoustics

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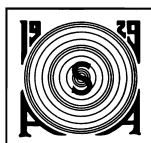
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Contents

1	Scope	1
2	General	1
3	Levels	11
4	Oscillation, vibration, and shock.....	18
5	Transmission and propagation	23
6	Transducers and linear systems	28
7	Acoustical apparatus and instruments	36
8	Underwater acoustics	45
9	Sonics and ultrasonic testing.....	48
10	Architectural acoustics.....	51
11	Physiological and psychological acoustics	58
12	Musical acoustics.....	63
	Bibliography	68
	Index	69

Tables

Table 1 — Resonance relations	19
Table 2 — Interval comparisons in different mathematical tuning systems	66
Table 3 — Frequencies in hertz (Hz) and frequency levels in semitones counted (sc) up from C_0 for the usual equal-tempered scale. Subscripts by octaves above C_0 . C_0 approximately equals 16.352 Hz so that $A_4 = 440$ Hz exactly.....	67

Foreword

[This Foreword is for information only, and is not a part of the American National Standard ANSI/ASA S1.1-2013 American National Standard Acoustical Terminology.]

This standard comprises a part of a group of definitions, standards, and specifications for use in acoustics. It was developed and approved by Accredited Standards Committee S1, Acoustics, under its approved operating procedures. Those procedures have been accredited by the American National Standards Institute (ANSI). The Scope of Accredited Standards Committee S1 is as follows:

Standards, specifications, methods of measurement and test, and terminology in the field of physical acoustics, including architectural acoustics, electroacoustics, sonics and ultrasonics, and underwater sound, but excluding those aspects which pertain to biological safety, tolerances, and comfort.

This standard is a revision of ANSI S1.1-1994, which has been technically revised.

At the time this Standard was submitted to Accredited Standards Committee S1, Acoustics for approval, the membership was as follows:

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The group would also like to recognize George Wong and Joseph Pope who provided input to the early drafts of the revision before passing away.

Suggestions for improvements of this standard will be welcomed. They should be sent to Accredited Standards Committee S1, Acoustics, in care of the Standards Secretariat of the Acoustical Society of America, 35 Pinelawn Road, Suite 114E, Melville, New York 11747-3177. Telephone: 631-390-0215; FAX: 631-390-0217; E-mail: asastds@aip.org.

American National Standard

Acoustical Terminology

1 Scope

This American National Standard provides definitions for terms used in acoustics and electroacoustics. Many terms apply to all branches of acoustics. A number of general terms from the fields of architectural acoustics, engineering acoustics, physical acoustics, physiological and psychological acoustics, sonics and ultrasonics, underwater sound, and music are also provided. Specialized terms relating to the field of vibration and shock and to the fields of psychoacoustics and bioacoustics are contained in Standards listed among the general references.

Definitions provided in this Standard are intended to be consistent with their counterparts in International Standards.

Terms defined in an earlier edition of this Standard for the field of recording and reproducing sound are not provided in this edition because they are more properly a subject for other Standards.

2 General

2.01 sound. (a) Oscillation in pressure, stress, particle displacement, particle velocity, etc., propagated in a medium with internal forces (e.g., elastic or viscous), or the superposition of such propagated oscillation. (b) Auditory sensation evoked by the oscillation described in (a).

NOTE 1 Not all sounds evoke an auditory sensation, e.g., ultrasound or infrasound. Not all auditory sensations are evoked by sound, e.g., tinnitus.

NOTE 2 The medium in which the sound exists is often indicated by an appropriate adjective, e.g., air-borne, water-borne, or structure-borne.

2.02 ultrasound. Sound at frequencies greater than 20 kHz.

NOTE A frequency of 20 kHz is the limit of the approximate upper range of human hearing.

2.03 infrasound. Sound at frequencies less than 20 Hz.

NOTE A frequency of 20 Hz is the approximate lower limit of the range of human hearing.

2.04 acoustics. (a) Science of sound, including its production, transmission, and effects, including biological and psychological effects. (b) Those qualities of a room that, together, determine its character with respect to auditory effects.

2.05 acoustic, acoustical. Qualifying adjectives meaning containing, producing, arising from, actuated by, related to, or associated with sound. Acoustic is used when the term being qualified designates something that has the properties, dimensions, or physical characteristics associated with sound waves; acoustical is used when the term being qualified does not designate explicitly something that has such properties, dimensions, or physical characteristics.

NOTE 1 Examples that should use the qualifying adjective *acoustic* are impedance, inertance, load (radiation field), output (sound power), energy, wave, medium, signal, absorptivity, and transducer.

NOTE 2 Examples not having the requisite physical characteristics and that therefore should use the qualifying adjective *acoustical* are: society, method, engineer, school, glossary, symbol, problem, measurement, point of view, end-use, device, and standard.

NOTE 3 Generic terms are usually modified by *acoustical*, whereas *acoustic* applies to terms with specific technical implication.

2.06 oscillation. Variation, usually with time, of the value of a quantity with respect to a specified reference when the value is alternately greater and less than the reference.

2.07 vibration. Mechanical oscillations about an equilibrium point. The oscillations may be periodic or random.

SOURCE ANSI/ASA S2.1-2009/ISO 2041:2009, 2.1.

2.08 acoustic variable. Time varying or oscillatory acoustic quantity; examples are acoustic pressure and vibrational acceleration.

2.09 periodic quantity. Oscillating quantity whose values identically recur at equal increments of the independent variable.

NOTE 1 If v is a function f of time t , and if $v = f(\omega t) = f[\omega(t + T)]$, for all values of t , where ω and T are constants, then v is a periodic quantity.

NOTE 2 In general, a periodic function can be expanded into a Fourier series of the form

$$y = A_0 + A_1 \sin(\omega t + a_1) + A_2 \sin(2\omega t + a_2) + \dots,$$

where ω , a positive constant, equals 2π divided by the period T , and A_0 , A_i and a_i ($i = 1, 2, 3, \dots$) are real constants which may be positive, negative, or zero.

2.10 period. Smallest increment of time for which a periodic function repeats itself; the duration of one cycle.

2.11 cycle. Complete sequence of values of a periodic quantity that occurs during a period.

2.12 frequency. The rate of change with time of the instantaneous phase of a sine function divided by 2π , with the dimensions of cycles per second or hertz (Hz).

2.13 fundamental frequency. For a function periodic in time, the reciprocal of the period. Unit, hertz (Hz).

NOTE See also 4.20 and 12.04.

2.14 angular frequency. Frequency multiplied by 2π . Unit, radian per second; symbol, ω .

2.15 audio frequency. Frequency of a sound wave nominally audible to humans. Unit, hertz (Hz).

NOTE 1 Audio frequencies range roughly from 15 Hz to 20 kHz.

NOTE 2 The word "audio" may be used as a modifier to indicate a device or system intended to operate at audio frequencies, e.g., "audio amplifier."

2.16 ultrasonic frequency. Frequency greater than 20 kHz, the nominal upper range of human hearing. Unit, hertz (Hz).

NOTE The term "ultrasonic" may be used as a modifier to indicate a device or system intended to operate at an ultrasonic frequency.

2.17 infrasonic frequency. Frequency less than 20 Hz, the nominal lower range of human hearing. Unit, hertz (Hz).

NOTE 1 The term "infrasonic" may be used to indicate a device or system intended to operate at an infrasonic frequency.

NOTE 2 The frequency range is often that between 1 Hz and 20 Hz when physiological effects are discussed.

2.18 peak-to-peak value. Algebraic difference between extremes of an oscillating quantity.

2.19 simple harmonic quantity. Quantity that is a sinusoidal function of the independent variable.

NOTE 1 For temporal variability, $y = A \sin(\omega t + \phi)$, where y is the simple harmonic quantity, A is the amplitude, ω is the angular frequency, and ϕ is the starting phase of the oscillation.

NOTE 2 For spatial variability, $y = A \sin(kx + \phi)$, where y is the simple harmonic quantity, A is the amplitude, k is the wave number, and ϕ is the starting phase of the oscillation.

NOTE 3 The maximum value of a simple harmonic quantity is amplitude A ; for emphasis it is sometimes called the single amplitude to distinguish it from the double amplitude which for a simple harmonic quantity is the same as the total excursion or peak-to-peak value.

2.20 amplitude. Magnitude of the largest departure from its equilibrium value of an acoustic variable.

2.21 simple harmonic motion. Motion such that the displacement is a sinusoidal function of time.

2.22 phase of a periodic quantity. For a particular value of an independent variable, the fractional part of a period through which the independent variable has advanced, measured from an arbitrary reference.

NOTE The arbitrary reference is generally so chosen as to be less than unity. In the case of a simple harmonic quantity, the reference is often taken as the last previous passage through zero instantaneous value from the negative to positive direction.

2.23 phase. A reference angle for the argument of a sine (or cosine) function.

2.24 instantaneous phase. The argument of a sine (or cosine) function at any given time. For the temporal function in NOTE 1 of 2.19, $\omega t + \phi$ is the instantaneous phase.

2.25 starting phase. The phase for time zero. For the functions in NOTE 1 and NOTE 2 of 2.19, ϕ is the starting phase.

2.26 wave. Disturbance such that the quantity serving as a measure of the disturbance varies with position and time in a manner that at pairs of neighboring positions the disturbance is similar except for a time difference.

NOTE 1 Any physical quantity that has the same relationship to some independent variable (usually time) that a propagated disturbance has at a particular instant, with respect to space, may be called a traveling wave. For a traveling wave, the velocity of propagation of the disturbance is equal to the distance between neighboring positions divided by the time difference.

NOTE 2 See also 5.06 through 5.23.

2.27 wavelength. For a simple harmonic wave in an isotropic medium, perpendicular distance between two wavefronts in which the displacements have a difference in phase of 2π radians. Unit, meter (m); symbol λ , $\lambda = c/f$.

2.28 wave number. (a) 2π divided by the wavelength of a periodic wave. (b) Angular frequency divided by speed of sound. Unit, reciprocal meter (1/m); symbol $k = \omega/c$.

2.29 harmonic. Sinusoidal quantity having a frequency which is an integral multiple of the fundamental frequency.

NOTE See also 12.06.

2.30 subharmonic. Sinusoidal quantity having a frequency which is an integral submultiple of the fundamental frequency of a periodic quantity to which it is related.

NOTE An integral submultiple is a fraction of the form $1/n$, where n is any integer greater than unity.

2.31 signal. (a) Disturbance that conveys information. (b) Information to be conveyed over a communication system.

2.32 noise. (a) Undesired sound. By extension, noise is any unwanted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device. (b) Erratic, intermittent, or statistically random oscillation.

NOTE 1 If ambiguity exists as to the nature of the noise a phrase such as "acoustic noise" or "electric noise" should be used.

NOTE 2 Since definitions 2.32 (a) and (b) are not mutually exclusive, it is usually necessary to depend upon context for the distinction.

2.33 ambient noise. All-encompassing sound at a given place, usually a composite of sounds from many sources near and far.

NOTE 1 When the intent is to measure or record a specific source or signal, the ambient noise does not include sounds of interest.

NOTE 2 See also 8.09.

2.34 background noise. Total of all sources of interference in a system used for the production, detection, measurement, or recording of a signal, independent of the presence of the signal.

NOTE 1 Ambient sound detected, measured, or recorded with the signal is part of the background noise.

NOTE 2 Included in the definition of background noise is the interference resulting from primary electric power supplies that is commonly described as *hum*.

2.35 flow noise. Noise due to flow-excited vibration or noise directly radiated from flow turbulence.

NOTE See also 8.12.

2.36 random noise. Oscillation for which instantaneous value is not specified for any given instant of time. The instantaneous values of a random noise are specified only by the probability distribution functions giving the fraction of total time that the value, or some sequence of values, lies within a specified range.

NOTE Random noise for which instantaneous values occur according to the Gaussian distribution is called "Gaussian random noise."

2.37 white noise. Noise for which the spectrum density (see 2.46) or spectrum level is independent of frequency over a specified range.

2.38 pink noise. Noise for which the spectrum density varies as the inverse of frequency.

2.39 pseudo-random noise. A noise with random properties but synthesized in accordance with defined mathematical parameters and therefore predictable and not random. Abbreviation: PRN.

NOTE 1 A noise spectrum can be independent of frequency over a desired bandwidth.

NOTE 2 PRN repeats itself periodically, depending on the switching speed and the number of states within a cycle.

NOTE 3 PRN is widely used in applications where large bandwidth is desired and where it can be detected in truly random background noise by using cross-correlation with the noise-free waveform.

2.40 reverberation. Sound that persists as a result of repeated reflection or scattering after the sound source has stopped.

NOTE Repeated reflections of residual sound in an enclosure can alternatively be described in terms of the transient behavior of the modes of vibration of the medium bounded by the enclosure.

2.41 echo. Wave that has been reflected or otherwise returned with sufficient magnitude and delay to be detectable as a wave distinct from that directly transmitted.

NOTE 1 An echo is separately localizable.

NOTE 2 See also 10.29.

2.42 modulation. Variation of some parameter characterizing a periodic oscillation. Thus amplitude modulation of a sinusoidal oscillation is a variation in the amplitude of the sinusoidal oscillation.

2.43 beats. Periodic variations that result from the superposition of two sinusoidal quantities of different frequencies, f_1 and f_2 . Beats involve the periodic increase and decrease of amplitude at the beat frequency, $(f_1 - f_2)$, where f_1 is greater than f_2 .

2.44 distortion. (a) Any change in the shape of a waveform not resulting from linear addition of another waveform. (b) Undesired change of waveform.

NOTE 1 Multiplication by a constant and time delay do not constitute distortion. Noise and certain desired changes in waveform, such as those resulting from modulation or detection, are not usually described as distortion.

NOTE 2 Harmonic distortion is harmonic power divided by fundamental power or the square root of this ratio. Use of power or the square root of the ratio should be clarified for the description of harmonic distortion.

2.45 spectrum. (a) Description, for a function of time, of the resolution of a signal into components, each of different frequency and (usually) different amplitude and phase. (b) "Spectrum" is also used to signify a continuous range of components, usually wide in extent, within which waves have some specified common characteristic; e.g., "audio frequency spectrum."

NOTE 1 The term "spectrum" is also applied to functions of variables other than time, such as distance.

NOTE 2 As defined here, "spectrum" defines a Fourier analysis of a signal or noise of a waveform. Basis functions other than sinusoids can be used, providing spectra other than Fourier.

2.46 spectrum density. Limit, as the bandwidth approaches zero, of the quotient of mean-square value of an acoustic variable by bandwidth.

NOTE 1 In mathematical terms, the spectrum density function of an oscillation $y(t)$ is the ensemble average $G(f)$ where (when a limit exists)

$$G(f) = \lim_{T \rightarrow \infty} \left[\frac{1}{T} \left| \int_{-T/2}^{T/2} y(t) e^{j2\pi ft} dt \right|^2 \right],$$

and f is frequency.

NOTE 2 Spectrum density is the time-mean-square amplitude of the output of a filter that has unity gain in a finite frequency band; spectrum density is given by the integral of $G(f)$ with respect to frequency over the band.

NOTE 3 The oscillatory function may be any time-dependent parameter, e.g., sound pressure, velocity, or acceleration of a component of a mechanical system. The unit of spectrum density is the square of the unit of the oscillatory function, divided by frequency. For example, the unit for acceleration spectral density is $(\text{m/s}^2)^2/\text{Hz}$.

NOTE 4 For a signal of finite duration, T , the spectrum density is computed as

$$G(f) = \frac{1}{T} \left| \int_0^T y(t) e^{j2\pi ft} dt \right|^2.$$

2.47 power spectral density; power spectrum density. Limit, as the bandwidth approaches zero, of sound power divided by bandwidth. Unit, watt per hertz (W/Hz).

2.48 line spectrum. Spectrum for which the components occur at a number of discrete frequencies.

2.49 pure tone. Signal with a line spectrum consisting of a single frequency.

NOTE See also 12.02.

2.50 continuous spectrum. Spectrum of a wave for which the components are continuously distributed over a frequency region.

2.51 displacement. Vector quantity that specifies the change of position of a body or particle. Units, meter (m), radian (rad).

2.52 velocity. Vector that specifies the time rate of change of translational displacement with respect to a reference frame. Unit, meter per second (m/s).

2.53 acceleration. Vector that specifies the time rate of change of velocity. Unit, meter per second-squared (m/s^2).

NOTE 1 Various self-explanatory modifiers such as peak and time-mean-square are often used. The time interval should be indicated over which the mean (for example) was taken.

NOTE 2 Acceleration may be (a) oscillatory, in which case it may be defined by acceleration amplitude (if simple harmonic) or the time-mean-square acceleration (if random), or (b) non-oscillatory, in which case it is designated "sustained" or "transient acceleration."

2.54 jerk. Vector that specifies the time rate of change of acceleration; jerk is the third derivative of translational displacement with respect to time. Unit, meter per second-cubed (m/s^3).

2.55 standard acceleration due to Earth's gravity. The value adopted in the International Bureau of Weights and Measures and confirmed in 1913 by the 5th General Conference on Weights and Measures as the standard for acceleration due to gravity. Unit, meter per second-squared. Symbol, g_n .

NOTE 1 This "standard value" ($g_n = 9.80665 \text{ m/s}^2 = 980.665 \text{ cm/s}^2 = 386.089 \text{ in/s}^2 = 32.1740 \text{ ft/s}^2$) should be used to determine the ratio of a measurement of the acceleration due to gravity at any location on Earth to the standard acceleration due to gravity.

NOTE 2 Frequently, the magnitude of acceleration is expressed as a multiplier of g_n .

NOTE 3 The actual acceleration produced by the force of gravity at or below the surface of the Earth varies with the latitude and elevation of the point of observation. This variable often is expressed using the symbol g . Caution should be exercised when this is done so as not to create an ambiguity with this use and the standard symbol for the unit of the gram as the unit of mass.

2.56 stiffness. Ratio of change of force to the corresponding change in translational displacement of an elastic element. Unit, newton per meter (N/m).

NOTE 1 In the case of torsional stiffness, "force" and "displacement," respectively, are replaced by "torque" and "angular displacement" and the unit is newton meter per radian (Nm/rad).

NOTE 2 See also 6.32.

2.57 compliance. Reciprocal of stiffness. Unit, meter per newton (m/N).

NOTE See also 6.33.

2.58 static pressure. Constant pressure that would exist at a point in the absence of a sound wave. Unit, pascal (Pa); symbol, p_s .

NOTE One pascal is equal to one newton per square meter.

2.59 sound pressure. Total instantaneous pressure at a point in a medium minus the static pressure at that point. Unit, pascal (Pa); symbol, p .

2.60 peak sound pressure. Greatest absolute value of instantaneous sound pressure within a specified time interval. Unit, pascal (Pa).

NOTE 1 Peak sound pressure may be measured with a standard frequency weighting that should be stated. The result is a peak sound level.

NOTE 2 Frequency weightings and exponential time weightings are specified in Part 1 of IEC 61672.

2.61 effective sound pressure. At a point, root-mean-square of a sound pressure signal at the time of observation. Unit, pascal (Pa).

2.62 sound exposure. Time integral of the square of an instantaneous frequency-weighted sound pressure signal. Unit, pascal-squared second; symbol, E , abbreviation, SE.

NOTE 1 Where the frequency weighting is not specified, A-frequency weighting is commonly understood for sound in air. However, it is good practice to specify the frequency weighting. An appropriate subscript should be added to the symbol; i.e., E_A or E_C . When no frequency weighting is used, the subscript Z should be used, e.g., E_Z .

NOTE 2 The duration of integration should be stated. For the sound exposure measured over a specified time interval such as one hour, a 15-hour day, or a 9-hour night, the duration should be indicated by the abbreviation or letter symbol, for example one-hour sound exposure (1HSE or E_{1h}) for a particular hour; day sound exposure (DSE or E_d) from 0700 to 2200 hours; and night sound exposure (NSE or E_n) from 0000 to 0700 hours plus from 2200 to 2400 hours.

NOTE 3 Day-night sound exposure (DNSE or E_{dn}) for a 24-hour day is the sum of the day sound exposure and ten times the night sound exposure.

NOTE 4 Unless otherwise stated, the unit for sound exposure is the pascal-squared second.

2.63 particle velocity. In a sound field, the vector velocity caused by a sound wave of a given infinitesimal part of the medium, with reference to the medium as a whole. Unit, meter per second (m/s); symbols, u , v .

NOTE The terms "instantaneous particle velocity," "effective particle velocity," and "peak particle velocity" have meanings that correspond with those of the related terms used for sound pressure.

2.64 wave velocity; propagation velocity. Vector quantity that specifies the speed and direction with which a sound wave passes through a medium. Unit, meter per second (m/s); symbol, c .

NOTE See also phase velocity, 5.33.

2.65 volume velocity. Rate of alternating flow of the medium through a specified surface as a result of a sound wave. Unit, cubic meter per second (m^3/s); symbols, q , U and Q .

NOTE 1 Expressed mathematically, volume velocity q is

$$q = \int_S u d\sigma,$$

where u is the component of particle velocity normal to the element of the surface $d\sigma$; the integration is performed over surface S through which the medium is oscillating.

NOTE 2 Similarly, the volume acceleration can be computed from the surface integral of normal particle acceleration.

2.66 sound energy. Total energy in a given part of a medium minus the energy that would exist at that same part of the medium with no sound waves present. Unit, joule (J).

2.67 sound energy density. Sound energy contained in an infinitesimal part of a medium at a point in a sound field divided by a representative volume at that part of the medium. Unit, joule per cubic meter (J/m^3).

NOTE 1 The terms "instantaneous energy density," "maximum energy density," and "peak energy density" have meanings analogous to the related terms used for sound pressure.

NOTE 2 When speaking of average energy density in general, it is necessary to distinguish between the space average (at a given instant) and the time average (at a given point).

2.68 acoustic radiation pressure. Unidirectional pressure exerted upon a surface exposed to a sound wave. Unit, pascal (Pa).

2.69 sound-energy flux. Time-average of the time rate of flow of sound energy through a specified area. Unit, watt (W); symbol, J .

NOTE 1 In a medium of density ρ , for a plane or spherical free wave having a velocity of propagation c , the sound energy flux J through the area S , corresponding to a time-mean-square sound pressure $\overline{p^2}$, is

$$J = (\overline{p^2} S \cos \theta) / \rho c$$

where θ is the angle between the direction of propagation of the sound and the normal to area S .

NOTE 2 To define an average it is sufficient that the field be statistically stationary with respect to time.

2.70 sound intensity; sound-energy flux density; sound-power density. Average rate of sound energy transmitted in a specified direction at a point through a unit area normal to this direction at the point considered. Unit, watt per square meter (W/m^2); symbol, $\vec{I}$.

NOTE 1 The instantaneous vector sound intensity is the product of acoustic pressure and vector particle velocity.

$$\vec{I}(t) = p(t)\vec{v}(t)$$

where

p = instantaneous sound pressure;

v = component of instantaneous particle velocity in the specified direction; and

t = time.

NOTE 3 In the case of a free plane or spherical wave having time-mean-square sound pressure $\overline{p^2}$, speed of propagation c , in a medium of density ρ , the magnitude of the intensity in the direction of propagation is given by

$$I = \overline{p^2} / \rho c.$$

2.71 sound power. For a specified sound source, sound energy radiated per unit of time. Unit, watt (W); symbols, W or P .

NOTE Sound power is the product of sound pressure times volume velocity.

2.72 efficiency. Ratio of the useful output of a device to its total input. Output and input are physical quantities that may be stored, transferred, or transformed.

NOTE Unless specifically stated otherwise, the term "efficiency" means efficiency with respect to energy or power.

2.73 sound absorption. Change in sound energy into some other form, usually heat, in passing through a medium or on striking a surface.

NOTE See also 10.01.

2.74 damping. Dissipation of energy with time or distance. Respective unit, joule per second (J/s) or watt (W), or joule per meter (J/m).

2.75 relaxation time; time constant. Time taken by an exponentially decaying quantity to decrease in amplitude by a factor of $1/e \approx 0.3679$. Unit, second (s); symbol, τ .

2.76 rise time. Time for a physical quantity to rise from 10% of its final value to 90% of its final value.

2.77 fall time. Time for a physical quantity to fall from 90% of its initial value to 10% of its initial value.

NOTE For an exponentially decaying quantity the fall time is approximately 2.1972 times the time constant.

2.78 simple sound source; omnidirectional sound source. Source that radiates sound uniformly in all directions under acoustic free-field conditions.

NOTE See 5.08 for definition of free field.

2.79 strength of a sound source; strength of a simple source. Maximum instantaneous rate of volume displacement produced by a source when emitting a sound wave with sinusoidal time variation. Unit, cubic meter per second (m^3/s).

NOTE "Strength" is properly applicable only to sources of dimensions small with respect to the wavelength.

2.80 point source; monopole. Source that radiates sound isotropically as if from a single point.

2.81 excitation; stimulus. External force (or other input) applied to a system that causes the system to respond in some way.

2.82 response. Motion or other output resulting from an excitation under specified conditions.

NOTE 1 Modifying phrases should be prefixed to the term "response" to indicate what kinds of input and output are being utilized.

NOTE 2 The response characteristic, often presented graphically, gives the response as a function of some independent variable such as frequency, direction, or time. For such purposes it is customary to assume that other characteristics of the input (for example, voltage) are held constant.

2.83 nonlinear acoustics. Science of sound in which the amplitude of particle displacement is sufficiently large that linear approximations to the properties of the medium and/or the equations of motion are no longer sufficient and consequently higher order effects need to be considered.

NOTE "Nonlinear" means that superposition and the wave equation do not apply to the situation considered.

3 Levels

3.01 level. In acoustics, logarithm of the ratio of a variable quantity to a corresponding reference value of the same units. The base of the logarithm, the reference value, and the kind of level are to be specified.

NOTE 1 Examples of the level of power-like quantities are sound power level, sound exposure (energy) level, and electric-power level. Examples of levels of acoustic variables are sound pressure level and acceleration level.

NOTE 2 The level of a power or power-like quantity is given, in decibels, by

$$L = 10 \log_{10}(Q/Q_0),$$

where, Q is a power or power-like quantity and Q_0 is the corresponding reference value.

NOTE 3 For applications that involve acoustic variables, it is necessary to work with time-mean-square values of the acoustic variable. In this case, the level of an acoustic variable, q , is given, in decibels, by

$$L = 10 \log_{10}(\overline{q^2}/q_0^2),$$

where q_0^2 is the square of the corresponding reference value.

NOTE 4 For common logarithms on the base ten, the symbol for logarithm is " $\log_{10}$." For natural logarithms on the Napierian base e , the symbol is " $\ln$."

NOTE 5 In symbols,

$$L = \log_r(q/q_0),$$

where

L = level of kind determined by the kind of variable under consideration;

r = base of logarithms

q = quantity under consideration;

q_0 = reference quantity of the same kind.

NOTE 6 Differences between levels, ΔL , of two like variables, q_1 and q_2 , are described by the same formula because, by the rules of logarithms, the reference quantity is divided out:

$$\Delta L = \log_r(q_1 / q_0) - \log_r(q_2 / q_0) = \log_r(q_1 / q_2).$$

where q_0 is the corresponding reference value.

NOTE 7 The reference value should be stated with the level, e.g., dB re q_0 .

3.02 bel. Unit of the level of a power or power-like quantity when the base of the logarithm is ten. Unit symbol, B.

NOTE 1 Examples of power-like quantities are sound power, sound exposure, and electrical power. The nature of the quantity under consideration should always be stated.

NOTE 2 The level of a power-like quantity is given, in bels, by

$$L = \log_{10}(Q / Q_0) \text{ B},$$

where Q is the power-like quantity concerned and Q_0 is the corresponding reference value.

NOTE 3 Also treated as power-like quantities, in the present context, are the time-mean-squares of acoustic variables. See 2.08.

NOTE 4 The level of mean-square acoustic variables is given, in bels, by

$$L = 1 \log_{10}(\overline{q^2} / q_0^2) \text{ B},$$

where q is the acoustic variable concerned, $\overline{q^2}$ is its time-mean-square value, and q_0 is the corresponding reference value.

NOTE 5 Use of the square of the instantaneous peak value of an acoustic variable, rather than the time-mean-square value, to form a level leads to the "peak level" of the quantity concerned; see item 3.14, where "peak sound level" is defined.

3.03 decibel. Unit of the level of a power or power-like quantity when the base of the logarithm is the tenth root of ten. Unit symbol, dB.

NOTE 1 In acoustics, the decibel is used more often than the bel for the unit of an acoustical level. The level of a quantity expressed in decibels is ten times greater than the level expressed in bels; for example, for a given quantity, the level in decibels could be 80 dB while the corresponding level in bels is 8 B.

NOTE 2 Examples of power-like quantities are sound power, sound exposure, and electrical power. The nature of the quantity under consideration should always be stated.

NOTE 3 The level of a power-like quantity is given, in decibels, by

$$L = 10 \log_{10} (Q / Q_0) \text{ dB},$$

where Q is the power-like quantity concerned and Q_0 is the corresponding reference value.

NOTE 4 Also treated as power-like quantities, in the present context, are time averages of the square of oscillatory quantities, E ; examples are time-mean-square acoustic pressure and time-mean-square vibrational acceleration. Such oscillatory quantities are sometimes referred to generically as "acoustic variables."

NOTE 5 The level of a time-mean-square acoustic variable is given, in decibels, by

$$L = 10 \log_{10} (\overline{q^2} / q_0^2) \text{ dB},$$

where q is the acoustic variable concerned, $\overline{q^2}$ is its time-mean-square value, and q_0 is the corresponding reference value.

NOTE 6 Use of the squared instantaneous peak value of an acoustic variable, rather than the time-mean-square value, to form a level leads to the "peak level" of the quantity concerned; see item 3.14, where "peak sound level" is defined.

3.04 neper. Logarithmic unit for the amplitude ratio of two sinusoidal acoustic variables of the same kind, or for the ratio of a sinusoidal amplitude to a reference value of the same kind, when the logarithm is on the Napierian (natural) base $e \approx 2.7183$.

NOTE 1 A logarithmic amplitude ratio of one neper corresponds to a difference between acoustic variables in decibels of $10 \log_{10}(e^2)$, or approximately 8.686 decibels.

NOTE 2 If two sinusoidally varying acoustic variables have amplitudes q_1 and q_2 the quantities are said to differ in amplitude by $\ln(q_1/q_2)$ nepers.

3.05 frequency level. Logarithm of the ratio of a given frequency to an appropriate reference value. The base of the logarithm and reference value should be indicated.

NOTE 1 If the base of the logarithm is 2, the unit of frequency level is the octave. The reference value is approximately equal to 16.352 Hz for musical acoustics.

NOTE 2 If the base of the logarithm is $2^{1/12}$, the unit of frequency level is the semitone. The reference value is approximately equal to 16.352 Hz for musical acoustics (see 12.23).

NOTE 3 If the base of the logarithm is 10, then the unit of frequency level is the decade; e.g., 20,000 Hz is three decades above 20 Hz.

3.06 power level. Ten times the logarithm to the base ten of the ratio of a given power to the corresponding reference value. The reference value should be indicated. Unit, decibel (dB).

NOTE In sound recording, a commonly used reference electric power is one milliwatt (1 mW).

3.07 sound power level. Ten times the logarithm to the base ten of the ratio of a given sound power, in a stated frequency band, to the reference value for sound power.

NOTE 1 Sound power level is expressed in decibels (dB).

NOTE 2 Abbreviation, PWL; general symbol L_W . L_P is a reserve symbol.

NOTE 3 Expressed mathematically, sound power level in decibels is given by

$$L_W = 10 \log_{10} (W / W_0),$$

where W is the sound power in watts and W_0 is the symbol for the reference value for sound power level with P_0 as reserve symbol.

NOTE 4 The reference value is $W_0 = 10^{-12}$ watts or one picowatt (1 pW).

NOTE 5 Sound power level is expressed in bels (B) for certain applications.

3.08 reference value for sound pressure. For sounds propagating in gases, twenty micropascals (20 μ Pa).

NOTE 1 The symbol for the reference value for sound pressure level is p_0 .

NOTE 2 For sounds in media other than gases, the reference value for sound pressure level is typically one micropascal (1 μ Pa).

NOTE 3 A sound pressure level with reference value of 1 μ Pa is numerically $10 \log_{10}(20^2/1^2) \approx 26$ dB greater than the sound pressure level for the same sound pressure but with reference value of 20 μ Pa.

3.09 sound pressure level. Ten times the base-ten logarithm of the ratio of a time-mean-square sound-pressure signal, in a stated frequency band, for a stated averaging time duration, to the square of the reference value for sound pressure level. Abbreviation, SPL; general symbol L_p .

NOTE 1 Sound pressure level is expressed in decibels (dB).

NOTE 2 The reference value should always be stated.

NOTE 3 If a stated frequency weighting is applied to the sound-pressure signal, then the result is a sound level, not a sound pressure level.

NOTE 4 Sound pressure level is given, in decibels, by

$$L = 10 \log_{10} (\overline{p^2} / p_0^2) \text{ dB},$$

where p is the instantaneous pressure and p_0 is the reference value.

3.10 band sound pressure level. Sound pressure level for sound contained within a restricted frequency band. Unit, decibel (dB); abbreviation, BSPL; symbol, L_{pb} .

NOTE A band may be identified by its nominal lower and upper band-edge frequencies, or by its nominal midband frequency and nominal bandwidth. The nominal width of the band may be indicated by a prefatory modifier, e.g., octave-band sound pressure level, one-third octave-band sound pressure level, or 50-Hz band level at 400 Hz.

3.11 spectrum density level; spectrum level. Level of the limit, as the width of the frequency band approaches zero, of the quotient of a specified power-like quantity distributed within a frequency band, by the width of the band. The words "spectrum level" should be preceded by a descriptive modifier. Unit, decibel (dB).

NOTE For illustration, sound pressure spectrum level L_{ps} at the midband frequency is obtained practically by

$$L_{ps} = 10 \log_{10} \left[\left(\overline{p_b^2} / \Delta f \right) / \left(p_0^2 / \Delta_0 f \right) \right],$$

where $\overline{p_b^2}$ is the time-mean-square of the sound pressure signal from some bandpass filter of the filter system; p_0 is the reference value for sound pressure; Δf is the nominal bandwidth of the bandpass filter; and $\Delta_0 f$ is the reference filter bandwidth of 1 Hz. For computational purposes, with L_{pb} for the band pressure level indicated at the output of the filter system, the above relation becomes

$$L_{ps} = L_{pb} - 10 \log_{10} [\Delta f / \Delta_0 f].$$

3.12 exponential-time-weighted sound level. Ten times the logarithm to the base ten of the ratio of a frequency-weighted exponential-time-weighted squared sound pressure to the square of the reference value for sound pressure, the squared sound pressure signal being obtained with fast (F) (125-ms) exponential time weighting. Alternatively, slow (S) (1000-ms) exponential time weighting may be specified. Unit, decibel (dB); examples of symbols L_{AF} , L_{AS} , L_{CF} , L_{CS} , where the subscript A or C would be replaced if another frequency weighting is used.

NOTE 1 Frequency weightings A, C, Z, and FLAT and exponential time weightings F and S are specified in Part 1 of IEC 61672.

NOTE 2 In symbols, A-weighted exponential-time-weighted sound level $L_{A\tau}(t)$ at running time t is

$$L_{A\tau}(t) = 10 \log_{10} \left\{ \left[(1/\tau) \int_{-\infty}^t p_A^2(\xi) e^{-(t-\xi)/\tau} d\xi \right] / p_0^2 \right\},$$

where τ is the exponential time constant in seconds; ξ is a dummy variable of integration; $p_A^2(\xi)$ is the squared, instantaneous, time-varying, A-weighted sound pressure in pascals; and p_0 is the reference value for sound pressure. Division by time constant τ yields the running time average of the exponential-time-weighted, squared sound-pressure signal. Initiation of the running time average from some time in the past is indicated by $-\infty$ for the beginning of the integral.

NOTE 3 Exponential-time-weighted sound level is often abbreviated as sound level.

3.13 maximum sound level. Greatest frequency-weighted and exponential-time-weighted sound level within a stated time interval. Unit, decibel (dB); abbreviation for F time weighting and A frequency weighting, for example, is MXFA; symbol L_{AFmx} (or C and S).

3.14 peak sound level. Level of the ratio of the square of a peak instantaneous sound-pressure signal with stated frequency weighting, within a stated time interval to the square of the reference value for sound pressure. Unit, decibel (dB), example abbreviation for C frequency weighting, for example, is PKC; symbol, L_{Cpk} .

3.15 time-averaged sound level; equivalent continuous sound level. Ten times the logarithm to the base ten of the ratio of time-mean-square frequency-weighted sound pressure signal, during a stated time interval T , to the square of the reference value for sound pressure. Unit, decibel (dB); respective abbreviations, TAV and TEQ; examples of symbols, L_{AT} and L_{AeqT} , where the subscript A would be replaced if another frequency weighting is applied.

NOTE 1 The frequency weighting should be specified explicitly.

NOTE 2 In symbols, time-averaged A-weighted sound level in decibels is

$$L_{A_T} = 10 \log_{10} \left\{ (1/T) \int_0^T p_A^2(t) dt / p_0^2 \right\} = L_{AeqT},$$

where $p_A^2(t)$ is the squared instantaneous A-weighted sound pressure signal, a function of elapsed time t ; p_0 is the reference value for sound pressure; and T is the duration of a stated time interval.

NOTE 3 Time-averaged sound level is often abbreviated as sound level.

3.16 one-hour-average sound level. Time-averaged frequency-weighted sound level during a time period of one hour. Unit, decibel (dB); abbreviation, 1 HL; symbol, L_{1h} .

NOTE 1 One-hour-average sound level in decibels is related to the corresponding one-hour sound exposure level, L_{E1h} , according to

$$L_{1h} = L_{E1h} - 10 \log_{10}(3,600/1),$$

where 3600 is the number of seconds in one hour; 1 s is the reference duration for sound exposure; and sound exposure E is in pascal-squared seconds.

NOTE 2 Frequency weighting A is understood unless another frequency weighting is specified explicitly.

3.17 day-average sound level. Time-average frequency-weighted sound level between 0700 and 2200 hours. Unit, decibel (dB); abbreviation, DL; symbol, L_d .

NOTE Day-average sound level in decibels is related to the corresponding day sound exposure level, L_{Ed} according to

$$L_d = L_{Ed} - 10 \log_{10}(54,000/1),$$

where 54,000 is the number of seconds in 15 hours.

3.18 night-average sound level. Time-averaged frequency-weighted sound level between 0000 and 0700 hours and 2200-2400 hours. Unit, decibel (dB); abbreviation, NL; symbol, L_n .

NOTE Night-average sound level in decibels is related to the corresponding night sound exposure level, L_{En} according to

$$L_n = L_{En} - 10 \log_{10}(32,400/1),$$

where 32,400 is the number of seconds in a given 9-hour night.

3.19 day-night-average sound level. On a given day of the week, twenty-four-hour average frequency-weighted sound level after addition of 10 decibels to levels from midnight to 0700 hours and from 2200 hours to midnight. Unit, decibel (dB); abbreviation, DNL; symbol, L_{dn} .

NOTE 1 Day-night-average sound level in decibels is related to the corresponding day-night sound exposure level, L_{Edn} , according to

$$L_{\text{dn}} = L_{\text{Edn}} - 10 \log_{10}(86,400/1),$$

where 86,400 is the number of seconds in 24 hours.

NOTE 2 Frequency weighting A is understood, unless another frequency weighting is specified explicitly.

3.20 community noise equivalent level. On a given day of the week, twenty-four hour-average A-weighted sound level after addition of 5 decibels to sound levels from 1900 hours to 2200 hours, and after addition of 10 decibels to sound levels from midnight to 0700 hours and from 2200 hours to midnight. Unit, decibel (dB); abbreviation, CNEL; symbol L_{den} .

3.21 normalized 8-hour average sound level. Level of time-mean-square, A-weighted sound pressure during a normalization period T_n of eight hours, such that the sound exposure therefrom is equal to the sound exposure of a time-varying sound at a place where total sound exposure occurs within a time period not necessarily eight hours. Unit, decibel (dB); abbreviation, N8hL; symbol, L_{A8hn} .

3.22 sound exposure level. Ten times the logarithm to the base 10 of the ratio of a sound exposure to the reference value.

NOTE In symbols, (A-weighted) sound exposure level in air is given by

$$L_{\text{AE}} = 10 \log_{10} \left\{ \left[\int_0^T p_A^2(t) dt \right] / p_0^2 T_0 \right\} = 10 \log_{10}(E / E_0) = L_{\text{AT}} + 10 \log_{10}(T / T_0).$$

where $p_A^2(t)$ is the squared instantaneous A-weighted sound pressure signal, a function of time t , and $p_0^2 T_0$ represents the reference value for sound exposure; T is the duration of a stated time interval; p_0 is the reference value for sound pressure; and $T_0 = 1$ s is the reference duration for sound exposure level.

3.23 particle velocity level. Ten times the logarithm to the base ten of the ratio of the time-mean-square particle velocity of a given sound or vibration to the square of a specified reference value for particle velocity. Unit, decibel (dB); symbol, L_v .

NOTE Clause A.1 of ANSI/ASA S1.8-1989 (R 2011) notes that a reference value for particle velocity of 10 nm/s was used in ANSI S1.8-1969, in contrast with 1 nm/s given in ISO 1683:2008. It is important to state the reference value for particle velocity level when describing velocity levels.

3.24 (vibratory) acceleration level. Ten times the logarithm to the base ten of the ratio of a time-mean-square vibratory acceleration to the square of a specified reference value for acceleration. Unit, decibel (dB); symbol, L_a .

NOTE 1 Clause A.2 of ANSI/ASA S1.8-1989 (R 2011) notes that a reference value for acceleration of $10 \mu\text{m/s}^2$ was used in ANSI S1.8-1969, in contrast with $1 \mu\text{m/s}^2$ given in ISO 1683-2008. It is particularly important to state the reference value for acceleration when describing acceleration levels.

NOTE 2 The numerical value of a given acceleration level is 20 dB less if based on $10 \mu\text{m/s}^2$ for the reference value than if based on $1 \mu\text{m/s}^2$. The reference value for acceleration of $10 \mu\text{m/s}^2$ is within 2% of one millionth of the international standard acceleration for free fall, $g_n = 9.806650 \text{ m/s}^2$.

3.25 sound intensity level. Ten times the logarithm to the base ten of the ratio of the time-average intensity of a given sound in a stated direction to the reference value for sound intensity of 1 picowatt per square meter (1 pW/m^2). Unit, decibel (dB); abbreviation, IL; symbol, L_I .

3.26 (vibratory) force level. Ten times the logarithm to the base ten of a time-mean-square force to the square of the reference value for (vibratory) force level of 1 micronewton ($1 \text{ }\mu\text{N}$). Unit, decibel (dB); symbol, L_F .

4 Oscillation, vibration, and shock

4.01 forced oscillation; forced vibration. Response of a system caused by external excitation.

NOTE For a linear system, if the response is periodic and continuing, the oscillation is steady-state.

4.02 free oscillation. Phenomenon that occurs in a system when it oscillates in the absence of forced oscillation as the result of an initial displacement or velocity.

4.03 self-induced vibration; self-excited vibration. Phenomenon that results within a system from conversion of nonoscillatory excitation to oscillatory excitation.

4.04 resonance. Phenomenon that exists for a linear system in harmonic forced oscillation when any change in the excitation frequency results in a decrease in the response of the system.

NOTE 1 The harmonic forcing frequency(ies) is near that of a modal or natural frequency(ies).

NOTE 2 The quantity that is the measure of response should be indicated (displacement, velocity or acceleration). Velocity resonance, for example, may occur at a frequency different from that for displacement resonance; see Table 1.

4.05 resonance frequency. Frequency at which resonance exists. Unit, hertz (Hz).

NOTE 1 In case of possible confusion, the type of resonance should be indicated, e.g., velocity resonance frequency.

NOTE 2 See Table 1 for resonance frequency equations for several types of resonance conditions.

4.06 anti-resonance. Phenomenon that occurs when the driving system produces zero response in the driven system at a frequency between two mode frequencies.

NOTE An anti-resonance frequency is a frequency at which anti-resonance occurs.